United States Patent

Forster

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[54] **HYDROSTATIC MACHINE**

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[51] **Int. Cl.**..........................**F16h 39/02, F16h 39/10**

[58] **Field of Search**.....60/53 A, 52 US, DIG. 5, 53 R

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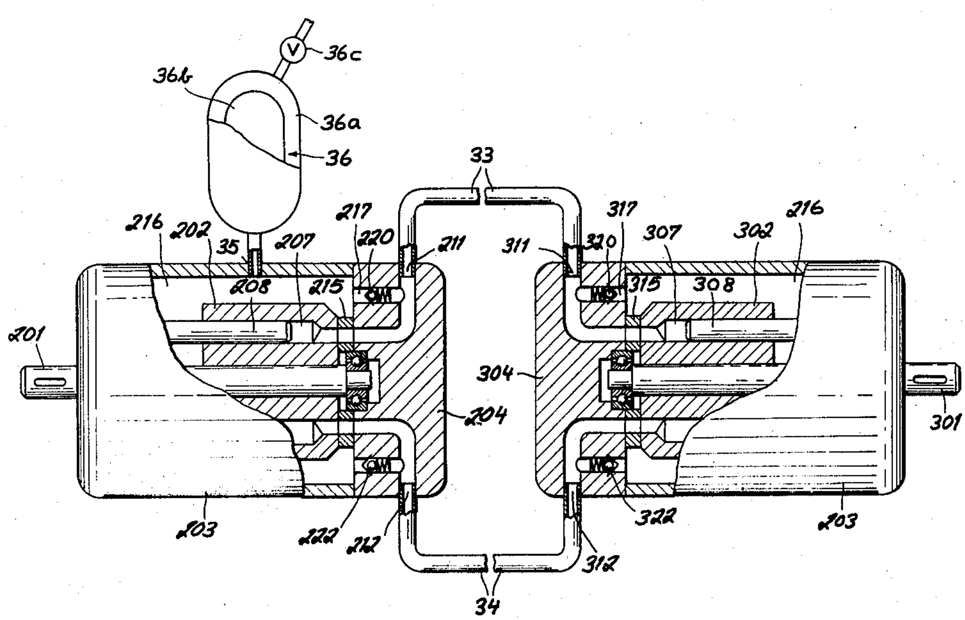
[57] **ABSTRACT**

A hydrostatic machine, e.g. a hydrostatic pump or hydrostatic motor operating in a closed fluid circuit and having a housing into which leakage of the hydraulic medium can occur, is provided with check valves communicating between the housing and the main ports to enable leakage fluid to pass directly into the main hydraulic circuit.

