United States Patent

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[54] **PRESSURE-COMPENSATED FLOW CONTROL**
12 Claims, 3 Drawing Figs.

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[51] Int. Cl. F15b 11/08, F15b 13/042
[50] Field of Search .... 91/426, 444, 445, 446, 448, 468, 44.5 PR, 117; 137/625.69, 538, 596.13, 117, 118, 596.13

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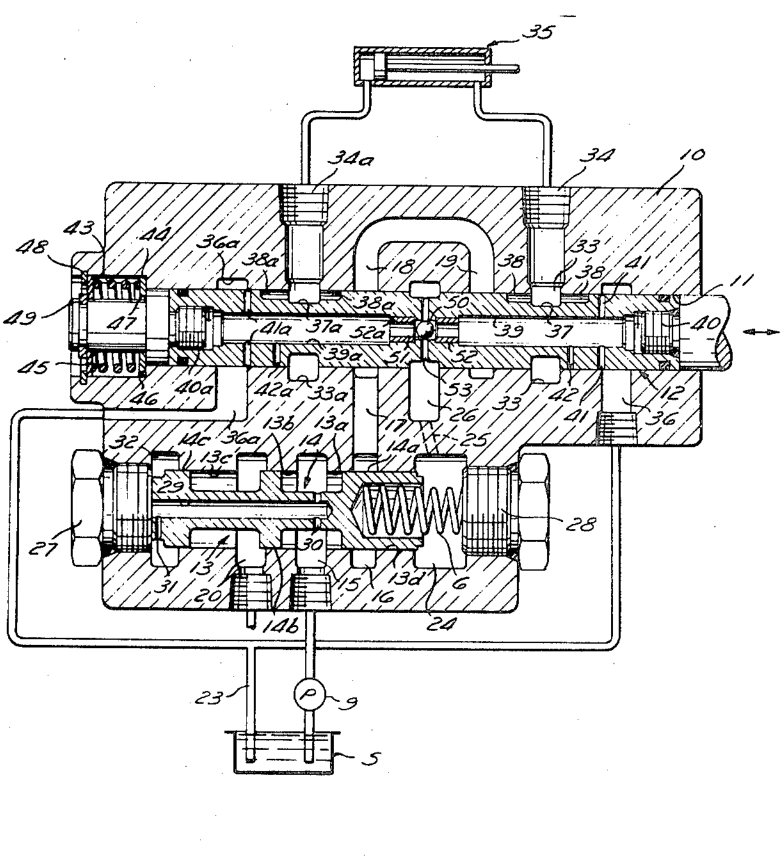
ABSTRACT: Spool valve having its inlet flow rate regulated by a pressure-compensating piston that is reference to the low-pressure return when the valve spool is in its neutral position holding a load. In a first embodiment the valve spool itself carries a ball shuttle valve that determines which motor port of the spool valve is connected to the pressure-compensating piston. In a second embodiment the bypass flow provided by the pressure-compensating piston may go to another load circuit, such as another pressure-compensated spool valve, or to the low-pressure return. In both embodiments, the pressure-compensating piston acts as a load check in the event of inlet pressure failure.



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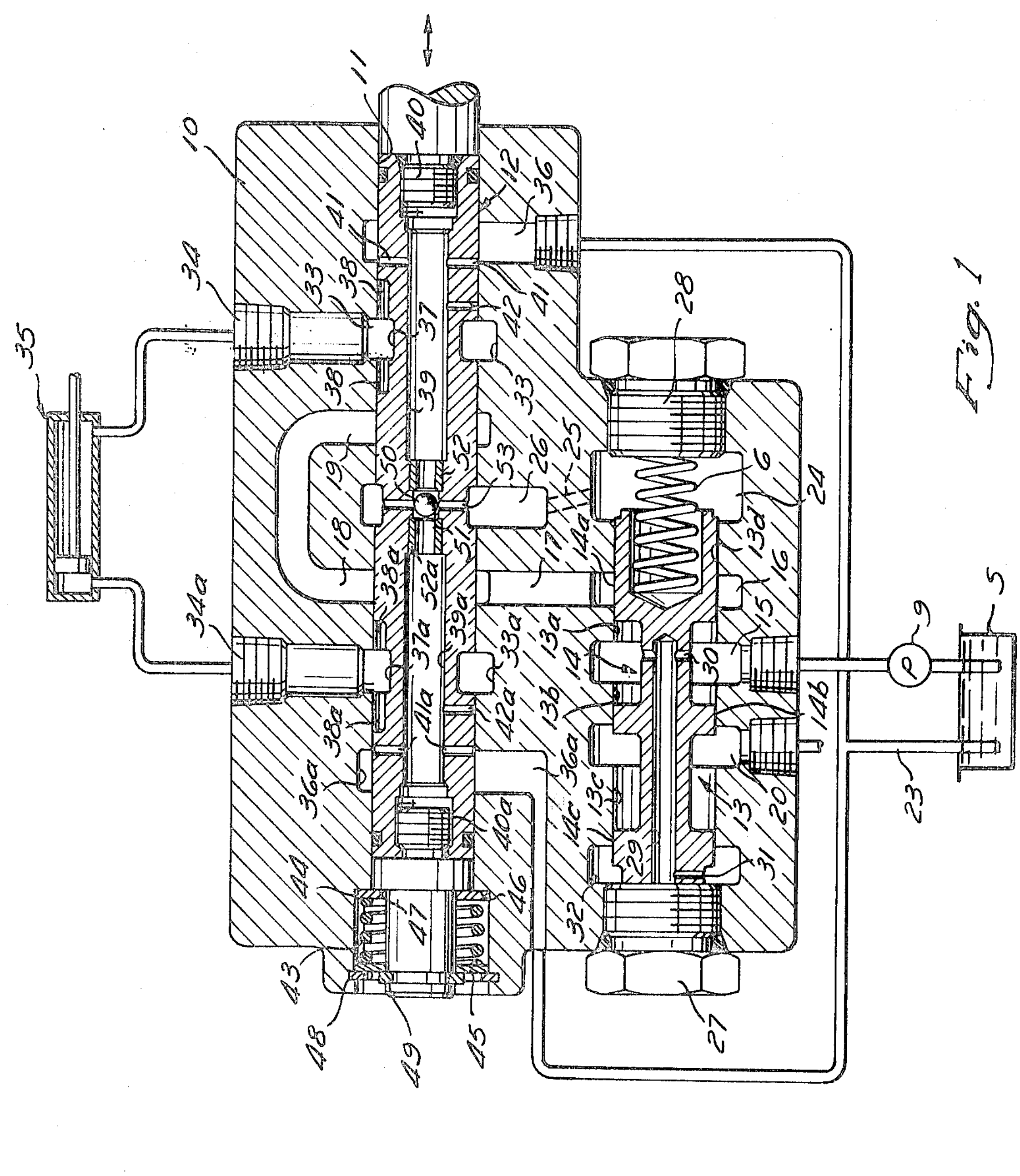

