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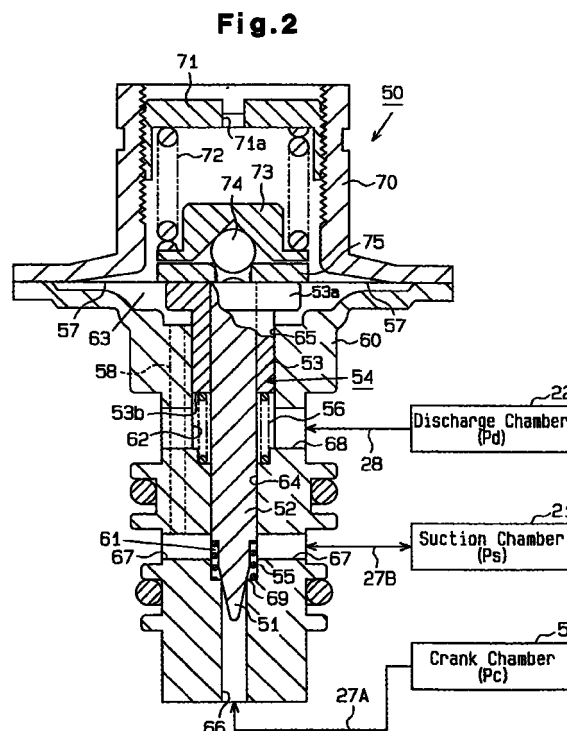
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(54) **Control valve for variable displacement compressor**

(57) A displacement control valve for controlling the amount of gas flowing through a bleed passage (27A, 27B) of a compressor to adjust pressure in a crank chamber (5) of the compressor. The control valve includes a housing (60), a pressure sensitive member, or diaphragm (57), which is arranged in the housing (60), and an actuator (54) extending from the diaphragm (57) and arranged in the housing (60). A valve body (51) is formed integrally with the distal end of the actuator (54). A pressure receiving body (53) is provided at the proximal end of the actuator (54). The diaphragm (57) drives the actuator (54) in accordance with a suction pressure. The pressure receiving body (53) urges the diaphragm (57) in a single direction in accordance with a discharge pressure. The diameter (or cross-sectional area) of the actuator (54) decreases in a stepped-like manner in the axial direction. This simplifies manufacture of the actuator (54) and facilitates assembly.



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## Description

### BACKGROUND OF THE INVENTION

[0001] The present invention relates to control valves for variable displacement compressors, which vary the amount of discharge of compressors by controlling the amount of gas discharged from a crank chamber of a variable displacement compressor.

[0002] Variable displacement compressors, which vary displacement by controlling the inclination angle of tiltable swash plates disposed in a crank chamber within a compressor, are well known as compressors used in automobile air conditioners. In these compressors, the inclination angle of the swash plate is regulated by controlling the pressure of the gas (crank pressure  $P_c$ ) in the crank chamber using a special valve.

[0003] One method to control the crank pressure is called outlet control. This type of control method regulates the crank pressure by controlling the amount of gas discharged from the crank chamber using an outlet control valve located within a bleed passage that links the crank chamber and the suction chamber. Additionally, the suction chamber of the compressor is connected to the outlet of an evaporator of an external refrigerant circuit.

[0004] In an ordinary outlet control valve, a pressure sensitive member deforms in response to changes in the pressure (suction pressure  $P_s$ ) at the suction chamber, which corresponds to the pressure at the outlet of the evaporator. This in turn actuates the valve body. A target value is set in advance for the suction pressure (target suction pressure) depending on the amount of force applied to the pressure sensitive member. The control valve automatically controls the opening of the valve body such that the suction pressure  $P_s$  converges on the target suction pressure.

[0005] When the pressure of the refrigeration gas (discharge pressure  $P_d$ ) that discharges into the external refrigerant circuit from the compressor is high, the pressure loss within the external refrigerant circuit will increase significantly. This increase causes a difference to occur between the pressure  $P_{s'}$  at the outlet of the evaporator and the suction pressure  $P_s$ . Stated with more detail, the suction pressure  $P_s$  becomes higher than the pressure  $P_{s'}$  at the outlet of the evaporator as the discharge pressure  $P_d$  increases. The control valve uses the suction pressure  $P_s$  as the pressure  $P_{s'}$  at the outlet of the evaporator. Consequently, it becomes impossible for the difference between both pressures  $P_s$  and  $P_{s'}$  to accurately control pressure  $P_{s'}$  at the outlet of the evaporator.

[0006] Technology that achieves this type of control sufficiently taking into consideration compensation for the difference between both pressures  $P_s$  and  $P_{s'}$  as well as the pressure  $P_{s'}$  at the outlet of the evaporator, has been proposed. For example, a control valve disclosed in Japanese Unexamined Patent Publication No.

3-53474 transfers changes in the discharge pressure  $P_d$  to the pressure sensitive member. The target suction pressure falls following increases in the discharge pressure  $P_d$ . As a result, the difference between the pressures  $P_s$  and  $P_{s'}$  is compensated for and the pressure  $P_{s'}$  at the outlet of the evaporator is accurately controlled.

[0007] In contrast, a control valve disclosed in Japanese Unexamined Patent Publication No. 5-52182 includes a diaphragm (pressure sensitive member) that deforms in response to suction pressure changes, a spherical valve body actuated by means of the diaphragm, and a rod that transmits the displacement of the diaphragm to the valve body. A pressure correction mechanism is located between the diaphragm and the valve body to compensate for differences between the suction pressure and the pressure at the outlet of the evaporator. This pressure correction mechanism has a chamber where discharge pressure is introduced and the rod passes through the chamber.

[0008] Because the valve body in the control valve of Japanese Unexamined Patent Publication No. 5-52182 is spherical, the valve body and the rod must be produced separately making the production of the control valve complicated. Further, the action of placing the valve body at established locations within the control valve and the action of placing the rod such that it passes through the chamber of the pressure correction mechanism must be carried out separately, making the assembly of the control valve tedious.

### SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to provide control valves for variable displacement compressors with a construction simpler than conventional valves as well as with simpler assembly.

[0010] To achieve the above object, the present invention provides a control valve for a variable displacement compressor. The control valve adjusts the pressure of a crank chamber in the compressor to vary the compressor displacement. The compressor includes a suction pressure region to which suction pressure is communicated, a discharge pressure region to which a discharge pressure is communicated, and a bleed passage connecting the crank chamber to the suction pressure region. The control valve includes a housing, a pressure sensitive member arranged in the housing to deform in accordance with the suction pressure, and an actuator extending from the pressure sensitive member and arranged in the housing. The actuator includes a valve body for adjusting the opened amount of the bleed passage and a pressure receiving body for receiving the discharge pressure. The pressure sensitive member drives the valve body in accordance with the suction pressure. The pressure receiving body urges the pressure sensitive member in a single direction with a force corresponding to the discharge pres-

sure, and the actuator is formed so that its cross-sectional area decreases in a stepped manner axially.

**[0011]** Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]** The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a cross-sectional view showing a variable displacement compressor according to a first embodiment of the present invention;

Fig. 2 is a cross-sectional view of a displacement control valve of the compressor of Fig. 1;

Fig. 3 is an schematic cross-sectional view showing one portion of the assembly procedure of the displacement control valve of Fig. 2;

Fig. 4 is a cross-sectional view showing a displacement control valve according to a further embodiment of the present invention;

Fig. 5 is a partial cross-sectional view showing a displacement control valve according to a further embodiment of the present invention;

Fig. 6 is a partial cross-sectional view showing a displacement control valve according to a further embodiment of the present invention;

Fig. 7 is a cross-sectional view showing a displacement control valve according to a further embodiment of the present invention;

Fig. 8 is a partial cross-sectional view showing a displacement control valve according to a further embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0013]** In the following, a displacement control valve according to the present invention and incorporated in a variable displacement type swash plate compressor will be described referring to Fig. 1 through Fig. 3.

