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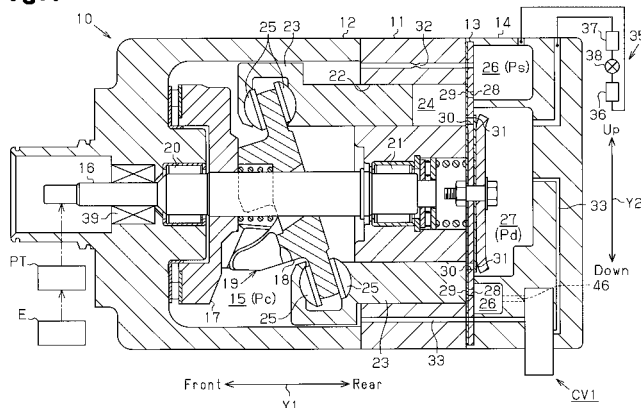
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(54) **Control valve of variable displacement compressor**

(57) A control valve of a variable displacement compressor is disclosed. The control valve includes a valve housing, a valve body, a valve opening spring, an electromagnetic actuator, and an urging plate. The valve housing has a valve chamber that forms a part of a supply passage. The valve body can selectively contact and separate from a valve seat in the valve chamber. The valve opening spring urges the valve body away from the valve seat. The electromagnetic actuator changes electromagnetic urging force acting on the movable iron core through control of externally supplied current. In a state

where the electromagnetic actuator is not energized and the valve body is held at a position separated from the valve seat by the urging force of the valve opening spring, the urging plate deforms in such a manner as to urge the valve body toward the valve seat when the temperature of the urging plate reaches a predetermined temperature. The urging force of the urging plate when the temperature reaches the predetermined temperature is set to be greater than the urging force of the valve opening spring in a state where the electromagnetic actuator is not energized.

**Fig.1**



## Description

### BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to a control valve that adjusts the opening degree of a supply passage connecting the discharge pressure zone to the crank chamber in a variable displacement compressor, thereby changing the displacement of the compressor.

**[0002]** As a type of swash plate type variable displacement compressor used in refrigerant circuits of vehicle air conditioners, a compressor that includes a rotary shaft coupled to a vehicle engine with a clutchless power transmission mechanism is known. This type of compressor changes the inclination angle of the swash plate, that is, the displacement by adjusting the pressure in the crank chamber accommodating the swash plate. The compressor also includes a control valve for adjusting the pressure in the crank chamber. The control valve is located in a supply passage connecting the crank chamber to a high pressure zone of the compressor.

**[0003]** The control valve disclosed in Japanese Laid-Open Patent Publication No. 2001-221164 includes a movable wall and a transmission rod that respond to the pressure difference between two pressure monitoring points set in a refrigerant circuit. The control valve autonomously adjusts the opening degree of the supply passage with the valve body of the transmission rod, so as to maintain a target value of the pressure difference between the two points (target pressure difference), which is determined by an electromagnetic urging force applied by a solenoid portion. Further, the control valve of the publication includes temperature detecting means that detects a temperature correlated to the temperature of a space to be air-conditioned. At the initial stage of cooling from when the air conditioner switch is turned on to when a predetermined time elapses, the target pressure difference is permitted to be changed in accordance with the detected temperature information so that a large amount of refrigerant is allowed to flow in the refrigerant circuit if necessary.

**[0004]** By adjusting the opening degree of the supply passage with the control valve, the flow rate of high-pressure refrigerant gas conducted from the high-pressure zone to the crank chamber via the supply passage is controlled, and the pressure in the crank chamber is determined. As a result of a change of the inclination angle of the swash plate in response to the change in the crank chamber pressure, the stroke of the pistons, that is, the displacement of the compressor is adjusted.

**[0005]** The rotary shaft of a clutchless compressor is always rotated by rotational drive force from a vehicle engine while the engine is running. In the control valve of Japanese Laid-Open Patent Publication No. 2001-221164, when the solenoid portion is not energized (OFF state), the valve body fully opens the supply passage, so that high-pressure refrigerant gas is conducted to the crank chamber through the supply passage. This

increases the pressure in the crank chamber. Accordingly, the inclination angle of the swash plate is reduced, and the compressor displacement is reduced. Therefore, if the engine is operated when lubricant for lubricating sliding parts of the compressor is stored in the crank chamber and the solenoid portion is not energized, the lubricant is agitated, for example, by the swash plate in the crank chamber. This abruptly increases the lubricant temperature. Further, when the engine speed increases and the rotary shaft is rotated at a high speed, the compressor itself is abruptly heated along with the abrupt temperature increase of the lubricant. This can decrease the reliability of the sealing portions of the rotary shaft and that of the compressor itself.

**[0006]** Accordingly, it is an objective of the present invention to provide a control valve for a variable displacement compressor, which is capable of causing a valve body to autonomously move in a direction for closing a supply passage and increasing the amount of lubricant conducted out of a crank chamber, even if an electromagnetic actuator is in the not energized.

**[0007]** To achieve the foregoing objective and in accordance with one aspect of the present invention, a control valve of a variable displacement compressor used in a refrigerant circuit of an air conditioner is provided. The compressor includes a rotary shaft and a cam plate. The rotary shaft is coupled to an external drive source through a clutchless power transmission mechanism, and the cam plate is accommodated in a crank chamber. The control valve adjusts the opening degree of a supply passage connecting a discharge pressure zone of the compressor to the crank chamber, thereby controlling the pressure in the crank chamber to change the displacement of the compressor. The control valve includes a valve housing, a valve body, a valve opening spring, and an electromagnetic actuator. The valve housing has a valve chamber, which forms a part of the supply passage. The valve body is located in the valve chamber. The valve body selectively contacts and separates from a valve seat in the valve chamber to selectively open and close the supply passage. The valve opening spring urges the valve body away from the valve seat. The electromagnetic actuator includes a fixed iron core and a movable iron core coupled to a transmission rod. The movable iron core is capable of contacting and separating from the fixed iron core. The electromagnetic actuator changes electromagnetic urging force acting on the movable iron core through control of externally supplied current. The control valve further includes urging means. In a state where the electromagnetic actuator is not energized and the valve body is held at a position separated from the valve seat by the urging force of the valve opening spring, the urging means deforms in such a manner as to urge the valve body toward the valve seat when the temperature of the urging means reaches a predetermined temperature. The urging force of the urging means when the temperature reaches the predetermined temperature is set to be greater than the urging force of the

valve opening spring in a state where the electromagnetic actuator is not energized.

**[0008]** Other aspects and advantages of the present invention will become apparent from the following description, taken into conjunction with the accompanying illustrating by way of example the principles of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** 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 longitudinal cross-sectional view illustrating a variable displacement compressor according to a first embodiment of the present invention;

Fig. 2 is a cross-sectional view of the control valve shown in Fig. 1;

Fig. 3 is a cross-sectional view showing a state in which the valve body has been moved in the control valve shown in Fig. 2;

Fig. 4 is a cross-sectional view illustrating a control valve according to a second embodiment;

Fig. 5 is a cross-sectional view showing a state in which the valve body has been moved in the control valve shown in Fig. 4;

Fig. 6 is a cross-sectional view illustrating a modification of the control valve according to the first embodiment; and

Fig. 7 is a partial cross-sectional view illustrating a further modification of the control valve according to the first embodiment.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0010]** A control valve CV1 of a variable displacement compressor according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 3. The compressor 10 is used in a refrigerant circuit of a vehicle air conditioner. The control valve CV1 is capable of changing a target suction pressure. Arrow Y1 of Fig. 1 represents the front-rear direction of the compressor 10. Arrow Y2 of Fig. 1 represents the up-down direction of the compressor 10.