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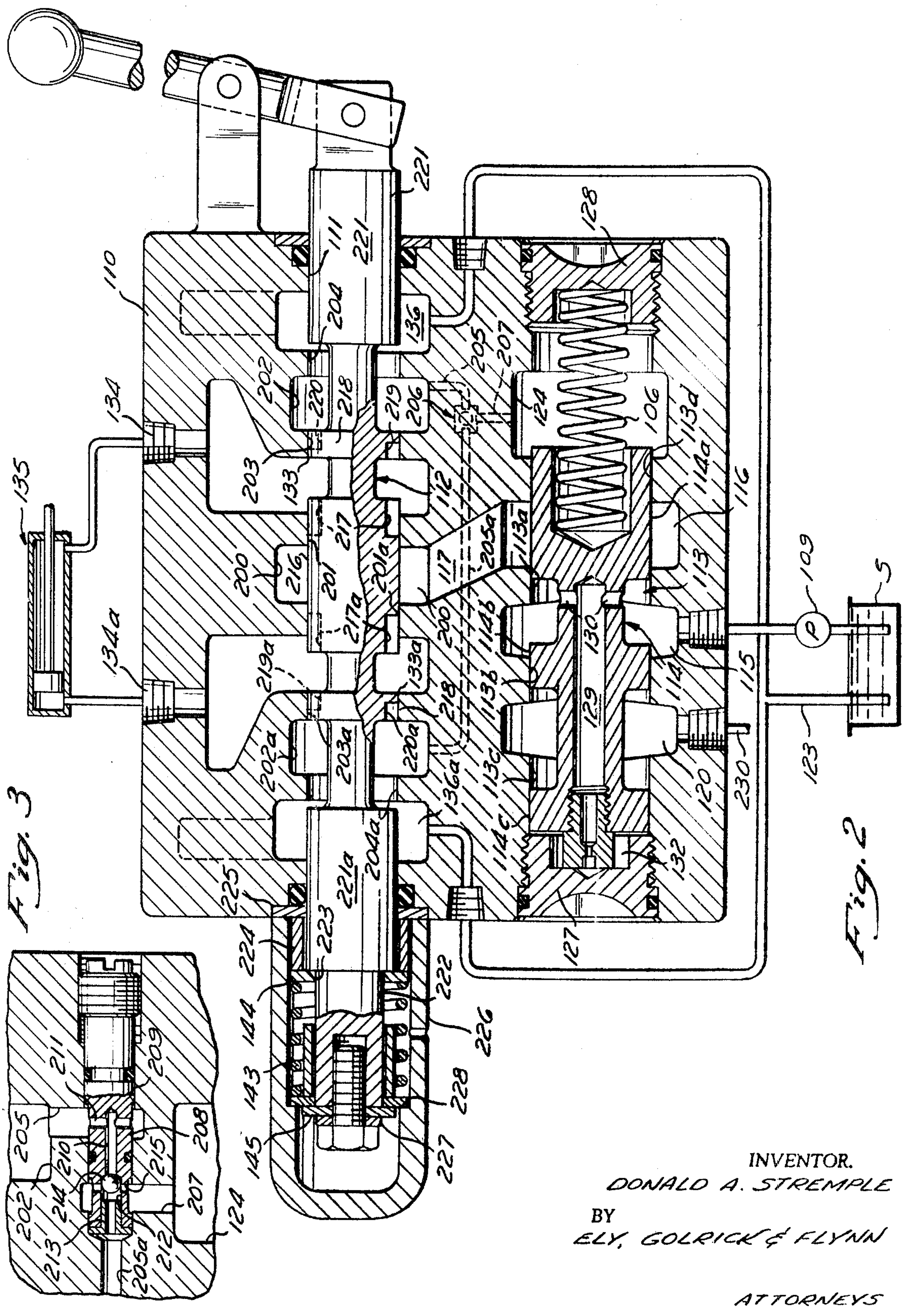

Fig. 2

Fig. 3

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PRESSURE-COMPENSATED FLOW CONTROL

This invention relates to a pressure-compensated flow control arrangement including a directional spool valve and a pressure-compensating valve for regulating the flow through the spool valve.

