United States Patent [19]

Dorff et al.

[11] **3,907,465**

[45] **Sept. 23, 1975**

[54] **HYDRAULIC POWER TRANSLATING DEVICE**

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[73] Assignee: **Hydraulic Products Incorporated**, Sturtevant, Wis.

[22] Filed: **Aug. 29, 1974**

[21] Appl. No.: **502,109**

[52] **U.S. Cl.** **418/71**; 418/171

[51] **Int. Cl.²** **F04C 15/00**

[58] **Field of Search** 418/71, 72, 171, 32; 417/315

[56] **References Cited**

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Assistant Examiner—Leonard Smith
Attorney, Agent, or Firm—Wegner, Stellman, McCord, Wiles & Wood

[57] **ABSTRACT**

A bi-directional hydraulic power translating device of the gerotor type having inner and outer rotatable partial meshing gear elements rotatably mounted in a casing with a clearance space surrounding the outer gear element and with fluid passage structure and valve means providing for a fluid flow through said clearance space in either direction of operation of the device for obtaining radial balance of the outer gear element in start-up operation and also during rotation by hydrodynamic effects.

9 Claims, 7 Drawing Figures

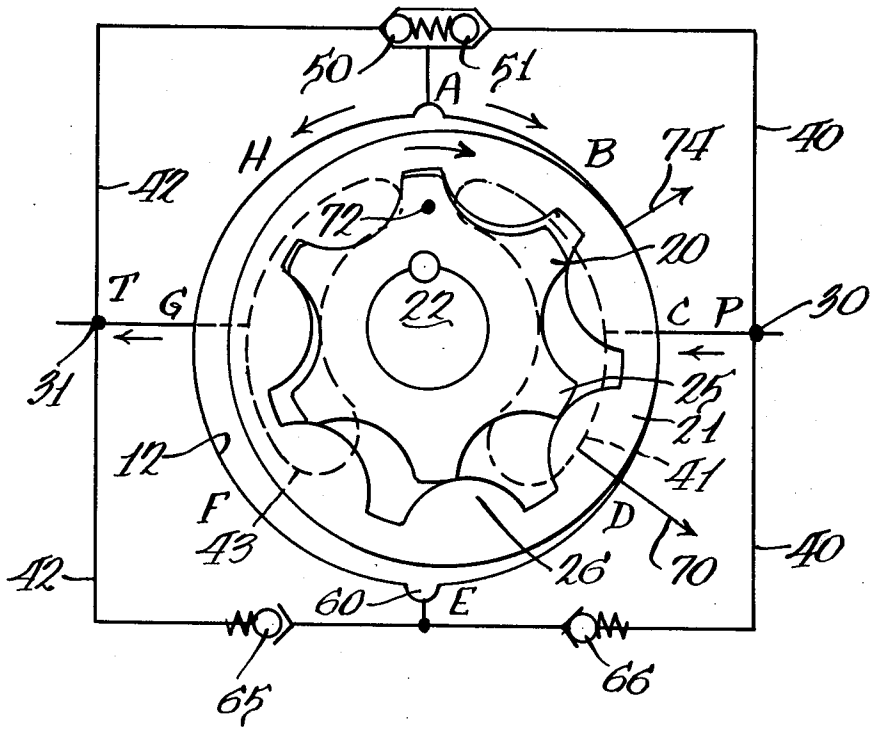


Fig. 1.

