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(54) Hydraulic supply system

(57) A conversion apparatus is provided for adapting a single-acting lifting cylinder (4) of an agricultural vehicle to a double-acting cylinder. The existing pressurised fluid supply of the vehicle provides a pump (2) supplying the fluid, a tank (3) to receive fluid and coupled to a first chamber (4b) of the cylinder, and a first control valve (30) operable to connect the other chamber (4a) of the cylinder to the pump or the tank. The conversion apparatus provides a second control valve (61) with a check valve (60). A first fluid connection (57) is established from the pump (2) upstream of the first control valve (30) to the second control valve (61), with the check valve (60) configured to oppose fluid flow toward the pump. A second fluid connection (58a-58b) is provided by the second control valve (61) interrupting the connection of the first chamber (4b) to the tank (3), whereby the second control valve (61) is operable to connect the first chamber (4b) to the first fluid connection (57) or the tank (3).

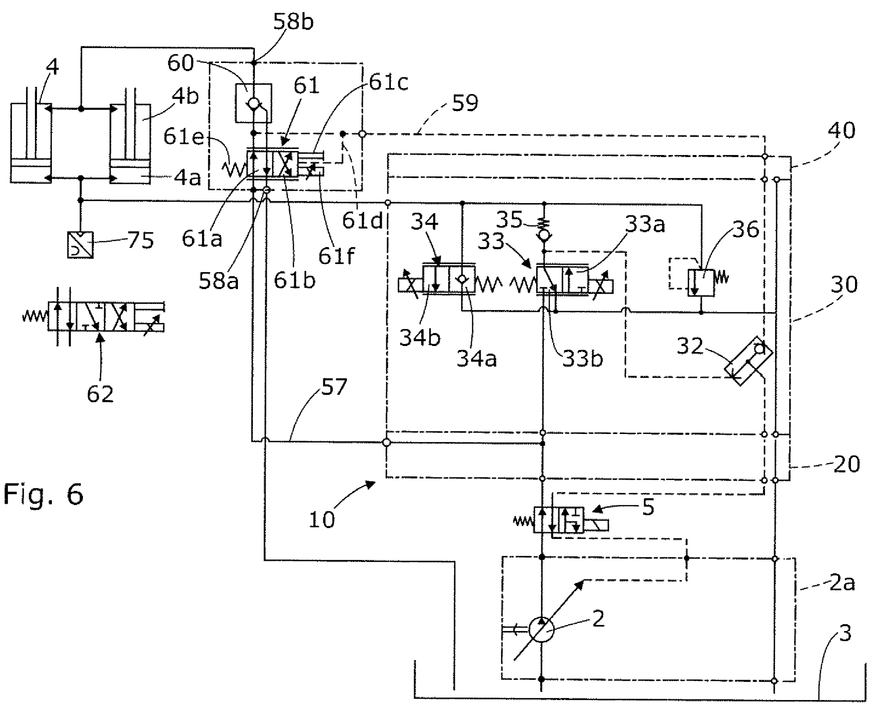

Fig. 6

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Description

[0001] The invention relates to a pressurised fluid supply system on an agricultural vehicle provided to supply hydraulic cylinders for example to move the lower links of a tractor three-point-linkage or the lifting unit for a header installed on a self-propelled harvesting machine.

Background:

[0002] Mobile fluid (hydraulic) supply systems are widely used to drive consumers on agricultural vehicles, such as tractors or a self-propelled harvesters, or on implements attached thereto. The term "control" in relation to supply systems hereby includes any adjustment of the supply system regarding direction, supply time or pressure of the fluid flow. These hydraulic systems are mostly provided with a pump, one or more consumers, control means and a tank to provide a fluid reservoir.

[0003] Referring to an agricultural tractor, a well-known form of consumers fixedly installed on this machinery is the hydraulic cylinders used to raise or lower the lower arm of a three-point linkage, which three-point linkage can be attached to the front or the rear of the vehicle. A similar system is provided on a self-propelled harvesting machine, like a forage harvester or a combine, and is used to lift or lower the harvesting header.

[0004] These hydraulic cylinders (also called lifting cylinders) mainly comprise a cylinder body which is formed like a tube, with a cylinder base on one end and a cylinder piston moving within the cylinder body. The cylinder piston is fixed to a piston rod extending through a cylinder head for connection with parts to be moved. The cylinder piston, cylinder body and the cylinder base form a first chamber, also called the piston side (or piston side chamber). The cylinder piston, cylinder body and the cylinder head (through which the rod extends) form a second and opposite chamber, also called annulus side (or annulus side chamber).

[0005] Each chamber can be connected to a hydraulic supply system, either on the pressure generating pump side or the pressure discharging tank side. Thereby, the hydraulic cylinder and the control system can be operated in two different ways:

1. A single-acting lifting cylinder is controllably connected to the pump on its piston side or annulus side, but not on both. The opposing side is connected to the tank so that e.g. if the piston side is charged with fluid, the fluid on the annular side is discharged to tank. Physically, the single acting cylinder would also work with no oil on the side not connected to pump, but the movement of the cylinder is smoother and also lubrication is improved. Furthermore, oil (hydraulic fluid) is protecting the cylinder from corrosion.
2. A double-acting cylinder can be connected to pump and tank on both piston and annular side by means of a valve alternating the connection of the chambers to tank and pump. If e.g if the piston side is connected to tank, the annular side is connected to tank and vice versa.

[0006] Comparing the two modes of operation, single-acting cylinder control systems are less complex and thereby cheaper. When used in a three-point linkage, the piston side is mainly connected to pump for lifting the lower links of a three-point linkage and thereby lifting a load, e.g. an implement while the weight of the load (on the three-point linkage) forces the cylinder to move in the opposite direction to lower the three-point linkage and its load (e.g. the implement). This control system is suitable for implements like fertilizer spreaders or hay tools. These systems can be found more frequently in low horsepower or low specification tractors.

[0007] When implements are used which require an additional force in direction of the ground, like tillage implements such as ploughs, a double-acting cylinder is used. Furthermore double-acting cylinders are often used to lift the vehicle off the ground, e.g. when changing tyres. These systems can be found more frequently in high horsepower or high specification tractors.

[0008] In general these linkage control systems are required to provide four modes:

1. A raising mode to lift the linkage
2. A lowering mode to lower the linkage
3. Floating position allowing free movement of the linkage
4. Locking position (for driving on the road)

[0009] If the customer orders a tractor, he has to decide which option to choose for the three-point-linkage so that the valve manifold is equipped with valves to supply/control double-acting or single acting cylinders. If he later wants to change from single-acting to double-acting cylinders this requires exchange of the respective valve plate of the manifold. This is costly and reduces operating time.

[0010] Furthermore, when designing a vehicle for low specification, the single-acting three-point linkage may be the option chosen by 95 % of the customers while only 5% require a double-acting three-point-linkage. This small percentage must still be considered which raises complexity for the manufacturer.

[0011] So it may be advantageous for customers, manufacturers and the after sales market to provide means to upgrade a single-acting control system to a double-acting control system without impacting the delivery condition, just by adding components beside the valve manifold.

[0012] Operational safety considerations require some operational conditions of double acting linkages to be considered, such that unintended movements of the linkage are prevented when the tractor is shut-down or a cable break occurs whereby the solenoids of the electric valves are not supplied by electric energy.

[0013] It is therefore a further aim to provide a conversion apparatus for upgrading a single-acting three-point-linkage control system to a double-acting three three-point-linkage control system whilst observing such operational safety considerations.

[0014] In accordance with a first aspect of the present invention there is provided a conversion apparatus for adapting a single-acting lifting cylinder of an agricultural vehicle to a double-acting lifting and lowering cylinder as recited in claim 1.

[0015] Further features of the invention are recited in the attached sub-claims, to which reference should now be made.

[0016] Embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of a prior art embodiment of a pressurised fluid supply system for a pair of double-acting cylinders;

Figures 2a and 2b are schematic representations of prior art embodiments of a pressurised fluid supply system for a pair of single-acting cylinders;

Figure 3 is a schematic representation of an embodiment of a conversion apparatus for upgrading a single-acting cylinder to a double-acting cylinder not in accordance with the present invention;

Figures 4, 5a, 5b, 6 and 7 are schematic representations of differing embodiments of a conversion apparatus for upgrading a single-acting cylinder to a double-acting cylinder in accordance with the present invention.

