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(72) Inventors:
• **TOYOTA, Toshihisa**
Kobe-shi, Hyogo 650-8670 (JP)
• **MITSUI, Hiroaki**
Kobe-shi, Hyogo 650-8670 (JP)
• **KONDO, Akihiro**
Kobe-shi, Hyogo 650-8670 (JP)
• **KUNISHIRO, Takaaki**
Kobe-shi, Hyogo 650-8670 (JP)

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(74) Representative: **Dehns**
St. Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(71) Applicant: **Kawasaki Jukogyo Kabushiki Kaisha**
Kobe-shi, Hyogo 650-8670 (JP)

(54) **HYDRAULIC SYSTEM**

(57) A closed-circuit hydraulic system includes: a pump driven by a rotating machine; a rod-side supply line that connects a first port of the pump to a rod-side chamber of a hydraulic cylinder; a head-side supply line that connects a second port of the pump to a head-side chamber of the hydraulic cylinder; a check valve provided on a first tank line that is branched off from the rod-side supply line and connects to a tank; and a head-side counter balance valve provided on a second tank line that is branched off from the head-side supply line and connects to the tank. The head-side counter balance valve is configured to allow a flow from the head-side supply line toward the tank when a head-side reference pressure is higher than a setting pressure, the head-side reference pressure being based on a pressure of the rod-side supply line and a pressure of the head-side supply line.

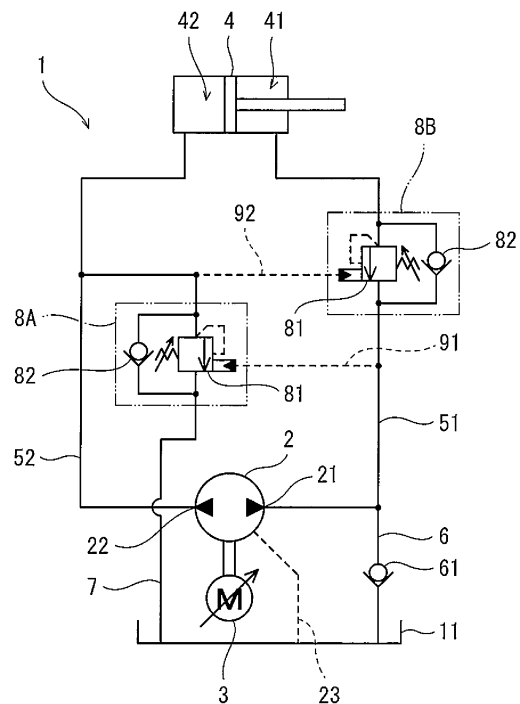


Fig. 1

Description

Technical Field

[0001] The present invention relates to a hydraulic system in which a single-rod hydraulic cylinder and a pump are connected in a manner to form a closed circuit.

Background Art

[0002] Conventionally, there is a known hydraulic system in which a single-rod hydraulic cylinder and a pump are connected in a manner to form a closed circuit. For example, Patent Literature 1 discloses a hydraulic system 100 as shown in FIGS. 4A and 4B.

[0003] In the hydraulic system 100, a single-rod hydraulic cylinder 120 and a pump 110 are connected by a rod-side supply line 131 and a head-side supply line 132 in a manner to form a closed circuit. A first tank line 141 is branched off from the rod-side supply line 131, and a second tank line 151 is branched off from the head-side supply line 132. The first tank line 141 and the second tank line 151 are provided with a pilot check valve 142 and a pilot check valve 152, respectively.

[0004] The pilot check valve 142 provided on the first tank line 141 stops exerting its reverse flow preventing function when the pressure of the head-side supply line 132 has become high, and the pilot check valve 152 provided on the second tank line 151 stops exerting its reverse flow preventing function when the pressure of the rod-side supply line 131 has become high.

[0005] Patent Literature 2 discloses a hydraulic system in which a single-rod hydraulic cylinder is disposed in such a manner that the cylinder extends downward. In the hydraulic system, a head-side supply line is provided with a counter balance valve.

Citation List

Patent Literature

[0006]

PTL 1: Japanese Laid-Open Patent Application Publication No. 2004-257448

PTL 2: Japanese Patent No. 3833291

Summary of Invention

Technical Problem

[0007] In the hydraulic system 100 disclosed by Patent Literature 1, if the load direction when the hydraulic cylinder 120 retracts is the extending direction of the cylinder 120 as shown in FIG. 4A, since the cylinder is moved in its retracting direction against the load, the pressure of the rod-side supply line 131 becomes high. Also, the pilot check valve 152 of the second tank line 151 is opened,

and a hydraulic liquid in an amount corresponding to the area difference between the head-side chamber and the rod-side chamber of the hydraulic cylinder 120 flows into a tank 160 through the second tank line 151. At the time, the speed of the hydraulic cylinder 120 is controlled by the delivery flow rate of the pump 110 (i.e., the flow rate at the rod side of the hydraulic cylinder 120).

[0008] However, if the load direction is reversed into the retracting direction as shown in FIG. 4B, the pressure of the head-side supply line 132 becomes high, and the pressure at the suction side of the pump 110 becomes high. Accordingly, the pump 110 is driven by this pressurized oil. Also, the pilot check valve 142 of the first tank line 141 is opened due to the pressure of the head-side supply line 132, and the hydraulic liquid in an amount corresponding to the area difference between the rod-side chamber and the head-side chamber of the hydraulic cylinder 120 flows into the tank 160 through the first tank line 141. At the time, the speed of the hydraulic cylinder 120 is controlled by the suction flow rate of the pump 110 (i.e., the flow rate at the head side of the hydraulic cylinder 4). That is, when the hydraulic cylinder 120 retracts, if the load direction is reversed from the extending direction to the retracting direction, or reversed from the retracting direction to the extending direction, not only a mechanical shock, but also a change in the speed of the hydraulic cylinder 120 occurs.

[0009] It should be noted that due to the orientation of the hydraulic cylinder in the hydraulic system disclosed by Patent Literature 2, Patent Literature 2 does not assume that the load is applied in the retracting direction when the hydraulic cylinder retracts.

[0010] In view of the above, an object of the present invention is to provide a hydraulic system that is capable of suppressing a change in the speed of a hydraulic cylinder even if the load direction is reversed when the hydraulic cylinder retracts.

Solution to Problem

[0011] In order to solve the above-described problems, a hydraulic system according to the present invention includes: a single-rod hydraulic cylinder including a rod-side chamber and a head-side chamber; a pump driven by a rotating machine, the pump including a first port and a second port; a rod-side supply line that connects the first port to the rod-side chamber; a head-side supply line that connects the second port to the head-side chamber in a manner to form a closed circuit together with the pump, the rod-side supply line, and the hydraulic cylinder; a first tank line that is branched off from the rod-side supply line and connects to a tank; a check valve provided on the first tank line, the check valve allowing a flow from the tank toward the rod-side supply line and preventing a reverse flow; a second tank line that is branched off from the head-side supply line and connects to the tank; and a head-side counter balance valve provided on the second tank line. A pressure of the rod-side supply line

is led to the head-side counter balance valve through an external pilot line. The head-side counter balance valve is configured to: allow a flow from the tank toward the head-side supply line; and prevent a flow from the head-side supply line toward the tank when a head-side reference pressure is lower than a setting pressure, and allow the flow from the head-side supply line toward the tank when the head-side reference pressure is higher than the setting pressure, the head-side reference pressure being based on the pressure of the rod-side supply line and a pressure of the head-side supply line. The setting pressure is set to be higher than an expected maximum pressure of the head-side chamber when the hydraulic cylinder extends.