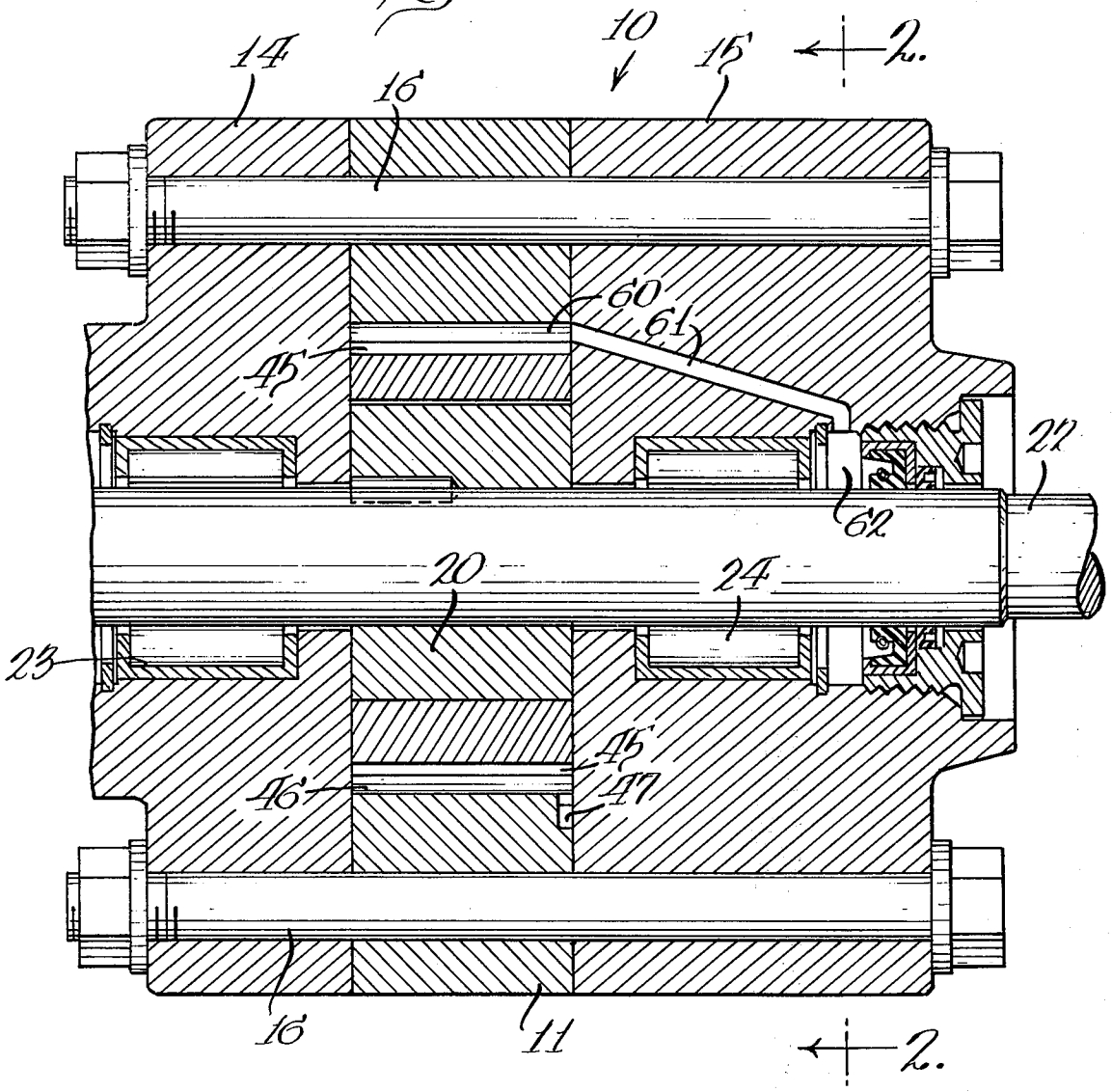


Fig. 2.

