ANTI-CAVITATION CONTROL SYSTEM AND VALVE

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This invention relates to a system for controlling the flow of fluid to and from a double acting hydraulic motor, as well as to a valve in which the essential components of such system are grouped in a single housing.

The invention is particularly adapted to control a double acting hydraulic motor used to swing the boom of a power shovel to and from opposite sides of its central or neutral position. Under such conditions of use, due to the great weight of the boom and its attached bucket, the swinging of the boom and its load builds up a very considerable inertia force. If the rapid swinging movement of the boom and its load is stopped abruptly by the blocking of fluid flow both to and from the opposite sides of the hydraulic motor, inertia forces cause excessive pressure to build up in that side of the motor from which the fluid is normally permitted to return to the system reservoir. Such excessive pressure causes hammer or shock throughout the hydraulic system and often causes breakage in parts of the actuating mechanism. To absorb the kinetic energy of the swinging boom and its load, however, it is necessary to afford the boom a slight additional movement after fluid flow is blocked. This additional movement is, of course, transmitted to the boom actuating rotor or plunger of the motor. Since the flow of supply fluid to the inlet side of the motor is blocked during this additional movement, cavitation occurs. Cavitation in either side of the motor results in poor operator control, and in delay of further boom operation until the supply source again fills the inlet side of the motor.

It is an important object of my invention to provide a means for bringing a swinging boom to a quick stop by absorbing the kinetic energy in the boom and its load, thus providing a hydraulically cushioned stop which eliminates hammer in the hydraulic system.

Accordingly, it is a further important object of my invention to prevent cavitation in either side of a double acting hydraulic motor during stopping of boom movement by affording a flow of auxiliary fluid to that side of the motor in which pressure drops below normal operating pressure after the normal flow of operating fluid to and from the motor has been blocked.

Other objects and advantages of the invention, together with the details of construction of one embodiment thereof, will be more clearly understood when the following description is read in connection with the accompanying drawing.

The single drawing FIGURE 1 is a longitudinal central sectional view through a unitary control valve embodying my invention, the valve being installed in a schematically illustrated hydraulic system which includes a rotary vane type hydraulic motor for swinging the boom of a power shovel. It will be understood by those familiar with this art that the system and valve illustrated and described herein can be used equally well to control the movement of a plunger type reciprocating hydraulic motor. Also, the valve shown in the drawing is specifically designed for cooperation with other valves in a multiple valve bank, and consequently includes a so-called zig-zag type neutral by-pass passage, designated by the numerals 10 and 11, through which fluid may continuously flow from the pump discharge through the valve bank and back to the reservoir when there is no demand on the system. However, it will be understood that the invention described herein can be embodied in a valve which is designed to function independent of any association with other valves in a multiple valve bank.

Excepting the control valve shown, the hydraulic system illustrated schematically is considered conventional. A pump 12 is supplied with fluid from a reservoir 13 through a conduit 14, and delivers fluid under pressure through a conduit 15 to a pressure fluid passage 16, in this case defined by a valve body 17. Fluid is selectively delivered to either side of the fluid motor 18 through lines 19 and 20 and is returned from the motor 18 to the reservoir through these same lines 19 and 20, through the valve body, through a return duct 21 and a connected return line 22.

The fluid motor illustrated includes a circular section outer casing or housing, a stationary vane 23, the inner end of which seals against the outer cylindrical surface of a rotor 24, which rigidly carries a radially extending vane 25. The outer end of vane 25 seals against the inner cylindrical surface of the casing. The boom 26 is rigidly connected to rotate with the rotor 24. The central or neutral position of the boom is designated by the broken lines 27. The boom is illustrated as carrying a bucket 28 on its outer end.

The valve illustrated has a longitudinal bore 29 which receives a reciprocable valve spool 30 which is shiftable longitudinally in the bore, and which is shown in its neutral position. The spool 30 is urged toward its neutral position by a conventional spring-type centering assembly 31.

The spool bore 29 is intersected by two communicating fluid pressure ducts 33 and 34 which communicate with the fluid supply passage 16 through a ball check valve 35. Bore 29 is also intersected by two circuit control passages 36 and 37, each located adjacent to a respective one of the ducts 33 and 34. The bore is also intersected by the opposite ends of a return passage 38, which is in open communication with the return duct 21.

