United States Patent

Denker

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[54] FLUID PRESSURE CONTROLLING

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[52] **U.S. Cl.** ....60/53 A, 91/501

[51] **Int. Cl.** F16d 31/06, F04b 9/08

[58] **Field of Search** ....91/472, 499, 501, 198; 418/232; 60/53 A

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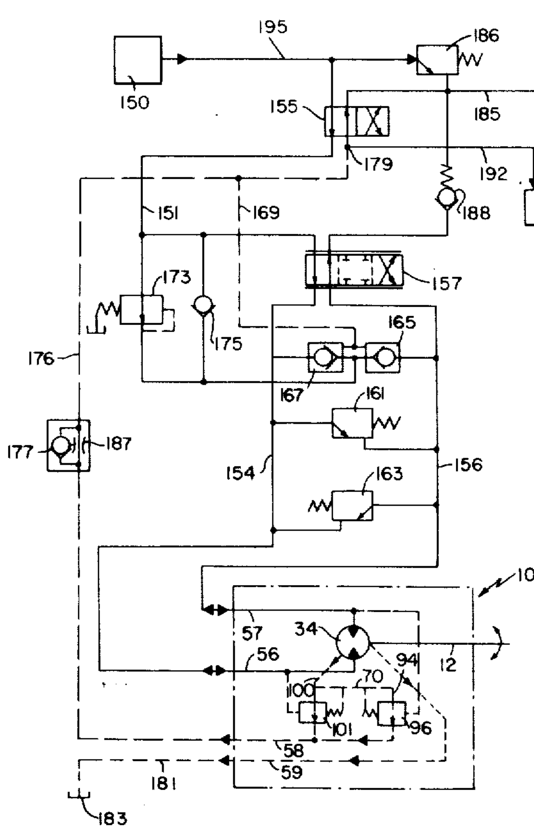
[57] **ABSTRACT**

In a rotary fluid device of the type comprising two elements, one of which is capable of operation as a pump and the other of which is capable of operation as a motor and which are coupled to a common shaft, the motor element having the inlet thereof adapted for communication with the main inlet of the device and the outlet thereof adapted for communication with an intermediate conduit, the pump element having the inlet thereof adapted for communication with the intermediate conduit and the outlet thereof adapted for communication with the main outlet of the device, in a first aspect that improvement comprising ducting extending from the intermediate conduit to a fluid drain and valving within the ducting and responsive to fluid pressure in either the main inlet or the main outlet for maintaining the fluid in the intermediate conduit at a pressure bearing a predetermined relationship to the pressure of fluid in the main inlet or main outlet. In a second aspect, a device having valving and ducting as above described and in which elements are pistons carried by a rotor mounted within a housing and the intermediate conduit is an annular chamber defined by the rotor and housing within which pistons are located during rotation of the rotor. In a third aspect, in which a second chamber surrounds the shaft on which the rotor is mounted, that improvement wherein the annular chamber is maintained at one pressure level and fluid in the second chamber is maintained at a second, significantly lower pressure level.