[0017] For illustrative purposes, the prior art is shown in Figures 1 and 2a, 2b whereby the two operating modes require different valve settings. Figures 1 to 6 show a hydraulic supply system 1 of a tractor comprising:

- a variable displacement pump 2, whereby the pump displacement is changed depending on a load sensing (LS) signal and controlled by means (not shown) framed by dashed line 2a,
- a fluid reservoir 3,
- hydraulic lifting cylinders 4 assigned to a three-point linkage (not shown),
- charge valve 5 (not needed in all embodiments)
- a valve manifold 10

[0018] Generally, the valve manifold 10 comprises first valve assembly 20 which is directly connected to pump 2 and tank 3, and final valve assembly 40 which closes or redirects ports. In between first valve assembly 20 and final valve assembly 40, intermediate valve assemblies 30 are provided to control fluid flow to consumers (not shown) on the tractor (e.g. linkage cylinders) or on an implement (via respective couplings which are not shown). Valve assemblies 20, 30, 40 are provided with shared ports which are named P for the ports connected to pump 2, R for the ports connected to tank 3 and Y for the ports connected to LS signal lines. Furthermore, exit ports A, B are for connection with the hydraulic lifting cylinders 4, e.g. port A may be connected to piston side 4a and port B may be connected to the opposing (annular) side 4b of the piston. Such a valve manifold 10 can be designed without internal connecting pipes or hoses and is very flexible in terms of the configurations which may be achieved. An example of such a manifold is the SB23 Control Block produced by Bosch Rexroth AG of Schwieberdingen, Germany.

[0019] In the shown embodiments, the pump 2 is of variable displacement. In this case valve assembly 20 provides connection to the aligned ports P, R, Y.

[0020] Alternatively a fixed displacement pump may be installed requiring different first valve assembly 20 including means to keep pressure differential constant and to provide the aligned ports P, R, Y.

[0021] Final valve assembly 40 is provided to close or redirect the ports. Ports not used can be closed with locking screws.

[0022] In an alternative to the stacked plate manifold construction, the first valve assembly 20 may be designed in that further intermediate valve assemblies can be attached on opposing sides as shown in applicant's published patent application EP 2472162A1.

[0023] Charge valve 5 is provided to short circuit the pump 2 for e.g. heating the oil circuit or loading the accumulator of an axle suspension system (not shown). In position 5a, the pump pressure is directly fed back to the pump adjustment so that the pump is at maximum delivery as long as position 5a is kept. Position 5b provides normal operation. Charge valve 5 may be optional but is required for some embodiments of the invention.

[0024] In Figure 1, valve assembly 30 comprises (in addition to other components not relevant for the invention and thereby not shown for better clarity) a control valve 31 for double-acting cylinder control. The control valve 31 has four positions (adjusted by solenoid and spring load) including intermediate positions:

1. Position 31 a for Raising mode

[0025] Piston side 4a is connected to pump 2. The load required to lift an implement is fed back via port 31 Y so that pump 2 is adjusted. In this position the annular side 4b is connected to tank.

2. Position 31 b for Lowering mode

[0026] Annular side 4b is connected to pump 2. In this position the piston side 4a is connected to tank.

3. Floating position 31 c

[0027] Piston side 4a and annular side 4b are connected to tank 3 and LS port 31 Y so that the linkage can freely move when external loads are applied e.g. during soil work.

4. Locking position 31 d

[0028] Piston side 4a and annular side 4b are blocked for road operation. The linkage is kept in position. This position is also the default setting when the solenoids are disconnected (e.g. by cable break).

[0029] As spool valves (valves which can take any position between to end positions) are characterised by the fact that, even in a closed position 31 d, fluid can pass through the gaps between spool and housing, a check valve 31 e is an integral part of control valve 31 to ensure seat tightness. Check valve 31 e is controlled with the spool so that the check valve is opened or closed depending on valve position - for example in position 31 b and 31 c the check valve must be opened to allow fluid flow to tank 3. Both lines to piston and annular side 4a, 4b may be equipped with such a valve so that no unintended movement is possible e.g. when the tractor is lifted up by the linkage for tyre changing.

[0030] In addition, valve assembly 30 is equipped with a shuttle valve 32 which ensures that the highest load sensing signal is forwarded for pump adjustment. This is especially needed if many valve assemblies 30 are installed.

Charge valve 5 is optional in this arrangement.

[0031] In Figure 2a, valve assembly 30 comprises means for single-acting cylinder control. This circuit enables the similar four positions (adjusted by solenoid and spring load) including intermediate positions, whereby these positions depend on the adjustment of a control valve 33 (with positions 33a/b) and lock valve 34 (with positions 34a/b). In this case annular side 4b is constantly connected to tank 3, and the load sensing LS signal is fed back to adjust pump displacement after (downstream of) control valve 33.

1. Raising mode

[0032] Control valve 33 is in position 33a so that piston side 4a is connected to pump 2. Lock valve 34 is in position 34a. Fluid on annular side 4b is discharged to tank 3 as piston side 4a fills.

2. Lowering mode

[0033] Control valve 33 is in position 33b and check valve 35 prevents any fluid from the cylinder 4 passing to the tank 3 via valve 33. Only the load sensing LS signal is discharged via valve 33. Lock valve 34 is in position 34b so that piston side 4a is connected to tank 3. Fluid can flow into annular side 4b as the lowering action causes it to be sucked from tank 3.

[0034] Thereby, an external load can force the piston rod and thereby the linkage downwards. There is no active fluid force supporting this movement.

3. Floating position

[0035] This has exactly the same valve configuration as the Lowering mode. With both piston side 4a and annular side 4b connected to tank 3, the linkage can be forced upwards or downwards.

4. Locking position

[0036] If Control valve 33 is in position 33b and lock valve 34 is in position 34a, no discharge from piston side 4a to tank is possible. As pump 2 is not connected to piston side 4a, the cylinder position is kept (for road travel). Consequently, external forces cannot pull the linkage (and thereby the piston) downwards, but upwards movement (caused by external forces) is possible as fluid would then be sucked from the tank.

[0037] The Locking position is kept if solenoid control cable break occurs for valves 33 and 34, or if the tractor is shut down, due to spring load on the valve spools.

[0038] Similarly to Figure 1 valve assembly 30 is equipped with a shuttle valve 32 which ensures that the highest load sensing signal is forwarded for pump adjustment. This is especially needed if many valve assemblies 30 are installed. A pressure limiting valve 36 prevents pressure levels above 230 bar which may occur e.g in locking position when travelling along a uneven road when the implements start to swing, or in any position wherein the external load exceeds maximum system pressure (defined by pump being 200 bar).

[0039] Charge valve 5 is optional in this arrangement.

[0040] In Figure 2b, the valves 33 and 34 of Figure 2a are merged into one control valve 37 still providing for single-acting cylinder control.

1. Raising mode

[0041] Control valve 37 in position 37a.

2. Lowering mode

[0042] Control valve 37 in position 37b. Check valve 38 is opened.

3. Floating position

[0043] As for the embodiment of Figure 2a, this is exactly the same as the Lowering mode with control valve 37 in position 37b. Check valve 38 is opened. As before, with both piston side 4a and annular side 4b connected to tank, the linkage can also be forced upwards.

4. Locking position

[0044] If Control valve 37 is in position 37c no discharge of piston side 4a to tank is possible. External forces cannot pull the piston (and thereby the linkage) upwards, as fluid cannot be sucked from tank.

[0045] This locking position is also taken in case of control cable break (with the valve spool centred at 37c by two springs).

[0046] Similarly to Figures 1 and 2a valve assembly 30 is equipped with a shuttle valve 32 which ensures that the highest load sensing signal is forwarded for pump adjustment and, as in Figure 2a, a pressure limiting valve 36 prevents pressure levels exceeding 230 bar.

[0047] Check valve 38 (between the piston side 4a and control valve 37) is also moved by the spool of valve 37 to open the connection to tank 3 e.g. in position 37b.

[0048] Charge valve 5 is optional in this arrangement.

