This invention relates to hydraulic valves and more particularly to two-stage hydraulic valves having a hydraulic feedback.

In the past, two-stage hydraulic valve systems have utilized some means of feedback from the second stage to the first stage to indicate the movement or response of the second stage. One method of accomplishing this feedback has been by mechanical means. That is, the second stage valve member is mechanically connected to the first stage and therefore any movement of the second stage is fed back to the first stage. The disadvantage of the mechanical feedback system is that it is very complex, costly and requires extra space. A second known method of feedback between a first and second valve is the pressure transducer, but again, the pressure transducer requires extra space, adds more complexity to the system and increases the cost of the system. It is also possible to use an electric pickoff on the valve member of the second stage to provide an electrical signal proportional to the movement of the valve member of the second stage. The electrical signal is picked up by a motor or other electrical operating mechanism which in turn operates the valve member of the first stage. The disadvantage of an electric pickoff is that the electrical pickoff is more subject to failure than is a hydraulic feedback and the electric pickoff is, again, more complex and more costly.

It is therefore an object of this invention to provide a two-stage hydraulic valve system requiring no external feedback.

It is another object of this invention to provide a hydraulic valve having hydraulic feedback.

Still another object of this invention is to provide a hydraulic valve which operates on a mechanical or electrical input and has hydraulic feedback.

Still another object of this invention is to provide a feedback from the second valve to the first, which really represents the fluid flow furnished by the second stage valve to the actuator.

Other objects and advantages of the present invention will become apparent from the following description when taken in conjunction with the drawings, in which:

FIGURE 1 is a cross section of the present invention; and

FIGURE 2 is a cross sectional view of a second embodiment of the present invention.

Referring now to FIGURE 1, there is shown a first valve body 10 which contains a valve cylinder 11 and valve member 12 reciprocally movable in valve cylinder 11. A mechanical lever 13 is mechanically connected to and drives the valve member 12 longitudinally within valve cylinder 11. The mechanical lever 13 may be operated by any means, e.g., a motor. The valve body 10 has an input port 14 and two return ports 15 and 16. The valve member has four portions 17, 18, 19 and 20 spaced longitudinally and connected by a shaft 21. The input port 14 is positioned between the portions 18 and 19 of the valve member 12 and the return ports 15 and 16 are positioned between the portions 17 and 18 and 19 and 20, respectively. The valve body 10 has a further passage 22 connected to both ends of the valve cylinder 11 by passages 23 and 24. Ports 25 and 26 are located on either side of input port 14 and are connected to the valve cylinder 11. Note that the ports 25 and 26 do not connect to the passage 22. An orifice 27 is positioned in passage 22 and located between the passages 23 and 24.

The input port 14 is connected by suitable conduit 30 to a fluid supply 31. The return ports 15 and 16 are connected by suitable conduit 32 to the fluid supply 31. Since the valve member 12 is in the neutral position, the valve portions 18 and 19 restrict the flow of fluid from the input port 14 to the passages 22 and 26. However, if the lever 13 moves the valve member 12 longitudinally one way or the other, the incoming fluid entering the port 14 is allowed to pass to either passage 25 or passage 26, depending upon which way the valve member 12 is moved.

A second valve body 33 contains a second valve cylinder 34 and a second valve member 35 reciprocally movable in valve cylinder 34. The valve member 35 also has four portions 36, 37, 38 and 39 spaced longitudinally and connected by shaft 40. The valve body 33 has an inlet port 41 connected to the fluid pressure source by way of suitable conduit 42 and conduit 28. The port 41 is positioned between the sections 37 and 38 of the valve member 35. The valve body 33 also has two return ports 43 and 44 connected to the fluid supply 31 by way of suitable conduit 45 and conduit 32. One end of valve cylinder is connected by suitable conduit 46 to passage 25. The other end of cylinder 34 is connected by suitable conduit 47 to passage 26. The valve body 35 also has two ports 48 and 49 located on the other side of port 41. The housing 50 contains a piston cylinder 51 and a piston 52 reciprocally movable in cylinder 51. A shaft 53 is connected to one side of piston 52 and extends through the housing 50. The piston cylinder 51 has a port 54 located at one end and a port 55 located at the other end of cylinder 51. The port 54 is connected to port 49 by suitable conduit 57.

