

(19)



Europäisches Patentamt

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(11)

EP 0 945 617 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
29.09.1999 Bulletin 1999/39

(51) Int. Cl.⁶: F04B 27/18

(21) Application number: 99105008.9

(22) Date of filing: 19.03.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 27.03.1998 JP 10036698

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(54) Displacement control valve for use in variable displacement compressor

(57) For use in a variable displacement compressor having a first and a second passage which are between a crank chamber and a suction chamber and between a discharge chamber and the crank chamber, respectively, a displacement control valve is provided with a first and a second valve mechanism for adjusting opening degrees of the first and the second passages. The second valve mechanism has a valve body which is placed in the second passage and movable in a predetermined direction for opening and closing the second passage with movement thereof in the predetermined direction. The second valve mechanism is provided with a pressure canceling arrangement for making the valve

body be canceled with influence of pressure of the second passage in the predetermined direction. A pressure sensing member senses pressure in the first passage. Responsive to the pressure sensed by the pressure sensing member, the first valve mechanism adjusts the opening degree of the first passage. Responsive to an operation of the first valve mechanism, the second valve mechanism adjusts the opening degree of the second passage. Responsive to an external signal, an external operation mechanism operates the first and the second valve mechanisms.

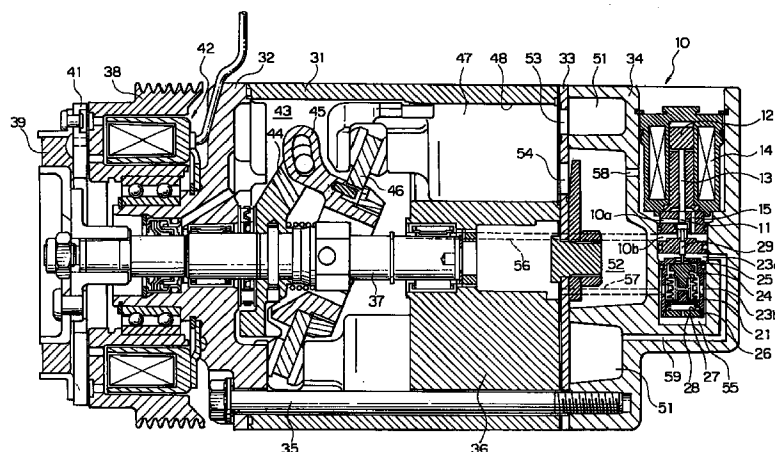


FIG. 3

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Description

Background of the Invention:

[0001] The present invention relates to a displacement control valve for use in a variable displacement compressor which is suitable for being used in an air conditioner of a vehicle, particularly of an automotive vehicle or the like.

[0002] This kind of variable displacement compressor is, for example, disclosed in USP No. 4,606,705. The variable displacement compressor is provided with a displacement control valve for controlling a displacement. The displacement control valve includes a bellows which senses a pressure within a suction chamber of the compressor and first and second valve mechanism which adjusts an opening degree of a passage in an interlocking manner in accordance with the pressure of the suction chamber. An electromagnetic actuator is connected to the bellows and is structured such that an electromagnetic force acts on the first valve mechanism.

[0003] In this displacement control valve, a pressure control point of the suction chamber is changed due to the pressure of the suction chamber even when an energizing amount of the electromagnetic actuator is fixed. That is, the pressure control point of the suction chamber is not definitely determined with respect to the energizing amount, so that a control method for obtaining an optimum discharge displacement becomes complex. Further, since a control for the suction chamber pressure has an upper limit, there is generated a case that a desired discharge displacement can not be maintained under a certain drive condition, so that a serious influence is given to a traveling performance of the vehicle.

Summary of the Invention:

[0004] It is therefore an object of the present invention to provide a displacement control valve structured such that a pressure control point of a suction chamber is definitely determined with respect to an energizing amount to an electromagnetic actuator.

[0005] It is another object of the present invention to provide a displacement control valve which can forcibly maintain a minimum displacement without being affected by a drive condition.

[0006] Other objects of the present invention will become clear as the description proceeds.

[0007] According to an aspect of the present invention, there is provided a displacement control valve for use in a variable displacement compressor having a discharge chamber, a suction chamber, a crank chamber, a first passage between said crank chamber and said suction chamber, a second passage between said discharge chamber and said crank chamber. The displacement control valve comprises a pressure sensing

member for sensing pressure in said first passage, a first valve mechanism for adjusting an opening degree of said first passage in response to said pressure sensed by said pressure sensing member, a second valve mechanism responsive to an operation of said first valve mechanism for adjusting an opening degree or said second passage, and an external operation mechanism responsive to an external signal for operating said first and said second valve mechanism, characterized in that said second valve mechanism comprises a valve body placed in said second passage and movable in a predetermined direction for opening and closing said second passage with movement thereof in said predetermined direction and pressure canceling means for making said valve body be canceled with influence of pressure of said second passage in said predetermined direction.

[0008] According to another aspect of the present invention, there is provided a variable displacement compressor having a discharge chamber, a suction chamber, a crank chamber, a first passage between said crank chamber and said suction chamber, and a second passage between said discharge chamber and said crank member and comprising the displacement control valve connected to said first and said second passages.

Brief Description of the Drawing:

[0009]

Fig. 1 is a vertical cross sectional view of a conventional displacement control valve;

Fig. 2 is a graph which shows a pressure control characteristic of the displacement control valve in Fig. 1;

Fig. 3 is a vertical cross sectional view of a variable displacement compressor provided with a displacement control valve in accordance with a first embodiment of the present invention;

Fig. 4A is a vertical cross sectional view which shows a valve close state of the displacement control valve included in the variable displacement compressor in Fig. 3;

Fig. 4B is a vertical cross sectional view which shows a valve open state of the displacement control valve in Fig. 4A;

Fig. 5 is an enlarged view of a main portion of the displacement control valve in Fig. 4A;

Fig. 6 is a graph which shows a pressure control characteristic of the displacement control valve in Figs. 4A and 4B;

Fig. 7A is a vertical cross sectional view which shows a valve close state of a displacement control valve in accordance with a second embodiment of the present invention; and

Fig. 7B is a vertical cross sectional view which shows a valve open state of the displacement con-

trol valve in Fig. 7A.