**[0011]** As shown in Fig. 1, a housing of the compressor 10 includes a cylinder block 11, a front housing member 12, and a rear housing member 14. The front housing member 12 is secured to the front end of the cylinder block 11. The rear housing member 14 is secured to the rear end of the cylinder block 11 with a valve plate assembly 13 in between. The cylinder block 11 and the front housing member 12 define a crank chamber 15 in between. In the crank chamber 15, a rotary shaft 16 is rotatably supported between the cylinder block 11 and the

front housing member 12 so as to extend through the crank chamber 15.

**[0012]** A front portion of the rotary shaft 16 is rotatably supported by a radial bearing 20, and a rear portion of the rotary shaft 16 is rotatably supported by a radial bearing 21. The rotary shaft 16 is coupled to a vehicle engine E, which is an external drive source, through a clutchless power transmission mechanism PT. When the engine E is running, the rotary shaft 16 is always rotated by receiving rotational drive force from the engine E. A shaft sealing assembly 39 is located between the circumference of the front portion of the rotary shaft 16 and the inner circumference of the front housing member 12 that faces the front circumference of the rotary shaft 16. The shaft sealing assembly 39 prevents refrigerant gas from leaking out of the compressor 10 from the crank chamber 15 along the rotary shaft 16.

**[0013]** A rotor 17 is coupled to the rotary shaft 16 and is located in the crank chamber 15. The rotor 17 rotates integrally with the rotary shaft 16. A substantially disk-shaped swash plate 18, which functions as a cam plate, is accommodated in the crank chamber 15. The rotary shaft 16 extends through a center portion of the swash plate 18. The swash plate 18 is supported to rotate integrally with and incline with respect to the rotary shaft 16. A hinge mechanism 19 is provided between the rotor 17 and the swash plate 18, so as to transmit that rotational force of the rotor 17 to the swash plate 18.

**[0014]** Cylinder bores 22 are formed in the cylinder block 11 about the rotary shaft 16 at equal angular intervals. The cylinder bores 22 extend along the axial direction of the rotary shaft 16 and through the cylinder block 11 in the front-rear direction. Each cylinder bore 22 accommodates a piston 23, which reciprocates along the front-rear direction of the compressor 10, that is, along the axial direction of the rotary shaft 16. The front and rear openings of each cylinder bore 22 are closed by the valve plate assembly 13 and the associated piston 23, so that a compression chamber 24 is defined in each cylinder bore 22. The volume of the compression chamber 24 changes according to the reciprocation of the corresponding piston 23. Each piston 23 is coupled to the peripheral portion of the swash plate 18 by a pair of shoes 25. When the swash plate 18 is rotated by rotation of the rotary shaft 16, the shoes 25 convert the rotation into reciprocation of each piston 23.

**[0015]** A suction chamber 26, which is a suction pressure zone, and a discharge chamber 27, which is a discharge pressure zone, are defined between the valve plate assembly 13 and the rear housing member 14. The valve plate assembly 13 has a suction port 28 and a suction valve flap 29 at a position between each compression chamber 24 and the suction chamber 26. The valve plate assembly 13 also has a discharge port 30 and a discharge valve flap 31 at a position between each compression chamber 24 and the discharge chamber 27.

**[0016]** The refrigerant circuit of the vehicle air conditioner includes the above described compressor 10 and

an external refrigerant circuit 35. The external refrigerant circuit 35 includes a gas cooler 37, an expansion valve 38, and an evaporator 36. Refrigerant gas is drawn into the suction chamber 26 of the compressor 10 from the evaporator 36. As each piston 23 moves from the top dead center position to the bottom dead center position, the refrigerant is drawn into the corresponding compression chamber 24 through the corresponding suction port 28 while flexing the suction valve flap 29. Refrigerant gas that has been drawn into the compression chamber 24 is compressed to a predetermined pressure as the piston 23 is moved from the bottom dead center to the top dead center. Then, the gas is discharged to the discharge chamber 27 through the corresponding discharge port 30 while flexing the discharge valve flap 31. The refrigerant gas discharged to the discharge chamber 27 is conducted out to the gas cooler 37 of the external refrigerant circuit 35. The gas cooler 37 cools and liquefies the refrigerant gas. The liquefied refrigerant is decompressed by the expansion valve 38 and sent to the evaporator 36, which in turn evaporates the refrigerant. The refrigerant gas that circulates in the refrigerant circuit 35 contains lubricant, which is stored in the crank chamber 15 when being returned to the compressor 10 with refrigerant gas. The lubricant lubricates components in the crank chamber 15 such as the pistons 23 and the shoes 25, the radial bearing 20, and the radial bearing 21, and also cools the shaft sealing assembly 39.

**[0017]** A bleed passage 32, a supply passage 33, and the control valve CV1 are provided in the housing of the compressor 10. The bleed passage 32 connects the crank chamber 15 with the suction chamber 26, and the supply passage 33 connects the discharge chamber 27 with the crank chamber 15. The control valve CV1 is arranged in the supply passage 33. The opening degree of the control valve CV1 is adjusted to adjust the cross-sectional flow area of the supply passage 33. This controls the balance between the flow rate of highly pressurized gas supplied to the crank chamber 15 from the discharge chamber 27 through the supply passage 33 and the flow rate of gas conducted out of the crank chamber 15 through the bleed passage 32. The pressure  $P_c$  in the crank chamber 15 is thus determined. The difference between the pressure  $P_c$  in the crank chamber 15 and the pressure in each compression chamber 24 is changed according to changes in the pressure  $P_c$  of the crank chamber 15. This alters the inclination angle of the swash plate 18. As a result, the stroke of each piston 23, that is, the displacement of the compressor 10, is adjusted.

**[0018]** For example, when the opening degree of the control valve CV1 is reduced so that the cross-sectional flow area of the supply passage 33 is reduced, the pressure  $P_c$  in the crank chamber 15 is lowered. Accordingly, the inclination angle of the swash plate 18 is increased, which in turn increases the stroke of the pistons 23. As a result, the displacement of the compressor 10 is increased. In contrast, when the opening degree of the control valve CV1 is increased so that the cross-sectional

flow area of the supply passage 33 is increased, the pressure  $P_c$  in the crank chamber 15 is raised. Accordingly, the inclination angle of the swash plate 18 is decreased, which in turn decreases the stroke of the pistons 23. As a result, the displacement of the compressor 10 is decreased.

**[0019]** The configuration of the control valve CV1 will now be described in detail.

**[0020]** As shown in Fig. 2, a valve chamber 42, a communication passage 43 communicating with the valve chamber 42, an insertion hole 44 communicating with the communication passage 43, and a pressure sensing chamber 45 communicating with the insertion hole 44 are defined in a valve housing 41 of the control valve CV1. The valve chamber 42 is connected to the discharge chamber 27 through an upstream section of the supply passage 33, and the communication passage 43 is connected to the crank chamber 15 through a downstream section of the supply passage 33. The valve chamber 42 and the communication passage 43 form a part of the supply passage 33. The pressure sensing chamber 45 is connected to the suction chamber 26 through a pressure sensing passage 46 (see Fig. 1) formed in the rear housing member 14. Therefore, the pressure sensing chamber 45 is exposed to the pressure in the suction chamber 26 (suction pressure  $P_s$ ) through the pressure sensing passage 46.

**[0021]** A transmission rod 47 extends through the valve chamber 42, the communication passage 43, and the insertion hole 44. The transmission rod 47 moves in the axial direction of the valve housing 41, or in the up-down direction as viewed in Fig. 2. The upper end portion of the transmission rod 47, which is inserted in the insertion hole 44, disconnects the communication passage 43 and the pressure sensing chamber 45 from each other. The transmission rod 47 includes a valve body 48 located in the valve chamber 42. The valve housing 41 has a valve seat 49 formed at the periphery of the opening of the communication passage 43 in the valve chamber 42. The valve seat 49 contacts and separates from the valve body 48. The transmission rod 47 moves in the axial direction so that the valve body 48 contacts or separates from the valve seat 49, thereby changing the opening degree of the communication passage 43. Accordingly, the cross-sectional flow area of the communication passage 43, that is, the cross-sectional flow area of the supply passage 33, is adjusted.

