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(54) Power transmission.

(57) A hydraulic control system comprising a hydraulic actuator (20,56,70) having openings adapted to alternately function as inlets and outlets for moving the element of the actuator in opposite directions, a pump (22) for supplying fluid to said actuator (20,56,70), pilot operated meter-in valve (27) to which the fluid from the pump is supplied for controlling the direction of movement of the actuator, and pilot operated meter-out valve (34) associated with at least one opening (20a,56a,70a) of the actuator for controlling the flow out of said actuator. The pressure of fluid being supplied to the actuator (20,56,70) by the meter-in valve means (27) is sensed (48) and caused to produce a force (at 47) opposing the movement of the meter-in valve means (27) by the pilot pressure (at 31) and also applied (via 51,58) to a device (49,55,57) for controlling an overhauling load resulting in a smooth and accurate control of the movement of the actuator (20,56,70).

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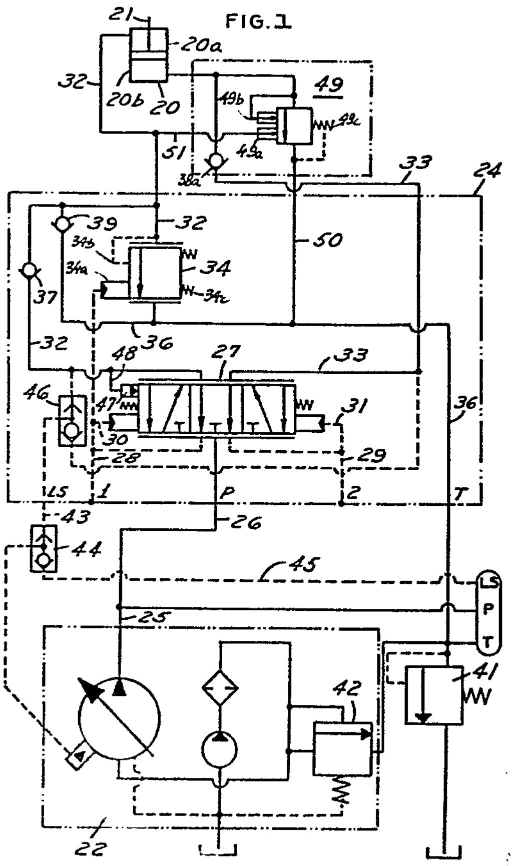
FIG. 1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POWER TRANSMISSION

This invention relates to power transmission in hydraulic systems that are found, for example, on mobile equipment such as excavators and cranes.

Background and Summary of the Invention

In United States Patent No. 4,201,052, incorporated herein by reference, there is disclosed a pilot pressure operated high pressure load sensing valve system incorporated in a valve body designed to be mounted directly on an actuator to be controlled such as a hydraulic cylinder or hydraulic motor. The valve system accurately controls the position and speed of operation of the actuator.

In brief, the valve system disclosed in the aforementioned patent comprises an independent pilot operated meter-in element; a pair of load drop check valves; a pair of independently operated normally closed meter-out elements; a pair of load pressure responsive valves; and a pair of anti-cavitation valves. The meter-in element functions to direct fluid flow to one or the other of the actuator ports. The normally closed meter-out elements are associated with each of the actuator ports for controlling fluid flow from the port opposite to the actuator port to which the meter-in element is directing fluid. The meter-out elements function as variable orifices metering fluid between the appropriate actuator port and a low pressure zone such as a reservoir tank. Each of the meter-out elements has associated therewith the load pressure responsive valves which act on the meter-out elements in response to load pressure to enable the meter-out elements to also provide pressure relief protection. The anti-cavitation valves are associated with each of the actuator ports and are adapted to open the appropriate port to tank.

The valve system is directly mounted on the actuator port manifold and is supplied by one full flow high pressure line, a pair of pilot pressure lines, and a load sensing line. The operation of the valve system is controlled through the pilot lines from a manually operated hydraulic remote control valve. In the absence of a command signal from the hydraulic remote control, the meter-in element assumes a centered or neutral position with the check valves, the meter-out elements, the pressure responsive valves, and the anti-cavitation valves, all in closed position. In the neutral position, the valve system hydraulically locks the load in position. Fluid flow from the actuator is blocked thereby preventing uncontrolled lowering of an overhauling load in the event of a rupture of any of the connecting hydraulic lines. Since the valve system is a load sensing system, the pump output is made to match that which is required by the load. In contrast, in a non-load sensing system, the pump output may exceed that required by the load with the excess power being dissipated as heat.

In certain high inertial loads such as swing drives on an excavator which utilize rotary actuators, smooth stopping and starting of the load and accurate positioning of the load are very essential. This problem is dealt with in a hydraulic system providing for smooth stopping and starting and accurate positioning of the load under high inertial loads is disclosed (not prepublished) in the European patent application 82 103 934.4 wherein means are provided for sensing the pressure being directed to the actuator by the meter-in element and providing a feedback pressure using a small piston on the meter-in element opposing the pilot pressure tending to open the meter-in valve element.

Under certain conditions, it may not be possible or desirable to mount the valve system directly on the actuator. Such conditions may exist due to space limitations on the actuator or wherein it is desirable to limit the number of supply and pilot lines, such as to the topmost section of a telescoping boom or when a brake, such as in a winch-type application, is used for counterbalancing the load. Under these conditions, the valve system is mounted on the equipment remote from the actuator with a pair of lines running to the actuator port manifold.