Description of the Preferred Embodiments:

[0010] In order to easily understand the present invention, at first, a conventional displacement control valve will be described below with reference to Fig. 1.

[0011] The illustrated displacement control valve corresponds to a structure used in the variable displacement compressor disclosed in USP No. 4,606,705, which includes a bellows 1 sensing a pressure of a suction chamber, a first valve mechanism 2 adjusting an opening degree of a passage extending from a crank chamber of a compressor to the suction chamber and a second valve mechanism 3 adjusting an opening degree of a passage extending from a discharge chamber of the compressor to the crank chamber. The first and second valve mechanisms 2 and 3 are interlocked with each other and controlled to be opened and closed. An electromagnetic actuator 4 is connected to the bellows 1, so that it is structured such that an electromagnetic force acts on the first valve mechanism 2. Accordingly, it is possible to change a pressure control point of the suction chamber in accordance with an energizing amount to the electromagnetic actuator 4.

[0012] However, since the second valve mechanism 3 is structured such that the valve body thereof receives the pressure of the discharge chamber, the pressure control point of the suction chamber changes as shown by Pd1, Pd2 and Pd3 in Fig. 2 due to the pressure of the discharge chamber even when the energizing amount of the electromagnetic actuator 4 is fixed. That is, the pressure control point of the suction chamber is not definitely determined with respect to the energizing amount, so that there is a problem that a control method for obtaining an optimum discharge displacement becomes complex.

[0013] Further, a control for the pressure of the suction chamber has an upper limit, so that, for example, it is impossible to control at the pressure of the suction chamber of 3.7 kg/cm²G or more. When the vehicle normally travels, the pressure of the suction chamber is frequently controlled near a state of 2 kg/cm²G. In the case of intending to reduce the discharge displacement from the state mentioned above when accelerating the vehicle or the like, the discharge displacement is controlled so as to maintain the pressure when the discharge displacement is reduced and the pressure of the suction chamber is increased to 3.7 kg/cm²G. Accordingly, in some drive conditions, there is generated the case that the minimum displacement can not maintained, so that a serious influence may be given to a traveling performance of the vehicle.

[0014] A variable displacement compressor provided with a displacement control valve in accordance with a first embodiment of the present invention will be described below with reference to Fig. 3.

[0015] The shown compressor is used for a vehicle air

conditioner and comprises a tubular casing 31, a front housing 32 closing one axial end of the casing 31, and a cylinder head 34 attached to the other axial end of the casing 31 via a valve plate assembly 33. The casing 31, the front housing 32 and the cylinder head 34 are fixed together by means of bolts 35.

[0016] The casing 31 is integrally provided with a cylinder block 36 therein. A shaft 37 axially extends at the center of the casing 31. The shaft 37 is rotatably supported by the front housing 32 and the cylinder block 36.

[0017] A pulley 38 is rotatably supported on the front housing 32. The pulley 38 is driven by an engine of the vehicle. A ring-shaped armature 41 is supported on an outer end of the shaft 37 via a rubber member 39 so as to be movable axially.

[0018] The armature 41 confronts an axial end surface of the pulley 38 and is controlled to be attached to or detached from the pulley 38 by means of an electromagnetic attracting unit 42. Specifically, when the electromagnetic attracting unit 42 is energized, the armature 41 is attracted and attached to the pulley 38 by an electromagnetic force, so that the torque of the engine is transmitted to the shaft 37. On the other hand, when the energization to the electromagnetic attracting unit 42 is stopped, the armature 41 is detached from the pulley 38 by a restoring force of the rubber member 39, so that the torque of the engine is not transmitted to the shaft 37.

[0019] A crank chamber 43 is defined between the front housing 32 and the cylinder block 36. In the crank chamber 43, a rotor 44 is fixed on the shaft 37. A swash plate 46 is coupled to the rotor 44 via a hinge mechanism 45. The hinge mechanism 45 renders variable an inclination of the swash plate 46 relative to an axis of the shaft 37. The swash plate 46 rotates together with the rotor 44.

[0020] A plurality of pistons 47 engage with peripheral portions of the swash plate 46 via shoes, respectively. The pistons 47 are received in corresponding cylinder bores 48 formed in the cylinder block 36 so as to be axially slidable. When the swash plate 46 rotates, each of the pistons 47 makes a reciprocating motion in the corresponding cylinder bore 48 with a stroke determined by an inclination of the swash plate 46.

[0021] The cylinder head 34 is formed with a suction chamber 51 along its peripheral portion and with a discharge chamber 52 at the center thereof. Between the suction chamber 51 and the discharge chamber 52 is connected a known refrigeration circuit.

[0022] The valve plate assembly 33 is provided with suction holes 53 and discharge holes 54 for establishing communication of the cylinder bores 48 with the suction chamber 51 and the discharge chamber 52, and with valve mechanism for those holes.

[0023] When the shaft 37 rotates, the pistons 47 make the reciprocating motion in the cylinder bores 48, respectively. Following the reciprocating motion of the piston 47, refrigerant gas in the refrigeration circuit is

sucked into the cylinder bores 48 from the suction chamber 51 and discharged into the refrigeration circuit from the discharge chamber 52.