[0049] Figure 3, shows an obvious but undesired approach to solving the problem of providing double-acting functionality to an existing single-acting system. Starting from the configuration shown in Figure 2a (whereby the Figure 2b arrangement could also be used) a valve 50 is added to selectively assign valve assembly 30 (including valves 33, 34 , 35 from Figure 2b) to piston side 4a or annular side 4b. This approach would enable a modular upgrade of single-acting to double-acting control but shows one major disadvantage referring to operational safety.

[0050] As mentioned above, the operational safety requires some operational conditions of double acting linkages to be considered:

1. If the implement is in lifted position, an unintended lowering must be prohibited as damage during road travel can result from lowering the implement. This is also the case when the operator works close to the implement and lowering could result in injury.
2. Furthermore, when the double acting linkage is used to lift the tractor by actively pushing the linkage to the ground (e.g. when the tyres are changed) an unintended lowering of the tractor may also cause injury to the operator.

[0051] These linkage positions should be kept safely when the tractor is shut-down or cable break occurs as in this case the solenoids of the electric valves are not supplied by electric energy.

[0052] In both situations, a very slow movement may be acceptable so that the operator may react and leave the area of the linkage. Preferred solutions are able to avoid any movement.

[0053] In case of cable break at valve 50, the spring of valve 50 can only adjust to one position 50a or 50b, depending which on valve configuration is the spring loaded default. In consequence, one of piston side 4a or annular side 4b would permanently be connected to pump 2 while the opposing side is permanently connected to tank so if the delivery of pump 2 is increased by demand of a further consumer (not shown) via the load sensing circuit, this would result in undesired movement of the linkage in an upwards or downwards direction.

[0054] This approach has the further major disadvantage that, as one of piston side 4a or annular side 4b is always connected to tank 3, so external forces can cause unintended movement. Integrating unlockable check valves in each line is technically difficult and costly.

[0055] In an alternative, a three-position valve 51 providing a central locking position 51 a may be installed in place of valve 50. However, this requires two solenoids to be controlled, increasing costs, and still fluid can pass through spool gaps such that unintended or undesired movement cannot be prohibited.

Charge valve 5 is optional in this arrangement.

[0056] Figure 4 shows a first embodiment of a solution according to the present invention, wherein a conversion apparatus includes a pressure piloted lockable check valve 60 and control valve 61 which is added beside the existing valve assembly 30 to provide a modular upgrade of the single-acting control to a double-acting control. The apparatus further includes a first fluid connection 57 from the pump upstream (i.e. on the pump side) of the valve assembly 30 to the control valve 61. A second fluid connection 58a - 58b is provided by the control valve 61 for connection of the annular side 4b to the tank 3. A third fluid connection 59 links a connection between the control valve 61 and check valve 60 with the load sensing LS circuit of the vehicle.

[0057] Control valve 61 is connected to pump 2 (via connection 57) and tank 3 by respective ports: two further connections couple the valve 61 to a main port and unlocking port of the check valve 60. In position 61 a, the annular side 4b is connected to pump 2 as lockable check valve 60 does not block the oil flow in the direction from pump to annular side 4b. In position 61 b, the connections within control valve 61 are reversed whereby the pump pressure unlocks lockable check valve 60 so that the annular side 4b is connected to tank 3. The pump pressure to unlock lockable check valve 60 must therefore be smaller than the stand-by-pressure of the pump to maintain responsiveness.

[0058] The control of the piston side is similar to that described above with reference to Figure 2a, providing the respective four positions / Modes.

1. Raising mode

[0059] Control valve 33 is in position 33a so that piston side 4a is connected to pump 2. Lock valve 34 is in position 34a. Control valve 61 is in position 61 b so that the annular side 4b is discharged to tank 3

2. Lowering mode

[0060] Control valve 33 is in position 33b and check valve 35 prevents any fluid from the cylinder 4 passing to the tank 3 via valve 33. Only the load sensing LS signal is discharged via valve 33. Lock valve 34 is in position 34b so that piston side 4a is connected to tank 3. Rather than fluid simply flowing into annular side 4b as the lowering action causes it to be sucked from tank 3, control valve 61 is in position 61 a so that the annular side 4b is connected to pump 2.

3. Floating position

[0061] Lock valve 34 is in position 34b so that piston side 4a is connected to tank 3. Control valve 61 is in position 61 b so that check valve 60 is unlocked and the annular side 4b is discharged to tank 3. With both piston side 4a and annular side 4b connected to tank 3 the linkage is free to move up and down.

4. Locking position

[0062] If Control valve 33 is in position 33b and lock valve 34 is in position 34a, no discharge of piston side 4a to tank is possible. As pump 2 is not connected to piston side 4a, the cylinder position is kept (for road travel). Additionally, control valve 61 is in position 61 a so that the annular side 4b is completely blocked by lockable check valve 60 and no movement of the pistons is possible.

[0063] Compared to the arrangement of Figure 3, this configuration enables a safe state for both piston side 4a and annular side 4b. The piston side 4a is secured by valve assembly 30 while the conversion/upgrade elements 60 and 61 secure the annular side 4b.

[0064] In case of a cable break or the vehicle shut down, valve 61 would be biased by spring 61 e into position 61 a blocking the return to tank 3. In case of a cable break, control valve 61 can be adjusted and locked manually by lever 61 c to position 61 b so that the single-acting mode is prohibited mechanically in a safe state.

Charge valve 5 is not needed in this embodiment of the invention.

[0065] Figure 5a shows a further embodiment with control valve 70 and check valve 71. The control means of the previous embodiment are only capable to adjust the oil flow (and thereby the speed and position of the linkage). Control valve 70 allows also the adjustment of the pressure in the annular side 4b which is advantageous for implements requiring a force downwards e.g. a stump grinder or a dozer blade.

[0066] Check valve 71 provides a safe state for annular side 4b in the case of a cable break of control valve 70. In order that the pressure in the annular side 4b can be balanced by pilot line 70a, check valve 71 must be installed before (on the upstream/pump side of) the control valve 70 as a check valve between annular side 4b and control valve 70 would make discharge to tank impossible.

[0067] Third fluid connection (as at 59 in Figure 4) for load sensing signal may be provided but has a disadvantage in some applications. If the tractor is lifted by pressurizing annular side 4b (so that linkage is forced downwards) the load of the tractor would also pressurize annular chamber 4b so a constant load sensing signal would be generated and the pump would constantly run at high performance which is not efficient during e.g. changing tyres.

[0068] To mitigate this problem the charge valve 5 is required. In this case third fluid connection 59 is not present, so that the annular side 4b is not connected to the Load sensing signal and any demand would not result in a pump adjustment. To mitigate this problem the pump delivery is increased by charge valve 5 switched to position 5a (short circuit mode normally used to heat up the oil in winter).After lifting the tractor, the operator can then switch charge valve 5 back to position 5b so that the tyres can be changed in a more efficient condition.

[0069] Figure 5b shows a further embodiment with control valve 70 and check valve 71 integrated in one control valve 72 providing the same function (including the involvement of charge valve 5) as described in Figure 5a. Note that the term "check valve means" as used herein encompasses both a discrete check valve component (as at 71 in Figure 5a) and the provision of check valve functionality in another valve component (as at 72a in the control valve 72 of Figure 5b).

[0070] So the invention provides a modular upgrade of a single-acting linkage control. The additional means to upgrade the system can easily installed in between the valve manifold 10 and the respective cylinder or cylinders 4. Connection to pump or tank can also be easily integrated via first valve assembly 20 or final valve assembly 40 or at any place within the circuit. There is no impact on the design of valve manifold 10. This is especially advantageous for after-sales market and for low specification tractors where only a small percentage are required to be equipped with double-acting linkage control.

[0071] Figure 6 shows a further embodiment with pressure piloted lockable check valve 60 and control valve 61. In the Figure 4 embodiment, the control means are only capable to adjust the oil flow (and thereby the speed and position of the linkage) while the arrangement of Figure 6 offers pressure adjustment. To achieve this, the load sensing signal is fed back from the third fluid connection 59 via feedback line 61 d to control valve 61 resulting in a pressure level adjustment as described below.

[0072] Solenoid 61f of the control valve initially adjusts the fluid pressure on the annular side 4b. This annular side pressure is generating the load sensing signal on line 59 and is also forwarded to the control valve 61. As annular side pressure plus the pressure adjusted with spool 61f are counteracting against spring 61 e then typically the spool must be set to 197 bar to adjust 3 bar on the annular side 4b, as 200 bar (set by spring 61 e) = 197 bar + 3 bar. Thereby, the pressure can be adjusted according to this state of balance.