42 Claims, 7 Drawing Figures



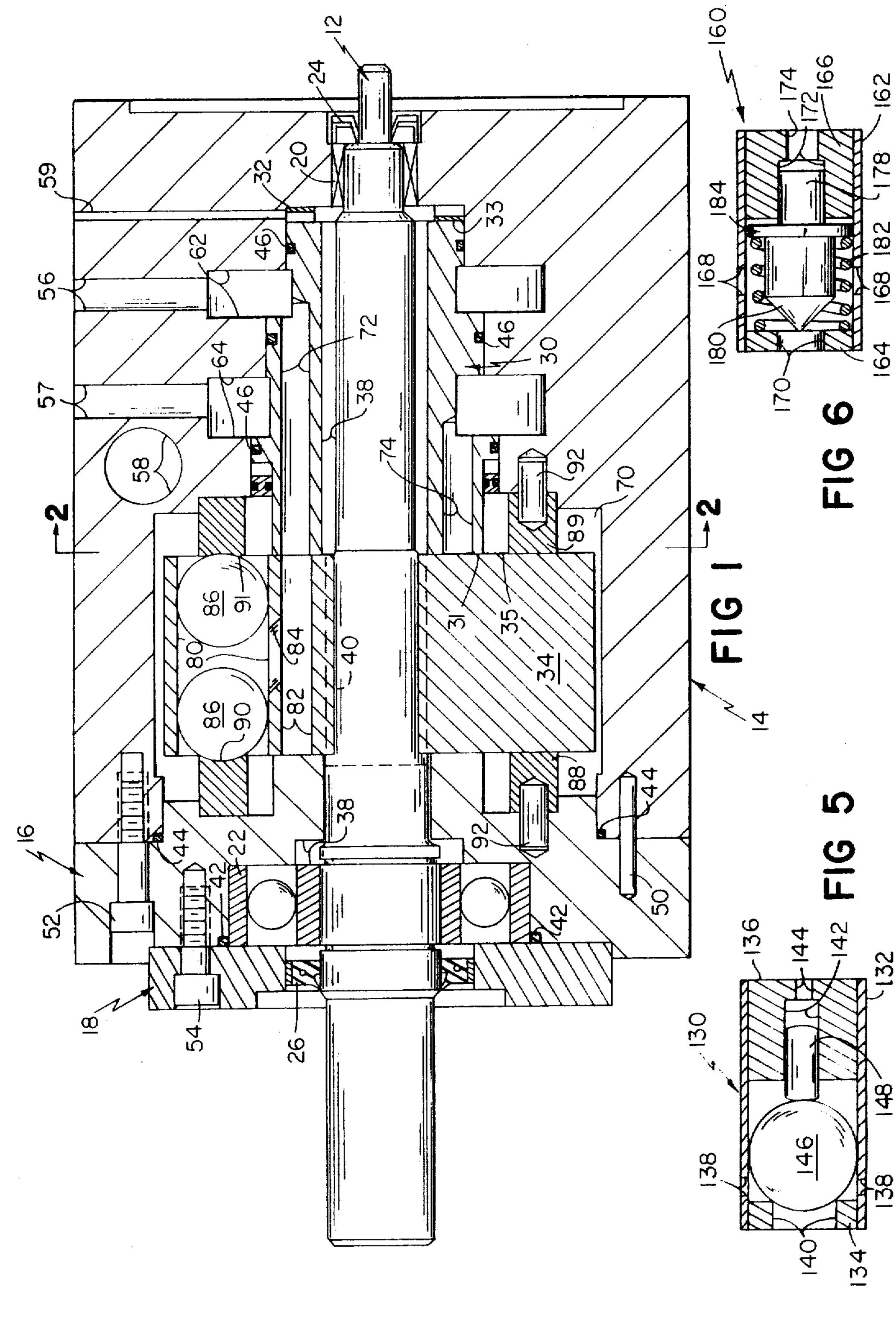


FIG 1

FIG 5

FIG 6

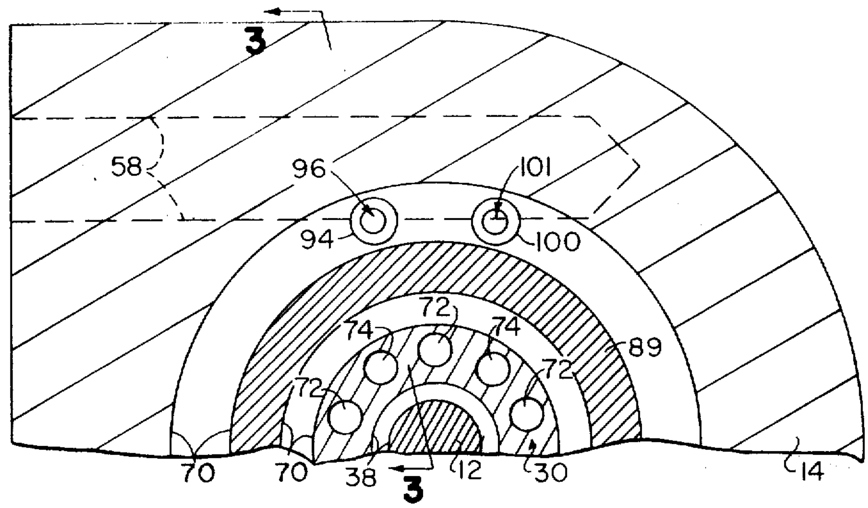


FIG 2

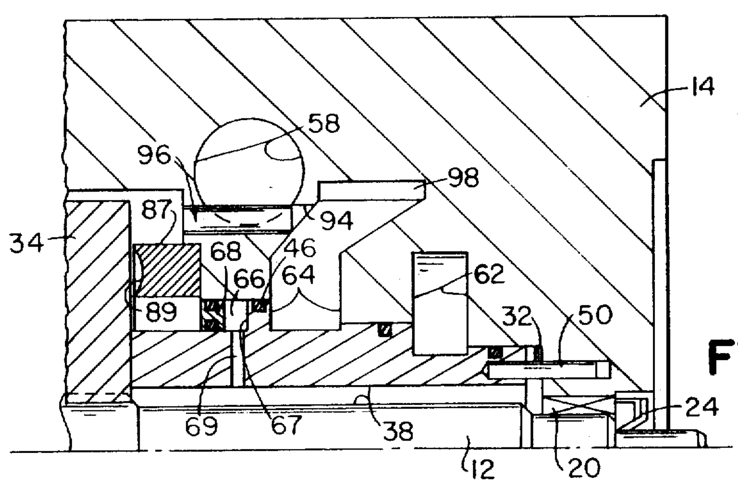


FIG 3

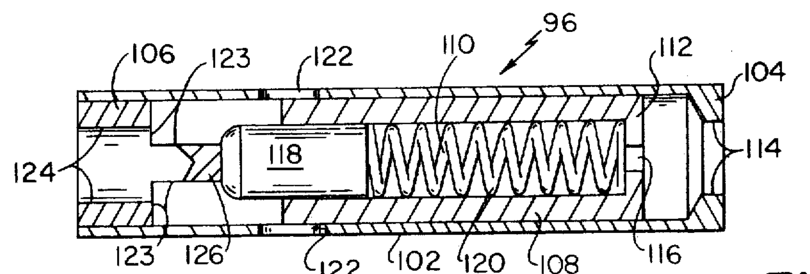
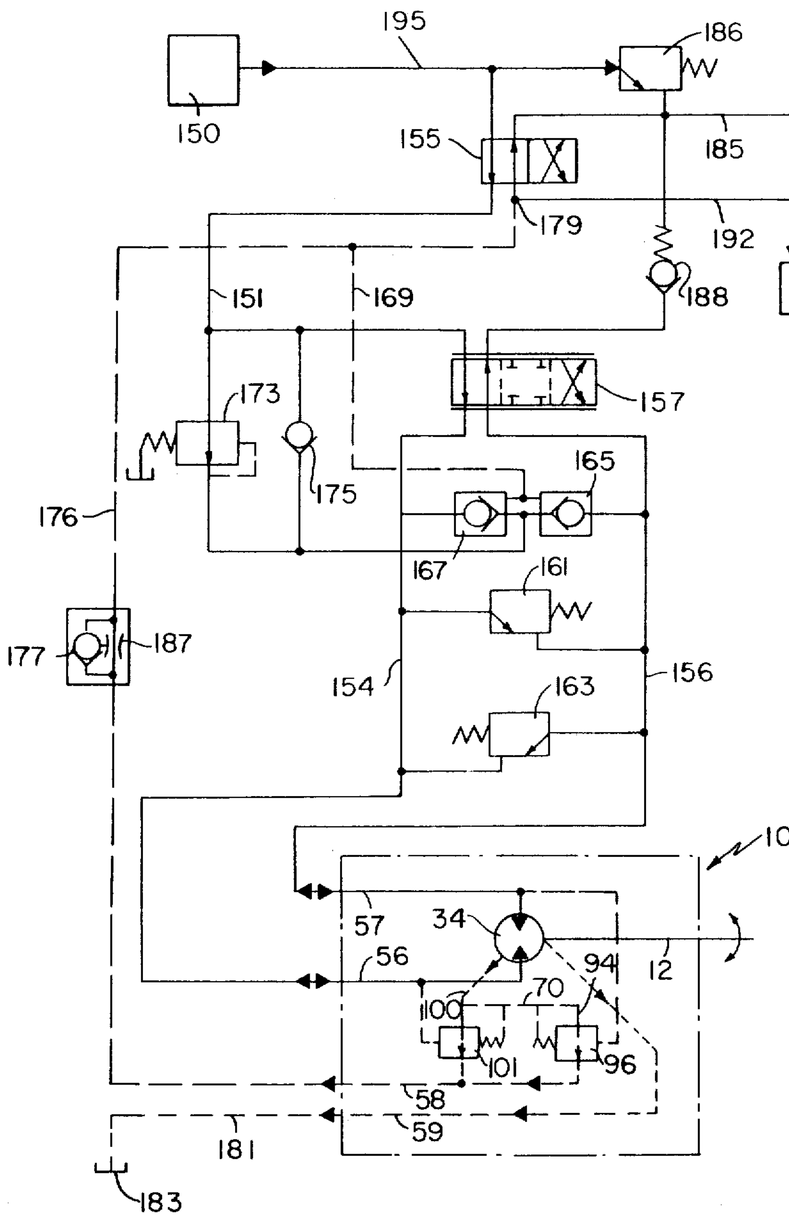


