ABSTRACT OF THE DISCLOSURE

A regenerative valve plunger for open center hydraulic control valves. The plunger has a pair of center necks which form part of the open center path, and contains a regeneration check valve. This check valve is so designed and arranged as to prevent it from by-passing flow through the center necks whenever the plunger is throttling flow through the open center path.

Background and summary of the invention

This invention relates to open center hydraulic control valves of the sliding plunger type, and is particularly concerned with the regenerative plungers which are commonly used in those valves.

In some hydraulic systems, the double-acting actuating cylinders may be subjected to loads which cause them to move at speeds in excess of that with which the supply pump can keep pace. This condition, which is referred to as an overhauling or overrunning load, can cause the expanding side of the cylinder to cavitate. Therefore, the system commonly is equipped with a regeneration device which automatically diverts to the expanding side of the cylinder some or all of the fluid displaced from the contracting side. The regenerative flow supplements the output of the supply pump and keeps the expanding side of the cylinder liquid-filled. Frequently, the regeneration device is incorporated in the valve plunger itself. Patent No. 3,006,372, issued Oct. 31, 1961, and co-pending application Ser. No. 529,473, filed Feb. 23, 1966, now Patent No. 3,591,708 disclose valve plungers of this type.

While the prior regenerative plungers just mentioned are satisfactory from the standpoint of preventing cavitation, they do have the disadvantage of precluding use of conventional flow force compensation techniques. The main flow forces acting on these plungers are generated at the center necks or grooves which form part of the open center flow path, and which can be subjected to large flow rates and pressure drops. When a plunger is shifted away from neutral position to meter flow to one side or the other of the controlled cylinder, flow through the center necks is throttled, and the plunger is subjected to a dynamic or flow force which acts at an angle to the plunger axis and urges the plunger in a direction to close the open center path. The usual method of reducing the magnitude of this force consists in using a special contour for each neck which is so designed that the flows into and out of the neck generate countervailing forces. While this technique does reduce the net flow force acting on each of the prior plungers when it is moved in one direction from neutral position, it has little effect when the plunger is shifted in the opposite direction. The reason for this is that the regenerative check valve opens and provides a shunt path which allows a substantial part of the open center flow to by-pass the contoured neck at which this flow is being metered. This obviously precludes realization of the full benefits which can be afforded by the special contour of the center neck.

The object of the present invention is to provide an improved regenerative valve plunger in which the regenerative check valve is so designed and arranged that it remains closed, and thus prevents by-passing of the center necks, whenever the plunger is metering flow to either side of the controlled cylinder.

Description of the preferred embodiment

The preferred embodiment of the invention is described herein with reference to the accompanying drawing in which:

FIG. 1 is an axial sectional view of the improved plunger, including a portion of the valve housing in which it is used and schematic representations of the other components of a typical hydraulic circuit.

FIG. 2 is an enlarged view of the center portion of the plunger shown in FIG. 1.

As shown in the drawing, the improved plunger 11 is embodied in a multi-plunger valve of the tandem type whose housing 12 is provided with the conventional center Y-core 13, and exhaust manifold branches 14 and 14a. The plunger is mounted for reciprocation in a bore 15 which extends through housing 12 and is interconnected by seven longitudinally spaced chambers 16-22; the chambers 16 and 17 communicating with a pump 23 through the upstream portion of Y-core 13, the chamber 18 communicating with a reservoir or tank 24 through the downstream portion of the Y-core, the chamber 19 communicating directly with the exhaust manifold branches 14 and 14a, and the chambers 21 and 22 being connected with the opposite sides of a double-acting cylinder 25. Plunger 11 is formed with a pair of center necks 26 and 27 which are shaped to afford flow force compensation in accordance with a known technique, and which define three valving lands 28, 29 and 31. In the illustrated neutral position N, necks 26 and 27 complete the open center path, and lands 28 and 31 isolate chambers 21 and 22, respectively, from each other and from the other fluid-containing spaces of the valve.

Extending through valve plunger 11 is an axial bore whose opposite ends are closed by threaded plugs 32 and 33, and which is divided into right and left bore portions 34 and 35, respectively, by an intermediate threaded plug 36. Right bore portion 34 is intersected by two sets of radial passages 37 and 38 and contains a conventional load drop check valve 39. Passages 37 and 38 are positioned to register with chambers 22 and 20, respectively, in the raise position R, and to register with chambers 17 and 22, respectively, in the lower position L.