9 Claims, 5 Drawing Figures



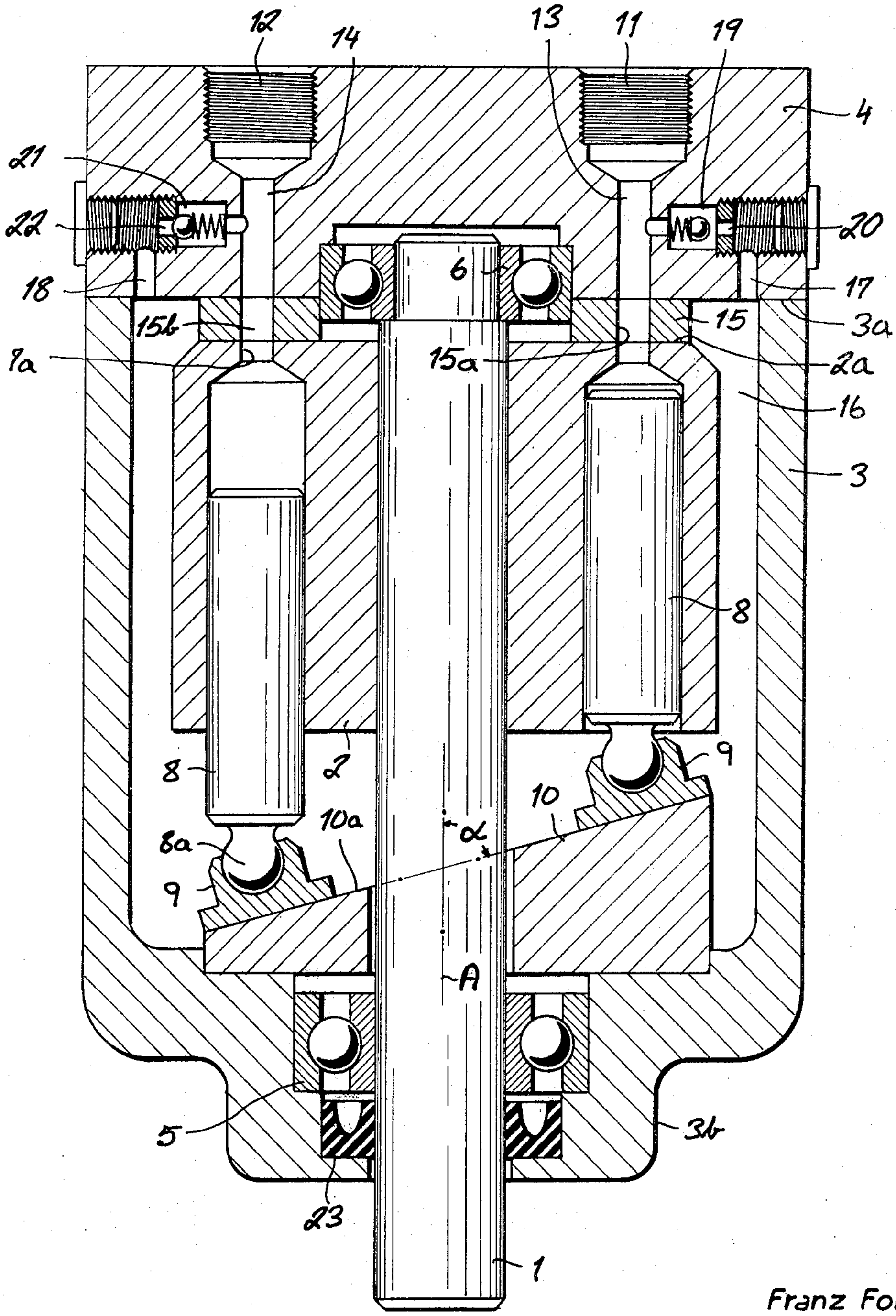


FIG. I

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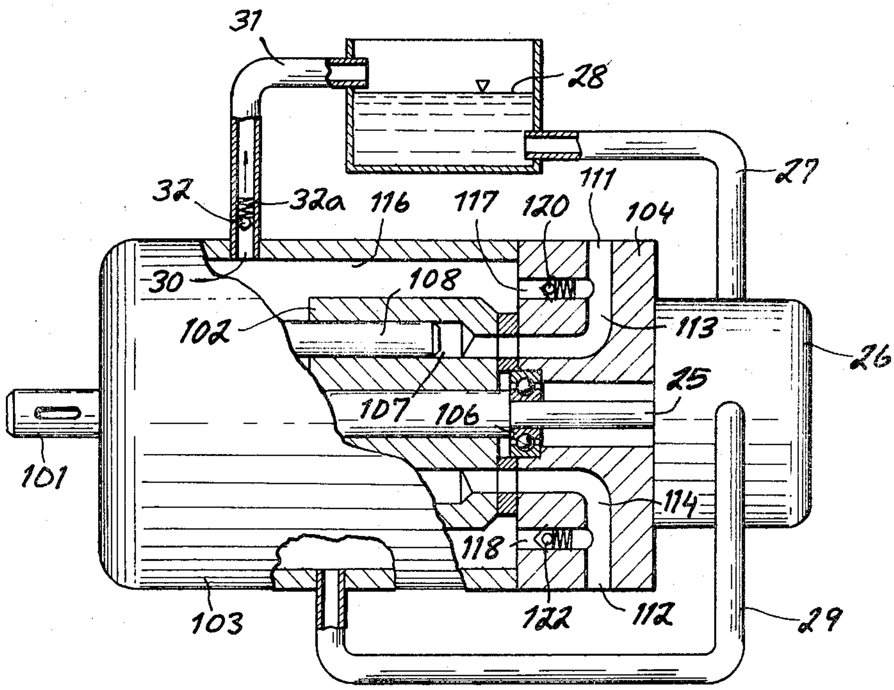