Various pressure-compensated flow control arrangements have been proposed heretofore in which a spool valve has its inlet flow rate regulated by a spring-biased pressure-compensating valve operating in response to the pressure differential between the spool valve inlet and the spool valve motor port which passes the inlet flow to the fluid motor. Commonly, in such flow control arrangements a reference pressure chamber of the pressure-compensating valve is connected to a motor port of the spool valve even when the spool valve is in neutral, at which time it may be used to hold the load on the fluid motor by keeping this motor port blocked. With such arrangements, in order to connect the pump output to the spool valve inlet it may be necessary for the pump pressure to overcome the fluid force exerted on the pressure-compensating valve by this motor port pressure in addition to the force exerted by the bias spring.

It is a principal object of the present invention to avoid this disadvantage by providing a novel and improved flow control arrangement in which the spring-biased pressure-compensating valve is referenced to a low-pressure return when the spool valve is in neutral and holding a load at one of its motor ports, so that the pump pressure is required to overcome only the spring bias on the pressure-compensating valve in order to connect the pump output to the spool valve inlet.

Another object of this invention is to provide a pressure-compensated flow control in which a pressure-compensating valve is arranged in a novel manner to act as a load check in the event of a failure of the inlet pressure.

Another object of this invention is to provide a pressure-compensated directional spool valve having a shuttle valve positioned in the valve spool and operable in response to the pressure differential between internal passages in the spool, which are connected respectively to the inlet and return motor ports of the spool valve, so as to connect the inlet motor port to the reference pressure chamber of the pressure-compensating valve for regulating the inlet flow rate through the spool valve.

Further objects and advantages of this invention will be apparent from the following detailed description of two presently preferred embodiments, which are illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a longitudinal sectional view through a first embodiment of the present flow control arrangement;

FIG. 2 is a similar view showing a second embodiment of the present flow control arrangement; and

FIG. 3 is a fragmentary longitudinal section showing the shuttle valve in the FIG. 2 flow control arrangement.

FIRST EMBODIMENT—FIG. 1

Referring to FIG. 1, a valve body or housing **10** has a main cylindrical bore **11** which snugly, but slidably, receives a valve spool **12** which is axially shiftable in the bore. The valve body **10** also has an auxiliary bore **13** extending parallel to its main bore **11** and slidably receiving a pressure-compensating valve member **14**.

Midway along its length the auxiliary bore **13** in the valve body communicates with an annular inlet port **15** connected to the outlet of a pump **9**. A short distance to the right of the inlet port **15** in FIG. 1, and separated from the latter by a cylindrical land **13*a***, the auxiliary bore **13** communicates with a annular controlled flow outlet port **16** which is connected by a passage **17** to a pair of axially spaced, arcuate inlet passages **18** and **19** leading into the main bore **11** in the valve body. A short distance to the left of the inlet port **15** in FIG. 1, and separated from the latter by a cylindrical land **13*b***, the auxiliary bore **13** in the valve body communicates with an annular bypass outlet port **20** that may be connected to a return line (not shown) leading back to the sump S or to another load circuit, such as the inlet of a valve similar to the one shown in FIG. 1,. A short distance to the right of the port **16**, and separated from the latter by a cylindrical land **13*d***, the auxiliary bore **13** communicates with an enlarged reference pressure chamber **24** that is connected by a passage **25** to an annular chamber **26** intersecting the main bore **11** midway between the latter's inlet passages **18** and **19**. The opposite ends of the intermediate bore **13** are closed by respective screw-threaded plugs **27** and **28**.

The pressure-compensating valve member **14** is an elongated piston having a cylindrical land **14*b*** for sealing engagement with the land **13*b*** of auxiliary bore **13** and an elongated cylindrical land **14*a*** for sealing engagement with the lands **13*a*** and **13*d*** of bore **13**. The piston **14** has an internal longitudinal passage **29** which at its right end in FIG. **1** communicates with the inlet port **15** through radial openings **30**. At its left end in FIG. **1**, the passage **29** communicates through a radial passage **31** with an annular recess **32** that intersects bore **13** to the left of port **20** and is separated from the latter by a cylindrical land **13*c*** of bore **13**. Piston **14** presents a cylindrical land **14*c*** which sealingly engages the bore land **13*c***.

With this arrangement, it will be seen that the piston **14** presents oppositely facing surfaces of equal areas (at recess **32** and chamber **24**) which are exposed respectively to the pump pressure and the pressure then prevailing in chamber **26** which intersects the main bore **11**.

A coil spring **6** is engaged under compression between the piston **14** and plug **28** to bias the piston to the left, as shown in FIG. **1**, so that the left end of the piston engages the inner end of plug **27**. In this position of the piston, its land **14*b*** sealingly engages the bore land **13*b***, its land **14*a*** sealingly engages bore lands **13*a*** and **13*d***, and its land **14*c*** sealingly engages the bore land **13*c***. Accordingly, the inlet port **15** is blocked by the piston **14** from the controlled flow outlet port **16** leading to the inlet passages **18**, **19** to the main bore **11** and from the bypass outlet port **20** leading to return.

