

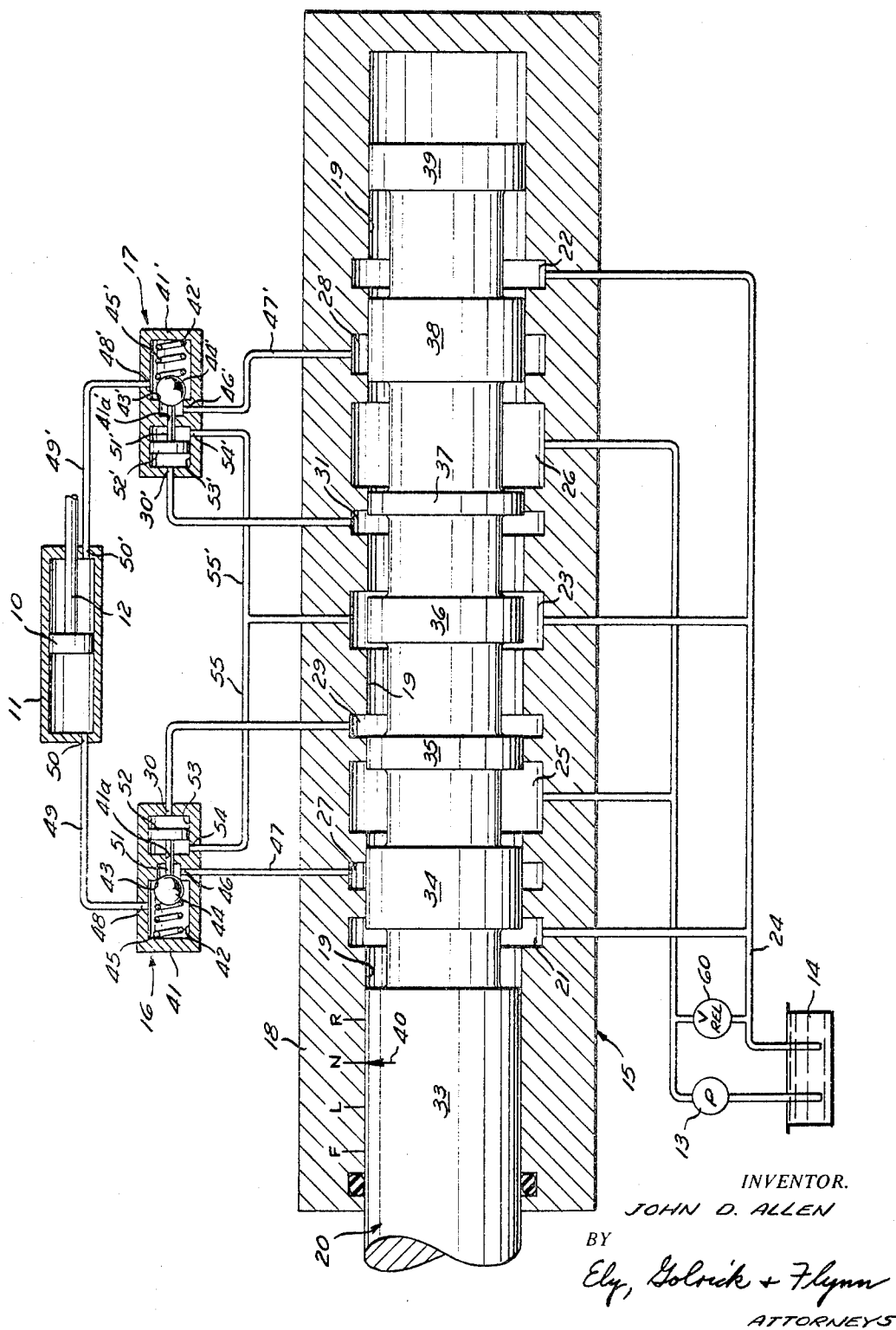
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HYDRAULIC SYSTEM

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HYDRAULIC SYSTEM

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This invention relates to a hydraulic system for controlling the operation of a fluid motor, such as a piston and cylinder, from a pump.

In high pressure hydraulic systems using a closed-center spool valve to selectively control the direction of a fluid motor, such as a piston and cylinder, serious difficulty has been encountered in preventing leakage from the fluid motor in the neutral, closed-center position of the spool valve. Even where lock valves are connected between the respective motor ports and the spool valve it has been found that if there is leakage in this spool valve in its neutral, closed-center position, this leakage may open the lock valves and permit leakage from the motor.