**[0014]** As shown in Fig. 1, the variable displacement type swash plate compressor includes a cylinder block 1, a front housing member 2 joined to the front end of the cylinder block 1, and a rear housing member

4 joined to the rear end of the cylinder block 1 through a valve plate 3. The cylinder block 1, front housing member 2, valve plate 3 and rear housing member 4 are held together with a plurality of bolts (not shown) to form the compressor housing.

**[0015]** A crank chamber 5 is defined between the cylinder block 1 and the front housing member 2. A drive shaft 6 is supported by the cylinder block 1 and the front housing member 2 with a plurality of radial bearings.

**[0016]** A bore housing a helical spring 7 and a thrust bearing 8 is formed substantially at the center of the cylinder block 1. In the crank chamber 5, a rotating support 11 is fixed on the drive shaft 6 to rotate integrally with the drive shaft 6. Another thrust bearing 9 is located between the rotating support 11 and an inner wall of the front housing member 2. The drive shaft 6 is supported in the axial direction by both thrust bearing 8, 9 and is urged toward the front by the spring 7.

**[0017]** The drive shaft 6 is connected through an electromagnetic clutch 40 to an engine E, which serves as an external power source. The electromagnetic clutch 40 includes a pulley 42, an annular solenoid coil 43, and an armature 45. The pulley 42 is supported by a bearing 41 at the front end of the front housing member 2 allowing it to rotate. The armature 45 is connected to the drive shaft 6 by a leaf spring 44.

**[0018]** When electric current is supplied to the coil 43, electromagnetic attraction is produced between the armature 45 and the pulley 42, which causes the armature 45 to engage the pulley 42, as shown in Fig. 1. Consequently, the driving power of the engine E is transmitted to the drive shaft 6 through a transmission belt 46, the pulley 42, the armature 45, and the leaf spring 44. When the supply of electric current to the coil 43 is interrupted, the armature 45 is separated from the pulley 42 by the force of the leaf spring 44 to interrupt the power transmission. Thus, the driving power of the engine E is selectively transmitted to the drive shaft 6 by controlling the supply of electric current to the coil 43.

**[0019]** A swash plate 12, or drive plate, is housed in the crank chamber 5. The drive shaft 6 passes through a hole formed at the center of the swash plate 12. The swash plate 12 is connected through a hinge mechanism 13 to the rotating support 11 and the drive shaft 6. The hinge mechanism 13 consists of a supporting arm 14 with a guide hole provided on the rotating support 11, and a guide pin 15 with a spherical head on the front surface of the swash plate 12. The hinge mechanism 13 causes the swash plate 12 and the drive shaft 6 to rotate together. This permits the swash plate 12 to move in the axial direction of the drive shaft 6 and to incline with respect to the axis of the drive shaft 6.

**[0020]** A coil spring 16 is fitted to the drive shaft 6 between the rotating support 11 and the swash plate 12. The spring 16 urges the swash plate 12 in a direction decreasing the angle of inclination of the swash plate 12. A snap ring 17 is fixed on the drive shaft 6 between the swash plate 12 and the cylinder block 1. The snap

ring 17 restricts the rearward movement of the swash plate 12 to determine the minimum inclination angle of the swash plate 12. The minimum inclination angle is, for example, 3 to 5 degrees. In contrast, the maximum inclination angle of the swash plate 12 is determined by the abutment of a counterweight 12a formed on the swash plate 12 against a restricting section 11a of the rotating support 11.

**[0021]** A plurality of cylinder bores 1a (only one bore is shown) extend through the cylinder block 1. The cylinder bores 1a are arranged at predetermined intervals along a circle drawn about the axis of the drive shaft 6. A single-headed piston 18 is located in each cylinder bore 1a. Each piston 18 is connected to the swash plate 12 through a pair of shoes 19.

**[0022]** A suction chamber 21, the pressure of which is referred to as the suction pressure  $P_s$ , and a discharge chamber 22, the pressure of which is referred to as the discharge pressure  $P_d$ , are defined in the rear housing member 4. The valve plate 3 contains a suction port 23, a suction valve 24, a discharge port 25 and a discharge valve 26 for each cylinder bore 1a. The suction chamber 21 is connected to each cylinder bore 1a through the corresponding suction port 23. Each cylinder bore 1a is connected to the discharge chamber 22 through the corresponding discharge port 25.

**[0023]** In the compressor shown in Fig. 1, the drive shaft 6 is rotated when the engine E is driven, and the swash plate 12 rotates with the rotation of the shaft 6. The rotational movement of the swash plate 12 is converted through the shoes 19 into reciprocating movement of the pistons 18. This reciprocating movement compresses a refrigerant gas drawn from the suction chamber 21, through the valve plate 3, into each cylinder bore 1a. Compressed refrigerant gas is discharged from each cylinder bore 1a into the discharge chamber 22.

**[0024]** The inclination angle of the swash plate 12 is determined according to various moments applied to the swash plate 12. The moments include a rotational moment, which is based on the centrifugal force of the rotating swash plate 12, a spring force moment, which is based on the force of the spring 16, and a gas pressure moment. The rotational moment continually acts on the swash plate 12 to increase the inclination angle. The gas pressure moment depends on the mutual relationship of the reactive force of compression acting upon the pistons 18 during the compression strokes, the internal pressure in the cylinder bore 1a acting upon the pistons 18 during the suction strokes, and the pressure in the crank chamber 5 (crank pressure  $P_c$ ). The gas pressure moment acts on the swash plate 12 to decrease the inclination angle.

**[0025]** In this embodiment, when the crank pressure  $P_c$  is maintained at a high pressure, the sum of the gas pressure moment and the spring 16 force moment becomes greater than the rotational moment. Accordingly, the swash plate 12 shifts to the minimum inclina-

tion angle position. The sum of the moment based on the gas pressure and the moment based on the spring force is balanced with the moment of the rotational movement by adjusting the crank pressure  $P_c$ . As a result, the inclination of the swash plate 12 is set at a desired angle between the minimum inclination angle and the maximum inclination angle. The stroke of each piston 18, or the discharge displacement of the compressor, is adjusted according to the inclination angle of the swash plate 12.

**[0026]** As shown in Figs. 1 and 2, the mechanism for controlling the crank pressure  $P_c$  consists of a displacement control valve 50 and a plurality of passages 27A, 27B, 28 and 29. Namely, the compressor housing is provided with a bleed passage 27A, 27B connecting the crank chamber 5 to the suction chamber 21. The displacement control valve 50 is located in the bleed passage 27A, 27B. The displacement control valve 50 regulates the amount of gas discharged from the crank chamber 5 to the suction chamber 21 by controlling the opening amount of the bleed passage 27A, 27B. The control valve 50 will be described in detail later. The downstream section 27B of the bleed passage, which is downstream of the control valve 50, also functions as a manometry passage to direct suction pressure  $P_s$  to the control valve 50.