[0024] The compression displacement of the variable displacement compressor depends on the stroke of the pistons 47 determined by the inclination of the swash plate 46. For controlling the inclination of the swash plate 46, a displacement control valve 10 is further provided in a control valve chamber 55 formed in the cylinder head 34. As a result of providing the displacement control valve 10 in the control valve chamber 55, the suction chamber 51 is communicated with the crank chamber 43 through passages 59, 23a, and, 23b, and a particularly narrow passage 57, the discharge chamber 52 being communicated with the crank chamber 43 through passages 58, 10a, 10b, and 56. A combination of the passages 59, 23a, 23b, and 57 is referred to as a first passage. A combination of the passages 58, 10a, 10b, and 56 is referred to as a second passage.

[0025] Referring now to Figs. 4A and 4B in addition, the displacement control valve 10 will be described.

[0026] The displacement control valve 10 is for adjusting the pressure in the crank chamber 43 so as to control the stroke of the pistons 47. The displacement control valve includes a first valve mechanism, a second valve mechanism, and an electromagnetic coil mechanism, as described below.

[0027] The first valve mechanism includes a valve casing 21, a bellows 22 arranged within the valve casing 21, having a vacuumed inner portion, having a spring arranged and receiving the pressure of the crank chamber, a valve body 24 adhered to the bellows 22 and opening and closing a communication passage 23 between the crank chamber and the suction chamber, a fixed throttle 25 bypassing the valve body 24, a guide 26 supporting a lower end in the drawing of the bellows 22 and movably supported to the valve casing 21, a spring 27 urging the guide 26 upward in the drawing, and an adjusting screw 28 adjusting an expansion and contraction amount of the bellows 22 and constituting a part of the valve casing 21.

[0028] The passage 10a is communicated with the discharge chamber 52 through the passage 58 and referred to as a first portion of the second passage. The passage 10b is communicated with the crank chamber 43 through the passage 56 and referred to as a second portion of the second passage. The second valve mechanism comprises a valve seat 10c between the passages 10a and 10b and a second valve body 11 placed in the passage 10a in the vicinity of the valve seat 10c. The second valve body 11 is movable in a predetermined direction, namely, an upward and downward direction.

[0029] The second valve mechanism further includes a transmission rod 29 having an end brought into contact with an upper end in the drawing of the first valve body 24 and movably supported to the valve casing 21. The second valve body 11 is brought into contact with

the other end of the transmission rod 29 and cooperated with the valve seat 10c to open and close the second passage with movement thereof in the predetermined direction in accordance with an expansion and contraction of the bellows 22.

[0030] The electromagnetic coil mechanism includes an electromagnetic coil 14 positioned above the second valve body 11. The electromagnetic coil 14 generates an electromagnetic force for urging the second valve body 11 to a valve close direction via a plunger 12 and a transmission rod 13. The electromagnetic coil mechanism is referred to as an external operation mechanism.

[0031] A side surface 11a of the second valve body 11 is movably supported to the valve casing 1, and a gap between the side surface 11a and an inserting portion in the side of the valve casing 1 is set such as to be significantly narrow. A surface 11c of the second valve body 11 in a side opposite to a contact surface 11b with the valve seat 10c is structured such as to receive the pressure of the crank chamber by a pressure introduction passage 15, adjusts a pressure receiving area of the pressure of the crank chamber in the side of the contact side 11b with the valve seat and a pressure receiving area of the pressure of the crank chamber of the opposite surface 11c, and removes the force of the pressure of the discharge chamber acting in an opening and closing direction of the second valve body 11.

[0032] The area is adjusted and negated so that the formula $P_k \times A_k = P_k \times A_b$ is established when setting the pressure operating to the surface 11c receiving a back pressure of the pressure of the crank chamber to P_k , the area to A_b , the pressure on the contact surface 11b to P_k and the area to A_k . Accordingly, the pressure of the crank chamber does not affect the valve.

[0033] Referring to Fig. 5 in addition, the description will be directed to a shape of the second valve body 11. The second valve body 11 has a first surface 11b facing the valve seat 10c in the predetermined direction and a second surface 11c opposite to the first surface 11b in the predetermined direction. Each of the first and the second surfaces 11b and 11c is inclined relative to the predetermined direction as shown in Fig. 5. Since the discharge pressure P_d is mutually negated on the first and the second surfaces 11b and 11c of the second valve body 11, an influence of the pressure of the discharge chamber is a little or can be lost. In this case, the contact point below the second valve body 11 is preferably structured such that the pressure in the upper portion and the pressure from the lower portion to the upper portion are balanced, that is, in the drawing, a contact point and an operation point of the pressure in the upper portion are, of course, aligned on the same line. A combination of the first and the second surface 11b and 11c serves as a pressure canceling arrangement which is of making the second valve body be canceled with influence of pressure of the second passage in the predetermined direction.

[0034] If the contact point is shifted inward, the dis-

charge force affects, so that the pressure of the crank chamber is also adjudged by the back pressure (for example, the case that the valve seat is in a surface contact is considered). As mentioned above, it is possible to balance the pressure of the crank chamber and remove an influence by the discharge pressure. Accordingly, the first valve body 4 and the second valve body 11 are going to substantially operate in response to the pressure of the suction chamber and the electromagnetic force.

[0035] In this case, in the embodiment mentioned above, the pressure of the crank chamber is employed, however, only the pressure of the suction chamber can be sufficient for keeping a balance.

[0036] In this case, the structure is made such that when the second valve body 11 is opened, the first valve body 24 is opened, and when the first valve body 24 moves to a closing direction, the second valve body 11 is opened, so that the opening degree of the valve is increased. Further, the opening degree of the fixed throttle 5 is set to be sufficiently smaller than the maximum opening degree of the second valve body 11.

[0037] Next, an operation of the displacement control valve will be described below with reference to Figs. 4A, 4B and 6.

