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(54) **CONTROL VALVE OF VARIABLE DISPLACEMENT COMPRESSOR**

(57) In order to reduce the amount of refrigerant circulating within a variable displacement compressor to thereby improve compression efficiency, a control valve is configured to comprise a ball valve (11) for controlling the flow rate of refrigerant flowing from a discharge chamber to a crankcase, a spool valve (12) for controlling the flow rate of refrigerant flowing from the crankcase to a suction chamber, a diaphragm (13) for sensing suction pressure (P_s), and a solenoid for setting the suction pressure, wherein the spool valve (12) starts flow rate control after the ball valve (11) is fully closed or nearly fully closed, and the ball valve (11) starts flow rate control after the valve lift of the spool valve (12) is minimized or nearly minimized. As a result, a region is almost eliminated in which the ball valve (11) and the spool valve (12) are both open simultaneously during switching of flow rate control between the ball valve (11) and the spool valve (12), which makes it possible to minimize the flow rate of the refrigerant circulating within the compressor without contributing to a refrigerating operation, to thereby improve the efficiency of the compressor.

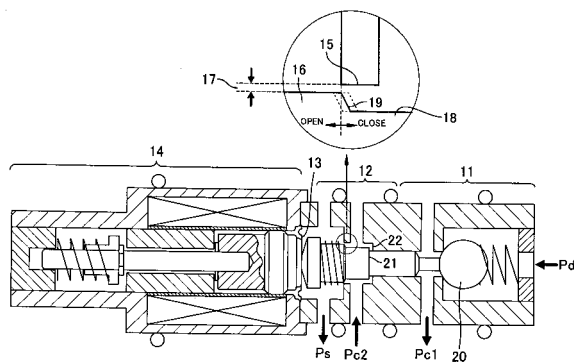


FIG. 1

Description

Technical Field

[0001] The present invention relates to a control valve for a variable displacement compressor, and more particularly to a control valve for a variable displacement compressor used in a refrigeration cycle of an automotive air conditioner.

Background Art

[0002] The rotational speed of an engine as a drive source of an automotive air conditioner is not constant, and hence the air conditioner is required to be controlled such that refrigerating power thereof is held constant regardless of the engine rotational speed. To meet this requirement, a swash plate variable displacement compressor capable of changing the discharge amount of refrigerant is generally used in an automotive air conditioner. In the variable displacement compressor, a swash plate disposed within a crankcase such that the inclination angle thereof can be changed is driven by the rotation of a rotating shaft, for performing wobbling motion, and the wobbling motion causes a plurality of pistons to perform reciprocating motion in a direction parallel to the rotating shaft, whereby refrigerant is drawn, compressed, and then discharged. In doing this, the inclination angle of the swash plate is varied by changing the pressure in the crankcase, whereby the stroke of the pistons is changed for changing the discharge amount of the refrigerant.

[0003] In general, the control valve is disposed in a refrigerant passage communicating between a discharge chamber and a crankcase, and controls the flow rate of refrigerant introduced at discharge pressure P_d from the discharge chamber into the crankcase, to thereby control pressure P_c within the crankcase. The refrigerant introduced into the crankcase is drawn into the suction chamber via a fixed orifice. In this control valve, suction pressure P_s in the suction chamber is sensed e.g. by a pressure-sensing member, such as a diaphragm, and the flow rate of the refrigerant introduced into the crankcase is controlled such that the suction pressure P_s is maintained at a constant level.

[0004] On the other hand, it is also conventional to dispose a control valve in a refrigerant passage communicating between the crankcase and the suction chamber, and provide a fixed orifice between the discharge chamber and the crankcase, so as to control the flow rate of the refrigerant drawn from the crankcase.

[0005] In either of the variable displacement compressors using these two types of control valves, the fixed orifice having an invariable flow passage area is interposed in the passage from the discharge chamber to the crankcase or the passage from the crankcase to the suction chamber in series with the passage. Consequently, in the variable displacement compressor using

one of the above-described control valves, increased amount of refrigerant circulates therein, which inevitably causes degradation of compression efficiency.

[0006] There has also been proposed a control valve having two valves disposed, respectively, in the refrigerant passage communicating between the discharge chamber and the crankcase and the refrigerant passage communicating between the crankcase and the suction chamber, such that the two valves operate in a manner interlocked with each other, so as to simultaneously control the flow rate of the refrigerant introduced into the crankcase and the flow rate of the refrigerant drawn from the crankcase (e.g. in Japanese Unexamined Patent Publication (Kokai) NO. S58-158382, FIG. 3). With this configuration, the control valve provides control such that when the flow rate of refrigerant in one of the refrigerant passage communicating between the discharge chamber and the crankcase and the refrigerant passage communicating between the crankcase and the suction chamber is increased, the flow rate of refrigerant in the other is reduced. This makes it possible to reduce the flow rate of refrigerant circulating in the variable displacement compressor, and hence construct a variable displacement compressor which is higher in compression efficiency than those using the control valves configured as described hereinbefore.

[0007] Further, there has been proposed a control valve having two valves disposed, respectively, in the refrigerant passage communicating between the discharge chamber and the crankcase and the refrigerant passage communicating between the crankcase and the suction chamber, such that the two valves operate in a manner interlocked with each other to hold one of the refrigerant passages in a closed state when the other passage is open in a controlled state (e.g. in Japanese Unexamined Patent Publication (Kokai) No. S64-41680, FIG. 2). According to this control valve, when the flow rate of refrigerant in one of the refrigerant passages is being controlled, the other refrigerant passage is closed, so that refrigerant circulating in the variable displacement compressor can be further reduced.

[0008] However, in the former control valve described in Japanese Unexamined Patent Publication (Kokai) No. S58-158382, in which the valves are disposed on the respective inlet and outlet sides of the crankcase, one of the two valves operated in an interlocked manner closes as the other opens, and hence there inevitably occurs a region where the two valves are both open. Consequently, the flow rate of refrigerant circulating in the compressor can only be reduced to a limited degree, which makes it impossible to obtain sufficiently improved compression efficiency.

[0009] On the other hand, in the latter control valve described in Japanese Unexamined Patent Publication (Kokai) No. S64-41680, in which while one of the valves is open, the other is held closed, when the suction pressure becomes not higher than a first set pressure, the refrigerant passage (outlet side) between the crankcase

and the suction pressure is fully closed, and hence the pressure in the crankcase sensitively reacts to a slight change in the valve in the refrigerant passage (inlet side) between the discharge chamber and the crankcase. As a consequence, when the pressure in the crankcase rises excessively, gaseous refrigerant compressed in the crankcase cannot be reduced by changing the valve lift of the valve on the inlet side, and not until the suction pressure spontaneously becomes higher than a second set pressure with decrease in the displacement of the compressor to open the outlet-side refrigerant passage, does the pressure in the crankcase fall. Then, the displacement of the compressor increases with decrease in the pressure in the crankcase, and the suction pressure becomes not higher than the first set pressure. Thereafter, a so-called hunting phenomenon occurs in which the above-described cycle is repeated. As described above, the latter control valve cannot ensure stable controllability.

Disclosure of the Invention

[0010] The present invention has been made in view of the above points, and an object thereof is to provide a control valve for a variable displacement compressor, which is capable of reducing the amount of refrigerant circulating within the compressor to thereby improve compression efficiency, while ensuring stable controllability.

[0011] To solve the above problems, the present invention provides a control valve for a variable displacement compressor, which is capable of controlling pressure in a crankcase to thereby change a discharge amount of refrigerant, comprising a first valve that is disposed between a discharge chamber and the crankcase of the compressor, for controlling a flow rate of refrigerant flowing from the discharge chamber to the crankcase, a second valve that is disposed between the crankcase and a suction chamber of the compressor, for controlling a flow rate of refrigerant flowing from the crankcase to the suction chamber to a predetermined minimum rate when the first valve is controlling the flow rate of the refrigerant flowing from the discharge chamber to the crankcase, and for controlling the flow rate of the refrigerant flowing from the crankcase to the suction chamber when the first valve is fully closed or nearly fully closed, and a pressure-sensing section that senses suction pressure in the suction chamber, for changing a lift amount of the first valve and a lift amount of the second valve.

[0012] According to this control valve for a variable displacement compressor, the second valve for controlling the flow rate of the refrigerant flowing from the crankcase to the suction chamber of the compressor starts flow rate control when the first valve is fully closed or nearly fully closed, and the first valve also starts flow rate control after the valve lift of the second valve is minimized or nearly minimized. As a result, it is possible to

minimize the flow rate of the refrigerant flowing from the discharge chamber to the crankcase and further from the crankcase to the suction chamber, i.e. the flow rate of the refrigerant circulating within the compressor without contributing to a refrigerating operation, and prevent the pressure in the crankcase from rising too sensitively. This makes it possible to improve compression efficiency while ensuring stable controllability.

[0013] The above and other objects, features, and advantages of the invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawings.

Brief Description of Drawings

[0014]

FIG. 1 is a conceptual view showing the arrangement of a control valve for a variable displacement compressor, according to the present invention.

FIG. 2 is an enlarged fragmentary view useful in explaining the control valve set to a first opening/closing timing.

FIG. 3 is a diagram showing characteristics of the control valve set to the first opening/closing timing.

FIG. 4 is an enlarged fragmentary view useful in explaining the control valve set to a second opening/closing timing.

FIG. 5 is a diagram showing characteristics of the control valve set to the second opening/closing timing.