**[0027]** Further, the compressor housing is provided with a connecting passage 28 connecting the control valve 50 to the discharge chamber 22 as well as an auxiliary supply passage 29 connecting the crank chamber 5 to the discharge chamber 22. The auxiliary supply passage 29 is provided with a fixed restriction 29a. The gas supply to the crank chamber 5 depends mainly on leakage from the gap between the piston 18 and the cylinder bore 1a during compression strokes. This is called blow-by gas. The supply of blow-by gas, however, is unstable. The auxiliary supply passage 29, which has the fixed restriction 29a, compensates for this instability.

**[0028]** The discharge chamber 22 and the suction chamber 21 are connected to each other through an external refrigerant circuit 30. The external refrigerant circuit 30 forms, together with the compressor, a cooling circuit of an automobile air conditioner. The external refrigerant circuit 30 is provided with a condenser 31, a thermostatic expansion valve 32, and an evaporator 33. The valve position of the expansion valve 32 is controlled based on the temperature detected by a temperature detector 34 located at the outlet of the evaporator 33 and the pressure at the outlet of the evaporator 33. The expansion valve 32 provides liquefied refrigerant to the evaporator 33 depending on the thermal load applied to the refrigerator circuit. This adjusts the flow rate of the refrigerant in the external refrigerant circuit 30.

**[0029]** The displacement control valve 50 regulates the amount of gas discharged from the crank chamber 5. As shown in Fig. 2, the displacement control valve 50 is provided with a lower first valve housing 60 and an

upper second valve housing 70 that are coupled together.

**[0030]** As shown in Figs. 2 and 3, the first valve housing 60 is cylindrical with three spaces 61, 62, 63 formed inside. The diameter of these spaces increase in steps from the lower to the upper space. Fig. 3 shows the first valve housing 60 before assembling the control valve 50. Prom among the three spaces 61, 62, 63, the first space 61, which is lowest, and the second, or middle, space 62 are connected through a lower through-hole 64, and the second space 62 and the third, or highest, space 63 are connected through an upper through-hole 65. The first space 61, lower through-hole 64, second space 62, upper through-hole 65, and third space 63 are all circular and coaxial. The first space 61 and the lower through-hole 64 have the same diameter  $d_1$ . The second space 62 and the upper through-hole 65 have the same diameter  $d_2$ . The inner diameter  $d_2$  is larger than the inner diameter  $d_1$ .

**[0031]** A first port 66 is formed directly below the first space 61. The first port 66 extends axially through the first valve housing 60. A plurality of second ports 67 are formed to extend substantially perpendicular to the first space 61. These second ports 67 extend radially through the first valve housing 60. Lastly, a plurality of third ports 68 are formed to extend substantially perpendicular to the second space 62. These second ports 67 extend radially through the first valve housing 60.

**[0032]** As shown in Fig. 2, when the control valve 50 is installed in the compressor, the first port 66 connects to the crank chamber 5 through the upstream section 27A of the bleed passage, the second port 67 connects to the suction chamber 21 through the downstream section 27B of the bleed passage, and the third port 68 connects to the discharge chamber 22 through the connecting passage 28. An annular stepped portion, or valve seat 69, is defined between the first port 66 and the first space 61. The stepped portion functions as a valve seat and a spring seat.

**[0033]** As shown Figs. 2 and 3, a pin-like actuator 54 is inserted through the first valve housing 60 from the third space 63 to the first port 66. The actuator 54 includes a valve body 51, a rod 52 and a pressure receiving body 53. The valve body 51 is integrally formed with the rod 52 and functions as a tapered needle valve extending from the end of the rod 52. The rod 52 is produced from a metallic material that resists wear and has excellent durability. The pressure receiving body 53 is cylindrical and fitted to the proximal end of the rod 52. The pressure receiving body 53 can be securely fixed to the rod 52 or can be movably engaged with the rod 52. Further, the pressure receiving body 53 is produced from a metallic or resin material (for example, engineering plastic) that costs less than the metallic material used for the rod 52. The pressure receiving body 53 has a flange 53a.

**[0034]** The valve body 51, rod 52, and the pressure receiving body 53 are all coaxial and have a circular

cross-section. The outer diameter of the rod 52 is substantially equal to the inner diameter  $d_1$  of the lower through-hole 64. The outer diameter of the principal portion of the pressure receiving body 53 is substantially equal to the inner diameter  $d_2$  of the upper through-hole 65.

**[0035]** As shown in Fig. 2, the actuator 54 is supported by a secondary retention spring 55, which is located in the first space 61, and a main retention spring 56, which is located in the second space 62. The springs 55, 56 allow the actuator to move in the axial direction within the first valve housing 60. The retention springs 55, 56 urge the actuator 54 upward and prevent the valve body 51 from strongly biting into the valve seat 69.

**[0036]** In addition, with the control valve in an assembled state as shown in Fig. 2, the rod 52 is inserted into the lower through-hole 64 thereby sealing the upper through-hole 65. In this state, the first space 61 defines a valve chamber that contains the valve body 51 and is disconnected from the second space 62. As a result, the bleed passage is formed between the crank chamber 5 and the suction chamber 21. The bleed passage includes the upstream section 27A, the first port 66, the valve chamber 61, the second port 67, and the downstream section 27B. The valve body 51 regulates the size of the gap between the valve seat in accordance with the position inside the valve chamber 61 or, in other words, the amount the bleed passage opens. The suction pressure  $P_s$  reaches the valve chamber 61 through the downstream bleed passage 27B and the second port 67.

**[0037]** The pressure receiving body 53 is inserted into the upper through-hole 65, which seals the through-hole 65. As a result, the second space 62 defines a pressure compensation chamber 62 that is disconnected from the third space 63. The discharge pressure  $P_d$  reaches the pressure compensation chamber 62 through the connecting passage 28 and third port 68. The lower end surface 53b of the pressure receiving body 53 is exposed to the inside of the pressure compensation chamber 62 and functions as a pressure receiving surface to receive the discharge pressure  $P_d$ . The pressure receiving body 53 is urged upward with a force corresponding to the discharge pressure  $P_d$ . This force acts on the lower end surface 53b (pressure receiving surface).

**[0038]** The second valve housing 70 is coupled to the upper end of the first valve housing 60 with a diaphragm 57, which acts as a pressure sensitive member, arranged in between. The space at the lower side of the diaphragm 57 is the third space 63. This third space 63 is defined as a pressure sensitive chamber 63 by the diaphragm 57. The upper end of the rod 52 is arranged inside the pressure sensitive chamber 63, and the flange 53a of the pressure receiving body 53 is secured to the lower surface of the diaphragm 57. The flange 53a has a relatively large diameter, which increases the

contact area against the diaphragm 57. This makes it easy to connect the flange to the diaphragm 57.

**[0039]** A connecting passage 58 is formed inside the first valve housing 60. The passage 58 allows the pressure sensitive chamber 63 to pass through the valve chamber 61 and the second port 67. The connecting passage 58, the second port 67, and the downstream section 27B of the bleed passage form a manometry passage to direct suction pressure  $P_s$  to the pressure sensitive chamber 63.

**[0040]** As shown in Fig. 2, an adjuster 71 is engaged into the upper portion of the second valve housing 70. An opening 71a is formed at the center of the adjuster 71. The opening 71a allows the space (space above the diaphragm 57) inside the second valve housing 70 to be opened to the atmosphere. Atmospheric pressure is used as a criterion pressure.

**[0041]** A set spring 72 is located inside the second valve housing 70. The upper end of the set spring 72 contacts the adjuster 71 and the lower end contacts a spring seat 73. Thus, the compressive force of the set spring 72 is applied to the diaphragm 57 through the spring seat 73, a ball 74 and a ball seat 75. The ball seat 75 is mounted to the upper surface of the diaphragm 57.