In the latter situation it may be desirable to provide for controlled lowering or holding of the load at the actuator port manifold. In that case a conventional counterbalance valve is interposed between one of the actuator ports and the line leading from the valve system to the actuator port. In such an arrangement as disclosed our copending United States application Serial No. 320,448 filed November 12, 1981, having a common assignee with the present application, the return flow from the actuator must pass through a normally open meter-out or exhaust element so as not to interfere with the desired control of the load through the counterbalance valve or brake. The normally open element is closed only when flow is delivered to the actuator in the opposite direction.

However, in the above described situation, when the meter-in valve is used as a flow control unit, it is usually difficult to obtain optimum stability of the load due to the high pressure gain in the outlet line of the meter-in valve.

Accordingly, it is an object of the present invention to provide a valve system of the aforementioned type which is operable in a counterbalance mode or with the use of external counterbalance valves or brakes with improved stability.

It is further an object of the invention to provide a hydraulic system having a proportional relationship between metered fluid flow and pressure in the output line of a flow control valve to maintain stability in the controlled lowering of an overhauling load.

It is another object of this invention to provide a hydraulic system which incorporates means for controlling an overhauling load and which hydraulic system has greater stability than prior hydraulic systems.

It is still another object of this invention to provide a hydraulic system incorporating a metering valve using pressure feedback to achieve system stability in the controlled lowering of an overhauling load.

In accordance with the invention the meter-in element of the above described valve system is provided with a small feedback or load piston to establish a steady-state relationship between the metered flow and the outlet pressure of the valve system. The controlled pressure established by this steady-state relationship is used to control external counterbalance valves or to provide for the controlled release of a brake if it is desired to control an overhauling load by braking rather than hydraulic metering. The present invention also provides for operating one of the meter-out elements of the valve system as a counterbalance valve when it is desirable to mount the valve system directly to the actuator port manifold.

Description of the Drawings

FIG. 1 is a schematic drawing of the hydraulic circuit embodying the invention.

FIG. 2 is a schematic drawing of another hydraulic circuit embodying the invention.

FIG. 3 is a schematic drawing of another hydraulic circuit embodying the invention.

FIG. 4 is a schematic drawing of another hydraulic circuit embodying the invention.

FIG. 5 is a schematic drawing of another hydraulic circuit embodying the invention.

Referring to FIG. 1, the hydraulic system embodying the invention comprises an actuator 20, herein shown as a linear hydraulic cylinder, a rod end 20a, a piston end 20b and output shaft 21 extending from the rod end that is moved in opposite directions by hydraulic fluid supplied from a variable displacement pump system 22 which has load sensing control in accordance with conventional construction. The hydraulic system further includes a manually operated controller, not shown, that directs a pilot pressure to a valve system 24 for controlling the direction of movement of the actuator, as presently described. Fluid from the pump 22 is directed to the line 25 and line 26 to a meter-in valve 27 that functions to direct and control the flow of hydraulic fluid to one or the other end 20a or 20b of the actuator 20. The meter-in valve 27 is pilot pressure controlled through pilot lines 28, 29 and lines 30, 31 which lead to the opposed ends of valve 27. Depending upon the direction of movement of the valve, hydraulic fluid passes through a motor line 32, connected with the rod end 20a, or a motor line 33 connected with the piston end 20b of the actuator 20. In the center closed position of the valve spool 27 both motor lines 32 and 33 are connected to low pressure through restrictors, not shown.

The hydraulic system further includes a meter-out valve 34 associated with the rod end 20a of the actuator and connecting line 32 to a tank line 36 for controlling the flow of fluid from the rod end 20a of the actuator. The meter-out valve 34 has two pistons 34a, 34b and spring means 34c, the former tending to open the valve 34 when there is pilot pressure in line 28, the latter tending to close the valve 34.

The hydraulic system further includes spring-loaded poppet valves 37, 38 in the lines 32, 33 and spring-loaded anti-cavitation valves 39, 40 shown in Fig.2-5, which are adapted to open the lines 32,33 to the tank passage 36.

The system also includes a back pressure valve 41 to keep the return or tank line 36 filled. A charge pump relief valve 42 is provided to take excess flow above the inlet requirements of the pump 22 and apply it to the back pressure valve 41 to augment the fluid in the tank line 36 available to the actuator, when an overrunning or a lowering load tends to drive the actuator down. Therefore, back pressure valve 41 functions to minimize cavitation.

Meter-in valve 27 comprises a bore in which a spool is positioned and in the absence of pilot pressure maintained in a neutral position by springs. The spool normally blocks the flow from the pressure passage 26 to the motor lines or passages 32, 33. When pilot pressure is applied to either passage 30 or 31, the meter-in spool is moved in the direction of the pressure until a force balance exists among the pilot pressure, the spring load and the flow forces. The direction of movement determines which of the passages or motor lines 32, 33 is provided with fluid under pressure from passage 26.

When pilot pressure is applied to line 28, leading to meter-out valve 34,the valve is actuated to allow flow from the rod end 20a of actuator 20 to tank passage 36.

It can thus be seen that the same pilot pressure (in line 28) which functions to open the meter-in valve 27 to meter fluid to piston end 20b (through line 33) also functions to determine and control the opening of the meter-out valve 34 so that the fluid in the rod end 20a of the actuator can return to the tank line 36.