[0012] According to the above configuration, the setting pressure of the head-side counter balance valve provided on the second tank line, which is branched off from the head-side supply line, is set to be higher than the expected maximum pressure of the head-side chamber. Therefore, when the hydraulic cylinder extends, the head-side counter balance valve does not open.

[0013] In a case where the load direction when the hydraulic cylinder retracts is the extending direction of the cylinder, since the cylinder is moved in its retracting direction against the load, the pressure of the rod-side supply line becomes high, and the head-side counter balance valve opens. As a result, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber and the rod-side chamber of the hydraulic cylinder flows into the tank through the second tank line.

[0014] On the other hand, in a case where the load direction when the hydraulic cylinder retracts is the retracting direction, the pressure of the rod-side supply line becomes high to some extent due to the function of the head-side counter balance valve, and the head-side counter balance valve opens. As a result, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber and the rod-side chamber of the hydraulic cylinder flows into the tank through the second tank line.

[0015] As thus described, according to this configuration, when the hydraulic cylinder retracts, the head-side counter balance valve opens regardless of the load direction. This makes it possible to control the speed of the hydraulic cylinder by the flow rate into the rod-side chamber of the cylinder, i.e., the delivery flow rate of the pump. Accordingly, even if the load direction is reversed when the hydraulic cylinder retracts, a change in the speed of the hydraulic cylinder can be suppressed.

[0016] The head-side reference pressure may be a sum value of a converted pressure and the pressure of the head-side supply line, the converted pressure being calculated by multiplying the pressure of the rod-side supply line by a coefficient. For example, if the coefficient used for calculating the converted pressure is set to be relatively great, the head-side counter balance valve opens even in a case where the pressure of the rod-side

supply line is relatively low. This makes it possible to reduce the generation of heat that is caused by the passing of the hydraulic liquid through the head-side counter balance valve.

[0017] The above hydraulic system may further include a rod-side counter balance valve provided on the rod-side supply line. The pressure of the head-side supply line may be led to the rod-side counter balance valve through an external pilot line. The rod-side counter balance valve may be configured to: allow a flow from the pump toward the rod-side chamber; and prevent a flow from the rod-side chamber toward the pump when a rod-side reference pressure is lower than a setting pressure, and allow the flow from the rod-side chamber toward the pump when the rod-side reference pressure is higher than the setting pressure, the rod-side reference pressure being based on the pressure of the head-side supply line and a pressure of the rod-side chamber.

[0018] According to the above configuration, in a case where the load direction when the hydraulic cylinder extends is the retracting direction, since the pressure of the head-side supply line is high, the rod-side counter balance valve opens. Meanwhile, the head-side counter balance valve is kept in a closed state due to the pressure of the head-side supply line and the setting pressure. Therefore, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber and the rod-side chamber of the hydraulic cylinder is led from the tank through the check valve of the first tank line.

[0019] On the other hand, in a case where the load direction when the hydraulic cylinder extends is the extending direction, the pressure of the rod-side chamber becomes high, and the rod-side counter balance valve opens. Unlike the head-side counter balance valve, the setting pressure of the rod-side counter balance valve can be set to be relatively low, which makes it possible to reduce the generation of heat that is caused by the passing of the hydraulic liquid through the rod-side counter balance valve. Although the pressure of the head-side supply line becomes high to some extent due to the function of the rod-side counter balance valve, the head-side counter balance valve is kept in a closed state due to the pressure of the head-side supply line and the setting pressure. Therefore, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber and the rod-side chamber of the hydraulic cylinder is led from the tank through the check valve of the first tank line.

[0020] As thus described, according to this configuration, when the hydraulic cylinder extends, the hydraulic liquid is led from the tank through the first tank line regardless of the load direction. This makes it possible to control the speed of the hydraulic cylinder by the flow rate into the head-side chamber of the cylinder, i.e., the delivery flow rate of the pump. Accordingly, even if the load direction is reversed when the hydraulic cylinder extends, a change in the speed of the hydraulic cylinder

can be suppressed.

[0021] The rod-side reference pressure may be a sum value of a converted pressure and the pressure of the rod-side chamber, the converted pressure being calculated by multiplying the pressure of the head-side supply line by a coefficient. For example, if the coefficient used for calculating the converted pressure is set to be relatively great, the rod-side counter balance valve opens even in a case where the pressure of the head-side supply line is relatively low. This makes it possible to reduce the generation of heat that is caused by the passing of the hydraulic liquid through the rod-side counter balance valve.

[0022] For example, the rotating machine may be a servomotor, and a delivery side and a suction side of the first and second ports of the pump may be switched with each other in accordance with a rotation direction of the rotating machine.

Advantageous Effects of Invention

[0023] The present invention makes it possible to suppress a change in the speed of a hydraulic cylinder even if the load direction is reversed when the hydraulic cylinder retracts.

Brief Description of Drawings

[0024]

FIG. 1 shows a schematic configuration of a hydraulic system according to one embodiment of the present invention.

FIGS. 2A and 2B each show a flow of a hydraulic liquid when a hydraulic cylinder retracts; FIG. 2A shows the flow in a case where the load direction is the extending direction of the cylinder; and FIG. 2B shows the flow in a case where the load direction is the retracting direction of the cylinder.

FIGS. 3A and 3B each show a flow of the hydraulic liquid when the hydraulic cylinder extends; FIG. 3A shows the flow in a case where the load direction is the retracting direction; and FIG. 3B shows the flow in a case where the load direction is the extending direction.

FIGS. 4A and 4B each show a schematic configuration of a conventional hydraulic system, and each show a flow of a hydraulic liquid when a hydraulic cylinder retracts.

FIGS. 5A and 5B each show a schematic configuration of the conventional hydraulic system, and each show a flow of the hydraulic liquid when the hydraulic cylinder extends.

Description of Embodiments

[0025] FIG. 1 shows a hydraulic system 1 according to one embodiment of the present invention. The hydraulic system 1 includes:

a single-rod hydraulic cylinder 4; a pump 2 connected to the hydraulic cylinder 4 in a manner to form a closed circuit; and a rotating machine 3 driving the pump 2. A hydraulic liquid flowing through the closed circuit is typically oil, but may be a liquid different from oil.

[0026] The hydraulic cylinder 4 includes a rod-side chamber 41 and a head-side chamber 42, which are partitioned from each other by a piston. A rod extends from the piston and penetrates the rod-side chamber 41.

[0027] The pump 2 includes a first port 21 and a second port 22. The first port 21 is connected to the rod-side chamber 41 of the hydraulic cylinder 4 by a rod-side supply line 51, and the second port 22 is connected to the head-side chamber 42 of the hydraulic cylinder 4 by a head-side supply line 52. With these rod-side supply line 51 and head-side supply line 52, the aforementioned closed circuit is formed between the pump 2 and the hydraulic cylinder 4.