**[0042]** The sum of the force of the atmospheric pressure (criterion pressure) acting on the diaphragm 57 and the compressive force of the set spring 72 determines the target value  $P_{set}$  (target suction pressure) for the suction pressure  $P_s$ . This target suction pressure  $P_{set}$  can be changed by adjusting the position of the adjuster 71 in the axial direction with respect to the second valve housing 70.

**[0043]** In this embodiment, the pressure sensitive mechanism includes the diaphragm 57, the adjuster 71, the set spring 72, the spring seat 73, the ball 74, and the ball seat 75. The pressure sensitive mechanism determines the target suction pressure  $P_{set}$  and moves the actuator 54 in accordance with changes in the suction pressure  $P_s$ .

**[0044]** While the compressor is operating, blow-by gas flows into the crank chamber S from the cylinder bore 1a, and the high pressure gas inside the discharge chamber 22 is supplied to the crank chamber 5 via the auxiliary supply passage 29. In the displacement control valve 50, the diaphragm 57 moves the actuator 54 in the axial direction in accordance with the suction pressure  $P_s$  applied to the pressure sensitive chamber 63 from the suction chamber 21. The opening size of the bleed passage 27A, 66, 61, 67, 27B is controlled in response to the position of the valve body 51 located on the end of the actuator 54. The refrigerant gas discharged from the crank chamber 5 into the suction chamber 21 changes in accordance with the opening size of the bleed passage and the crank pressure  $P_c$  is adjusted accordingly. The inclination angle of the swash plate 12 is determined in accordance with the crank pressure  $P_c$ , which changes the amount of gas discharged by the compressor.

**[0045]** The pressure sensitive mechanism includes the diaphragm 57 and activates the valve body 51 such that the suction pressure  $P_s$  is maintained at approximately the target suction pressure  $P_{set}$ . The function of a compressor that incorporates an air conditioning circuit of an HVAC system is to maintain the pressure  $P_s'$  at the outlet of the evaporator 33 close to a desired value that reflects the air conditioning load. Consequently, the compressor uses the control valve 50 to perform feedback control of the inclination angle of the swash plate 12 (discharge amount) such that the pressure (suction pressure  $P_s$ ) at the suction chamber 21, which is almost equal to the pressure  $P_s'$  at the outlet of the evaporator 33, is maintained at the target suction pressure  $P_{set}$ .

**[0046]** When the pressure of the refrigeration gas (discharge pressure  $P_d$ ) that discharges into the external refrigerant circuit 30 from the compressor is high, the pressure loss within the external refrigerant circuit 30 will increase. This causes a difference between the pressure  $P_s'$  at the outlet of the evaporator 33 and the suction pressure  $P_s$ . For example, as the discharge pressure  $P_d$  grows large, the suction pressure  $P_s$  becomes smaller than the pressure  $P_s'$  at the outlet of the evaporator 33.

**[0047]** The pressure receiving body 53 is provided to correct the difference between both pressures  $P_s$ ,  $P_s'$ . In other words, as the discharge pressure  $P_d$  increases, the upward force of the pressure receiving body 53 increases. This upward force of the pressure receiving body 53 reduces and cancels the force of the set spring 72, which presses the diaphragm 57 downward. Stated differently, the pressure receiving body 53 compensates the target suction pressure  $P_{set}$  in accordance with the discharge pressure  $P_d$ . Therefore, even if the discharge pressure  $P_d$  is high, the opening of the control valve 50 is controlled to stabilize the pressure  $P_s'$  at the outlet of the evaporator 33 close to a desired value.

**[0048]** In the following, the advantages of this embodiment will be described.

**[0049]** The diameter (or cross-sectional area) of the actuator 54 that consists of the valve body 51, the rod 52 and the pressure receiving body 53 becomes smaller at locations further from the diaphragm 37. The openings (including the spaces 61, 62, 63 and the through-holes 64, 65) formed in the first valve housing 60 have a diameter (or cross-sectional area) that changes to adjust to the shape of the actuator 54. This makes it easy to manufacture the actuator 54 and the first valve housing 60 and makes it possible to reduce the number of parts compared to a conventional compressor. This reduction in the number of parts improves the durability of the control valve 50.

**[0050]** In addition, it is possible to incorporate the actuator 54 into the first valve housing 60 just by inserting a pre-assembled actuator 54 from the opening at the upper side of the first valve housing 60 (refer to Fig. 3).

Accordingly, the assembly of the control valve is simpler compared to a conventional valve, which reduces the number of assembly steps and the costs.

**[0051]** The actuator 54 is an integrated member including the valve body 51 and the rod 52 and is formed separately from the pressure receiving body 53. Because of this, it is possible to form the pressure receiving body 53 using a comparatively low-cost metallic or resin material that does not require much durability. This improves the design from the viewpoint of cost. Further, high-cost materials are used for the valve body 51 to avoid damage to the valve body 51 and the valve seat 69.

**[0052]** The pressure receiving body 53 is fitted to the rod 52 so as to encompass the rod 52. This decreases the length of the actuator 54 in the axial direction, which limits the axial length of the control valve 50. Moreover, the size of the pressure receiving body 53 can be freely set without regard to the size of the rod 52.

**[0053]** The contact area between the inner peripheral surface of the lower through-hole 64 and the outer peripheral surface of the rod 52 is relatively large. Consequently, the lower through-hole 64 is reliably sealed by the rod 52 even if a special seal member is not provided. Due to the same reasons, the area of contact between the inner peripheral surface of the upper through-hole 65 and the outer peripheral surface of the pressure receiving body 53 serves as a seal.

**[0054]** The actuator is elastically supported using the two retention springs 56, 55. Consequently, the load per spring is reduced.

**[0055]** The present invention can also be embodied as described below.

**[0056]** In a further embodiment according to the present invention, as shown in Fig. 4, the valve body 51, the rod 52 and the pressure receiving body 53 are integral and made from the same material to form the actuator 54. In this case, the secondary retention spring 55 (refer to Fig. 2) may be omitted to simplify the internal construction of the valve chamber 61. The number of parts are reduced in this embodiment. Further, the three members 51, 52, 53 have shapes, the diameters (or cross-sectional areas) of which change in a stepped manner from the lower end to the upper end, to facilitate machining.

**[0057]** In a further embodiment according to the present invention, as shown in Fig. 5, the valve body 51 does not have a tapered shape and has a flat end. In a further embodiment according to the present invention, as shown in Fig. 6, the end of the valve body 51 is semi-spherical. As long as the diameter (or cross-sectional area) of the valve body 51 does not exceed the diameter (or cross-sectional area) of the rod 52, the valve body 51 can be formed in any shape.

**[0058]** In another embodiment according to the present invention shown in Fig. 7, the installation of the actuator 54 in the first valve housing 60 is facilitated by

tapering various surfaces in the first valve housing 60 and the actuator 54. In the example shown in Fig. 7, a tapered surface 81 is formed on the stepped portion between the valve body 51 and the rod 52 and a tapered surface 82 is formed on the stepped portion between the pressure compensation chamber 62 and the lower through-hole 64. Further, a tapered surface 83 is formed on the lower end of the peripheral edge of the pressure receiving body 53, and a tapered surface 84 is formed on the stepped portion between the pressure sensitive chamber 63 and the upper through-hole 65. The tapered surfaces 81, 82, 83 and 84 make it easier to insert the actuator 54 into the lower through-hole 64.