FIG 4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183

FIG 7

FLUID PRESSURE CONTROLLING

This invention relates to fluid devices.

It is a principal object of one aspect of the invention to provide a high gain fluid device in which the differential pressure across any operating element is kept at a minimum. In a second aspect, a principal object is to eliminate stuttering or jumping of pistons on their track during rotation of the device. A principal object of a third aspect is to eliminate the need for high pressure shaft seals. Other objects include providing during working of the device an outward piston bias force that is either constant or bears a predetermined relationship to one of the working fluid pressures, and providing an override for causing free-wheeling of the device.

In its first aspect, the invention features, in a rotary fluid device of the type comprising two elements, one of which is capable of operation as a fluid pump and the other of which is capable of operation as a fluid motor, and which are coupled to a common shaft, the motor element having the inlet thereof adapted for communication with the main inlet of the device and the outlet thereof adapted for communication with an intermediate conduit, the pump element having the inlet thereof adapted for communication with the intermediate conduit and the outlet thereof adapted for communication with the main outlet of the device, that improvement comprising ducting extending from the intermediate conduit to a fluid drain, and valving within the ducting and responsive to fluid pressure within one of the main inlet and main outlet for maintaining the fluid in the intermediate conduit at a pressure bearing a predetermined relationship to the pressure of fluid in the one. In a second aspect there is featured, a device having valving and ducting as above described and in which the elements are pistons carried by a rotor mounted within a housing and the intermediate conduit is an annular chamber intermediate the rotor and housing in which the pistons are located during rotation of the rotor. In a third aspect, the invention features maintaining the annular chamber at one pressure level and maintaining a second chamber surrounding the shaft on which the rotor is mounted at a significantly lower, preferably substantially atmospheric, pressure level. Preferred embodiments feature, in devices including all three aspects and in which the elements are capable of operation as pumps and motors, maintaining the pressure in the annular chamber a predetermined amount below the lesser of the pressure levels of the main inlet and main outlet and providing override means for maintaining the annular chamber pressure level at a level not less than that of the pressure level of a selected one of the main inlet and main outlet.

Other objects, features and advantages will become apparent from the following detailed disclosure of a preferred embodiment of the invention, taken together with the attached drawings, in which:

FIG. 1 is a longitudinal cross-sectional view of a rotary fluid motor constructed in accordance with the present invention;

FIG. 2 is a partial transverse cross-section of the motor of FIG. 1 taken at 2—2 of FIG. 1;

FIG. 3 is a partial longitudinal cross-section of the motor of FIG. 1 taken at 3—3 of FIG. 2;

FIG. 4 is a longitudinal sectional view of a pressure control valve of the motor of FIG. 1;

FIG. 5 is a longitudinal sectional view of a second form of pressure control valve;

FIG. 6 is a longitudinal sectional view of a third form of pressure control valve; and

FIG. 7 is a diagrammatic view of a fluid control circuit useful with the motor of FIG. 1.

Referring more particularly to the drawings, there is illustrated a rotary fluid motor comprising an output shaft 12 extending coaxially through a multi-part housing including, in coaxial alignment, a cylindrical main housing 14, a cylindrical support housing section 16 and end plate 18. At one end of the housing, output shaft 12 is journaled within a roller bearing 20 (whose inner face engages the shaft periphery and whose outer face engages the inner wall of housing section 14); and

the other end of the housing, shaft 12 is journaled within a ball bearing 22 (whose inner face engages the shaft periphery and whose outer face engages the inner wall of housing section 16. Rubber lip seals 24, 26 are provided intermediate and prevent leakage between shaft 12 and, respectively, housing section 14 and end plate 18.

A stepped cylindrical fluid distribution manifold 30 and rotor 34 are mounted within annular cavities within main housing 14 and surrounding shaft 12. One axial face 35 of rotor 34 is in face-to-face engagement with the adjacent face 31 of manifold 30. A wave washer 32 engages the other axial face 33 of manifold 30 and the portion of main housing 14 defining the adjacent end wall of the cavity. Rotor 34 is fixed on shaft 12 for rotation therewith by spline 40.