In operation, the lever 13 or any other means for actuating valve member 12 moves the valve member 12, for example, to the right, causing fluid to flow through the port 25, conduit 46 and into cylinder 34 to create a pressure against the portion 39 of the valve member causing the valve member 35 to move to the left as seen in the drawing, which in turn causes the fluid entering port 41 to flow through the port 48 to the passage 22 by way of suitable conduit 58, through the orifice 27 to the piston 52. It can be seen that there is a pressure differential at the opposite ends of the orifice 27. The passage 22 being connected to the cylinder 11 transmits the pressure differential to the portion 20 of valve member 12, urging the valve member 12 to the left, as seen in the drawing, to close off the outlet port 25. At the same time, the piston 52 and shaft 53 are driven to the right by the fluid flow. The fluid on the other side of the piston 52 passes through port 55 and conduit 57 into cylinder 34 and then to the fluid supply by way of port 43 and conduits 45 and 32. It can be seen that for a given flow of fluid through the orifice 27, a given amount of pressure will exist on the position 20 of valve member 12 thus counteracting the initial urging force on valve member 12 produced by motor 13. The port 25 will remain open until the flow of fluid against the valve member 12 is sufficient to urge the valve member 12 in a position to close the port 25. Once the valve member 12 has returned to the neutral position, any further pressure on the portion causes valve member 12 to open the port 26 which in turn causes the valve member 35 to move to the right to shut off the flow of fluid to the piston 52. Hence, the piston 51 receives a given amount of pressure from the fluid flow for a given movement of valve member 12.

If now the motor 13 drives the valve member 12 to the left as seen in the drawing, the fluid from port 14 passes through the port 26 and then through the conduit 47 against the portion 36 of the valve member 35 causing the valve member 35 to move to the right which in turn causes the input fluid entering the valve body 33 through port 41 to pass through the port 49 and conduit
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57 to the piston cylinder 51 to urge the piston 52 and shaft 53 to the left. The fluid on the other side of the piston 52 is forced through conduit 56 and orifice 27, passage 22, conduit 58 and port 48 to the return port 44. The return fluid flow from the piston 52 in passing through the orifice 27 again sets up a pressure differential. The pressure differential at the opposite ends of the orifice 27 is transmitted to the portion 17 of valve member 12, therefore urging the valve member 12 to the right in opposition of the urging of the motor 13. When the pressure on the portion 17 of valve member 12 is sufficient to close the port 26 then the valve member 35 returns to a neutral position and maintains the piston 52 in a new position.

It is seen that the orifice 27 is small, in the range from .01 to .1 inch in diameter, so that the differential pressure on either side of the orifice is established as soon as valve member 35 moves from the neutral position. For a typical supply pressure of the fluid, e.g., 3000 psi., and for a typical differential pressure on the opposite ends of the orifice of 100 psi., the rate of flow through the orifice, if the orifice is, for example, .05 inch in diameter, will be approximately one gallon per minute, depending upon the characteristics of the design.

It can be seen then that by the above method there is provided a hydraulic feedback proportional to the rate of flow of fluid through the orifice 27.

Note, also, that in place of the passage 22 and orifice 27, it is possible to make a hole in the shaft 21 to serve the same purpose.

