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DIRECTIONAL CONTROL VALVE

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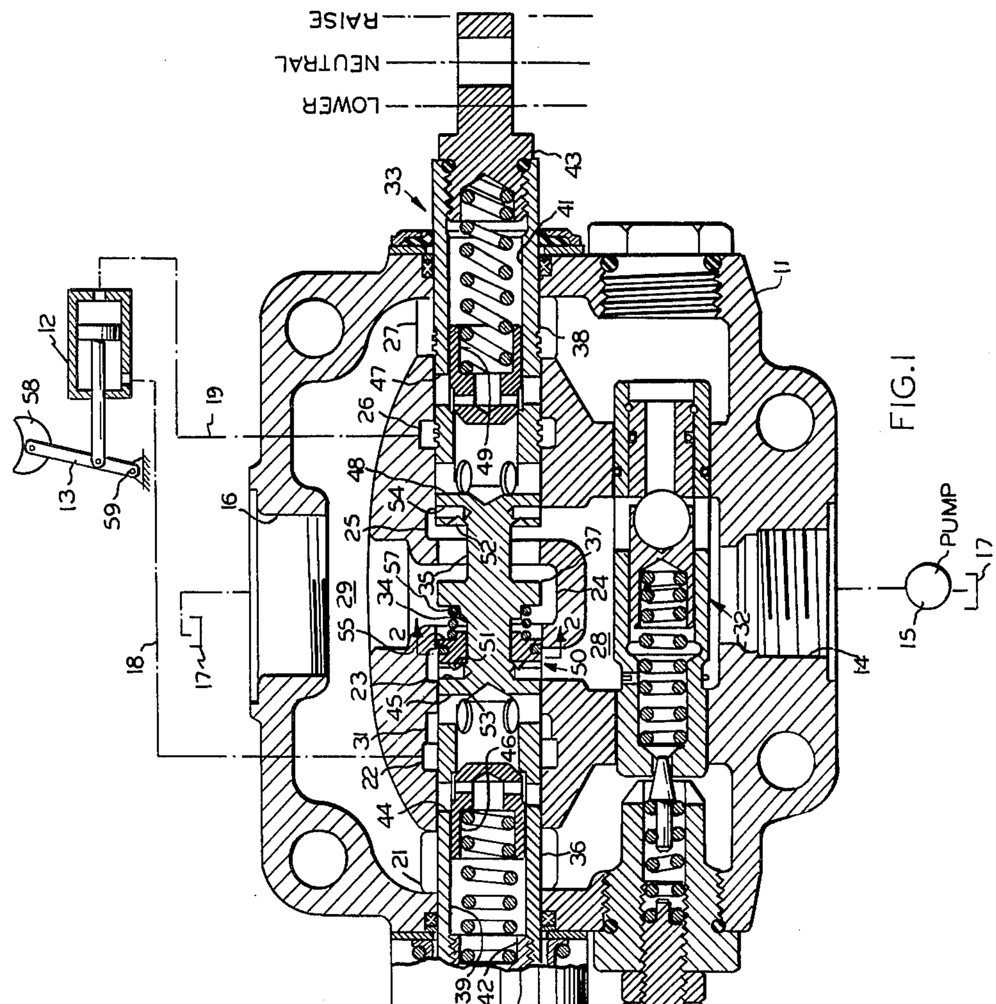

FIG.1

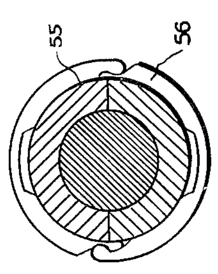

FIG.2

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DIRECTIONAL CONTROL VALVE

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This invention relates to hydraulic valves of the directional control type.

Valves of this type are frequently used in hydraulic circuits for actuating double-acting motors. In general, the valve includes an inlet passage which is connected with a pump, an exhaust passage which is connected with a reservoir, first and second motor passages which are connected with the opposite sides of the double-acting motor, and a movable valve element which has a "neutral" or "hold" position in which each motor passage is isolated from the other three passages, a "raise" position in which the first motor passage is connected with the inlet passage and the second motor passage is connected with the exhaust passage, and a "lower" position in which the connections between the motor passages and the inlet and exhaust passages are reversed. In some cases, the movable valve element, or at least that part of it controlling flow to and from the first motor passage, is of the hollow type, i.e., it contains an internal flow passage that forms part of the supply path to the motor in the "raise" position and part of the exhaust path from the motor in the "lower" position. This internal flow passage is usually provided with a spring biased check valve that prevents dropping of the load acting on the motor whenever pump supply pressure is below the pressure in the side of the motor that would be contracted by the load.