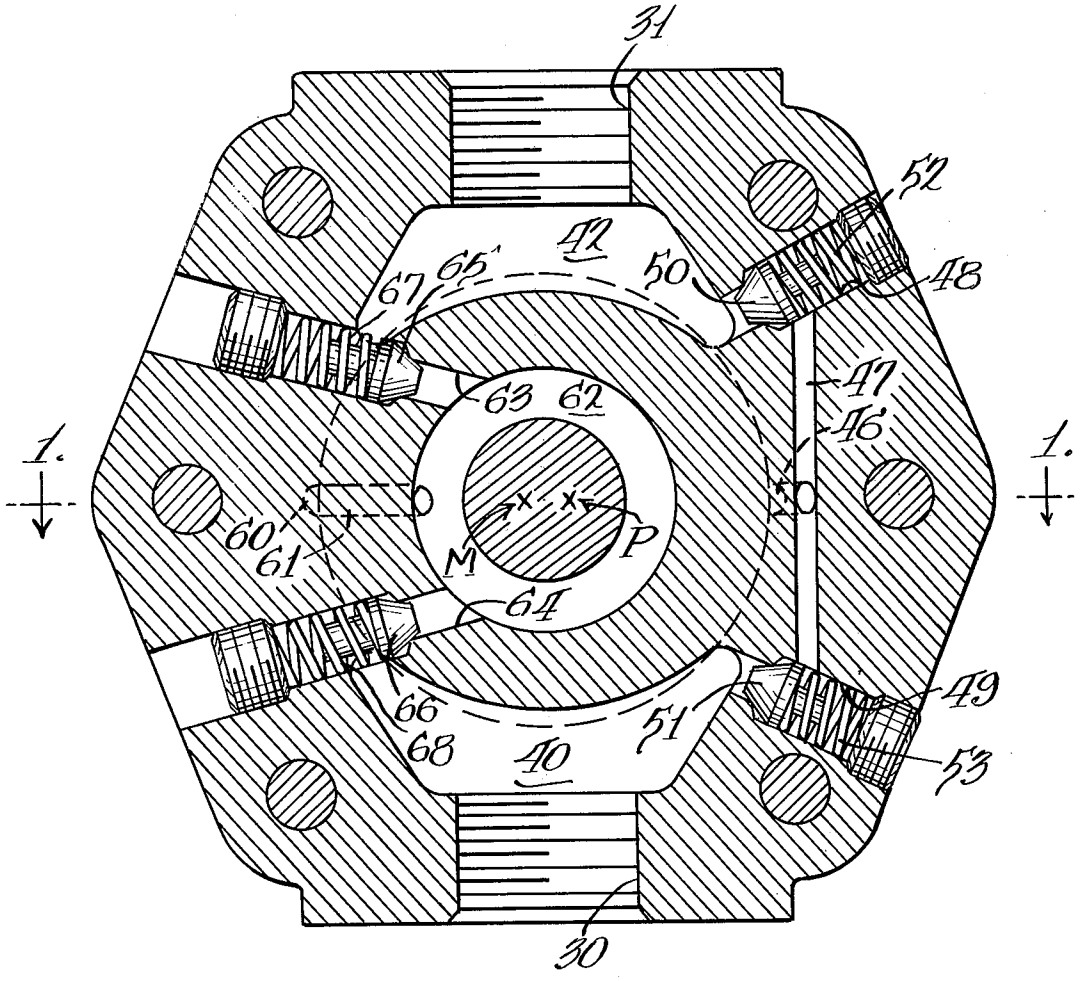


Fig. 3.

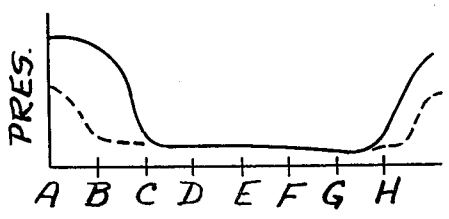


Fig. 4.

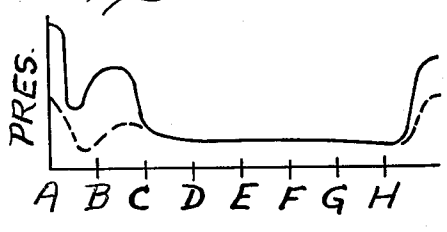


Fig. 5.

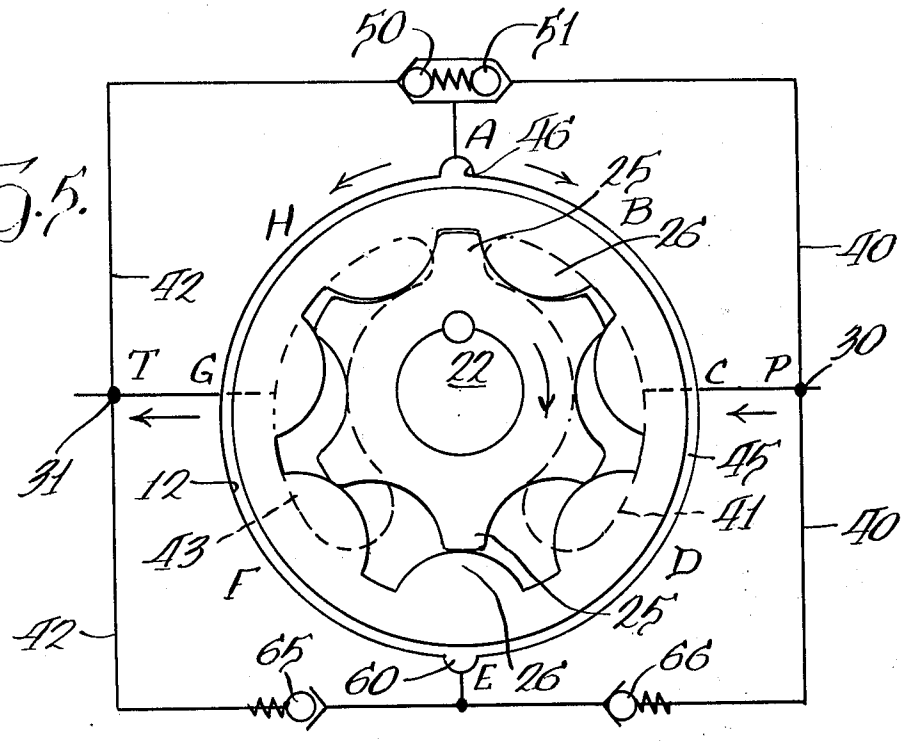

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Fig. 6.