To the right of its inlet passage **19** the main bore **11** in the valve body is intersected by an annular passage **33** connected to a motor port **34** in the valve body, which is connected to the rod end of a cylinder-and-piston fluid motor **35**. To the right of this motor passage **33**, the bore **11** is intersected by an annular passage **36** which is connected to a return line **23** leading back to the sump S.

The valve spool **12** has on its periphery an annular circumferential groove **37** and a longitudinal groove **38** which intersects groove **37** and extends beyond it in both directions axially. In the neutral, centered position of the valve spool, as shown in FIG. **1**, the annular groove **37** in the valve spool registers with the motor passage **33** in the valve body and is blocked from both the inlet passage **19** and the return passage **36**.

The right half of the valve spool has a longitudinal internal passage **39** whose outer end is closed by a plug **40**. Passage **39** is intersected by a first set of radially disposed transverse ports **41** in the valve spool which partially overlap the return passage **36** in the valve body when the valve spool is in its neutral position, as shown in FIG. **1**.

Passage **39** also is intersected by a second set of radially disposed transverse ports **42** in the valve spool, which in the neutral position of the valve spool, as shown in FIG. **1**, are blocked from both the motor passage **33** and the return passage **36** in the valve body.

In the neutral position of the valve spool, as shown in FIG. **1**, its internal passage **39** is connected to the return passage **36** in the valve body by way of the transverse ports **41** in the valve spool, and the motor passage **33** is blocked from both the inlet passage **19** and the return passage **36**.

When the valve spool is displaced far enough to the left from its neutral position, its peripheral grooves **38**, **37** connect the inlet passage **19** to the motor passage **33**, its transverse ports **42** register with the motor passage **33** to connect the latter to the internal passage 39 in the valve spool, and its transverse ports 41 are blocked from the return passage 36.

Conversely, when the valve spool is shifted far enough to the right from its neutral position, its peripheral grooves 38, 37 connect the motor passage 33 to the return passage 36, and either the transverse ports 41 or 42 in the valve spool register with the return passage 36 to connect the internal valve spool passage 39 to this return passage.

To the left of its inlet passage 18 the main bore in the valve body is intersected by an annular passage 33*a* which is connected through a motor port 34*a* to the head end of the cylinder and piston 35. To the left of this motor passage 33*a* the main bore 11 in the valve body is intersected by an annular return passage 36*a*, which is connected to the return line 23.

The left half of the valve spool has an internal longitudinal passage 39*a*, transverse ports 41*a* and 42*a*, and peripheral grooves 37*a* and 38*a*, which correspond to the similarly numbered internal passage, transverse ports and peripheral grooves in the right half of the valve spool. The left end of the internal valve spool passage 39*a* is closed by a plug 40*a*.

In the neutral centered position of the valve spool, as shown in FIG. 1, its annular peripheral groove 37*a* registers with the motor passage 33*a* in the valve body and is blocked from both the inlet passage 18 and the return passage 36*a*, the transverse ports 41*a* in the valve spool partially overlap the return passage 36*a* to connect the internal passage 39*a* in the valve spool to this return passage, and the transverse ports 42*a* in the valve spool are blocked from both the motor passage 33*a* and the return passage 36*a*.

When the valve spool is shifted sufficiently far to the right from its neutral position, its peripheral grooves 38*a*, 37*a* connect the inlet passage 18 in the valve body to the motor passage 33*a*, its transverse ports 42*a* register with the motor passage 33*a* to connect this motor passage to the internal passage 39*a* in the valve spool, and its transverse ports 41*a* are blocked from the return passage 36*a*.

Conversely, when the valve spool is shifted sufficiently far to the left from its neutral position, its peripheral grooves 38*a*, 37*a* connect the motor passage 33*a* to the return passage 36*a*, and either the transverse ports 41*a* or 42*a* in the valve spool register with the return passage 36*a* to connect the internal passage 38*a* in the spool to this return passage.

The valve spool 12 is biased to its neutral position by a coil spring 43 which is engaged under compression between a pair of annular washers 44 and 45 slidably surrounding the plug 40*a* beyond the left end of the main bore 11 in the valve body. Normally, the spring 43 positions the inner washer 44 abutting against an outwardly facing annular shoulder 46 on the valve body at the left end of bore 11 and it positions the outer washer 45 abutting against a snap ring 48 carried by the valve body and abutting against a snap ring 49 on the valve spool.

When the valve spool is displaced axially to the left from its neutral position, the valve spool shoulder 47 forces washer 44 to the left while the outer washer 45 remains against the snap ring 48 on the valve body, thereby further compressing the centering spring 43.

Conversely, when the valve spool is displaced to the right from its neutral position, the snap ring 49 on the valve spool forces the outer washer 45 to the right while the inner washer 44 remains against the valve body shoulder 46, thereby further compressing the centering spring 43.

For the purpose of shifting the valve spool 11 axially, a suitable operating handle (not shown) is pivotally connected to its right end.

In accordance with one aspect of the present invention, a ball shuttle valve is connected between the two internal passages 39 and 39*a* in the valve spool and the valve body passage 26 which is connected to the reference pressure chamber 24 at one end of the pressure-compensating valve piston 14.