Charge valve 5 is not needed in this embodiment of the invention.

[0073] Figure 6 shows a preferred solution compared to Figures 5a, 5b in that it also provides pressure adjustment but is relatively simple and does not require the use of the charge valve 5. In a modification to the embodiment, the two-position control valve 61 may be replaced by a three-position control valve (indicated at 62) again supplied with load sensing feedback on line 61 d but now with an intermediate position in which the pressure may be adjusted more precisely.

[0074] Figure 7 shows a modification to the embodiment of Figure 6 in which a shuttle valve 63 is provided to compare the pressure on piston side 4a and annular side 4b. As explained with Figure 6, the operator can adjust a pressure on the annular side to e.g. 200 bar. Due to the cylinder ratio between piston surface and annular surface of say 1.3, the pressure on the piston side would be 153 bar. This pressure is superimposed by a pressure caused by the implement weight of e.g. 80 bar, giving a pressure at the piston side 4a of 233 bar. This would result in pressure limiting valve 36 opening and piston side 4a would be connected to tank 3. As a consequence, the cylinder 4 would be inadvertently lowered.

[0075] Shuttle valve 63 mitigates this problem in that the pressure of the piston side 4a being higher then 200 bar would move valve 61 in position 61 b so that annular side 4b is discharged to tank. Thereby, the pump 2 is not constantly delivering against pressure limiting valve 36 with 230 bar which is more efficient.

[0076] However, this approach has a disadvantage. If the operator wants to adjust only a low pressure on the annular side 4b, e.g. to make sure that the annular 4b side is constantly filled with fluid to maintain responsiveness, even the own weight of the linkage would result in a higher pressure at the piston side 4a which would then be forwarded to valve 61 via shuttle valve 63. So the operator would only be able to adjust a pressure on the annular side which is higher then the pressure on the piston side.

[0077] To mitigate this problem, a further pressure limiting valve 64 is introduced in the line between piston side 4a and shuttle valve 63. Compared to the pressure limiting valve 36, the pressure limiting valve 64 is operates differently. Pressure limiting valve 36 opens the connection depending on the pressure difference between port 36a and 36b. As port 36b is connected to tank 3, pressure on port 36b is 0 bar so that the pressure difference only depends on the pressure at port 36a. In contrast to that, pressure limiting valve 64 is designed so that the valve position only depends on the pressure at port 64a. In the embodiment, the pressure limiting valve 64 valves opens at 200 bar charged on port 64a independent on the pressure on port 64b which is not connected to tank so that the pressure can vary.

[0078] By adding this pressure limiting valve 64 the pressure on the piston side is only forwarded if the pressure on piston side 4a exceeds a level of 200 bar. Beneath this pressure, the connection is cut so that the pressure on annular side 4b can adjusted independently with spool 61 f.

[0079] This limitation in pressure is also advantageous in case of a cable break with spool 61 f being blocked at a certain pressure adjustment and the pump pressure at maximum e.g. when the steering or any other consumer becomes blocked. In this case, shuttle valve 63 in combination with pressure limiting valve 64 prevents the cylinder lowering inadvertently.

Charge valve 5 is not needed in this embodiment of the invention.

[0080] Both, shuttle valve 63 and pressure limiting valve 64 could also be used with the embodiments shown in Figure 5a or 5b.

[0081] The embodiments of Figures 4 to 7 may additionally be equipped with a pressure sensor 75. This sensor may be used to monitor the pressure on the piston side. This sensor may be used for linkage control as described in the applicants co-pending application WO2013/053645. In this case, the sensor could be used to detect whether pressure on annular side (decreased by cylinder ratio) plus pressure caused by weight of the implement causes an overpressure not released to tank so that the pressure limiting valve 36 constantly discharges fluid to tank, which is inefficient. The sensor could give a warning signal in this event.

[0082] Furthermore sensor 75 can also be used to detect if the implement touches the ground. This is of use e.g. when the rear axle of the tractor should be raised to lift the rear wheels clear of the ground to change the tyres. To lower the cylinders and linkage, a lower pressure (on annular side 4b) is applied at annular side 4b, but the weight of the implement is added to this pressure. When the linkage touches ground, the weight of the implement is borne by the ground so that the pressure shown at sensor 75 is lower as only the pressure adjusted at annular side 4b (decreased by cylinder ratio) would be shown. Knowing this the pressure on annular side 4b can then be increased to bear the weight of the tractor. In this manner, the linkage is lowered slowly, avoiding accidents, and can then be switched to more powerful operation to lift the tractor. This is also more efficient.

Claims

1. A conversion apparatus for adapting a single-acting

lifting cylinder of an agricultural vehicle to a double-acting lifting and lowering cylinder, wherein the single-acting cylinder is provided with a pump supplying pressurised fluid, a tank to receive fluid and coupled to a first chamber of the cylinder, and a first control valve operable to connect the other chamber of the cylinder to the pump or the tank, the conversion apparatus comprising:

- a second control valve;
- a check valve means to block the fluid flow from first chamber to pump or tank;
- a first fluid connection from the pump upstream of the first control valve to the second control valve, with the check valve means configured to oppose fluid flow toward the pump;
- a second fluid connection of the second control valve for connection of the first chamber to the tank;

whereby the second control valve is operable to connect the first chamber to the first fluid connection or the tank.

2. A conversion apparatus as claimed in claim 1, wherein the check valve means is a pressure piloted lockable check valve.

3. A conversion apparatus as claimed in claim 1 or claim 2, wherein the check valve means is disposed in a fluid path between the first chamber and the second control valve.

4. A conversion apparatus as claimed in any of claims 1 to 3, including a third fluid connection from downstream of the second control valve to a load sensing pressure circuit of the vehicle.

5. A conversion apparatus as claimed in claim 4, wherein the second control valve includes a spring bias and fluid pressure from the third fluid connection is fed back to the second control valve in opposition to the spring bias.

6. A conversion apparatus as claimed in claim 1, wherein the check valve means is disposed in the first fluid connection.

7. A conversion apparatus as claimed in claim 6, wherein the second control valve is an adjustable device operable to vary fluid pressure in the first chamber.

8. A conversion apparatus as claimed in claim 1, wherein the check valve means and second control valve are integrated in a single valve device.

9. A conversion apparatus as claimed in claim 5, wherein fluid pressure from the third fluid connection is fed back to the second control valve in opposition to the spring bias via a shuttle valve coupled to compare the pressure on the third fluid connection against the pressure in the other chamber of the cylinder.