The two circuit control passages 36 and 37 communicate respectively with motor ports 39 and 40 which are in turn connected to the lines 19 and 20. A pair of settable relief valves 41 and 42 are mounted in the valve body and are associated with the respective circuit control passages 36 and 37 and with the adjacent ends of the return passage 38. These relief valves are the subject of a co-pending United States application filed April 30, 1959, Serial No. 809,946, in the name of Marvin L. Wolf. They are oriented to afford flow of fluid under excessive pressure from either circuit control passage into return passage 38 when the pressure in either circuit control passage rises to a predetermined value above the normal system pressure maintained by the pump—say 200 pounds higher than pump output pressure.

A pair of check valves 43 and 44 are housed in blind bores 45 and 46 in opposite ends of the spool 30. The valves have seats 47 and 48 which afford communication between the return passage 38 and the respective circuit control passages 36 and 37, under conditions which will be herein explained. It is not essential that the check valves 43 and 44 be housed within the spool 30. They could as well be located in partitions separating the return passage 38 from the respective circuit control passages 36 and 37.

When spool 30 is in its neutral position, as shown, it blocks communication between the supply ducts 33 and 34 and the respective circuit control passages 36 and 37. It also blocks the flow of fluid from either circuit control passage through the bore directly into the return passage 38.
When it is desired to swing the boom 26 from either of the dotted line positions 49 or 27 to the solid line position shown in the drawing, the operator moves spool 30 to the sides of its neutral position. This movement connects supply passage 33 with circuit control passage 36 through the bore 29, and simultaneously connects circuit control passage 37 with return passage 38 and return duct 21. Pressure fluid flows from supply passage 36 through check valve 35, duct 33, through circuit control passage 36 and line 19 into the chamber 50 in the hydraulic motor 18. Fluid pressure is thus applied against vane 25, and the rotor 24 and the boom 26 are consequently swung counter-clockwise. Simultaneously this movement of the vane 25 forces fluid from chamber 23 through check valve 44 and 40, circuit control passage 37 and into return passage 38, from which it flows through return duct 21 and line 22 to the reservoir 13.

When the boom 26 has been swung a sufficient distance counter-clockwise, spool 30 is returned to its neutral position. The inertia force in the boom 25 and its load is capable of bringing the boom to move a short distance counter-clockwise in its housing after the spool has cut off the flow of fluid to and from the motor. This forces additional fluid from chamber 51 into circuit control passage 37 and the pressure in that passage builds up quickly. Relief valve 42 is set to open when the pressure in the circuit control passage exceeds a predetermined value. Valve 42 is forced to open and allows fluid to flow into return passage 38 and back to the reservoir, relieving passage 37 of excess pressure. During this slight continued counter-clockwise movement of the vane 25 the volume of chamber 50 in the motor increases. Since the spool is in a position to block the flow of supply fluid into the chamber 50, cavitation would ordinarily result. Instead, at the least drop of pressure in chamber 50 due to the increase in volume of that chamber, pressure in circuit control passage 36 drops below the pressure in return passage 38. Fluid simultaneously flows from return passage 38 through ports 52, valve 43, and ports 53 into circuit control passage 36, and through line 19 to chamber 50. Chamber 50 is thus maintained full of fluid during the slight additional movement of the vane 25 due to the inertia forces in the boom.

My invention provides the same anti-cavitation feature for chamber 51 of the motor when the boom 26 is swung in a clockwise direction. After the boom has swung a desired distance and the spool 30 is returned to a neutral fluid blocking position, continued boom movement causes pressure in circuit control passage 37 to drop, and fluid immediately flows from return passage 38 through ports 52, valve 43, and ports 53 into circuit control passage 36, and through line 19 to chamber 50. Chamber 50 is thus maintained full of fluid during the slight additional movement of the vane 25, due to the inertia forces in the boom.