**[0022]** A suction pressure sensing member 50, which is a bellows, is located in the pressure sensing chamber 45. A recess 50a is formed in the bottom of the pressure sensing member 50, and the upper end of the transmission rod 47 is fixed to the recess 50a (second end). The pressure sensing member 50 includes an upper end (first end) contacting an inner surface of the pressure sensing chamber 45. An urging spring 51 is arranged in the pressure sensing member 50. The urging spring 51 urges and extends the pressure sensing member 50. The pressure sensing member 50 is deformed based on changes

in the pressure in the pressure sensing chamber 45, that is, the pressure in the suction chamber 26. The pressure sensing member 50 is involved in determining the position of the valve body 48 relative to the valve seat 49 in the valve chamber 42.

**[0023]** An electromagnetic actuator 52 is arranged in a lower portion of the valve housing 41. A bottomed accommodation cylinder 54 is arranged in a casing 53 of the electromagnetic actuator 52. A cylindrical fixed iron core 55 is arranged in an upper portion of the accommodation cylinder 54. A lower portion of the transmission rod 47 is movably inserted in the fixed iron core 55. A movable iron core 56 is movably accommodated in the lower portion of the accommodation cylinder 54, so as to contact and separate from the fixed iron core 55. The movable iron core 56 is loosely fitted to the lower end of the transmission rod 47. The movable iron core 56 can be moved in the axial direction relative to the transmission rod 47.

**[0024]** A contact portion 47a having a larger diameter than the remainder of the transmission rod 47 is formed in a lower end portion of the transmission rod 47. The contact portion 47a extends over the entire circumference of the transmission rod 47. The fixed iron core 55 has an accommodation recess 55a at a portion of the inner circumferential surface that faces the circumference of a lower portion of the transmission rod 47. In other words, in the through hole of the fixed iron core 55 through which the transmission rod 47 extends, a part that corresponds to the lower portion of the fixed iron core 55 forms the accommodation recess 55a, which has a larger diameter than the remainder. A valve opening spring 57 is accommodated in the accommodation recess 55a. The valve opening spring 57 urges the valve body 48 (the transmission rod 47) away from the valve seat 49 (in a valve opening direction). The upper end (first end) of the valve opening spring 57 contacts an upper inner surface of the accommodation recess 55a, and the lower end (second end) of the valve opening spring 57 contacts the contact portion 47a of the transmission rod 47. The inner diameter of the accommodation recess 55a is larger than the outer diameter of the contact portion 47a so that the contact portion 47a enters the accommodation recess 55a when the transmission rod 47 is moved upward.

**[0025]** A coil 58 is wound about the accommodation cylinder 54 so as to face both of the fixed iron core 55 and the movable iron core 56. The coil 58 is supplied with drive current through current control performed by an air conditioner ECU (not shown) located outside of the control valve CV1. The current control to the coil 58 is performed by adjusting voltage applied to the coil 58. In the present embodiment, the applied voltage is adjusted through duty cycle control.

**[0026]** In the control valve CV1, an urging plate 60, which is an urging means to urge the valve body 48, is located between the contact portion 47a and a support surface 56a of the movable iron core 56 that faces the

contact portion 47a. The urging plate 60 is formed by a bimetal spring, which is formed by bonding two metal plates of different coefficients of thermal expansion. The urging plate 60 changes its manner of bending according to temperature changes. In the present embodiment, when the temperature reaches a predetermined first temperature (for example,  $150^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ), the urging plate 60 abruptly bends. That is, the urging plate 60 has a jumping property. The urging plate 60 of the present embodiment abruptly restores to the original shape from the deformed shape when its temperature is lowered to a second temperature, which is lower than the first temperature and is, for example,  $130^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . The first temperature is slightly lower than the upper limit of a temperature range in which the safety of the compressor 10 against heat is ensured, and is provided to protect the compressor 10.

**[0027]** The urging plate 60 is annular and is loosely fitted to a small diameter portion at the lower end of the transmission rod 47 (a portion inserted in the movable iron core 56). The lower end of the movable iron core 56 contacts the inner bottom surface of the accommodation cylinder 54, when the movable iron core 56 is at the lowest position. When the movable iron core 56 is at the lowest position, and the transmission rod 47 has been moved by the urging force of the valve opening spring 57 in a direction to move the valve body 48 away from the valve seat 49, the space between the contact portion 47a and the support surface 56a is wider than the thickness of the urging plate 60. That is, the urging plate 60 is arranged to be movable in the axial direction of the transmission rod 47 in a space between the contact portion 47a and the support surface 56a of the movable iron core 56.

**[0028]** The force generated by bending deformation of the urging plate 60 when the temperature reaches the first temperature, that is, the urging force of the urging plate 60 is set to be greater than the urging force of the valve opening spring 57 (spring force) in a state where the electromagnetic actuator 52 is not energized (hereinafter, referred to as an OFF state), and the valve body 48 is separated from the valve seat 49 by the urging force of the valve opening spring 57. Also, the force generated by bending deformation of the urging plate 60 when the temperature reaches the first temperature is set to be smaller than electromagnetic urging force generated by the electromagnetic actuator 52 when drive current sufficient for maintaining the displacement of the compressor 10 to a value greater than the minimum displacement is supplied to the coil 58 (acting on the movable iron core 56).

**[0029]** In the control valve CV1, when the urging plate 60 is at a temperature lower than the first temperature, and the electromagnetic actuator 52 is in the OFF state, the position of the valve body 48 (the transmission rod 47) is determined by the urging forces of the urging spring 51 and the valve opening spring 57. At this time, the valve body 48 of the transmission rod 47 is away from the valve seat 49, and the communication passage 43 is fully opened. As a result, the pressure in the crank chamber

15 has the maximum value under the current conditions, which decreases the inclination angle of the swash plate 18. Accordingly, the displacement of the compressor 10 becomes minimum.

[0030] In the control valve CV1, when the urging plate 60 is at a temperature lower than the first temperature, and the electromagnetic actuator 52 is in the ON state, that is, when drive current is supplied to the coil 58, the upward electromagnetic force acting on the movable iron core 56 is greater than the downward urging force of the urging spring 51 and the valve opening spring 57. As a result, the transmission rod 47 starts moving upward. This reduces the opening degree of the communication passage 43, and the suction pressure Ps is lowered as the displacement of the compressor 10 is increased. As the suction pressure Ps is lowered, the pressure sensing member 50 extends. The position of the valve body 48 (the transmission rod 47) is determined such that the downward urging force of the pressure sensing member 50 due to its extension and the downward urging force of the valve opening spring 57 are balanced with the upward electromagnetic force acting on the movable iron core 56, so that the opening degree of the communication passage 43 is determined. Thus, the control valve CV1 functions to determine the control target (target suction pressure) by using electromagnetic urging force.

[0031] In the compressor 10 having the control valve CV1, the rotary shaft 16 is always rotated while the engine E is running. At this time, if the control valve CV1 is in the OFF state, the displacement of the compressor 10 is minimized.

[0032] In a state where the pressure in the crank chamber 15 is high and a certain amount of lubricant is retained in the crank chamber 15, the lubricant is agitated by rotation of the swash plate 18, which rapidly increases the temperature of the lubricant. Further, when the speed of the engine E is increased and the rotary shaft 16 is rotated at a high speed, the temperature of the compressor 10 itself is increased, which increases the temperature of the control valve CV1. Accordingly, the temperature of the urging plate 60 is increased so that the urging plate 60 gradually bend.

[0033] Thereafter, when the temperature reaches the first temperature, the urging plate 60 abruptly bends as shown in Fig. 3 due to its jumping property. At this time, the bending deformation force of the urging plate 60 is greater than the urging force of the valve opening spring 57 (spring force) in the OFF state of the electromagnetic actuator 52. Thus, the urging force of the bent urging plate 60 presses the contact portion 47a of the transmission rod 47 upward. As a result, the transmission rod 47 is moved (upward) in a direction away from the movable iron core 56 against the urging force of the valve opening spring 57. Such an autonomous operation of the control valve CV1 moves the valve body 48 toward the valve seat 49 (upward), so that the opening degree of the control valve CV1 is reduced. This forcibly reduces the cross-sectional flow area of the communication passage 43

(the supply passage 33).