It is a principal object of this invention to provide a novel and improved hydraulic system which overcomes this difficulty.

Another object of this invention is to provide a novel and improved hydraulic system in which the spool valve has a "float" position which frees the piston in a piston-and-cylinder fluid motor to follow the movement of the load, such as a snow plow or a bulldozer blade following the contour of the ground.

Further objects and advantages of this invention will be apparent from the following detailed description of a presently-preferred embodiment thereof, which is shown schematically in the single figure of the accompanying drawing.

Referring to the drawing, the hydraulic system of the present invention shown therein comprises a piston 10 operating in a cylinder 11 and having a shaft 12 connected to a load (not shown), a pump 13 for pumping hydraulic liquid from a sump 14, a four-way spool valve 15 controlling the inlet flow from the pump to one end of the cylinder 11 and the return flow from the opposite end of the cylinder back to the sump, and pilot-operated check valves 16 and 17 connected between the spool valve 14 and the respective opposite ends of cylinder 11.

The spool valve 15 comprises a valve body or housing 18 having a longitudinal bore 19 which slidably receives a reciprocable valve spool 20. The spool valve body has a plurality of annular recesses intersecting the bore 19 at successive locations spaced apart along its length and separated from each other by cylindrical land surfaces of the bore. These recesses include a pair of end recesses 21 and 22 and a central recess 23, all connected to a return line 24 leading back to the sump 14 and referred to hereinafter as "return" recesses. A pair of inlet recesses 25 and 26 are both connected to the outlet side of the pump 13 and are referred to hereinafter as "pump" recesses. Pump recess 25 is located along the bore 19 in the spool valve body between the return recesses 21 and 23, and pump recess 26 is located between the return recesses 23 and 22. A left motor port recess 27 in the spool valve body between recesses 21 and 25 is connected through a first check valve 16 to the left

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end of cylinder 11. A right motor port recess 28 in the spool valve body between recesses 26 and 22 is connected through a second check valve 17 to the right end of cylinder 11. A left pilot port recess 29 located between pump recess 25 and return recess 23 is connected to the outside pilot port 30 of check valve 16. A right pilot port recess 31 located between return recess 23 and pump recess 26 is connected to the outside pilot port 30' of the second check valve 17.

The valve spool 20 has a series of longitudinally spaced cylindrical lands 33, 34, 35, 36, 37, 38 and 39 which are sealingly engageable with the land surfaces of bore 19 in the valve body. Successive lands on the spool are interconnected by reduced diameter stem portions of the spool. The valve spool 20 may be positioned, manually or otherwise, at any one of four different selected positions along the bore. These positions are indicated by the arrow 40 on the left end land 33 of the spool and the longitudinally spaced lines on the valve body 18 which are designated "L," "N," "R" and "F" in the drawing. It will be understood that these indicia will actually be outside the spool valve so as to be visible to the operator and the schematic showing in the drawing is merely for purposes of facilitating the present description.

The first- or left-hand check valve 16 includes a body 41 having a chamber 42 with an annular valve seat 43 at its right end in FIG. 1. A valve member in the form of a ball 44 in this chamber is urged against this valve seat by a spring 45, which is engaged under compression between the ball and the left end wall of the valve body. To the right of the valve seat 43, the check valve body 41 has a first flow port 46 which is connected by a line 47 to the left motor port recess 27 in the spool valve.

At the same side of the valve seat 43 as the ball 44, the check valve body 41 has a second flow port 48 which is connected by a line 49 to a port 50 at the left end of cylinder 11. To the right of its first flow port 46, the check valve body 41 has a bore 41a which slidably receives the stem 51 of a pilot piston 52, which is slidably disposed in a piston chamber 53 formed in the right end of the check valve body 41. Pilot piston 52 constitutes a pressure responsive member which is movable inwardly to unseat valve member 44 or movable outwardly (to the position shown) to permit valve member 44 to close on its seat 43. The previously-mentioned outside pilot port 30 is at the right end of the piston chamber 53. Near its opposite, inner end, the piston chamber has an inside pilot port 54 which is connected by a line 55 to the central return flow recess 23 in the spool valve 15.