The left bore portion 35 is intersected by three sets of radial passages 41, 42 and 43, and contains a set of poppet valves 44 and 45 constructed and arranged in accordance with the teachings in application Ser. No. 529,473, referred to earlier. These passages are so positioned that, in the raise position, passages 42 and 43 register with chambers 21 and 16, respectively, and, in the lower position, passages 41 and 43 register with chambers 19 and 21, respectively, and passages 42 are closed by the wall of bore 15. Poppet valve 44, which serves as a load drop check valve, is biased closed by a light spring 46 and by the pressure in passages 42, and is urged in the opening direction by the pressure in a space 47 communicating with radial passages 43. Poppet valve 45, on the other hand, serves to control the closing bias on valve 44. It is biased closed by a spring 48 and by the pressure in a space 49 at its left end, and is urged in the opening direction by the pressure in radial passages 42 which acts upon its right end. Longitudinally extending grooves formed in the outer periphery of poppet valve 45 connect space 49 with radial passages 41. Spring 48 exerts a greater force than spring 46, and thereby maintains valve 45 on its seat against the unseating action of the spring 46 which reacts against it.

At its right end, bore portion 34 contains a regenerative check valve 51 which controls communication between space 47 and a set of radial passages 52 which
open through plunger 11 in the region of center neck 26. Check valve 51 is biased closed by a coil compression spring 23 to the pressure in chamber 54 at its right end, and is urged by the open center flow in the same direction by the pressure in space 47. This chamber 54 communicates with plunger neck 27 through a restricted radial passage 55, and with plunger neck 26 through axial and radial passages 56 and 57, respectively, formed in check valve 51. A small check valve 58 prevents reverse flow from chamber 54 to plunger neck 26 through passages 56 and 57. The restriction to flow afforded by passage 55 is much greater that afforded by passages 56 and 57 and check valve 58; therefore, when check valve 58 opens to allow fluid into chamber 54, the pressure in the chamber will rise.

As will become evident from the following description of operation, leakage from chamber 54 must be kept to a minimum during load-raising operations in order to prevent opening of regenerative check valve 51. In the illustrated embodiment, this leakage-minimizing function is performed by a close fit between check valve 58 and the wall of bore portion 35, but a sealing device may also be used.

When the control valve is in operation and valve plunger 11 is in the illustrated neutral position N, the oil from Y-core 13 by pump 23 passes through chambers 16 and 17 and axial and radial passages 27 to central chamber 18, and then flows to the succeeding valving units or to tank 24 through the downstream portion of the Y-core. This open center flow is not restricted by plunger 11; therefore, if none of the succeeding plunger is in its operative position, pump 23 will be unloading. In this position of plunger 11, lands 28 and 31 isolate chambers 21 and 22, respectively, from the other fluid-containing spaces of the valve, so cylinder 25 is hydraulically locked.

As valve plunger 11 is shifted to the right to the raise position, central land 29 interrupts flow from chamber 17 to chamber 18, and then the right end of land 28 commences to restrict or throttle flow from chamber 16 to chamber 18. Simultaneously, or approximately simultaneously, radial passages 43 commence to register with chamber 16, and radial passages 37 and 38 commence to register with chambers 22 and 20, respectively. When the backpressure resulting from throttling of the open center flow exceeds the load pressure in chamber 21, poppet valve 44 will open and oil will flow to the rod end of cylinder 25 via chamber 16, radial passages 43, space 47, check valve 44, radial passages 42 and chamber 21. The pressure check valve 44, radial passages 37, bore portion 34, check valve 39, radial passages 38, chamber 20 and branch 14 of the exhaust manifold. The rate at which fluid is supplied to cylinder 25, and consequently the speed at which piston 25a moves the load, depends upon the position of valve plunger 11 since this governs the degree to which the open center flow is throttled. When the plunger 11 is shifted all the way to the raise position R, land 28 will completely interrupt flow from chamber 16 to chamber 18, and the entire output of pump 23 will be delivered to the cylinder.

During load-raising operations, the chamber 54 behind regenerative check valve 51 is in constant communication with the upstream portion of Y-core 13 through passage 55 and chamber 17. Since leakage from chamber 54 is minimized by the close fit between check valve 51 and bore portion 35, the pressure in the chamber will be very close to the supply pressure in the Y-core. Therefore, regenerative check valve 51 will remain closed even though space 47 contains oil under supply pressure. This result insures not only that all of the open center flow will pass through center neck 26, and thus be available for flow force compensation, but also, and even more importantly, that the regeneration scheme does not divert the output of pump 23 to tank 24 and preclude actuation of the cylinder 25.