The inner cylindrical surfaces of housing 14, manifold 30 and housing section 16 are of slightly greater diameter than are the portions of the outer peripheral surface of shaft 12 they respectively surround, thereby providing an annular chamber 38 about the shaft. Communication between the portions of chamber 38 on opposite sides of rotor 34 is provided by interstitial passages of spline 40.

The various interfaces between parts of the motor, that is, the interfaces between end plate 18 and support section 16, the interface between support section 16 and main housing 14, and the interfaces between main housing 14 and manifold 30, are sealed with a plurality of O-rings designated 42, 44, and 46 respectively. Pins 50 and bolts 52 and 54 locate and prevent relative rotation of manifold 30 and housing 14, housing 14 and housing section 16, and end plate 18 and housing section 16 respectively.

Main housing 14 includes drilled inlet, outlet, main drain and shaft drain conduits, designated 56, 57, 58 and 59, respectively, extending through the wall of the main housing section. The outer portion of each conduit is tapped for receiving fluid couplings. A pair of axially spaced, radially inwardly facing annular channels 62, 64 are provided in housing section 14 at the periphery of manifold 30. Inlet conduit 56 communicates at its inner end with channel 62, and outlet conduit 57 communicates at its inner end with channel 64. Shaft conduit 59 communicates at its inner end with the annulus in which wave washer 32 is mounted.

An annular chamber 66, defined by an annular seal 68 and adjacent portions of manifold 30 and housing section 14, surrounds manifold 30 adjacent the annular surface 67 thereof facing but spaced from rotor 34, with surface 67 providing one end wall of chamber 66. Seal 68 comprises an aluminum ring having radially inwardly and outwardly facing circumferential recesses in which are mounted O-rings. A drilled conduit 69 extends from chamber 66 through the radial thickness of manifold 30 to chamber 38.

A total of six drilled conduits 72, arranged in a ring and spaced at regular 60° intervals therearound extend axially within manifold 30 from surface 31 to channel 62. A total of six additional drilled conduits 74, extending axially within manifold 30 from surface 31 to channel 64, are provided in the ring, spaced midway between adjacent ones of conduits 72.

Rotor 34 includes a total of ten cylindrical bores 80 and 10 cylindrical conduits 82 (arranged in a ring within the rings of bores 80) extending axially through the full thickness of the rotor. The bores and ports of each ring are evenly spaced about the circumference of the ring with one port 82 and one bore 80 from each of the two rings in radial alignment. The ring of ports 82 of rotor 34 and of conduits 72, 74 of manifold 30 are of equal diameter. A drilled conduit 84 extends from each port 82 to the bore 80 aligned therewith. Two steel balls 86 are fitted within each of bores 80 for movement within the bore.

As shown, an annular chamber 70, of substantially U-shaped cross-section and defined by adjacent surfaces of rotor 34, housing 14 and housing section 16, surrounds the portion of rotor 34 including bores 80 and balls 86. An annular wave cam 88, 89 including circular undulating ball-engaging surface

90, 91 is mounted on each axial side of rotor **34**, coaxially therewith, with the ball-engaging surfaces **90**, **91** of each cam engaging one of the balls **86** in each bore **80**. Each ball-engaging surface **90**, **91** is a trapezoidal acceleration cam surface comprising alternating parabolic and intermediate fairing sections. The period of the cam is 60° (that is, each entire annular surface includes **6** substantially identical complete cycles each having one high point or peak and one low point or valley) and its total amplitude (peak-to-valley) is slightly less than one-half the diameter of one of balls **86**. The high points of each are aligned midway between conduits **72** and **74**. Pins **92** hold each cam in position relative to the housing.

Referring now to FIGS. **2** and **3**, a cylindrical duct **94**, in which is provided a control valve **96**, extends from chamber **70** through the lower portion of main drain conduit **58** to a gallery **98** connected to and extending radially outwardly from channel **64**. A second, identical, duct **100** in which is provided an identical control valve **101**, extends (circumferentially spaced **30°** from duct **94**) from chamber **70** through main drain conduit **58** to a gallery (not shown) connected to and extending outwardly from channel **62**. Control valve **96** (see FIG. **4**) includes a tubular body **102**, closed at one end by end wall **104** and at its other end by a valve seat **106** press-fitted therewithin, and a cylindrical piston **108** movably fitted within body **102**. A coaxial cylindrical recess **110** extends most of the length of piston **108**, terminating at axial end wall **112** at the end of piston **108** nearest end wall **104**. An inlet opening **114** and a damping orifice **116** extend coaxially through end walls **104**, **112**, respectively. A cylindrical pin **118**, one end of which engages seat **106**, is movably fitted partially within recess **110**. A helical spring **120** within recess **110** engages end wall **112** and the adjacent end of pin **118**. Four circular openings **122**, spaced circumferentially at 90° intervals, extend through the side wall of body **102** at a distance slightly greater than the overall length of piston **108** from end wall **104**. At least two of openings **122** communicate with drain conduit **58**. Seat **106** comprises a cylinder which has been relieved, along opposite sides thereof, for about one-half its length, the relieved sections **123** being in cross-section circular segments. A drilled hole **124** extends, from the unrelieved end of the seat, approximately four-fifths the overall length of the seat, connecting with the relieved portions and leaving, at the end of seat **106** nearest piston **108**, a diametrically extending bar **126** engaging pin **118**.