When circuits of this kind are used to lower large loads, it sometimes happens that the motor moves so fast that its flow demand exceeds the delivery rate of the pump. This condition causes cavitation in the expanding side of the double-acting motor and obviously is undesirable. The co-pending application of Orval L. Rice, Serial No. 247,974, filed December 28, 1962, discloses a hollow plunger directional control valve which, in the "lower" position, splits the return flow from the contracting side of the motor so that at least a portion of that fluid passes through a regeneration path leading to the expanding side of the motor and the balance is delivered to the reservoir. This supplemental flow to the expanding side of the motor maintains a positive pressure in that side and prevents cavitation. While this valve is satisfactory in installations wherein the load imposed by the device being actuated always tends to contract one and the same side of the motor, it cannot be used in installations wherein the direction of action of the load reverses during movement of the actuated device because it connects both sides of the motor with the reservoir and thus precludes development of a high working pressure.

The object of the present invention is to provide an improvement in the regeneration scheme of application Serial No. 247,974 that permits that scheme to be used in installations wherein the load exerted by the actuated device is bidirectional, i.e., it may tend to contract either side of the motor. According to this invention, the regeneration path includes a check valve whose seat is defined by a transverse end face of one of the plunger lands, and whose head is an annular member that encircles the plunger and is positioned in an annular peripheral groove formed in the plunger between that land and one of the other plunger lands. In the "lower" position of the plunger, the downstream side of the annular valve head communicates with the inlet passage of the directional control valve so that the head remains seated, and thus closes the regeneration path, whenever a high working pressure is required in that side of the motor which normally receives supplemental delivery. This arrangement enables the motor to move a load through an overcenter position, i.e., through a position in which its direction of action reverses. When the load moves beyond this position, and its direction of action reverses, the supply pressure decreases, the check valve opens, and normal regeneration action is resumed.

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

FIG. 1 is a cross-sectional view of the improved directional control valve including, in schematic form, the other circuit components with which it is used.

FIG. 2 is a sectional view, on enlarged scale, taken on line 2—2 of FIG. 1.

As shown in FIG. 1, the improved directional control valve **11** is employed in a circuit for actuating a double-acting motor **12** that raises and lowers the bucket-carrying boom **13** of a loader. The valve **11** includes an inlet port **14** which is connected with a pump **15**, an exhaust port **16** which is connected with a reservoir **17**, and a pair of motor ports (not shown) which are connected with the rod and head ends of motor **12** through conduits **18** and **19**, respectively. The housing of valve **11** contains a through valve bore which is intersected by seven longitudinally spaced annular chambers **21–27**. Annular chambers **23** and **25** are connected with inlet port **14** by a branched supply passage **28**, annular chambers **21**, **24** and **27** are connected with exhaust port **16** by manifold **29**, and annular chambers **22** and **26** are connected with the motor ports (not shown). Annular chamber **22** is provided with a longitudinal extension **31** which, as explained in application Serial No. 247,974, forms part of the regeneration path. As in the usual control valve, a relief valve **32** is interposed between supply passage **28** and the exhaust manifold **29**.

Slidable in the valve bore is a hollow valve plunger **33** formed with two annular grooves **34** and **35** that define three valve lands **36**, **37** and **38**. A pair of axial bores **39** and **41** extend into the valve plunger from its opposite ends and these bores are closed and sealed by threaded plugs **42** and **43**, respectively. Axial bore **39** is intersected by two sets of longitudinally spaced, radial passages **44** and **45** and contains a spring-biased load-drop check valve **46** which is arranged to prevent flow through bore **39** from passages **44** to passages **45**. Axial bore **41** is provided with similar sets of radial passages **47** and **48** and a spring-biased load-drop check valve **49**. The transverse end faces of lands **36** and **38** contain conical undercuts **51** and **52**, which are intersected by radial passages **53** and **54**, respectively. These undercuts and passages are provided in accordance with the teachings of Hodgson Reissue Patent 24,580, granted December 23, 1958, for reducing the axial components of the dynamic reaction forces acting on the valve plunger. In addition, undercut **51** and radial passages **53** cooperate with chamber extension **31** to define the regeneration flow path.

The directional control valve described thus far is essentially the same as the one described in application Serial No. 247,974. However, in this case, the regeneration flow path is provided with a check valve **50** whose seat is defined by the right transverse end face of valve land **36** and whose head is a split annular member **55** that encircles plunger **33** and is positioned within the annular peripheral groove **34**. The two halves of the annular valve head **55** are held together by a Waldes Truarc interlocking snap ring **56**. This head is guided for sliding movement on the inner peripheral wall of groove **34** and is biased toward the transverse end face of land **36** by a coil compression spring **57**, which also encircles plunger **33**. Spring **57** is supported on steps formed on the right and left ends of head **55** and plunger land **37**, respectively.