[0038] Since the electromagnetic force is not generated in the state of not energizing the electromagnetic coil 14, there is no force of urging the second valve body 11 to a valve closing direction in the pressure balance state, and further, since the bellows 22 having a high balance pressure is contracted, however, is urged upward in the drawing, the first valve body 24 is closed and the second valve body 11 is opened at the maximum opening degree (Fig. 4B). In the case of starting the compressor in this state, since the first valve body 24 is closed, a gas of the crank chamber can flow into the suction chamber only via the fixed throttle 25, however, since the opening degree of the fixed throttle 25 is sufficiently smaller than the maximum opening degree of the second valve body 11, the gas of the discharge chamber is excessively supplied, so that a pressure difference between the crank chamber and the suction chamber is increased so as to be maintained in a minimum displacement. At this time, the pressure difference between the crank chamber and the suction chamber is set so as to be 1 kg/cm² or less.

[0039] Since the urging force of the spring 27 is small and the pressure difference between the crank chamber and the suction chamber acting in a direction of closing the first valve body 24 in the minimum displacement state is small at 1 kg/cm² or less, for example, in a current range of a little energizing amount i0 A to the electromagnetic coil 14, the second valve body 11 can be closed and the first valve body 24 can be opened. For example, when starting the compressor from the state that the pressure is balanced at 6 kg/cm²G and adjusting the energizing amount to the electromagnetic coil 14 so that the pressure of the suction chamber becomes 2

kg/cm²G (a current value i3 A), the second valve body 11 is closed, and the first valve body 24 is opened. Accordingly, since the pressure of the crank chamber is reduced to the same value as the pressure of the suction chamber, the compressor is maintained in the maximum displacement and the pressure of the suction chamber is gradually reduced.

[0040] In accordance that the pressure of the suction chamber is reduced, the bellows 22 is extended, and the lower end in the drawing of the guide 26 is brought into contact with the adjusting screw 28 (Fig. 4A), so that the function of the spring 27 is lost. At this time, since the force due to the pressure of the crank chamber acting on the second valve body 11 is canceled in the surface 11b side and the surface 11c side, and the pressure of the discharge chamber does not act in an axial direction of the valve body 11, the first valve body 24 and the second valve body 11 area controlled to be opened and closed in accordance with the electromagnetic force and the pressure of the suction chamber acting on the bellows 22. That is, when the pressure of the suction chamber is reduced to 2 kg/cm²G, the bellows 22 is extended, the first valve body 4 is operated in a closing direction and the second valve body 11 is operated in an opening direction, so that the gas of the discharge chamber is introduced into the crank chamber, and further, since the opening degree of the communication passage 23 is reduced, the pressure difference between the crank chamber and the suction chamber is increased and the discharge displacement is reduced. Accordingly, when the pressure of the suction chamber is increased, the bellows 22 is contracted, the first valve body 24 is operated in an opening direction and the second valve body 11 is operated in a closing direction, the amount of the gas of the discharge chamber introduced into the crank chamber is reduced, and further, since the opening degree of the communication passage 23 is increased, the pressure difference between the crank chamber and the suction chamber is reduced and the discharge displacement is increased.

[0041] As mentioned above, the opening degrees of the first valve body 24 and the second valve body 11 are adjusted so that the pressure of the suction chamber becomes a predetermined value, so that the discharge displacement is controlled. Accordingly, as shown in Fig. 6, the control point of the pressure of the suction chamber is substantially determined in a definite manner by the current value.

[0042] In this case, when making the current value 0 from the state, the bellows 22 is extended, the first valve body 24 is fully closed, and the second valve body 11 is fully opened, so that the pressure difference between the crank chamber and the suction chamber is significantly increased and moves to the minimum displacement in a moment. Therefore, even when the pressure of the suction chamber is increased and the bellows is contracted, the bellows 22 is urged by the spring 27 upward in the drawing, so that the first valve body 24 is

closed and the second valve body 11 is maintained in an open valve state. Accordingly, in the case that the current value is 0, the minimum displacement is always in the minimum displacement.

[0043] In accordance with the displacement control valve mentioned above, since the structure is made such as to adjust the pressure receiving area on the surface in the contact side with the valve seat of the valve body of the second valve mechanism and in the opposite side so as to substantially remove the pressure of the discharge chamber acting in the opening and closing direction of the valve body, a pressure control characteristic in the suction chamber can be obtained stably and without affected by the pressure of the discharge chamber. Since the crank chamber and the suction chamber are communicated with each other by the fixed throttle even when the valve body of the first valve mechanism is fully closed, the pressure difference between the crank chamber and the suction chamber does not become excessive at the minimum displacement, and a durability of the compressor is not deteriorated. In the electromagnetic coil mechanism, in the case of setting the energizing to the electromagnetic actuator to 0, the pressure sensing member is shifted upward in the drawing by the spring member, the valve body of the first valve mechanism is closed and the valve body of the second valve mechanism is opened, so that the minimum displacement can be always maintained. In the electromagnetic coil mechanism, in the case of setting the energizing to the electromagnetic actuator to 0, the valve body of the first valve mechanism is shifted upward in the drawing by the spring member so as to close the valve and the valve body of the second valve mechanism is opened, so that the minimum displacement can be always maintained.

[0044] Accordingly, when applying to an air conditioner for the vehicle or the automotive vehicle, the minimum displacement can be always maintained, so that a stable traveling of the automotive vehicle can be secured without giving an excessive load.

[0045] A displacement control valve in accordance with a second embodiment of the present invention will be described below with reference to Figs. 7A and 7B. The same reference numerals are attached to the same elements, and an explanation thereof will be omitted.