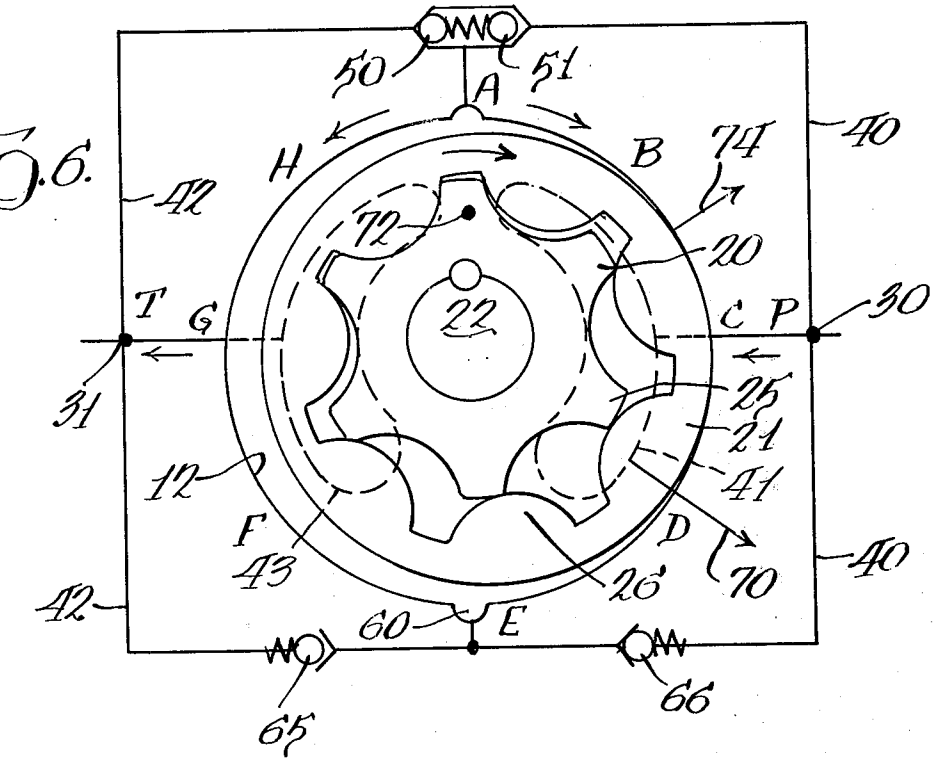
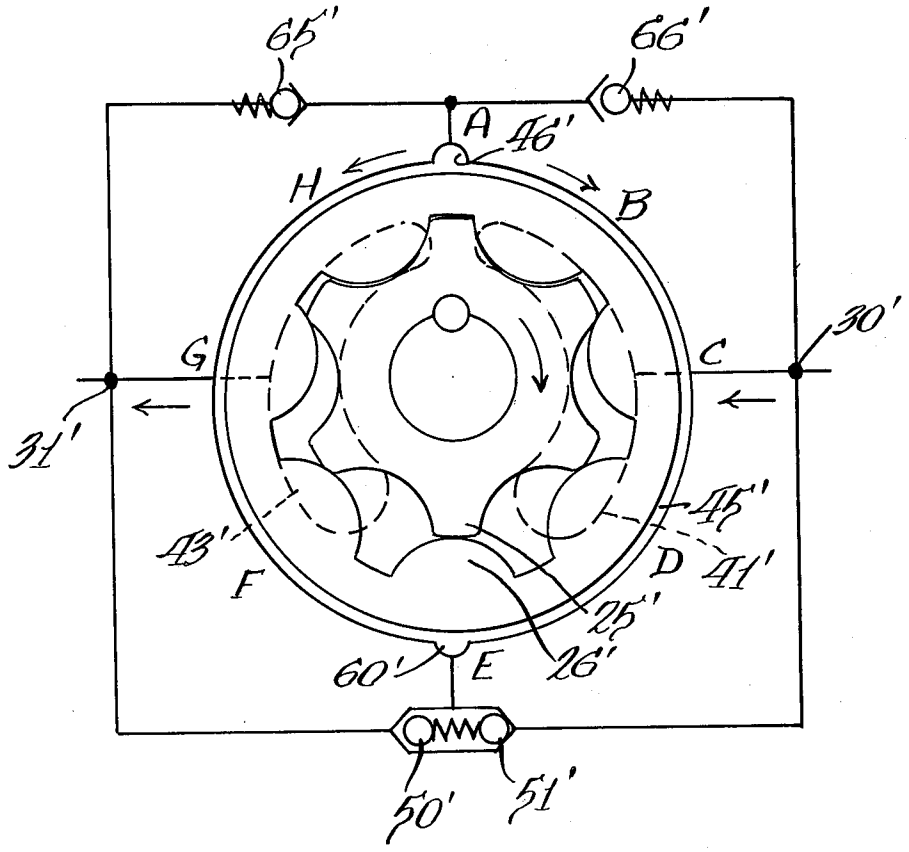

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Fig. 7.



HYDRAULIC POWER TRANSLATING DEVICE

BACKGROUND OF THE INVENTION

This invention pertains to bi-directional power translating devices of the gerotor type and more particularly to such a device functioning either as a hydraulic motor or a pump.