In the drawing, the second or right-hand check valve 17 is a mirror image of the left check valve 16, and corresponding elements of this valve and the lines and ports connected to it are given the same reference numerals, with a prime subscript added, as those for the left check valve. A detailed description of the right check valve 17 is considered to be unnecessary since it involves essentially a repetition of the description already given of the left check valve 16.

A relief valve 60 is connected between the output side of pump 13 and the return line 24.

In the operation of this system, when the valve spool 20 is in its neutral position as shown, with the arrow 40 on the valve spool registering with the line "N" on the

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spool valve body 18, the pump 13 is blocked from both ends of the cylinder 11 because the spool land 34 sealingly engages the bore 19 of the spool valve body 18 between recesses 25 and 27 and the spool land 38 sealingly engages the bore between recesses 26 and 28.

At the same time, the outside pilot port 30 in the left check valve 16 is connected to the sump return line 24 by way of recesses 29 and 23 in the spool valve body 18, which are in fluid communication with each other around the reduced diameter stem portion of the spool between its lands 35 and 36. Also, the inside pilot port 54 in the left check valve 16 is connected to the sump return line 24 by way of line 55 and the central return recess 23 in the spool valve body 18. Consequently, the ball 44 in the left check valve 16 is held closed against its seat 43 by spring 45 to thereby block the left end port 50 of cylinder 11.

Also, at this time the outside pilot port 30' of the right check valve 17 is connected to the return line 24 by way of the recesses 31 and 23 in the spool valve body, which are in fluid communication with each other around the reduced stem portion of the valve spool 20 between its lands 37 and 36. The inside pilot port 54' in the right check valve 17 is connected to the return line by way of line 55' and the central return recess 23 in the valve spool body. Consequently, the ball 44' in the right check valve 17 is held closed against its seat 43' by spring 45' to thereby block the right end port 50' of cylinder 11.

To move piston 10 to the right, the valve spool 20 is shifted from neutral to the left to a position where the arrow 40 on the valve spool registers with the line "L" on the body 18. In this position of the valve spool, the pump output is passed to the left end of cylinder 11 by way of pump recess 25 in the valve spool body around the valve spool stem between spool lands 35 and 34 to recess 27 in the spool valve body and from there through line 47 to the first flow port 46 of the left pilot valve 16, past the pilot valve ball 44 to the second flow port 48 of pilot valve 16, thence through line 49 to the left end port 50 of cylinder 11. Pump pressure also is applied to the outside pilot port 30 of the left check valve 16 by way of pump recess 25 in the spool valve body 18, around the valve spool between its lands 35 and 36 to spool valve recess 29 connected to the outside pilot port 30. The inside pilot port 54 of the left check valve 16 is connected back to the sump 14 by way of line 55, spool valve recess 23 and return line 24. Consequently, the pilot piston 52 is urged to the left to unseat ball 44.

At the right check valve 17, the outside pilot port 30' is connected to the pump by way of pump recess 26 in the spool valve body 18, the space around the valve spool between its lands 38 and 37, and the spool valve recess 31. The inside pilot port 54' of the right check valve 17 is connected to the sump by way of line 55', spool valve recess 23 and return line 24. Consequently, piston 52' in the right check valve 17 is urged to the right to unseat ball 44'. This permits return flow from the right end of cylinder 11 through the cylinder port 50' into the second flow port 48' in the right check valve 17, past the unseated ball 44' and out through the first flow port 46' therein to the spool valve recess 28, around the valve spool between its lands 38 and 39 to the spool valve recess 22 and then to return line 24.

In this position of the valve spool, its land 34 sealingly engages the bore 19 of the spool valve body 18 between the latter's recesses 27 and 21 to block the pump from recess 21 and the return line 24. Also, the spool land 38 sealingly engages the bore of the valve spool body between its recesses 26 and 28 to block the pump from recess 28 and the return line 24.

To move piston 10 to the left, the valve spool 20 is shifted to the right in the drawing to a position where arrow 40 on the spool registers with line "R" on the valve body 18. In this position of the valve spool, the

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pump output is passed to the right end of cylinder 11 by way of pump recess 26 in the valve spool body 18, around the valve spool between its lands 37 and 38, to recess 28 in the spool valve body and from there through line 47' to the first flow port 46' of the right pilot valve 17, past the ball 44' therein to its second flow port 48', and thence through line 49' to the right end port 50' of cylinder 11. Pump pressure also is applied to the outside pilot port 30' of the right check valve 17 by way of spool valve recess 26, around the valve spool between its lands 37 and 36, to the valve spool recess 31 connected to pilot port 30'. The inside pilot port 54' of the right check valve 17 is connected back to the sump 14 by way of line 55', spool valve recess 23 and return line 24. Consequently, the pilot piston 52' is urged to the right to unseat ball 44'.

