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(71) Applicant: **SANDEN CORPORATION**
Isesaki-shi Gunma-ken (JP)

(72) Inventors:
- **Terauchi, Kiyoshi, Sanden Corporation Isesaki-shi, Gunma 372 (JP)**
- **Taguchi, Yukihiko, Sanden corporation Isesaki-shi, Gunma 372 (JP)**
- **Ogura, Toshiyuki, Sanden Corporation Isesaki-shi, Gunma 372 (JP)**

(74) Representative: **Prüfer, Lutz H., Dipl.-Phys. et al**
PRÜFER & PARTNER GbR,
Patentanwälte,
Harthauser Strasse 25d
81545 München (DE)

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

(57) In a displacement control valve (10) for use in a variable displacement compressor, a valve casing (11) defines a communication passage (17) for communicating a discharge chamber (52) with a crank chamber (43) to conduct gas from the discharge chamber to the crank chamber. A valve member (18) is coupled to said communication passage and movable between a open position and a close position in a predetermined direction. The valve member is biased towards the open position on expansion of a pressure sensitive member (12) which causes the expansion in the predetermined direction in response to a pressure in at least one of the suction chamber and the crank chamber. The pressure sensitive member is movable in relation to the valve casing in the predetermined direction. A spring (14) urges the pressure sensitive member in the predetermined direction to make the pressure sensitive member urge the valve member towards the open position.

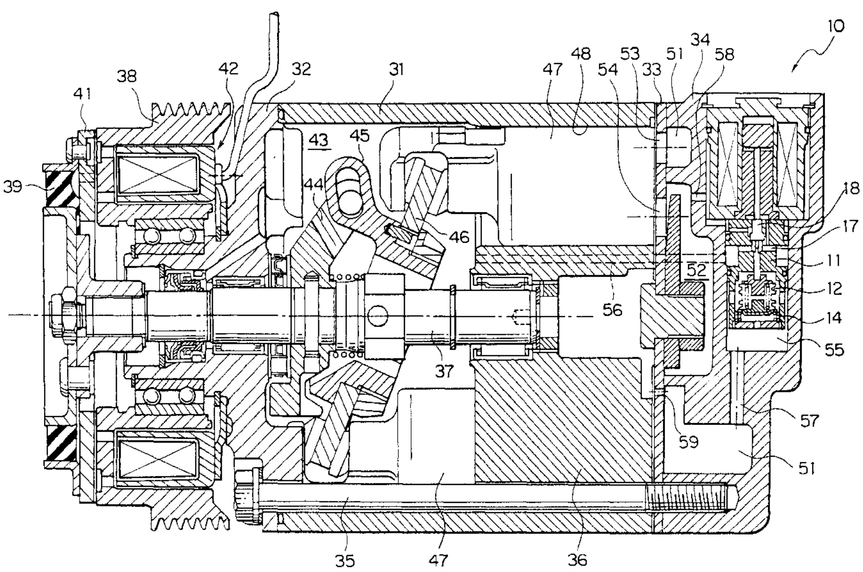

FIG. 1

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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 included in, for example, a vehicle air conditioner.

[0002] As such a variable displacement compressor, there has been a type having a piston. In the manner known in the art, the compressor of the type comprises a crank chamber, a suction chamber, and a discharge chamber. The piston has a piston stroke controlled in response to the pressure in the crank chamber. Therefore, the compressor has a displacement which is variable and determined in accordance with the piston stroke.

[0003] For making the displacement be variable, a displacement control valve is assembled to the variable displacement compressor to control the piston stroke. Various displacement control valves have been known in the art.

[0004] Referring now to Fig. 6, description will be made as regards an example of the conventional displacement control valves. The shown displacement control valve monitors the pressure in the suction chamber by means of a bellows 1 and opens/closes a ball valve 2 depending on the monitored suction chamber pressure so as to adjust the amount of gas introduced into the crank chamber from the discharge chamber. This is a bellows valve structure of a so-called internal control type.

[0005] On the basis of the bellows valve structure of this type, an electromagnetic actuator 3 is further disposed over the ball valve 2 so that an electromagnetic force is exerted on the ball valve 2. Thus, the operation point of the bellows valve, i.e. the pressure control point of the suction chamber, can be changed according to the current amount supplied to the electromagnetic actuator 3. In Fig. 6, it is assumed that the pressure in the discharge chamber is constant.

[0006] According to the structure shown in Fig. 6, there should be an upper limit in suction chamber pressure. For example, in Fig. 7, the suction chamber pressure can not be controlled over 3.7kg/cm^{2}G.

