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(54) Pump device

(57) A fixed capacity pump (P) sucks working oil from a reservoir (R) through a conduit (Rp) and a suction passage (1), and discharges the pressurized working oil into a discharge passage (2) connected to an actuator (A). A choke (21) is disposed in the discharge passage (2), and a flow control valve (F) recirculates a part of the working oil in the discharge passage (2) upstream of the choke

(21) to the suction passage (1) according to a pressure loss generated by the choke (21). The characteristic of the choke (21) which significantly increases the flow resistance in a low temperature state makes the flow rate of the recirculated working oil increase, thereby preventing cavitation/noise from occurring in the pump (P) when operated at high speed and in a low temperature state.

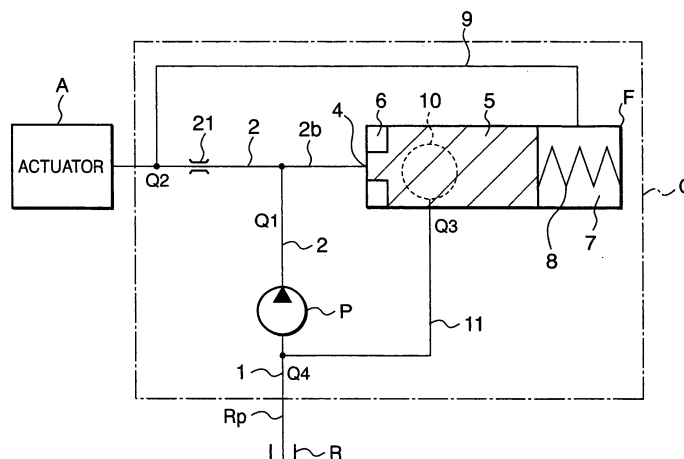


FIG. 1

Description

FIELD OF THE INVENTION

[0001] This invention relates to flow control of a fixed capacity pump used for example in the power steering of a vehicle.

BACKGROUND OF THE INVENTION

[0002] JPH09-170569A published by the Japan Patent Office in 1997 discloses a flow control valve for a fixed capacity pump that can be used in the power steering of a vehicle.

[0003] The flow control valve supplies working oil discharged from the fixed capacity pump to an actuator via a variable orifice. The flow control valve is provided with a spool that displaces in response to a pressure loss in the orifice and, according to its displaced position, causes a part of the discharged working oil to flow into a recirculation passage. Working oil that is sucked by the pump is supplied from a reservoir via a suction passage. The recirculation passage recirculates working oil into the suction passage.

SUMMARY OF THE INVENTION

[0004] The orifice has a feature whereby the flow characteristic is constant irrespective of the temperature of the working oil that passes therethrough. For example, when the viscosity of the working oil is high due to low temperature, the pressure loss in the working oil passing through the orifice does not become very large with respect to the flow rate. On the other hand, when the viscosity of the working oil increases, frictional resistance in the suction passage inevitably increases, and the suction resistance of the pump increases.

[0005] The working oil recirculated from the recirculation passage is under a pushing force originating in the discharge pressure of the pump, and therefore the suction resistance of the pump when it sucks the recirculated working oil is small. On the other hand, when the pump sucks working oil from the reservoir via the suction passage, it suffers a large suction resistance. The entire suction resistance of the pump therefore depends on the ratio of the flow rate of the recirculated working oil to the flow rate of the working oil supplied from the reservoir.

[0006] When the pump rotation speed rises in a low temperature state and flow control is performed depending on the pressure loss in the orifice, flow rate increase in the recirculation passage is small with respect to the increase in the discharge flow rate of the pump. As a result, the flow rate of working oil supplied from the reservoir to the pump increases. In this state, the frictional resistance in the suction passage is high due to the high viscosity of the working oil, and hence the suction resistance of the suction passage is large.

[0007] Thus, in a low temperature state, it is possible

that the working oil supply flow rate of the suction passage becomes insufficient with respect to the flow rate of the working oil that the pump requires according to its rotation speed. When the pump suffers a shortage of working oil for suction, a negative pressure is generated in the pump, which results in cavitation or noise generation. Such an inconvenience is apt to occur when the rotation speed of the fixed capacity pump increases after being started in a low temperature state.

[0008] It is therefore an object of this invention to prevent an insufficient working oil supply in a low temperature state for a fixed capacity pump that is combined with a recirculation circuit.

[0009] In order to achieve the above object, this invention provides a pump device for supplying working oil to an actuator, comprising a fixed capacity pump, a choke through which working oil discharged by the pump flows, and a flow control valve which recirculates a part of the working oil discharged by the pump to a suction side of the pump, according to a pressure loss generated by the choke.