FIG. 2

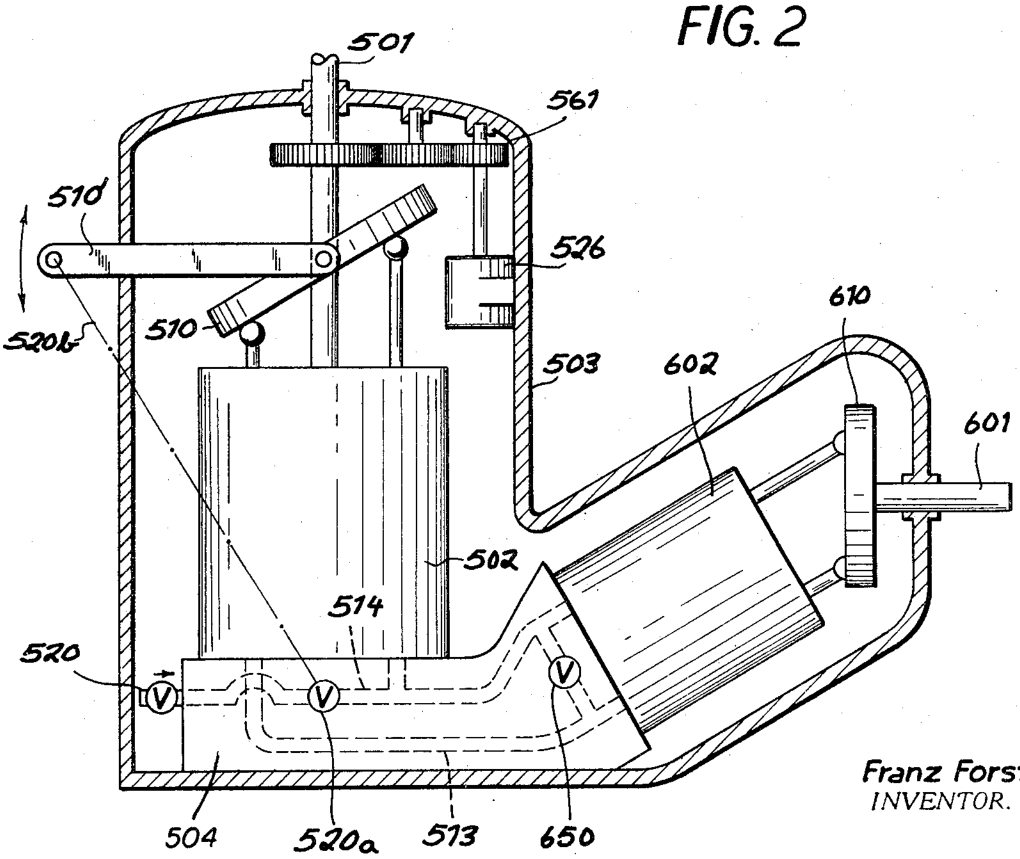

FIG. 5

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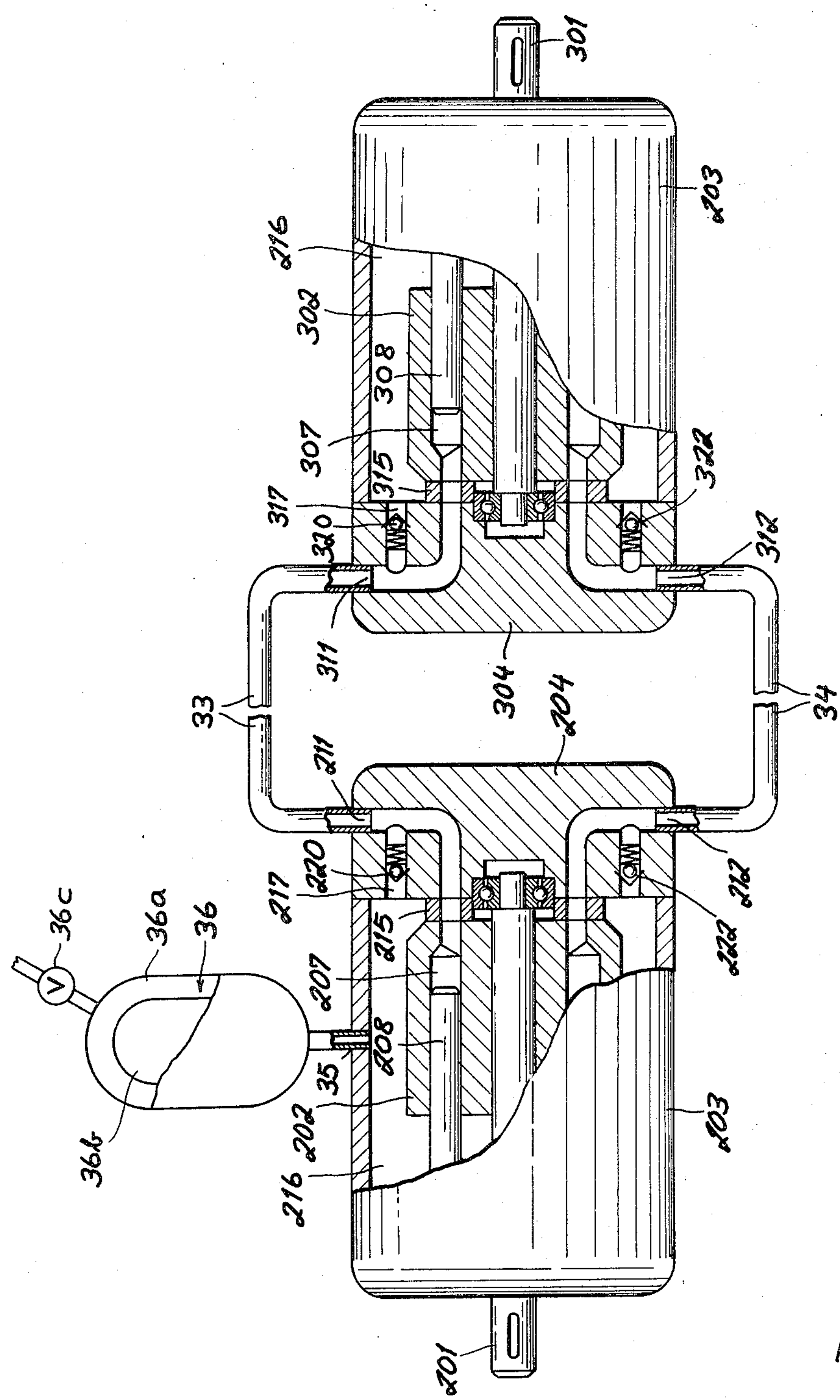