As shown in the drawing, the ball valve 50 is loosely disposed in a cylindrical recess 51 in the valve body positioned midway between the inner ends of the respective internal passages 39 and 39*a* in the valve body and connected to the latter by respective sleeves 52 and 52*a*. Radial passages 53 connect this recess 51 to the valve body passage 26. The diameter of the ball valve 50 is less than the axial spacing between the inner ends of sleeves 52 and 52*a*, so that when the ball valve sealingly engages one of these sleeves the other sleeve is in fluid communication with the radial passages 53.

OPERATION

When the valve spool 12 is in its neutral position and assuming that the pump 16 is off, then spring 6 will position the pressure-compensating piston 14 as shown in FIG. 1, blocking the pump output from the controlled flow outlet port 16 leading to the inlet passages 18, 19 of the spool valve and from the bypass outlet port 20.

A particular advantage of the present arrangement resides in the fact that in the neutral position of the valve spool the reference pressure chamber 24 behind the pressure-compensating piston 14 is connected to the low-pressure return 23 by way of valve body passages 25 and 26 and past the ball shuttle valve 50 to the internal passages 39 and 39*a* in the valve spool, which are connected by the respective sets of transverse ports 41 and 41*a* to the return passages 36 and 36*a* in the valve body. Under these circumstances, chamber 24 will have substantially no hydraulic pressure therein, and the only pump pressure required to move the pressure-compensating piston 14 far enough to the right to connect the inlet port 15 to controlled flow outlet port 16 is that necessary to overcome the biasing force exerted by spring 6. That is, there is substantially no hydraulic force at chamber 24 adding to the force of spring 6, and tending to oppose such opening of the pressure-compensating valve.

This is in contrast to prior systems of this general type in which the reference pressure chamber behind the pressure-compensating piston is connected to a motor port of the spool valve when the valve spool is in neutral. In such systems, if the spool valve is holding a load at one of its motor ports, to open the pressure-compensating valve would require a pump pressure sufficient to overcome this motor port pressure acting on the pressure-compensating piston plus the spring force, whereas in the present arrangement the pump pressure is required to overcome only the spring force in order to open the pressure-compensating valve.

When the valve spool 11 is displaced axially from its neutral position to connect either inlet passage 18 or 19 to the respective motor passage 33*a* or 33 and to connect the other motor passage to return, the reference pressure chamber 24 behind the pressure-compensating piston 14 will be connected to the motor passage 33 or 33*a* which is passing the inlet flow to the cylinder and piston 35. This inlet flow motor passage will be at a slightly higher pressure than the motor passage which is conducting the return flow from the cylinder. The ball shuttle valve 50 will respond to this pressure differential and will move over to seat against the sleeve 52 or 52*a* at the inner end of the respective internal spool valve passage 39 or 39*a* which is then connected to the return motor passage, thereby connecting the motor inlet flow passage to the reference pressure chamber 24 of the pressure-compensating valve.

The pressure-compensating piston 14 senses the pressure differential between the pump output pressure (which at this time is essentially the same as the pressure at passage 17 leading into the spool valve) and the pressure at the motor passage 33 or 33*a* which is conducting the inlet flow to the cylinder and piston 35. That is, the pressure compensating piston effectively senses the pressure drop through the inlet flow passage of the spool valve. It maintains this pressure differential constant, thereby maintaining constant the inlet flow rate to the cylinder and piston 35, by bypassing excess flow from its inlet port 15 past the land 14*b* on the pressure-compensating piston 14 to the bypass port 20. Thus, for any given setting of the valve spool 11, if the inlet flow rate through the spool valve attempts to increase, the pressure-compensating piston 14 will move farther to the right and will thereby increase the bypass flow to return so as to eliminate the attempted inlet flow rate increase. The reverse action takes place if the inlet flow rate through the spool valve tends to decrease below the rate called for by the axial setting of the valve spool 11.

If the amount of this bypass flow is not sufficient to reduce the inlet flow through the spool valve in accordance with the latter's setting, the continued movement of piston 14 to the right will cause its land 14*b* to progressively restrict the fluid flow from the inlet port 15 to the controlled flow outlet port 16, thereby providing a series flow restriction ahead of the spool valve inlet in addition to providing a bypass passage to the bypass outlet port 20.

The biasing force exerted by spring 6 may be adjusted simply by turning the screw-threaded plug in or out.

The inlet flow rate through the spool valve depends, of course, upon the axial position of the valve spool 12 because the spool position determines the amount of axial overlap between the inner spool groove 38 or 38*a* and the inlet passage 19 or 18. This overlap provides a variable restriction orifice in the inlet flow passage through the spool valve, and the pressure-compensating piston senses the pressure differential across this restriction orifice to regulate the inlet flow rate, as described.

SECOND EMBODIMENT—FIGURES 2 and 3

FIGS. 2 and 3 show a second embodiment of the present invention which in many particulars is essentially similar to the embodiment of FIG. 1. Elements of the valve arrangement of FIGS. 2 and 3 which correspond to the elements of the FIG. 1 valve arrangement have the same reference numerals plus 100, and the detailed description of these elements will not be repeated.

Referring to FIG. 2, the spool valve has just a single annular inlet passage 200 connected to the controlled flow outlet passage 117 from the pressure-compensating valve. The respective motor passages 133 and 133*a* intersect the main bore 111 on opposite sides axially from the inlet passage 200 and are separated from passage 200 by respective cylindrical lands 201 and 201*a* of the main bore.