In operation, fluid is introduced, at high pressure (typically 1,000 p.s.i.), into the motor through conduit **56** and exits from the motor, at low pressure (typically about 500 p.s.i.), through conduit **57**. A power stroke of the balls **86** within a bore **80** commences when the balls engage a crest or high point of the ball-engaging surfaces **90**, **91** of wave cams **88**, **89** and, therefore, are in their nearest relative position. With the balls in this position, the rotor port **82** associated with the bore communicates with the end of the conduit **72** that is adjacent to the high point of wave cam **89**. High pressure fluid from inlet conduit passes from the inlet through annular channel **62**, conduits **72** of manifold **30**, rotor port **82** and rotor conduit **84** into the bores **80**, thereby forcing the balls within the bore away from each other against the ball-engaging surfaces **90**, **91** of wave cams **88**, **89**. The force of the balls against the ball-engaging surfaces imparts a torque to and causes rotation of rotor **34**. As the rotor rotates, balls **86** roll down the slopes of the ball-engaging surfaces with which they are in contact, the balls within each bore **80** thereby moving apart. When, after 30° rotation of rotor **34**, the balls have reached their most distant relative position, rotor port **82** moves out of communication with conduit **72** and into communication with adjacent conduit **74** in manifold **30**. Conduit **74** is connected, through channel **64** to low pressure fluid outlet conduit **57**. During the next 30° rotation of rotor **34**, balls **86** roll up the slopes of ball-engaging surfaces **90**, **91** thereby moving together and discharging fluid from the bore **80** into the outlet.

The control valves in ducts **94**, **100** maintain the leakage fluid in chamber **70** at a pressure, P_3, that is a predetermined amount below the lesser of the pressures P_1, P_2 of the fluid in chambers **62** and **64** respectively, so that balls **86** will always be biased outwardly against surfaces **90**, **91**. As is evident, control valve **96** is open when, as viewed in FIGS. **3** and **4**, piston **108** has moved all the way to the right, permitting fluid in chamber **70** to flow through hole **124** in seat **106** and, exiting from valve **96** through the openings **122** communicating with connecting duct **58**, the main drain. The force tending to move piston **108** toward its open position is equal to that exerted by spring **120** plus that exerted by fluid from chamber **70** against the end of piston **108** surrounding pin **118**. Tending to move piston **108** in the opposite direction is the force exerted by fluid entering body **102** through opening **114** against a portion (having an area equal to that of the piston end surrounding pin **118**) of piston end **112**. Thus, valve **96** will maintain a differential between pressure P_3 and the lesser of pressures P_1 and P_2 that depends only on the force exerted by spring **120**. If, as in the preferred embodiment, the desired differential is **50** psi, the spring is chosen so that it, when the valve opens, exerts a force F equal to 50 times the area, in square inches, of the end of piston **108** surrounding pin **118**.

The control valve connected to the greater of pressures P_1, P_2 will at all times be closed. Thus, if channel **62** is always connected to high inlet pressure, duct **100** and the control valve **101** therein may be eliminated. Provision of a control valve in ducts leading to each of the channels **62**, **64**, however, makes the motor completely reversible.

Reference is now made in FIG. **7** which diagrammatically illustrates a preferred fluid control circuit useful with motor **10**. In the configuration shown, high pressure fluid from pressure source **150** flows through a four-way, two-position valve **155** and an infinitely adjustable, three-position, four-way valve **157** to the line **154** connected to high pressure inlet conduit **56**; and returns from motor **10**, at lower pressure, to reservoir **152** through line **156**, valve **157**, and back-pressure check valve **188**. A pair of cross-over pressure relief valves **161**, **163** are connected in parallel, in opposed relationship, between lines **154**, **156** to maintain the pressure differential between the lines at or below a predetermined level, in the preferred embodiment 1,250 p.s.i.d. Also connected between lines **154**, **156**, opposed and in series, are a pair of pilot operated check valves **165**, **167**. A 50 p.s.i.g. pressure reducing valve **173** is mounted in a line extending from the junction between the check valve **165**, **167** to the high pressure supply line **151** upstream of valve **157**. A check valve **175** is connected in parallel with valve **173** to bypass reverse flow around valve **173** when check valves **165**, **167** are piloted to the open condition.

A drain line **181** extends from drain conduit **59** to a sump **183**, generally one and the same as reservoir **152**. A control line **176**, in which a check valve **177** and a restriction **187** (0.1 g.p.m. nominal flow at 1,250 p.s.i.d.) are mounted in parallel, extends from motor main drain **58** to a port **179** of valve **155**. A second control line **169** extends from the pilot connection of check valves **165**, **167** to control line **176**, upstream of valve **177** and restriction **187**.

Valve **155** is connected to main reservoir **152** through line **185**. A 1,250 p.s.i.g. system relief valve **186** is provided between line **185** and high pressure line **195** upstream of valve **155**. A back pressure check valve **188**, with a 65 p.s.i.d. bias, is provided in the line extending from valve **157** to line **185**. A high speed fluid motor **194** or if desired a pressure relief valve (not shown), is connected by lines **190** and **192** respectively, to line **185** and port **179**.

As previously indicated, the direction of rotation of rotor **34** of motor **10** can be reversed by introducing high pressure fluid into the motor through conduit **57**, rather than conduit **56**. This is done, in the preferred embodiment, by adjusting valve **157** so that fluid flows from line **151** into line **156**, rather than into line **154** as shown in FIG. **7**. Valve **157** also permits the flow rate, for either direction of rotor rotation, to be varied continuously between no-flow and full-flow.

In some circumstances, it is desirable to stop effective working of motor **10** by making rotor **34** free-wheeling. In the motor of FIG. 1, this can be done by raising the fluid in chamber 70 to a pressure level that is at least as great as (assuming little or no pressure loss in the motor itself) in conduits 56 and 57, thereby forcing balls 86 inwardly into the rotor, away from cams 88, 89. Using the control system of FIG. 7, free-wheeling is achieved by moving valve 155 from the configuration illustrated to its other position, in which high pressure fluid flows through the valve to port 179, most of the fluid from source 150 flowing to motor 194 and very small fluid volume flowing through restriction 187 to chamber 70. As shown, high fluid pressure is applied, through line 169, to the pilot connection of check valves 165, 167, opening the check valves and permitting any fluid trapped within rotor 34 to quickly flow therefrom through check valve 175, back through line 151 and valve 155, and through line 185 to reservoir 152.