When valve plunger **33** is in the illustrated "neutral" position, lands **36** and **38** isolate annular chambers **22** and **26**, respectively, from the other chambers, so double-acting motor **12** is hydraulically locked. At this time, pump **15** is unloaded to reservoir **17** along a path comprising inlet port **14**, supply passage **28**, annular chambers **23** and **25**, plunger grooves **34** and **35**, annular chamber **24**, exhaust manifold **29** and exhaust port **16**.

In order to raise the boom **13**, valve plunger **33** is shifted to the right to its "raise" position in which radial passages **44**, **45**, **48** and **47** register, respectively, with annular chambers **22**, **23**, **26** and **27**, lands **36** and **37** isolate annular chamber **24** from annular chambers **23** and **25**, respectively, and thus load the pump, and radial passages **53** register with annular chamber **24**. Fluid under pressure now flows to the rod end of motor **12** along a path comprising inlet port **14**, supply passage **28**, annular chamber **23**, radial passages **45**, axial bore **39**, check valve **46**, radial passages **44**, annular chamber **22** and conduit **18**. Fluid expelled from the head end of motor **12** is returned to reservoir **17** along a path comprising conduit **19**, annular chamber **26**, radial passages **48**, axial bore **41**, check valve **49**, radial passages **47**, annular chamber **27**, exhaust manifold **29** and exhaust port **16**. It will be apparent to those skilled in the art that check valve **46** serves to prevent dropping of the boom **13** during the time required for pump **15** to build up operating pressure and also at such other times as supply pressure decreases below the pressure in the rod end of motor **12**. After the boom **13** has been moved to the desired position, valve plunger **33** is returned to its "neutral" position to again hydraulically lock motor **12** and unload pump **15**.

Lowering of the boom **13** is accomplished by shifting valve plunger **33** to the left to the "lower" position in which radial passages **44**, **45**, **48** and **47** register, respectively, with annular chambers **21**, **22**, **25** and **26**, lands **36** and **38** isolate annular chamber **24** from annular chambers **23** and **25**, respectively, and radial passages **53** register with chamber extension **31**. In this position of the valve plunger **33**, the fluid delivered to supply passage **28** by pump **15** is transmitted to the head end of motor **12** via annular chamber **25**, radial passages **48**, axial bore **41**, check valve **49**, radial passages **47**, annular chamber **26** and conduit **19**. The fluid displaced from the rod end of motor **12** is delivered to annular chamber **22** through conduit **18**, whence, depending upon the position of check valve **50**, either all of it is transmitted to reservoir **17** through a return path comprising radial passages **45**, axial bore **39**, check valve **46**, radial passages **44**, annular chamber **21**, exhaust manifold **29** and exhaust port **16**, or a part is transmitted to the reservoir along this path and the rest passes into the supply passage **28** through the regeneration path defined by chamber extension **31**, radial passages **53**, conical undercut **51**, check valve **50**, and annular chamber **23**. When boom **13** is in the illustrated position, in which the center of gravity of bucket **58** is on the right side of the vertical plane passing through boom pivot **59**, the load acting on motor **12** tends to contract its head end, and, therefore, the pressure in the supply path leading to this side of the motor is rather high. Under these conditions, the forces developed by spring **57** and by the supply pressure in annular chamber **23** hold annular valve head **55** on its seat against the opposing pressure force developed by the fluid in undercut **51** and thus maintain the regeneration path closed. Since the two sides of the motor **12** are now completely isolated from each other, the high pressure required to move bucket **58** over center can be developed in the supply path and all of the fluid returned to valve **11** from the rod end of motor **12** is transmitted to the reservoir **17**.

As the center of gravity of the bucket **58** moves over center, i.e., through the vertical plane passing through pivot **59**, the direction of action of the load imposed on motor **12** reverses. Since the load now tends to contract the rod end of motor **12**, the pressure in the supply path

leading to the head end, and consequently the closing force acting on annular valve head **55**, decrease. When this closing bias becomes less than the opposing force developed by the fluid in undercut **51**, annular valve head **55** shifts to the right and opens the regeneration flow path. Now some of the fluid being returned to annular chamber **22** flows into the supply passage **28** through extension **31**, radial passages **53**, conical undercut **51**, and annular chamber **23**, and check valve **46** moves in the closing direction. The supply pressure at which regenerative action occurs depends upon the back pressure created by check valve **46**, and the spring used in this valve is so chosen that the back pressure is always sufficient to maintain the head end of motor **12** liquid-filled. If not all of the fluid being returned to annular chamber **22** is required to maintain the desired supply pressure in the head end of motor **12**, that portion which is not transmitted to the head end through the regeneration path is delivered to reservoir **17** through the return path mentioned previously.