[0007] During the normal running of the vehicle, the pressure in the suction chamber is controlled across 2kg/cm^{2}G so that no problem is raised. On the other hand, during acceleration of the vehicle, the discharge displacement may be reduced for enhancing the acceleration performance. In this case, the discharge displacement is reduced while the pressure in the suction chamber increases. When the pressure in the suction chamber increases up to 3.7kg/cm^{2}G, the discharge displacement is controlled to keep this pressure. Accordingly, depending on the vehicle operating condition, the required minimum displacement can not be achieved to given a serious influence onto the vehicle running performance.

Summary of the Invention:

[0008] It is therefore an object of the present invention to provide a displacement control valve which makes it possible to forcibly keep a variable displacement compressor at the minimum displacement.

[0009] Other objects of the present invention will become clear as the description proceeds.

[0010] A displacement control valve to which the present invention is applicable is for use in a variable displacement compressor having a suction chamber, a crank chamber, and a discharge chamber. The displacement control valve comprises a valve casing defining a communication passage for communicating the discharge chamber with the crank chamber to conduct gas from the discharge chamber to the crank chamber, a valve member coupled to the communication passage and movable between an open position and a close position in a predetermined direction to open the communication passage at the open position and to close the communication passage at the close position, and a pressure sensitive member for causing expansion thereof in the predetermined direction in response to a pressure in at least one of the suction chamber and the crank chamber to bias the valve member towards the open position on the expansion. The displacement control valve is characterized in that the pressure sensitive member is movable in relation to the valve casing in the predetermined direction and by further comprising an elastic member for urging the pressure sensitive member in the predetermined direction to make the pressure sensitive member urge the valve member towards the open position.

Brief Description of the Drawing:

[0011]

Fig. 1 is a longitudinal sectional view showing the overall structure of a variable displacement compressor;

Figs. 2A and 2B are longitudinal sectional views of a displacement control valve according to a first embodiment of the present invention, wherein Fig. 2A shows the state of a normal operation of the compressor while Fig. 2B shows the state of the minimum displacement of the compressor;

Fig. 3 is a graph showing a pressure control characteristic of the displacement control valve shown in Figs. 2A and 2B;

Fig. 4 is a longitudinal sectional view of a second embodiment of the present invention;

Fig. 5 is a longitudinal sectional view of a third embodiment of the displacement control valve shown in Figs. 2A and 2B;

Fig. 6 is a longitudinal sectional view of a conventional displacement control valve; and

Fig. 7 is a graph showing a pressure control characteristic of the displacement control valve shown in Fig. 6.

Description of the Preferred Embodiments:

[0012] Referring to Fig. 1, description will at first be made as regards a variable displacement compressor including a displacement control valve according to a first embodiment of the present invention.

[0013] 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.

[0014] 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.

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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.

[0020] 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 mechanisms for those holes.

[0021] When the shaft 37 rotates, the pistons 47 make the reciprocating motion in the cylinder cores 48, respectively. Following the reciprocating motion of the pistons 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.

[0022] 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.

[0023] The control valve chamber 55 communicates with the crank chamber 43, the suction chamber 51 and the discharge chamber 52 via passages 56, 57 and 58, respectively. Further, the suction chamber 51 communicates with the crank chamber 43 via a narrow passage 59.

[0024] Referring now to Figs. 2A and 2B in addition, the displacement control valve 10 will be described.

[0025] The displacement control valve 10 adjusts the pressure in the crank chamber 43 so as to control the stroke of the pistons 47. The displacement control valve 10 comprises a valve casing 11 having an opening at its lower end in the figures and a bellows 12 disposed as a pressure sensitive member in the cavity of the valve casing 11. The inside of the bellows 12 is under vacuum and provided with a spring.

[0026] The displacement control valve 10 further comprises a guide 13 receiving a lower end (in the figures) of the bellows 12 and disposed in the cavity of the valve casing 11 so as to be slidable along the valve casing 11 in an upward and downward direction in the figures, a compressed coil spring 14 as an elastic member for biasing the guide 13 upward (in the figures) in the cavity of the valve casing 11, and an adjusting screw 15 screwed in the opening of the valve casing 11 to close the opening and adjusting the expansion/contraction amount of the bellows 12. The adjusting screw 15 is movable in the upward and downward direction so at to enable adjustment of urging force of the spring 14. Form figs. 2A and 2B, it will be noted that the guide is placed between the bellows 12 and the adjusting screw 15 in the upward and downward direction.