Provision is made for sensing the maximum load pressure in one of a multiple of valve systems 24 controlling a plurality of actuators and applying that higher pressure to the load sensitive variable displacement pump 22. Each valve system 24 includes a line 43 extending to a shuttle valve 44 that receives load pressure from an adjacent actuator through line 45. Shuttle valve 44 senses which of the pressures is greater and shifts to apply the higher pressure to pump 22. Thus, each valve system in succession incorporates a shuttle valve 46 which compares the load pressure in lines 32 and 33 and signals the higher of the two pressures to shuttle valve 46 which is then compared with the load pressure of an adjacent valve system. The higher pressure is transmitted to the adjacent valve system in succession and finally the highest load pressure is applied to pump 22.

The above described circuit is similar to that shown and described in the aforementioned United States Patent No. 4,201,052 which is incorporated herein by reference. The single meter-in valve 27 may be replaced by two meter-in valves.

The details of the preferred construction of the elements of the hydraulic circuit are more specifically described in the aforementioned United States Patent No. 4,201,052 which is incorporated herein by reference.

In accordance with the invention a single side (here the left side) of meter-in valve 27 is provided with a load piston 47 which is connected by line 48 so that it senses the motor line or outlet pressure which may drive an overhauling load, f.i. is directed to the rod end 20a of the actuator and provides a pressure on the meter-in valve 27 opposing the pilot pressure (here at 31) which is tending to open the meter-in valve 27 in a direction to supply fluid to the rod end 20a of the actuator. In addition, a conventional counterbalance valve 49 is connected in a line 50 between piston end 20b (line 33) and tank line 36. Pressure from line 32 is applied to the counterbalance valve 49 through a line 51 to tend to open the counterbalance valve. To this end, the counterbalance valve 49 has pistons 49a, 49b and a spring means 49c, the latter acting to close the valve 49. Depending upon the pressure on these pistons 49a, 49b, the movable element of the counterbalance valve 49 takes a position to throttle the flow in line 50 to a greater or lesser extend.

When the meter-in valve 27 is operated to shift its spool to the left and supply fluid to the rod end 20a of the actuator 21, the pressure of the fluid will open the counterbalance valve 49 and permit fluid to be exhausted from the piston end 20b of the actuator to tank line 36. When the load tends to overrun, the pressure in lines 32 and 51 will be reduced and the counterbalance valve 49 will tend to close. However, the lessening in the pressure will be sensed in line 48 lessening the pressure on the load piston 47 so that the meter-in valve 27 can open to a greater degree under the control of the pilot pressure. Thus, vacuum in the motor line 32 and cavitation is avoided, on the other hand, pressure is low enough to shift the valve 49 in its throttling position. As a result, there is established a more stable system under overhauling loads.

When the meter-in valve 27 is operated to shift its spool to the right, line 33 supplies fluid to piston end 20b through a check valve 38a, which can be constructed similar to spring-loaded poppet valve 37.

In the hydraulic system shown in Fig.2, the counterbalance valve 49 is interposed between line 33 and piston end 20b and a second meter-out valve 52 is provided between line 33 and tank line 36 in series with the counterbalance valve 49. Meter-out valve 52 has a piston 52a, which is connected to pilot pressure line 28 through a line 53, a further piston 52b connected to line 33 and spring means 52c acting against the pistons 52a, 52b. Meter-out valve 52 is normally open. When pilot pressure is provided in line 28 to open the meter-in valve 27 to direct fluid to the piston end 20b of actuator through line 33, the same pilot pressure closes meter-out valve 52 through line 53 and opens meter-out valve 34 to direct the fluid to the tank line 36. When pilot pressure is in line 29, fluid is applied to the rod end 20a of the actuator through line 32 and the system functions to stabilize an overhauling load condition in the same manner as the circiut in Fig.1.

Referring to Fig. 3 , a circuit is shown wherein a hydraulic brake 55 is utilized to control a lowering or possible overhauling load and the actuator comprises a rotary hydraulic motor 56 having ports 56a and 56b. The brake 55 has a piston 55a connected to the motor line 32 through line 51, and spring means 55b acting against the force of the piston 55a. Otherwise the circuit of Fig.3 is the same as shown in Fig. 2.

When the meter-in valve 27 is operated by pilot pressure 29 to direct fluid to lower a load, the pressure of the main fluid in lines 32, 51 is applied to disengage the brake 55. If the load tends to overrun, the pressure in line 32 is becoming reduced tending to re-engage the brake. However, vacuum is avoided, since the line 48 senses the reduced pressure and applies this lesser pressure to piston 47 so that the meter-in valve 27 will open to a greater degree. Pressure in lines 32, 51 will somewhat increase and cause to somewhat disengage the brake 55, thereby providing greater stability.

Where the meter-in and meter-out valves can be located at the actuator,the hydraulic system shown in Fig. 4 can be used. This is similar to that of Fig. 1 except that the counterbalance valve is omitted. The system comprises the meter-in valve 27 and the normally closed meter-out valves 34 and 57 instead of a single meter-out valve pilot operated. Again the left hand end of meter-in valve 27 includes the piston 47 and line 48. In addition, the spring chambers of the meter-out valves 34 and 57 are connected to the pilot pressure lines 29 and 28, resp.

The second meter-out valve 57 includes two pistons 57a, 57b and spring means 57c acting in opposed directions on the valve 57. The piston 57a is connected to the motor line 32 through a line 58 which may include restrictors 59 and 60. A line 61 including a further restrictor 62 branches off from the line 58 between the restrictors 59 and 60 and is connected to the pilot pressure line 28. The second meter-out valve 57 is not opened by pilot pressure but by pressure of the main fluid in line 32 to the rod end 20a of the actuator applied through line 58.