At the left check valve 16, the outside pilot port 30 is connected to the pump by way of spool valve recess 25, the space around the valve spool between its lands 34 and 35, and the valve spool recess 29. The inside pilot port 54 of the left check valve 16 is connected to the sump by way of line 55, spool valve recess 23 and return line 24. Consequently, piston 52 in the left check valve 16 is urged to the left to unseat ball 44. This permits return flow from the left end of cylinder 11, through the cylinder port 50, into the second flow port 48 in the left check valve 16, past the ball 44 therein, and out through the first flow port 46 to the spool valve recess 27, around the valve spool between its lands 34 and 33, to the spool valve recess 21 and then to return line 24.

In this position of the valve spool, its land 34 sealingly engages the bore 19 of the spool valve body 18 between the latter's recesses 25 and 27 to block the recess 27 from the pump. Also, the spool land 38 sealingly engages the bore of the valve spool body between its recesses 28 and 22 to block the recess 22 from the pump.

The "float" position of the valve spool 20 is for the purpose of letting the piston 10 follow the movement of the load, instead of vice versa. For example, when the load on the piston is a bulldozer blade or a snow plow, the operator at certain times wants the blade or plow to freely follow the contour of the ground. Under these circumstances the valve spool 20 is positioned with its arrow 40 registering with the line "F" on the spool valve body 18. In this position of the valve spool, the pump 13 is blocked from both ends of cylinder 11 as follows:

The valve spool land 35 sealingly engages the bore 19 of the spool valve body 18 between its recesses 25 and 27, and thereby prevents the flow of hydraulic liquid from the pump to the line 47 leading to the left end port 50 of cylinder 11 by way of the left check valve 16.

The valve spool land 38 sealingly engages the bore 19 of the spool valve body 18 between its recesses 26 and 28, and thereby prevents the flow of hydraulic liquid from the pump to the line 47' leading to the right end port 50' of cylinder 11 by way of the right check valve 17.

At the same time, both ends of cylinder 11 are connected to the sump 14 as follows:

Pump pressure is applied to the outside pilot port of the left check valve 16 by way of recess 25 in the spool valve body 18, around the valve spool 20 between its lands 35 and 36, and the recess 29 in the spool valve body. The inside pilot port 54 of the left check valve is connected to the sump 14 by way of line 55, the recess 23 in the spool valve body 18, and return line 24. Consequently, piston 52 moves to the left to unseat ball 44 in check valve 16. The hydraulic liquid in the left end of cylinder 11 can flow back to the sump by way of cylinder port 50, line 49, the second flow port 48 of check valve 16, past the ball 44 therein to its first flow port 46, and from there through line 47 to recess 27 in the spool valve body 18, around the valve spool 20 between its lands 35 and 34, to recess 21 in the spool valve

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body, and from there to the return line 24 leading back to the sump.

Pilot pressure is applied to the outside pilot port 30' of the right check valve 17 by way of recess 26 in the spool valve body 18, around the valve spool 20 between its lands 38 and 37, and the recess 31 in the spool valve body. The inside pilot port 54' of the right check valve 17 is connected to the sump 14 by way of line 55', recess 23 in the spool valve body 18, and return line 24. Consequently, pilot piston 52' moves to the right to unseat ball 44' in check valve 17. The hydraulic liquid in the right end of cylinder 11 can flow back to the sump by way of cylinder port 50', line 49' the second flow port 48' of check valve 17, past the ball 44' therein to its first flow port 46', and from there through line 47' to recess 28 in the spool valve body 18, around the valve spool 20 between its lands 38 and 39, to recess 22 in the spool valve body, and from there to the return line 24 leading back to the sump.

In this system the check valves 16 and 17 function as lock valves to prevent leakage from either end of the cylinder 11 when the spool valve is in its closed-center, neutral position. Even if there is leakage in the spool valve in its closed-center position, this will not cause either check valve to open because the respective outside pilot ports 30 and 30' are both connected to the low pressure return line 24 at this time, so that both check valves remain closed to prevent leakage from the respective ends of the cylinder 11 back to the return line. However, when the spool valve is in its float position, these check valves are held open to permit the piston 10 to follow freely the movement of the load and locking up of the cylinder and piston is completely avoided.