10. An agricultural vehicle adapted by the installation of a conversion apparatus as claimed in any preceding claim.

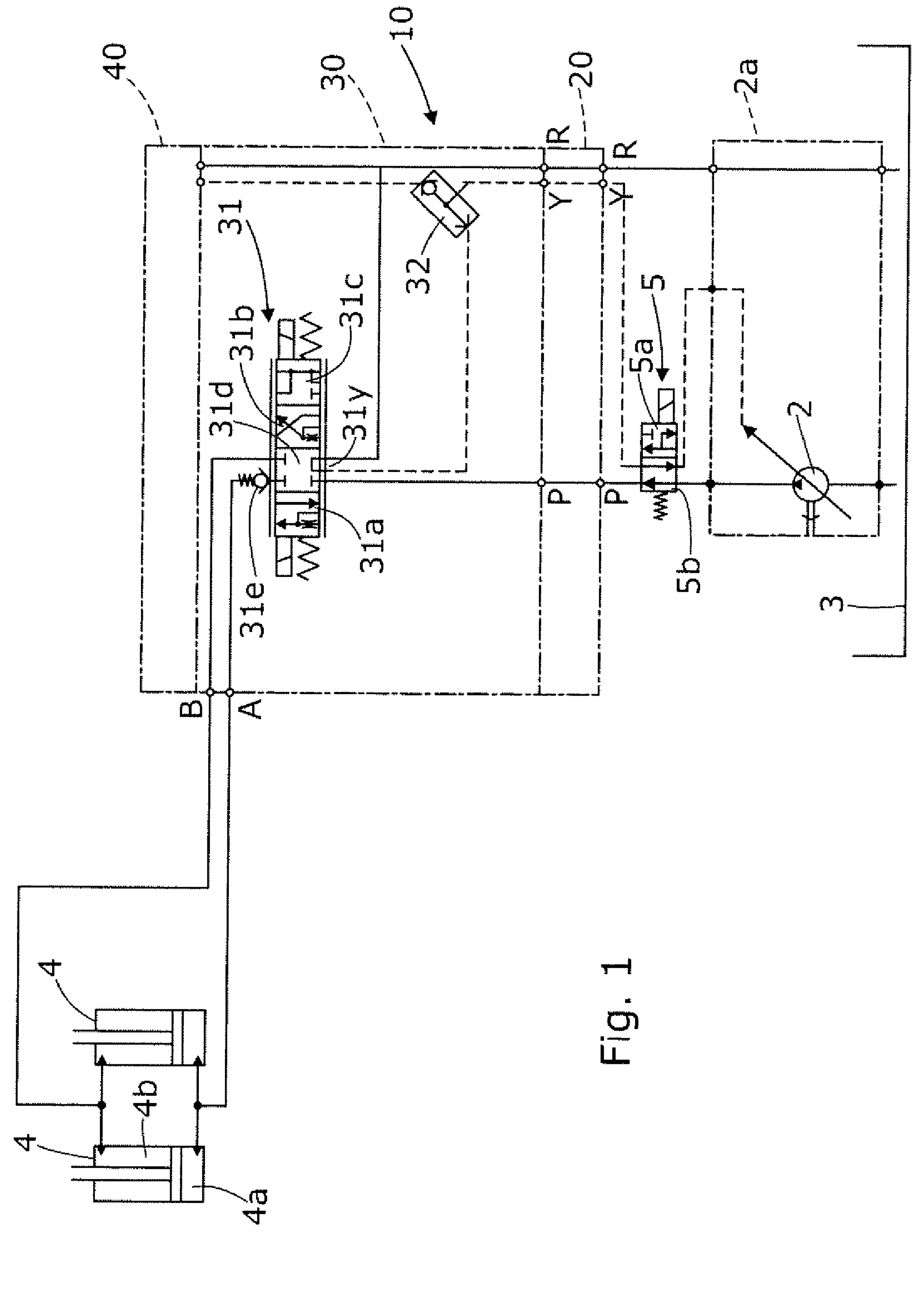
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Fig. 1