When meter-in valve 27 is operated to direct fluid to the rod end 20a of the actuator for lowering a load, the second meter-out valve 57 functions as a counter-balance valve. Initially it is opened, but if the load tends to overrun, the subsequent reduction in pressure in line 32 and line 58 tends to close meter-out valve 57.

However, this pressure reduction is sensed through line 48 and reduces the force on piston 47 thereby permitting the meter-in valve 27 to open further increasing the pressure in lines 32, 33 and again causing the meter-out valve 57 to throttle the flow to tank.

When the meter-in valve 27 is moved to a neutral position from a moved position, anti-cavitation valves 39, 40 serve to supply additional fluid to the inlet of the actuator to prevent cavitation of the actuator. In this situation pressure in line 32 decays through line 28. The decay in pressure is sensed at the second meter-out valve 57 through line 58 causing the second meter-out valve 57 to move in closing direction. Inertia of the load tends to force fluid out of the exhaust port of the actuator building up pressure in line 33. When the pressure on piston 57b exceeds the relief setting of the second meter-out valve 57, the meter-out valve 57 moves in opening direction allowing the throttled exhaust fluid to join the fluid being pumped through line 36 to the anti-cavitation valve 39 or 40 by the charge pump.

When meter-in valve 27 is operated by pilot pressure in line 29 to direct fluid to the actuator 20, there will be a bleed flow through the restrictors 59 and 62 from line 32 to line 28 which provides for an approximately four to one (4:1) build-up of pressure between the pressure in lines 32 and 58 (at 57a). The second meter-out valve 57 has been set on a crack-open value at one-fourth the pressure in line 32. The build-up of the pressure in line 32 will apply back pressure on anti-cavitation valve 39 preventing recirculation of fluid exhausing from the second meter-out valve 57 to the actuator. Such recirculation of fluid would result in undesirable overspeeding when the actuator is driven by an overhauling load. Applying back pressure to the anti-cavitation valve 39 also prevents overheating of the actuator by allowing fresh fluid to be applied to the actuator by the pump. Restrictors 59 and 62 in combination with restrictor 60 in line 58 also augment the load stability by providing additional damping to the system, i.e. slowing the speed of response of the second meter-out valve 57 when subjected to sudden pressure surges.

Referring to FIG. 5, the valve system shown is similar to that shown in FIG. 4 wherein the meter-out valve 57 functions in a counterbalance mode as previously described. However, in this case the actuator comprises a rotary hydraulic motor 70 having ports 70a and 70b.

Again the second meter-out valve 57 is not opened by pilot pressure but by pressure of fluid applied to port 70a through line 32 and applied to the meter-out valve 57 through line 58. As in the case of the actuator of FIG. 4, restrictors 59, 62 placed in lines 58 and 61 prevent recirculation of fluid through the rotary motor which would result in an overspeeding condition of the motor or overheating of the motor.

It can thus be seen that the controlled outlet pressure out of the meter-in valve means is utilized to control either a counterbalance valve or a hydraulic brake for controlling the overhauling load. The meter-out valve which normally controls the flow in the direction of the overhauling load can be omitted or operated as a normally open valve when an external counterbalance is used. The meter-out valve must also be normally open when a brake is used and when a meter-out valve is used as a counterbalance valve is must be normally closed.

Claims

1. A hydraulic control system comprising a hydraulic actuator or motor (20,56,70) having opposed openings (20a,20b,56a,56b,70a,70b) adapted to alternately function as inlets and outlets for moving the element of the actuator in opposite directions,
a pump (22) for supplying fluid for said actuator,
meter-in valve means (27) to which the fluid from the pump is supplied, for selectively metering fluid to one or the other of said openings to control the direction of movement of the actuator (20,56,70),
said meter-in valve means (27) being pilot controlled by alternately applying fluid at pilot pressure to opposed ends of said meter-in valve means (27),
a pair of motor lines (32,33) extending from said meter-in valve means (27) to said respective openings of said actuator (20,56,70),
meter-out valve means (34) associated with at least one opening of the actuator (20,56,70) for controlling the flow out of said actuator,
said meter-out valve means (34) being pilot operated by the pilot pressure, applied (via 28,30) to said meter-in valve means (27), the improvement comprising means (47,48) for sensing the output pressure (in motor line 32) from the meter-in valve means (27) being directed to the actuator (20,56,70) when said meter-in valve means (27) is operated on one direction, wherein the load may be overhauling,
said sensing means (47,48) also providing a pressure in said meter-in valve means (27) opposing the pilot pressure (at 31) tending to actuate the meter-in valve means (27) in said one direction,
means (49,55,57) for controlling an overhauling load when fluid is being directed to one (20a,56a,70a) of said openings of actuator (20,56,70),
said controlling means (49,55,57) including means

operable to retard movement of said actuator (20,56,70) and including a line (51,58) extending from said motor line (32) supplying fluid to said actuator, when the pressure of fluid being supplied by said meter-in valve means (27) to said one opening (20a,56a,70a) of said actuator (20,56,70),a pressure (at 47) to said meter-in valve means (27) is provided opposing the pilot pressure (at 31) tending to actuate the meter-in valve means (27) in a direction to supply fluid to said one end (20a,56a,70a) of said actuator (20,56,70) such that in an overhauling load mode, the pressure of fluid to said one opening (20a,56a,70a) is reduced tending to actuate said means (49,55,57) operable to retard movement of the actuator and the pressure of fluid (at 47) being supplied (via 48) to said meter-in valve means (27) is reduced permitting the pilot pressure (at 31) to open the meter-in valve means (27) to a greater degree permitting more fluid to flow to said one opening (20a,56a,70a) of said actuator (20,56,70) and increasing the pressure of fluid to said controlling means (49,55,57).