[0034] Then, the reduction in the amount of high pressure discharge gas supplied to the crank chamber 15 through the supply passage 33 lowers the pressure in the crank chamber 15, and increases the inclination angle of the swash plate 18. Accordingly, the displacement of the compressor 10 is increased. This increases the amount of lubricant conducted from the crank chamber 15 to the suction chamber 26 through the bleed passage 32. The lubricant conducted out to the suction chamber 26 is conducted out to the external refrigerant circuit 35 through the compression chambers 24 and the discharge chamber 27. This reduces the amount of lubricant in the crank chamber 15 and thus lowers the heat value of the lubricant.

[0035] When the control valve CV1 is set to the ON state (a state where drive current is supplied to the coil 58) to maintain the compressor 10 in a state other than the minimum displacement state, an upward electromagnetic urging force acts on the movable iron core 56. At this time, the bending deformation force of the urging plate 60 that urges the valve body 48 toward the valve seat 49 is smaller than the electromagnetic urging force (the electromagnetic force). Therefore, the electromagnetic force becomes greater than the downward urging force of the urging spring 51 and the valve opening spring 57, while acting against the bending deformation force of the urging plate 60. As a result, the transmission rod 47 starts being moved upward by the movable iron core 56 and the urging plate 60. Thus, while the switching of the control valve CV1 to the ON state is not hindered by the bending deformation force (urging force) of the urging plate 60, the position of the transmission rod 47 is determined according to changes in the actual suction pressure Ps, such that the control target (target suction pressure) of the suction pressure Ps determined by the electromagnetic force is maintained.

[0036] The present embodiment has the following advantages.

- (1) The urging plate 60, which bends when the temperature reaches the predetermined first temperature, is arranged between the transmission rod 47 and the movable iron core 56. The bending deformation force of the urging plate 60 when the temperature reaches the first temperature is set to be greater than the urging force of the valve opening spring 57 in the OFF state of the electromagnetic actuator 52. While the engine E is running, if the control valve CV1 is in the OFF state and the temperature of the compressor 10 becomes high due to agitation of lubricant in the crank chamber 15, the transmission rod 47 is moved by bending of the urging plate 60, so that the opening degree of the supply passage 33 is forcibly reduced. Therefore, even if the control valve CV1 is in the OFF state, the displacement of the compressor 10 can be increased so as to increase the amount of lubricant that is conducted out

to the external refrigerant circuit 35 from the crank chamber 15. As a result, the amount of lubricant in the crank chamber 15 is reduced and its heating value is lowered, accordingly. Thus, the shaft sealing assembly 39 is not heated by heated lubricant, and its reliability is maintained. Also, the lubricity of the radial bearings 20, 21 and sliding parts of the pistons 23 and the shoes 25 are prevented from being reduced. That is, the reliability of the compressor 10 is prevented from being reduced.

(2) To maintain the compressor 10 in a state other than the minimum displacement state, the bending deformation force of the urging plate 60 when the temperature reaches the first temperature is set to be smaller than the electromagnetic force that is generated by the electromagnetic actuator 52. Therefore, the bending deformation force (urging force) of the urging plate 60 does not block the upward movement of the movable iron core 56 when the control valve CV1 is in the ON state, and the control target (the target suction pressure) determined by the electromagnetic force, that is, the position of the valve body 48, is accurately maintained.

(3) The transmission rod 47 is movable relative to the movable iron core 56, and the urging plate 60 is located between the contact portion 47a of the transmission rod 47 and the support surface 56a of the movable iron core 56. Therefore, when bending, the urging plate 60 only moves the transmission rod 47. Therefore, compared to, for example, a case where the transmission rod 47 and the movable iron core 56 are integrated, and the urging plate 60 moves the valve body 48 together with the movable iron core 56, the bending deformation force (urging force) of the urging plate 60 required for moving the valve body 48 is reduced so that the urging plate 60 is capable of quickly moving the valve body 48 in the valve closing direction.

(4) The urging plate 60 is formed as a ring that is continuous in the circumferential direction. Thus, unlike a plate with a cutout, the urging plate 60 reliably exhibits its jumping property. As a result, the bending deformation of the urging plate 60, the temperature of which has reached the first temperature, rapidly moves the transmission rod 47 such that the valve body 48 approaches the valve seat 49.

(5) It is possible to add a control valve to the compressor 10 in addition to the control valve CV1, and to control the additional control valve to increase the displacement when the control valve CV1 is in the OFF state. However, the addition of another control valve undesirably leads to a larger size of the compressor 10. In the present embodiment, the amount of lubricant that is conducted out to the external refrigerant circuit 35 from the crank chamber 15 is increased by simply having the control valve CV1 with the urging plate 60, that is, without increasing the size of the compressor 10.

**[0037]** A flow rate control valve CV2 according to a second embodiment of the present invention will now be described with reference to Figs. 4 and 5. In the present embodiment, an orifice 35a is provided in the external refrigerant circuit 35 at a position upstream of the gas cooler 37.

**[0038]** As shown in Fig. 4, a valve chamber 72, a communication passage 73 communicating with the valve chamber 72, an insertion hole 70 communicating with the communication passage 73, and a pressure sensing chamber 74 communicating with the insertion hole 70 are defined in a valve housing 71 of the control valve CV2, in the order from the bottom along the axial direction of the control valve CV2. A transmission rod 75 extends through the valve chamber 72, the insertion hole 70, and the communication passage 73. The transmission rod 75 moves in the axial direction of the valve housing 71, or in the up-down direction. The upper end portion of the transmission rod 75, which is inserted in the insertion hole 70, disconnects the communication passage 73 and the pressure sensing chamber 74 from each other.

**[0039]** The communication passage 73 is connected to the discharge chamber 27 through an upstream section of the supply passage 33, and the valve chamber 72 is connected to the crank chamber 15 of the compressor 10 through a downstream section of the supply passage 33. The transmission rod 75 includes a valve body 76 located in the valve chamber 72. The valve housing 71 has a valve seat 77 formed at the periphery of the opening of the communication passage 73 in the valve chamber 72. The valve seat 77 contacts and separates from the valve body 76. The transmission rod 75 moves in the axial direction so that the valve body 76 contacts or separates from the valve seat 77, thereby changing the valve opening degree of the valve seat 77. Accordingly, the cross-sectional flow area of the communication passage 73, that is, the cross-sectional flow area of the supply passage 33, is adjusted.

**[0040]** A valve opening spring 78 is arranged in the valve chamber 72. On the inner surface of the valve chamber 72, a step surface (spring seat) 73a is formed at the boundary between the valve chamber 72 and the communication passage 73. The upper end of the valve opening spring 78 contacts and is supported by the step surface 73a, and the lower end of the valve opening spring 78 contacts and is supported by a spring seat 79 attached to the transmission rod 75. The valve opening spring 78 urges the transmission rod 75 in a direction for moving the valve body 76 away from the valve seat 77 (valve opening direction).

**[0041]** A pressure sensing member 80, which detects pressure difference and is formed by a bellows, is located in the pressure sensing chamber 74. The upper end of the pressure sensing member 80 is fixed to the upper end portion of the valve housing 71, and the lower end of the pressure sensing member 80 contacts the upper end of the transmission rod 75. The transmission rod 75 is coupled to the pressure sensing member 80, and

moves upward and downward in accordance with extension and contraction of the pressure sensing member 80. The pressure sensing member 80 shaped like a bottlenecked cylinder divides the pressure sensing chamber 74 into a first pressure chamber 81, which is the interior of the pressure sensing member 80, and a second pressure chamber 82, which is the exterior of the pressure sensing member 80.