FIG. 3

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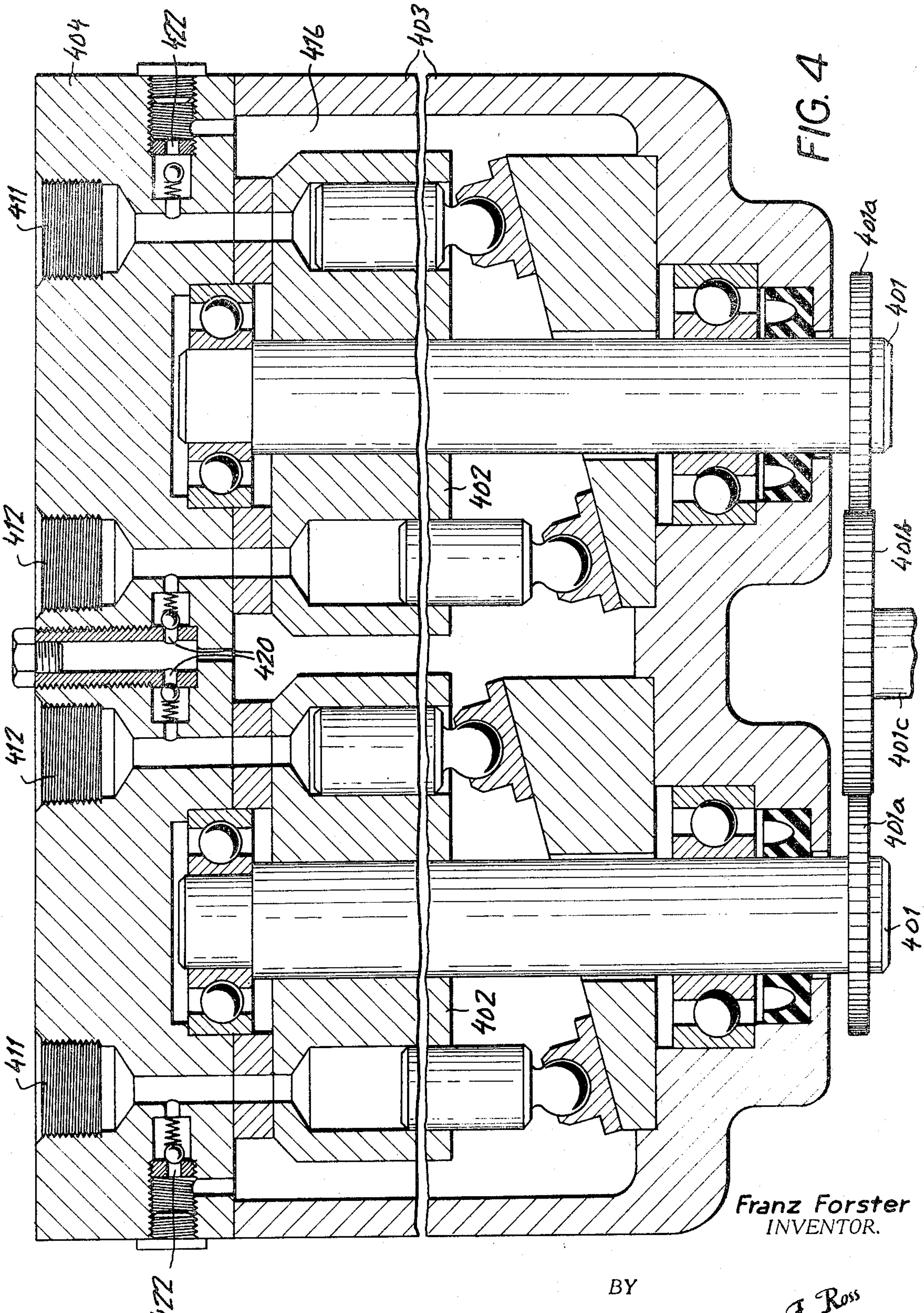

FIG. 4

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HYDROSTATIC MACHINE

FIELD OF THE INVENTION

My present invention relates to hydraulic machines and, more particularly, to hydrostatic machines operating in a closed fluid circuit.

BACKGROUND OF THE INVENTION

Hydrostatic machines, e.g. hydrostatic pumps and motors, generally are provided with a closed circuit and a pair of main ports connected with a hydraulic load and serving as discharge or intake ports, depending upon the sense of operation of the machine. Among the important hydrostatic machines of this class are the so-called axial-piston pumps and axial-piston motors which serve, respectively, to displace the hydrostatic fluid under the drive of a power source, e.g. an internal-combustion engine or an electric motor and/or may be driven by hydraulic fluid pressure to operate, in turn, a mechanical member such as the output shaft. Axial-piston devices and the principles involved therein are described in FLUID POWER, U.S. Government Printing Office, 1966, at pages 109–112 and pages 199 and following, respectively.

For the most part, an axial-piston pump may comprise a rotary cylinder barrel provided with a plurality of angularly equispaced cylinder bores successively communicating with a pair of kidney-shaped fluid-distribution apertures on a fluid-distribution surface against which the cylinder barrel is held under axial pressure. The pistons within the cylinders are reciprocated by virtue of rotation of the barrel and the fact that the pistons bear upon a control surface which is inclined to the axes of rotation of the barrel so that during about half of each rotation the pistons are urged inwardly while the pistons are able to move outwardly during the remainder of each rotation.

Inward displacement of the pistons, of course, corresponds to a reduction in the volume of the chamber behind the piston to expel fluid in the form of a hydraulic medium through one kidney-shaped aperture while outward movement of the piston expands the chamber to draw the hydraulic medium into the cylinder bore from the other kidney-shaped aperture. The kidney-shaped apertures, of course, are connected to the discharge and intake ports of the hydraulic machine, respectively, depending upon the angle and direction of tilt of the control surface, the displacement of the pump and the function of the main port (as high-pressure or low-pressure port) can be established. The pump shaft may be connected to the control surface to drive the latter and may also be coupled with the barrel via means as described, for example, in the commonly assigned copending application Ser. No. 68,254 filed Aug. 31, 70 by Walter HEYL. A hydrostatic motor operating in accordance with the same principles, will generally comprise a cylinder barrel having a surface perpendicular to its axis of rotation abuting a fluid-distribution surface whose arcuate apertures communicate with the individual cylinder bores opening at this surface. The pistons may bear against an inclined control surface and are coupled with an output shaft via the latter so that fluid entering through one of the apertures forces the piston successively outwardly to drive the barrel and, consequently, rotate the shaft. Inclination of the control surface in this case, determines the

speed of the shaft and the torque delivered to any load which may be coupled therewith.

