

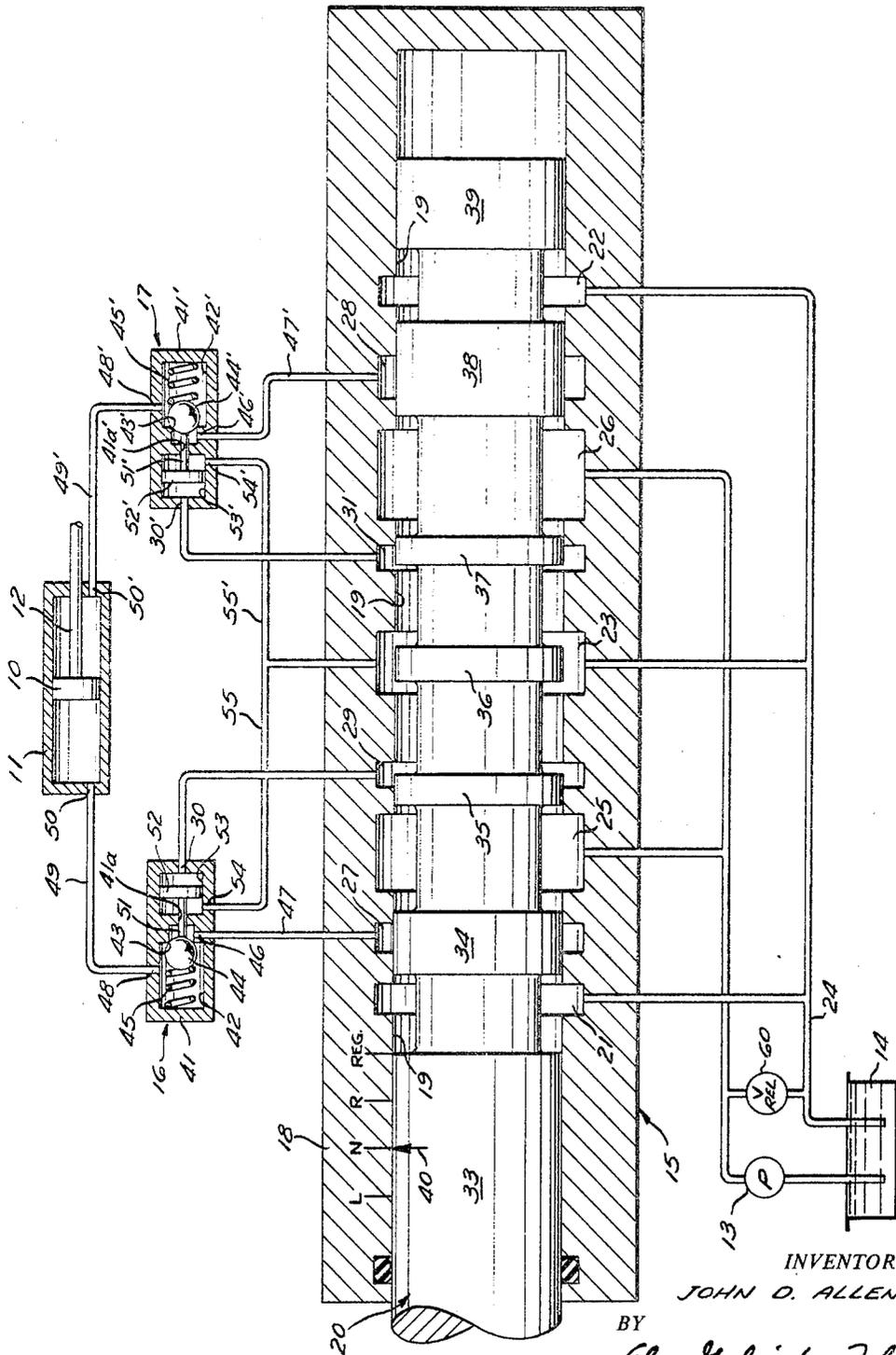
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HYDRAULIC SYSTEM WITH REGENERATIVE POSITION

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**3,273,468**  
**HYDRAULIC SYSTEM WITH REGENERATIVE POSITION**

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This invention relates to a hydraulic system for controlling the operation of a piston and cylinder from a pump, and more particularly to such a system in which a four-way spool valve may be selectively operated to hold the piston stopped with substantially no leakage from either end of the cylinder, or to move the piston in either direction, or to move the piston rapidly in one direction when there is a substantially reduced load on it.