[0027] A transfer rod 16 engages at its one end with an upper end (in the figures) of the bellows 12 and supported by the valve casing 11 so as to be movable. A valve member 18 engages with the other end of the transfer rod 16 so as to open/close a communication passage 17 between the discharge chamber 52 and the crank chamber 43 depending on the expansion/contraction of the bellows 12. In other words, the valve member is coupled to the communication passage 17 and is movable between a open position and a close position in a predetermined direction or the upward and down ward direction to open the communication passage 17 at the open position and to close the communication passage at the close position.

[0028] In addition, an electromagnetic coil 21 generates an electromagnetic force urging the valve member 18 in a valve closing direction via a plunger 19 and a transfer rod 20. A combination of the electromagnetic coil 21, the plunger 19, and the transfer rod 20 is referred to as an externally biasing mechanism which is supplied with an external signal and is for generating a biasing force to apply the biasing force to the valve member towards the close position.

[0029] The valve casing 11 has a plurality of lateral holes 11a. The adjusting screw 15 has a through hole 15a. Each of the lateral holes 11a and the through hole 15a communicates the cavity of the valve casing 11 with the suction chamber 51 through the passage 57 and the control valve chamber 55. Therefore, the cavity of the valve casing 11 is subjected to the pressure of the suction chamber 51.

[0030] Referring now to Fig. 3 in addition, the description will be made as regards an operation of the displacement control valve 10. It is assumed that the pressure in the discharge chamber 52 is constant.

[0031] Since no electromagnetic force is generated in the state where the electromagnetic coil 21 is not energized, there is no force urging the valve member 18 in the valve closing direction in a pressure balanced state. Thus, although the bellows 12 is contracted when the pressure in the suction chamber 51 is high, since the valve member 18 is biased upward (in the figures) by means of the spring 14, the valve member 18 is constantly opened. If the compressor is activated in this state, the gas in the discharge chamber 52 is constantly introduced into the crank chamber 43 to increase a pressure differential between the crank chamber 43 and the suction chamber 51, so that the compressor is kept at the minimum displacement.

[0032] The biasing force of the spring 14 is set to be small, for example, smaller than an electromagnetic force generated by a current value i0(A) supplied to the electromagnetic coil 21. Thus, the valve member 18 can be closed in a current region of i0(A) or greater.

[0033] Assuming that the compressor is activated in the state where the pressures are balanced under 6kg/cm^{2}G and that the current amount supplied to the electromagnetic coil 21 is adjusted to a current value i3(A) for controlling the pressure in the suction chamber 51 to be 2kg/cm^{2}G, since an electromagnetic force generated by the electromagnetic coil 21 is greater than the biasing force of the spring 14, the valve member 18 is closed. Thus, the pressure in the crank chamber 43 is lowered to be equal to the pressure in the suction chamber 51. Therefore, the compressor is kept at the maximum displacement, and the pressure in the suction chamber 51 is gradually lowered. As the pressure in the suction chamber 51 is lowered, the bellows 12 is expanded to cause a lower end (in the figures) of the guide 13 to abut the adjusting screw 15, so that a function of the spring 14 is lost, and thus, the same function as the conventional displacement control valve shown in Fig. 6 is obtained. Specifically, when the pressure in the suction chamber 51 is lowered to 2kg/cm^{2}G, the bellows 12 is expanded to move the valve member 18 in a valve opening direction. Therefore, the gas in the discharge chamber 52 is introduced into the crank chamber 43 to increase a pressure differential between the crank chamber 43 and the suction chamber 51, so that the discharge displacement is reduced. Following this, when the pressure in the suction chamber 51 increases, the bellows 12 is contracted to move the valve member 18 in the valve closing direction. Accordingly, the pressure in the crank chamber 43 is lowered to reduce a pressure differential between the crank chamber 43 and the suction chamber 51, so that the discharge displacement increases.

[0034] In this fashion, the opening degree of the valve member 18 is adjusted to converge the pressure in the suction chamber 51 to a given value, so that the discharge displacement is controlled. If the current value is set to be zero in this state, the bellows 12 is expanded to cause the valve member 18 to be fully open. Thus, since a pressure differential between the crank chamber 43 and the suction chamber 51 highly increases, the minimum displacement is realized. Even if this increases the pressure in the suction chamber 51 up to greater than 3.5kg/cm^{2}G in Fig. 3 to contract the bellows 12, since the valve member 18 is urged upward (in the figures) by the spring 14 to be constantly opened, the compressor is kept at the minimum displacement.

[0035] Turning to Fig. 4, the description will be directed to a displacement control valve according to a second embodiment of the present invention. The displacement control valve is also designated by the reference numeral 10 and comprises similar parts designated by like reference numerals.