FIG. 6 is an enlarged fragmentary view useful in explaining the control valve set to a third opening/closing timing.

FIG. 7 is a diagram showing characteristics of the control valve set to the third opening/closing timing.

FIG. 8 is an enlarged fragmentary view useful in explaining a control valve in which a fixed orifice is formed in each of an inlet side and an outlet side.

FIG. 9 is a diagram showing characteristics of the control valve set to a fourth opening/closing timing.

FIG. 10 is a conceptual view showing a control valve in which a fixed orifice is formed in each of an inlet side and an outlet side.

FIG. 11 is a diagram showing characteristics of the control valve set to a fifth opening/closing timing.

FIG. 12 is a conceptual view showing the arrangement of a mechanical control valve for a variable displacement compressor.

FIG. 13 is a conceptual view showing the arrangement of a mechanical control valve for a variable displacement compressor.

FIG. 14 is a conceptual view showing the arrangement of a control valve for a variable displacement compressor, in which the fixed orifice function of a second valve is provided independently.

Best Mode for Carrying Out the Invention

[0015] The present invention will now be described in detail with reference to the accompanying drawings showing preferred embodiments thereof.

[0016] FIG. 1 is a conceptual view showing the arrangement of a control valve for a variable displacement compressor, according to the present invention.

[0017] The control valve for a variable displacement compressor, according to the present invention has a ball valve 11 forming a first valve, a spool valve 12 forming a second valve, a diaphragm 13 forming a pressure-sensing section, and a solenoid 14 forming a pressure-setting section, which are arranged in the mentioned order.

[0018] The ball valve 11 introduces refrigerant discharged at discharge pressure P_d from a discharge chamber of the variable displacement compressor, and controls the flow rate of the introduced refrigerant to supply the refrigerant at pressure P_{c1} to a crankcase. The spool valve 12 introduces refrigerant delivered at pressure P_{c2} from the crankcase, and controls the flow rate of the introduced refrigerant to supply the pressure to a suction chamber of the compressor in a manner interlocked with operation of the ball valve 11. The diaphragm 13 receives suction pressure P_s from the suction chamber, and when the suction pressure becomes lower than a predetermined suction pressure setting point, the diaphragm 13 displaces the ball valve 11 and the spool valve 12 to increase pressure in the crankcase. With increase in the pressure in the crankcase, the displacement of the compressor is reduced. As a consequence, the suction pressure of an air conditioner is controlled to a level in the vicinity of the predetermined suction pressure setting point. The solenoid 14 applies urging load to the diaphragm 13 to set the suction pressure setting point. The urging load is set according to the value of an electric current externally supplied.

[0019] The spool valve 12 comprises a valve seat 15 and a valve element 16 removably inserted into a valve hole. Between the valve seat 15 and the valve element 16, there is formed a predetermined clearance 17. This clearance 17 forms a fixed orifice with an invariable flow passage area between the crankcase and the suction chamber when the valve element 16 is inserted into the valve hole. The clearance 17 is determined depending on the stability of the swash plate of the compressor. The valve element 16 is integrally formed with a shaft 18 for driving the ball valve 11. The valve element 16 and the shaft 18 are joined to each other by a joining part 19 having a frustoconical shape with a taper in cross section.

[0020] The spool valve 12 can be freely modified according to characteristics, such as hunting, controllability, and stability, of the variable displacement compressor such that the spool valve 12 has a different opening/closing timing from that of the ball valve 11 interlocking with operation of the spool valve 12. The change in the

opening/closing timing of the spool valve 12 can be easily achieved by changing the distance between an end of the valve element 16 as a boundary to the joining part 19 and a forward end of the shaft 18 in contact with a valve element 20 of the ball valve 11 to thereby axially shift a position where the end of the valve element 16 is held in a fully-closed state of the ball valve 11.

[0021] In the ball valve 11, as the shaft 18 moves rightward as viewed in FIG. 1, the valve element 20 moves in a valve-opening direction, and the maximum valve lift of the ball valve 11 is limited by abutment of a stepped part 21 of the shaft 18 against a stepped part 22 of a body.

[0022] FIG. 2 is an enlarged fragmentary view useful in explaining the control valve set to a first opening/closing timing, and FIG. 3 is a diagram showing characteristics of the control valve set to the first opening/closing timing.

[0023] The first opening/closing timing is set such that the opening/closing timing of the ball valve 11 and that of the spool valve 12 coincide with each other, and more specifically such that when the ball valve 11 is fully closed, the end of the valve element 16 of the spool valve 12 is aligned with a solenoid-side open end face of the valve seat 15.

[0024] With this configuration, the characteristics exhibited by the control valve when the valve element 16 of the spool valve 12 is axially moved are as shown in FIG. 3. In FIG. 3, the abscissa represents a stroke of the shaft 18, and the origin represents a state where the stepped part 21 of the shaft 18 is in abutment with the stepped part 22 of the body and at a position closest to the ball valve side (or a deenergized state of the solenoid). The ordinate in FIG. 3 represents the opening area of the ball valve 11 and that of the spool valve 12. A line indicated by P_d - P_c represents changes in the opening area of the ball valve 11, while a line indicated by P_c - P_s represents changes in the opening area of the spool valve 12.

[0025] In the first opening/closing timing, as long as the ball valve 11 is open, the spool valve 12 has an opening area corresponding to the clearance 17, and operates as the fixed orifice. When the shaft 18 moves toward the solenoid 14 and reaches a position s_1 , the valve element 20 of the ball valve 11 is seated to fully close the ball valve 11. When the shaft 18 further moves toward the solenoid 14, the forward end of the shaft 18 moves away from the valve element 20 of the ball valve 11, whereby the ball valve 11 is held in its fully-closed state, and the spool valve 12 starts opening from the state operating as the fixed orifice to increase its opening area in accordance with increase in the stroke of the shaft 18. When the ball valve 11 is in its fully-closed state, compressed refrigerant cannot flow into the crankcase via the control valve, but a slight amount of blowby gas leaks into the crankcase through a gap between a piston for drawing and compressing refrigerant and a cylinder having the piston slidably received there-

in, which makes it possible to control pressure $P_c (= P_{c1} = P_{c2})$ within the crankcase.

[0026] FIG. 4 is an enlarged fragmentary view useful in explaining the control valve set to a second opening/closing timing, and FIG. 5 is a diagram showing characteristics of the control valve set to the second opening/closing timing.

[0027] The second opening/closing timing is set such that the opening timing of the spool valve 12 is retarded with respect to the closing timing of the ball valve 11, and hence in the second opening/closing timing, when the ball valve 11 is fully closed, the spool valve 12 is still in its closed state (fixed orifice state). To this end, the distance between the ball valve-side end of the valve element 16 and the forward end of the shaft in contact with the valve element 20 of the ball valve 11 is made shorter by a distance "a" than in the first opening/closing timing such that when the ball valve 11 is closed, the ball valve-side end of the valve element 16 of the spool valve 12 is positioned within the valve hole.

[0028] With this configuration, in the second opening/closing timing, as shown in FIG. 5, as the shaft 18 moves toward the solenoid 14, first, the ball valve 11 is fully closed when the shaft 18 reaches the position s1. At this time, the spool valve 12 has the opening area corresponding to the clearance 17. Then, when the shaft 18 further moves toward the solenoid 14 and reaches a position s2, the spool valve 12 starts opening.

[0029] FIG. 6 is an enlarged fragmentary view useful in explaining the control valve set to a third opening/closing timing, and FIG. 7 is a diagram showing characteristics of the control valve set to the third opening/closing timing.

[0030] The third opening/closing timing is configured such that the opening timing of the spool valve 12 is advanced with respect to the closing timing of the ball valve 11. To this end, the distance between the ball valve-side end of the valve element 16 and the forward end of the shaft in contact with the valve element 20 of the ball valve 11 is made longer by a distance "b" than in the first opening/closing timing whereby when the ball valve 11 is closed, the ball valve-side end of the valve element 16 of the spool valve 12 is positioned closer to the solenoid 14 than the valve seat 15.

[0031] With this configuration, in the third opening/closing timing, as shown in FIG. 7, as the shaft 18 moves toward the solenoid 14, first, the spool valve 12 starts opening when the shaft 18 reaches a position s1, and then when the shaft 18 reaches a position s2, the ball valve 11 is fully closed.

[0032] FIG. 8 is an enlarged fragmentary view useful in explaining a control valve in which a fixed orifice is formed in each of an inlet side and an outlet side, and FIG. 9 is a diagram showing characteristics of the control valve set to a fourth opening/closing timing. It should be noted that component elements in FIG. 8 identical to those in FIG. 1 are designated by identical reference numerals.

[0033] This control valve is configured such that the fixed orifices are formed on the respective inlet and outlet sides of the crankcase. In the control valve, the forward end of the shaft 18 in contact with the valve element 20 of the ball valve 11 is formed into a spool shape, and a clearance 24 is formed between the outer periphery of a contact end part 23 of the shaft 18 and the inner wall of the valve hole. When the ball valve 11 is in the vicinity of its fully-closed position, the clearance 24 is formed within the valve hole to form a fixed orifice with an invariable flow passage area between a compression chamber and the crankcase. The fixed orifice is provided for stably maintaining the flow rate of refrigerant introduced from the discharge chamber into the crankcase in a region where refrigerant is introduced into the crankcase by blowby gas, and the flow rate of refrigerant discharged from the crankcase is controlled by the spool valve 12. The distance between the rear end (diameter reduction start position) of the contact end part 23 and the seated position of the valve element 20 is set to a distance "c". Further, in the present example, the distance "d" between the end of the valve element 16 of the spool valve 12 and a valve closing start position of the spool valve 12 is set such that it becomes equal in value to the distance "c" when the ball valve 11 is fully closed with the valve element 20 thereof held in contact with the contact end part 23.