**[0042]** The first pressure chamber 81 is connected to a section of the external refrigerant circuit 35 that is upstream of the orifice 35a, that is, to a section closer to the discharge chamber 27, through a first pressure introduction passage 83. That is, the first pressure chamber 81 is connected to a high pressure discharge pressure zone P1, which is a pressure monitoring point in the refrigerant circuit. The second pressure chamber 82 is connected to a section downstream of the orifice 35a through a second pressure introduction passage 84. That is, the second pressure chamber 82 is connected to a low pressure discharge pressure zone P2, which is a pressure monitoring point in the refrigerant circuit.

**[0043]** When refrigerant is flowing through the high pressure discharge pressure zone P1 and the low pressure discharge pressure zone P2, the pressure at the high pressure discharge pressure zone P1, which is upstream of the orifice 35a, is higher than the pressure at the low pressure discharge pressure zone P2, which is downstream of the orifice 35a, so that there is a pressure difference between the two pressure monitoring points. When the flow rate of refrigerant in the external refrigerant circuit 35 is increased, the pressure difference between both sides of the orifice 35a is increased, and when the flow rate of refrigerant in the external refrigerant circuit 35 is reduced, the pressure difference between both sides of the orifice 35a is reduced. When the pressure difference between both sides of the orifice 35a is increased, the pressure difference between the first pressure chamber 81 and the second pressure chamber 82 is increased. When the pressure difference between both sides of the orifice 35a is reduced, the pressure difference between the first pressure chamber 81 and the second pressure chamber 82 is reduced. The pressure difference between the first pressure chamber 81 and the second pressure chamber 82 generates a force that urges the transmission rod 75 through the pressure sensing member 80.

**[0044]** Therefore, since the position of the lower end of the pressure sensing member 80 is displaced in accordance with the pressure difference between both sides of the orifice 35a, the pressure sensing member 80 causes the pressure difference to be reflected on the determination of the position of the transmission rod 75 (the valve body 76). The pressure sensing member 80 actuates the valve body 76 to change the displacement of the compressor 10 such that the pressure difference between both sides of the orifice 35a is cancelled.

**[0045]** An electromagnetic actuator 85, which has the same structure as that in the first embodiment, is located

in a lower portion of the valve housing 71. That is, in the electromagnetic actuator 85, a fixed iron core 87 is arranged in an accommodation cylinder 86. Also, a lower portion of the transmission rod 75 is movably inserted in the fixed iron core 87. Further, a movable iron core 88 is movably accommodated in a lower portion of the accommodation cylinder 86, and the lower end portion of the transmission rod 75 is loosely fitted to the movable iron core 88 so as to move relative to the movable iron core 88. A coil 89 is wound about the accommodation cylinder 86 so as to face both of the fixed iron core 87 and the movable iron core 88.

**[0046]** In the control valve CV2, electromagnetic urging force applied to the valve body 76 through the movable iron core 88 is changed in accordance with the amount of drive power supplied from the outside, so that a control target of the pressure difference between both sides of the orifice 35a (target pressure difference), which is a reference in the determination of the position of the valve body 76 performed by the pressure sensing member 80, can be changed. That is, the control valve CV2 autonomously determines the position of the transmission rod 75 (the valve body 76) in accordance with changes in the pressure difference, so as to maintain the target pressure difference, which is determined by the amount of drive power supplied to the coil 89. The target pressure difference can be externally controlled by adjusting the amount of drive current supplied to the coil 89.

**[0047]** In the control valve CV2, an urging plate 90, which has the same structure as the urging plate 60 of the first embodiment, is located between the upper surface of the fixed iron core 87 and the spring seat 79. The urging plate 90 functions as valve body urging means (urging means). The urging plate 90 has an annular shape. The urging plate 90 surrounds the transmission rod 75.

**[0048]** The thickness of the urging plate 90 is slightly less than the space between the spring seat 79 and the fixed iron core 87 in the state where the valve body 76 is maximally separated from the valve seat 77. The force generated by bending of the urging plate 90 when the temperature reaches the first temperature (the urging force) is set to be greater than the urging force of the valve opening spring 78 (spring force) in a state where the electromagnetic actuator 85 is in the OFF state, and the valve body 76 is separated from the valve seat 77 by the urging force of the valve opening spring 78. Also, the bending deformation force of the urging plate 90 when the temperature reaches the first temperature is smaller than the electromagnetic force that is generated by the coil 89 when it receives drive current sufficient to maintain the compressor 10 in a state other than the minimum displacement state.

**[0049]** When the electromagnetic actuator 85 is in the OFF state, the valve body 76 of the transmission rod 75 is separated from the valve seat 77 by the valve opening spring 78, so that the communication passage 73 is fully open. As a result, the pressure in the crank chamber 15

has the maximum value under the current conditions, which minimizes the inclination angle of the swash plate 18. Accordingly, the displacement of the compressor 10 becomes minimum.

**[0050]** In a state where the pressure in the crank chamber 15 is high and a certain amount of lubricant is retained in the crank chamber 15, the lubricant is agitated by rotation of the swash plate 18, which rapidly increases the temperature of the lubricant. Further, when the speed of the engine E is increased and the rotary shaft 16 is rotated at a high speed, the temperature of the compressor 10 itself is increased, which increases the temperature of the control valve CV2. Accordingly, the temperature of the urging plate 90 is increased so that the urging plate 90 gradually bend.

**[0051]** Then, when the temperature reaches the first temperature, the urging plate 90 abruptly bends due to its jumping property. At this time, the bending deformation force of the urging plate 90 is greater than the urging force of the valve opening spring 78 in the OFF state of the electromagnetic actuator 85. Thus, as shown in Fig. 5, the bent urging plate 90 presses the transmission rod 75 through the spring seat 79 from below, so that the transmission rod 75 is moved (upward) away from the movable iron core 88 against the urging force of the valve opening spring 78. Such an autonomous operation of the control valve CV2 moves the valve body 76 toward the valve seat 77 (upward), so that the opening degree of the control valve CV2 is reduced. This forcibly reduces the cross-sectional flow area of the communication passage 73 (the supply passage 33). Then, as in the first embodiment, the pressure in the crank chamber 15 is lowered, and the displacement of the compressor 10 is increased. As a result, the amount of lubricant that is conducted out from the crank chamber 15 to the external refrigerant circuit 35 is increased.

**[0052]** The present embodiment has the following advantage in addition to the advantages (2) to (5) of the first embodiment.

(6) The urging plate 90, which bends when the temperature reaches the first temperature, is arranged between the fixed iron core 87 and the spring seat 79. The bending deformation force generated by the urging plate 90 when the temperature reaches the first temperature is greater than the urging force of the valve opening spring 78 when the electromagnetic actuator 85 is in the OFF state. While the engine E is running, if the control valve CV2 is in the OFF state and the temperature of the compressor 10 becomes high due to agitation of lubricant in the crank chamber 15, the transmission rod 75 is moved by bending of the urging plate 90, so that the opening degree of the supply passage 33 is forcibly reduced. Therefore, even if the control valve CV2 is in the OFF state, the displacement of the compressor 10 can be increased so as to increase the amount of lubricant that is conducted out to the external refrigerant circuit

35 from the crank chamber 15. As a result, the amount of lubricant in the crank chamber 15 is reduced and the heat value of the lubricant is lowered. Thus, the shaft sealing assembly 39 is not heated by heated lubricant, and its reliability is maintained. Also, the lubricity of the radial bearings 20, 21 and sliding parts of the pistons 23 and the shoes 25 are prevented from being reduced. That is, the reliability of the compressor 10 is prevented from being reduced.

**[0053]** The above embodiments may be modified as follows.

**[0054]** In the first embodiment, the valve body urging plate 60, which is valve body urging means (urging means), may be arranged between the inner bottom surface of the accommodation cylinder 54 and the end face of the movable iron core 56 that faces the inner bottom surface as shown in Fig. 6. In this case, the movable iron core 56 is integrated with the transmission rod 47, and the valve opening spring 57 is arranged between the fixed iron core 55 and the inner bottom surface of the movable iron core 56.