[0010] The details as well as other features and advantages of this invention are set forth in the remainder of the specification and are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a hydraulic circuit diagram of a pump device according to this invention.

[0012] FIG. 2 is a longitudinal sectional view of a vane pump as a component of the pump device.

[0013] FIG. 3 is a longitudinal sectional view of a flow control valve according to this invention.

[0014] FIG. 4 is a diagram showing a result of an experiment performed by the inventors to test the effect of the working oil temperature on the flow characteristics of an orifice and a choke.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Referring to FIG. 1 of the drawings, a pump device according to this invention comprises a fixed capacity pump P and a flow control valve F enclosed in a casing C shown by a single dotted line.

[0016] The fixed capacity pump P is connected to a motive power source such as an internal combustion engine and, when driven by the motive power source, sucks work oil through a suction passage 1 formed in the casing C. The suction passage 1 is connected, via an external conduit Rp, to a reservoir R disposed outside the casing C. The fixed capacity pump P discharges pressurized work oil to a discharge passage 2 that is also formed in the casing C.

[0017] The discharge passage 2 is connected to an actuator A located outside the casing C. A choke 21 is disposed in the discharge passage 2. A branch passage 2b branches off from the discharge passage 2 at a posi-

tion upstream of the choke 21. The branch passage 2b is connected to an inlet port 4 of the flow control valve F. In other words, the discharge passage 2 downstream of the choke 21 communicates with the actuator A and the discharge passage 2 upstream of the choke 21 communicates with the inlet port 4 of the flow control valve F via the branch passage 2b.

[0018] The flow control valve F comprises a spool 5, a control pressure chamber 6 and a spring chamber 7. The control pressure chamber 6 and the spring chamber 7 are separated by the spool 5. The control pressure chamber 6 communicates with the branch passage 2b via the inlet port 4. The spring chamber 7 communicates with the discharge passage 2 downstream of the choke 21 via a pilot passage 9. A spring 8 is enclosed in the spring chamber 7.

[0019] The flow control valve F comprises a recirculation port 10. The recirculation port 10 communicates with the control pressure chamber 6 according to displacement of the spool 5 toward the right hand side of the figure. The recirculation port 10 communicates with the suction passage 1 via a recirculation passage 11 formed within the casing C.

[0020] When the recirculation port 10 communicates with the control pressure chamber 6 as a result of the displacement of the spool 5, the working oil that has flown into the control pressure chamber 6 from the inlet port 4 recirculates to the suction passage 1 via the recirculation port 10 and recirculation passage 11, and is sucked again by the fixed capacity pump P. It can be said that the oil that has flown into the recirculation port 10 recirculates in the casing C.

[0021] When the fixed capacity pump P operates, working oil in the reservoir R is sucked into the pump P via the conduit Rp located outside the casing C and the suction passage 1 formed within the casing C. The fixed capacity pump P pressurizes the sucked working oil and discharges it into the discharge passage 2. The working oil discharged into the discharge passage 2 is supplied to the actuator A via the choke 21.

[0022] When working oil flows through the choke 21, it incurs a pressure loss and a difference in pressure upstream and downstream of the choke 21 arises. The pressure in the discharge passage 2 upstream of the choke 21 is led to the control pressure chamber 6 of the flow control valve F via the branch passage 2b and the inlet port 4, and the pressure in the discharge passage 2 downstream of the choke 21 is led to the spring chamber 7 of the flow control valve F via the pilot passage 9.

[0023] The working oil pressure in the control pressure chamber 6 acts on the spool 5 as a thrust force from the left hand side of the figure. The working oil pressure in the spring chamber 7 and the pressure of the spring 8 act on the spool 5 as a thrust force from the right hand side of the figure. Accordingly, the spool 5 displaces to a position where these two forces balance. The opening of the recirculation port 10 depends on the balanced position of the spool 5.

[0024] When the opening of the recirculation port 10 varies, the flow rate of working oil that recirculates from the recirculation port 10 to the suction passage 1 via the recirculation passage 11 also varies. This variation results in a change in the ratio of the flow rate of the working oil that flows into the actuator A to the flow rate of the working oil that is recirculated to the suction passage 1.