[0034] The control valve set as above has the following characteristics: As shown in FIG. 9, first, when the solenoid is not energized, the stepped part 21 of the shaft 18 is in contact with the stepped part 22 of the body, and hence the ball valve 11 is in its fully-open state, and the spool valve 12 is in the fixed orifice state.

[0035] With an increase in electric current for energizing the solenoid, the ball valve 11 turns from the fully-open state in the direction of reducing its opening area, whereas the spool valve 12 maintains its fixed orifice state. Then, when the shaft moves to a position s1, the rear end of the contact end part 23 reaches the seated position of the valve element 20, and the spool valve 12 reaches a valve opening start position at which it starts to get out of the fixed orifice state. When the shaft 18 further moves from the position s1, the rear end of the contact end part 23 enters the valve hole, whereby the ball valve 11 enters its fixed orifice state, and the spool valve 12 changes from its fixed orifice state in the direction of increasing its opening area.

[0036] Thereafter, the fixed orifice state of the ball valve 11 is maintained until the opening area of the ball valve 11 becomes smaller than that of the fixed orifice, and finally the ball valve 11 is seated to be fully closed.

[0037] Although in the above example, the distance "c" and the distance "d" are set to the same value, the distance "d" may be increased or decreased according to the characteristics of the variable displacement compressor to thereby easily change the opening/closing timing of the spool valve 12.

[0038] FIG. 10 is a conceptual view showing the ar-

rangement of a control valve in which a fixed orifice is formed in each of the inlet side and the outlet side, and FIG. 11 is a diagram showing characteristics of the control valve set to a fifth opening/closing timing. It should be noted that component elements in FIG. 10 identical to those in FIG. 1 are designated by identical reference numerals.

[0039] In this control valve, a valve disposed between the compressor and the crankcase and a valve disposed between the crankcase and the suction chamber are implemented by respective spool valves 11a and 12. The valve element 16 of the spool valve 12, the shaft 18, and a valve element 20a of the spool valve 11a are integrally formed with each other. The valve element 20a is smaller in diameter than the shaft 18 supported by the body, and the clearance 24 is formed between the valve element 20a and the inner wall of the valve hole. Further, a portion between the valve element 20a and the shaft 18 is reduced in diameter to have a spool shape. The distance between the rear end (diameter reduction start position) of the valve element 20a and a valve closing start position where the valve element 20a enters the valve hole is set such that it becomes equal to a distance "e" when the spool valve 12 is in a valve closing start position.

[0040] The control valve set as above has the following characteristics: As shown in FIG. 11, first, when the solenoid is not energized, the stepped part 21 of the shaft 18 is in contact with the stepped part 22 of the body, and hence the spool valve 11a is in its fully-open state, and the spool valve 12 is fully closed and in its fixed orifice state.

[0041] With an increase in electric current for energizing the solenoid, the rear end of the valve element 20a of the spool valve 11a approaches the valve hole and changes from its fully-open state in the direction of reducing its opening area, whereas the spool valve 12 maintains its fixed orifice state. Then, when the shaft 18 moves to a position s1, the spool valve 11a reaches the valve closing start position, and the spool valve 12 reaches a valve opening start position at which it starts to get out of its fixed orifice state. When the shaft 18 further moves from the position s1, the valve element 20a enters the valve hole, whereby the spool valve 11a enters its fixed orifice state, and the spool valve 12 changes from its fixed orifice state in the direction of increasing its opening area.

[0042] In the above embodiments, the electric control valves are described which use, as means for setting the suction pressure Ps in the suction chamber, the solenoid that enables a set point (pressure control point) thereof to be freely set by external electric control current. Next, mechanical control valves will be describe in which the suction pressure Ps is set to a fixed value.

[0043] FIG. 12 is a conceptual view showing the arrangement of a mechanical control valve for a variable displacement compressor. It should be noted that component elements in FIG. 12 identical to those in FIG. 1

are designated by identical reference numerals, and detailed description thereof is omitted.

[0044] This control valve has the ball valve 11 forming the first valve, the spool valve 12 forming the second valve, the diaphragm 13 forming the pressure-sensing section, and a spring 25 forming a pressure-setting section, which are arranged in the mentioned order.

[0045] This control valve is also configured such that as long as the ball valve 11 is variably controlling its opening area, the spool valve 12 functions as a fixed orifice, and when the ball valve 11 is in its fully-closed state, the spool valve 12 variably controls its opening area. Of course, the opening/closing timing of the spool valve 12 is set to one of the above described first to third opening/closing timings in accordance with the characteristics of the variable displacement compressor.

[0046] The diaphragm 13 has a disk 26 provided on a spring-side surface thereof, and the spring 25 urges the diaphragm 13 toward the spool valve 12 via the disk 26. The spring 25 is adjusted to have a spring load corresponding to a predetermined suction pressure control point. Therefore, when the suction pressure Ps received from the suction chamber becomes lower than the suction pressure control point, the diaphragm 13 urges the ball valve 11 and the spool valve 12 such that the pressure in the crankcase is increased, whereby the control valve controls the displacement of the variable displacement compressor to thereby control suction pressure in the air conditioner to a level in the vicinity of the predetermined suction pressure control point.

[0047] Of course, the present control valve can also be configured as a control valve set to the fourth opening/closing timing, by forming the contact end part 23 at the end of the shaft 18 to form the fixed orifice shown in FIG. 8 and thereby forming the fixed orifices on the respective refrigerant inlet and outlet sides of the crankcase.

[0048] FIG. 13 is a conceptual view showing the arrangement of a mechanical control valve for a variable displacement compressor. It should be noted that component elements in FIG. 13 identical to those in FIGS. 1 and 10 are designated by identical reference numerals, and detailed description thereof is omitted.

[0049] This control valve has the spool valve 11a forming the first valve, the spool valve 12 forming the second valve, the diaphragm 13 forming the pressure-sensing section, and the spring 25 forming the pressure-setting section, which are arranged in the mentioned order.

[0050] The spool valve 11a is identical in construction to that shown in FIG. 10. Therefore, the present control valve has the characteristic of the fifth opening/closing timing shown in FIG. 11.

[0051] Also in this control valve, the suction pressure Ps is received from the suction chamber to change the lift amount of each of the spool valves 11a and 12, and the pressure in the crankcase is controlled such that the suction pressure Ps is held constant as a consequence.

[0052] FIG. 14 is a conceptual view showing the arrangement of a control valve for a variable displacement compressor, in which the fixed orifice function of the second valve is provided independently. It should be noted that component elements in FIG. 14 identical to those in FIG. 1 are designated by identical reference numerals, and detailed description thereof is omitted.

[0053] The present control valve is distinguished from the control valve shown in FIG. 1, in which the clearance 17 formed between the valve element 16 of the spool valve 12 and the inner wall of the valve hole provides the fixed orifice function, in that a fixed orifice 27 having an opening area equivalent to that formed by the clearance 17 is formed in the body. In this case, the clearance 17 formed between the valve element 16 of the spool valve 12 and the inner wall of the valve hole is minimized. As a result, when the refrigerant passage between the crankcase and the suction chamber is narrowed by the spool valve 12, refrigerant is caused to flow through the fixed orifice 27 larger in diameter, and prevented from flowing through the clearance 17 which is small. This provides an advantageous effect that a change in the flow rate of refrigerant due to deposition of sludge contained in the refrigerant can be reduced.

[0054] More specifically, assuming that the clearance 17 between the valve element 16 of the spool valve 12 and the inner wall of the valve hole is e.g. 0.1 mm, the fixed orifice 27 having an opening area equivalent to the clearance 17 is a through hole with a diameter of 1 mm, and sludge deposited on the valve element 16 or the inner wall of the valve hole, or on the inner wall of the fixed orifice 27 has grown e.g. to a thickness of 0.1 mm, the clearance 17 is almost clogged with the sludge, whereas the diameter of the fixed orifice 27 is reduced only to 0.8 mm, which makes smaller the change in the flow rate of refrigerant due to deposition of sludge. Further, since refrigerant mainly flows through the fixed orifice 27 which is easier for refrigerant to flow through, the amount of refrigerant flowing through the narrow clearance 17 is small, which makes it difficult for sludge to deposit.

[0055] Although the arrangement in which the fixed orifice 27 is formed in parallel with the spool valve 12 forming the second valve is described based on an example of application thereof to the control valve of a type having the solenoid 14 shown in FIG. 1, it can also be applied to the mechanical control valves shown in FIGS. 12 and 13.