[0036] In the displacement control valve 10, the valve casing 11 has a flange portion 11b at its lower end. The flange portion 11b is inwardly extended to define the opening of the valve casing 11. The opening has a relatively small portion 11c and a relatively large portion 11d. The adjusting screw 15 is screwed in the relatively small portion 11c of the opening and receives the spring 14 thereon. On the other hand, the guide 13 is slidably inserted in the relatively large portion 11d. As a result, the spring 14 is in contact with the adjusting screw 15, while the guide 13 is in contact with the valve casing 11 in an axial direction or the upward and downward direction in the figure. It should be noted here that the guide 13 is placed between the valve casing 11 and the bellows 12 in the predetermined direction.

[0037] According to this structure, a biasing force of the spring 14 can be desirably adjusted by operating the adjusting screw 15. The displacement control valve shown in Fig. 4 is operated like the displacement control valve shown in Figs. 2A and 2B.

[0038] Turning to Fig. 5, the description will be directed to a displacement control valve according to a third embodiment of the present invention. The displacement control valve is also designated by the reverence numeral 10 and comprises similar part designated by like reference numerals.

[0039] In the displacement control valve 10, the guide 13 is fixed to an upper end (in the figure) of the bellows 12 and slidable along the valve casing 11 in the upward and downward direction. The adjusting screw 15 is screwed in the opening of the valve casing 11. The through hole 15a of the adjusting screw 15 is slidably received with an attachment 22 attached to a lower end of the bellows 12. The spring 14 is placed between the guide 13 and the adjusting screw 15 to surround the bellows 12 and urges the guide 13 upwardly. The displacement control valve shown in Fig. 5 is also operated like the displacement control valve shown in Figs. 2A and 2B. It should be noted here that the bellows 12 is placed between the guide 13 and the adjusting screw 15 in the predetermined direction.

[0040] 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, the cavity of the valve casing may communicate with the crank chamber in addition to the suction chamber or in place of the suction chamber. The spring may comprise a coil spring, a leaf spring, or the like. As the elastic member, use may be made of a plastic member or a rubber member in place of the spring.

Claims

1. A displacement control valve (10) for use in a variable displacement compressor having a suction chamber (51), a crank chamber (43), and a discharge chamber (52), said displacement control valve comprising a valve casing (11) defining a communication passage (17) for communicating said discharge chamber with said crank chamber to conduct gas from said discharge chamber to said crank chamber, a valve member (18) coupled to said communication passage and movable between an open position and a close position in a predetermined direction to open said communication passage at said open position and to close said communication passage at said close position, and a pressure sensitive member (12) for causing expansion thereof in said predetermined direction in response to a pressure in at least one of said suction chamber and said crank chamber to bias said valve member towards said open position on said expansion, characterized in that said pressure sensitive member is movable in relation to said valve casing in said predetermined direction, and by further comprising an elastic member (14) for urging said pressure sensitive member in said predetermined direction to make said pressure sensitive member urge said valve member towards said open position.

2. A displacement control valve as claimed in claim 1, wherein said valve casing defines a cavity containing said pressure sensitive member therein, characterized by further comprising a guide (13) coupled to said pressure sensitive member in said cavity and slidable along said valve casing in said predetermined direction and an adjusting member (15) attached to said valve casing to face said guide in said predetermined direction, said elastic member being placed between said adjusting member and said guide, said adjusting member being movable in said predetermined direction so as to enable adjustment of urging force of said spring.

3. A displacement control valve as claimed in claim 2, wherein said guide is placed between said pressure sensitive member and said adjusting member in said predetermined direction.

4. A displacement control valve as claimed in claim 2, wherein said guide is placed between said valve casing and said pressure sensitive member in said predetermined direction.

5. A displacement control valve as claimed in claim 2, wherein said pressure sensitive member is placed between said guide and said adjusting member.

6. A displacement control valve as claimed in any one of claims 2 through 5, wherein said adjusting member is screwed in said valve casing to close an opening of said cavity.

7. A displacement control valve as claimed in any one of claims 2 through 6, further comprising at least one hole (11a, 15a) for communicating said cavity with at least one of said suction chamber and said crank chamber.

8. A displacement control valve as claimed in any one of claims 1 through 7, wherein said pressure sensitive member comprises a bellows (12) causing expansion/contraction thereof in said predetermined direction in response to a change of said pressure.

9. A displacement control valve as claimed in any one of claims 1 through 8, further comprising an externally biasing mechanism (19, 20, 21) supplied with

an external signal for generating a biasing force to apply said biasing force to said valve member towards said close position.