The prior art discloses power translating devices of the gerotor type in which radial balancing of the outer element is attempted as shown, for example, in Brundage U.S. Pat. No. 3,427,983. The inadequacies thereof are listed in a later Brundage U.S. Pat. No. 3,680,989. In a gerotor type device, the forces generated are variable both in magnitude and in direction because the area of operation on the internal part of the outer gear element is based on two shifting seal points and the timing with respect to the fluid port supplying the space between the gear elements. This area varies in frequency and magnitude with the frequency being a function of the number of teeth on the inner gear element times the speed of rotation thereof and with the magnitude being a function of the geometry of the inner and outer gear elements. Further, the force acting on the outer gear element results in a pivoting of the outer gear element relative to the casing about a generally fixed point which establishes a minimum space in the clearance area surrounding the outer gear element. This location varies with the variation in magnitude and direction of the forces created by operation of the device.

The prior art referred to above attempts to balance the outer gear element by porting operating pressure to a plurality of locations externally of the outer gear element. These attempts do not recognize the variation in the magnitude and direction of the forces.

A solution to the aforesaid problems is disclosed in the pending application of the applicants, Ser. No. 205,164, filed Dec. 6, 1971, now U.S. Pat. No. 3,834,842. The prior application of applicants discloses a solution to providing radial balance for the outer gear element by utilizing a hydrodynamic sleeve bearing effect wherein fluid may flow in the clearance space between the outer gear element and the casing and in the same direction as the rotation of the outer gear element and with a build-up in pressure resulting from the forces urging the outer gear element toward the casing. Applicant's prior device was constructed for operation in one direction.

SUMMARY OF THE INVENTION

A primary feature of the invention disclosed herein is to provide a bi-directional power translating device wherein an outer gear element of a gerotor type device is radially balanced by a hydrodynamic sleeve bearing effect in either direction of rotation of the device.

In carrying out the invention disclosed herein the outer gear element of the gerotor type device is mounted within a casing and with a clearance space therebetween and with a fluid inlet connected to said clearance space along a line coinciding generally with the axis of rotation of the inner gear element and the pivot point for the outer gear element along with a fluid outlet from the clearance space diametrically opposite from the fluid inlet and with valve means operable in response to fluid pressure to connect the fluid inlet to either of the two casing ports for the device which is receiving the fluid pressure and for connecting the fluid outlet to the other of the casing ports that is connected to tank.

With the location of a fluid inlet and a fluid outlet relative to a clearance space in the casing surrounding the outer gear element of the power translating device, it is possible to establish a hydrostatic pressure gradient on initial start-up of the device as a motor and with a hydrodynamic pressure established during normal operation of the device as a pump or motor to obtain radial balance of the outer gear element and to absorb varying loading resulting from a shifting resultant of forces acting about the pivot point of the outer gear element and also to resist deflections of the shaft mounting the inner gear element, particularly at higher operating pressures. It is contemplated that the operating pressure could be as high as 5,000 psi.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan central section of the bi-directional power translating device taken along the line **1—1** in FIG. **2**;

FIG. **2** is a vertical section taken generally along the line **2—2** in FIG. **2**;

FIG. **3** is a graph showing the relation of hydrostatic pressures at different points about the outer gear element and at two different values of supply pressure;

FIG. **4** is a graph similar to FIG. **3** showing the relation of hydrodynamic pressures at two different supply pressures;

FIG. **5** is a schematic view of the power translating device as a motor at stall;

FIG. **6** is a schematic view of the power translating device as a motor in operation in one direction of rotation; and

FIG. **7** is a view similar to FIG. **5** with the device as a pump.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The bi-directional power translating device is shown in FIGS. **1–6** as a motor and has a casing indicated generally at **10** with a central part **11** defining a cylindrical chamber **12** and with a pair of cover blocks **14** and **15** positioned to either side of the plate **11** and with the casing secured by a series of bolts **16.** The power translating device is of the gerotor type wherein an inner gear element **20** is positioned within an outer gear element **21.** The inner gear element **20** is mounted on a shaft **22** for rotation therewith, with the shaft being supported in the casing by bearings **23** and **24.** The cylindrical chamber **12** has its internal wall offset eccentrically from the axis of rotation of the shaft **22** and the inner gear element **20.** This is conventional in a gerotor type hydraulic power translating device. With the six teeth **25** on the inner gear element **20** and the seven internal teeth **26** on the outer gear element **21,** there is thus established a plurality of fluid chambers in spaces between the gear elements.