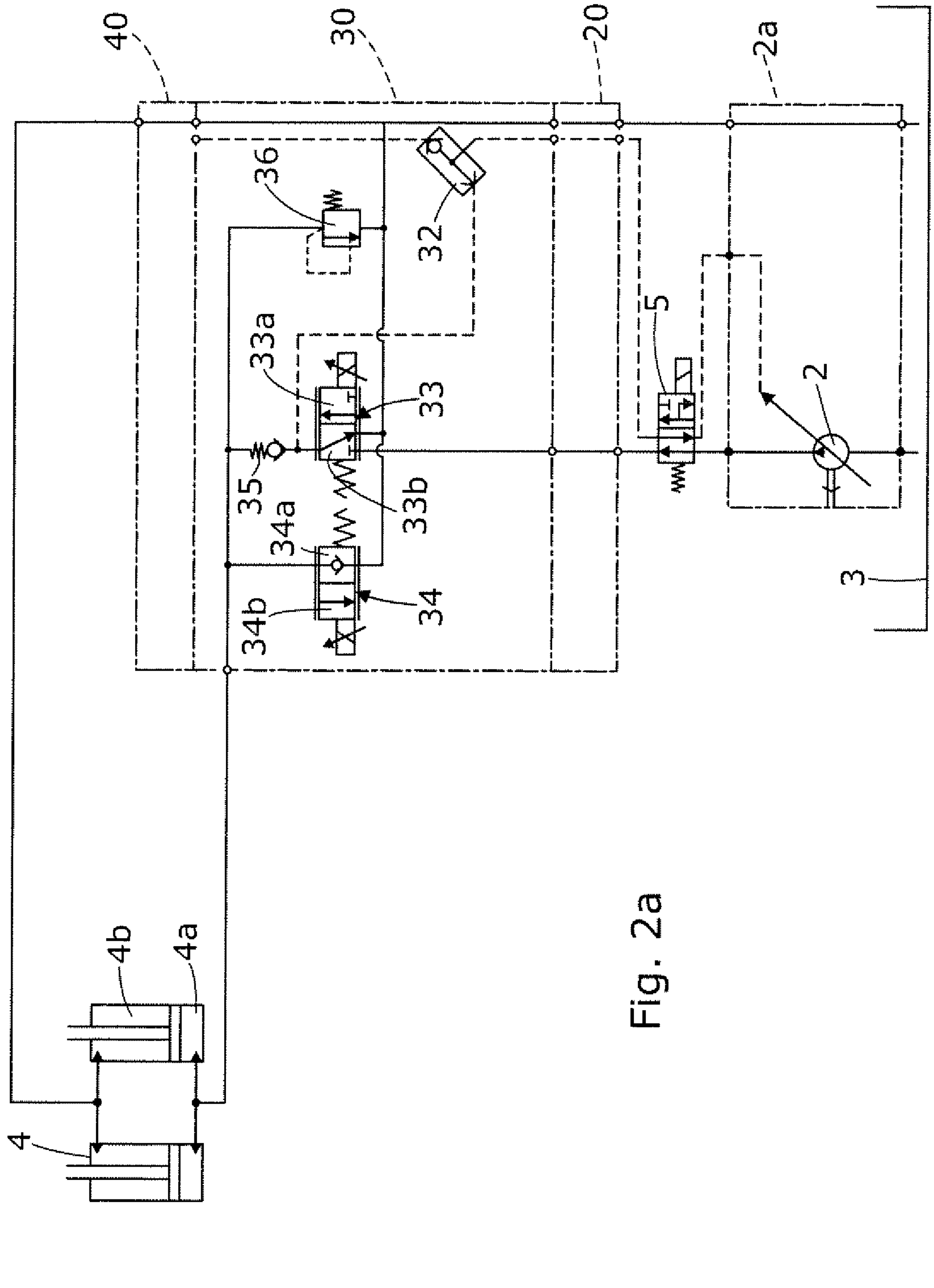


Fig. 2a

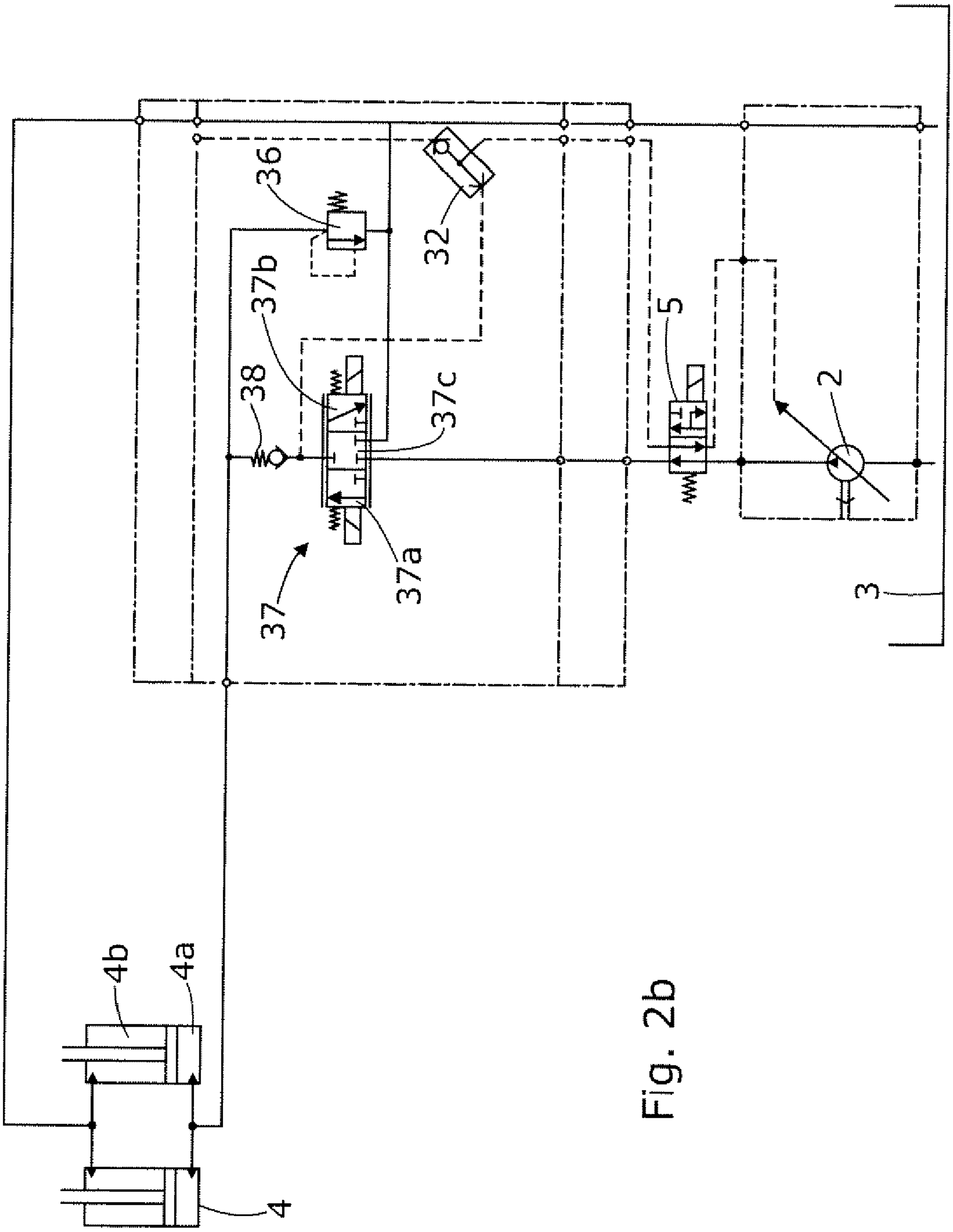