[0046] In this displacement control valve, the first valve body 24 is movably supported to a guide 26 fixed to the bellows 22. A spring 27 is interposed between the first valve body 24 and the bellows 22 and urges the first valve body 24 in a closing direction.

[0047] Also in accordance with this displacement control valve, the same effects can be obtained with respect to a maintenance of the minimum displacement in the same manner as the displacement control valve shown in Figs. 4A and 4B.

[0048] While the present invention has thus far been described in connection with a few embodiments thereof, it will readily be possible for those skilled in the

art to put this invention into practice in various other manners. For example, it is a matter of course that the present invention can be applied to the other various types of variable displacement compressors.

Claims

1. A displacement control valve for use in a variable displacement compressor having a discharge chamber, a suction chamber, a crank chamber, a first passage between said crank chamber and said suction chamber, a second passage between said discharge chamber and said crank chamber, said displacement control valve comprising a pressure sensing member for sensing pressure in said first passage, a first valve mechanism for adjusting an opening degree of said first passage in response to said pressure sensed by said pressure sensing member, a second valve mechanism responsive to an operation of said first valve mechanism for adjusting an opening degree of said second passage, and an external operation mechanism responsive to an external signal for operating said first and said second valve mechanism, characterized in that said second valve mechanism comprises a valve body placed in said second passage and movable in a predetermined direction for opening and closing said second passage with movement thereof in said predetermined direction and pressure canceling means for making said valve body be canceled with influence of pressure of said second passage in said predetermined direction.
2. A displacement control valve as claimed in claim 1, wherein said second passage has a first and a second portion which are connected to said discharge chamber and said crank chamber, respectively, said second valve mechanism further comprising a valve seat between said first and said second portions, said valve body being placed in said first portion and having a first surface facing said valve seat in said predetermined direction and a second surface opposite to said first surface in said predetermined direction, a combination of said first and said second surfaces serving as said pressure canceling means.
3. A displacement control valve as claimed in claim 2, wherein each of said first and said second surfaces is inclined relative to said predetermined direction.
4. A displacement control valve as claimed in anyone of claims 1 through 3, further comprising throttle means for bypassing said first valve mechanism to communicate said crank chamber with said suction chamber.
5. A displacement control valve as claimed in anyone

of claims 1 through 4, further comprising a spring member urging said pressure sensing member to close said first valve mechanism.

6. A displacement control valve as claimed in claim 5, further comprising a valve casing for receiving said pressure sensing member, said spring member being interposed between said valve casing and said pressure sensing member. 5
7. A displacement control valve as claimed in claim 5, wherein said spring member is interposed between said first valve mechanism and said pressure sensing member. 10
8. A variable displacement compressor having a discharge chamber, a suction chamber, a crank chamber, a first passage between said crank chamber and said suction chamber, and a second passage between said discharge chamber and said crank chamber and comprising the displacement control valve claimed in anyone of claims 1 through 7 and connected to said first and said second passages. 15 20

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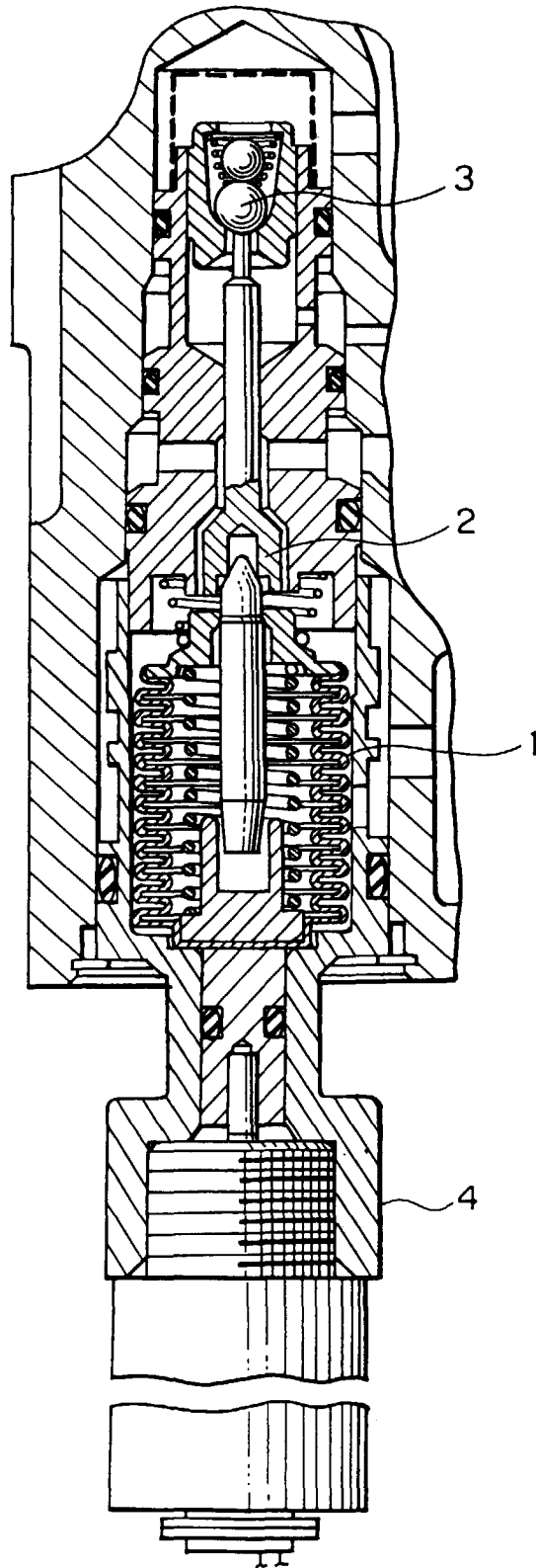