It is not uncommon to interconnect the discharge port of the pump with the intake side of the motor and the outlet side of the motor with the intake side of the pump by suitable conduits and thereby create a hydrostatic drive or transmission in which the transmission ratio between the input shaft of the pump and the output shaft of the motor is established by the inclination of the barrel axes of the hydrostatic machines to the axis of the respective shaft. Such transmissions may be wholly contained in a common housing or may be mounted remote from one another so that they can be connected by relatively long lines. One advantage of the hydrostatic transmission is precisely the possibility of providing the hydrostatic pump in the vicinity of a prime mover or other energy source, while the hydrostatic motors are mounted directly adjacent the load driven thereby. Transmissions of this nature have been found to be particularly suitable in vehicular applications wherein the prime mover is an internal-combustion engine and the load is the vehicle wheel. Of course, a number of hydrostatic motors can be connected to a single pump or a number of pumps may be provided to service a single hydrostatic motor. In general, however, it is found to be advantageous to provide each hydrostatic pump with a hydrostatic motor in a closed fluid path.

It should be understood that the term "closed fluid path" is intended herein to refer to a system in which the pump is connected directly to the load, i.e. each of the conduits communicating with the ports of the pump run to the corresponding ports of the motor. While one of the conduits may be operated as a high-pressure transmission line while the other conduit is at low pressure, the hydrostatic machines are generally reversible to interchange the functions of these lines. Furthermore, both machines may be provided in a closed housing so that the entire transmission network and fluid supply is contained within this housing from which only the input and output shafts emerge. In closed circulating paths of the character described, it is necessary to hold the low-pressure side at a predetermined pressure level and an auxiliary pump and/or a pressure-regulating valve may be used to this end.

It will be appreciated that effective operation of the axial-piston pump or axial-piston motor is accompanied and in fact may require some leakage of the hydraulic medium from the system, e.g. at the fluid-distribution surfaces of a valve plate and the rotating cylinder drum, respectively. When a closed circulating path was required, it has been necessary in some prior-art devices to provide a further conduit between the pump and load to convey the leakage fluid from one hydrostatic machine to the other. This is, of course, a significant disadvantage when the pump is greatly removed from the motor and when complex mechanisms are interposed between them. In an excavating machine, for example, the hydrostatic pump may be mounted upon a chassis carrying a turntable which, in turn, is provided with the excavating scoops and like devices. When the turntable is used, it rotates relatively to the chassis. Hence hydrostatic motors carried by the turntable must be connected through a rotating seal with the hydrostatic pump and the need for an additional conduit between the hydrostatic motor and the hydrostatic pump complicates such systems to a further extent. It will be appreciated that conduits for the indicated purposes must be capable of withstanding pressure and the use of an additional conduit involves increasing complexities because of the associated seals.

In open hydraulic circuits, moreover, i.e. those using a collecting reservoir into which fluid flows in a pressureless state, it is common to connect the leakage-fluid conduit to the reservoir so that the fluid returns to the power cycle, the leakage path being pressureless. It is also known to provide, in such systems (open fluid-circulating path), pumps which are disposed directly in the reservoir and leakage can occur directly into the reservoir. These systems make use of a relatively large housing for the pump and possible pressurization of the fluid therein to prevent cavitation at the inlet side of the pump. In all cases, however, techniques which have been found to be satisfactory for handling the leakage fluid of the open hydraulic circuit, i.e. those using fluid reservoirs, have not been found to be practical or satisfactory in closed fluid circuits while the need for added leakage-fluid conduits renders earlier closed systems expensive and complex.

OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide an improved hydrostatic machine arrangement of the closed-circulation type wherein the aforementioned disadvantages are obviated.

Another object of my invention is to provide an improved hydrostatic machine, e.g. axial-piston pump or axial-piston motor, in which the handling of leakage fluids is simplified, which is of lower cost and simpler operation than earlier systems, and which can be used for arrangements such as excavators in which two hydraulic machines are interconnected but separated by means creating sealing difficulties.

SUMMARY OF THE INVENTION

The above and other objects of the invention, which will become apparent hereinafter, are attained in a hydraulic machine which comprises a housing, preferably closely surrounding the axial-piston barrel which is connected directly with the low-pressure port of the machine, i.e. the intake port of a hydrostatic pump or the discharge port of a hydrostatic motor, via a check valve designed to permit unidirectional flow of the hydraulic medium from the housing surrounding the barrel into the low-pressure port. The housing sealingly closes the hydrostatic machine and, when the ports of the machine are functionally interchangeable, both of them may be connected with the housing chamber by respective check valves, only the check valve communicating with the low-pressure port being open to permit the pressure differential thereacross to feed the leakage fluid into the low-pressure side. The high-pressure side, of course, maintains its check valve closed when the ports are functionally interchanged; again the pressure differential favors flow of leakage fluid from the sealed housing to the low-pressure side.

Consequently, the present invention provides a housing which may be sustained at elevated pressure and, at any rate, a pressure equal to or in excess of that of the low-pressure side of the hydrostatic machine, a check valve connecting the interior of the housing with the low-pressure duct, conduit or port, and a hydrostatic machine disposed within this housing and having a leakage path opening from the machine into the housing whereby the leakage medium can traverse the check valve into the low-pressure ducts. A separate leakage-fluid collector is thereby eliminated, the system does not require a separate line between the pump and motor for conducting the leakage fluid and compensating for leakage losses, and only two ducts need bridge the hydrostatic pump and motor. Furthermore, the cooling of the hydrostatic machine is improved by virtue of the fact that there is a continuous circulation of the leakage medium from the machine into the space surrounding the machine and enclosed by the housing, and from the housing into the low-pressure side of the machine.