Fig. 2b

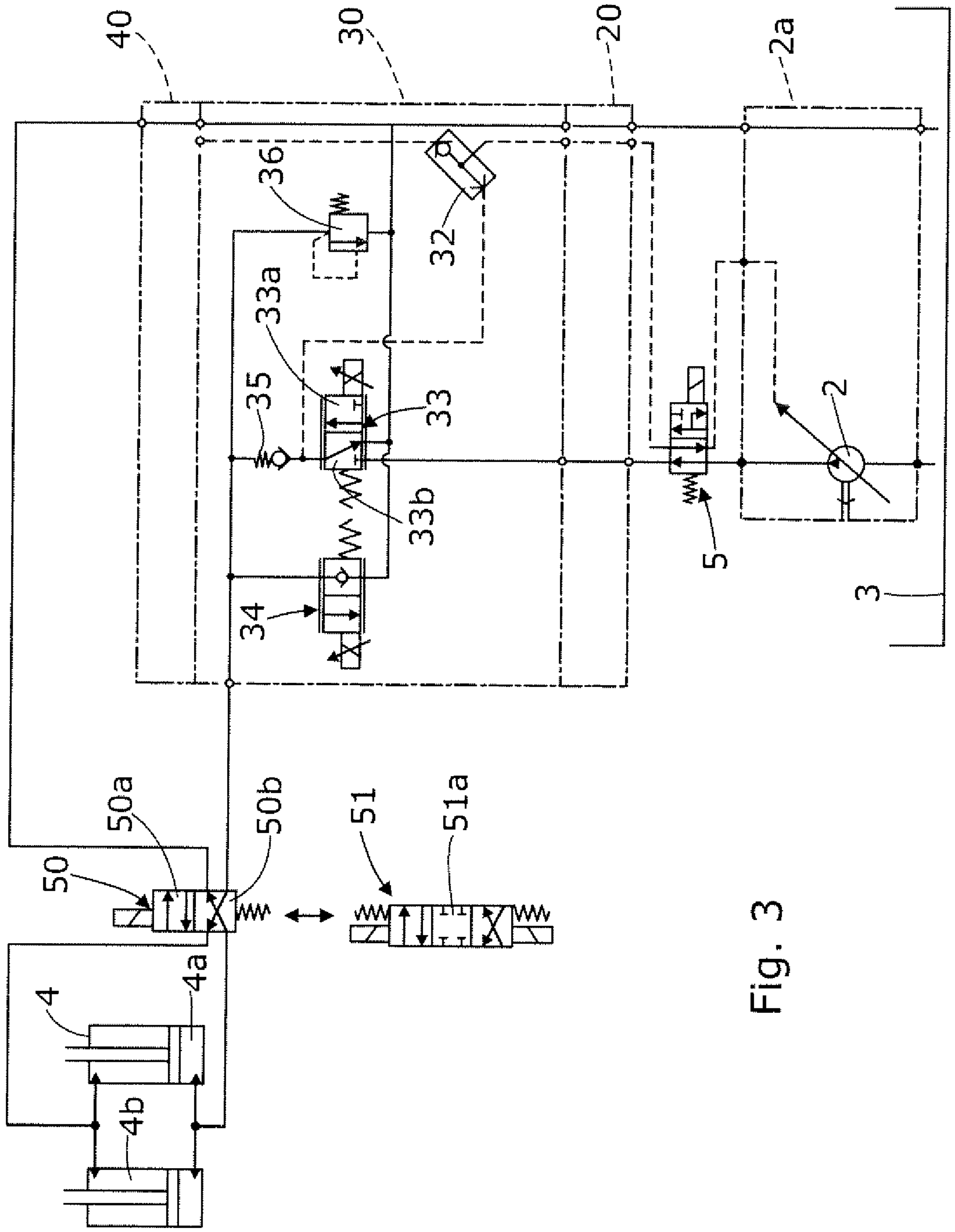
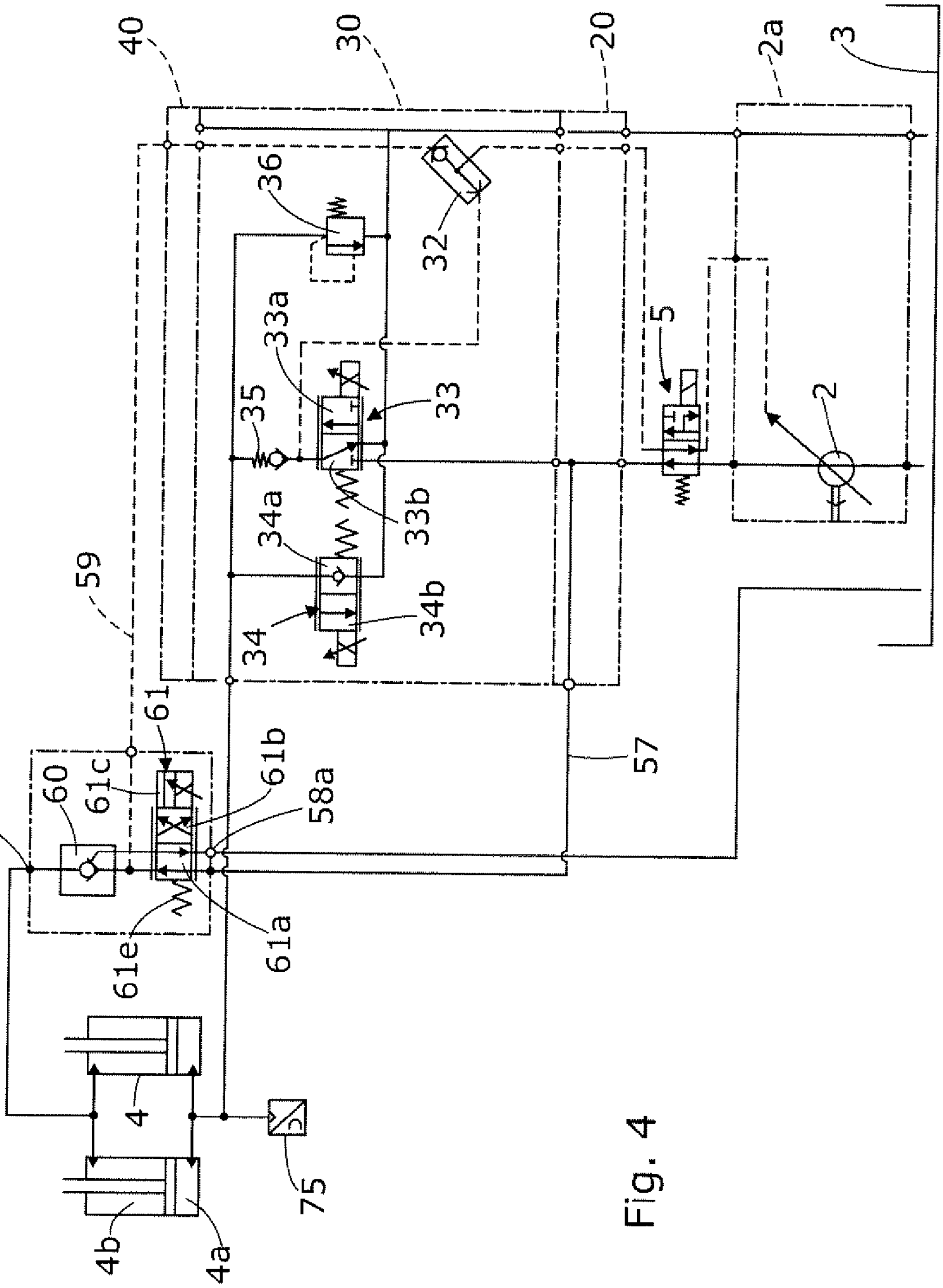