**[0059]** In the embodiment of Fig. 7, an upper end (proximal end) 52a of the rod 52 is formed with a diameter larger than that of the pressure receiving body 53, and the upper end surface of the pressure receiving body 53 defines a conical surface 85. This makes it easier to insert the rod 52 into the pressure receiving body 53, which simplifies the insertion of the rod 52 in the pressure receiving body 53. Moreover, the large diameter upper end member 52a makes it easier to mount the rod 52 to the diaphragm 57.

**[0060]** In a further embodiment according to the present invention shown in Fig. 8, a small space 86 is formed between the rod 52 and the pressure receiving body 53. The space 86 is sealed by a ring seal 87, which allows the rod 52 and the pressure receiving body 53 to move radially. This compensates for axes misalignment between the lower through-hole 64 and the upper through-hole 65 that may be caused by machining tolerances. Consequently, it becomes possible to lower the processing accuracy required for the first valve housing 60, which simplifies the manufacture of the first valve housing 60. The ring seal 87 acts to prevent gas leaks from the pressure compensation chamber 62 to the pressure sensitive chamber 63. Further, it is preferred that the ring seal 87 be formed by an elastic material such as rubber that allows movement in the radial direction between the rod 52 and the pressure receiving body 53.

**[0061]** The seal material can be provided between the inner peripheral surface of the lower through-hole 64 and the outer peripheral surface of the rod 52. The seal material can also be provided between the inner peripheral surface of the upper through-hole 65 and the outer peripheral surface of the pressure receiving body 53.

**[0062]** A bellows can be used as a pressure sensitive member in place of the diaphragm 57.

**[0063]** The present invention can also be applied to a control valve that can change the target suction pressure  $P_{set}$  in response to external commands. For example, an actuator (for instance, an electromagnetic solenoid) that can apply force to a pressure sensitive member (diaphragm 57) can be provided in a control valve. The suction pressure  $P_s$  is detected by a sensor, and a computer regulates the electromagnetic transfer force of the electromagnetic solenoid in response to the

detected pressure. This electromagnetic transfer force is equivalent to the force of the set spring 72 of Fig. 2 and the target suction pressure  $P_{set}$  can be suitably changed in response the electromagnetic transfer force.

[0064] The cross-sectional shape of the actuator 54 and the cross-sectional shape of the spaces 61, 62, 62 and the through-holes 64, 65 defined in the first valve housing 60 can also be other than circular.

[0065] The present invention is not limited to the swash plate type compressor shown in Fig. 1 but can also be applied to other types of variable displacement compressors.

[0066] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

[0067] A displacement control valve for controlling the amount of gas flowing through a bleed passage (27A, 27B) of a compressor to adjust pressure in a crank chamber (5) of the compressor. The control valve includes a housing (60), a pressure sensitive member, or diaphragm (57), which is arranged in the housing (60), and an actuator (54) extending from the diaphragm (57) and arranged in the housing (60). A valve body (51) is formed integrally with the distal end of the actuator (54). A pressure receiving body (53) is provided at the proximal end of the actuator (54). The diaphragm (57) drives the actuator (54) in accordance with a suction pressure. The pressure receiving body (53) urges the diaphragm (57) in a single direction in accordance with a discharge pressure. The diameter (or cross-sectional area) of the actuator (54) decreases in a stepped-like manner in the axial direction. This simplifies manufacture and of the actuator (54) and facilitates assembly.

## Claims

1. A control valve for a variable displacement compressor, wherein the control valve adjusts the pressure of a crank chamber (5) in the compressor to vary the compressor displacement, wherein the compressor includes a suction pressure region (21) to which suction pressure is communicated, a discharge pressure region (22) to which a discharge pressure is communicated, and a bleed passage (27A, 27B) connecting the crank chamber (5) to the suction pressure region (21), the control valve comprising:
  - a housing (60); and
  - a pressure sensitive member (57) arranged in the housing (60) to deform in accordance with the suction pressure, the control valve being

## characterized by:

an actuator (54) extending from the pressure sensitive member (57) and arranged in the housing (60), wherein the actuator (54) includes a valve body (51) for adjusting the opened amount of the bleed passage (27A, 27B) and a pressure receiving body (53) for receiving the discharge pressure, wherein the pressure sensitive member (57) drives the valve body (51) in accordance with the suction pressure, wherein the pressure receiving body (53) urges the pressure sensitive member (57) in a single direction with a force corresponding to the discharge pressure, and the actuator (54) is formed so that its cross-sectional area decreases in a stepped manner axially.

2. The control valve according to claim 1 **characterized in that** the cross-sectional area of the actuator (54) decreases in a stepped manner such that the cross-sectional area of the actuator (54) is smaller at locations further from the pressure sensitive member (57).
3. The control valve according to claims 1 or 2 characterized in that the diameter of the actuator (54) decreases in a stepped manner axially.
4. The control valve according to claim 3 **characterized in that** the valve body (51) is formed at a portion of the actuator (54) where the diameter is smallest.
5. The control valve according to any one of claims 1 to 4 **characterized in that** the valve body (51) is formed integrally with the actuator (54).
6. The control valve according to any one of claims 1 to 5 **characterized in that** the valve body (51) is tapered.
7. The control valve according to any one of claims 1 to 6 **characterized in that** the actuator (54) includes a rod (52) formed integrally with the valve body (51), the diameter of the valve body (51) being equal to or smaller than that of the rod (52).
8. The control valve according to claim 7 **characterized in that** the diameter of the pressure receiving body (53) is greater than that of the rod (52).
9. The control valve according to claim 8 **characterized in that** the pressure receiving body (53) is formed separately from the rod (52) and fitted to the rod (52) so as to surround the rod (52).
10. The control valve according to claim 9 **characterized in that** the rod (52) and the pressure receiving

body (53) form a space (86) therebetween to allow radial movement between the rod (52) and the pressure receiving body (53), and wherein an elastic seal (87) is arranged between the rod (52) and the pressure receiving body (53).

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11. The control valve according to claim 8, wherein the pressure receiving body (53) is formed integrally with the rod (52).

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12. The control valve according to any one of claims 7 to 11 **characterized in that** the rod (52) has a proximal end, which is connected to the pressure sensitive member (57), and an opposite, distal end, the pressure receiving body (53) being arranged at the proximal end, and the valve body (51) being arranged at the distal end.

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13. The control valve according to any one of claims 1 to 12 **characterized in that** the housing (60) includes a bore (61, 62, 63, 64, 65) corresponding to the outer shape of the actuator (54) to accommodate the actuator (54).

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14. The control valve according to any one of claims 7 to 12 **characterized in that** the housing (60) includes a valve chamber (61) forming part of the bleed passage (27A, 27B), a pressure chamber (62) to which the discharge pressure is communicated, and a pressure sensitive chamber (63) to which the suction pressure is communicated, the valve chamber (61), the pressure chamber (62) and the pressure sensitive chamber (63) being arranged axially in the housing (60), the housing (60) further including a first bore (64) connecting the valve chamber (61) to the pressure chamber (62) and a second bore (65) connecting the pressure chamber (62) to the pressure sensitive chamber (63), wherein the valve body (51) is accommodated in the valve chamber (61), the rod (52) is inserted into the first bore (64) to seal the valve chamber (61) from the pressure chamber (62), and the pressure receiving body (53) is inserted into the second bore (65) to seal the pressure chamber (62) from the pressure sensitive chamber (63), wherein the pressure receiving body (53) has a pressure receiving surface (53b) for receiving the discharge pressure of the pressure chamber (62), and wherein the suction pressure of the pressure sensitive chamber (63) acts on the pressure sensitive member (57).