2. The hydraulic system set forth in claim 1 wherein said means for controlling an overhauling load comprises a counterbalance valve (49,57) connected to the other opening (20b,70b) of said actuator (20,70) through a line (50,33) and being controlled by pressure connected (via 51,58) to said supplying motor line (32).

3. The hydraulic system set forth in claim 1 wherein said means for controlling an overhauling load comprises normally open meter-out valve means (52) associated with said other opening (20b), of said actuator (20) and operable to be closed when said meter-in valve means (27) is operated to direct fluid to said

other (20b) opening of said actuator, and a counterbalance valve (49) between said other opening (20b) and said normally open meter-out valve means (52), a line (51) extending to said counterbalance valve (49).

4. The hydraulic system set forth in claim 1 wherein said means for controlling an overhauling load comprises normally open meter-out valve means (52) associated with said actuator (56) and operable to be closed when said meter-in valve means (27) is operated to direct fluid to said other opening (56b) of said actuator (56), and hydraulic load brake means (55) associated with said actuator (56), a line (32,51) extending to said load brake means (55).

5. The hydraulic system set forth in claim 4 wherein said actuator comprises a rotary actuator (56).

6. The hydraulic system set forth in claim 1 wherein said means for controlling an overhauling load comprises normally closed meter-out valve means (57) associated with the other opening (20b,70b) of said actuator (20,70), and means (58) for applying pressure - being directed to said first opening (20a, 70a) - to said last-mentioned meter-out means (57) to tend to open the same when fluid is being directed to said one opening (20a,70a) of said actuator (20,70).

7. The hydraulic system set forth in claim 6 wherein said actuator comprises a rotary actuator (70).

8. The hydraulic control system set forth in claim 6 including at least one restrictor means (59, 62) for applying reduced pressure to said last-mentioned meter-out means (57).

9. The hydraulic system set forth in claim 8 including an anti-cavitation valve means (39) associated with the exhaust side of said last-mentioned normally closed meter-out valve means (57) and having restrictor means (59,62) associated with said normally closed meter-out valve means (57) to provide a back pressure on said anti-cavitation valve means (39).

10. The hydraulic system set forth in claim 9 wherein restrictor means (59,62) associated with said normally closed meter-out valve means (57) such that the back pressure on said anti-cavitation valve (39) means is greater than the pressure applied to said normally closed meter-out valve means (57).

11. The hydraulic system set forth in claim 10 including additional restrictor means (60) in the line to said normally closed meter-out valve means (57) for augmenting system damping.

FIG.1

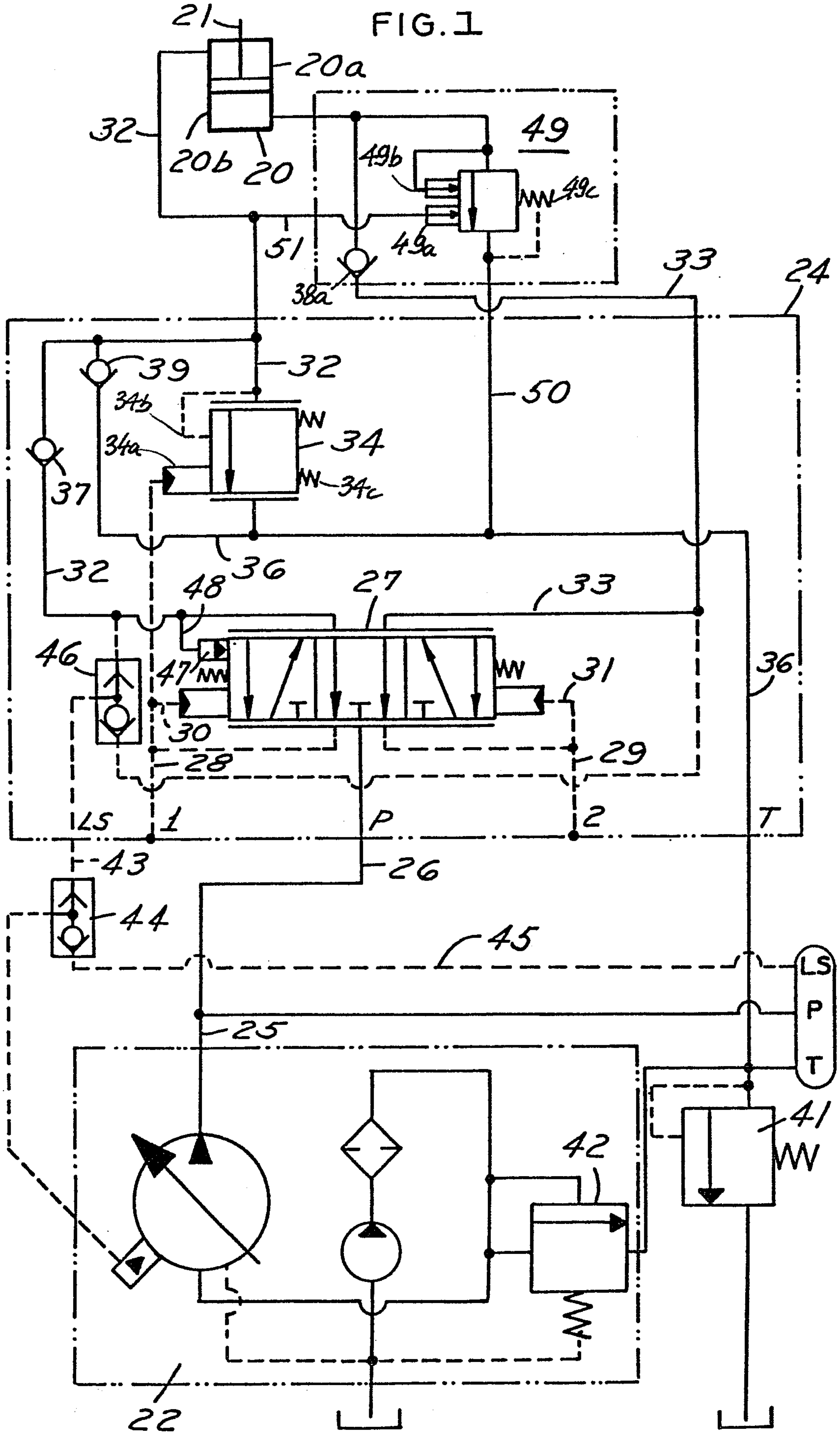
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FIG.2