**[0055]** In the first embodiment, a restriction member 91 serving as a restriction portion may be provided on the inner bottom surface of the valve housing 41, which defines pressure sensing chamber 45 (in pressure sensing chamber 45) as shown in Fig. 7. The restriction member 91 restricts the extension of the pressure sensing member 50 to a predetermined degree. The restriction member 91 is annular and has a predetermined thickness. The restriction member 91 is fixed to the inner bottom surface of the pressure sensing chamber 45. The thickness of the restriction member 91 is set to such value that when the suction pressure is low the restriction member 91 prevents the pressure sensing member 50 from being excessively extended so that the extension of the pressure sensing member 50 is stopped at a predetermined position. The predetermined position is where the urging force of the bent urging plate 60 is capable of reliably returning the valve body 48 to the position where the valve body 48 reduces the opening degree of the valve body 48. When the temperature of the urging plate 60 is increased with the extension of the pressure sensing member 50 being restricted by the restriction member 91, the bent urging plate 60 reliably moves the valve body 48 to a position where the valve body 48 reduces the opening degree of the supply passage 33 even if the pressure sensing member 50 has been extended.

**[0056]** In Fig. 7, the extension of the pressure sensing member 50 is restricted by the restriction member 91, which is additionally provided in the pressure sensing chamber 45. However, the inner bottom surface of the valve housing 41, which defines the pressure sensing chamber 45, may be used as a restricting portion. In this case, the extension of the pressure sensing member 50 is restricted by contact of the pressure sensing member 50 with the inner bottom surface of the valve housing 41.

[0057] In each of the above embodiments, the urging plates 60, 90 may be replaced by a shape memory alloy spring, which functions as valve body urging means (urging means). When the temperature reaches a first temperature (for example,  $150^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ), the shape memory alloy spring rapidly extends. When cooled to a second temperature (for example,  $130^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ), which is lower than the first temperature, the shape memory alloy spring returns to the original state from the extended state. Therefore, when the temperature of the compressor 10 is increased by agitating lubricant, the extension of the shape memory alloy spring moves the valve body 48, 76 in the valve closing direction.

[0058] The control valves CV1, CV2 of the illustrated embodiments may be used in a variable displacement compressor of air conditioners other than vehicle air conditioners.

[0059] The present invention does not necessarily have to be applied to a swash plate type variable displacement compressor, but may be applied to a wobble type compressor having a wobble plate serving as a cam plate.

[0060] A control valve of a variable displacement compressor is disclosed. The control valve includes a valve housing, a valve body, a valve opening spring, an electromagnetic actuator, and an urging plate. The valve housing has a valve chamber that forms a part of a supply passage. The valve body can selectively contact and separate from a valve seat in the valve chamber. The valve opening spring urges the valve body away from the valve seat. The electromagnetic actuator changes electromagnetic urging force acting on the movable iron core through control of externally supplied current. In a state where the electromagnetic actuator is not energized and the valve body is held at a position separated from the valve seat by the urging force of the valve opening spring, the urging plate deforms in such a manner as to urge the valve body toward the valve seat when the temperature of the urging plate reaches a predetermined temperature. The urging force of the urging plate when the temperature reaches the predetermined temperature is set to be greater than the urging force of the valve opening spring in a state where the electromagnetic actuator is not energized.

## Claims

1. A control valve (CV1, CV2) of a variable displacement compressor (10) used in a refrigerant circuit of an air conditioner, wherein the compressor (10) includes a rotary shaft (16) and a cam plate (18), the rotary shaft (16) being coupled to an external drive source (E) through a clutchless power transmission mechanism (PT), and the cam plate (18) being accommodated in a crank chamber (15), wherein the control valve (CV1, CV2) adjusts the opening degree of a supply passage (33) connecting a discharge

pressure zone (27) of the compressor (10) to the crank chamber (15), thereby controlling the pressure in the crank chamber (15) to change the displacement of the compressor (10), wherein the control valve (CV1, CV2) comprises:

a valve housing (41, 71) having a valve chamber (42, 72), the valve chamber (42, 72) forming a part of the supply passage (33);

a valve body (48, 76) located in the valve chamber (42, 72), wherein the valve body (48, 76) selectively contacts and separates from a valve seat (49, 77) in the valve chamber (42, 72) to selectively open and close the supply passage (33);

a valve opening spring (57, 78) that urges the valve body (48, 76) away from the valve seat (49, 77); and

an electromagnetic actuator (52, 85) including a fixed iron core (55, 87) and a movable iron core (56, 88) coupled to a transmission rod (47, 75), the movable iron core (56, 88) being capable of contacting and separating from the fixed iron core (55, 87), wherein the electromagnetic actuator (52, 85) changes electromagnetic urging force acting on the movable iron core (56, 88) through control of externally supplied current,

the control valve (CV1, CV2) being **characterized by** an urging means, wherein, in a state where the electromagnetic actuator (52, 85) is not energized and the valve body (48, 76) is held at a position separated from the valve seat (49, 77) by the urging force of the valve opening spring (57, 78), the urging means deforms in such a manner as to urge the valve body (48, 76) toward the valve seat (49, 77) when the temperature of the urging means reaches a predetermined temperature,

wherein the urging force of the urging means when the temperature reaches the predetermined temperature is set to be greater than the urging force of the valve opening spring (57, 78) in a state where the electromagnetic actuator (52, 85) is not energized.

2. The control valve (CV1, CV2) according to claim 1, wherein the urging force of the urging means when the temperature reaches the predetermined temperature is set to be smaller than the electromagnetic urging force generated by the electromagnetic actuator (52, 85) when the electromagnetic actuator (52, 85) receives drive current sufficient for maintaining the displacement of the compressor (10) to a value other than the minimum displacement.
3. The control valve (CV1, CV2) according to claim 1 or 2, further comprising a pressure sensing chamber