[0025] When the pressure upstream of the choke 21 greatly rises with respect to the pressure downstream of the choke 21 and the thrust force generated by the control pressure chamber 6 becomes larger than that generated by the spring chamber 7, the spool 5 displaces towards an opening increase direction of the recirculation port 10, i.e., towards the right hand side in the figure. Conversely, when the pressure upstream of the choke 21 approaches the pressure downstream of the choke 21 and the thrust force generated by the spring chamber 7 becomes larger than that generated by the control pressure chamber 6, the spool 5 displaces towards an opening decrease direction of the recirculation port 10, i.e., towards the left hand side in the figure. In the recirculation passage 11, as the opening of the recirculation port 10 increases, the recirculation flow rate increases, and as the opening of the recirculation port 10 decreases, the recirculation flow rate decreases.

[0026] Providing that the discharge flow rate of the fixed capacity pump P is $Q1$, the flowrate of the working oil supplied to the actuator A is $Q2$, the flow rate of the working oil that is recirculated to the suction passage 1 from the recirculation port 10 via the recirculation passage 11 is $Q3$, and the flow rate of the working oil supplied to the fixed capacity pump P from the reservoir R is $Q4$, the following relations (1) and (2) hold.

[0027]

$$Q1 = Q3 + Q4$$

$$Q2 = Q1 - Q3$$

[0028] The flow rate $Q4$ of the oil that is sucked by the pump P from the reservoir R outside the casing C is represented by the following relation (3).

[0029]

$$Q4 = Q1 - Q3$$

[0030] From the relations (2) and (3), it is apparent that when the flow rate $Q2$ of the oil supplied to the actuator A decreases, the flow rate $Q4$ of the oil supplied from the reservoir R also decreases.

[0031] Next, referring to FIG. 2 and FIG. 3, the actual construction of the pump device will be described.

[0032] The casing C comprises a body 12 and a cover 14 that closes a bore 13 formed in the body 12.

[0033] In the bore 13, a side plate 15 and a cam ring 16 are enclosed in this order from the bottom. The cam ring 16 accommodates a rotor 17 which is fixed to a rotation shaft 20. The rotor 17 comprises plural vane grooves 18 formed in radial directions at equal angular intervals. In each vane groove 18, a vane 19 is accommodated so as to be free to protrude radially therefrom.

[0034] When the rotor 17 undergoes rotation, vanes 19 protrude from the vane grooves 18 as a result of centrifugal force and their protruding tips contact the inner circumference of the cam ring 16. By means of the contact between the protruding tips of the vanes 19 and the inner circumference of the cam ring 16, oil chambers are formed between adjacent vanes 19.

[0035] The rotation shaft 20 penetrates through the body 12 and connects to the motive power source such as an internal combustion engine outside the casing C.

[0036] As the rotor 17 rotates in the cam ring 16, the vanes that are in contact with the inner circumference of the cam ring 16 move forward and backward, and accordingly the oil chambers formed by the vanes and the inner circumference of the cam ring 16 expand and shrink. The expansion and shrinkage of oil chambers take place simultaneously. More precisely, some oil chambers expand while others shrink.

[0037] The suction passage 1 is formed in the cover 14. The suction passage 1 communicates with the expanding oil chambers and the discharge passage 2 communicates with the shrinking oil chambers through one or both of two side faces of the cam ring 16.

[0038] Each of the oil chambers sucks working oil from the suction passage 1 when it expands, or in other words, when it is in a suction stroke. When the suction passage 1 shrinks, or in other words when it is in a discharge stroke, it pressurizes the sucked working oil and discharges it to the discharge passage 2.

[0039] Referring back to FIG. 1, the branch passage 2b branches off from the discharge passage 2 as the discharge passage 2 extends toward the choke 21. The branch passage 2b communicates with the control pressure chamber 6 via the inlet port 4. However, this configuration in the circuit diagram has been drawn for the purpose of explanation. The real construction is somewhat different as shown in FIG. 3. Specifically, the branch passage 2b shown in FIG. 1 is imaginary and in reality the discharge passage 2 directly communicates with the control pressure chamber 6 as shown in FIG. 3. The working oil in the control pressure chamber 6 is separated into two oil streams by the spool 5, i.e., a stream to the actuator A via the choke 21, and a stream to the suction passage 1 via the recirculation port 10. The branch passage 2b and the inlet port 4 are therefore not shown in FIG. 2 and FIG. 3.

[0040] Next, the differences between this invention and the aforesaid prior art will be explained.

[0041] This invention provides the choke 21 instead of

an orifice in the discharge passage 2. Pressure loss caused by an orifice is not affected by the temperature of the working oil, or the viscosity thereof.

[0042] FIG. 4 shows an experimental result obtained by the inventors with respect to the effect of the temperature of working oil on the flow characteristics of an orifice and a choke. In the experiment, the orifice and choke have a same diameter D and the flow path length L of the choke is set at 1.33 times of the diameter D.