[0028] In the present embodiment, the pump 2 is a fixed displacement pump, and the rotating machine 3 is a servomotor. The delivery side and the suction side of the first and second ports 21 and 22 of the pump 2 are switched with each other in accordance with the rotation direction of the rotating machine 3. The speed and position of the hydraulic cylinder 4 are controlled by controlling the rotation speed and rotation angle of the servomotor.

[0029] It should be noted that the pump 2 may be a variable displacement pump, such as a swash plate pump or a bent axis pump. Alternatively, the pump 2 may be an over-center pump configured such that, even though the rotation direction remains the same direction, the delivery side and the suction side of the first and second ports 21 and 22 are switchable with each other by tilting the swash plate or the tilted axis bi-directionally over a reference line (in a case where the pump 2 is a swash plate pump, the reference line is a line orthogonal to the center line of the pump 2, whereas in a case where the pump 2 is a bent axis pump, the reference line is the center line of the pump 2). In this case, the rotating machine 3 may be an engine, or may be an inverter motor.

[0030] In the present embodiment, a drain line 23 extends from the pump 2 to a tank 11. When the pump 2 is driven, a slight amount of hydraulic liquid flows from the pump 2 to the tank 11 through the drain line 23.

[0031] A first tank line 6 is branched off from the rod-side supply line 51, and a second tank line 7 is branched off from the head-side supply line 52. The first tank line 6 and the second tank line 7 connect to the tank 11.

[0032] The first tank line 6 is provided with a check valve 61. The check valve 61 allows a flow from the tank 11 toward the rod-side supply line 51, and prevents the reverse flow.

[0033] The second tank line 7 is provided with a head-side counter balance valve 8A. The head-side counter balance valve 8A moves in accordance with an internal pilot pressure and an external pilot pressure. A pressure

Prl of the rod-side supply line 51 (to be exact, the pressure of a portion of the rod-side supply line 51 between the pump 2 and a rod-side counter balance valve 8B described below) is led to the head-side counter balance valve 8A through an external pilot line 91.

[0034] The head-side counter balance valve 8A allows a flow from the tank 11 toward the head-side supply line 52. On the other hand, the head-side counter balance valve 8A prevents a flow from the head-side supply line 52 toward the tank 11 when a head-side reference pressure Ps1 is lower than a setting pressure P1, and allows the flow from the head-side supply line 52 toward the tank 11 when the head-side reference pressure Ps1 is higher than the setting pressure P1. The head-side reference pressure Ps1 is based on the pressure Prl of the rod-side supply line 51, which is the external pilot pressure, and a pressure Ph1 of the head-side supply line 52, which is the internal pilot pressure. Specifically, the head-side reference pressure Ps1 is the sum value of a converted pressure Pc1 and the pressure Ph1 of the head-side supply line 52 ($Ps1 = Pc1 + Ph1$). The converted pressure Pc1 is calculated by multiplying the pressure Prl of the rod-side supply line 51 by a coefficient C1 ($Pc1 = Prl \times C1$).

[0035] The setting pressure P1 of the head-side counter balance valve 8A is set to be higher than an expected maximum pressure of the head-side chamber 42 when the hydraulic cylinder 4 extends. The aforementioned coefficient C1 is, for example, 1.5 to 10.

[0036] To be more specific, the head-side counter balance valve 8A has a structure in which a relief valve 81 and a check valve 82, which are parallel to each other, are incorporated in a housing. The relief valve 81 includes: a spool that slides within the housing; and a spring that urges the spool in the axial direction of the spool from one side. The spool receives the pressure Ph1 of the head-side supply line 52 (i.e., internal pilot pressure) and the pressure Prl of the rod-side supply line 51 (i.e., external pilot pressure), which are applied to the spool from the other side of the axial direction of the spool. The setting pressure P1 is the setting pressure of the relief valve 81. The aforementioned coefficient C1 indicates the ratio between an area over which the spool receives the internal pilot pressure and an area over which the spool receives the external pilot pressure.

[0037] It should be noted that the head-side reference pressure Ps1 may be the sum value of the pressure Prl of the rod-side supply line 51 and a converted pressure Pd1 ($Ps1 = Prl + Pd1$). The converted pressure Pd1 is calculated by multiplying the pressure Ph1 of the head-side supply line 52 by a coefficient D1 ($Pd1 = Ph1 \times D1$). In this case, the coefficient D1 is a value less than 1.

[0038] In the present embodiment, the rod-side supply line 51 is provided with the rod-side counter balance valve 8B. The rod-side counter balance valve 8B moves in accordance with an internal pilot pressure and an external pilot pressure. The pressure Ph1 of the head-side supply line 52 is led to the rod-side counter balance valve 8B

through an external pilot line 92. In the illustrated example, the external pilot line 92 connects to a portion of the second tank line 7 between the head-side counter balance valve 8A and the head-side supply line 52. Of course, the external pilot line 92 may connect to the head-side supply line 52.

[0039] The rod-side counter balance valve 8B allows a flow from the pump 2 toward the rod-side chamber 41. On the other hand, the rod-side counter balance valve 8B prevents a flow from the rod-side chamber 41 toward the pump 2 when a rod-side reference pressure Ps2 is lower than a setting pressure P2, and allows the flow from the rod-side chamber 41 toward the pump 2 when the sum value Ps2 is higher than the setting pressure P2. The rod-side reference pressure Ps2 is based on the pressure Ph1 of the head-side supply line 52, which is the external pilot pressure, and a pressure Prc of the rod-side chamber 41, which is the internal pilot pressure. Specifically, the rod-side reference pressure Ps2 is the sum value of a converted pressure Pc2 and the pressure Prc of the rod-side chamber 41 ($Ps2 = Pc2 + Prc$). The converted pressure Pc2 is calculated by multiplying the pressure Ph1 of the head-side supply line 52 by a coefficient C2 ($Pc2 = Ph1 \times C2$). It should be noted that the specific internal structure of the rod-side counter balance valve 8B is the same as that of the head-side counter balance valve 8A.

[0040] The setting pressure P2 of the rod-side counter balance valve 8B may be set to be lower than, higher than, or equal to the aforementioned setting pressure P1 of the head-side counter balance valve 8A. The aforementioned coefficient C2 is, for example, 1.5 to 10.

[0041] It should be noted that the rod-side reference pressure Ps2 may be the sum value of the pressure Ph1 of the head-side supply line 52 and a converted pressure Pd2 ($Ps2 = Ph1 + Pd2$). The converted pressure Pd2 is calculated by multiplying the pressure Prc of the rod-side chamber 41 by a coefficient D2 ($Pd2 = Prc \times D2$). In this case, the coefficient D2 is a value less than 1.

[0042] Next, operations of the hydraulic system 1 are described for the following two cases separately: when the hydraulic cylinder 4 retracts; and when the hydraulic cylinder 4 extends.

(1) When Hydraulic Cylinder 4 Retracts

[0043] As shown in FIG. 2A, in a case where the load direction when the hydraulic cylinder 4 retracts is the extending direction of the cylinder 4, the pressure of the rod-side supply line 51 becomes high. The head-side counter balance valve 8A opens due to the external pilot pressure (the pressure Prl of the rod-side supply line 51), and the hydraulic liquid in an amount corresponding to the area difference between the rod-side chamber 41 and the head-side chamber 42 of the hydraulic cylinder 4 flows into the tank 11 through the second tank line 7. At the time, if the coefficient C1, which is used when converting the pressure Prl of the rod-side supply line 51

into the converted pressure P_{c1} , is set to be relatively great, the head-side counter balance valve 8A opens even in a case where the pressure P_{r1} of the rod-side supply line 51 is relatively low. This makes it possible to reduce the generation of heat that is caused by the passing of the hydraulic liquid through the head-side counter balance valve 8A.