FIG. 1 PRIOR ART

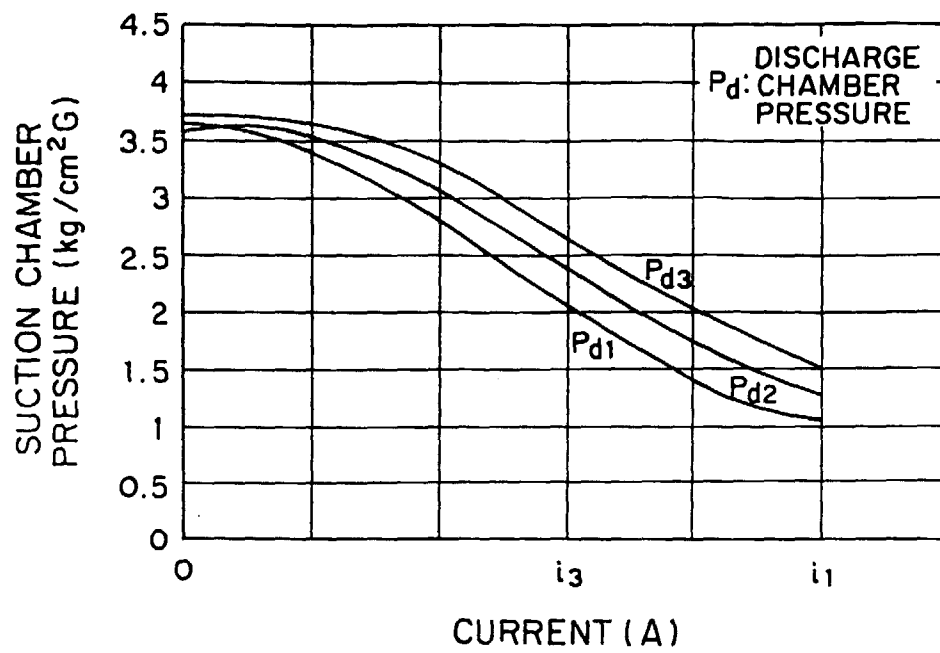


FIG. 2

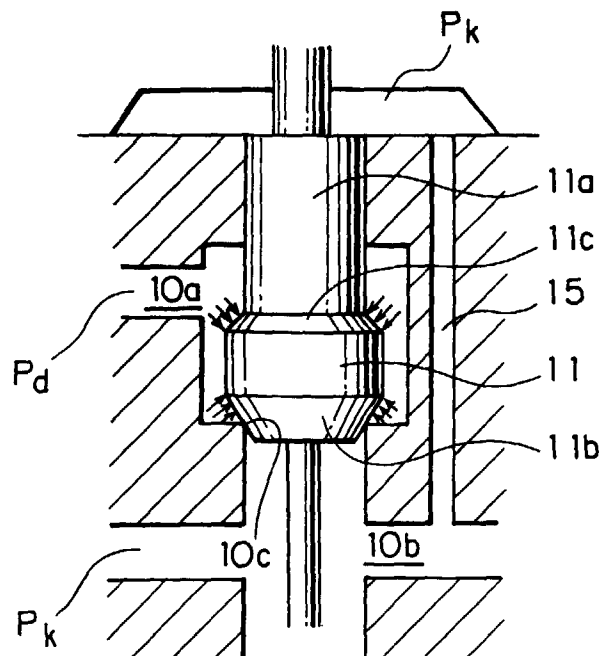


FIG. 5