FIGURE 2 shows a further modification of the present invention wherein a valve body 59 has a valve cylinder 60 therein and an enlarged portion 61 of valve cylinder 60. A valve member 62 is reciprocally movably within valve cylinder 60. The valve member 62 has two pistons 63 and 64, and a spool member 65 connected by shaft 66. The valve body 59 has an inlet port 67 positioned between the portion 64 and 65 of the valve member 62 and a return port 68 positioned between the portion 63 and 65 of valve member 62. The valve body 59 also has two outlet ports 69 and 70. The outlet port 69 is positioned between the inlet port 67 and the return port 68 and the outlet port 70 is positioned between the portion 64 and 65 of valve member 62. The valve housing 59 also has a passage 71 therein. The end of piston 62 of valve member 62 is hydraulically connected to the inside portion of the piston 64 of valve member 62 by way of passages 72, 71 and 73. Enlarged portion 61 of valve chamber 60 is connected by suitable conduit 79 to one end of the piston cylinder 51. In the case of FIGURE 2, it is necessary to modify the valve member 35 so that one end portion is larger than the other and so that a larger fluid flow to the smaller end balances a smaller fluid flow to the larger end and maintains the valve member 35 in a neutral position. The rest of the device shown in FIGURE 2 is substantially the same as that shown in FIGURE 1.

To understand the operation of FIGURE 2, first consider that the valve member 61 is in a neutral position when the portion 65 of valve member 62 is positioned so that there is a small opening to the outlet port 69 and there is a balance of pressure on both ends of valve member 35. If the torque motor moves valve member 62 to the right, more fluid enters the input port 67 and passes to the outlet port 69, to the portion 39 of valve member 35 causing the valve member 35 to move to the left, as seen in the drawing, thereby causing the fluid entering port 41 of the valve body 33 to pass to the outlet port 48 of the valve body 33 through the conduit 58 to the passage 51. The fluid in passage 51 will pass through the port 73, through the space 75 around piston 64 through the conduit 55 and into the piston chamber 51. The fluid on the other side of piston 52 is forced to the return port 43 by way of conduit 57 and port 48. The fluid as it flows through the opening 75 around the piston 75 creates a differential pressure between the passage 73 and the conduit 74. The differential pressure acts on the piston 64 in a direction to urge the valve member 62 to the right to close the port 69. If the valve member 62 moves beyond the neutral point while moving to the right, the pressure in the port 69 is exposed to the return port 68 thereby decreasing the pressure on one side of the valve member 35 causing the valve member 35 to return to the neutral position which in turn decreases the pressure on the valve member 62 and causes the valve member 62 to also return to the neutral position. A movement of the valve member 62 to the left, caused by the motor 13, tends to close port 69 causing an unbalance of pressure on valve member 35 which causes valve member 35 to move to the right causing fluid flow from the intake port 41 to flow to the outlet port 49 and to the piston chamber 51 by the way of the conduit 57 and port 55. The back pressure or flow of fluid on the opposite side of the piston 52 causes fluid to flow in conduit 74 and around the piston 64. Again, the differential pressure created by the fluid flowing around the small opening around piston 64 causes the differential pressure to be transmitted to the piston 64 in a direction to urge the valve member 62 to the right to open the port 69 and again put a balance of pressure on the valve member 34 to return the valve member 34 to the neutral position.

It can be seen that the bituminous in FIGURE 2 provides a hydraulic feedback proportional to the rate of flow of the fluid around the piston 64.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by limitation, spirit and scope of this invention being limited only by the terms of the appended claims.

1. A valve system comprising a fluid pressure source, a first valve means connected to said fluid pressure source, a second valve means hydraulically connected to said fluid pressure source and said first valve means such that said second valve means is responsive to the output of said first valve means, means to actuate said first valve, the output of said second valve being connected by way of an orifice to a load, conduit means connecting one end of said first valve means to the other side of said first valve means to the other side of said orifice such that fluid flow through said orifice creates a pressure differential on either side of said orifice which is applied to the ends of said first valve means to operate said first valve means in opposition to the mechanical input means to operate said first valve.

2. A two-stage valve system comprising a first valve body having a first valve member reciprocally movable therein, an inlet port and two outlet ports in said first valve body wherein said first valve member controls the flow of fluid between said inlet port and said outlet ports, a second valve body having a second valve member reciprocally movable therein wherein said second valve body has an inlet port and two regulated outlet ports and said second valve member controls the flow of fluid between said inlet port and said two regulated outlet ports, suitable conduit connecting said outlet ports of said first valve body to the ends of said second valve member such that second valve member is responsive to the output of said first valve body, said second valve body having suitable outlet conduit and an orifice in said outlet conduit of said second valve body and means for hydraulically connecting one end of said first valve member to one side of said orifice and the other end of said first valve member to the other side of said orifice such that fluid flow through said orifice creates a differential pressure between the opposite ends of said orifice and said differential pressure is transmitted to one end of said first valve member.