To the right of the motor passage 133, an annular reference pressure passage 202 intersects the main bore 111, being separated from motor passage 133 by a cylindrical land 203 of the main bore. Similarly, a reference pressure passage 202*a* intersects the main bore to the left of the motor passage 133*a*, being separated from the latter by a cylindrical land 203*a* of the main bore.

The right end of the main bore 111 is intersected by an annular return passage 136, located to the right of the reference pressure passage 202 and separated from the latter by a cylindrical land 204 of the main bore. This return passage 136 is connected to the return line 123 leading back to the sump S. Similarly, the left end of the main bore is intersected by an annular return passage 136*a*, located to the left of the reference pressure passage 202*a* and separated from the latter by a cylindrical land 204*a* of the main bore. The reference pressure passages 202 and 202*a* are connected through respective passages 205 and 205*a* in the valve body to ball shuttle valve 206, shown in detail in FIG. 3, and having an outlet passage 207 connected to the reference pressure chamber 124 of the pressure-compensating valve.

Referring to FIG. 3 the ball shuttle valve has a cartridge body 208 received in a bore 209 in the valve body 110. This cartridge body has a longitudinal bore 210 and radial openings 211 connecting this bore to the passage 205 leading from the reference pressure chamber 202 at the main bore 111 of the valve body. The right end of the cartridge body 208 in FIG. 3 has an enlarged counterbore 212 which intersects and is coaxial with bore 210. This counterbore snugly receives a flanged sleeve 213 whose outer end communicates with the passage 205*a* leading from the reference pressure chamber 202*a* at the main bore 111 of the valve body.

A ball shuttle valve member 214 is loosely received in the counterbore 212 between a valve seat provided by the inner end of sleeve 213 and a valve seat provided at the juncture between counterbore 212 and bore 210. Between these valve seats the cartridge body has radial openings 215 which provide fluid communication between the counterbore 212 and the valve body passage 207 leading to the reference pressure chamber 124 of the pressure-compensating valve.

In the operation of this ball shuttle valve, when the fluid pressure at reference chamber 202 is higher than the fluid pressure at reference chamber 202*a*, the fluid pressure differential acting on the ball valve member 214 will force it into seating engagement with the valve seat on the inner end of sleeve 213, thereby connecting passage 205 to the passage 207 leading to chamber 124 and blocking passage 205*a* from this chamber. Conversely, when the fluid pressure is higher at reference chamber 202*a* than at reference pressure chamber 202, the ball valve member 214 will seat against the valve seat at the inner end of bore 210, thereby connecting passage 205*a* to chamber 124 and blocking passage 205 from this chamber.

Referring again to FIG. 2, the valve spool 112 is of solid cross section, presenting a cylindrical central land 216 for sealing engagement with the lands 201 and 201*a* of the main bore 111 on either side of the inlet passage 200. This spool land has longitudinal metering slots or notches 217 which open into the motor passage 133 and similar metering slots or notches 217*a* opening into the other motor passage 133*a*.

Spaced to the right of its central land 216, the valve spool presents an intermediate cylindrical land 218 having a metering slot 219 which opens into the motor passage 133 and a metering slot 220 which opens into the reference pressure passage 202. Spaced to the left of its central land, the valve spool presents a second intermediate cylindrical land 218*a* having a metering slot 219*a* which opens into the motor passage 133*a* and a metering slot 220*a* which opens into the reference pressure passage 202*a*.

The valve spool has a cylindrical land 221*a* on its right end which sealingly engages the main bore 111 to the right of the return passage 136 and which is sealingly engageable with the bore land 204 between passages 202 and 136 when the spool is displaced axially to the left from the neutral position shown in FIG. 2. Similarly, the left end of the valve spool has a cylindrical lanu 221*a* which sealingly engages the main bore to the left of the return passage 136*a* and which is sealingly engageable with the bore land 204*a* between passages 202*a* and 136*a* when the spool is displaced axially to the right from the neutral position shown in FIG. 2.

The centering spring assembly for the valve spool includes a coil spring 143 engaged under compression between a pair of annular inner and outer washers 144 and 145 which loosely encircle the reduced outer end 222 of the spool. The inner washer 144 engages an outwardly facing annular shoulder 223 on the valve spool. Washer 144 also engages the outer end of a sleeve 224, whose inner end engages a washer 225 which is clamped between the valve body 110 and an end cap 226 enclosing the centering spring assembly. The outer washer 145 engages a washer 227 clamped on the outer end of the spool, and it also abuts against an inwardly facing annular shoulder 228 on the end cap 226.

The bypass outlet port 120 of the pressure-compensating valve is connected to a bypass passage 230, which may be connected either to the low-pressure return line or to the inlet side of another load circuit, such as the inlet to a valve arrangement similar to the one shown in FIG. 2 and connected to operate an additional fluid motor in the same manner. In this fashion, the excess flow into the first pressure-compensating valve which is bypassed via port 120 may provide the inlet flow to a similar second valve arrangement.

OPERATION

When the valve spool 112 is in its neutral position and assuming that the pump is off, spring 106 will position the pressure-compensating piston 114 as shown in FIG. 2, blocking the pump output from the controlled flow outlet port 116 leading to the spool valve inlet and from the bypass outlet port 120.