FIG. 6 illustrates another form of control valve 160 for maintaining chamber 70 at a pressure which is a predetermined number of psi below the lesser of pressures P_1, P_2. Control valve 160 comprises a tubular body 162, each end of which is closed by end plugs, designated 164, 166 respectively, and within which a circular in cross-section plunger is coaxially mounted for movement axially within body 162. Four equally spaced drain openings 168, the axes of which lie in a common plane perpendicular to the axis of body 162, extend through the cylindrical wall of body 162. A drilled opening 170 extends through plug 164; a stepped cylindrical opening having inner portion 172 of diameter equal to that of opening 170 and outer lesser diameter portion 174 extends coaxially through plug 166. A cylindrical stem portion 178 of the plunger is slip-fitted within opening portion 172. The conical head 180 of the plunger is of diameter slightly greater than that of opening 170. A helical spring 182 surrounds the head 180 and a portion of the plunger body, one end of the spring engaging the inner surface of plug 164 and the other end of the spring engaging an annular stop ring portion 184 of the plunger. Valve 160 is closed when head 180 is seated over opening 170 and, as the cross-sectional areas of opening 170 and stem 178 are equal, operates to maintain a differential between pressure P_3 and the lesser of pressures P_1, P_2 that depends only on the force exerted by spring 182.

In some working environments, it is desirable to maintain chamber 70 at a pressure P_3 which is a predetermined fraction of, rather than a predetermined number of psi below, the lesser of pressures P_1, P_2. In such circumstances, control valve 130 (see FIG. 5) is substituted for the control valves 96 and 101 in ducts 94, 100. Control valve 130 comprises a tubular body 132 each end of which is closed by end plugs 134, 135 and through the cylindrical wall of which four equally circumferentially spaced drain openings 138 extend. A drilled opening 140 extends through plug 134; a stepped circular opening having inside greater diameter portion 142 and outer lesser diameter portion 144, extends through plug 136. A ball 146 is mounted within body 132 intermediate plugs 134, 136; and a pin 148, one end of which engages ball 146, is movably fitted within portion 142 of plug 136. Valve 130 is closed when ball 146 is seated over opening 140, and is open when ball 146 is spaced from plug 134. The valve operates to maintain pressure P_3 at such a level that:

$$P_3 = P_r \frac{(A_{148})}{(A_{140})},$$

wherein P_r is the lesser of pressures P_1 and P_2, A_{140} is the cross-sectional area of opening 140 and A_{148} is the cross-sectional area of pin 148.

Chamber 38 is connected to an atmospheric pressure sump (not shown) through conduit 59, and the pressure of fluid in chamber 38, and in chamber 66 which is connected to it through conduit 69, is substantially zero.

As should be apparent from the foregoing, each of balls 86 alternatively acts as a motor driving piston (during the period of time when the bore 80 of the respective piston is connected to high pressure inlet conduit 56 and the high pressure fluid forces the piston outwardly against its respective cam 90, 91, thereby causing rotation of rotor 34), and as a pumping piston (during the period of time when the bore 80 is connected to low pressure outlet conduit 57 and the respective cam 90, 91 forces the ball inwardly into its bore). During motor driving, the outward movement of the ball 86 forces fluid from the outer portion of the respective bore 80 into chamber 70; during pumping, fluid flows from chamber 70 into the respective bore 80. Thus, it will be seen that, at any time during working and with reference to any pair of balls 86 (one of which is acting as a motor driver and the other of which is acting as a pumper) chamber 70 acts as a conduit between the outlet of the motor driving ball and the inlet of the pumping ball. The inlet of the motor driving ball is, of course, connected to inlet 56, and the outlet of the pumping ball is connected to outlet 57.

Accordingly, the operation of the entire motor is substantially equivalent to that produced by coupling two differential elements (such as gear or gerotor motors) to a common shaft (here shaft 12), connecting the inlet of one element to the main fluid inlet (here inlet 56), connecting the outlet of the other element to the main fluid outlet (here outlet 57), and providing controlled pressure intermediate conduit (here chamber 70 the fluid pressure in which is controlled by the ducting and valving previously described) to which the outlet of the one element and the inlet of the other element are connected. In the disclosed motor, all elements are capable of operation as either pumps or motors. In an equivalent device, the element whose inlet is connected to the main inlet must be capable of operation as a motor and the element whose outlet is connected to the main outlet must be capable of operation as a pump. If reversibility is desired, both elements must be capable of operation, as in the disclosed motor, as either pumps or motors.

Other embodiments within the scope of the following claims will occur to those skilled in the art.

What is claimed is:

1. In a fluid device of the type including within a housing an output shaft, a cam and a rotor mounted coaxially of the shaft for relative rotation, a plurality of pistons engaging the cam carried by the rotor for movement relative thereto, fluid means including a fluid inlet and a fluid outlet for selectively forcing the pistons against the cam to cause relative rotation of the cam and rotor, and an internal chamber defined by adjacent portions of the device generally surrounding portions of the rotor carrying the pistons and portions of the cam engaging the pistons, that improvement comprising:

a fluid drain outlet;

ducting extending from said chamber to said fluid drain; and

valving within said ducting and responsive to fluid in one of said fluid inlet and said fluid outlet for permitting fluid flow from said chamber to said drain when the pressure of fluid within said chamber is greater than a pressure bearing a predetermined relationship to the pressure of said fluid within said one, and preventing said fluid flow when said pressure of said fluid within said chamber is not greater than said pressure bearing a predetermined relationship.