It is the principal object of this invention to provide a novel and improved hydraulic system adapted to operate in the manner just described.

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 15 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 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 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 "Reg." 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 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 this 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 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

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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, and 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 18, 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 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.

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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 "regenerative" position of the valve spool 20 is for the purpose of moving piston 10 to the right at low hydraulic force and high speed when there is only a very light load on the piston. For example, on a fork lift truck when there is no load on the fork, it may be moved up or down quickly in this manner.

When the valve spool 20 is positioned with its arrow 40 registering with the line designated "Reg." on the spool valve body 18, the pump is connected to both ends of cylinder 11 through the respective check valves 16 and 17 as follows:

The pump is connected to the left end port 50 of cylinder 11 by way of the pump recess 25 in the spool valve body 18, the space around the valve spool between its lands 34 and 33, the recess 27 in the spool valve body, line 47, the first flow port 46 of check valve 16, past the ball 44 therein, through the second flow port 48 of check valve 16 and line 49.

The pump is connected to the right end port 50' of cylinder 11 by way of the pump recess 26 in the spool valve body 18, the space around the valve spool between its lands 37 and 38, the recess 28 in the spool valve body, line 47', the first flow port 46' of check valve 17, past the ball 44' therein, through the second flow port 48' of check valve 17 and line 49'.

At the same time, the pump is connected to outside pilot port 30 of the left check valve 16 by way of the pump recess 25 in the spool valve body 18, around the valve spool 20 between its lands 34 and 35, and through the recess 29 in the spool valve body. The inside pilot port 54 of this check valve is connected to the sump by way of line 55, the central recess 23 in the spool valve body, and return line 24. Consequently, pilot piston 52 is urged to the left to maintain ball 44 in this check valve unseated.

Also, the pump is connected to the outside pilot port 30' of the right check valve 17 by way of the pump recess 26 in the spool valve body 18, around the valve spool 20 between its lands 37 and 36, and through the recess 31 in the spool valve body. The inside pilot port 54' of this check valve is connected to the sump by way of line 55', the central recess 23 in the spool valve body, and return line 24. Consequently, pilot piston 52' is urged to the right to maintain ball 44' in this check valve unseated.

In this position of the valve spool 20, the spool land 38 blocks the spool valve recess 28 from recess 22 connected to the return line 24, and the spool land 36 blocks recess 28 from recess 23 connected to return line 24. Consequently, these spool lands prevent return flow from the right end port 50' of cylinder 11 to the return line 24. Also, the spool land 33 blocks the spool valve recess 27 from recess 21 connected to the return line 24, and the spool land 35 blocks recess 27 from recess 23 connected to the return line 24. Consequently, these spool lands prevent fluid flow from the left end of cylinder 11 to the return line 24.

As already stated, the pump pressure is applied to both ends of piston 10. However, the left end of the piston has a larger area exposed to the pump pressure than does its right end, from which the cross-sectional area of the piston shaft 12 is subtracted. Consequently, the fluid force acting on the left end of piston 10 is larger than the fluid force acting on its right end, and piston 10 moves to the right, forcing liquid out of the right end of cylinder 11. This return flow from the cylinder is blocked from the return line 24, as described, and therefore it can only flow to the left end of the cylinder, by way of the now open right check valve 17, line 47', spool valve recess 28, around the valve spool between its lands 38 and 37,

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spool valve recess 26 to the spool valve recess 25 adding to the flow coming directly from the pump.