[0044] It should be noted that if the flow rate into the tank 11 is Q_0 , then $Q_0 = Q_h - Q_r - \alpha$.

[0045] On the other hand, as shown in FIG. 2B, in a case where the load direction when the hydraulic cylinder 4 retracts is the retracting direction of the cylinder 4, the pressure of the rod-side supply line 51 becomes high to some extent due to the function of the head-side counter balance valve 8A, and the head-side counter balance valve 8A opens due to the internal pilot pressure (the pressure P_{h1} of the head-side supply line 52) and the external pilot pressure (the pressure P_{r1} of the rod-side supply line 51). As a result, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber 42 and the rod-side chamber 41 of the hydraulic cylinder 4 flows into the tank 11 through the second tank line 7.

[0046] As described above, in the present embodiment, when the hydraulic cylinder 4 retracts, the head-side counter balance valve 8A opens regardless of the load direction. This makes it possible to control the speed of the hydraulic cylinder 4 by the delivery flow rate of the pump 2 (the flow rate at the rod side of the hydraulic cylinder 4). Accordingly, even if the load direction is reversed when the hydraulic cylinder 4 retracts, a change in the speed of the hydraulic cylinder 4 can be suppressed.

(2) When Hydraulic Cylinder 4 Extends

[0047] First, for the sake of comparison, operations of the conventional hydraulic system 100 are described with reference to FIGS. 5A and 5B.

[0048] In the conventional hydraulic system 100, in a case where the load direction when the hydraulic cylinder 120 extends is the retracting direction as shown in FIG. 5A, since the pressure of the head-side supply line 132 is high, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber 42 and the rod-side chamber 41 of the hydraulic cylinder 120 is led from the tank 160 through the pilot check valve 142 of the first tank line 141. At the time, the speed of the hydraulic cylinder 120 is controlled by the delivery flow rate of the pump 110 (the flow rate at the head side of the hydraulic cylinder 4).

[0049] However, as shown in FIG. 5B, if the load direction is reversed into the extending direction, the pressure of the rod-side supply line 131 becomes high, and the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber 42 and the rod-side chamber 41 of the hydraulic cylinder 120 is led from the tank 160 through the pilot check valve 152

of the second tank line 151. At the time, the speed of the hydraulic cylinder 120 is controlled by the suction flow rate of the pump 110 (the flow rate at the rod side of the hydraulic cylinder 4). That is, when the hydraulic cylinder 120 extends, if the load direction is reversed from the extending direction to the retracting direction, or reversed from the retracting direction to the extending direction, not only a mechanical shock, but also a change in the speed of the hydraulic cylinder 120 occurs.

[0050] In this respect, in the hydraulic system 1 of the present embodiment, when the hydraulic cylinder 4 extends, even if the load direction is reversed, a change in the speed of the hydraulic cylinder 4 can be suppressed for the reasons described below.

[0051] It should be noted that the setting pressure P_1 of the head-side counter balance valve 8A provided on the second tank line 7, which is branched off from the head-side supply line 52, is set to be higher than the expected maximum pressure of the head-side chamber 42. Therefore, when the hydraulic cylinder 4 extends, the head-side counter balance valve 8A does not open.

[0052] As shown in FIG. 3A, in a case where the load direction when the hydraulic cylinder 4 extends is the retracting direction, since the pressure of the head-side supply line 52 is high, the rod-side counter balance valve 8B opens due to the external pilot pressure (the pressure P_{h1} of the head-side supply line 52). At the time, if the coefficient C_2 , which is used when converting the pressure P_{h1} of the head-side supply line 52 into the converted pressure P_{c2} , is set to be relatively great, the rod-side counter balance valve 8B opens even in a case where the pressure P_{h1} of the head-side supply line 52 is relatively low. This makes it possible to reduce the generation of heat that is caused by the passing of the hydraulic liquid through the rod-side counter balance valve 8B. Meanwhile, the head-side counter balance valve 8A is kept in a closed state due to the pressure P_{h1} of the head-side supply line 52 and the setting pressure P_1 . Therefore, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber 42 and the rod-side chamber 41 of the hydraulic cylinder 4 is led from the tank 11 through the check valve 61 of the first tank line 6.

[0053] It should be noted that if the flow rate led from the tank 11 is Q_i , the flow rate into the head-side chamber 42 is Q_h , the flow rate out of the rod-side chamber 41 is Q_r , and the drain amount from the pump 2 is α , then $Q_i = Q_h + \alpha - Q_r$.

[0054] On the other hand, as shown in FIG. 3B, in a case where the load direction when the hydraulic cylinder 4 extends is the extending direction, the pressure of the rod-side chamber 41 becomes high, and the rod-side counter balance valve 8B opens due to the internal pilot pressure (the pressure P_{rc} of the rod-side chamber 41). Unlike the head-side counter balance valve 8A, the setting pressure P_2 of the rod-side counter balance valve 8B can be set to be relatively low, which makes it possible to reduce the generation of heat that is caused by the

passing of the hydraulic liquid through the rod-side counter balance valve 8B. Although the pressure of the head-side supply line 52 becomes high to some extent due to the function of the rod-side counter balance valve 8B, the head-side counter balance valve 8A is kept in a closed state due to the pressure Ph1 of the head-side supply line 52 and the setting pressure P1. Therefore, the hydraulic liquid in an amount corresponding to the area difference between the head-side chamber 42 and the rod-side chamber 41 of the hydraulic cylinder 4 is led from the tank 11 through the check valve 61 of the first tank line 6.

[0055] As described above, in the present embodiment, when the hydraulic cylinder 4 extends, the hydraulic liquid is led from the tank 11 through the first tank line 6 regardless of the load direction. This makes it possible to control the speed of the hydraulic cylinder 4 by the delivery flow rate of the pump 2 (the flow rate at the head side of the hydraulic cylinder 4). Accordingly, even if the load direction is reversed when the hydraulic cylinder 4 extends, a change in the speed of the hydraulic cylinder 4 can be suppressed.

(Variations)

[0056] The present invention is not limited to the above-described embodiment. Various modifications can be made without departing from the scope of the present invention.

[0057] For example, depending on the usage, the rod-side supply line 51 need not be provided with the rod-side counter balance valve 8B.