In the neutral position of the valve spool, the spool valve reference passage 202 is connected to the return passage 136 and the reference passage 202*a* is connected to the return passage 136*a*. Consequently, the reference pressure chamber 124 of the pressure-compensating valve is connected via passage 207, shuttle valve 206 and passages 205 and 205*a* to the return passages 136 and 136*a* of the spool valve. Consequently, the only pump pressure required to open the pressure-compensating valve is that necessary to overcome the biasing force of spring 106 on the pressure-compensating piston.

When the pump is turned on and the valve spool is shifted axially to connect the inlet passage 200 to either motor passage 133 or 133*a* and to connect the other motor passage to the adjacent return passage 136*a* or 136, the motor passage which is conducting the inlet flow from the inlet passage 200 to the fluid motor will be connected to the corresponding reference passage 202 or 202*a* of the spool valve. At the same time, the valve spool will block the adjacent return passage from this reference passage. Consequently, the fluid pressure in the reference pressure chamber 124 of the pressure-compensating valve will now be substantially equal to the fluid pressure at the spool valve motor passage which is conducting the inlet flow. The pressure-compensating piston will respond to the pressure differential between the spool valve inlet passage 200 and this motor passage to regulate the inlet flow rate through the spool valve by bypassing excess flow to the bypass outlet port 120 of the pressure-compensating valve and, if necessary, by restricting the flow from the inlet port 115 to the controlled flow port 116 leading to the spool valve inlet, as described.

LOAD CHECK OPERATION

In both illustrated embodiments of the invention, the pressure-compensating piston (14 or 114) acts as a load check in the event of a failure of the input pressure, such as by a failure of the pump or a break in the line connecting the pump output to the inlet port (15 or 115) of the pressure-compensating valve. In that event, the absence of input pressure urging this piston to the right will enable the bias spring (6 or 106) to move the piston to the position shown in FIG. 1 or FIG. 2. With the controlled-flow outlet port (16 or 116) of the pressure-compensating valve blocked from both its inlet port (15 or 115) and its bypass outlet port (20 or 120) by the pressure-compensating piston there can be no return of fluid through the spool valve and the pressure-compensating valve back to the break in the inlet line.

I claim:

1. A pressure-compensated flow control arrangement for controlling the operation of a fluid motor comprising:

a spool valve having a bore, and an inlet passage, a motor passage and a return passage intersecting said bore, and a valve spool movable in said bore to control the fluid connections between said inlet passage and said motor passage and between said motor passage and said return passage, said valve spool having a neutral position blocking said motor passage from both said inlet passage and said return passage, said valve spool being movable from said neutral position to a position connecting said inlet passage to said motor passage and blocking said motor passage from said return passage;

a pressure-compensating valve for regulating the inlet flow through said spool valve, said pressure-compensating valve having an inlet port for connection to the source of pressure fluid for the spool valve, a bypass port for bypassing pressure fluid away from said inlet passage of the spool valve, a reference pressure chamber, a pressure-compensating piston disposed between said inlet and bypass ports to control the fluid flow therebetween, said piston having oppositely facing surfaces which are exposed respectively to the fluid pressure at said inlet port and the fluid pressure at said reference pressure chamber, and spring means biasing said piston to a position blocking said bypass port from said inlet port;

and connecting passage means including a shuttle valve for connecting said spool valve to said reference pressure chamber of the pressure-compensating valve;

said valve spool in its neutral position connecting said return passage to said reference pressure chamber through said connecting passage means;

and said valve spool, when displaced from said neutral position to a position connecting said inlet passage to said motor passage, also connecting said motor passage to said reference pressure chamber through said connecting passage means.

2. A flow control arrangement according to claim 1 wherein said connecting passage means includes an internal longitudinal passage in the valve spool, and transverse port means in the valve spool connecting said internal passage to said bore and registering with said return passage when the valve spool is in its neutral position, said transverse port means registering with said motor passage when the valve spool is displaced to a position connecting said inlet passage to said motor passage and blocking said motor passage from said return passage.

3. A flow control arrangement according to claim 1, wherein said connecting passage means includes a reference passage intersecting said spool valve bore between said motor passage and said return passage, said valve spool in its neutral position providing fluid communication between said reference passage and said return passage, said valve spool when displaced to said position connecting said inlet passage to said motor passage also providing fluid communication between said motor passage and said reference passage, and said connecting passage means also includes a passage extending from said spool valve reference passage to said reference pressure chamber of the pressure-compensating valve.

4. A flow control arrangement according to CLAIM 1, wherein said pressure-compensating valve has a controlled flow outlet port connected to said inlet passage of the spool valve, and sad spring means biases said piston to a position blocking said inlet port and said bypass port and said controlled flow outlet port from one another.

5. A flow control arrangement according to claim 4 wherein said inlet port is disposed between said bypass port and said controlled flow outlet port, and said piston has a pair of axially spaced lands which respectively block said bypass port and said controlled flow outlet passage from said inlet port in said last-mentioned position of the piston.