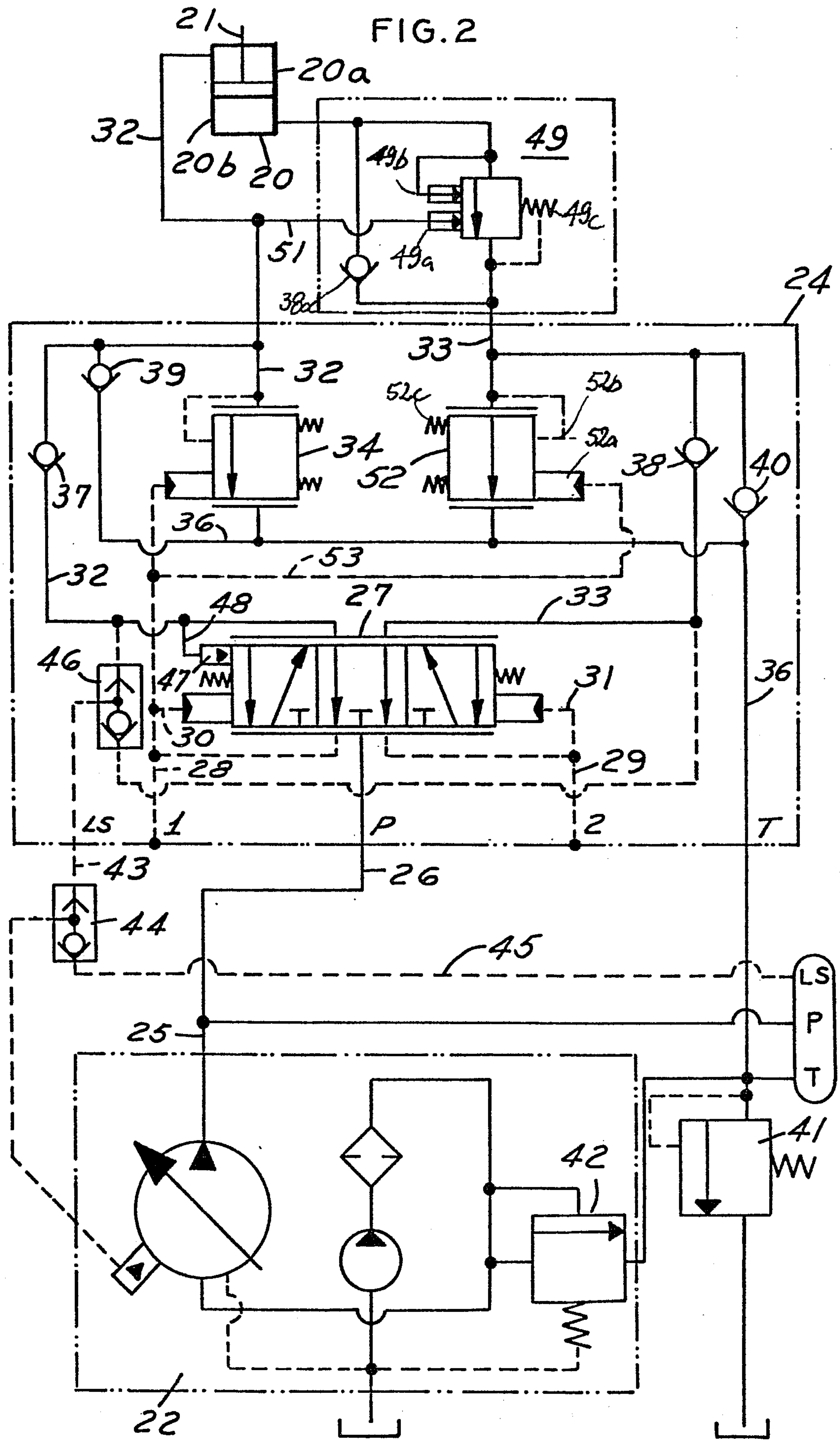

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FIG.3