The casing **10** has a pair of opposed casing ports **30** and **31** for connection to a supply of pressure fluid and to tank with the connections being reversible because of the power translating device being bi-directional in operation. For the schematic views of FIGS. **5** and **6,** it is assumed that the casing port **30** is connected to a source of pressure fluid and that the casing port **31** is connected to tank. The casing ports **30** and **31** are interconnected by passage means including a flow pas-

sage 40 which terminates in a kidney-shaped fluid port 41 whereby fluid under pressure is delivered to fluid chambers defined between the inner and outer gear elements. The passage means includes a second flow passage 42 extending from the casing port 31 and terminating in a kidney-shaped fluid port 43 whereby fluid delivered from certain of the fluid chambers between the inner and outer gear elements may flow to the casing port 31.

As shown in FIG. 5, a tooth 25 of the inner gear element meshes with two teeth 26 of the outer gear element to define one cross-over area between the pressure and tank sides of the device with a second cross-over area being defined by surface engagement between the tip of a tooth 25 of the inner gear element and a tip of a tooth 26 of the outer gear element. The kidney-shaped fluid ports 41 and 43 are positioned intermediate said cross-over areas.

The outer gear element 21 has a diameter less than that of the cylindrical chamber 12 whereby there is a clearance space 45 therebetween. For the device to have operating characteristics of high starting torque as well as radial balance during operation, fluid is supplied to the clearance space 45 for flow around the outer gear element and exhaust from the clearance space to tank. This is accomplished by having a fluid inlet 46 to the clearance space defined by a groove in the casing plate 11 which communicates with a groove 47 on a face of the casing plate 11 and which extends to upper and lower valve bores 48 and 49 connected to the flow passages 40 and 42 to thereby define passage means interconnecting the casing ports 30 and 31. A pair of pressure responsive valves are positioned in the valve bores 48 and 49 and specifically comprise a pair of check valves 50 and 51 which are spring-loaded by springs 52 and 53, respectively, to seat against associated valve seats and open in response to fluid pressure. As seen in the schematic view of FIG. 5 the check valve 51 opens in response to pressure at casting port 30 and in flow passage 40 to deliver pressure fluid to the fluid inlet 46 while the assocaited check valve 50 prevents communication of the fluid inlet with the casing port 31. With the pair of check valves 50 and 51, it is possible to have bi-directional operation of the power translating device with either of the casing ports 30 and 31 connected to a source of fluid under pressure and to have fluid pressure conducted to the fluid inlet 46 to supply pressure fluid to the clearance space 45.

Fluid is exhausted from the clearance space 45 through a fluid outlet 60 formed as a groove in the casing plate 11 and which connects by a passage 61 to a space 62 in the casing block 15 surrounding the shaft 22. This space communicates with the flow passages 40 and 42 through a pair of passages 63 and 64 (FIG. 2) each of which have associated therewith a pressure responsive valve in the form of check valves 65 and 66 which are urged by their respective springs 67 and 68 in a direction to close the space 62 from communication with the flow passages 40 and 42. The back side of the check valve 65 and 66 are exposed to the flow passages 40 and 42 whereby existence of fluid under pressure in one of said flow passages will maintain the associated check valve seated. In the direction of operation referred to herein, there is fluid pressure in the flow passage 40 whereby check valve 66 is maintained closed while the pressure of fluid exhausted from the clearance space 45 is sufficient to unseat the check valve 65 and permit fluid to flow to the flow passage 42 which is connected to tank.

The hydrostatic and hydrodynamic pressures involved in the device in obtaining good start-up characteristics and radial balancing during operation are shown in the graphs of FIGS. 3 and 4. In each of FIGS. 3 and 4, a pressure curve is shown in full line for operating at a relatively high pressure and a pressure curve shown in broken line for operating at a lower supply of pressure and with the points along the abscissa of the graph identified from A to H corresponding to the circumferential locations identified in FIGS. 5 and 6. The hydrostatic pressures are shown in FIG. 3 which when delivered to the fluid inlet 46 are at a value shown at point A. The pressure progressively drops to point C and continues at a relatively low value until a point shortly prior to point H. The hydrostatic pressure results from the flow of oil under pressure to fluid inlet 46 and then in both directions, as indicated by the arrows in FIG. 5, toward points C and G. The amount of this flow is a function of clearance, system pressure and capacity. As the outer gear element 21 begins to rotate it first climbs the wall of the cylindrical chamber 12 in a direction opposite to the clockwise rotation of FIGS. 5 and 6. This restricts the clearance on one side of the outer gear element thus causing a greater flow from A to G than from A to C. This differential flow rate will cause the pressure gradient between A and B to be greater than between A and H due to variance of flow and this will balance the outer gear element.

In considering the hydrodynamic pressures, it should be noted that forces resulting from pressure acting in the fluid chambers of the device act generally in the direction of the arrow 70 in FIG. 6 but with variations in the direction thereof as previously explained. This force causes a pivoting of the outer gear element 21 about a point 72 which is fixed relative to the casing in all rotative positions of the gear elements with the result that the outer gear element is urged toward the wall of the cylindrical chamber 12 in a direction generally indicated by the arrow 74 in FIG. 6. The fluid inlet 46 to the clearance space lies along a line which includes the pivot point 72 and the rotational axis of the shaft 22 to provide the maximum bearing area in either direction of rotation of the device and well in advance of the minimum clearance space between points B and C of FIG. 6 and generally in the area of the arrow 74.