Fig. 3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61e
61a
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4b
4a

Fig. 4

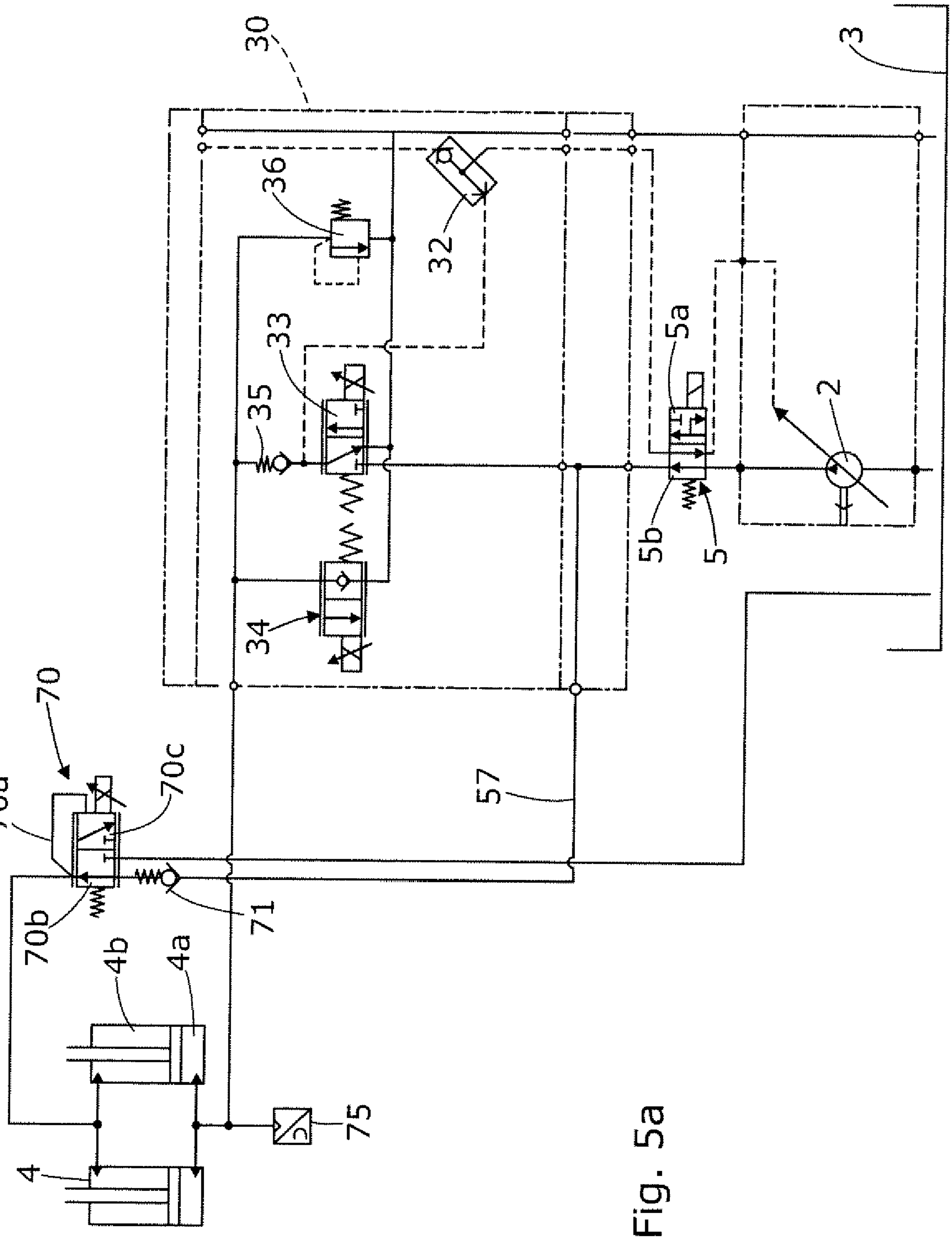


Fig. 5a

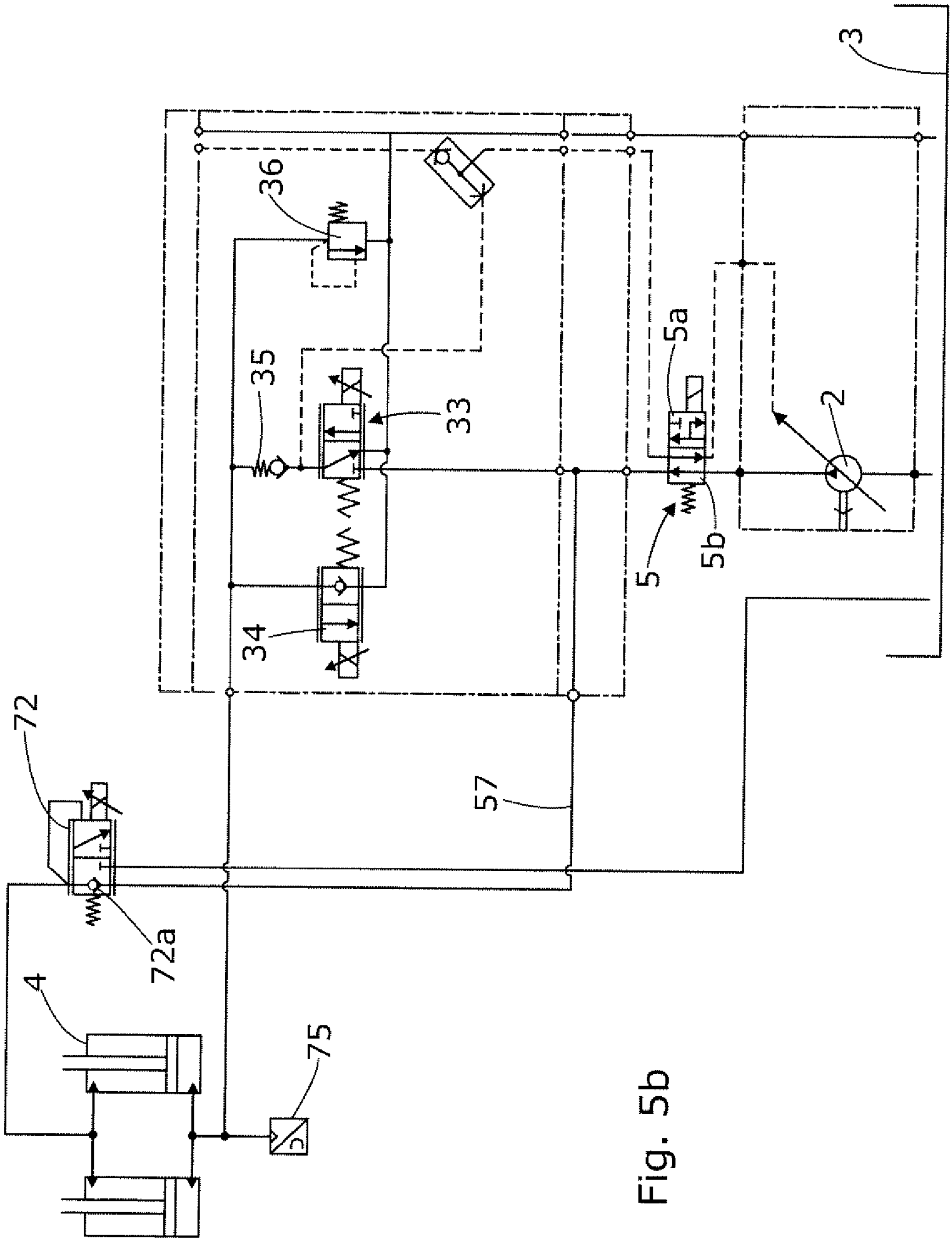
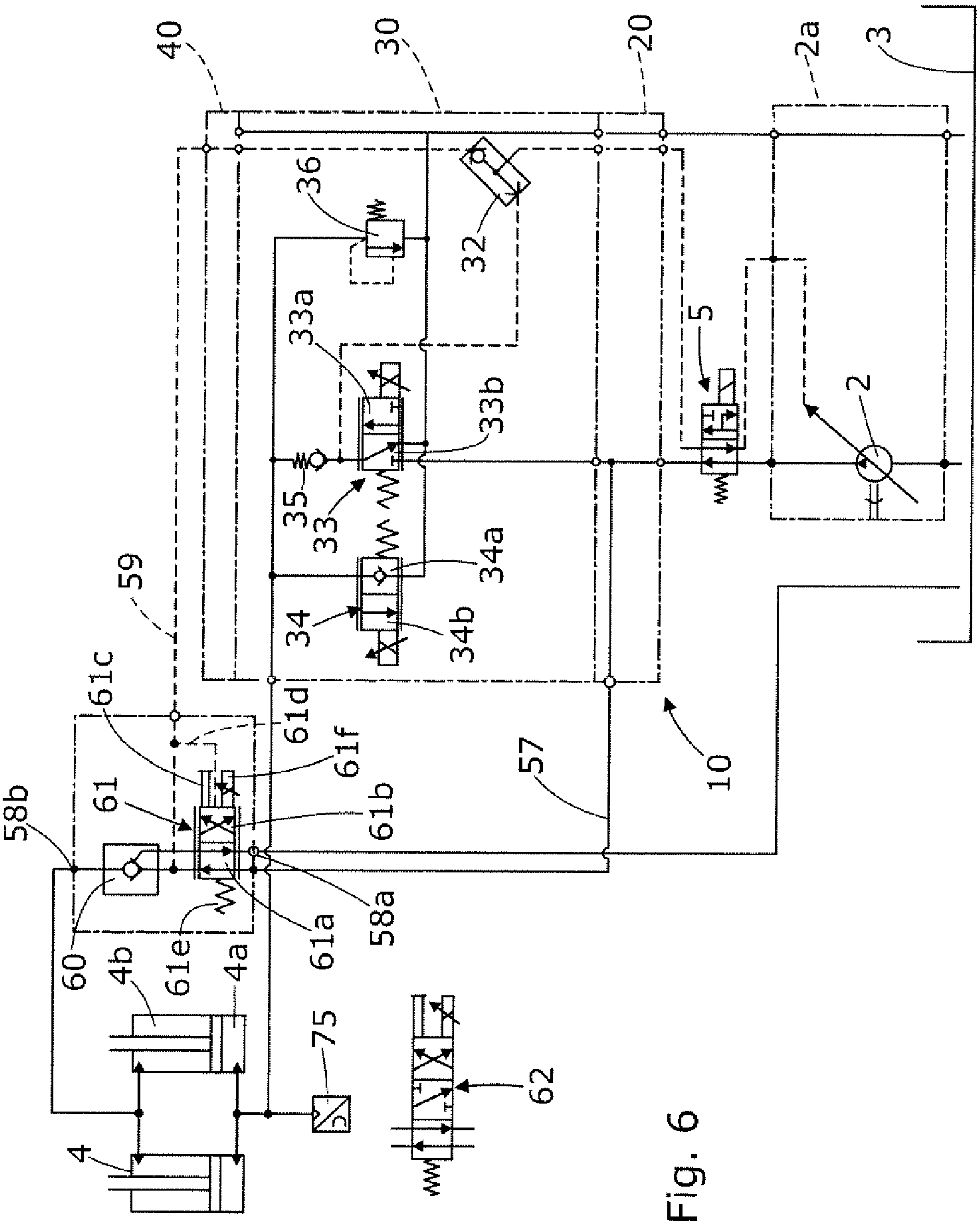


Fig. 5b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61e
61a
4a
75
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4

Fig. 6

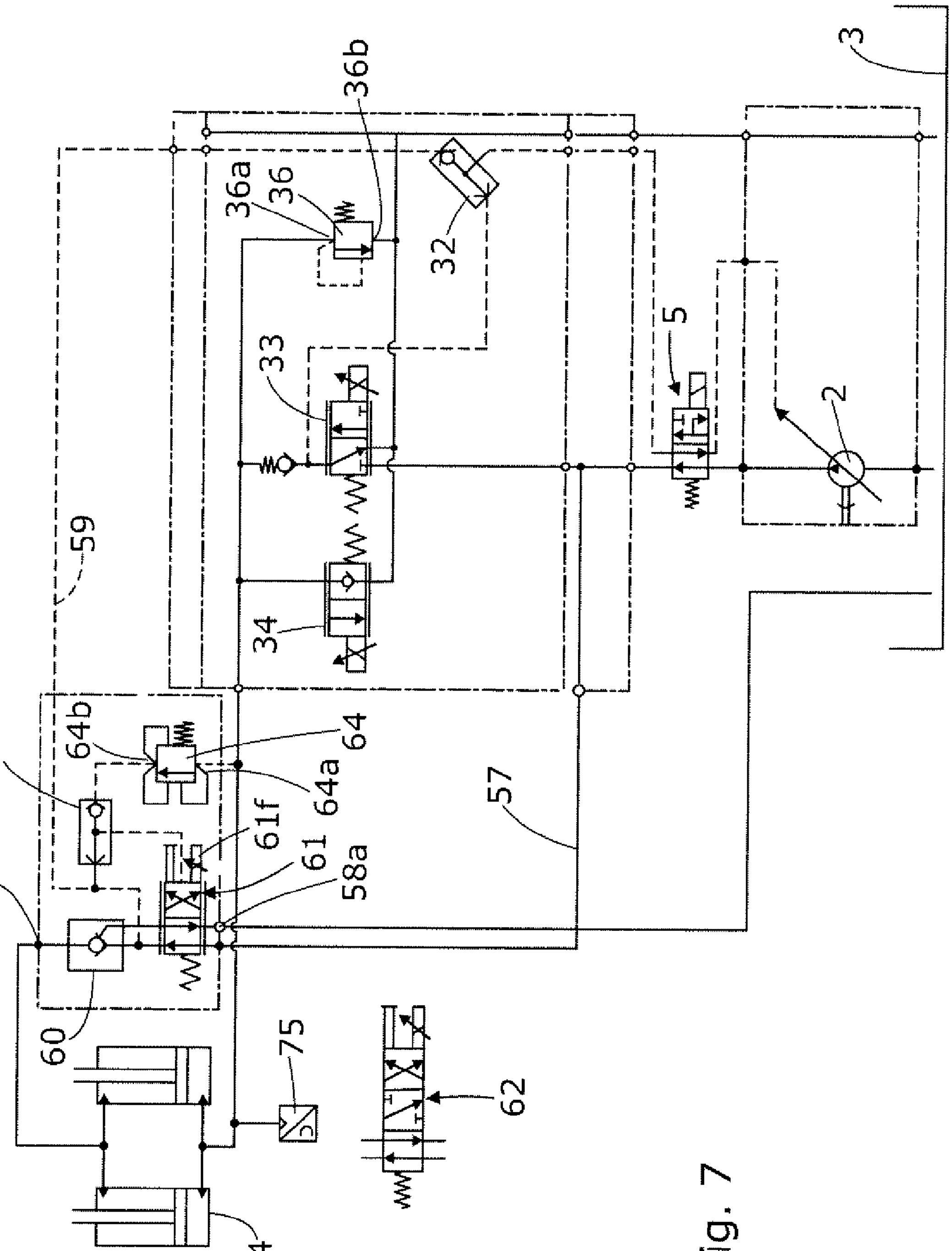

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 14 18 7181

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	5 May 2015	Toffolo, Olivier

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