It has been assumed in this description that regenerative flow from the head end to the rod end is not required in the "raise" position of valve plunger **33**, even though bucket **58** can move over center, because of the substantial difference between the flow demands of the head and rod ends of motor **12**. However, if it is found that cavitation does occur in the rod end of motor **12** as the center of gravity of bucket **58** moves in the clockwise direction beyond the vertical plane passing through pivot **59**, it will be obvious that that condition can be eliminated by providing a second regeneration flow path. In this case, annular chamber **26** would be formed with an extension, corresponding to chamber extension **31**, that cooperates with radial passages **54** and undercut **52** to define the flow path, and a second check valve **50**, located in annular groove **35**, would be employed to selectively open and close it.

As stated previously, the drawing and description relate only to the preferred embodiment of the invention. Since changes can be made in the structure of this embodiment without departing from the inventive concept, the following claims should provide the sole measure of the scope of the invention.

What we claim is:

1. In combination

(a) a valve housing containing a valve bore intersected by first, second, third and fourth longitudinally spaced passages, the third and fourth passages being intermediate the other two;

(b) a valve plunger reciprocable in the bore and formed with an annular peripheral groove that defines two spaced valve lands having opposing transverse end faces;

(c) a fifth passage formed in one of said lands;

(d) a separate sixth passage formed in said one land and terminating at its opposite ends at first and second openings formed in the outer peripheral surface and in the transverse end face, respectively, of said land;

(e) the valve plunger having a first position in which said one land isolates the third passage from the other passages and the peripheral groove interconnects the second and fourth passages, a second position in which said one land isolates the second passage from the fourth passage, the fifth passage interconnects the third and fourth passages, and the first opening registers with the second passage, and a third position in which the other land isolates the second passage from the fourth passage, the peripheral groove registers with the fourth passage, the fifth passage interconnects the first and third passages, and the first opening registers with the third passage; and

(f) an annular valve head encircling the plunger and located in said annular peripheral groove, said valve head being guided for sliding movement along the inner peripheral surface of said groove between first and second positions in which, respectively, it closes and opens said second opening.

2. The combination defined in claim 1 including a coil spring located in said annular peripheral groove and encircling the plunger, said spring reacting between the transverse end face of the other of said lands and the valve head and urging the valve head toward said first position.

3. A directional control valve including

(a) a housing containing inlet, exhaust, and first and second motor passages, and a valve bore intersected by at least four longitudinally spaced chambers, there being first and second exhaust chambers that are connected with the exhaust passage, a motor chamber located between the exhaust chambers and connected with the first motor passage, and a supply chamber located between the motor chamber and the first exhaust chamber and connected with the inlet passage;

(b) a valve plunger reciprocable in the valve bore and formed with at least two lands that are separated by an annular peripheral groove, the two lands having opposed transverse end faces;

(c) a longitudinal passage formed in the plunger and intersected by first and second longitudinally spaced transverse passages that open through the outer peripheral surface of the first of said lands,

(d) the plunger having a first position in which the first land isolates the motor chamber from the other chambers, a second position in which the first land interrupts communication between the supply chamber and the first exhaust chamber, and the first and second transverse passages register, respectively, with the supply and motor chambers, and a third position in which the second land interrupts communication between the supply chamber and the first exhaust chamber, the first and second transverse passages register, respectively, with the motor chamber and the second exhaust chamber, and the annular peripheral groove registers with the supply chamber;

(e) a separate flow passage formed in the first land and terminating at its opposite ends in openings located in its outer peripheral surface and in the transverse end face, the opening in the outer peripheral surface being positioned so that it registers with the motor chamber in said third position, is isolated from the motor chamber in said first position, and is isolated from both the motor chamber and the supply chamber in said second position;

(f) an annular valve head encircling the plunger and located in said annular peripheral groove, the valve head being guided for sliding movement on the inner peripheral surface of said groove between first and second positions in which, respectively, it closes and opens said opening in the transverse end wall;

(g) a coil spring encircling the plunger and located in said annular peripheral groove, the spring reacting between the transverse end face of the second land and the valve head and urging the valve head toward its first position; and

(h) means carried by the valve member and the housing for isolating the second motor passage from the other three passages when the plunger is in its first position, for connecting the second motor passage with the exhaust passage when the plunger is in its second position, and for connecting the second motor passage with the inlet passage when the plunger is in its third position.

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