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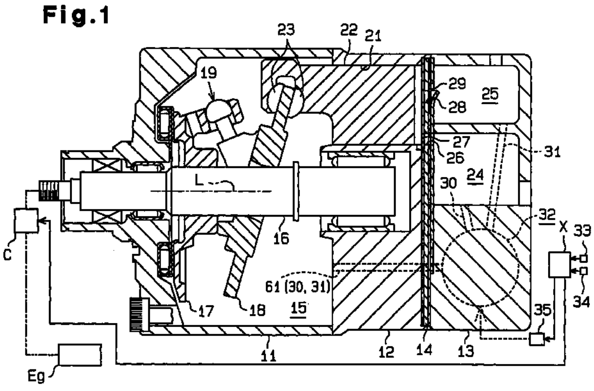
(54) Displacement control valve for variable displacement type compressors

(57) A control valve for a variable displacement type compressor includes a movable body (43) supported by the housing (38) such that the movable body (43) moves in the housing (38). The movable body (43) includes a first valve hole (46) that forms part of a bleed passage (30). A first valve body (41) adjusts the opening of the first valve hole (46). The first valve body (41) abuts against the movable body (43) such that the first valve hole (46) is closed. A second valve hole (49) extends in the housing (38) and forms part of a supply passage (31). A second valve body (48) adjusts the opening of the second valve hole (49). The second valve body (48) is movable integrally with the movable body (43). When the movable body (43) is located at an initial position, the second valve body (48) closes the second valve hole (49). However, when the first valve body (41) separates the movable body (43) from the initial position while abutting against the movable body (43), the second valve body (48) is moved to open the second valve hole (49). In this control valve, the first valve hole (46) and the second valve hole (49) are never open at the same time. Furthermore, the control valve controls the compressor displacement with high accuracy and an responsiveness.

Fig.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to displacement control valves used in variable displacement type compressors for varying compressor displacement as a function of crank chamber pressure.

[0002] A typical variable displacement type compressor includes a crank chamber, a suction chamber, and a discharge chamber. A bleed passage connects the crank chamber with the suction chamber, while a supply passage connects the crank chamber with the discharge chamber. The crank chamber accommodates a swash plate fitted around a drive shaft in the crank chamber. The swash plate inclines with respect to the drive shaft. The inclination angle of the swash plate is varied as a function of the pressure in the crank chamber. The compressor further includes pistons. The stroke of each piston is altered in relation to the variation of the swash plate inclination angle such that the compressor displacement is varied. The pressure in the crank chamber is altered depending on the amount of refrigerant gas sent from the crank chamber to the suction chamber through the bleed passage and the amount of refrigerant gas supplied from the discharge chamber to the crank chamber through the supply passage. A displacement control valve is provided for adjusting the amount of the gas flowing in the bleed passage and the supply passage.

[0003] Unexamined Japanese Patent Publication No. 5-99136 describes the displacement control valve illustrated in Figs. 6 and 7. As shown in Figs. 6 and 7, a first valve chamber 101 communicates with a crank chamber 202 via a first valve hole 102 and an upstream section of a bleed passage 201. The first valve chamber 101 further communicates with a suction chamber 203 via a downstream section of the bleed passage 201. The first valve chamber 101 accommodates a first valve body 103.

[0004] A second valve chamber 104 communicates with a discharge chamber 205 via an upstream section of a supply passage 204. The second valve chamber 104 also communicates with the crank chamber 202 via a second valve hole 105 and a downstream section of the supply passage 204. The second valve chamber 104 accommodates a second valve body 106. A first spring 107 urges the second valve body 106 in a direction to close the second valve hole 105.

[0005] The first valve body 103 is fitted around a first rod 108 such that the first rod 108 slides with respect to the first valve body 103. A second rod 109 is secured to the end of the first rod 108 that is closer to the second valve chamber 104. The second rod 109 extends in the second valve hole 105 toward the second valve body 106. A second spring 111 is arranged between a stop ring 110 secured to the first rod 108 and the first valve body 103. The second spring 111 urges the first valve body 103 toward a step 108a formed in the first rod 108 (see Figs. 6A and 7A). A third spring 112 urges the first valve body 103 such that the first rod 108 is pressed against a diaphragm 113.