2. In fluid apparatus including

first and second differential elements each capable of operation as one of a fluid motor and a fluid pump,

a rotatable member to which said elements are coupled,

a main fluid inlet,

a main fluid outlet, and

an intermediate fluid conduit,

said first element having the inlet thereof adapted for communication with said main inlet and the outlet thereof adapted for communication with said intermediate conduit,

said second element having the inlet thereof adapted for communication with said intermediate conduit and the outlet thereof adapted for communication with said main outlet, and, the displacement of each of said elements per revolution of said member being substantially equal, that improvement comprising:

ducting extending from said intermediate conduit to a fluid drain; and,

a controller responsive to fluid in one of said main inlet and said main outlet for regulating fluid flow from said intermediate conduit to said drain to maintain the pressure of fluid within said intermediate conduit at a pressure level bearing a predetermined relationship to the pressure of said fluid within said one.

3. The apparatus of claim 2 wherein said first element is capable of operation as a pump, said second element is capable of operation as a motor, said first and second elements are of substantially equal displacement, and said controller comprises valving within said ducting for permitting fluid flow from said intermediate conduit to said drain when said pressure of fluid within said conduit is greater than said pressure level and preventing said fluid flow when said pressure of fluid within said conduit is not greater than said pressure level.

4. The apparatus of claim 2 comprising a device wherein said member is an output shaft and including a cam and a rotor mounted coaxially of the shaft for relative rotation, each of said elements being a piston engaging the cam and carried by the rotor for movement relative thereto, and said conduit being an internal chamber defined by adjacent portions of the apparatus generally surrounding the portions of the rotor carrying the pistons and the portions of the cam engaging the pistons.

5. The device of claim 4 wherein said controller includes valving within said ducting and responsive to fluid in one of said inlet and said outlet for permitting fluid flow from said chamber to said drain when the pressure of fluid within said chamber is greater than a pressure bearing a predetermined relationship to the pressure of said fluid in said one, and preventing said fluid flow when said pressure of said fluid within said chamber is not greater than said pressure bearing a predetermined relationship.

6. The device of claim 4 wherein said shaft and adjacent portions of said apparatus define a generally annular chamber extending coaxially of said shaft, at least one end portion of said annular chamber being defined by an annular seal surrounding said shaft, and including means for maintaining the fluid in said annular chamber at a level of pressure substantially less than the pressure of fluid in said internal chamber during working.

7. The device of claim 6 wherein said means maintains fluid in said annular chamber at a level of pressure not substantially greater than atmospheric pressure and said controller maintains fluid in said internal chamber at a level of pressure bearing a predetermined relationship to the pressure of fluid in one of said inlet and outlet during said working.

8. The device of claim 5 wherein said valving permits said flow when said pressure within said chamber is greater than a predetermined number of p.s.i. below said pressure of said fluid in said one.

9. The device of claim 8 wherein said valving includes a valving member movable between a first position wherein said valving permits said flow and a second position wherein said valving prevents said flow and a spring engaging said valving member and exerting thereupon a force tending to move said member towards said first position, said valving member defining a pair of oppositely facing valving surfaces, the effective area of each of said surfaces projected on planes perpendicular to the direction of movement of said member being equal.

10. The device of claim 9 wherein said valving includes a tubular body member having at least one port in the circumferential surface thereof, and said valving member is mounted within said body member, said valving member being positioned over said port in said second position and being spaced from said port in said first position.

11. The device of claim 10 wherein said valving surfaces are annular and lie in planes perpendicular to said direction.

12. The device of claim 5 wherein said valving permits flow when said pressure of fluid in said chamber is greater than a predetermined fraction of said pressure of fluid in said one.

13. The device of claim 12 wherein said valving includes a valving member movable between a first position wherein said valving permits said flow and second position wherein said valving prevents said flow and defines a pair of generally oppositely facing valving surfaces, the ratio of the effective areas of said surfaces projected on planes perpendicular to the direction of movement of said member being equal to said predetermined fraction.

14. The device of claim 5 including valving responsive to each of said fluid inlet and said fluid outlet for permitting said fluid flow when said pressure within said chamber is greater than a pressure bearing a predetermined relationship to the lesser of the pressure of fluid within said inlet and the pressure of fluid within said outlet.

15. The device of claim 14 wherein said device defines a first valving conduit extending from said chamber to said inlet, a second valving conduit extending from said chamber to said outlet, each of said valving conduits communicating with said drain, and a valve within each of said conduits, each of said valves being responsive to the pressure of fluid in the respective one of said inlet and outlet for permitting fluid flow through said each valve to said drain when said pressure in said chamber is greater than a predetermined number of psi below the pressure of fluid in said respective one.

16. The device of claim 15 wherein at least one of said valves comprises a tubular body member having at least one port in the cylindrical wall thereof, a valving member mounted therein for movement between a first position spaced from said port and a second position overlying said port, and a spring engaging said valving member and exerting thereupon a force tending to move said valving member towards said first position, said valving member defining a pair of oppositely facing valving surfaces, the effective area of each of said surfaces projected on planes perpendicular to the direction of movement of said valving member being equal.

17. The device of claim 16 wherein said valving surfaces are annular and line in planes perpendicular to said direction.

18. The device of claim 14 wherein said device defines a first valving conduit extending from said chamber to said inlet, a second valving conduit extending from said chamber to said outlet, each of said valving conduits communicating with said drain, and a valve within each of said conduits, each of said valves being responsive to the pressure of fluid in the respective one of said inlet and outlet for permitting fluid flow through said each valve to said drain when said pressure in said chamber is greater than a predetermined fraction of the pressure of fluid in said respective one.

19. The device of claim 18 wherein at least one of said valves comprises a tubular body member having at least one port in the cylindrical wall thereof and a valving member movable between a first position wherein said valve permits flow from said chamber to said drain and a second position when said valve prevents flow from said chamber to said drain, said valve defining a pair of generally oppositely facing surfaces, the ratio of the effective areas of said surfaces projected on planes perpendicular to the direction of movement of said member being equal to said predetermined fraction.