[0056] As described above, according to the present invention, the control valve is configured to comprise the first valve for controlling the flow rate of refrigerant flowing from the discharge chamber to the crankcase, the second valve for controlling the flow rate of refrigerant flowing from the crankcase to the suction chamber, the pressure-sensing section for sensing suction pressure, and the pressure-setting section for setting the suction pressure P_s , wherein the second valve starts flow rate control after the first valve is fully closed or nearly fully

closed, and the first valve starts flow rate control after the valve lift of the second valve is minimum or nearly minimum. As a result, a region is eliminated in which the first and second valves are both open simultaneously during switching of control between the first valve and the second valve, which makes it possible to minimize the flow rate of refrigerant flowing from the discharge chamber to the crankcase and further from the crankcase to the suction chamber, i.e. the flow rate of refrigerant circulating within the variable displacement compressor without contributing to a refrigerating operation, to thereby improve the efficiency of the compressor. Further, since the second valve is equipped with the fixed orifice function for reducing the flow rate of refrigerant flowing from the crankcase to the suction chamber to a predetermined minimum flow rate, it is possible to stably adjust the pressure in the crankcase to thereby provide excellent controllability.

[0057] The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.

Claims

1. A control valve for a variable displacement compressor, which is capable of controlling pressure in a crankcase to thereby change a discharge amount of refrigerant, comprising:

a first valve that is disposed between a discharge chamber and the crankcase of the compressor, for controlling a flow rate of refrigerant flowing from the discharge chamber to the crankcase;

a second valve that is disposed between the crankcase and a suction chamber of the compressor, for controlling a flow rate of refrigerant flowing from the crankcase to the suction chamber to a predetermined minimum rate when the first valve is controlling the flow rate of the refrigerant flowing from the discharge chamber to the crankcase, and for controlling the flow rate of the refrigerant flowing from the crankcase to the suction chamber when the first valve is fully closed or nearly fully closed; and

a pressure-sensing section that senses suction pressure in the suction chamber, for changing a lift amount of the first valve and a lift amount of the second valve.

2. The control valve according to claim 1, wherein the

second valve has a clearance set between a diameter of a valve hole and a diameter of a valve element inserted into the valve hole when the first valve is controlling the flow rate of the refrigerant flowing from the discharge chamber to the crankcase, the clearance being provided with a fixed orifice function for controlling the flow rate of the refrigerant flowing from the crankcase to the suction chamber to the predetermined minimum rate.

3. The control valve according to claim 1 or 2, comprising a shaft extending through the valve hole of the second valve coaxially with the valve hole, for transmitting an opening/closing operation of the second valve to the first valve.

4. The control valve according to claim 3, wherein the shaft has a joining part joined to the valve element, formed such that the joining part has a frustconical shape.

5. The control valve according to claim 3, wherein the shaft has an end thereof in contact with a valve element of the first valve, formed such that the end has a spool shape.

6. The control valve according to claim 3, wherein the shaft can be brought into contact with and left the valve element of the first valve.

7. The control valve according to claim 3, wherein a clearance set between a diameter of an end of the shaft in contact with the valve element of the first valve and a valve hole of the first valve is provided with a fixed orifice function for controlling the flow rate of the refrigerant flowing from the discharge chamber to the crankcase to the predetermined minimum rate.

8. The control valve according to claim 1, wherein the first valve is a spool valve.

9. The control valve according to claim 1, comprising a fixed orifice that is formed in parallel with the second valve, for controlling the flow rate of the refrigerant flowing from the crankcase to the suction chamber to the predetermined minimum rate when the first valve is controlling the flow rate of the refrigerant flowing from the discharge chamber to the crankcase.

10. The control valve according to any one of claims 1 to 9, comprising a pressure-setting section that applies urging load to the pressure-sensing section to set a pressure control point of the control valve.

11. The control valve according to claim 10, wherein the pressure-setting section is a solenoid that sets the

pressure control point by applying the urging load in response to an external signal.

12. The control valve according to claim 10, wherein the pressure-setting section is a spring that sets the pressure control point by a spring force.