From the above description it will be seen that my invention embraces both a system and a type of valve, both of which are capable of bringing the boom to a cushioned stop by quickly absorbing the kinetic energy in the moving boom through its actuating hydraulic motor, and both of which are capable, during such energy absorption period, of preventing cavitation in either side of the hydraulic motor by furnishing an auxiliary supply of fluid thereto after the normal supply of fluid has been cut off in order to initiate a stoppage of boom travel.

Having described the invention with sufficient clarity to enable those familiar with this art to construct and use it, I claim:

1. A system for controlling the operation of a fluid actuated motor and for preventing cavitation therein when large inertia forces are inherent, the system comprising: fluid supply and fluid return passages; two circuit control passages connected respectively to the opposite ends of the motor and connectible to the fluid supply and return passages; shiftable valve means interposed between the respective circuit control passages and the supply and return passages and effective in a neutral position to afford a direct flow of fluid from the supply passage to both circuit control passages and from both circuit control passages directly into the return passage, and shiftable to selectively connect the supply passage with either circuit control passage while directing the other circuit control passage with the return passage; and independent valve means effective when said shiftable valve means is in its neutral position to afford flow of fluid from the return passage directly into either of said circuit control passages when the pressure therein drops below the pressure in the return passage.

2. The fluid flow control system described in claim 1, and two pressure relief valves, one associated with each circuit control passage, each relief valve being oriented and located to afford flow of fluid from its respective circuit control passage directly into said return passage.

3. The control system described in claim 1 in which said independent valve means is of the form of two separate check valves, each associated with each circuit control passage, and oriented and located to afford the specified fluid flow.

4. A control valve for eliminating cavitation in a fluid motor controlled by the valve, comprising: a housing having a vane receiving bore therein; pressure fluid supply and return passages communicating with said bore; two circuit control passages defined by the housing, both communicating with said bore and respectively in communication with the opposite ends of the motor to be controlled; a shiftable valve spool in said bore effective in a neutral position to block flow of fluid from the supply passage through the bore to either circuit control passages and from both circuit control passages through the bore to the return passage, and shiftable to selectively afford flow of fluid from the supply passage through the bore to either circuit control passage while also affording flow of fluid from the other circuit control passage through the bore into the return passage; and independent valve means effective when said valve spool is in its neutral fluid blocking position to afford flow of fluid from the return passage directly into either circuit control passages when the pressure therein drops below the pressure in the return passage.

5. A control valve described in claim 4 in which said independent valve means is in the form of two separate check valves, each associated with a respective one of said circuit control passages, and oriented and located to afford the specified fluid flow.

6. The valve described in claim 4 in which said independent valve means is in the form of two separate check valves, each associated with any one of said circuit control passages, and oriented and located to afford the specified fluid flow.

7. The valve described in claim 6 in which said two separate valves are housed within and carried by said valve spool; and ports in the valve spool affording the specified flow through the respective separate valves.

8. A fluid flow control valve for controlling a double acting fluid actuated motor, and for preventing cavitation in both sides thereof, comprising: flow control means within the valve shiftable to either of two positions to selectively direct fluid pressure to either side of the motor while affording flow of return fluid from the other side thereof, and shiftable to a neutral position to block the flow of fluid to and from both sides of the motor; means affording release of fluid under excess pressure from either side of the motor regardless of the position of the shiftable control fluid pressure block means; and means responsive to a negative pressure condition on either side of the motor to afford direct flow of fluid being released under excess pressure from one side thereof into that side thereof in which the negative pressure condition has arisen.
9. A valve capable of connection to a fluid motor and of controlling the flow of fluid to and from the chambers in the opposite ends thereof, comprising: a housing having a fluid supply passage, a fluid return passage and two circuit control passages; shiftable valve means interposed between the two circuit control passages and the supply and return passages, said valve means having two main operative positions in which the motor chambers are selectively connected to the supply and return passages through the said circuit control passages, and a neutral position in which both motor chambers are simultaneously isolated from both the supply and return passages; pressure relief valve means for venting fluid under excess pressure from either circuit control passage into the return passage regardless of the position of the shiftable valve means; and valve means through which fluid may pass directly from the return passage to either circuit control passage when the pressure therein drops below normal operating pressure, regardless of the position of said shiftable valve means.

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