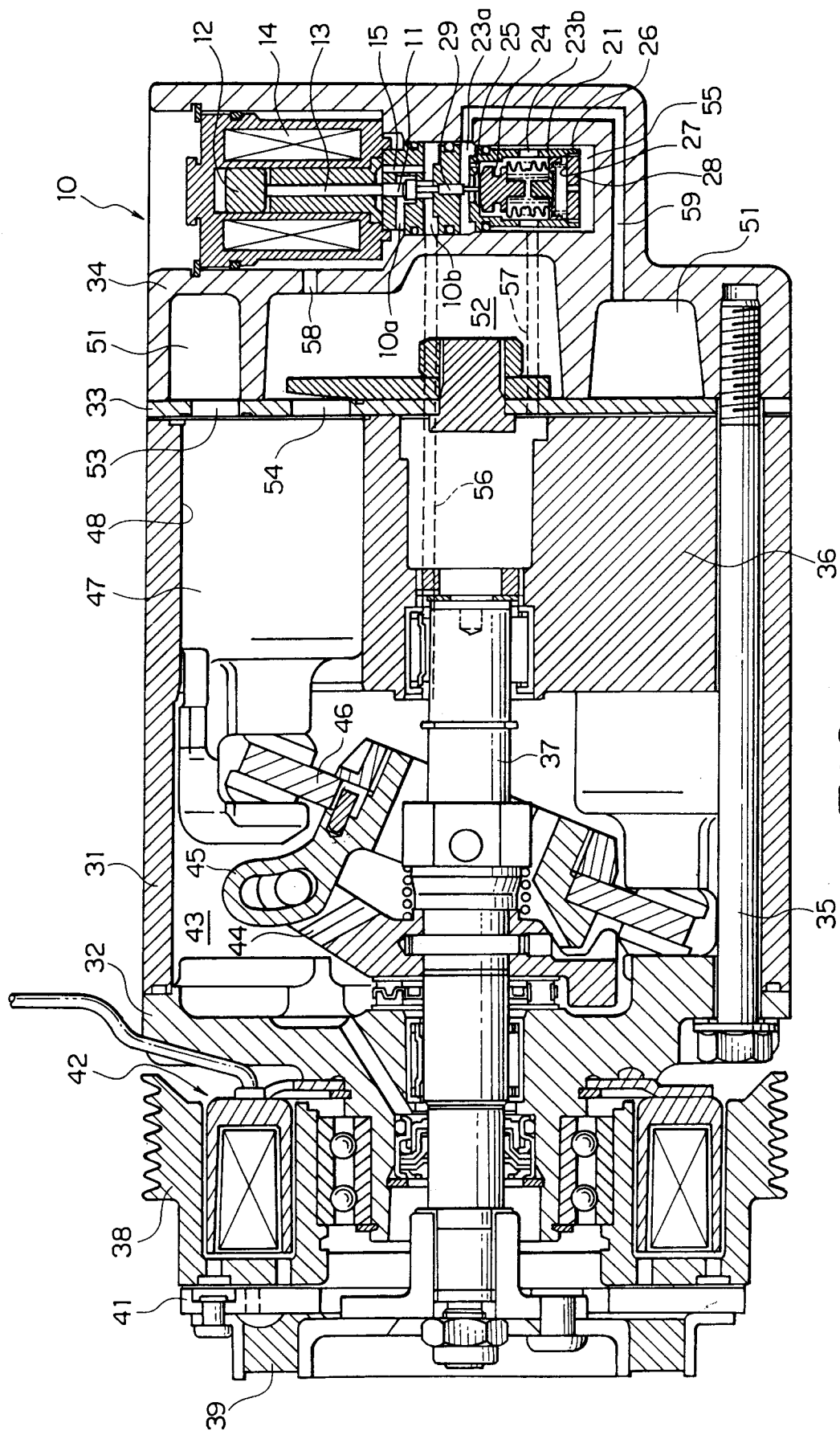


FIG. 3

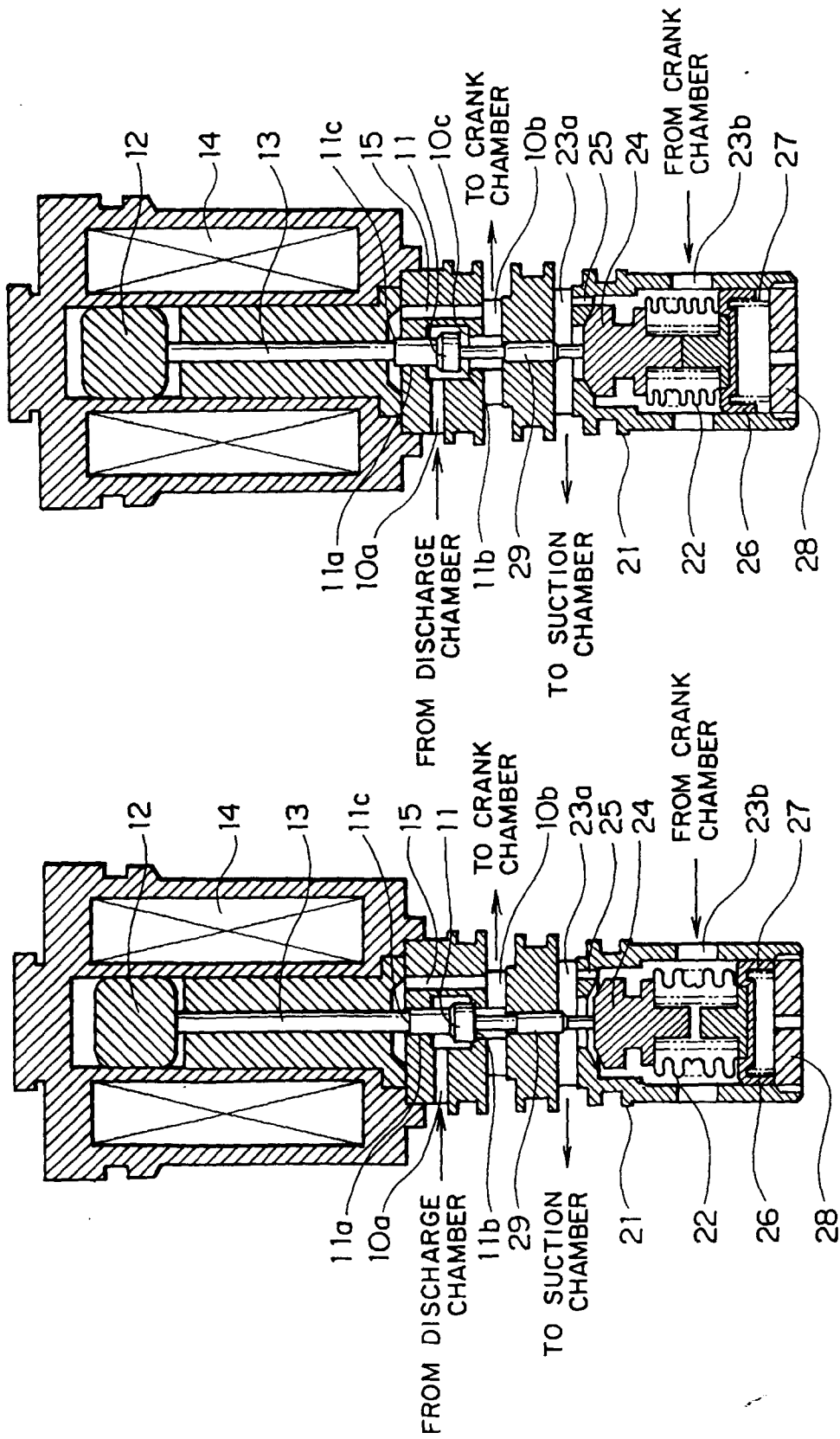
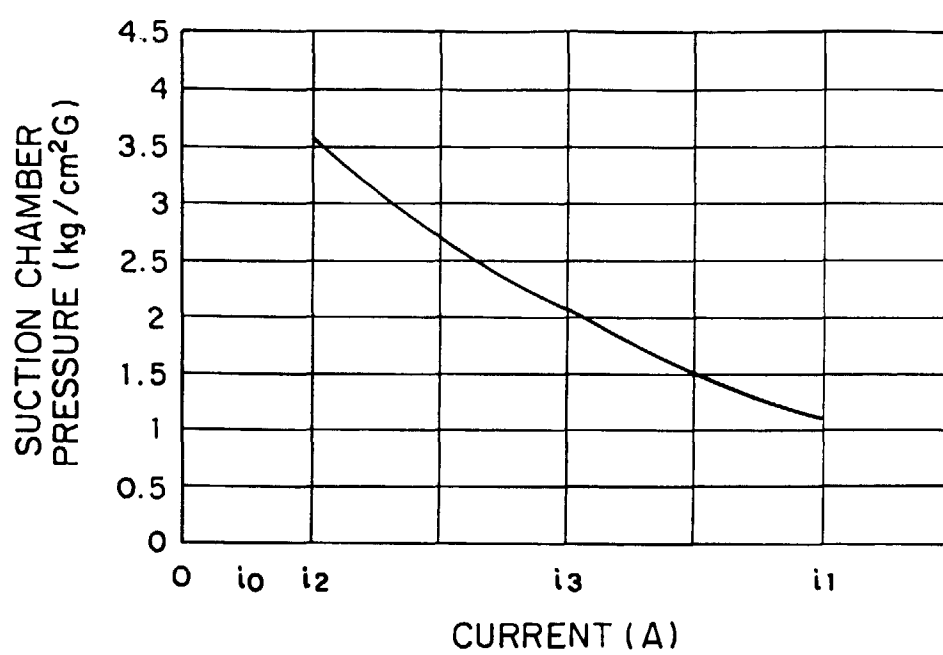