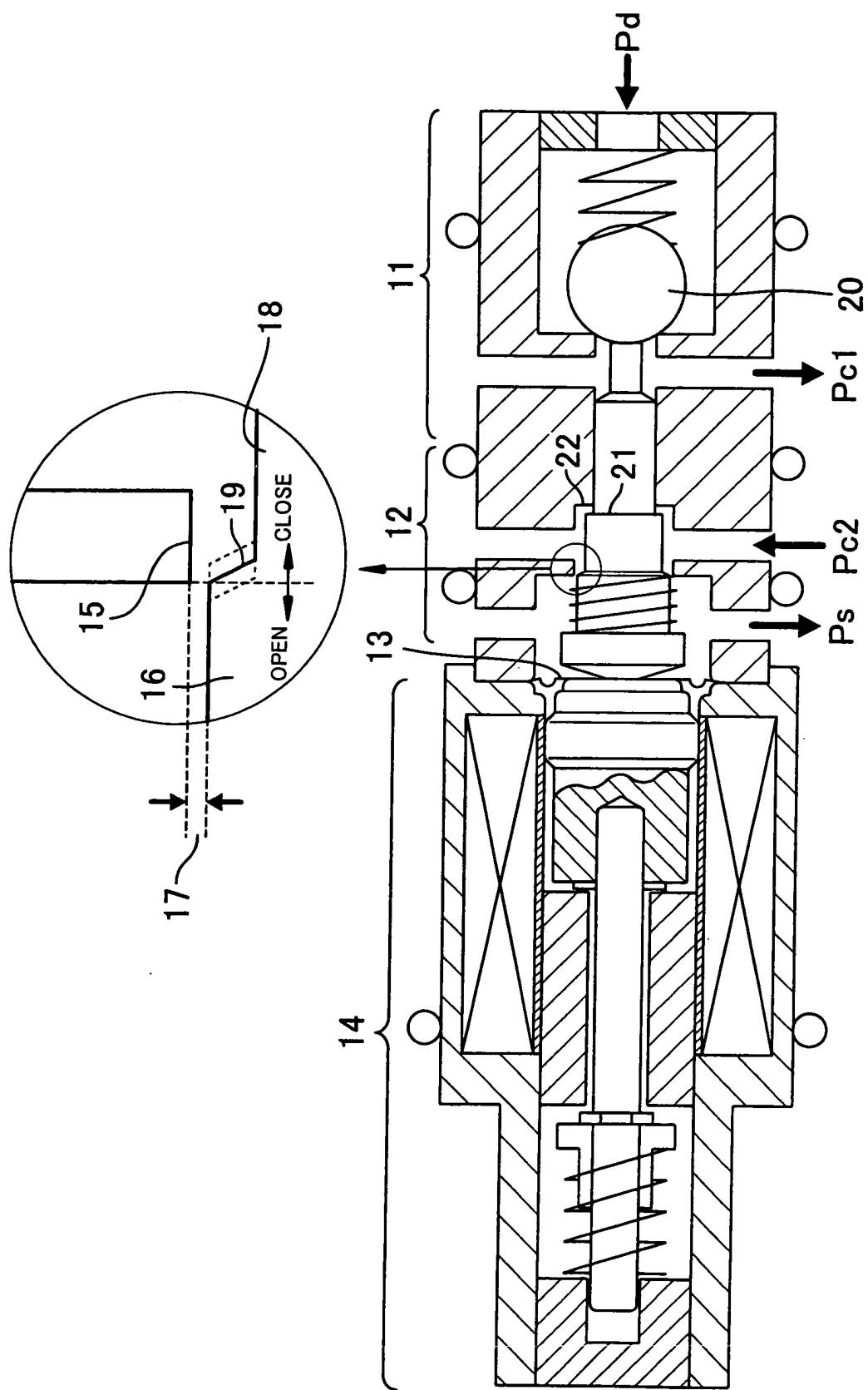


FIG. 1

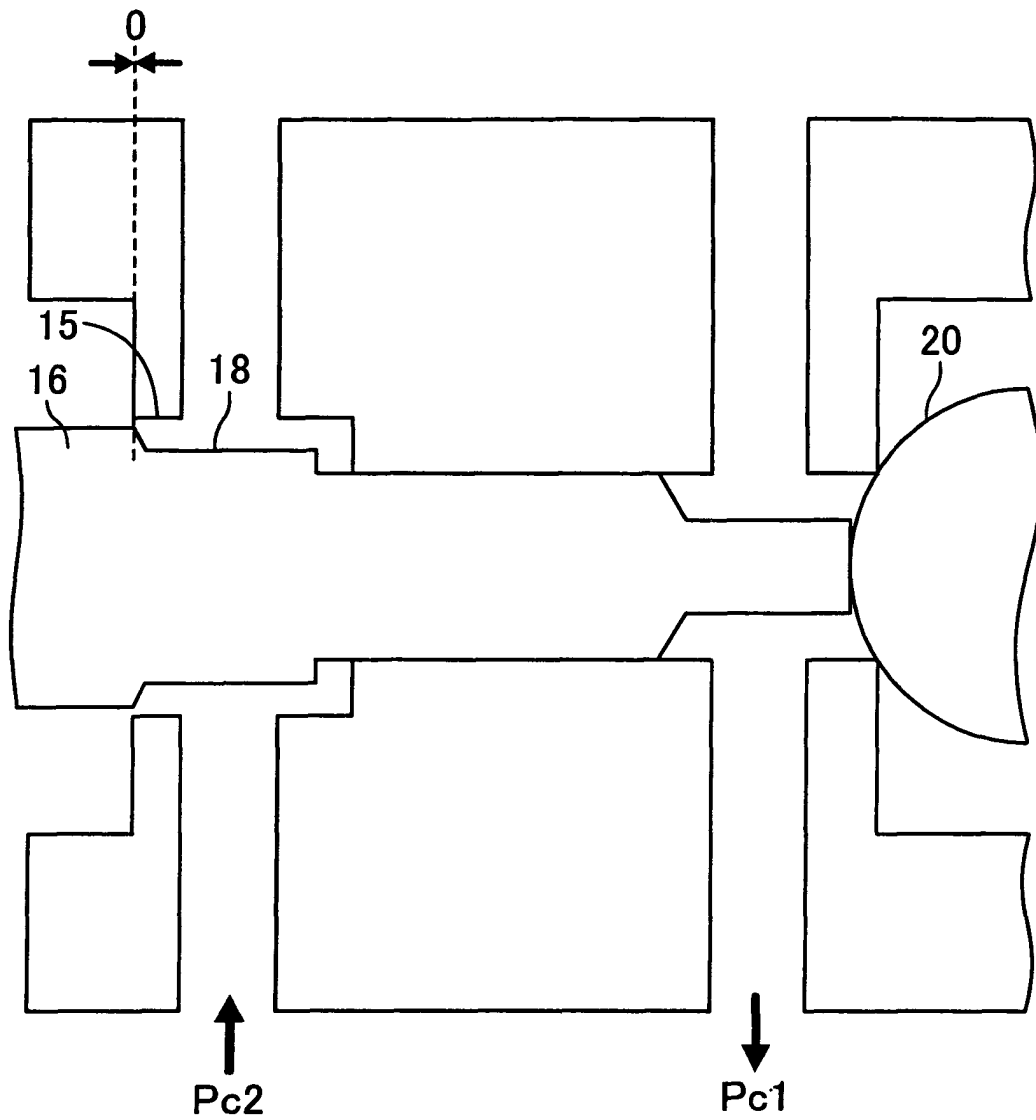


FIG. 2

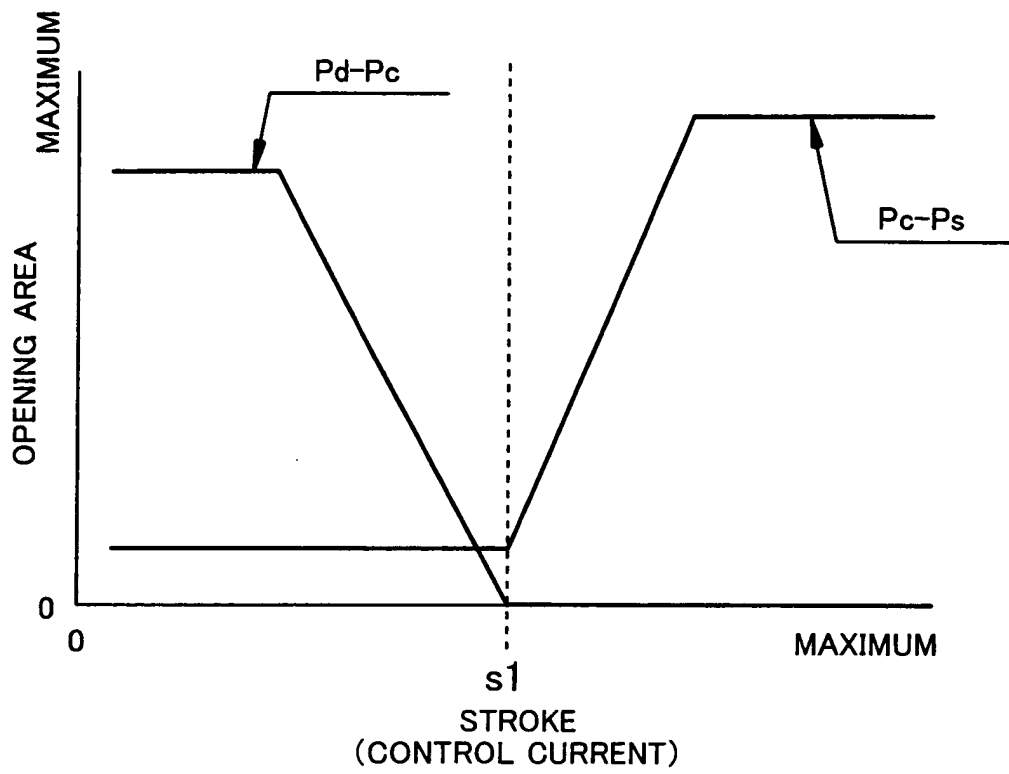


FIG. 3

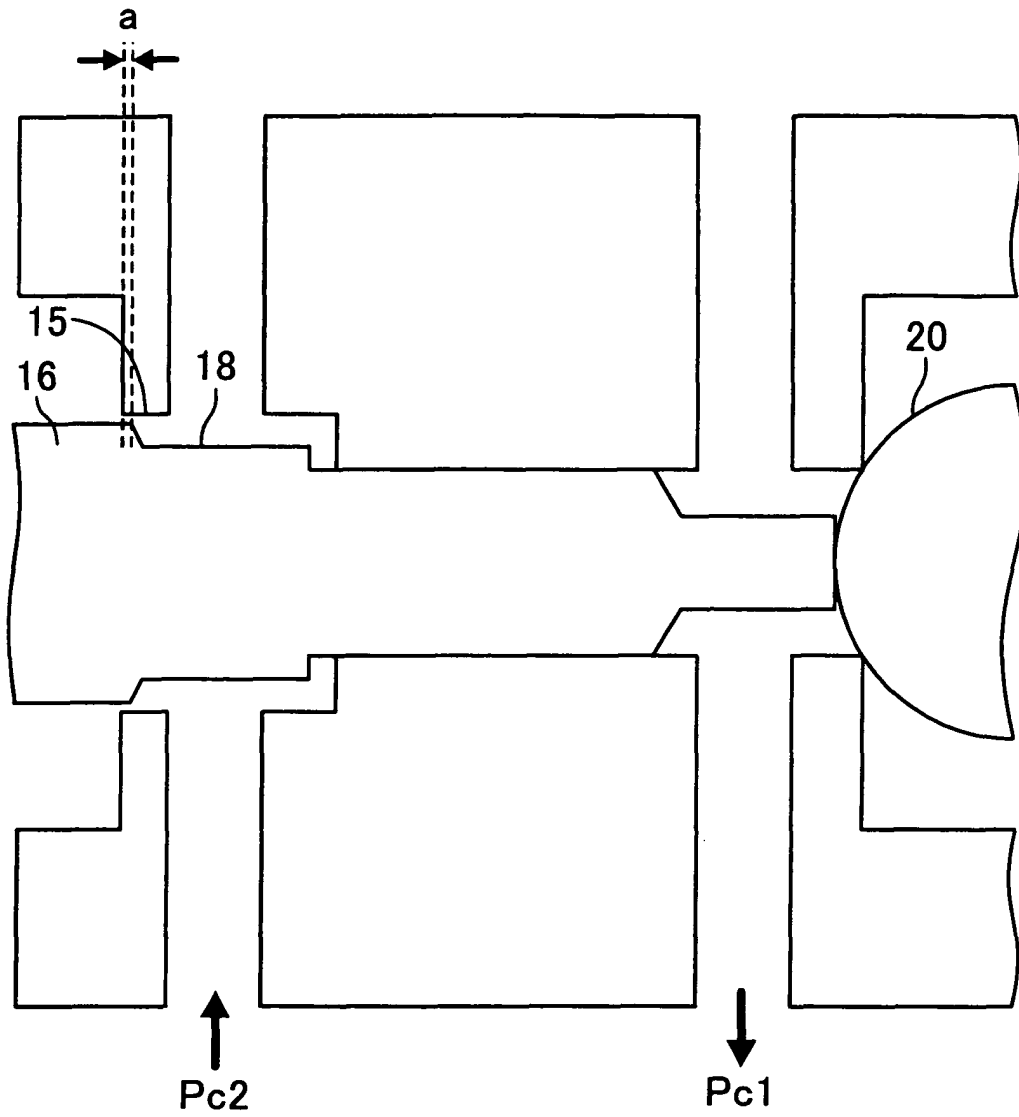


FIG. 4

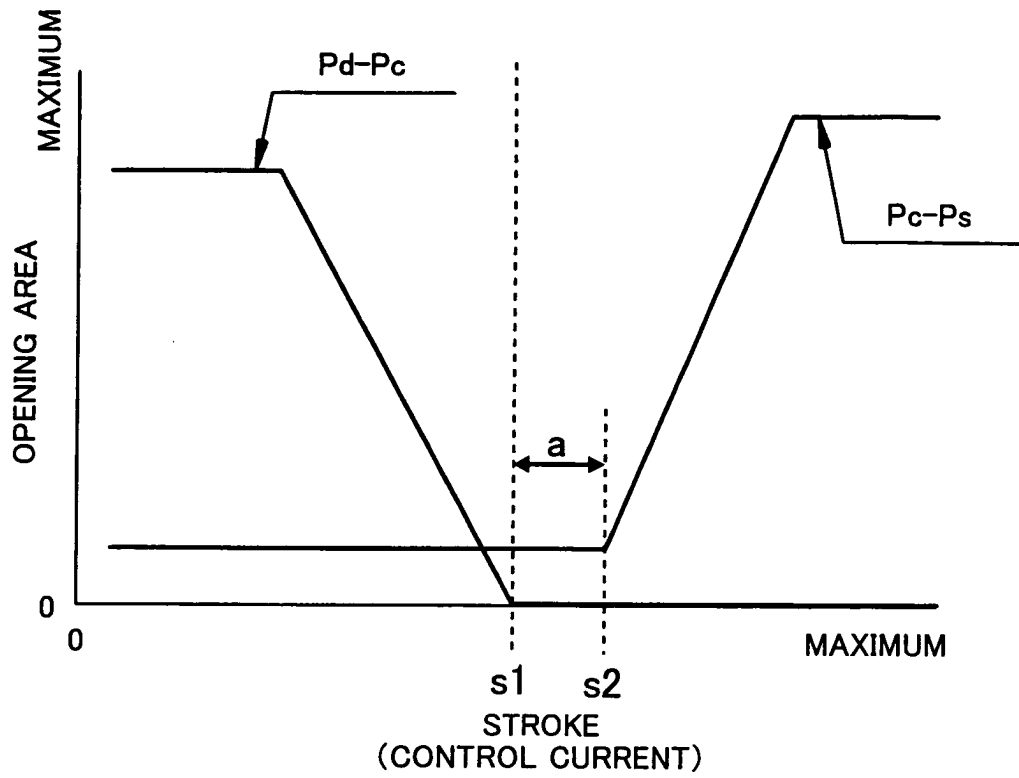


FIG. 5

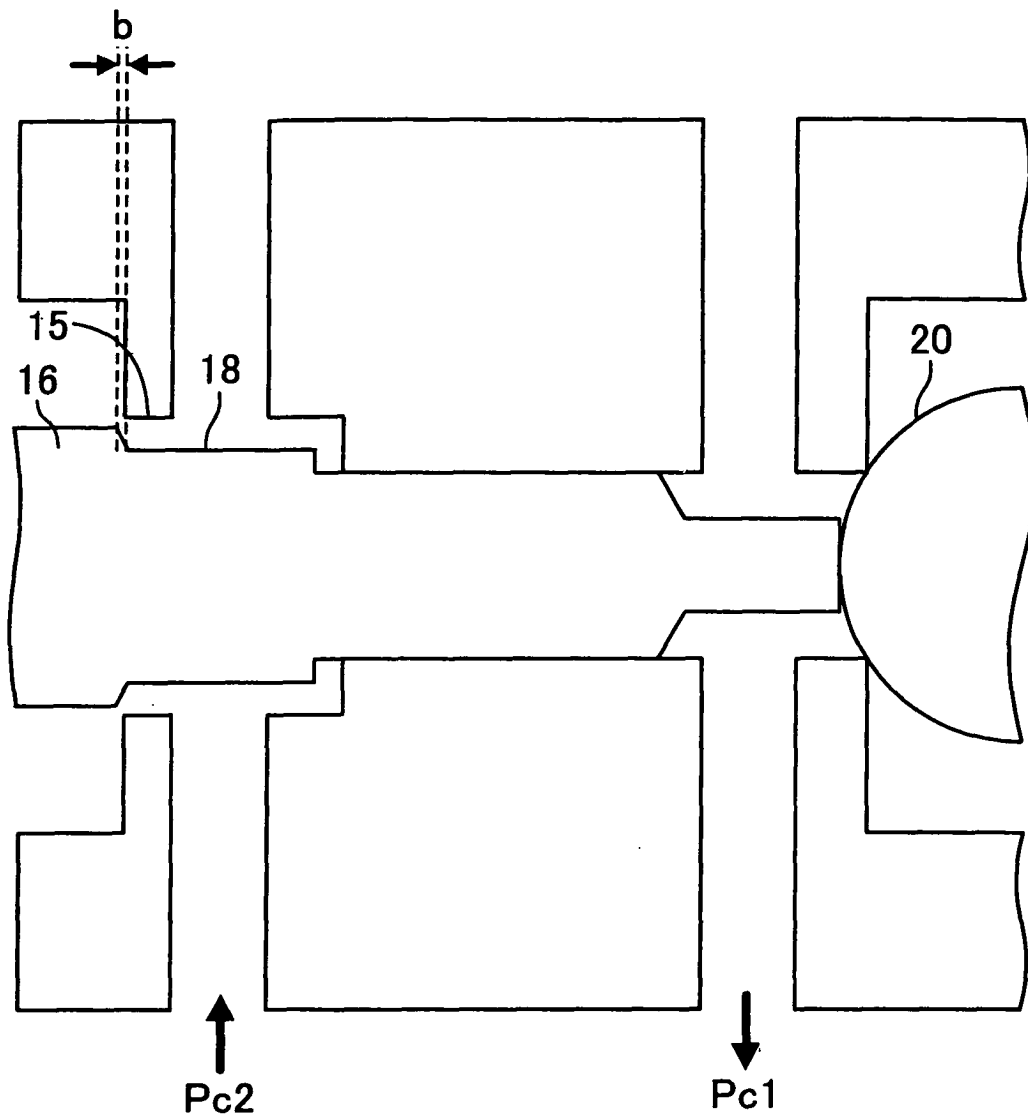


FIG. 6

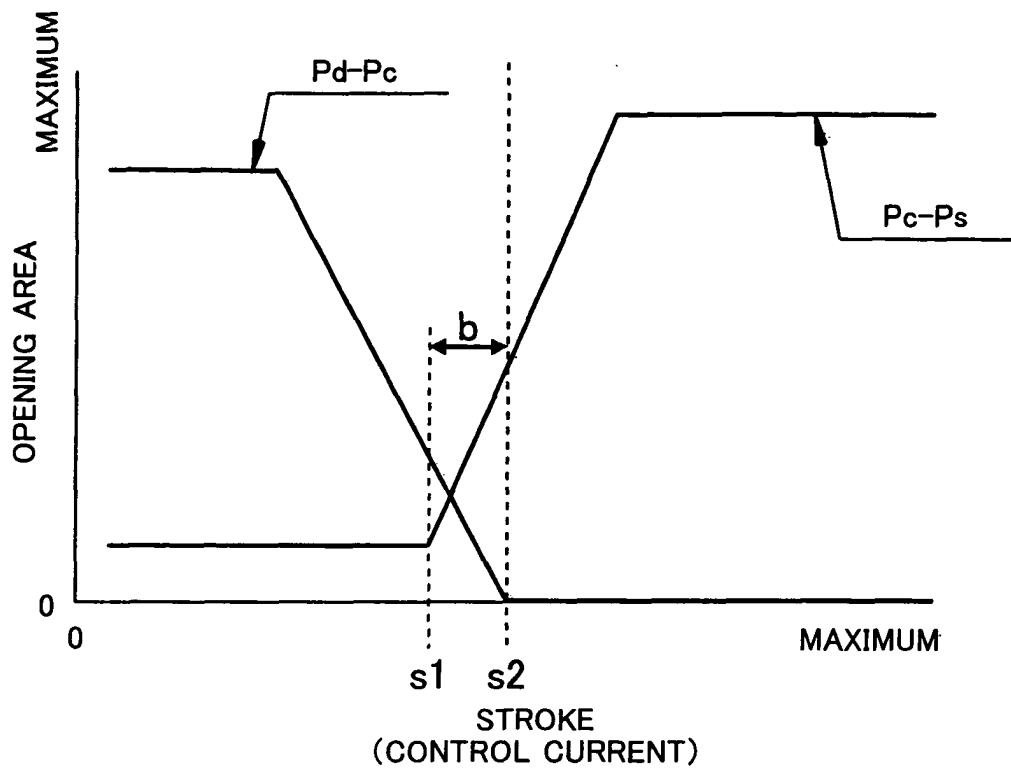


FIG. 7

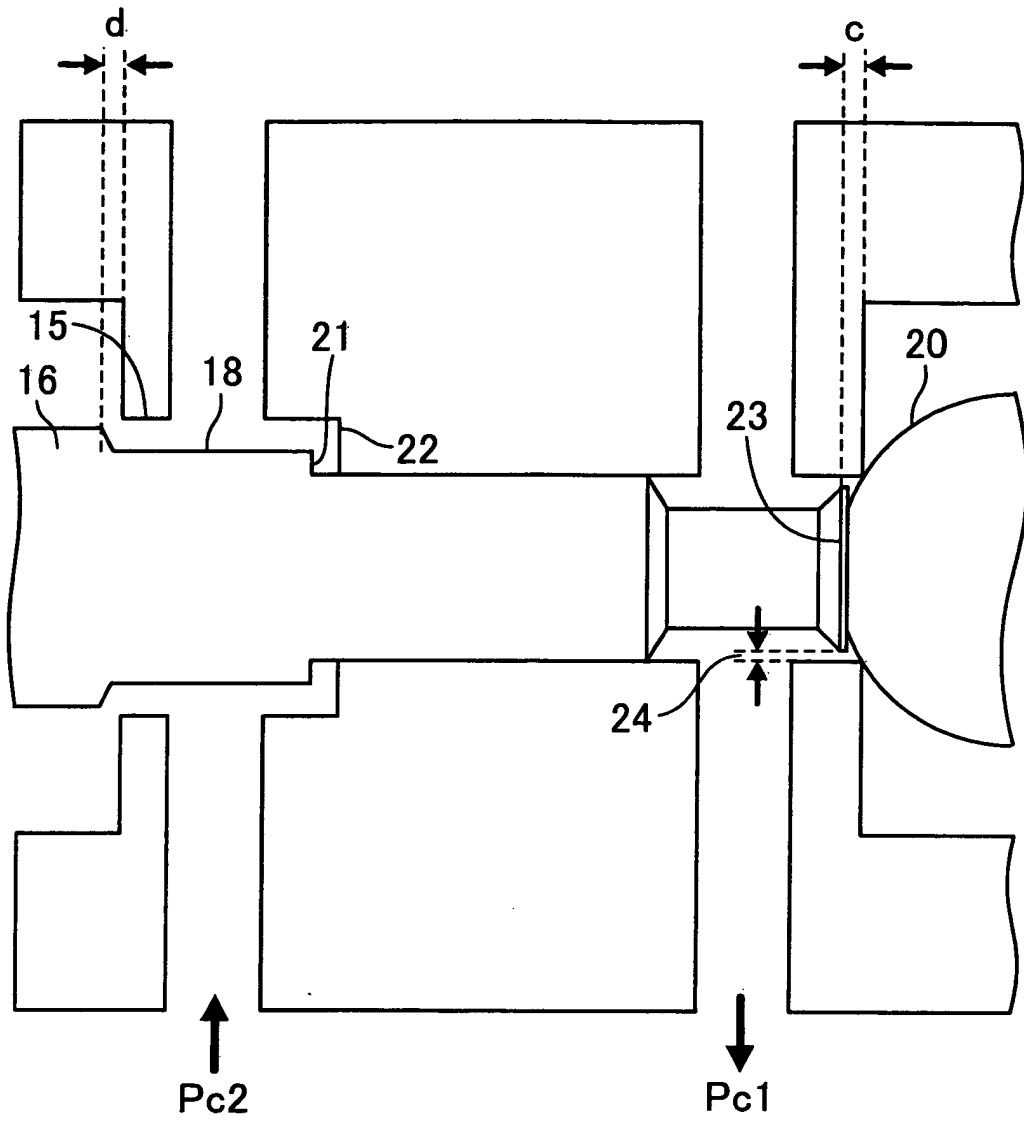


FIG. 8