While a specific presently-preferred embodiment of the present invention has been described in detail herein and illustrated in the accompanying drawing, it is to be understood that the invention is susceptible of other embodiments and that modifications, omissions and refinements which depart from the disclosed embodiment may be adopted without departing from the spirit and scope of this invention. For example, in certain practical applications of this system the float position may be omitted, in which case the spool valve may operate as a three-way, closed-center valve or it may have a fourth position for a different purpose than the float operation described.

I claim:

1. A hydraulic system for operating a fluid motor from a pump comprising:

- a closed-center spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong and including pump recess means for connection to the pump and return recess means for connection to a low pressure return line and additional recesses, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore and having reduced diameter portions between its lands;
- a first normally-closed check valve connected to one of said additional recesses in the spool valve body and having a port for connection to one side of the fluid motor, a first pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve;
- a second normally-closed check valve connected to another of said additional recesses in the spool valve body and having a port for connection to the opposite side of the fluid motor, a second pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve;

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said spool in a first position thereof along the bore in the spool valve body blocking said pump recess means from both check valves and connecting the respective pressure responsive members in both check valves to the low pressure return through the spool valve body to maintain both check valves closed to block the flow of hydraulic liquid from either side of the fluid motor;

said spool in a second position thereof along the bore in the spool valve body connecting said pump recess means therein to the first check valve to open the latter for flow from the pump to said one side of the fluid motor, said spool in said second position thereof connecting said pump recess means therein to said second pressure responsive member to open the second check valve and connecting said second check valve to said return recess means therein for return flow from the opposite side of the fluid motor;

said spool in a third position thereof along the bore in the spool valve body connecting said pump recess means therein to the second check valve to open the latter for flow from the pump to said opposite side of the fluid motor, said spool in said third position thereof connecting said pump recess means therein to said first pressure responsive member to open the first check valve and connecting said first check valve to said return recess means for return flow from said one side of the fluid motor.

2. A hydraulic system for operating a fluid motor from a pump comprising:

- a spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong and including a pair of pump recesses for connection to the pump and return recesses for connection to a low pressure return and additional recesses, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands;
- a first normally-closed check valve connected to one of said additional recesses in the spool valve body and having a port for connection to one side of the fluid motor, a first pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve;
- a second normally-closed check valve connected to another of said additional recesses in the spool valve body and having a port for connection to the opposite side of the fluid motor, a second pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve;

said spool in a first position thereof along the bore in the spool valve body blocking the pump recesses from both check valves and connecting the respective pressure responsive members in both check valves to the low pressure return through the spool valve body to maintain both check valves closed to block the flow of hydraulic liquid from either side of the fluid motor;

said spool in a second position thereof along the bore in the spool valve body connecting a pump recess therein to the first check valve to open the latter for flow from the pump to said one side of the fluid motor, said spool in said second position thereof connecting a pump recess therein to said second pressure responsive member to open the second check valve and connecting said second check valve to a return recess therein for return flow from said opposite side of the fluid motor;

said spool in a third position thereof along the bore in the spool valve body connecting a pump recess

therein to the second check valve to open the latter for flow from the pump to said opposite side of the fluid motor, said spool in said third position thereof connecting a pump recess therein to said first pressure responsive member to open the first check valve and connecting said first check valve to a return recess for return flow from said one side of the fluid motor.

3. A hydraulic system comprising:

a fluid motor having first and second ports on opposite sides thereof;

a sump;

a pump for pumping hydraulic liquid from said sump;

a closed-center spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands;

a first normally-closed check valve connected between one of said recesses in the spool valve body and said first motor port, a first pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve;

a second normally-closed check valve connected between another of said recesses in the spool valve body and said second motor port, a second pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve;

said spool in a first position thereof along the bore in the spool valve body blocking the pump from both check valves and connecting the respective pressure responsive members in both check valves to the sump to maintain both check valves closed to block the flow of hydraulic liquid from either of said motor ports;

said spool in a second position thereof along the bore in the spool valve body connecting the pump to the first check valve to open the latter for flow from the pump to said first motor port, said spool in said second position thereof connecting the pump to said second pressure responsive member to open the second check valve and connecting said second check valve to the sump for return flow from said second motor port through the second check valve to the sump;

said spool in a third position thereof along the bore in the spool valve body connecting the pump to the second check valve to open the latter for flow from the pump to said second motor port, said spool in said third position thereof connecting the pump to said first pressure responsive member to open the first check valve and connecting said first check valve to the sump for return flow from said first motor port through the first check valve to the sump.