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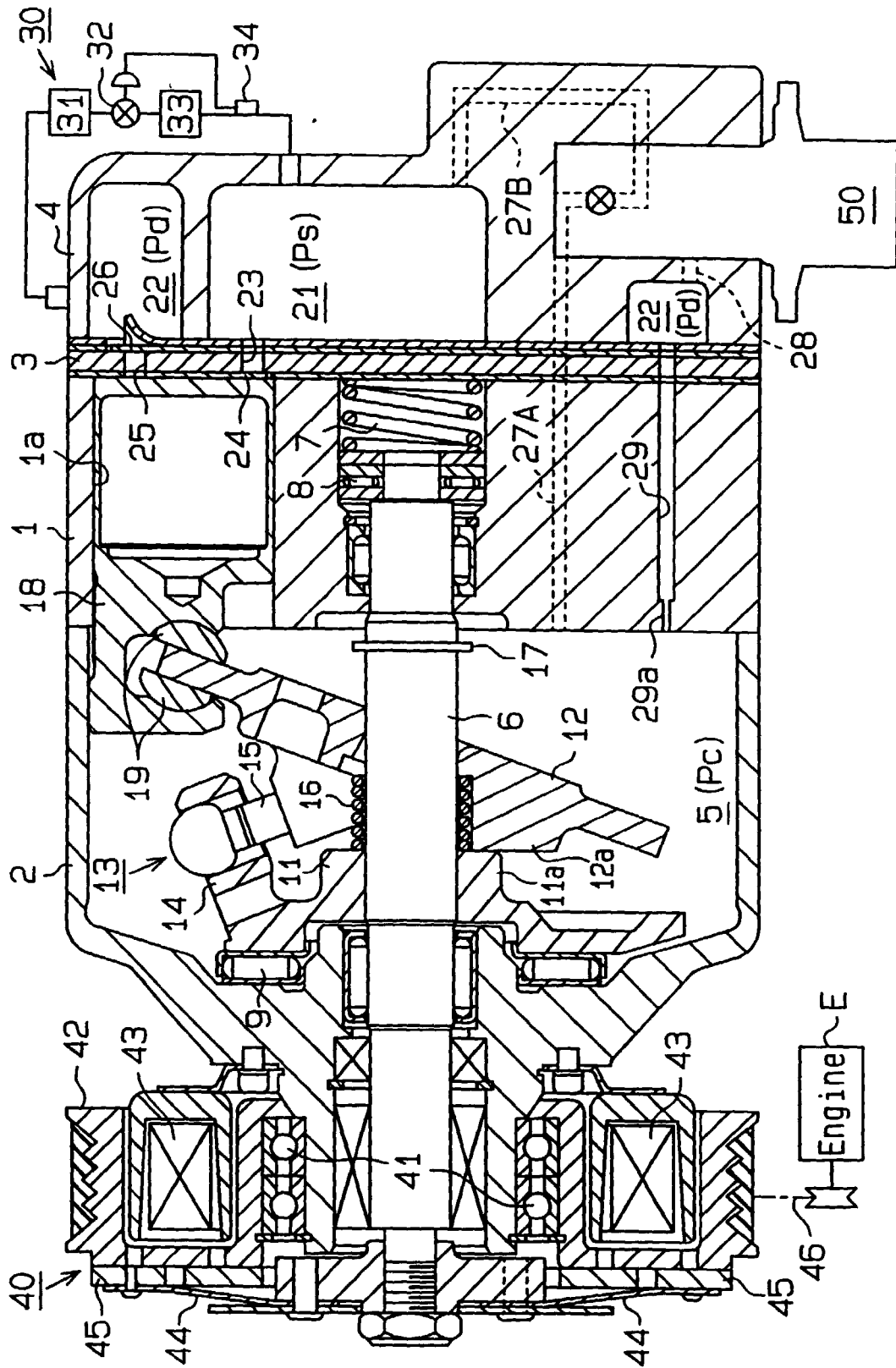
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