Reference Signs List

[0058]

1	hydraulic system
11	tank
2	pump
21	first port
22	second port
3	rotating machine
4	hydraulic cylinder
41	rod-side chamber
42	head-side chamber
51	head-side supply line
52	rod-side supply line
6	first tank line
61	check valve
7	second tank line
8A	head-side counter balance valve
8B	rod-side counter balance valve
91, 92	external pilot line

Claims

1. A hydraulic system comprising:

a single-rod hydraulic cylinder including a rod-side chamber and a head-side chamber;
a pump driven by a rotating machine, the pump including a first port and a second port;
a rod-side supply line that connects the first port to the rod-side chamber;
a head-side supply line that connects the second port to the head-side chamber in a manner to form a closed circuit together with the pump, the rod-side supply line, and the hydraulic cylinder;
a first tank line that is branched off from the rod-side supply line and connects to a tank;
a check valve provided on the first tank line, the check valve allowing a flow from the tank toward the rod-side supply line and preventing a reverse flow;
a second tank line that is branched off from the head-side supply line and connects to the tank; and
a head-side counter balance valve provided on the second tank line, wherein
a pressure of the rod-side supply line is led to the head-side counter balance valve through an external pilot line,
the head-side counter balance valve is configured to:

allow a flow from the tank toward the head-side supply line; and
prevent a flow from the head-side supply line toward the tank when a head-side reference pressure is lower than a setting pressure, and allow the flow from the head-side supply line toward the tank when the head-side reference pressure is higher than the setting pressure, the head-side reference pressure being based on the pressure of the rod-side supply line and a pressure of the head-side supply line, and

the setting pressure is set to be higher than an expected maximum pressure of the head-side chamber when the hydraulic cylinder extends.

2. The hydraulic system according to claim 1, wherein the head-side reference pressure is a sum value of a converted pressure and the pressure of the head-side supply line, the converted pressure being calculated by multiplying the pressure of the rod-side supply line by a coefficient.

3. The hydraulic system according to claim 1 or 2, further comprising a rod-side counter balance valve provided on the rod-side supply line, wherein

the pressure of the head-side supply line is led to the rod-side counter balance valve through an external pilot line, and the rod-side counter balance valve is configured to:

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allow a flow from the pump toward the rod-side chamber; and

prevent a flow from the rod-side chamber toward the pump when a rod-side reference pressure is lower than a setting pressure, and allow the flow from the rod-side chamber toward the pump when the rod-side reference pressure is higher than the setting pressure, the rod-side reference pressure being based on the pressure of the head-side supply line and a pressure of the rod-side chamber.

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4. The hydraulic system according to claim 3, wherein the rod-side reference pressure is a sum value of a converted pressure and the pressure of the rod-side chamber, the converted pressure being calculated by multiplying the pressure of the head-side supply line by a coefficient. 20
5. The hydraulic system according to any one of claims 1 to 4, wherein the rotating machine is a servomotor, and a delivery side and a suction side of the first and second ports of the pump are switched with each other in accordance with a rotation direction of the rotating machine. 25 30

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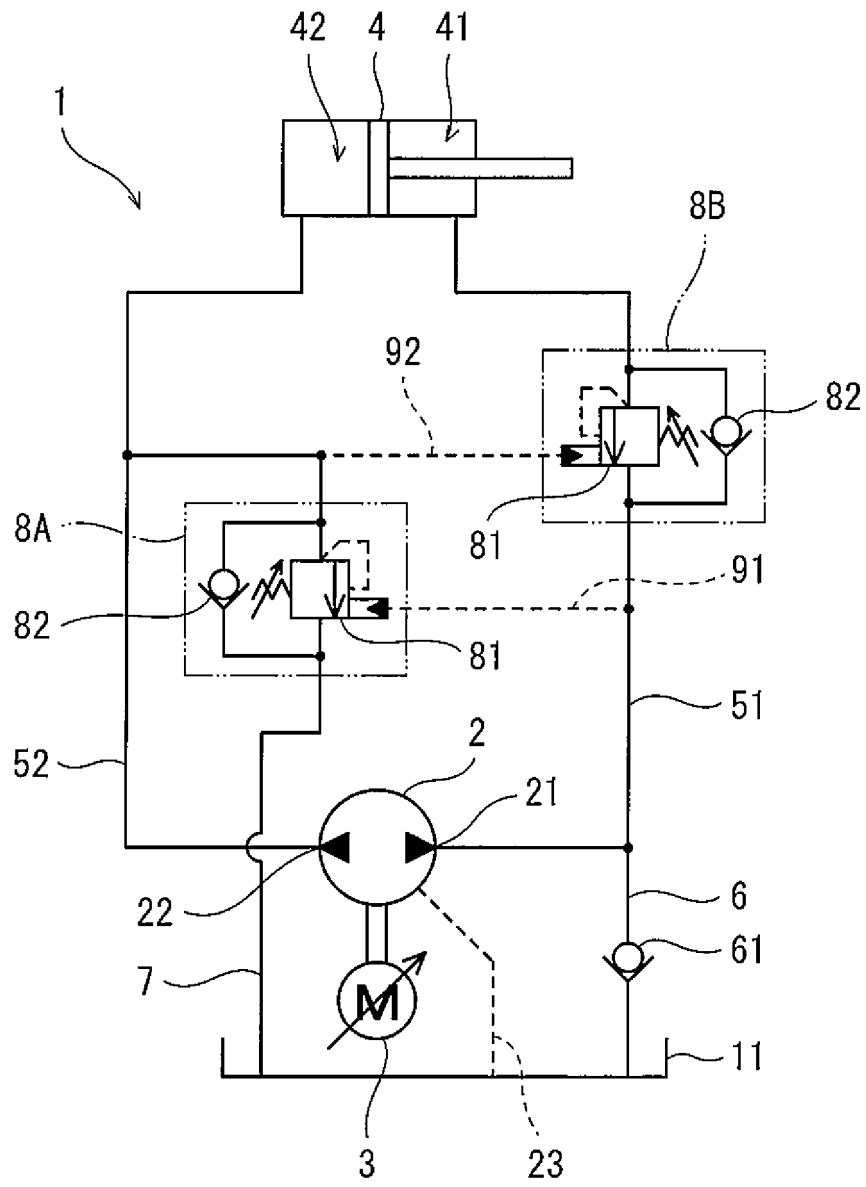