4. A hydraulic system comprising:

a cylinder having ports at its opposite ends, a piston slidable in said cylinder;

a sump;

a pump for pumping hydraulic liquid from said sump;

a closed-center spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands;

a first pilot-operated check valve having a valve seat therein, a valve member engageable with said valve

seat, spring means urging said valve member into engagement with said valve seat, a first flow port at the opposite side of said valve seat from said valve member connected to one of said recesses in the spool valve body, a second flow port at the same side of the valve seat as said valve member connected to one end port of the cylinder, a first pressure responsive member movable inwardly to unseat said valve member and movable outwardly to permit said valve member to close on said valve seat, an outside pilot port at the opposite side of said first pressure responsive member from said valve member and connected to a different one of said recesses in the spool valve body, and an inside pilot port between said first pressure responsive member and said valve member connected to the sump;

a second pilot-operated check valve having a valve seat therein, a valve member engageable with said valve seat, spring means urging said valve member into engagement with its valve seat, a first flow port at the opposite side of said valve seat from said valve member connected to another of said recesses in the spool valve body, a second flow port at the same side of said valve seat as said valve member connected to the opposite end port of the cylinder, a second pressure responsive member movable inwardly to unseat said valve member and movable outwardly to permit said valve member to close on its valve seat, an outside pilot port at the opposite side of said second pressure responsive member from said valve member and connected to a different one of said recesses in the spool valve body, and an inside pilot port between said second pressure responsive member and said valve member connected to the sump;

said spool in a first position thereof along the bore in the spool valve body blocking the pump from the respective first flow ports of both check valves and connecting the respective outside pilot ports of both check valves to the sump, said spring means in each check valve seating the respective valve member against its valve seat in said first position of said spool to prevent the flow of hydraulic liquid from either end of the cylinder through the respective check valve;

said spool in a second position thereof along the bore in the spool valve body connecting said pump to said first flow port of the first check valve to unseat the valve member therein for the flow of liquid through the first check valve to said one end port of the cylinder, said spool in said second position thereof connecting the pump to the outside pilot port of the second check valve for moving the second pressure responsive member in the second check valve inwardly to unseat the valve member therein, said spool in said second position thereof connecting said first flow port of the second check valve to the sump for passing the return flow of liquid from said opposite end of the cylinder to the sump;

said spool in a third position thereof along the bore in the spool valve body connecting said pump to said first flow port of the second check valve to unseat the valve member therein for the flow of liquid through the second check valve to said opposite end port of the cylinder, said spool in said third position thereof connecting the pump to the outside pilot port of the first check valve for moving the first pressure responsive member in the first check valve inwardly to unseat the valve member therein, said spool in said third position thereof connecting said first flow port of the first check valve to the sump for passing the return flow of liquid from said one end of the cylinder to the sump.

5. A hydraulic system for operating from a pump a piston and cylinder in which the cylinder has first and

second ports on opposite sides of the piston, said system comprising:

- a spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong and including a pair of pump recesses for connection to the pump and return recesses for connection to a return line and additional recesses, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands;
 - a first normally-closed check valve connected to one of said additional recesses in the spool valve body and having a port for connection to the cylinder at one side of the piston, a first pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve;
 - a second normally-closed check valve connected to another of said additional recesses in the spool valve body and having a port for connection to the cylinder at the opposite side of the piston, a second pressure responsive member connected to another of said additional recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve;
 - said spool in a first position thereof along the bore in the spool valve body blocking the pump recesses from both check valves and connecting the respective pressure responsive members in both check valves to the return line through the spool valve body to maintain both check valves closed to block the flow of hydraulic liquid from the cylinder at either side of the piston;
 - said spool in a second position thereof along the bore in the spool valve body connecting a pump recess therein to the first check valve to open the latter for flow from the pump to the cylinder at said one side of the piston, said spool in said second position thereof connecting a pump recess therein to said second pressure responsive member to open the second check valve and connecting said second check valve to a return recess therein for return flow from the cylinder at the opposite side of the piston;
 - said spool in a third position thereof along the bore in the spool valve body connecting a pump recess therein to the second check valve to open the latter for flow from the pump to the cylinder at said opposite side of the piston, said spool in said third position thereof connecting a pump recess therein to said first pressure responsive member to open the first check valve and connecting said first check valve to a return recess for return flow from the cylinder at said one side of the piston;
 - said spool in a fourth position thereof along the bore in the spool valve body connecting both pump recesses to the respective pressure responsive members to open the respective check valves and connecting both check valves to return recesses therein for the flow of hydraulic liquid from the cylinder at both sides of the piston.
6. A hydraulic system comprising:
- a cylinder, a piston slidable in said cylinder, said cylinder having first and second portions on opposite sides of said piston;
 - a sump;
 - a pump for pumping hydraulic liquid from said sump;
 - a spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and