Consequently, even though the net hydraulic force acting on piston 10 is low, its movement to the right takes place very rapidly. This setting is particularly advantageous when there is a very low load on the piston and it is desired to move the piston rapidly, even though the hydraulic force acting on it is low.

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 neutral position. However, when the spool valve is in its regenerative position the check valves are kept open to connect the opposite ends of the cylinder to each other for rapid movement of the piston toward the end of the cylinder at the smaller area side of the piston.

While a specific presently-preferred embodiment of the present invention has been described in detail 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.

I claim:

1. 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 and the piston has a larger exposed area on one side, 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 pilot valves and connecting the respective pressure responsive members in both pilot valves to the return line through the spool valve body to maintain both pilot 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

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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 check valves and connecting the pump to the second pressure responsive member for the flow of hydraulic liquid from the pump to the larger area side of the piston and return flow from the smaller area side of the piston to the larger area side.

2. A hydraulic system comprising:

- a cylinder, a piston slidable in said cylinder and having a larger area at one side thereof exposed to the fluid pressure in the cylinder than the area at its opposite side which is exposed to the fluid pressure in the cylinder thereat, said cylinder having first and second ports respectively located at said larger and smaller area sides of the 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 at said larger area side of the piston, 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 at the smaller area side of the piston, 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 pilot valves and connecting the respective pressure responsive members in both pilot valves to the sump to maintain both pilot 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 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;

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said spool in a fourth position thereof along the bore in the spool valve body connecting the pump to both check valves and connecting the pump to said second pressure responsive member to open said second check valve for the flow of hydraulic liquid from the pump to the larger area side of the piston and return flow from the smaller area side of the piston to the larger area side. 5

3. A hydraulic system comprising:

a cylinder having ports at its opposite ends, a piston slidable in said cylinder and having a larger area at one side thereof exposed to the fluid pressure in the cylinder than the area at its opposite side which is exposed to the fluid pressure in the cylinder thereat; 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 body of the spool valve, 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 pilot valves and connecting the respective outside pilot ports of both pilot valves to the sump, said spring means in each pilot 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

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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 first flow ports of both check valves and connecting the pump to the outside pilot port of the second check valve for opening both check valves for the flow of hydraulic liquid from the pump to the larger area side of the piston and return flow from the smaller area side of the piston to the larger area side.

4. A system according to claim 3 wherein: said spool valve has a recess therein which is connected to the respective inside pilot ports of both pilot valves and which is connected to the sump in each of said four positions of the spool.

5. A system according to claim 3, wherein: said spool in its first position blocks the respective first flow ports of both pilot valves from the sump.

6. A system according to claim 3, 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.

7. A system according to claim 6, 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.

8. A system according to claim 3, wherein: said spool in its fourth position blocks the pump and the respective first flow ports of both check valves from the sump, and connects the pump to the respective outside pilot ports of both check valves, and blocks the respective outside pilot ports of both check valves from the sump.

9. A system according to claim 3, wherein: said spool in its first position also blocks the respective first flow ports of both pilot valves from the sump; 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; 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 pump and the respective first flow ports of both check valves from the sump, and connects the pump to the respective outside pilot ports of both check valves, and blocks the respective outside pilot ports of both check valves from the sump.

10. A hydraulic system comprising:  
 a cylinder, a piston slidable in said cylinder and having  
 a larger area side thereof exposed to the fluid pressure  
 in the cylinder than its opposite side which is  
 exposed to the fluid pressure in the cylinder thereat,  
 said cylinder having first and second ports respectively  
 located at said larger and smaller 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 pilot valves to the  
 sump to maintain both pilot 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 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  
 check valves and connecting the pump to said second  
 pressure responsive member for opening both check  
 valves for the flow of hydraulic liquid from the pump  
 to the larger area side of the piston and return flow  
 from the smaller area side of the piston to the larger  
 area side.

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