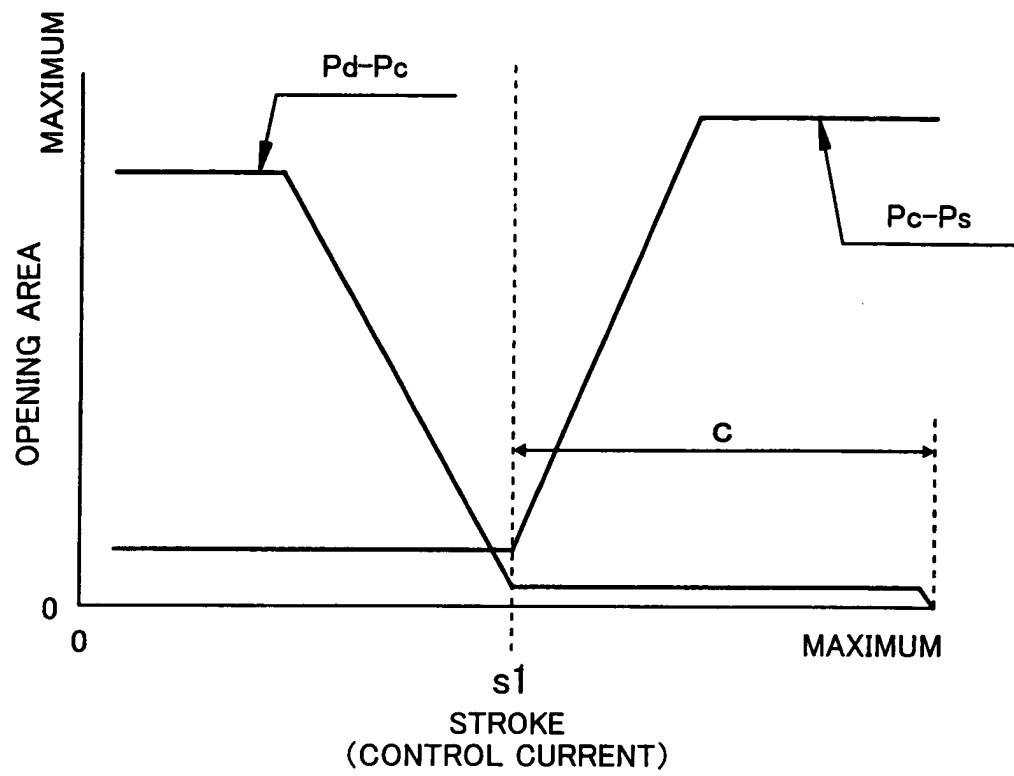


FIG. 9

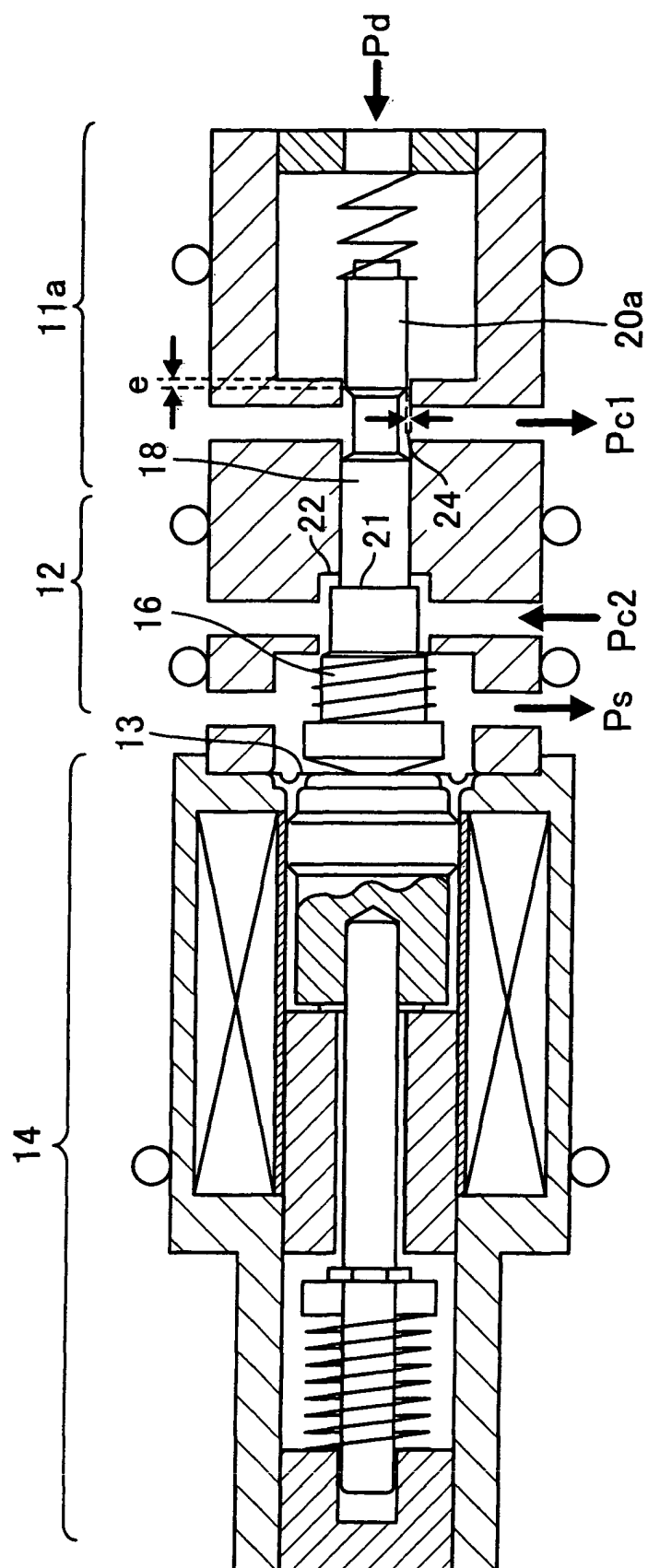


FIG. 10

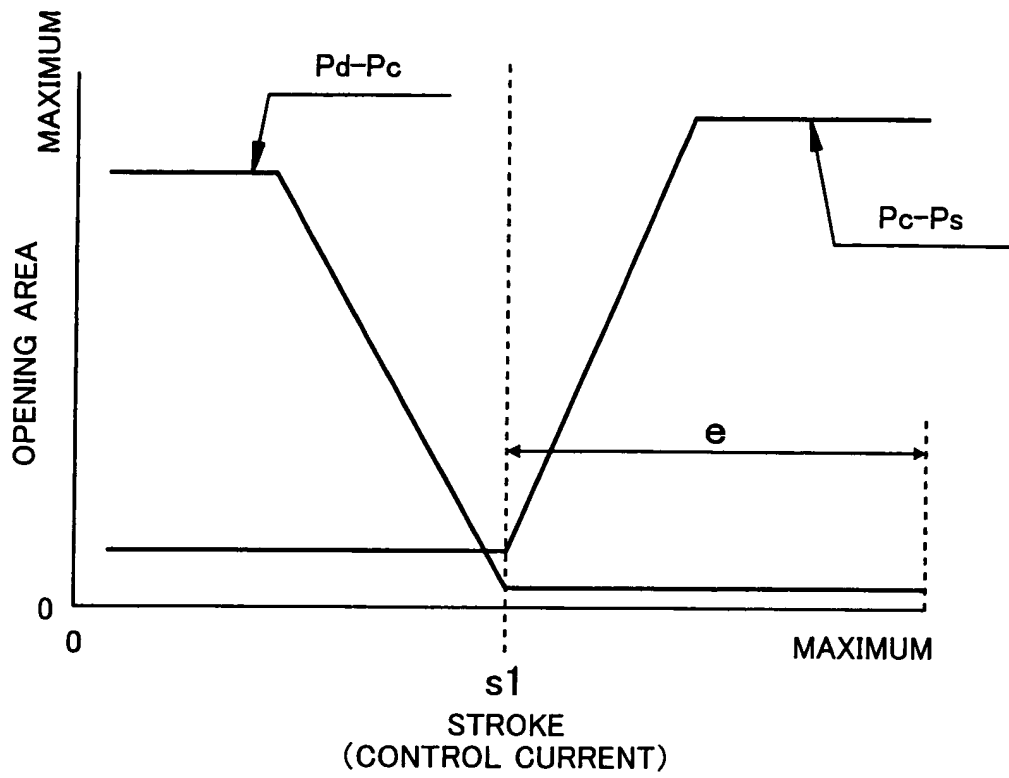


FIG. 11

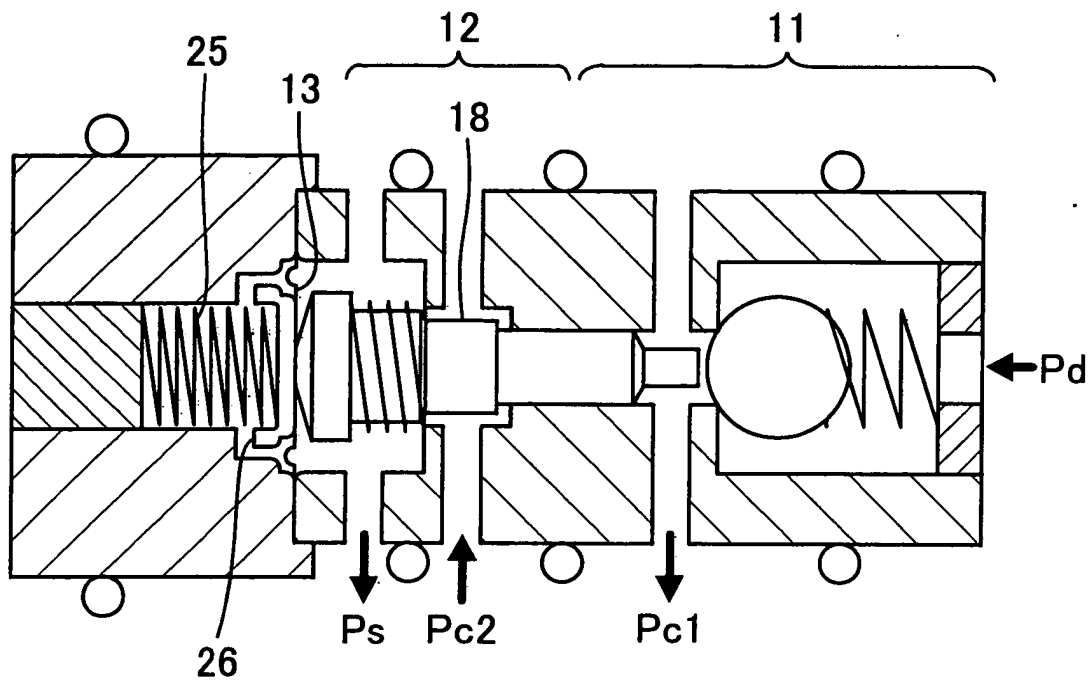


FIG. 12

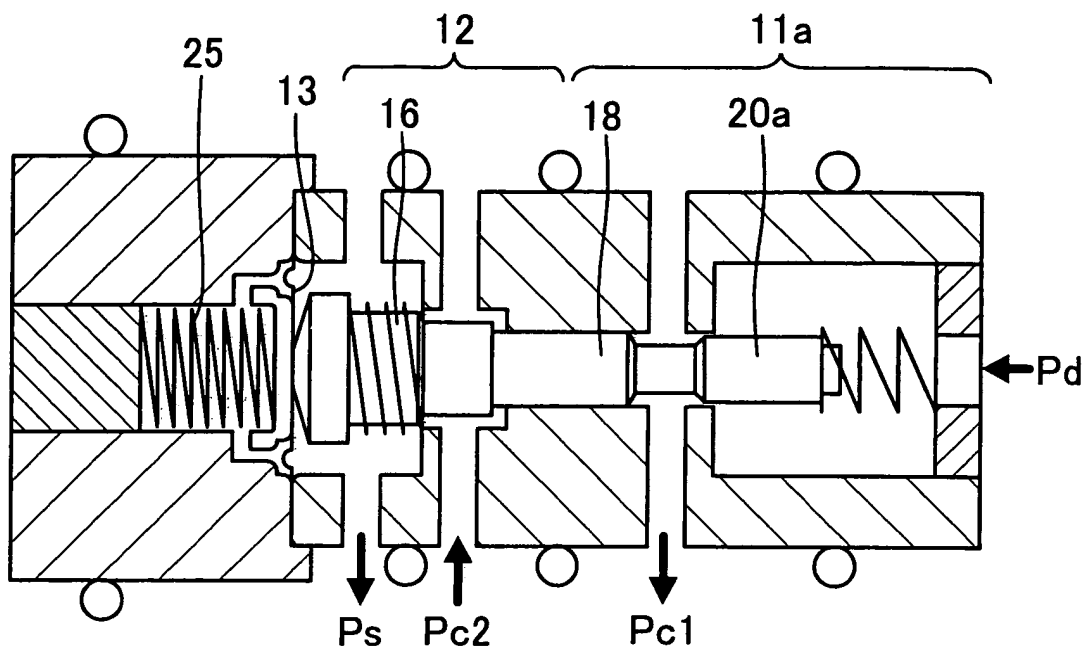


FIG. 13

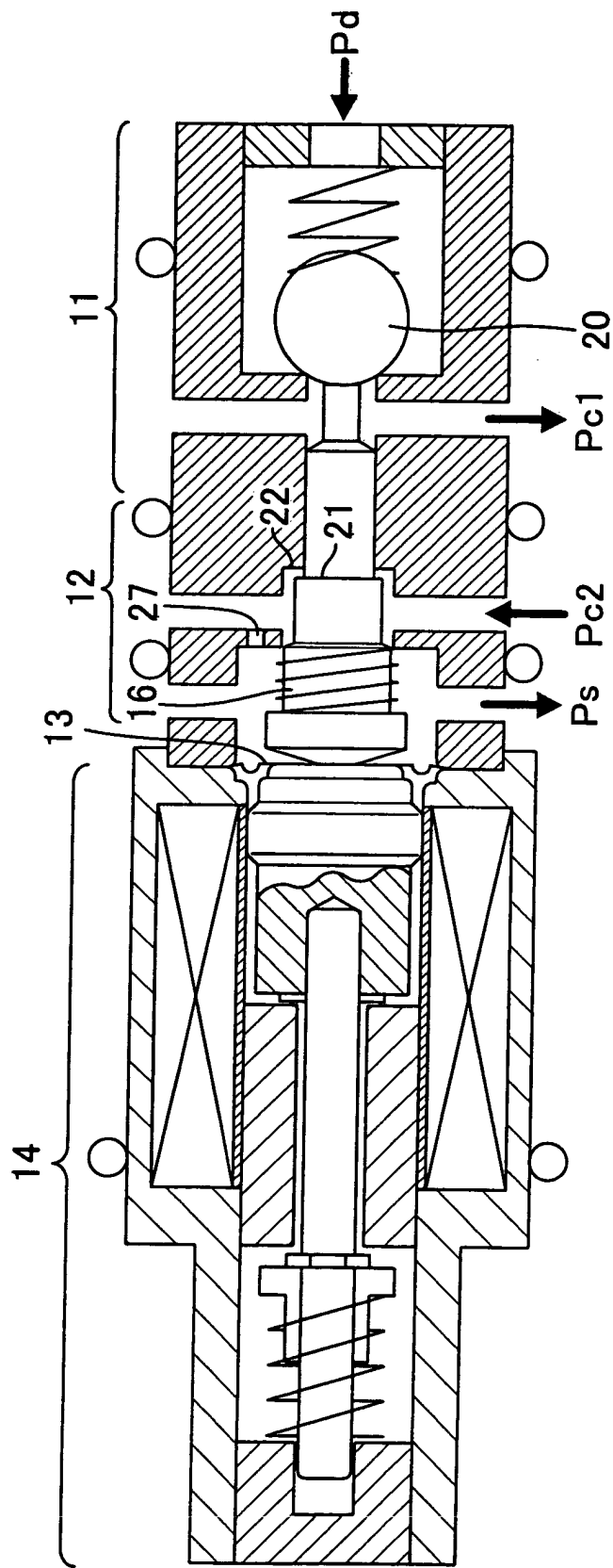


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/000505

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ F04B27/08, 49/08

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.Cl⁷ F04B27/08, 49/08

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2004
Kokai Jitsuyo Shinan Koho 1971-2004 Toroku Jitsuyo Shinan Koho 1994-2004

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.
A	JP 64-41680 A (Honda Motor Co., Ltd.), 13 February, 1989 (13.02.89), (Family: none)	1-12
A	JP 63-243469 A (Toyoda Automatic Loom Works, Ltd.), 11 October, 1988 (11.10.88), & US 4846630 A1	1-12
A	JP 62-240482 A (Toyoda Automatic Loom Works, Ltd.), 21 October, 1987 (21.10.87), & US 4723891 A1	1-12

☐ 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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search
19 April, 2004 (19.04.04)

Date of mailing of the international search report
11 May, 2004 (11.05.04)

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