The present invention is applicable to hydrostatic pumps and motors, the intake of the former being the low-pressure side whereas the discharge of the latter is at low pressure. However invention can also apply to more than one hydrostatic machine in a single housing, i.e. a double-pump assembly in which two hydrostatic pumps are provided within a single housing, two hydrostatic drives including a pump and one or more motors, the housing in each case being generally closed. However, it has been found that increasing the size of the housing to accommodate more than one hydrostatic machine opens the door to difficulties with respect to maintaining the seal of the housing and it is therefore preferred to provide a housing for each machine which closely surrounds the axial-piston drum thereof. It should be noted that one not only achieves a saving in the cost of a leakage-fluid duct when the present invention is used, but also reduces the complexities of the pump and motor structures themselves since fittings, ports, chambers and like structure associated with the leakage ducts are eliminated as well. It is possible by such simplification of the overall structure to eliminate the tendency of the machine to leak and thereby reduce maintenance and surveillance.

The reduction of the leakage losses from the main closed hydraulic circuit into the housing surrounding the hydrostatic machine is a consequence in part of the high back pressure maintained in the sealed housing and, therefore, prevalent at the outlet side of the leakage path. As a result, no feed pump need be used to compensate for leakage loss in a great many cases and, wherever a feed pump is required in a system under the present invention, it may be dimensioned to have a smaller capacity and energy consumption than the feed pumps which have been used heretofore with similar hydraulic machines operating, for example, in closed circuits with pressureless housings or the like.

When no feed pump is required, I have found it to be advantageous to provide, at one or more locations along the closed hydraulic path, equalization reservoirs or hydropneumatic accumulators adapted to deliver, while maintaining the pressure in the housing, fluid to the latter to compensate for the leakage losses from the main hydraulic circuit. Such accumulators may be of the type described at pages **86 – 89** of FLUID POWER, cited earlier. The accumulator, which is maintained at the predetermined pressure within the sealed housing, compensates for changes in the volume of fluid available in the main circulating path as a result of thermal expansion and contraction of the fluid and the conduits containing same, elastic yieldability of the conduit walls, etc.

When a hydropneumatic accumulator is employed, I have found it advantageous after a period determined by experience, e.g. a thousand operating hours, to charge the accumulator and restore the pressure therein. Of course, the accumulator should only be provided at the low-pressure side of the closed circulation path and, when the hydraulic machine is reversible so that the ports alternate in function between high-pressure and low-pressure ports, reversing-valve means is used in accordance with the invention to connect the low-pressure side with the accumulator at all times. Two such accumulators may, of course, be provided and connected with the sides of the hydraulic network by cutoff valve means so that the accumulator currently at the high-pressure side is blocked while the other accumulator is rendered effective. Furthermore, when a pair of interconnected hydrostatic machines are employed, the accumulator can communicate directly with the interior of one of the machine housings or the common housing of both machines to maintain the pressure in the low-pressure side of the network substantially constant indirectly.

When a feed pump is provided, i.e. when the hydrostatic machine is provided with a pump designed to deliver the hydraulic medium to the closed fluid path to compensate for leakage losses, a secondary circulation is established between the housing chamber of one machine preferably the motor and the low-pressure line thereof. A cooling system can be provided in the latter case at the discharge side of the feed pump. The cooler may be a conventional radiator built onto the housing of the apparatus or other conventional heat-dissipating device. Hence the interior of the housing is constantly rinsed with fresh cool hydraulic medium and the machine is able to operate with increasing efficiency.

According to still another feature of this invention, the hydrostatic machine forms part of a hydraulic transmission driven by an internal-combustion engine and the working fluid of the hydrostatic drive is also the lubricant for the internal combustion engine. The feed pump and cooling pump can thereby constitute the means for maintaining the predetermined pressure within the housing, the means for cooling the latter, and the means for lubricating the engine.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is an axial cross-sectional view through an embodiment of a hydrostatic machine according to the invention;

FIG. 2 is a side-elevational view, partly in axial section and partly in diagrammatic form, illustrating another embodiment of the invention wherein the hydrostatic machine employs a feed pump;

FIG. 3 is a view similar to FIG. 2 of a hydrostatic transmission according to the invention;

FIG. 4 is a view similar to FIG. 1 illustrating how the invention is applied to a double-pump assembly; and

FIG. 5 is an elevational view diagrammatically illustrating the application of the invention to another hydrostatic transmission having a single housing.

SPECIFIC DESCRIPTION

In FIG. 1 I have shown a hydrostatic machine having a shaft **1** which may serve as the input shaft of the hydrostatic pump and which is journaled in a pair of axially spaced bearings **5** and **6** of a housing **3**, **4** interconnected at **3***a*. The shaft **1** carries a cylinder drum **2** provided with a plurality of angularly equispaced axially extending cylinder bores **7**, each slidably receiving a piston **8** shiftable into and out of the cylinder bore **7** parallel to its own axis and the axis of the shaft **1**. Each of the pistons **8** is provided with a swivel head or ball **8***a* which is received swivelably within a shoe plate **9** of annular configuration, slidably bearing against a control disk **10** whose surface **10***a* is inclined at the angle α to the axis A of the shaft. Spring means (not shown) may be provided to ensure that the pistons **8** and the shoe **9** seats firmly against the control surface **10***a* at all operating speeds of the rotary machine.