[0043] As can be understood from this diagram, in the case of the orifice, the relation between the oil temperature and the flow rate is almost linear as shown by the broken line in the diagram. In other words, the flow rate of the orifice is hardly affected by the oil temperature and the differential pressure upstream and downstream of the orifice does not increase significantly in a low temperature state.

[0044] In contrast, in the case of the choke, the flow rate significantly decreases in a low temperature state as shown by the solid line in the diagram. In other words, the flow rate of the choke is highly affected by the temperature or the viscosity of the working oil and the differential pressure between the upstream and downstream sides of the choke significantly increases in a low temperature state at an identical flow rate. In the descriptions below, a differential pressure between the upstream and downstream sides of an orifice is explained as a differential pressure of an orifice, and a differential pressure between the upstream and downstream sides of a choke is explained as a differential pressure of a choke.

[0045] Due to the above difference in the flow rate characteristics, in the hydraulic circuit shown in FIG. 1, if an orifice were used instead of the choke 21, the balanced position of the spool 5 in a low temperature state would move towards the left hand side with respect to the case where the choke 21 is used, and therefore a smaller flow rate of working oil that flows into the recirculation passage 11 through the recirculation port 10 would be the result.

[0046] The discharge flow rate $Q1$ of the fixed capacity pump P is obtained as a product of a unit discharge volume and a rotation speed of the pump P. The rotation speed of the fixed capacity pump P depends on the rotation speed of the motive power source such as an internal combustion engine. When the rotation speed of the motive power source increases, the discharge flow rate $Q1$ of the fixed capacity pump P increases accordingly, even in a low temperature state. If the differential pressure of the orifice were large in this situation, the recirculation flow rate $Q3$ via the recirculation port 10 would increase, so the suction flow rate of the fixed capacity pump P would not suffer a shortage. However, in reality, the differential pressure of the orifice is small even in a low temperature state, and so the flow rate $Q2$ of working oil supplied to the actuator A increases and the recirculation flow rate $Q3$ decreases relatively.

[0047] When the recirculation flow rate $Q3$ decreases, in order to maintain the suction flow rate of the fixed capacity pump P that is required according to the pump

rotation speed, the flow rate Q_4 of the working oil supplied from the reservoir R increases. As a result, the suction resistance of the fixed capacity pump P varies.

[0048] With respect to the working oil that is recirculated through the recirculation passage 11, the suction resistance by the pump P is small, because the recirculated working oil is under the influence of a pushing force originating from the discharge pressure of the fixed capacity pump P. With respect to the fresh working oil that is supplied from the reservoir R through the conduit Rp and the suction passage 1, since there is no pushing force applied to the fresh working oil supplied from the reservoir R, all the frictional resistance in the conduit Rp and the suction passage 1 acts as suction resistance of the fixed capacity pump P. Accordingly, the suction resistance of the fresh working oil supplied from the reservoir R is larger than the suction resistance of the recirculated working oil. As a result, as the ratio of the flow rate Q_4 to the flow rate Q_3 increases, the suction resistance by the pump P increases.

[0049] If the fixed capacity pump P tends to suck a large amount of working oil from the reservoir R when the oil temperature is low and the oil viscosity is large, the suction flow rate of the fixed capacity pump P may not match the discharge flow rate thereof due to an excessively large suction resistance. This situation generates a negative pressure in the pump P which causes cavitation and generates noise.

[0050] This invention focuses attention on the temperature characteristics of an orifice and choke as shown in FIG. 4, and by the use of the choke 21 that generates a large differential pressure under low temperature, achieves a relative increase in the recirculation flow rate Q_3 with respect to the flow rate Q_4 of the working oil supplied from the reservoir R in a low temperature state.

[0051] This invention defines the term "choke" as follows. Both the choke and orifice generate pressure loss due to restriction of the flow area. In general, the choke denotes a narrow flow area with a long flow path length L , while the orifice denotes a narrow flow area that has a short flow path length L . According to this invention it should be understood that the choke indicates a narrow flow path in which the pressure loss decreases as the working oil temperature increases and takes a constant value when the working oil temperature is above a predetermined temperature.

[0052] In FIG. 4, it can be seen that, when the oil temperature is lower than twenty degrees Centigrade, especially when it is lower than zero degrees Centigrade, the pressure loss of the choke is extremely large. In this temperature range, the flow rate of the working oil passing through the choke is small.