20. In a fluid device of the type including within a housing an output shaft, a cam and a rotor mounted for relative rotation coaxially of the shaft, a plurality of pistons engaging the cam carried by the rotor for movement relative thereto, and fluid means including a fluid inlet and a fluid outlet for selectively forcing the pistons against the cam to cause relative rotation of the cam and rotor, that improvement wherein:

said shaft and adjacent portions of said device define a first generally annular chamber extending coaxially of said shaft, at least one end portion of said first chamber being defined by an annular seal surrounding said shaft,

adjacent portions of said housing, rotor and other components of said device define a second generally annular chamber generally surrounding portions of said rotor carrying said pistons and portions of said cam engaging said pistons; and

said device includes means for maintaining fluid in said first chamber at a level of pressure substantially less than the pressure of fluid in said second chamber during working of said device.

21. The device of claim **20** wherein said means maintains fluid in said first chamber at a level of pressure not substantially greater than atmospheric pressure and maintains fluid in said second chamber at a level of pressure bearing a predetermined relationship to the pressure of fluid in one of said inlet and outlet during said working.

22. The device of claim **20** wherein said means includes first chamber ducting connecting said first chamber to a drain outlet, said drain outlet being maintained at a level of pressure that is less than the pressure of fluid within said inlet and outlet.

23. The device of claim **22** wherein said means includes second chamber ducting extending from said second chamber to a drain outlet and a valve within said second chamber ducting responsive to fluid in one of said inlet and outlet for permitting fluid flow from said second chamber through said valve when the pressure of fluid within said second chamber is greater than a pressure bearing a predetermined relationship to the pressure of fluid within said one and preventing said flow when said pressure of fluid within said chamber is less than pressure bearing a predetermined relationship.

24. The device of claim **23** wherein said valve permits said flow when said pressure within said chamber is greater than a predetermined number of psi below said pressure of fluid in said one.

25. The device of claim **24** wherein said valve includes a valving member movable between a first position wherein said valve permits said flow and a second position wherein said valve prevents said flow and a spring engaging said valving member and exerting thereupon a force tending to move said member towards said first position, said valving member defining a pair of oppositely facing valving surfaces, the effective area of each of said surfaces projected on planes perpendicular to the direction of movement of said member being equal.

26. The device of claim **23** wherein said valve permits said flow when said pressure within said second chamber is greater than a predetermined fraction of said pressure of fluid in said one.

27. The device of claim **26** wherein said valve includes a valving member movable between a first position wherein said valve permits said flow and a second position wherein said valve prevents said flow and defines a pair of generally oppositely facing valving surfaces, the ratio of the effective areas of said surfaces projected on planes perpendicular to the direction of movement of said member being equal to said predetermined fraction.

28. The device of claim **5** including override means for maintaining the pressure of fluid in said chamber at a level of pressure not less than the pressure of fluid in a selected one of said inlet and said outlet.

29. The device of claim **28** wherein said override means is operative for maintaining said pressure in said chamber at a pressure greater than the pressure of fluid in said fluid inlet and said fluid outlet whereby said fluid in said chamber forces said pistons out of engagement with said cam.

30. In combination with a fluid device of the type including within a housing an output shaft, a cam and a rotor mounted coaxially of the shaft for relative rotation, a plurality of pistons engaging the cam carried by the rotor for movement relative thereto, fluid means including a fluid inlet and a fluid outlet for selectively forcing the pistons against the cam to cause relative rotation of the cam and rotor, and an internal chamber defined by adjacent portions of the device generally surrounding the portions of the rotor carrying the pistons and portions of the cam engaging the pistons, that improvement wherein:

said device includes a fluid drain outlet and ducting extending from said chamber to said fluid drain outlet; and,

control means for regulating flow of fluid in said ducting to maintain the pressure of flow of fluid within said chamber at a pressure level bearing a predetermined relationship to the pressure of fluid within at least one of said fluid inlet and said fluid outlet.

31. The combination of claim **4** wherein said controller is operative for maintaining said pressure within said chamber at a pressure level greater than the pressure within said fluid inlet and outlet.

32. The combination of claim **4** wherein said controller is operative for maintaining said pressure within said chamber at a pressure level that is a selected one of a pressure level greater than the pressure within said fluid inlet and outlet and a pressure level less than the pressure within said fluid inlet and outlet.

33. The combination of claim **32** wherein said controller is operative for reducing the pressure of fluid in at least one of said fluid inlet and outlet.

34. The combination of claim **4** wherein said controller includes valving within said ducting and responsive to fluid in one of said fluid inlet and said fluid outlet for maintaining the fluid within said chamber at a pressure less than and bearing a predetermined relationship to the pressure of fluid within said one, and override means for maintaining the pressure of the fluid within said chamber at a pressure greater than said pressure within said one.

35. The combination of claim **34** wherein said override means is operative for reducing the pressure of fluid within said one.

36. The combination of claim **34** wherein said override means is operative for maintaining the pressure of the fluid within said chamber at a pressure greater than the pressure within said fluid inlet and said fluid outlet.

37. The device of claim **3** including valving responsive to pressure of fluid in each of said main inlet and said main outlet for permitting said fluid flow when said pressure within said intermediate conduit is greater than a pressure bearing a predetermined relationship to the lesser of the pressure within said main inlet and the pressure of fluid within said main outlet.

38. The device of claim **37** wherein each of said elements is capable of operation as a pump and as a motor.

39. The device of claim **38** including a cam and a rotor mounted coaxially of said shaft for relative rotation, and wherein each of said elements comprises a piston engaging said cam and carried by said rotor for movement relative thereto.

40. The device of claim **3** wherein said valving permits said flow when said pressure of fluid in said intermediate conduit is greater than a predetermined fraction of said pressure of fluid in said one.

41. The device of claim **3** wherein said valving permits said flow when said pressure of fluid in said intermediate conduit is greater than a predetermined number of p.s.i. below said pressure of said fluid in said one.

42. The device of claim **3** including override means for maintaining the pressure of fluid in said chamber at a level of pressure not less than the pressure of fluid in a selected one of said inlet and said outlet.

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