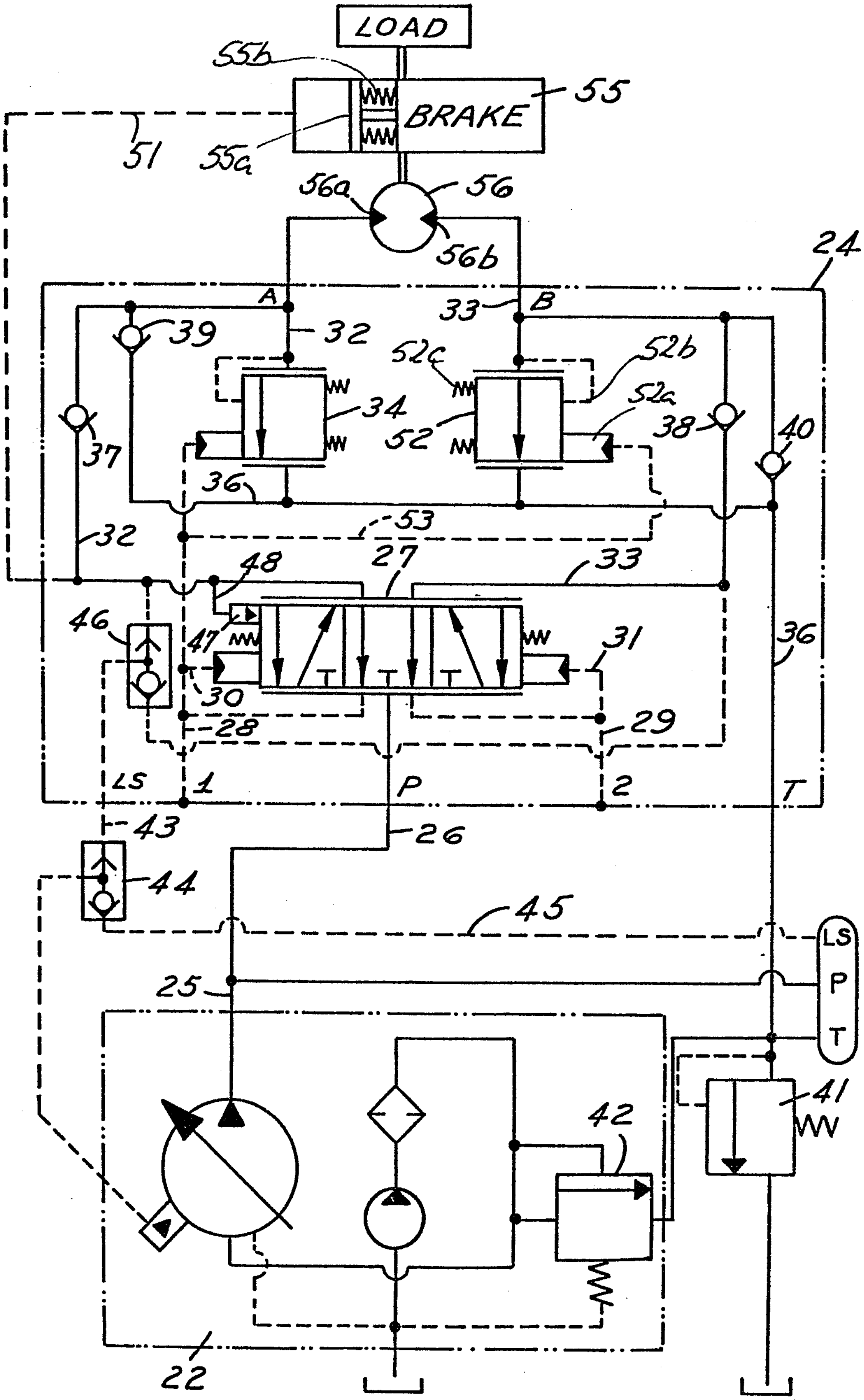
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FIG. 4