3. A two-stage valve system comprising a first valve
body having a valve cylinder therein and a valve member reciprocally movable within said valve cylinder, said first valve body having provisions for an inlet and two outlet ports whereby said first valve member controls the flow of fluid from said inlet port to outlet port, said first valve member having a passage therethrough from one end of said first valve member to the other end of said first valve member, a second valve body having a second valve cylinder therein and a second valve member reciprocally movable within said second valve body, said second valve body having the provisions of an inlet port and two outlet ports, said second valve member controlling the flow of fluid from said inlet port to said two outlet ports of said second valve body, one of said outlet ports of said second body being hydraulically connected to one end of said first valve member by means of suitable conduit, the other outlet port of said second valve body being hydraulically connected to the other end of said first valve member by suitable conduit, said second valve member being responsive to the output of said first valve body whereby the output of said second valve body passing through said first valve member creates a differential pressure on either end of said first valve member so that said first valve member is urged in a direction to move said first valve member in a position to close said outlet ports of said first valve body.

4. A two-stage valve system comprising a first valve body having a first valve member reciprocally movable therein, said first valve body having an inlet port and two outlet ports positioned between the ends of said first valve member, said first valve body being a control valve for fluid flow between said inlet ports and said outlet ports in said first valve body, the ends of said first valve member extending into respective chambers such that one of the ends of said first valve member extends into an enlarged chamber whereby said enlarged chamber has an inlet and outlet port and said one end of said valve member is positioned between said inlet and outlet ports with a gap between said one end of said valve member and the walls of said chamber such that fluid may flow from said inlet port of said chamber to said outlet port of said chamber, torque means to operate said first valve member, a second valve body having a second valve member reciprocally movable therein, said second valve member being responsive to the output of said first valve body whereby the output of said second valve body is connected by suitable conduit to the input and output ports of said enlarged cylinder such that flow of fluid out of said second valve body and around said one end of said valve member causes a differential pressure on either side of said first valve member thereby urging said first valve member in a direction opposite to the urging of said torque means.

5. A hydraulic valve system comprising a first valve body and a first valve member reciprocally movable therein, said first valve body having the provisions of an inlet port, two return pressure ports and two regulated pressure ports, said valve member controlling the flow of fluid between said inlet port and said two regulated pressure ports, means mechanically connected to said valve member to operate said valve member within said valve body, a second valve body and a second valve member reciprocally movable therein, said second valve body having the provisions of two inlet ports connected respectively to said two regulated pressure outlet ports of said first valve body such that said regulated input ports of said second valve body are connected to either end of said body whereby said second valve member is positioned between said two inlet ports, a third inlet port within said second valve body, two return ports within said second body, valve body and two regulated pressure outlet ports within said second valve body, a housing having a chamber therein and a piston movably mounted within said chamber, suitable conduit connecting one of said two regulated outlet ports from said second valve member to one side of said piston chamber, suitable conduit connecting the other of said two regulated outlet ports of said second valve member to the other side of said piston chamber by way of an orifice in said suitable conduit connecting said other regulated outlet port of said valve member to said other side of said piston cylinder, said first valve body having ports therein on either side of said valve member and suitable conduit connecting said ports on either side of said valve member to said conduit connecting said second regulated pressure outlet ports of said second valve body wherein said orifice is positioned between said ports on either side of said valve member in said first body, said first valve member moving in response to said mechanical means, said second valve member moving in response to movement of said first valve member and said piston moving in response to said second valve member to force fluid through said orifice thereby creating a differential pressure on the opposite ends of said orifice, said differential pressure being transmitted to one end of said first valve member to urge said first valve member in a direction opposite the urging of said mechanical operating means.

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