10. A displacement control valve as claimed in any one of claims 1 through 9, wherein said elastic member comprises a spring (14).

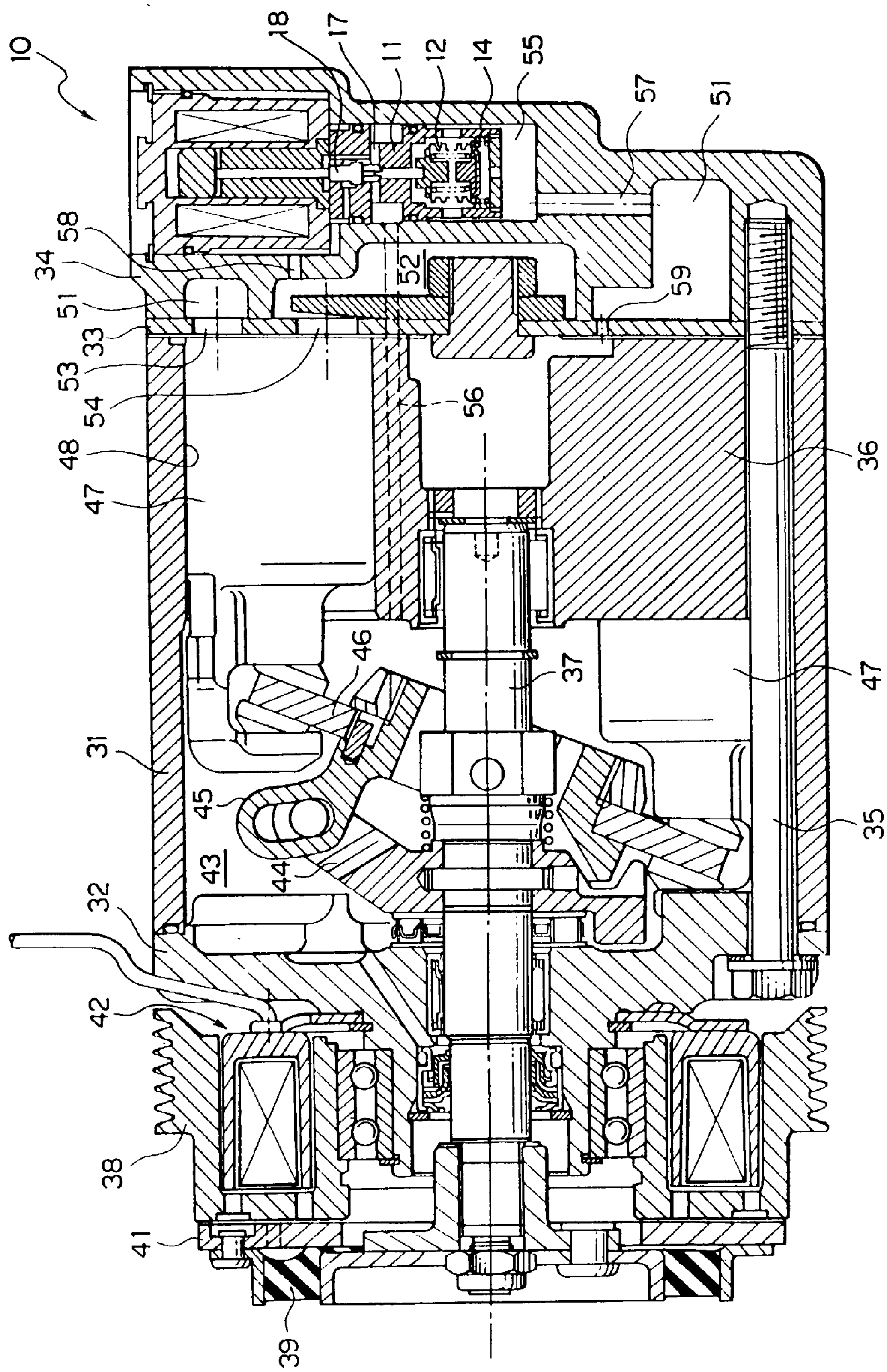
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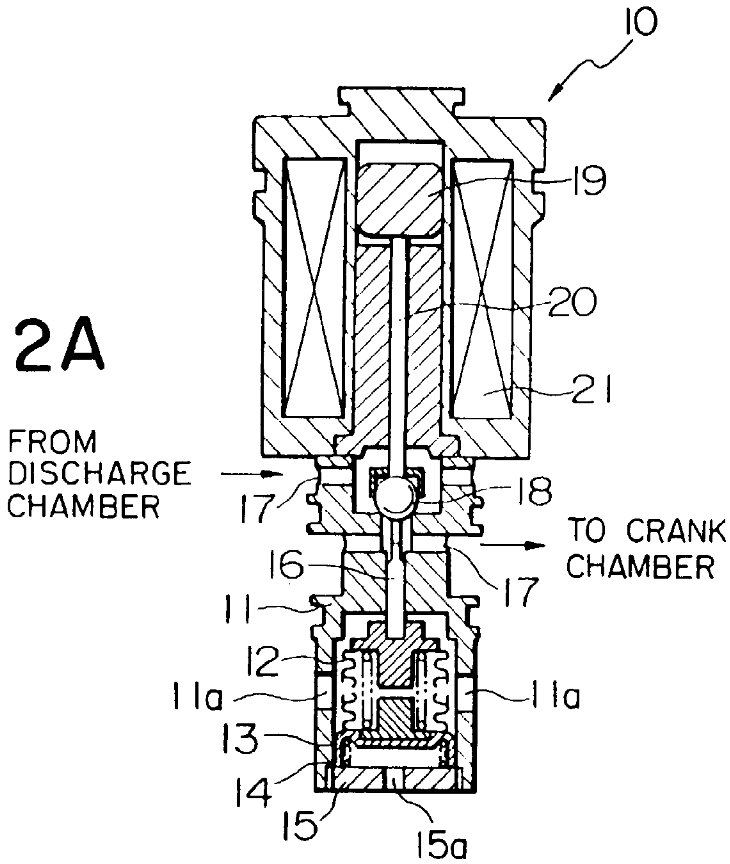
FIG. 1