6. A pressure-compensated directional flow control arrangement for controlling the operation of a reversible fluid motor comprising:

a spool valve having a bore, inlet passage means, a pair of motor passages for connection to the opposite sides of the fluid motor, and return passages intersecting said bore, and a valve spool movable in said bore to control the fluid connections between said inlet passage means and said motor passages and between said motor passages and said return passages, said valve spool having a neutral position blocking both said motor passages from said inlet passage means and from said return passages, said valve spool being movable from said neutral position to a position establishing an inlet flow passage between said inlet passage means and a selected motor passage and establishing a return flow passage between the other motor passage and the corresponding return passage;

a pressure-compensating valve for regulating the inlet flow through said spool valve, said pressure-compensating valve having an inlet port for connection to the source of pressure fluid for the spool valve, a bypass port for bypassing pressure fluid away from said inlet passage means of the spool valve, a reference pressure chamber, a piston slidably disposed between said inlet and bypass ports to control the fluid flow therebetween, said piston having oppositely facing surfaces which are exposed respectively to the fluid pressure at said inlet port and the fluid pressure at said reference pressure chamber, and spring means biasing said valve means to a position blocking said bypass port from said inlet port;

and a shuttle valve connected between the spool valve and said reference pressure chamber of the pressure-compensating valve and operable, when the valve spool is positioned to establish said inlet and return passages, to connect the motor passage which is in said inlet flow passage to said reference pressure chamber;

said valve spool in said neutral position thereof blocking both motor passages from said shuttle valve and connecting the return passages to said reference pressure chamber of the pressure-compensating valve through said shuttle valve.

7. A flow control arrangement according to claim 6, wherein said shuttle valve is in the valve spool.

8. A flow control arrangement according to claim 6, wherein:

said valve spool has a pair of longitudinal internal passages therein, and transverse port means connecting said internal passages to the spool valve bore and registrable selectively with said motor passages and return passages in different positions of the valve spool;

and said shuttle valve comprises a pair of oppositely facing valve seats connected to the respective internal passages of the valve spool, and a movable valve member reciprocably disposed between said valve seats for sealing engagement with either valve seat while spaced from the other valve seat, and an outlet passage disposed between said valve seats for fluid communication with the valve seat from which the valve member is spaced, said outlet passage being connected to said reference pressure chamber of the pressure-compensating valve.

9. A flow control arrangement according to claim 8, wherein said transverse port means connect both internal spool passages to said return passages when the valve spool is in said neutral position.

10 A flow control arrangement according to claim 6, wherein:

said spool valve has a pair of reference passages intersecting its bore between the motor passages and the respective return passages;

said shuttle valve is connected between both said reference passages and the reference pressure chamber of the pressure-compensating valve;

said valve spool in its neutral position connects said reference passages to the respective return passages and blocks said reference passages from the respective motor passages;

and said valve spool, when positioned to establish said inlet and return flow passages through the spool valve, connects both said reference passages to the respective motor passages.

11. A pressure-compensated flow control arrangement for controlling the operation of a fluid motor comprising:

a flow control valve having inlet and motor ports and a low-pressure return passage, and selectively operable valve means in said control valve controlling the fluid communication between said ports and passages, said valve means having a neutral position blocking said motor port from both said inlet port and said return passage, said valve means being shiftable from said neutral position to a flow-conducting position connecting said inlet port to said motor port and providing a flow restriction between them which varies with the position of said valve means;

a pressure-compensating valve connected ahead of the inlet port of said control valve to control the inlet flow thereto; said pressure-compensating valve having one side thereof connected to said motor port and being operable to regulate the inlet flow to the control valve in accordance with the pressure differential across said flow restriction when said valve means in the control valve is in a flow-conducting position; said pressure-compensating valve having one side thereof connected to said return passage when said valve means in the flow control valve is in said neutral position;

and a shuttle valve interposed said one side of said pressure-compensating valve and said flow control valve.

12. A pressure-compensated directional flow control arrangement for controlling the operation of a reversible fluid motor comprising:

a spool valve having a bore, inlet passage means, a pair of motor passages and a pair of return passages intersecting said bore, and a valve spool movable in said bore to control the fluid connections between said inlet passage means and said motor passages and between said motor passages and said return passages;

said valve spool having a pair of longitudinal internal passages spaced apart axially of the spool therein and transverse port means connecting said internal passages to the spool valve bore, and a shuttle valve in the spool operatively connected between said internal passages and exposed to the fluid pressure in each, said shuttle valve comprising a pair of oppositely facing valve seats connected individually to the respective internal passages of the spool, a movable valve member reciprocably disposed between said valve seats for sealing engagement with either valve seat while spaced from the other valve seat, and an outlet passage disposed between said valve seats for fluid communication with the valve seat from which the valve member is spaced, said transverse port means connecting both internal passages of the valve spool to said return passages when the valve spool is in a neutral position blocking said inlet passage means from said motor passages,

said valve spool means being shiftable longitudinally to connect said inlet passage means to a selected one of said motor passages and to connect the other of said motor passages to a return passage and to connect the motor passages to the respective internal passages in the valve spool through said transverse port means therein;

a pressure-compensating valve for regulating the inlet flow through said spool valve, said pressure-compensating valve having an inlet port for connection to the source of pressure fluid for the spool valve, a bypass port for bypassing pressure fluid away from said inlet passage means of the spool valve, a reference pressure chamber, a piston slidably disposed between said inlet and bypass port to control the fluid flow therebetween, said piston having oppositely facing surfaces which are exposed respectively to the fluid pressure at said inlet port and the fluid pressure at said reference pressure chamber, spring means biasing said valve means to a position blocking said bypass port from said inlet port, and passage means connecting said reference pressure chamber to said shuttle valve in the spool to apply to said reference pressure chamber the fluid pressure in the longitudinal internal passage which is in communication with the valve seat which is spaced from said valve member.