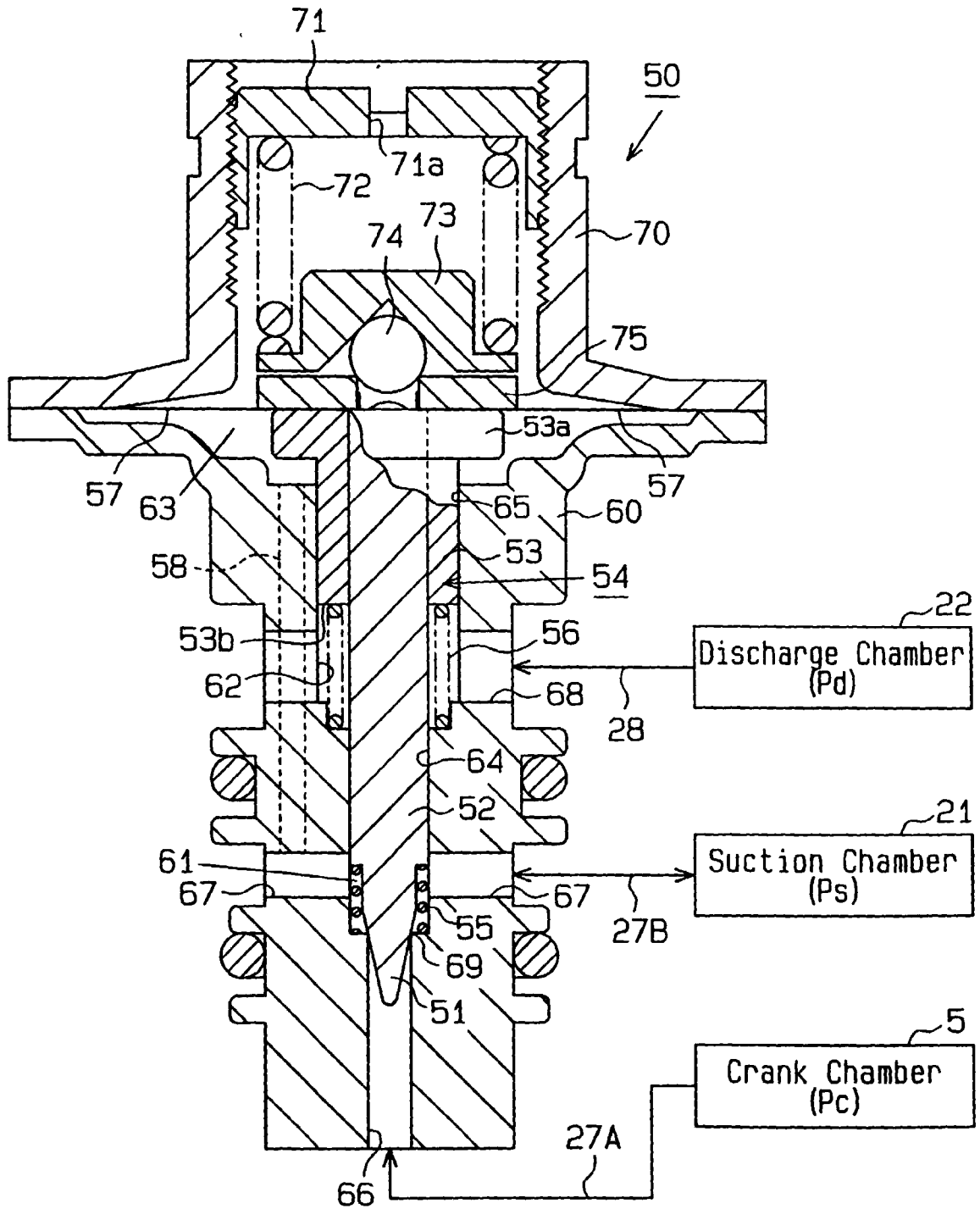
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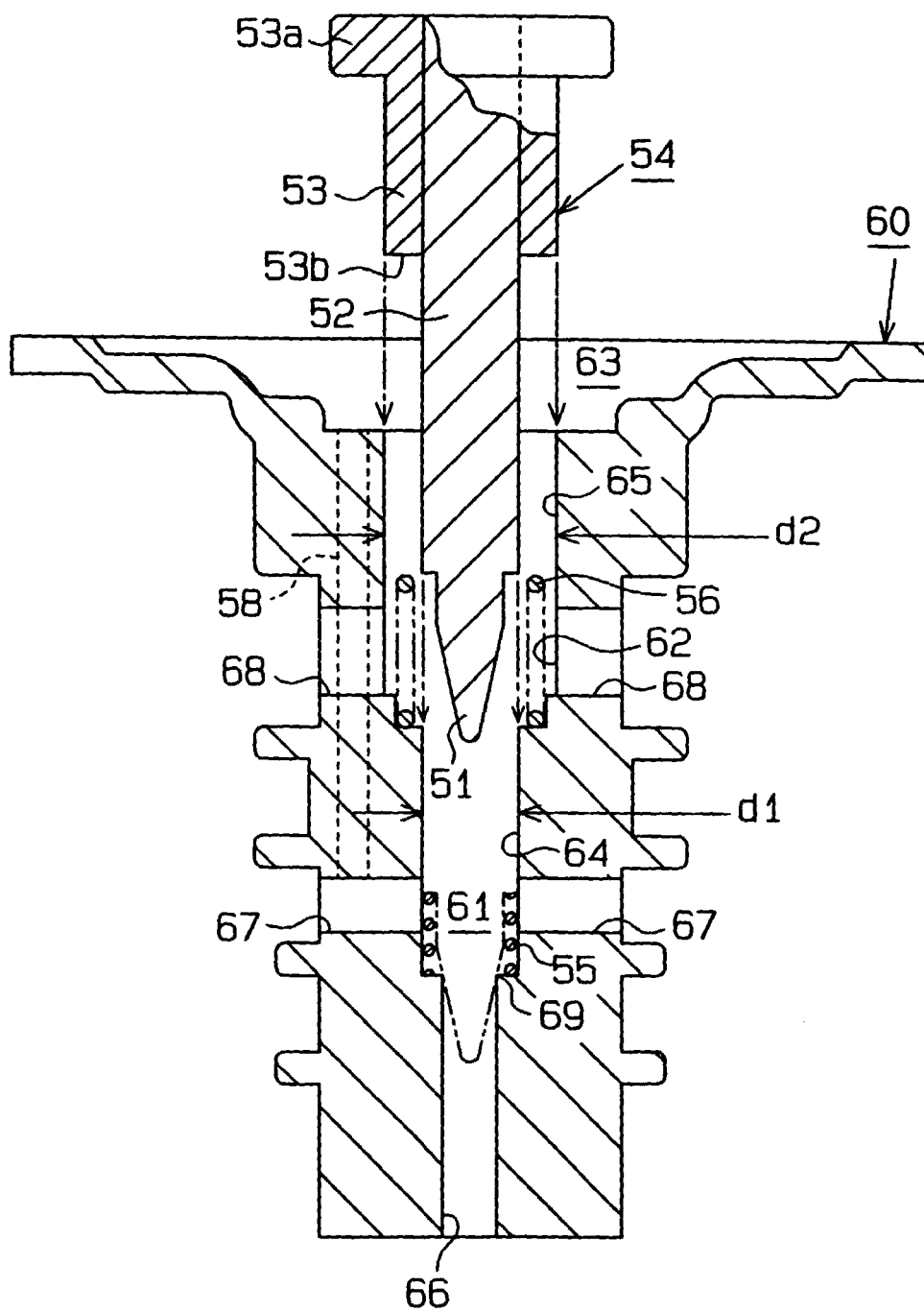
**Fig.1**