In the opposite direction of rotation the minimum clearance area would be between the points G and H. For the direction of rotation shown in FIG. 6, it will be seen from the graph of FIG. 4 that there is a build-up of pressure between points B and C which counteracts the forces tending to pivot the outer gear element 21 toward the cylindrical chamber wall. Thus the hydrodynamic pressure radially balances the outer gear element while the hydrostatic pressure is diminishing. With the hydrodynamic sleeve bearing effect, it is inherent that the peak pressure as illustrated between B and C in the graph of FIG. 4 will vary peripherally of the cylindrical chamber 12 as the location of the arrow 74 representing the direction of pivoting varies. Thus the hydrodynamic bearing effect inherently provides radial balance even though the resultant of the forces indicated by arrow 70 varies as is inherent in a gerotor type device. The curves of FIG. 4 will vary dependent upon viscosity of the fluid, clearance and speed of rotation of the device.

The pressure peak will move toward point C as viscosity increases and clearance decreases. With a speed increase the pressure peak will widen because of a greater flow through the clearance space resulting from the carrying of fluid around the outer gear element as the outer gear element rotates.

It is believed obvious from the foregoing that if the casting port **31** is connected to pressure and the casing port **30** connected to tank, then the check valve **50** will open to deliver fluid under pressure to the fluid inlet **46** with the check valve **51** being closed to block communication with the casing port **30.** The check valve **65** will be held closed by pressure in the flow passage **42** and the check valve **66** will open to permit fluid to flow from the fluid outlet **60** to the casing port **30.**

With this construction, a bi-directional power translating device is provided wherein, in either direction of operation, fluid is delivered to the clearance space to obtain hydrostatic pressure at stall and start-up of the device and to obtain hydrodynamic balancing pressure for operation at various speeds and loads and with a shift in the maximum pressure location responsive to the shift in the forces acting on the outer gear element.

The previous description of the structure shown in FIGS. **1–6** has been of a motor which is one form of a bi-directional power translating device. The desirability of obtaining radial balance of the outer gear element is equally applicable to a pump of the gerotor type. Generally, in the description and in the claims, reference to a power translating device is intended to be generic to both motors and pumps. In a pump there are no adverse forces in start-up operation since there is no initial loading of the gear elements. There is, however, the same reactive force on the outer gear element during normal rotation which is balanced by the hydrodynamic bearing effect.

FIG. **7** is a view similar to FIG. **5** and schematically showing the power translating device with valving associated therewith for pump operation. In FIG. **7,** parts corresponding to those shown in FIG. **5** have been given the same reference numeral with a prime affixed thereto. It will be noted that the direction of rotation of the unit is the same as FIG. **5,** with the casing port **30'** being connected to a supply of fluid and the casing port **31'** being the pressure outlet port. There has been a reversal of location of the two pairs of check valves with the check valves **50'** and **51'** acting in opposition to pressure conditions at casing ports **30'** and **31'**. With the direction of operation shown in FIG. **7,** check valve **50'** opens to permit flow of fluid to the groove **60'** which now functions as a fluid inlet. In the other direction of operation as a pump, the check valve **51'** opens to permit flow to the groove **60'** from the casing port **30'**.

The second pair of check valves **65'** and **66'** function to permit flow from the groove **46'** to the casing port **30'** or **31'** which is at the lower pressure.

Another way of adapting the disclosed structure to bi-directional pump operation would be a change in eccentricity of the outer gear element **21.** Specifically referring to FIG. **2,** the point M identifies the center of rotation of the outer gear element within the casing for operation as a motor. With the valving unchanged and as disclosed in FIGS. **1–6,** the chamber **12** in the central part **11** of the casing could be changed to provide for a center of rotation of the outer gear element **21** about point P in pump operation.

It should be recognized that there are several different designs for a power translating device of the gerotor type. In the specific embodiment disclosed, reference has been made to a **6–7** teeth relation. It is also known to have teeth relationships of **8–9, 10–11** and **12–13,** and there are possibly other variations. The key principle common to these devices is the lower relative velocity between the coacting surfaces of the inner and outer gear elements.

Also contemplated within the invention in referring to inner and outer gear elements are structures of the type shown in U.S. Pat. No. 3,623,829, wherein the inner gear element has external teeth which are in the form of spherical elements.