- having reduced diameter portions between its lands;
 - a first normally-closed check valve connected between one of said recesses in the spool valve body and said first cylinder port, a first pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve;
 - a second normally-closed check valve connected between another of said recesses in the spool valve body and said second cylinder port, a second pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve;
 - said spool in a first position thereof along the bore in the spool valve body blocking the pump from both check valves and connecting the respective pressure responsive members in both check valves to the sump to maintain both check valves closed to block the flow of hydraulic liquid from either of said cylinder ports;
 - said spool in a second position thereof along the bore in the spool valve body connecting the pump to the first check valve to open the latter for flow from the pump to said first cylinder port, said spool in said second position thereof connecting the pump to said second pressure responsive member to open the second check valve and connecting said second check valve to the sump for return flow from said second cylinder port through the second check valve to the sump;
 - said spool in a third position thereof along the bore in the spool valve body connecting the pump to the second check valve to open the latter for flow from the pump to said second cylinder port, said spool in said third position thereof connecting the pump to said first pressure responsive member valve to open the first check valve and connecting said first check valve to the sump for return flow from said first cylinder port through the first check valve to the sump;
 - said spool in a fourth position thereof along the bore in the spool valve body connecting the pump to both said pressure responsive members to open the respective check valves and connecting both check valves to the sump for the flow of hydraulic liquid from both cylinder ports to the sump.
7. A hydraulic system comprising:
- a cylinder having ports at its opposite ends, a piston slidable in said cylinder;
 - a sump;
 - a pump for pumping hydraulic liquid from said sump;
 - a spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands;
 - a first pilot-operated check valve having a valve seat therein, a valve member engageable with said valve seat, spring means urging said valve member into engagement with said valve seat, a first flow port at the opposite side of said valve seat from said valve member connected to one of said recesses in the spool valve body, a second flow port at the same side of the valve seat said said valve member connected to one end port of the cylinder, a first pressure responsive member movable inwardly to unseat said valve member and movable outwardly to permit said valve member to close on said valve seat, an outside pilot port at the opposite side of said first pressure responsive member from said valve member and connected to a different one of said recesses in the spool valve body, and an inside pilot port between said first pressure responsive member and said valve member connected to the sump;