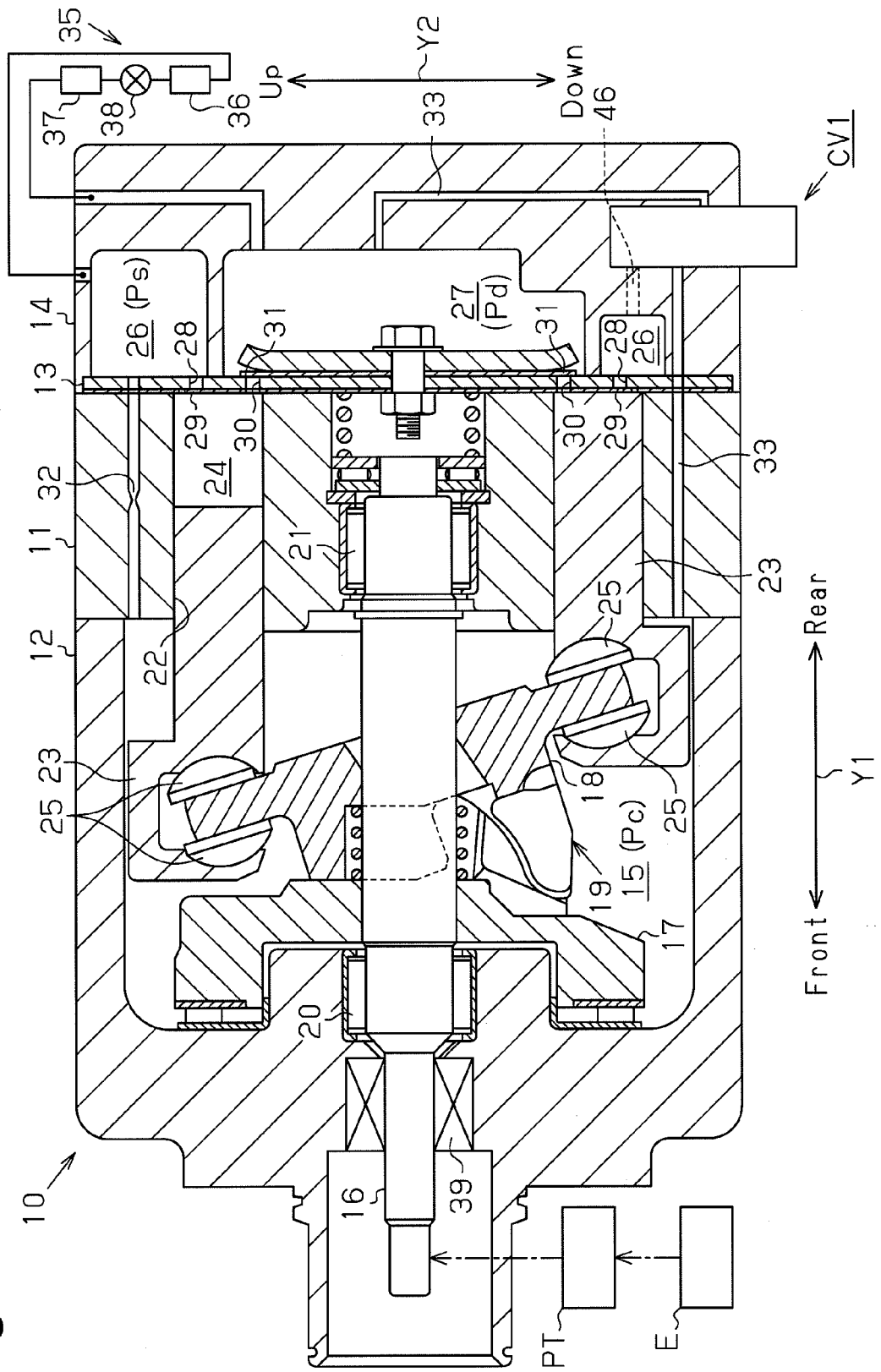
(45, 74) exposed to the pressure of a suction pressure zone (26) of the compressor (10), and a pressure sensing member (50, 80) located in the pressure sensing chamber (45, 74), wherein the pressure sensing member (50, 80) is displaced according to changes in the pressure in the pressure sensing chamber (45, 74), so as to be involved in determining the position of the valve body (48, 76) relative to the valve seat (49, 77).

4. The control valve (CV1, CV2) according to claim 3, wherein the transmission rod (47, 75) has the valve body (48, 76) and is coupled to the movable iron core (56, 88) so as to be movable relative to the movable iron core (56, 88), and wherein the urging means is located between the movable iron core (56, 88) and the transmission rod (47, 75), and moves the valve body (48, 76) together with the transmission rod (47, 75).
5. The control valve (CV1, CV2) according to claim 3 or 4, wherein the pressure sensing member (50, 80) includes a first end contacting an inner surface of the pressure sensing chamber (45, 74) and a second end (50a) supported by the transmission rod (47, 75), and wherein a restriction portion (91) that restricts extension of the pressure sensing member (50, 80) to a predetermined degree is located in the pressure sensing chamber (45, 74).
6. The control valve (CV2) according to claim 1 or 2, further comprising a pressure sensing member (80) that applies to the valve body (76) a force based on a pressure difference between two pressure monitoring points provided in the refrigerant circuit, thereby being involved in determining the position of the valve body (76) relative to the valve seat (77), wherein the valve opening spring (78) is located in the valve chamber (72) and has a first end contacting an inner surface of the valve chamber (72) and a second end supported by a spring seat (79) attached to the transmission rod (75), and wherein the urging means is located between the spring seat (79) and an inner surface of the valve chamber (72) that faces the valve seat (77), so as to move the valve body (76) through the spring seat (79) and the transmission rod (75).
7. The control valve (CV1, CV2) according to claim 3, wherein the transmission rod (47, 75) has the valve body (48, 76) and is coupled to the movable iron core (56, 88), wherein the movable iron core (56, 88) is accommodated in an accommodation cylinder (54, 86) located in the valve housing (41, 71), and wherein the urging means is located between an inner bottom surface of the accommodation cylinder

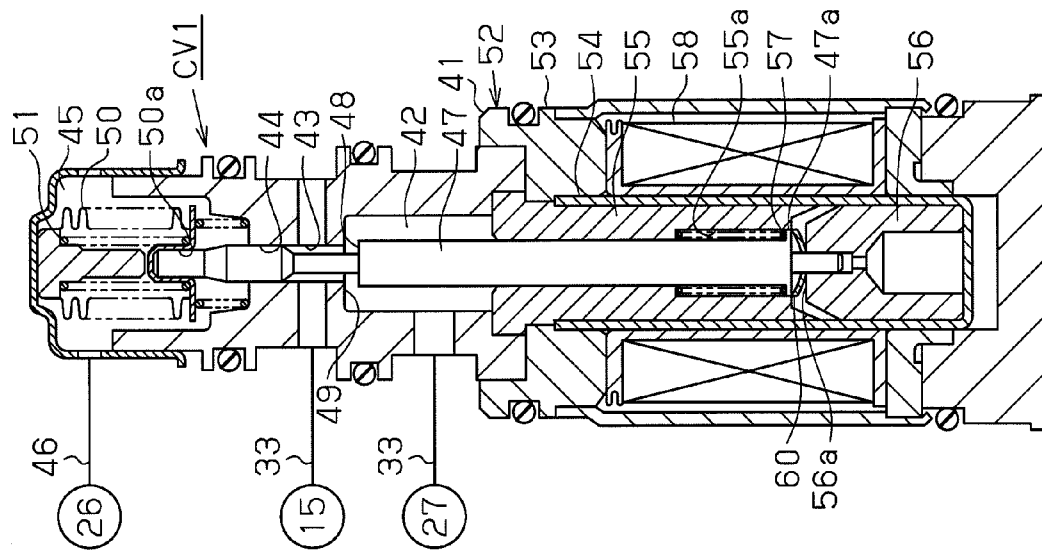
(54, 86) and an end face of the movable iron core (56, 88) that faces the inner bottom surface, and moves the transmission rod (47, 75) and the valve body (48, 76) together with the movable iron core (56, 88).

8. The control valve (CV1, CV2) according to any one of claims 1 to 7, wherein the urging means is an urging plate (60, 90) that is formed by a bimetal spring.