Fig. 1

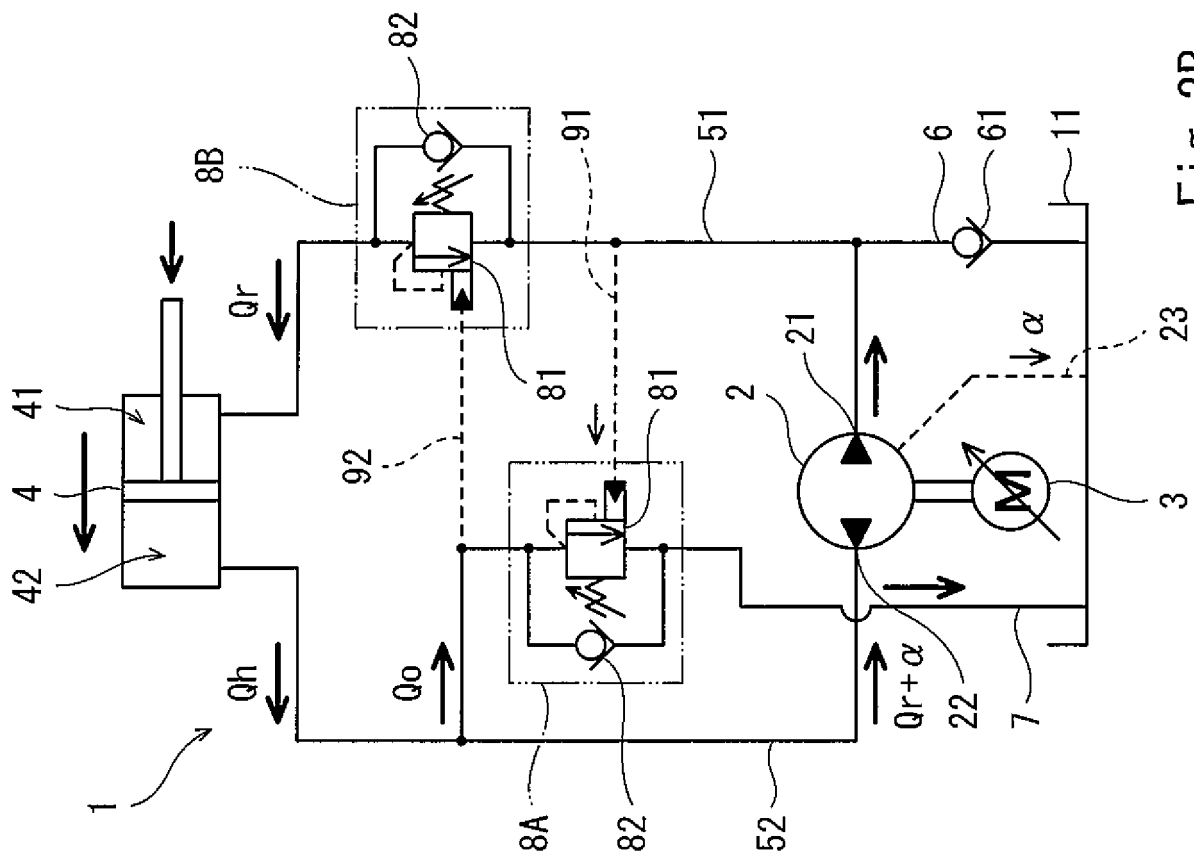


Fig. 2B

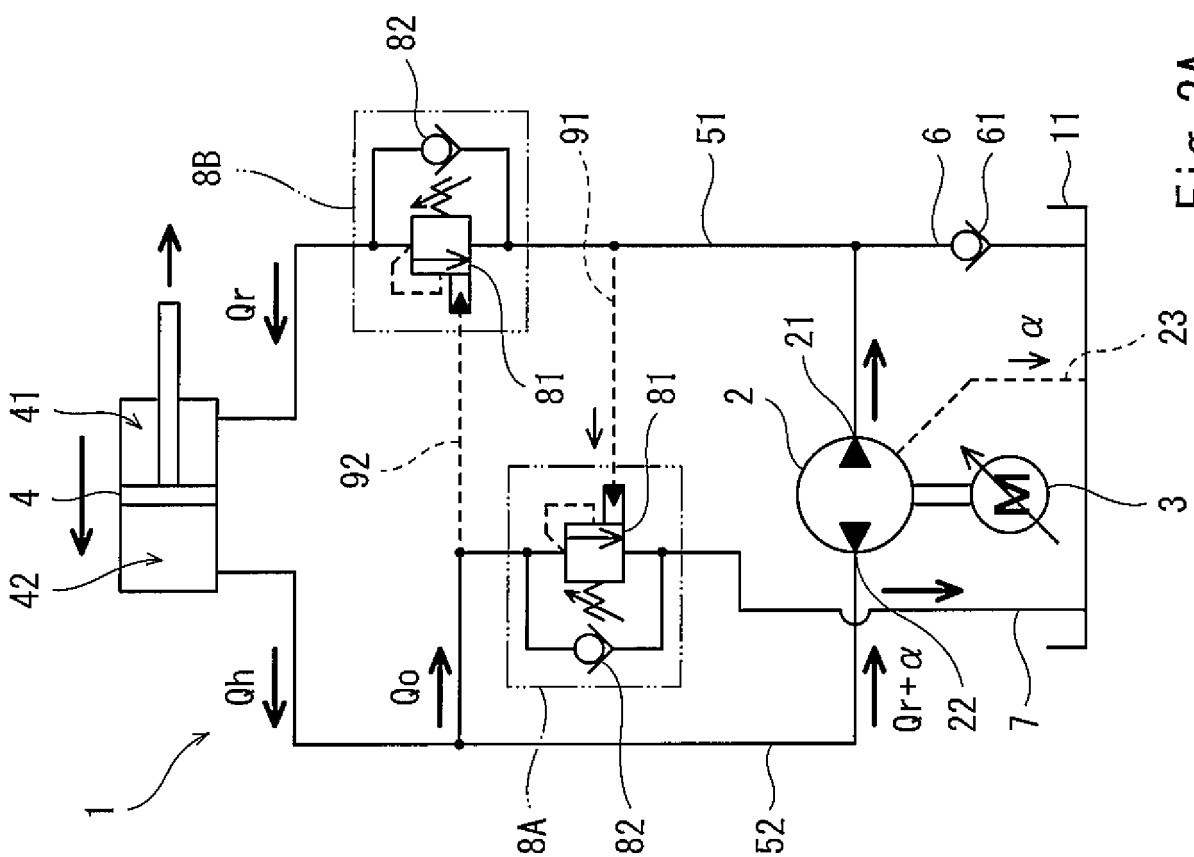


Fig. 2A

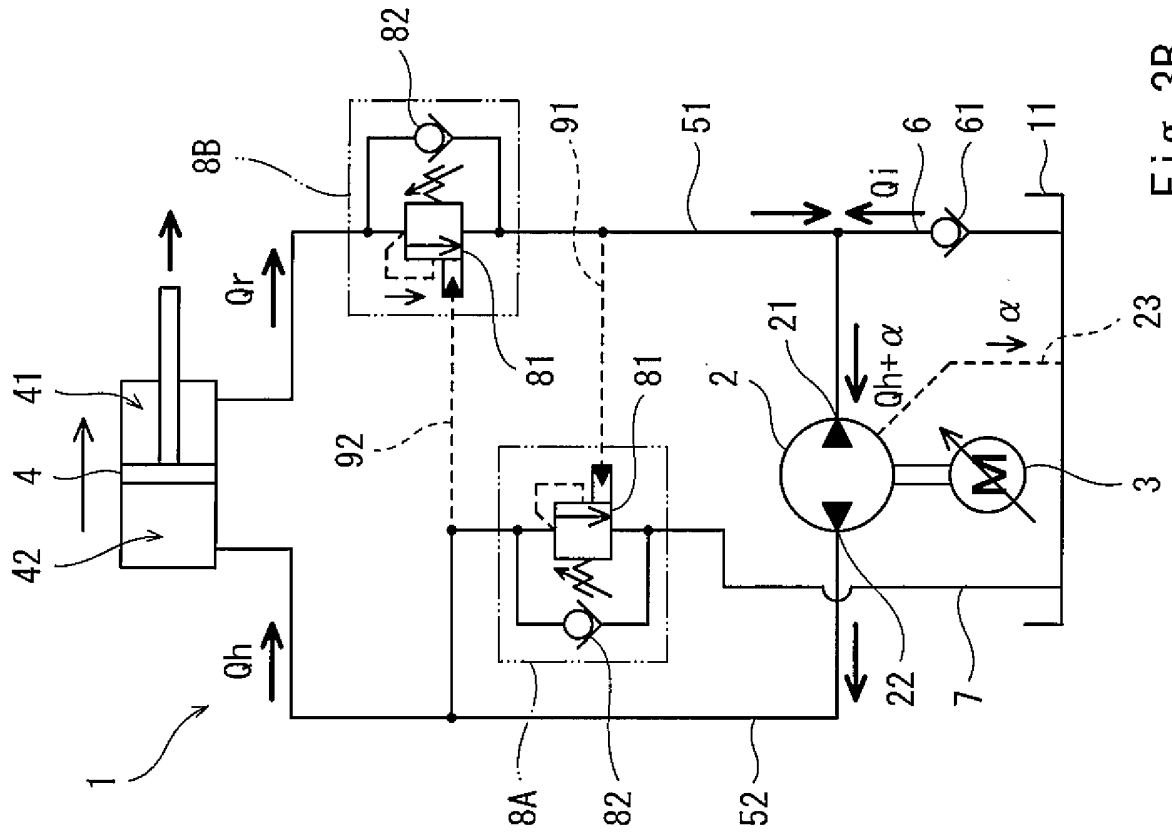