The housing **3**, **4** comprises a bell-shaped member **3** having a neck **3***b* in which the bearing **5** is received and which is formed with a lip-type seal capable of maintaining a subatmospheric pressure in a chamber **16** surrounding the cylinder barrel **2**. The latter is provided with apertures **7***a* which open at a valve surface **2***a* bearing against the opposing surface of a valve or distributing plate **15** composed of low-friction material, e.g. bronze, seated against the plate **4**. The plate **15** is provided with a pair of arcuate apertures **15***a* and **15***b*, respectively registering with several of the apertures **7***a* as the barrel **2** rotates relative to the plate **15**. Such arcuate apertures are disclosed in the aforementioned publication. Each of the apertures **15***a* and **15***b* registers, in turn, with a respective connecting passage **13** or **14** communicating, in turn, with the ports **11** and **12** to which suitable conduit means may be connected for joining the hydrostatic machine of FIG. 1 in a closed hydraulic circuit. A typical circuit is that illustrated in FIG. 3. When port **11** forms the high-pressure side of the machine, port **12** represents the low-pressure side and vice versa. The pressure at the low-pressure side may be maintained constant by a feed pump or pressure-regulation valve interconnecting the high and low-pressure sides. The low-pressure side preferably is held at about **6** to **8** atmospheres gauge. The same pressure is maintained by seal **23** within the housing. When the system is a hydrostatic motor, the discharge is at this pressure while, when the machine is a hydrostatic pump, the supply or intake is at this pressure.

The interior **16** of the housing communicates via respective bores **17** and **18**, formed directly in plate **4**, with respective check valves **20** and compartments **19** and **21** operating, respectively, into the passages **13** and **14** mentioned earlier. The check valves **20** are poled, oriented and constructed to permit unidirectional flow of fluid from the housing into the low-pressure conduit or branch when a pressure differential in favor of such flow is established and to block reverse flow of fluid under any circumstances. Since reverse flow is blocked when the pressure differential favors an outflow from the network into the chamber 16, whenever the operating high pressure is maintained in one of the networks, the corresponding check valve blocks flow therethrough and only the other check valve can operate, this only when the pressure within the housing exceeds the pressure within the low-pressure side as indicated.

The shaft 1 may be coupled to a prime mover, e.g. an electric motor or an internal combustion engine for use of the machine as a pump, or may be connected to a load such as the driving wheels of an automotive vehicle having a hydrostatic transmission. In the mode of operation of the machine as a pump, the barrel 2 is rotatably entrained by the shaft 1 while the pistons 8 ride with the shoe 9 along the control surface 10*a* which is inclined to the axis of rotation of the barrel as noted earlier. As the pistons 8 are shifted between their fully extended position and a fully retracted position, they vary the size of the chamber 7 behind the piston and thereby draw fluid through one port and force it out through the other in a repetitive intake/discharge cycle. When the machine is operated as a motor, hydraulic fluid is delivered by a hydrostatic pump at one port to drive the pistons outwardly as the barrel swings into registry with that port, the fluid then passing at low pressure into the discharge side for return to the pump. In either case, one of the ports 11 or 12 will be a high-pressure port while the other is the low-pressure port.

When port 11 is under high pressure and port 12 is under low pressure, the fluid in line 13 is likewise at an elevated pressure to bias the check valve 19 into a closed position. Fluid from the chamber 16 cannot enter the closed hydraulic network via line 17. However, the normal pressure in the housing chamber 16 is 6 to 8 atmospheres (gauge) and suffices, when the pressure drops at the low-pressure duct 14 and port 12, to bleed the leakage fluid from the chamber 16 into the hydraulic line 14 for return to the main circulating path. The fluid within the chamber 16 in part derives from leakage at the control surfaces 2*a*. When the control surface 10*a* is adjusted to vary the functions of the ports or the sense of rotation is altered, only the check valve associated with the low-pressure side will be operative. The high-pressure check valve will invariably be closed.

In FIG. 2, I show a hydrostatic machine according to the invention which is constituted as a pump and embodies many of the features already described in connection with FIG. 1. In this embodiment, the shaft 101, extending out of the housing portion 103 is connected with a drive means such as an inlet combustion engine or electric motor. The shaft 101 is provided with an extension 25 beyond the bearing 106 running to a feed pump 26, the latter being bolted onto the housing portion 104 forming the fluid-distribution ports 111 and 112 as well as ducts 113 and 114 as previously described.

The intake line 27 of the pump 26 is fed from a reservoir 28 while the pressure side of the pump 26 is connected via line 29 to the using compartment 116 through the wall 103 thereof, preferably at the bottom of the wall. A return line 31 communicates with the compartment 116 at the upper side thereof via a fitting which is provided with a check valve 32 allowing unidirectional flowing from the housing to the reservoir 28. Valve 32 is provided with a strong spring 32*a* so that it simultaneously constitutes a pressure-regulating valve maintaining an adjustable pressure in the compartment 116 at about 6 to 8 atmospheres. In this case, the reservoir 28 can be open to the atmosphere and can constitute a heat exchanger or heat-dissipating cooler directly. As an alternative, the reservoir 28 may be closed to maintain a given pressure within the system and the cooler may be provided as a separate heat exchanger or radiator in a fluid circuit with the pump 26. The pump 26, consequently, circulates fresh fluid through the interior of the housing constantly with the advantages already set forth. In general, the machine of FIG. 2 operates in the manner previously described in FIG. 1 when the barrel 102 is rotated by shaft 101 to shift the pistons 107 in the cylinder bores 108 of the closed hydraulic circuit and permit the check valve 120 or 122 associated with the low-pressure side to connect the respective passage 113 or 114 with the interior of the housing.