[0053] When the oil temperature is low, the viscosity of the oil is large and the pressure loss of the choke 21 in FIG. 1 is large. In other words, the differential pressure of the choke 21 is large when the oil temperature is low. As a result, the difference in pressure in the control pressure chamber 6 and spring chamber 7 increases beyond

the difference in pressure at a normal working oil temperature, and the spool 5 displaces towards the spring chamber 7 so as to increase the opening of the recirculation port 10 at the same discharge flow rate Q_1 of the fixed capacity pump P as in the case where the working oil temperature is high. Accordingly, the flowrate Q_2 of the working oil supplied to the actuator A decreases and the recirculation flow rate Q_3 of the working oil recirculated from the recirculation port 10 to the fixed capacity pump P via the recirculation passage 11 increases.

[0054] Decrease in the flow rate Q_2 of the working oil supplied to the actuator A and increase in the flow rate Q_3 of the recirculated working oil leads to a decrease in the flow rate Q_4 of the working oil supplied from the reservoir R. When the flow rate Q_4 of the working oil sucked from the reservoir R decreases, the pressure loss generated in the working oil passing through the conduit Rp decreases. Therefore, cavitation or noise generation in the fixed capacity pump P does not occur even at a high rotation speed in a low temperature state.

[0055] As a result, the fixed capacity pump P does not suffer from a shortage of work oil for suction, while the flow rate Q_4 of the working oil sucked through the conduit Rp remains small.

[0056] Further, the flow rate Q_3 represents the flow rate of the working oil that recirculates through the recirculation passage 11 formed internally in the casing C, and so the pressure loss due to recirculation is small.

[0057] Referring again to FIG. 4, when the oil temperature rises above twenty degrees Centigrade, the flow characteristic of the choke is no longer affected by the viscosity of the oil. In this situation, the choke 21 functions in the same way as an orifice. Moreover, when the working oil temperature is high, the suction resistance due to friction in the conduit Rp does not become very large. The fixed capacity pump P can therefore suck an adequate amount of working oil without suffering a large suction resistance, and the working oil is supplied to the actuator A at a constant flow rate defined depending on the flow diameter D and flow path length L of the choke 21.

[0058] As described above, according to this invention, the fixed capacity pump does not suffer from an insufficient suction flow rate, and therefore cavitation or generation of noise is prevented from occurring even when the rotation speed of the motive power source increases in a low temperature state.

[0059] According to the experiment by the inventors, when the diameter D of the flow area is set within a range of two to eight millimeters, by setting the flow path length L to a value that makes L/D larger than unity, a preferable cavitation/noise prevention effect is obtained.

[0060] The contents of Tokugan 2004-370463, with a filing date of December 22, 2004 in Japan, are hereby incorporated by reference.

[0061] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the em-

bodiments described above will occur to those skilled in the art, within the scope of the claims.

[0062] For example, in the above embodiment, this invention is applied to a pump device wherein the fixed capacity pump P is connected to the reservoir R via the conduit Rp, but this invention may also be applied to a pump device wherein the fixed capacity pump is directly connected to the reservoir, not via a conduit.

[0063] By directly connecting the pump with the reservoir, it is possible to reduce the suction resistance of the pump, but even in this case the suction resistance of the working oil supplied from the reservoir is larger than the suction resistance of the working oil recirculated through the recirculation passage 11, because the working oil in the recirculation passage 11 is under the influence of the pushing force originating from discharge pressure of the pump.

[0064] Therefore, by applying this invention to a pump device where the fixed capacity pump is directly connected to the reservoir, a preferable effect is obtained in preventing an insufficient working oil supply in a low temperature state for the fixed capacity pump.

[0065] The opening of the choke 21 is not limited to a circular shape. When the shape of the opening is polygonal, the diameter D of a circular opening that has the same cross-sectional area should be used to determine the flow path length L of the choke 21.

[0066] The embodiments of this invention in which an exclusive property or privilege is claimed are defined as follows:

4. The pump device as defined in Claim 3, wherein the flow control valve (F) comprises a spool (5) which regulates a flow rate of the working oil recirculated by the flow control valve (F) according to a difference in pressure between an upstream side of the choke (21) and a downstream side of the choke (21).
5. The pump device as defined in any one of Claim 1 through Claim 4, wherein a diameter (D) of the choke (21) is set within a range of two to eight millimeters, and a ratio of the diameter (D) to a length (L) of the choke (21) is set to be equal to or less than unity.