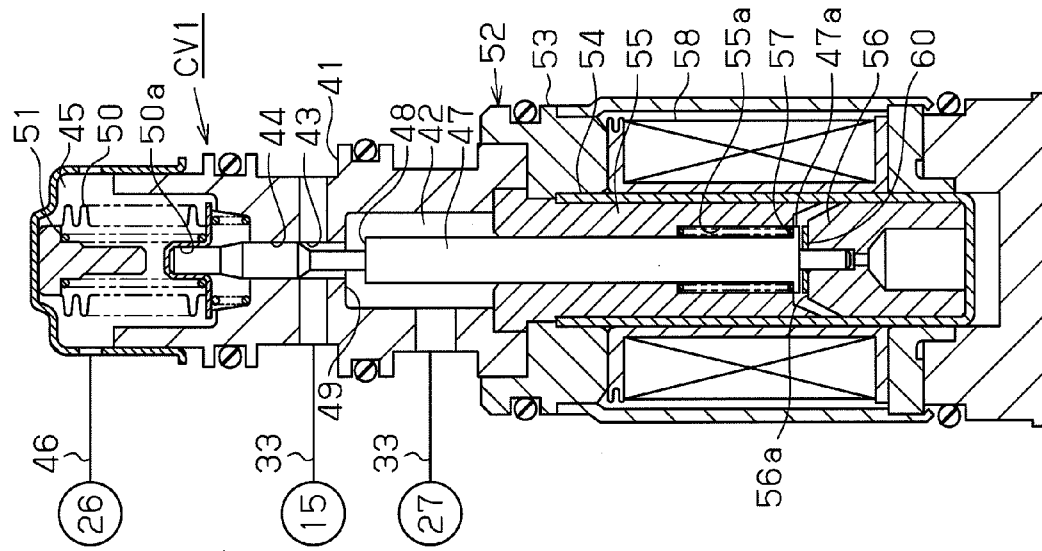
**Fig.1**

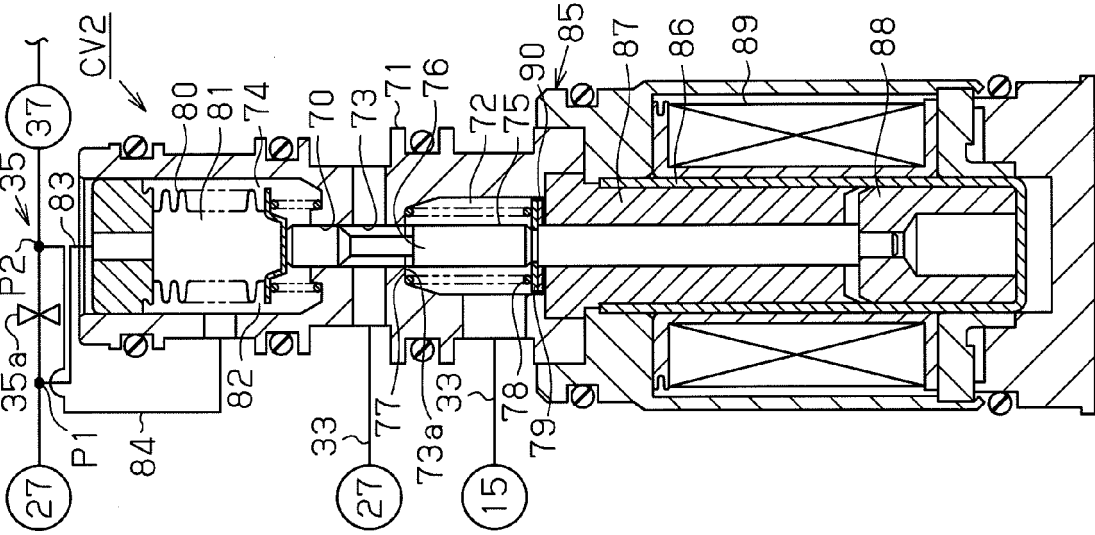


**Fig. 3**

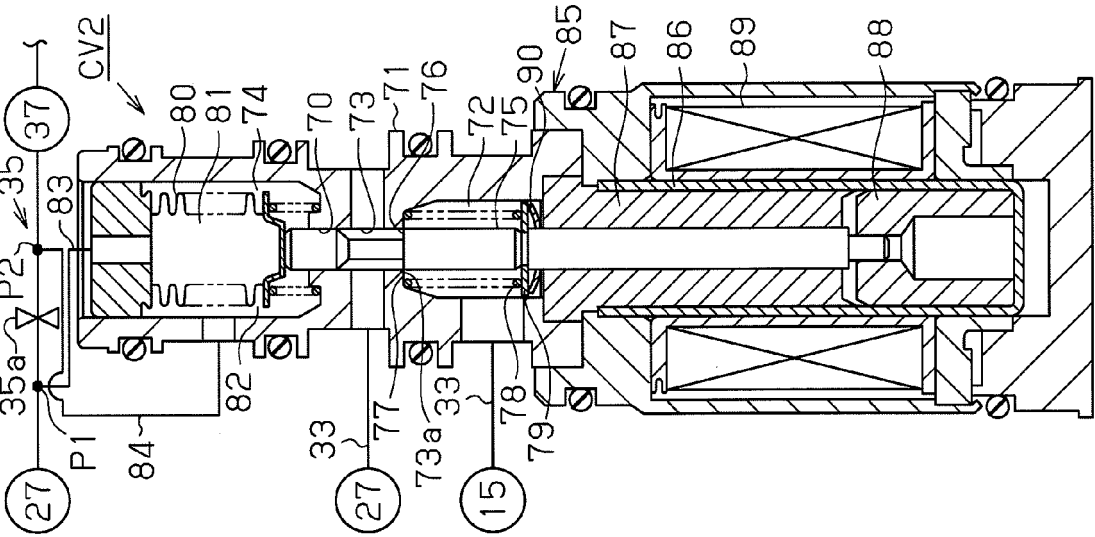


**Fig. 2**



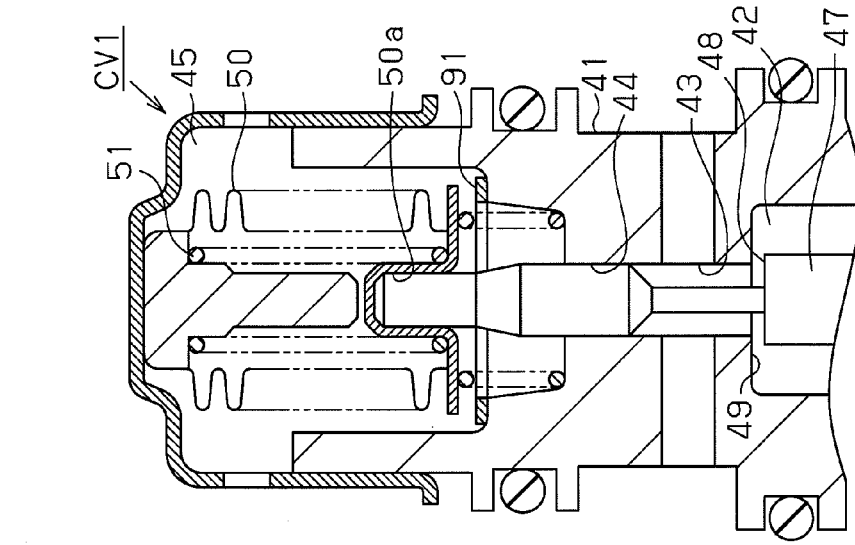


**Fig. 4**

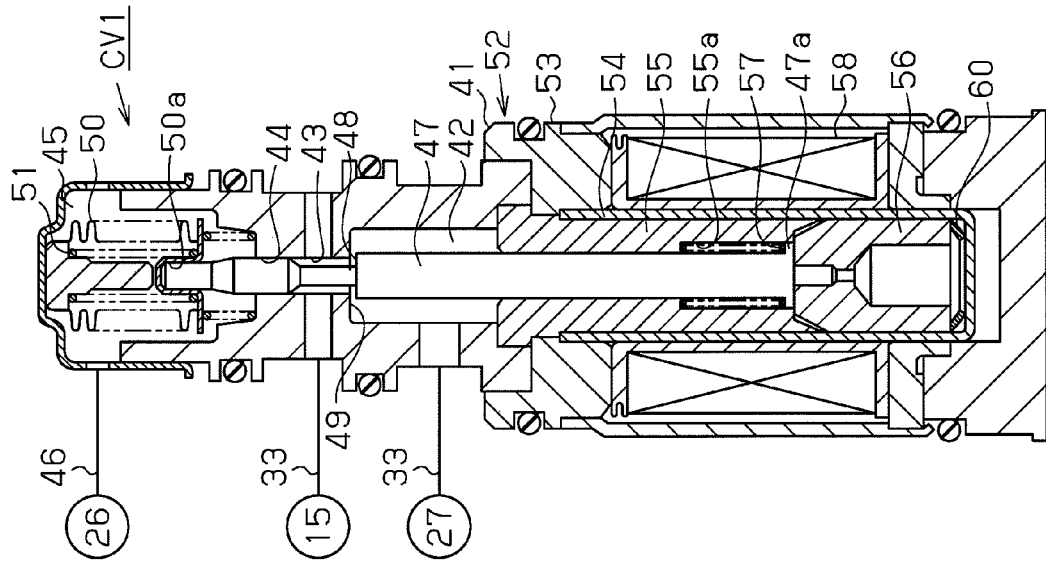


**Fig. 5**

**Fig. 7**



**Fig. 6**



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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