FIG. 2A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FROM
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TO CRANK
CHAMBER
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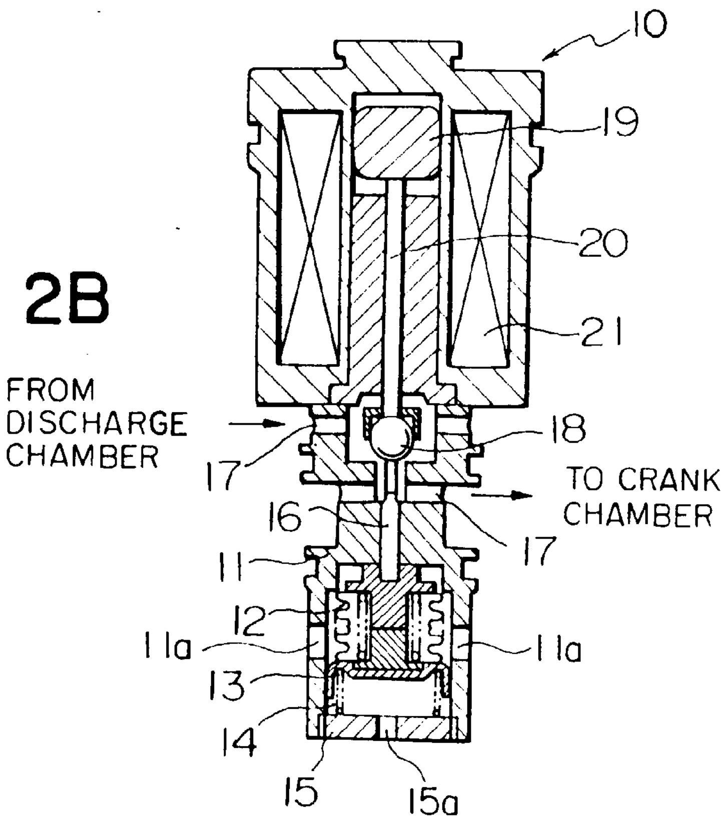
FIG. 