Claims

1. A pump device for supplying oil to an actuator (A), comprising:
 - a fixed capacity pump (P);
 - a choke (21) through which working oil discharged by the pump (P) flows; and
 - a flow control valve (F) which recirculates a part of the working oil discharged by the pump (P) to a suction side of the pump (P), according to a pressure loss generated by the choke (21).
2. The pump device as defined in Claim 1, further comprising a casing (C) in which the pump (P), the choke (21) and the flow control valve (F) are enclosed.
3. The pump device as defined in Claim 2, further comprising a suction passage (1) which supplies working oil to the suction side of the pump (P), a discharge passage (2) which supplies a part of the working oil discharged by the pump (P) to the actuator (A), the choke (21) being disposed in the discharge passage (2), and a recirculation passage (11) which supplies the working oil recirculated by the flow control valve (F) to the suction passage (1).

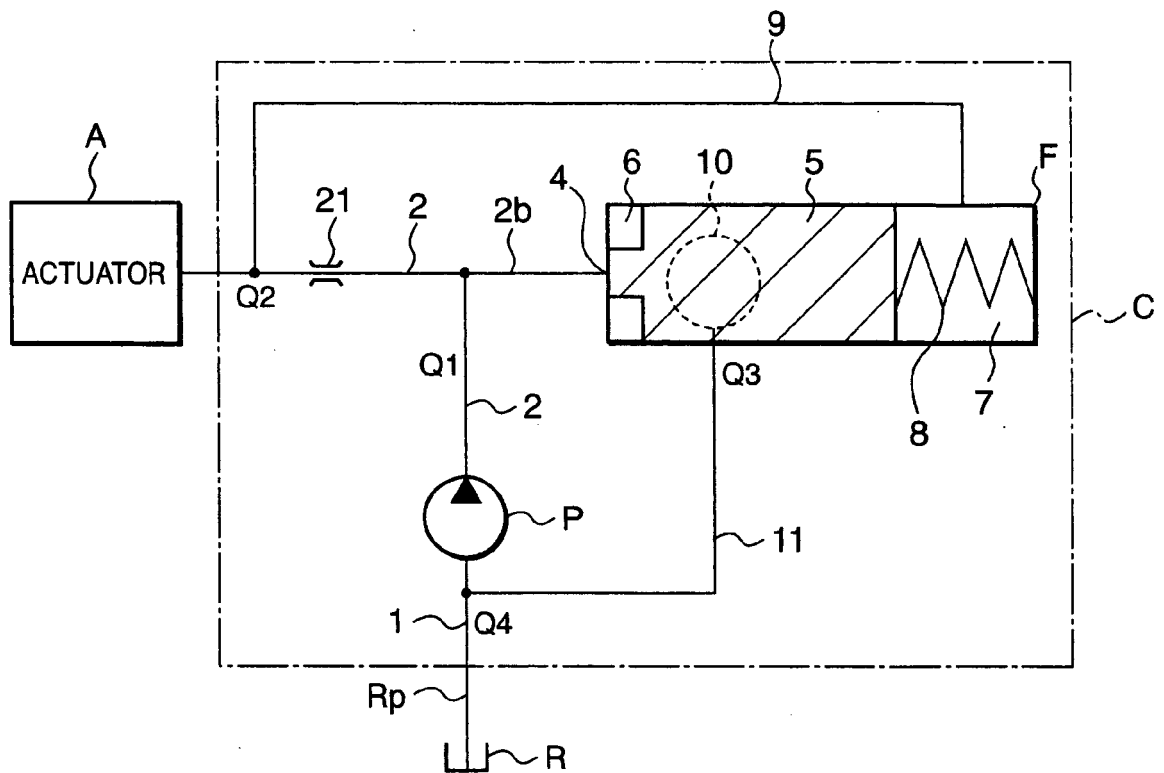


FIG. 1

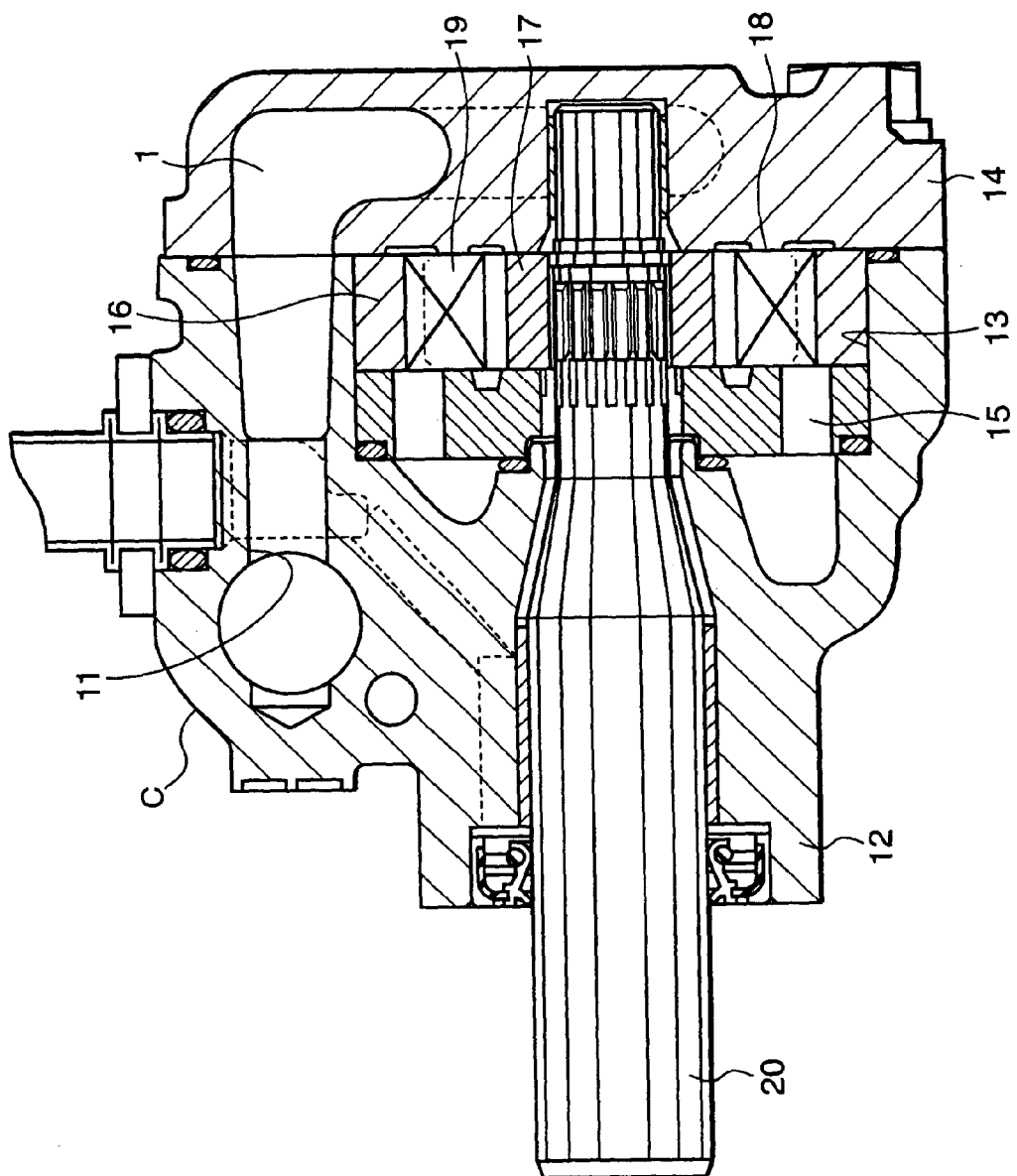


FIG. 2

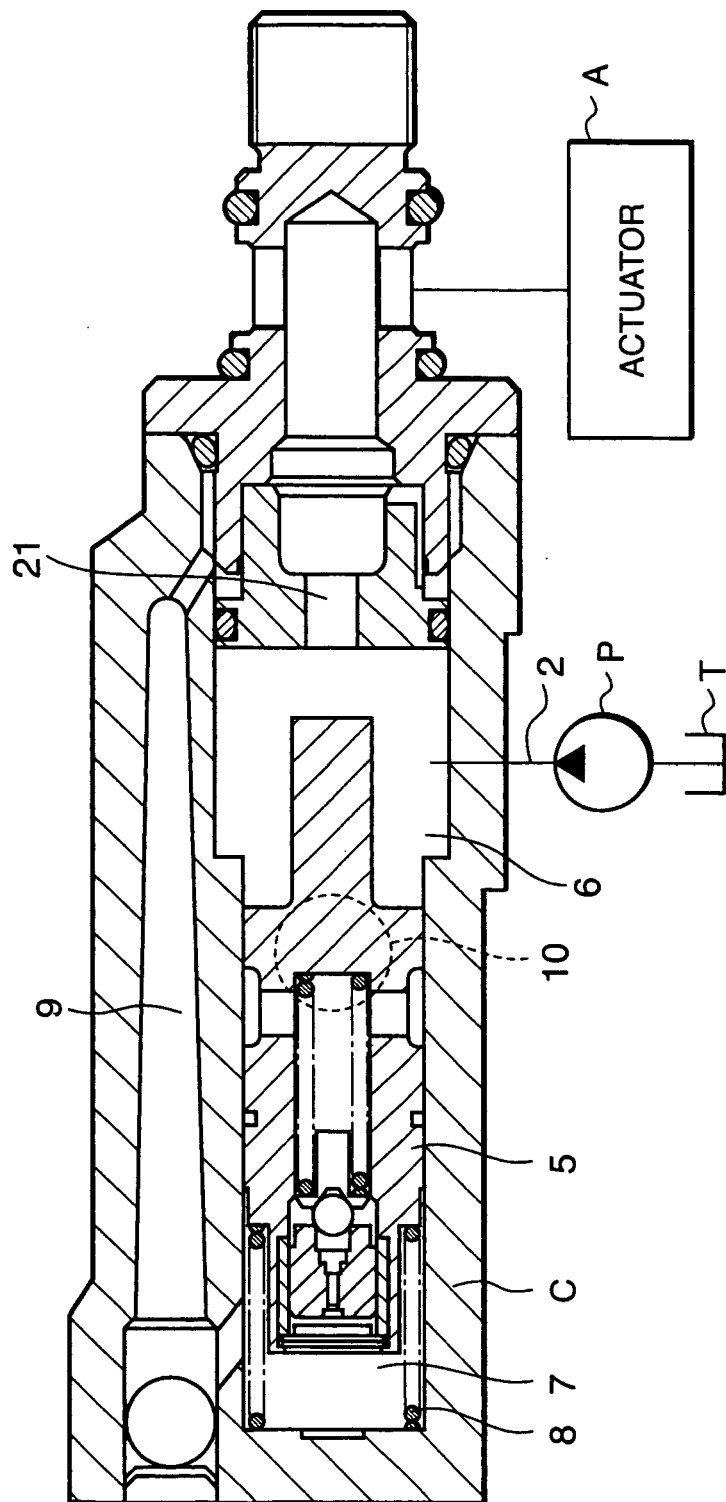


FIG. 3

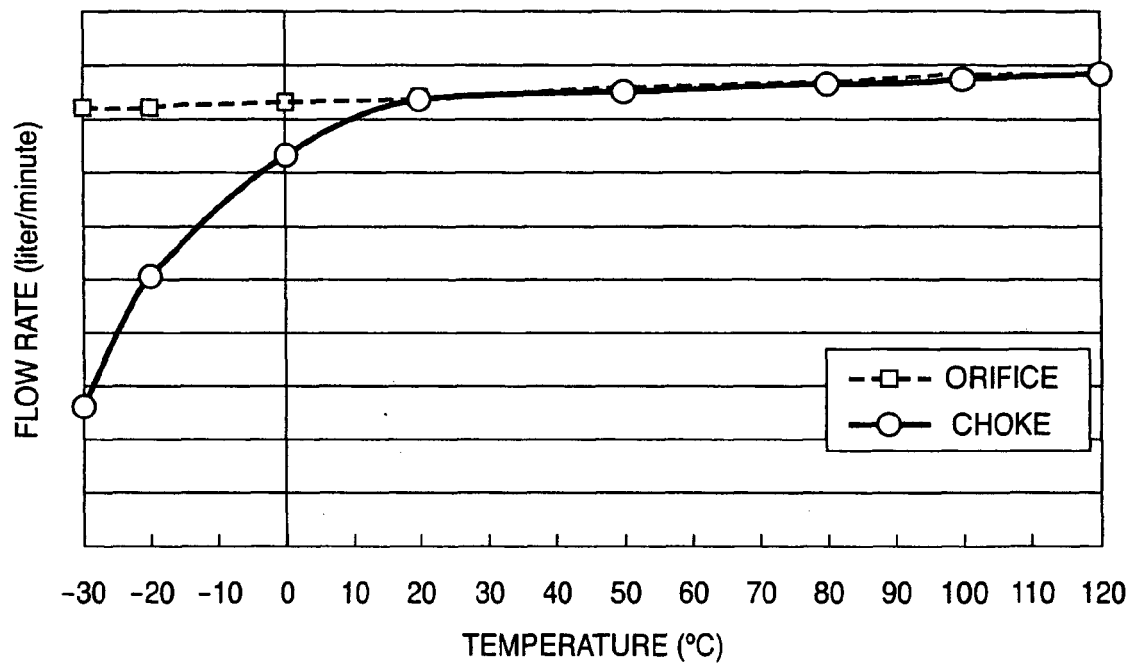


FIG. 4