- a second pilot-operated check valve having a valve seat therein, a valve member engageable with said valve seat, spring means urging said valve member into engagement with its valve seat, a first flow port at the opposite side of said valve seat from said valve member connected to another of said recesses in the spool valve body, a second flow port at the same side of said valve seat as said valve member connected to the opposite end port of the cylinder, a second pressure responsive member movable inwardly to unseat said valve member and movable outwardly to permit said valve member to close on its valve seat, an outside pilot port at the opposite side of said second pressure responsive member from said valve member and connected to a different one of said recesses in the spool valve body, and an inside pilot port between said second pressure responsive member and said valve member connected to the sump;
- said spool in a first position thereof along the bore in the spool valve body blocking the pump from the respective first flow ports of both check valves and connecting the respective outside check ports of both pilot valve to the sump, said spring means in each check valve seating the respective valve member against its valve seat in said first position of said spool to prevent the flow of hydraulic liquid from either end of the cylinder through the respective check valve;
- said spool in a second position thereof along the bore in the spool valve body connecting said pump to said first flow port of the first check valve to unseat the valve member therein for the flow of liquid through the first check valve to said one end port of the cylinder, said spool in said second position thereof connecting the pump to the outside pilot port of the second check valve for moving the second pressure responsive member in the second check valve inwardly to unseat the valve member therein, said spool in said second position thereof connecting said first flow port of the second check valve to the sump for passing the return flow of liquid from said opposite end of the cylinder to the sump;
- said spool in a third position thereof along the bore in the spool valve body connecting said pump to said first flow port of the second check valve to unseat the valve member therein for the flow of liquid through the second check valve to said opposite end port of the cylinder, said spool in said third position thereof connecting the pump to the outside pilot port of the first check valve for moving the first pressure responsive member in the first check valve inwardly to unseat the valve member therein, said spool in said third position thereof connecting said first flow port of the first check valve to the sump for passing the return flow of liquid from said one end of the cylinder to the sump;
- said spool in a fourth position thereof along the bore in the spool valve body connecting the pump to the respective outside pilot ports of both check valves so as to move the respective pressure responsive members in both check valves inwardly to unseat the respective valve members therein, said spool in said fourth position thereof connecting the respective first flow ports of both check valves to the sump for the flow of hydraulic liquid from both ends of the cylinder to the sump.
8. A system according to claim 7, wherein: said spool valve has a recess therein which is connected to the respective inside pilot ports of both check valves and which is connected to the sump in each of said four positions of the spool.
9. A system according to claim 7, wherein: said spool in its first position blocks the respective first flow ports of both check valves from the sump.

10. A system according to claim 7, wherein: said spool in its second position blocks the pump and the first flow port of the first check valve from the sump, and connects the pump to the outside pilot port of the first check valve, and blocks the pump from the first flow port of the second check valve.
11. A system according to claim 10, wherein: said spool in its third position blocks the pump and the first flow port of the second check valve from the sump, and connects the pump to the outside pilot port of the second check valve, and blocks the pump from the first flow port of the first check valve.
12. A system according to claim 7, wherein: said spool in its fourth position blocks the respective outside pilot ports of both check valves from the sump, and blocks the pump from the respective first flow ports of both check valves.
13. A system according to claim 7, wherein: said spool in its first position also blocks the respective first flow ports of both check valves from the sump; said spool in its second position blocks the pump and the flow port of the first check valve from the sump, and connects the pump to the outside pilot port of the first check valve, and blocks the pump from the first flow port of the second check valve; said spool in its third position blocks the pump and the first flow port of the second check valve from the sump, and connects the pump to the outside pilot port of the second check valve, and blocks the pump from the first flow port of the first check valve; and said spool in its fourth position blocks the respective outside pilot ports of both check valves from the sump, and blocks the pump from the respective first flow ports of both check valves.
14. A hydraulic system comprising: a cylinder, a piston slidable in said cylinder, said cylinder having first and second ports on opposite sides of said piston; a sump; a pump for pumping hydraulic liquid from said sump; a spool valve comprising a valve body having a bore therein and a plurality of recesses intersecting said bore at spaced locations therealong, and a spool slidably received in said bore and having a plurality of longitudinally spaced lands thereon for sealing engagement with the bore between said recesses and having reduced diameter portions between its lands; a first normally-closed check valve connected between one of said recesses in the spool valve body and said first cylinder port, a first pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said check valve; a second normally-closed check valve connected between another of said recesses in the spool valve body and said second cylinder port, a second pressure responsive member connected to another of said recesses in the spool valve body and movable in response to fluid pressure thereat to open said second check valve; said spool in a first position thereof along the bore in the spool valve body connecting the respective pressure responsive members in both check valves to the sump to maintain both check valves closed to block the flow of hydraulic liquid from either of said cylinder ports; said spool in a second position thereof along the bore in the spool valve body connecting the pump to the first check valve to open the latter for flow from the pump to said first cylinder port, said spool in said second position thereof connecting the pump to said second pressure responsive member to open the second check valve and connecting said second check valve to the sump for return flow from said second cylinder port through the second check valve to the sump;

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said spool in a third position thereof along the bore in the spool valve body connecting the pump to the second check valve to open the latter for flow from the pump to said second cylinder port, said spool in said third position thereof connecting the pump to said first pressure responsive member to open the first check valve and connecting said first check valve to the sump for return flow from said first cylinder port through the first check valve to the sump;
 said spool in a fourth position thereof along the bore in the spool valve body connecting the pump to both said pressure responsive members to open the respective check valves and connecting both check valves

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to the sump for the flow of hydraulic liquid from both cylinder ports to the sump.

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