The hydrostatic drive illustrated in FIG. 3 comprises, in accordance with the usual practice, a hydrostatic pump whose shaft 201 is connected with an internal combustion engine and whose hydrostatic motor has its shaft 301 connected with a load. The shafts 201 and 301 are rotatably connected with the cylinder barrels 202, 302 whose pistons 208, 308 are axially shiftable, via inclined control surfaces not shown, within the cylinder bores 207, 307 to displace hydrostatic fluid along a closed path inter-connecting the ports 211 and 311 via a line 33 and the ports 212, 312 via a line 34. It will be appreciated that the lines 33 and 34 may be relatively long when the pump and the motor are to be separated by some distance or can be eliminated when a single support block is provided in place of the separate fluid distribution plates 204, 304. The remainder of the system, including the fluid-distribution antifriction plates 215, 315 the ports 217 and 317 connected to the low-pressure side of the network and the check valves 220, 320 and 222, 322 is, of course, identical with the corresponding parts of the system of FIG. 1. In addition, a pressure-equalization reservoir 36, in which a compressed gas is maintained in the compartment 36*a* to form a yieldable cushion for the membrane 36*b* connected with line 35 and the chamber 216. A valve 36*c* serves to permit recharging of the accumulator. With expansion of the fluid within the transmission as a result of heating, there is a volume increase which is taken up by the accumulator 36 with compression of the gas cushion therein. Should there be a leak from the housing or an elastic yielding of the ducts from a housing and portions thereof, additional fluid is delivered by the accumulator. No separate feed pump is necessary.

In FIG. 4, I show a system wherein a housing 403, 404 is common to a pair of cylinder drums 402, with respective shafts 401 driven via gears 401*a* from a gear 401*b* on the crankshaft 401*c* of an automotive vehicle or like installation using a double pump aggregate. Since separate closed hydraulic networks may be provided with the low-pressure ports 412 at the same pressure and the high-pressure ports 411 at respective elevated pressures, a check valve 420 is provided to connect both ports 412 with the interior 416 of the housing. The other check valves **422** for the high-pressure side are provided as previously described.

FIG. **5** shows a system wherein the cylinder drums **502** and **602** of the hydrostatic pump and hydrostatic motor are mounted in a common housing **503** and have input and output shafts **501** and **601** respectively connected to a source of rotary movement and a load. The control member **510** is here shown to be pivotal via lever **510'** to adjust the displacement of the pump and a similar means may be provided for tilting the control plate **610**. A single valve block **504** is here used with the intake side of the duct **514** connected with the check valve **520**. Pressure within the system may be controlled by a regulating valve **650** connecting the high and low pressure lines or by a feed pump **526** driven by gearing **561** from the pump shaft **501**. The major distinction between the system of FIG. **5** and that of FIG. **4** is the single housing for the barrels of both the pump and motor of this latter system.

In FIG. **5**, I also show a distributing valve **520*a*** by which the check valve **520** and the duct associated therewith may be switched between the current low-pressure line **514** and the high-pressure line **513** when the hydraulic machines are reversed as described earlier. In this case only a single check valve need be used. The valve **520*a*** may be coupled as represented by the dot-dash line **520*b*** with lever **510'** to effect automatically the change-over.

I claim:

1. A hydraulic system comprising a hydrostatic pump and a hydrostatic motor constituting hydrostatic machines; means connecting said machines in a closed fluid-circulating path and including a high-pressure passage and a low-pressure passage; a pressure-retentive housing surrounding at least one of said machines and forming a chamber maintainable at an elevated pressure corresponding substantially to that of said low-pressure passage; and a duct wholly within said housing constituting the sole leakage-fluid path therefrom and connecting said low-pressure passage with said chamber, and a check valve in said duct for unidirectional flow of fluid between said chamber and said low-pressure passage and blocking reverse flow of fluid through said duct between said low-pressure passage and said chamber.

2. The hydraulic system defined in claim **1** wherein a respective duct connects each of said passages with said chamber and is provided with a respective check valve permitting unidirectional flow of fluid from the chamber into said passages.

3. The hydraulic system defined in claim **1**, further comprising distributing valve means for selectively connecting said duct with one of said passages.

4. The hydraulic system defined in claim **1**, further comprising a feed pump connected with said chamber for circulating fluid therethrough.

5. The hydraulic system defined in claim **4**, further comprising a heat-dissipating cooler in a hydraulic circuit with said feed pump.

6. The hydraulic system defined in claim **1** wherein both said machines are provided within said housing.

7. The hydraulic system defined in claim **1**, further comprising a hydropneumatic accumulator connected to said chamber for maintaining a predetermined pressure level therein.

8. The hydraulic system defined in claim **1**, further comprising means for maintaining the pressure within said chamber at a level of substantially 6 to 8 atmospheres gauge.

9. The hydraulic system defined in claim **1** wherein said housing encloses a pair of hydrostatic pumps, coupled together in a double-pump aggregate.

* * * * *