Fig. 3B

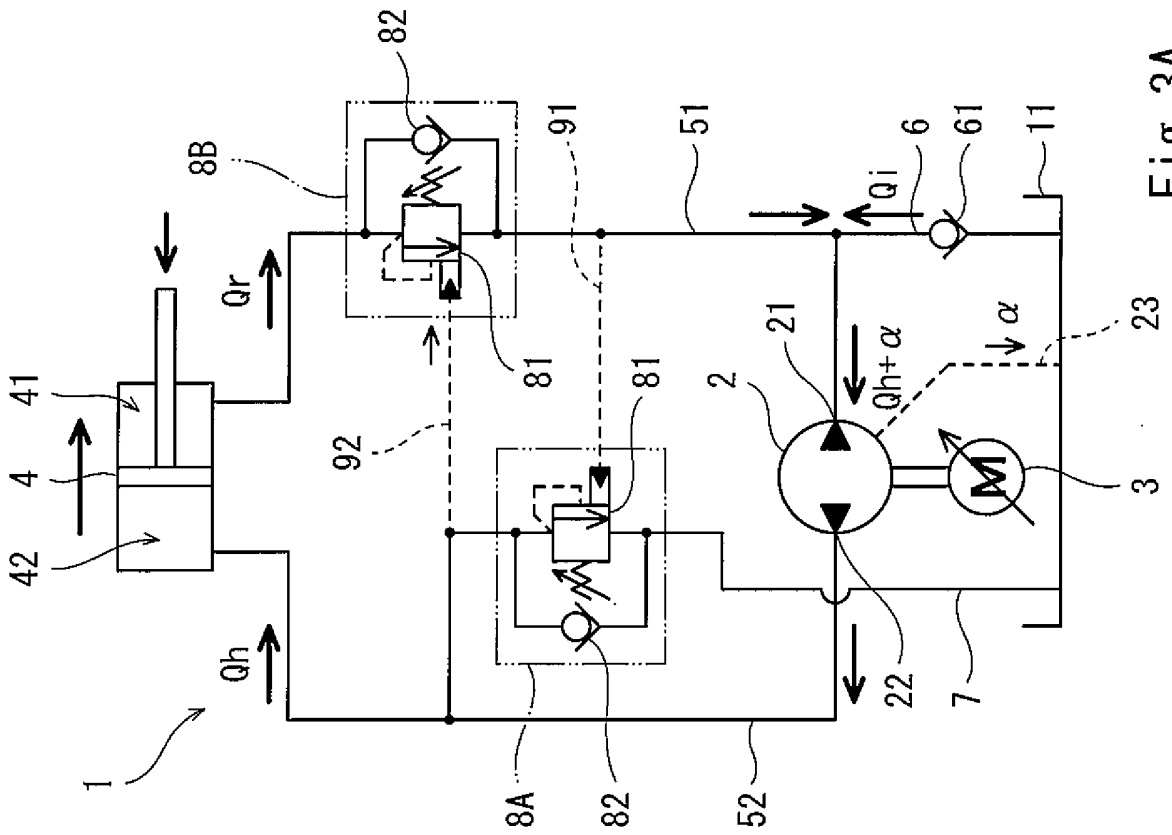
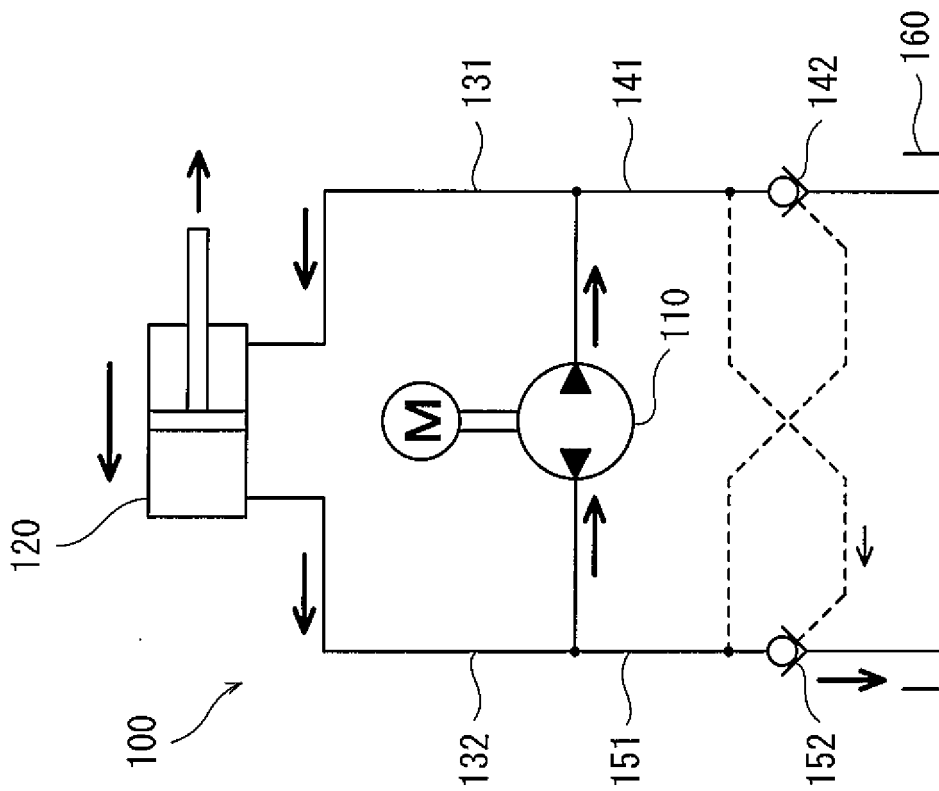
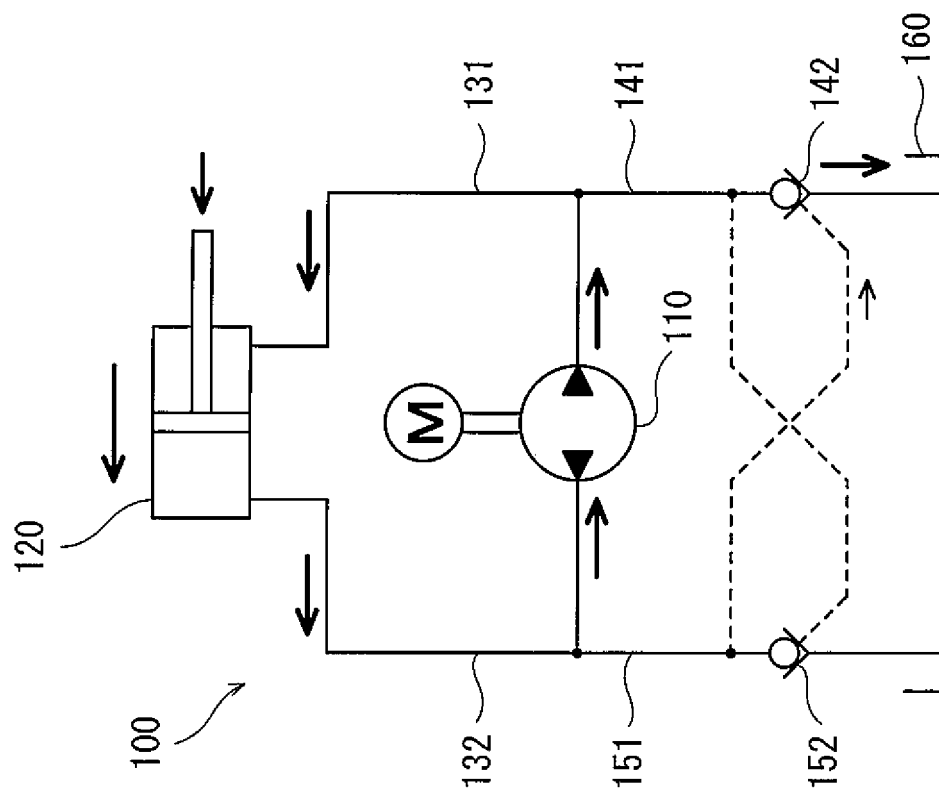