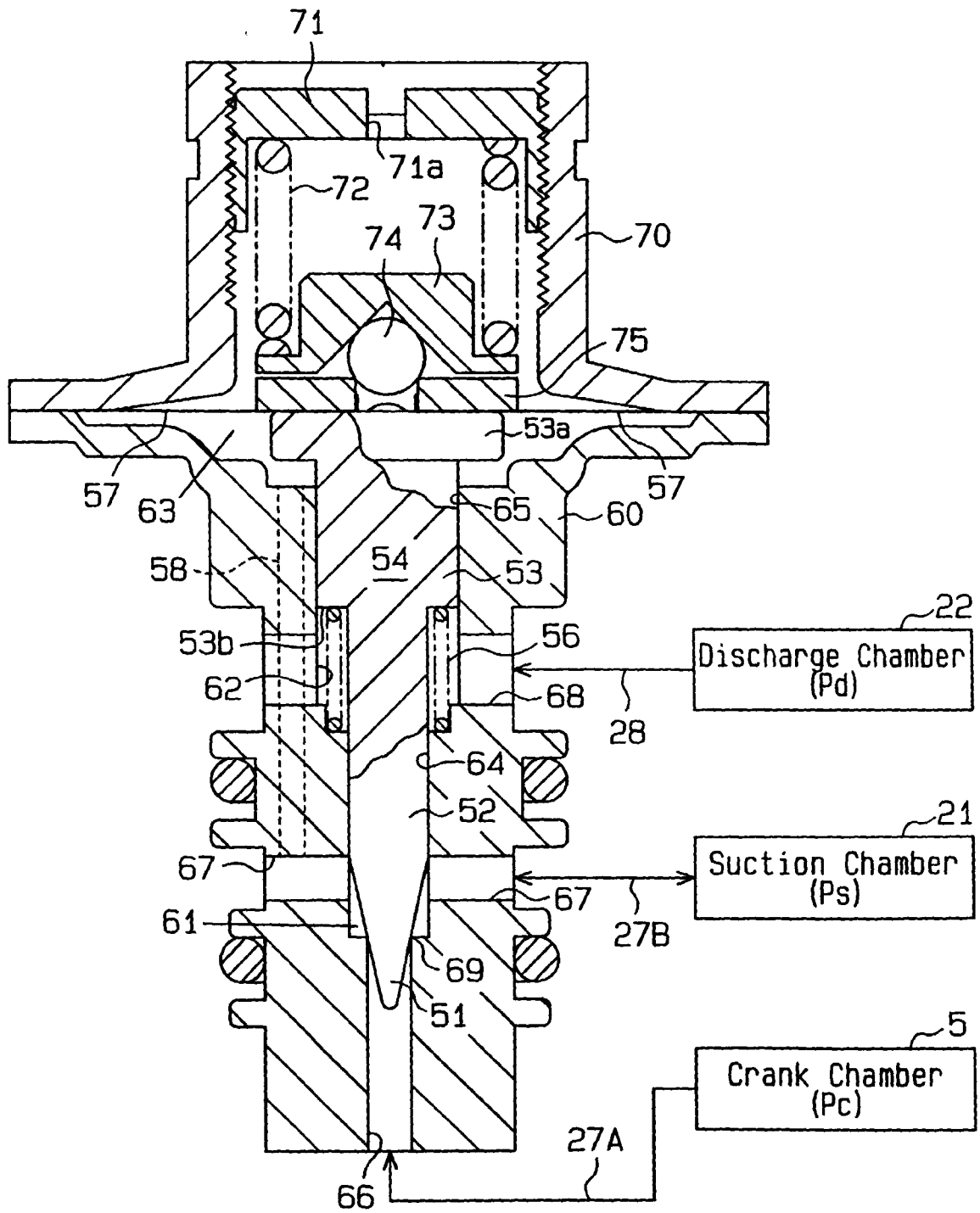
**Fig.2**



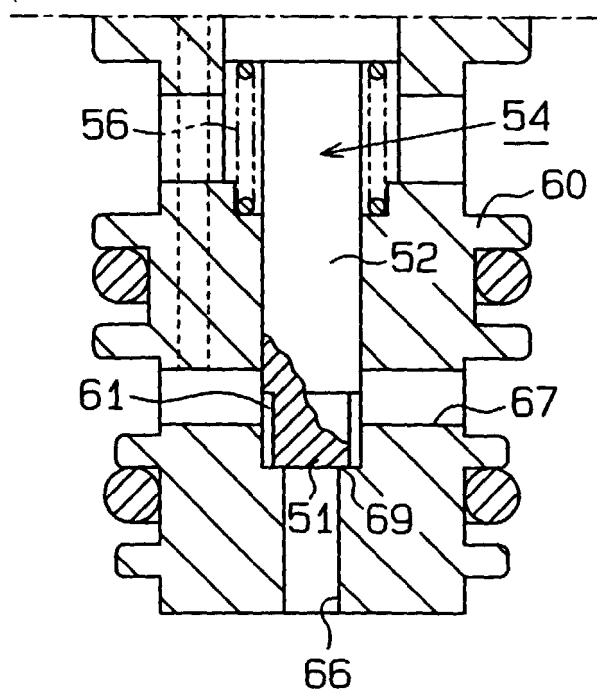
**Fig.3**



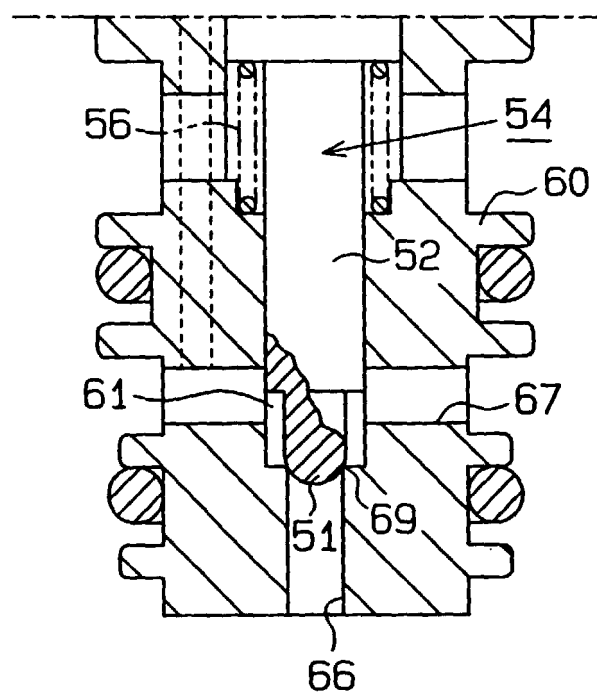
**Fig.4**



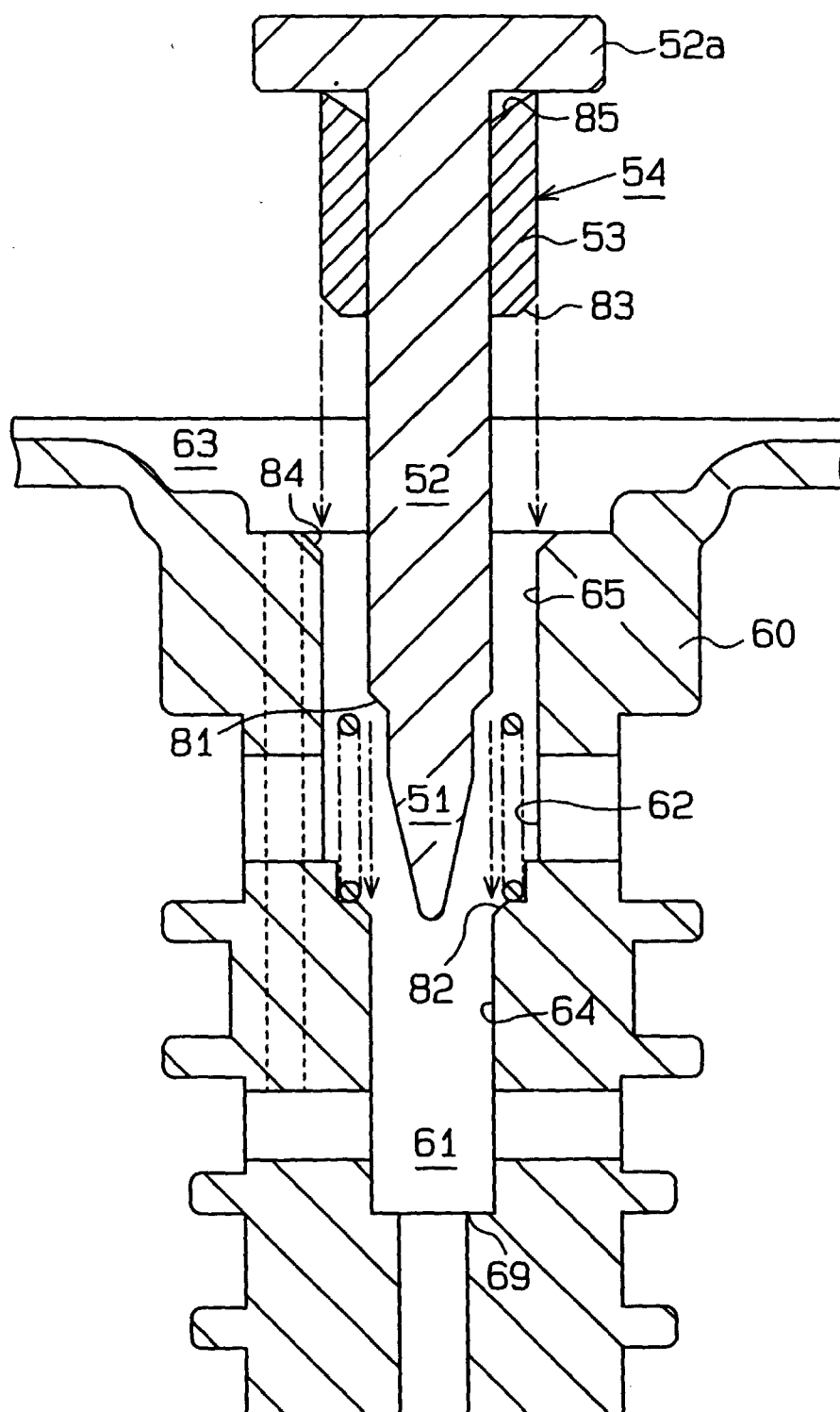
**Fig.5**



**Fig.6**



**Fig.7**



**Fig.8**