2B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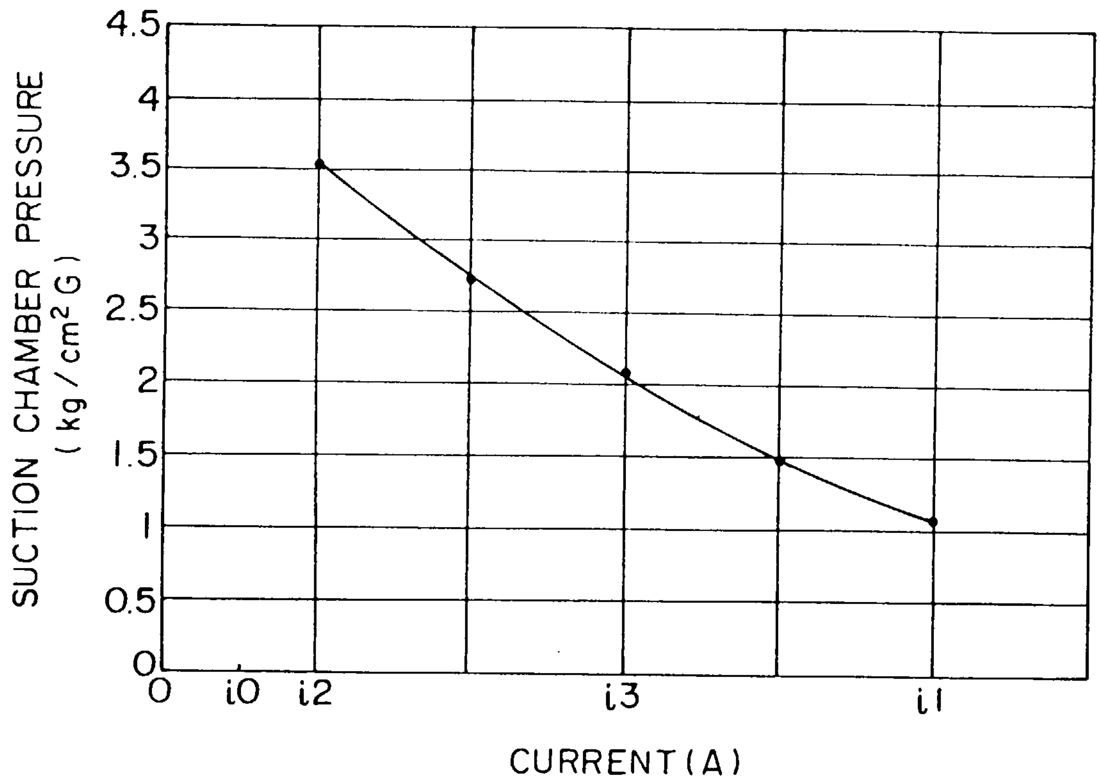
SUCTION CHAMBER PRESSURE
(kg / cm² G)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
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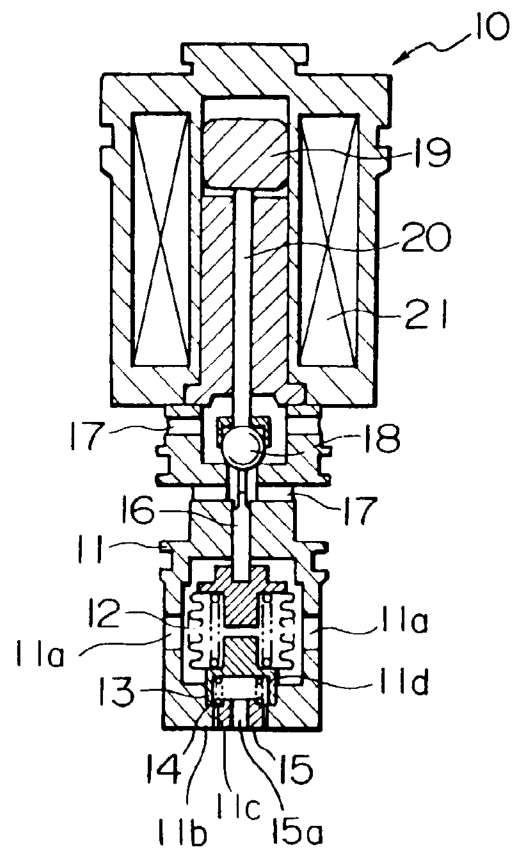
O
i0
i2
i3
i1
CURRENT (A)