Fig. 3A



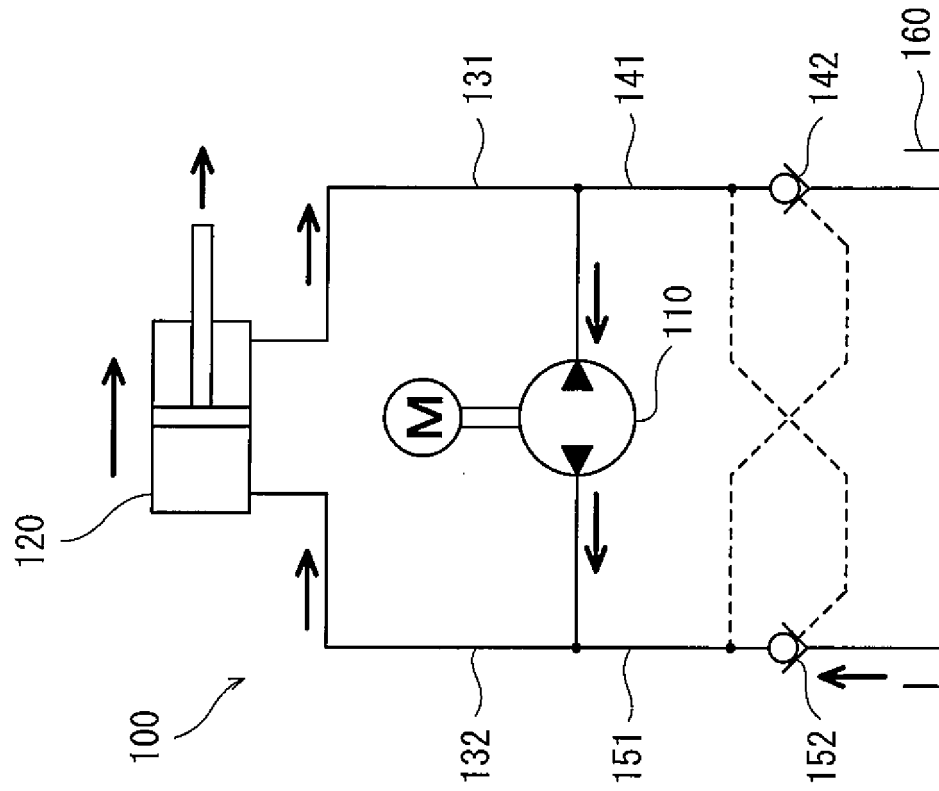


Fig. 5B

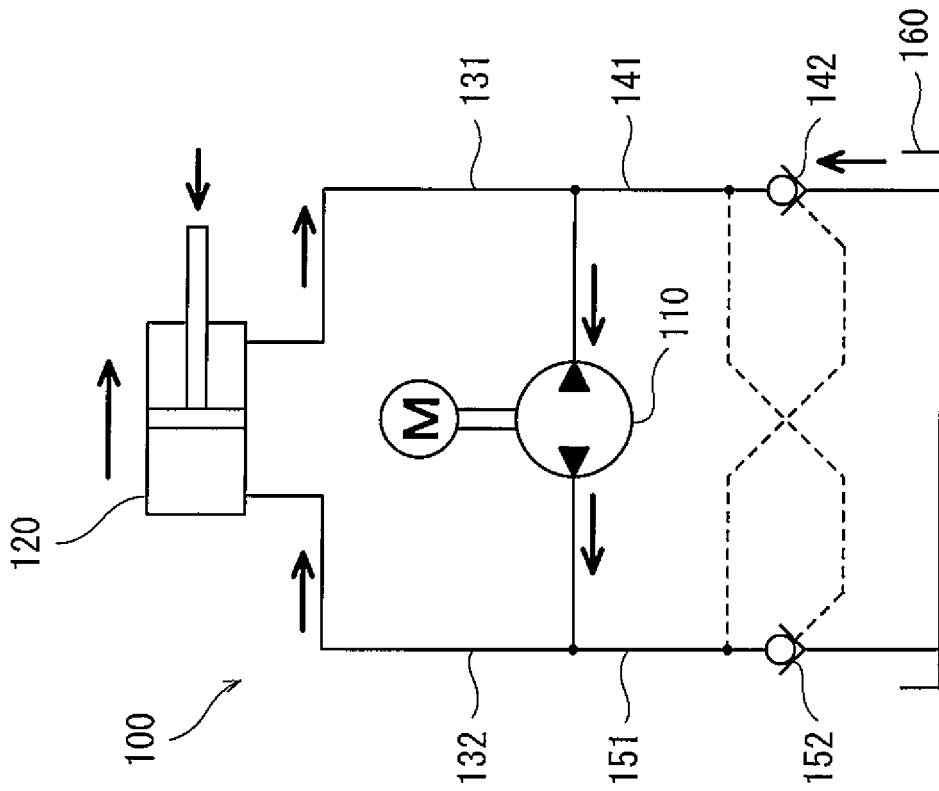


Fig. 5A

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/035100

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F15B11/00 (2006.01) i, F15B11/08 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. F15B11/00-11/22; 21/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 10-166199 A (DAIICHI DENKI CORPORATION) 23 June 1998, paragraphs [0007], [0021]-[0038], fig. 7 (Family: none)	1-2, 5 3-4

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
27 November 2018 (27.11.2018)Date of mailing of the international search report
11 December 2018 (11.12.2018)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004257448 A [0006]
- JP 3833291 B [0006]