When plunger 11 is shifted to the left from the neutral position, land 29 blocks communication between chambers 16 and 18, and the left edge of land 31 becomes effective to throttle the open center flow. In this case, radial passages 37 and 38 are brought into registration with chambers 17 and 22, respectively, radial passages 41 and 43 are brought into registration with chambers 19 and 21, respectively, and radial passages 42 are closed by the wall of bore 15. At the same time, radial passages 52 are isolated from chamber 18 and brought into free communication with the upstream portion of Y-core 13 through chamber 16, and restricted passage 55 is placed in free communication with chamber 18. Now oil is supplied to the head end of cylinder 25 through chamber 17, radial passages 37, bore portion 34, check valve 39, radial passages 38 and chamber 22, and the return flow from the cylinder is delivered to the space 47 in bore portion 35 through chamber 21 and radial passages 43. The pressure in space 47 tends to move poppet 44 off its seat, but, since passages 42 are now blocked, this valve cannot open until the pressure rises to a value sufficient to overcome the bias of spring 48. When plunger neck 27 is unblocked and the time that poppet valve 45 will open and destroy the temporary hydraulic lock which has been holding valve 44 closed. This permits poppet 44 to open and allow the oil returning to space 47 to flow to tank 24 via poppet 45, radial passages 41, chamber 19 and branch 14 of the exhaust manifold.

Since, during this load-lowering operation, radial passages 52 and the connected passages 57 in regenerative check valve 51 are in free communication with the upstream portion of Y-core 13, and passage 55 is in free communication with chamber 18, small check valve 58 will also be open. Therefore, a portion of the oil delivered by pump 23 will be diverted to tank 24 via chamber 16, passages 52 and 57, check valve 58, passage 56, chamber 54, restricted passage 55, chamber 18 and the downstream portion of the Y-core. Because of the difference between the restrictions afforded by the paths leading into and out of the pilot, the backpressure will be high, and therefore, the supply pressure in the upstream portion of Y-core 13. This pressure acts on the right end of regenerative check valve 51 and develops a force which, in conjunction with the bias of spring 53, urges valve 51 toward its seat. If the load being actuated opposes movement of piston 25a, the supply pressure will be relatively high, and the closing force acting on regenerative check valve 51 will maintain it closed against the opposing force developed by the backpressure in space 47. Therefore, under this condition, all of the return flow from cylinder 25 passes to tank 24 through the poppet valves 44 and 45. On the other hand, in cases where the load aids movement of piston 25a and is large enough to cause it to move at a speed which exceeds the capacity of pump 23, the backpressure in chamber 54 will decrease below the pressure in space 47. Now, regenerative check valve 51 will open to divert at least some of the return flow to the upstream portion of Y-core 13 through radial passages 52 and chamber 16, and thereby supplement the output of pump 23. The proportion of the return flow diverted to the expanding end of the cylinder depends upon the severity of the overrun condition and will always be sufficient to maintain the backpressure in Y-core 13 at approximately the level of the backpressure in space 47. This last mentioned backpressure can be varied by changing the bias exerted by spring 48 and is set high enough to ensure that the supply pressure will always be adequate to overcome line losses and keep cylinder 25 lightly closed even at very low pressure.
chamber 18 so the regenerative check valve 51 is inherently prevented from by-passing open center flow around plunger neck 27. Therefore, the flow force compensation scheme is fully effective. Although check valve 58 always is open, and some oil continuously escapes to tank through passages 56 and 57, chamber 54 and passage 55, the rate of flow through this path is very small and has no material effect upon either the flow force compensation scheme or the work capability of the system. In a typical case where the pump delivers 20 gallons per minute, the pilot flow is only about 0.7 gallon per minute at 3000 p.s.i. supply pressure.

Although the preferred valve plunger 11 described herein employs dual poppet valves 44 and 45, and thus is able to produce the backpressure in space 47 required for satisfactory regenerative action without increasing pressure losses in the raise position, it should be understood that this is not an essential feature of the invention. The dual poppet arrangement could be replaced by the simple load drop check valve used in the regeneration scheme of Patent 3,006,372, mentioned above.

What is claimed is:

1. A double-acting valve plunger (11) including at least a central land (29) flanked by a pair of necks (26, 27); a longitudinal bore (35) in the plunger which connects three longitudinally spaced transverse passages (52, 43, 42) that open through the outer peripheral surface of the plunger, the first transverse passage (52) opening through the plunger in the region of the first neck (26) and the second transverse passage (43) being intermediate the other two; and a regenerative check valve (51) and a load drop check valve (44) in said bore and arranged to prevent flow from the first and third transverse passages, respectively, to the second transverse passage through said bore (35), each check valve being urged in the opening direction by the pressure in that portion (47) of the bore between them, and the regenerative check valve being urged closed by the pressure in a bias chamber (54) at its rear end; and wherein the improvement comprises

(a) a first control passage (52, 56, 57) connecting the bias chamber (54) with the first neck (26);
(b) a second, restricted control passage (55) connecting the bias chamber with the other neck (27); and
(c) a check valve (58) for preventing flow from the bias chamber (54) to the first neck (26) through the first control passage (56, 57).

2. A valve plunger as defined in claim 1 wherein
(a) the first control passage consists of one portion which is defined by said first transverse passage (52), and another portion (56, 57) which extends through the regenerative check valve (51); and
(b) the check valve (58) is located within the regenerative check valve (51) in said another portion (56, 57) of the first control passage.

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