We claim:

1. A bi-directional power translating device of the gerotor type having a casing with a cylindrical chamber, inner and outer gerotor elements rotatably positioned in said chamber with a clearance space between the chamber wall and the outer periphery of the outer gerotor element, a pair of casing ports connectable to pressure and tank respectively, passage means in said casing interconnecting said casing ports and including flow passages to fluid ports associated with the gerotor elements, means for delivering a flow of fluid to said clearance space in either direction of operation including a fluid inlet to said clearance space and generally in line with a line through the axis of rotation of the inner gerotor element and the pivot axis of the outer gerotor element, a fluid outlet from the clearance space through which fluid passes and which is diametrically opposed to said fluid inlet, each of said fluid inlet and outlet being connected to said passage means, and means to connect the fluid inlet to whichever of the casing ports that receives pressure fluid and the fluid outlet to the other casing port.

2. A bi-directional hydraulic motor of the gerotor type comprising, a casing having a pair of ports, an inner gear element and an outer gear element rotatably mounted in said casing with said outer gear element eccentrically mounted relative to the inner gear element whereby a series of fluid chambers are defined between said gears and with said gears having their teeth interrelated at two cross-over areas wherein fluid communication is blocked between said fluid chambers at either side of said cross-over areas, a pair of kidney-shaped fluid ports intermediate said cross-over areas, and means subjecting the exterior of said outer gear element where the outer gear element is a minimal distance from the casing to a fluid pressure to obtain radial balance thereof upon start-up to free the outer gear element for rotation relative to the case and to balance said outer gear element during rotation, said means including a single fluid pressure inlet and a diametrically opposed single fluid outlet externally of the outer gear to provide a restricted fluid flow path with flow in the direction of outer gear element rotation to said fluid outlet and extending around the exterior or the outer gear element from a location in advance of said point where the outer gear is a minimal distance from the case to a location beyond said point, and means connecting said fluid pressure inlet to both of said casing ports with flow communicating only to the casing port receiving pressure fluid.

3. A bi-directional hydraulic motor as defined in claim **2** wherein said last mentioned means includes a

pair of check valves positioned in the flow path to either side of the fluid inlet.

4. A bi-directional power translating device comprising, a casing with a cylindrical chamber, partially meshing inner and outer gear elements rotatably mounted in said chamber with a clearance space between a wall of said chamber and the outer periphery of said outer gear element, said gear elements being eccentrically related to define a series of fluid chambers and with said gear elements having their teeth interrelated at two cross-over areas wherein fluid communication is blocked between said fluid chambers at either side of the cross-over areas, a pair of kidney-shaped fluid ports in said casing intermediate said cross-over areas, a pair of flow passages connected to respective ones of said ports, a fluid pressure inlet to said clearance space circumferentially located intermediate said fluid ports and connected to said flow passages, a fluid pressure outlet from said clearance space diametrically opposed to said pressure inlet and connected to said flow passages, and valve means for placing only one of said flow passages in communication with said fluid pressure inlet and the other flow passage in communication with said fluid pressure outlet.

5. A power translating device as defined in claim **4** wherein said valve means is pressure responsive.

6. A power translating device as defined in claim **5** wherein said valve means includes first and second pairs of check valves with one pair of preventing flow from said clearance space and between said flow passages and the other pair permitting flow from said clearance space but blocking flow between said flow passages.

7. A bi-directional hydraulic motor of the gerotor type comprising, a casing, an inner gear element and an outer gear element rotatably mounted in said casing with said outer gear element eccentrically mounted relative to the inner gear element whereby a series of fluid chambers are defined between said gears and with said gears having their teeth interrelated at two cross-over areas wherein fluid communication is blocked between said fluid chambers at either side of said cross-over areas, a pair of kidney-shaped fluid ports intermediate said cross-over areas, a pair of flow passages connected one to each of said fluid ports, and means subjecting the exterior of said outer gear element where the outer gear element is a minimal distance from the case to a fluid pressure whereby the outer gear element is supported for rotation relative to the case, said means including a single fluid pressure inlet and a diametrically opposed single fluid outlet externally of the outer gear element to provide a restricted fluid flow path with flow in the direction of outer gear element rotation to said fluid outlet and extending around the exterior of the outer gear element and with both said fluid inlet and fluid outlet connected to said flow passages, and valve means to connect the flow passage having pressure fluid to said fluid pressure inlet and the fluid pressure outlet to the other flow passage.

8. A bi-directional hydraulic motor as defined in claim **7** wherein passage means including said flow passages extend through said casing between casing ports connectable to a source of pressure and to tank, and the valve means includes a pair of pressure responsive check valves positioned in said passage means to either side of said fluid inlet and responsive to pressure whereby either of said casing ports may supply pressure fluid and provide by-directional operation.

9. A bi-directional hydraulic motor as defined in claim **8** wherein said valve means includes a second pair of check valves to connect said fluid outlet to whichever of the casing ports is connected to tank.

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