FIG. 3

FIG. 4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11c
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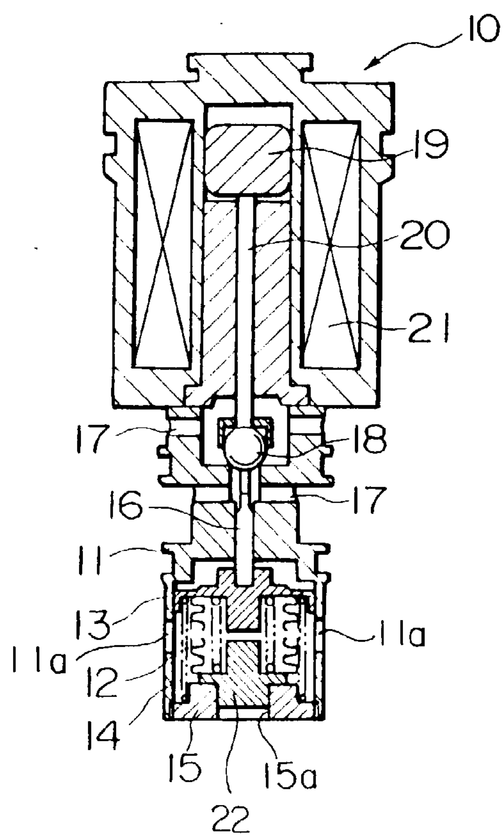
FIG. 5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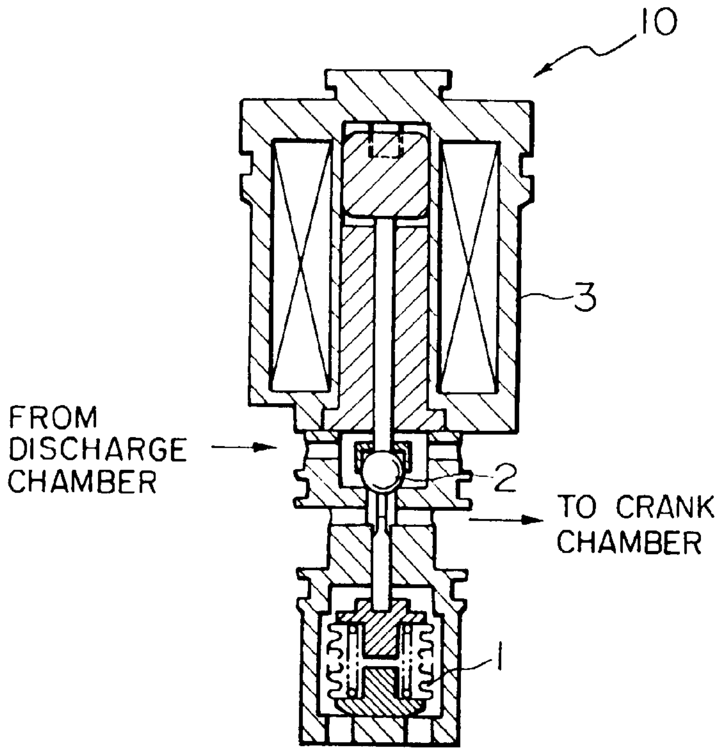

FIG. 6 PRIOR ART

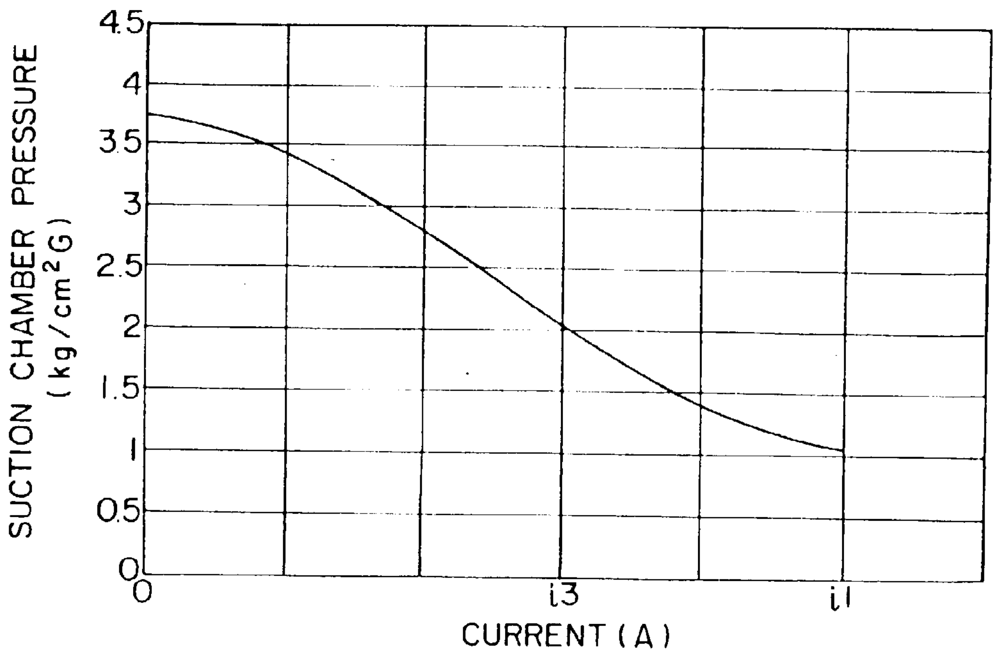

FIG. 7 PRIOR ART