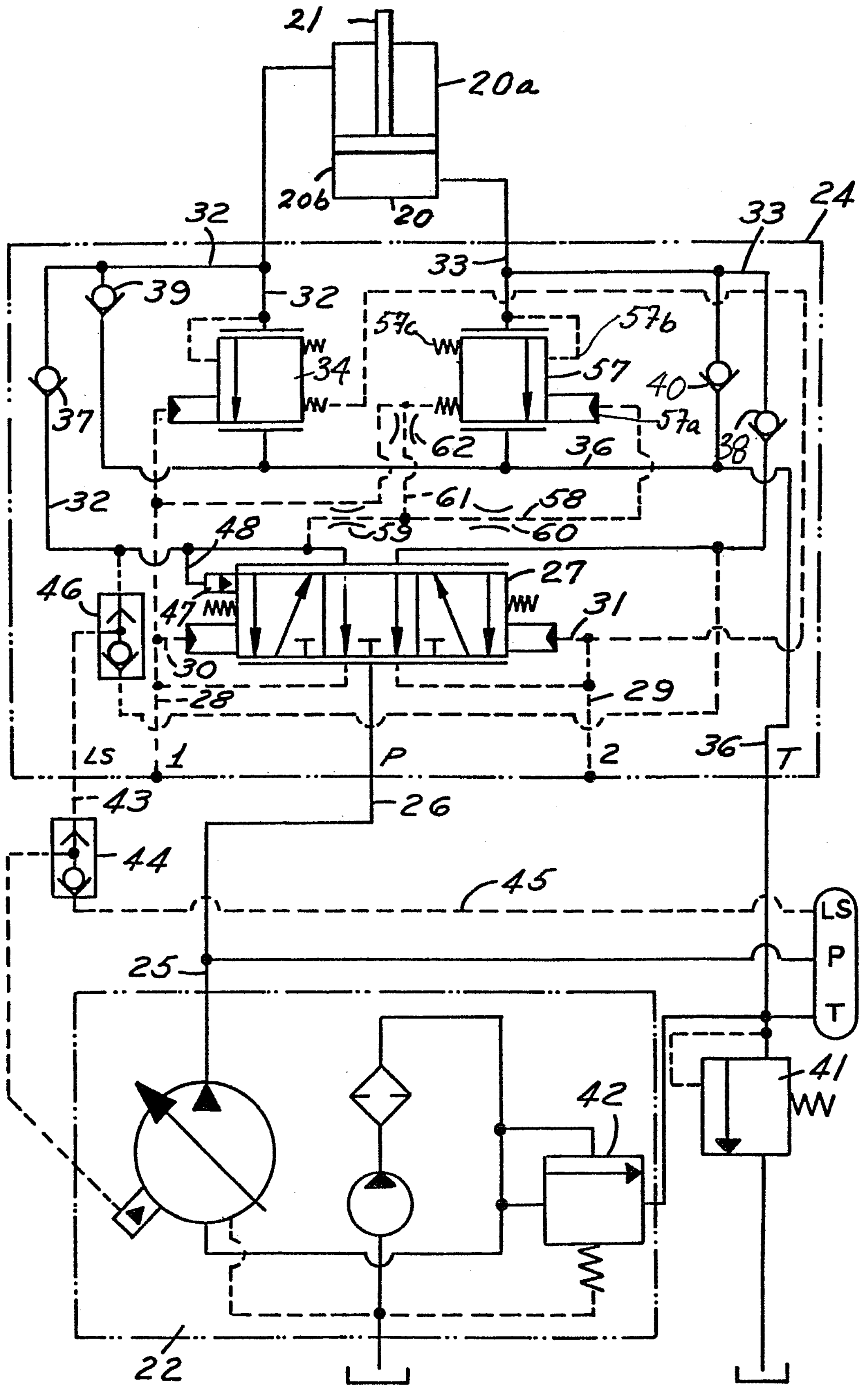
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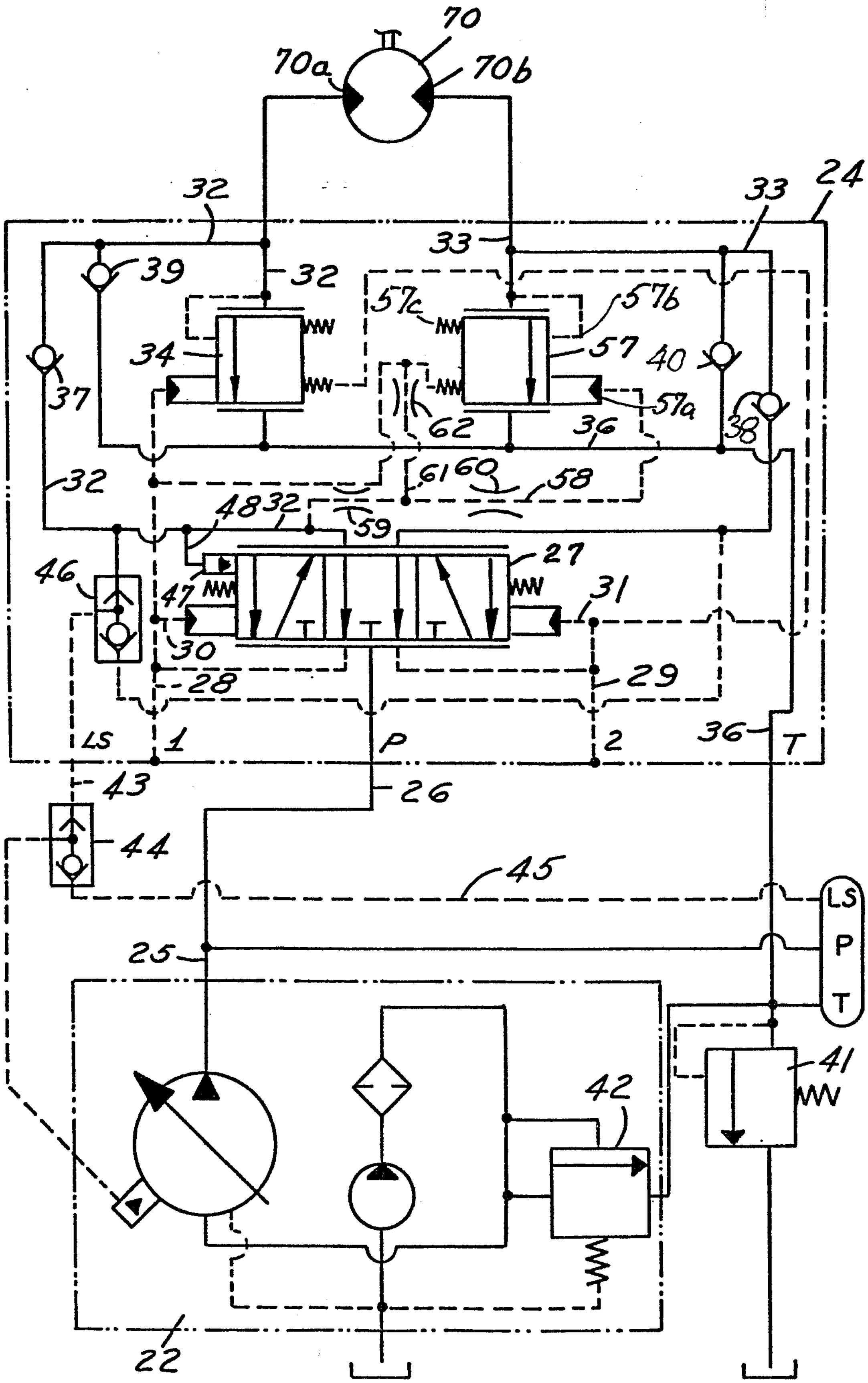
FIG.5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