FIG. 4B

FIG. 4A

**FIG. 6**

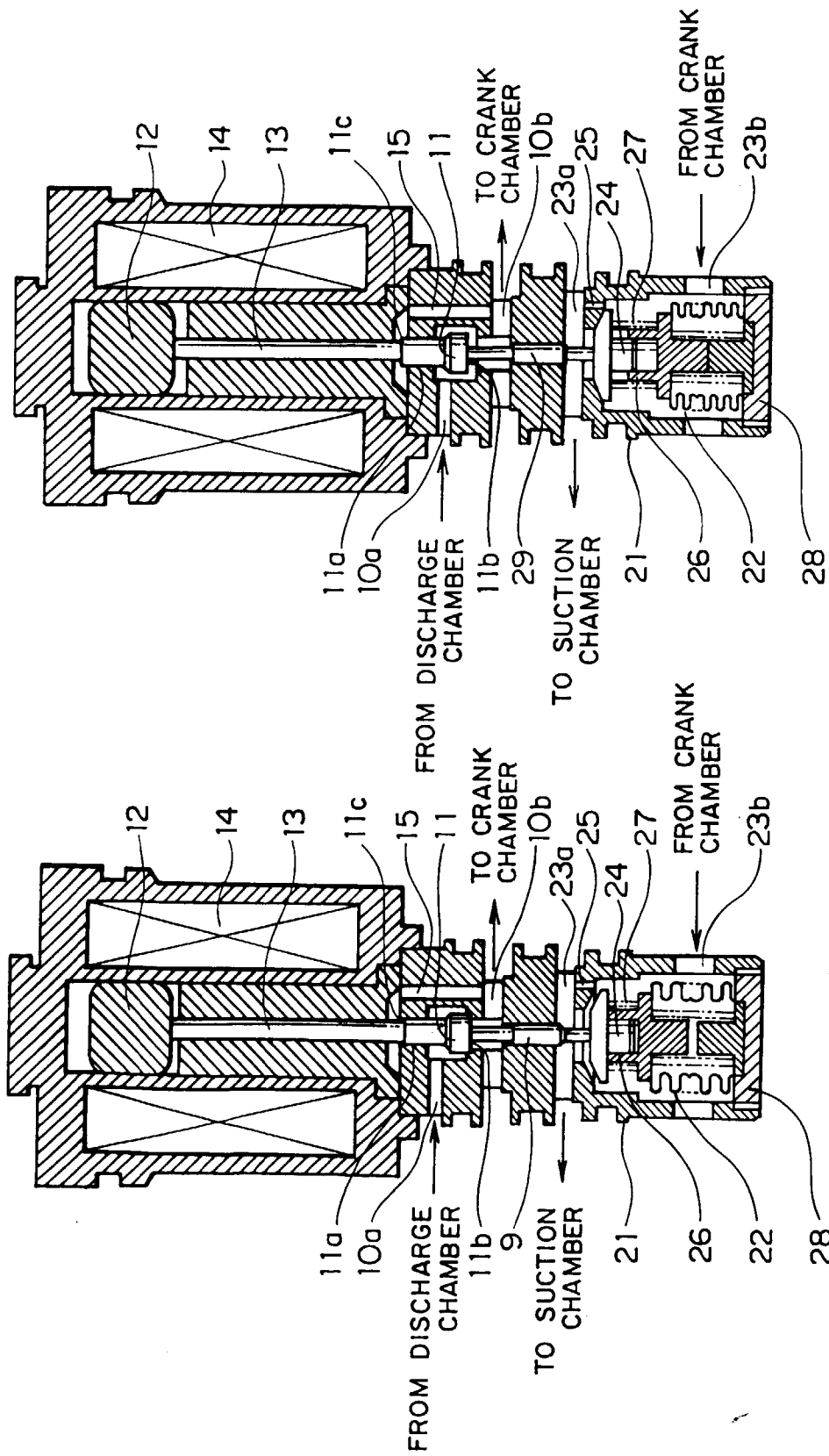


FIG. 7A

FIG. 7B