[0006] The diaphragm 113 is arranged in a pressure sensitive chamber 114 communicating with the first valve chamber 101. The pressure in the suction chamber 203, or suction pressure, is applied to the pressure sensitive chamber 114 via the bleed passage 201 and the first valve chamber 101. The diaphragm 113 deforms in relation to the pressure in the pressure sensitive chamber 114, or the suction pressure. When the diaphragm 113 deforms, the diaphragm 113 moves the first rod 108 such that the first valve body 103 changes the opening size of the first valve hole 102.

[0007] If the pressure in the pressure sensitive chamber 114 is higher than a target value determined by a solenoid 115, which will be discussed later, the diaphragm 113 deforms such that the first valve body 103 increases the opening size of the first valve hole 102. The amount of refrigerant gas flowing from the crank chamber 202 to the suction chamber 203 thus increases. Accordingly, the pressure in the crank chamber 202 falls and the compressor displacement increases. As a result, the suction pressure is reduced toward the target value.

[0008] If the pressure in the pressure sensitive chamber 114 is lower than the target value, the diaphragm 113 deforms such that the first valve body 103 decreases the opening of the first valve hole 102. The amount of refrigerant gas flowing from the crank chamber 202 to the suction chamber 203 thus decreases. Accordingly, the pressure in the crank chamber 202 increases such that the compressor displacement decreases. As a result, the suction pressure is raised toward the target value.

[0009] As shown in Figs. 6 and 7, the solenoid 115 includes a coil 116, a fixed core 118, and a plunger 117. If the solenoid 115 is excited, electric current is supplied to the coil 116. When supplied with electric current, the coil 116 produces electromagnetic force acting to move the plunger 117 toward the fixed core 118. The magnitude of the electromagnetic force acting to move the plunger 117 toward the fixed core 118 varies according to the level of the electric current supplied to the coil 116. The electromagnetic force produced by the coil 116 corresponds to the target value of the suction pressure, or target suction pressure. A third rod 119 coupled with the plunger 117 transmits this electromagnetic force to the diaphragm 113.

[0010] If the electric current supplied to the coil 116 is increased such that the electromagnetic force produced by the coil 116 increases, the target suction pressure is raised. If the electric current supplied to the coil 116 is reduced such that the electromagnetic force produced by the coil 116 decreases, the target suction pressure is lowered.

[0011] If the electric current supplied to the coil 116 is increased such that the target suction pressure is maximized, the coil 116 produces a maximum electromagnetic force acting to move the plunger 117 toward the fixed core 118. Thus, the diaphragm 113 pushes the first rod 108 and the second rod 109 such that the first valve body 103 closes the first valve hole 102.

[0012] The diaphragm 113 continuously deforms and pushes the first rod 108 and the second rod 109 toward the second valve body 106. Meanwhile, the first valve hole 102 is closed by the first valve body 103. Accordingly, as shown in Fig. 7, the second rod 109 presses the second valve body 106 such that the second valve hole 105 is opened. An increased amount of compressed refrigerant gas is thus drawn from the discharge chamber 205 to the crank chamber 202. As a result, the pressure in the crank chamber 202 rapidly increases, and the compressor displacement decreases quickly.

[0013] As the compressor displacement decreases, the pressure in the pressure sensitive chamber 114, or the suction pressure, increases. An increased force thus acts on the diaphragm 113 and the diaphragm 113 deforms accordingly. While changing its position, the diaphragm 113 pulls the first rod 108 and the second rod 109 away from the second valve body 106. Thus, the second valve body 106 decreases the opening size of the second valve hole 105. When the pressure in the pressure sensitive chamber 114, or the suction pressure, is reduced the target suction pressure, the second valve body 106 closes the second valve hole 105. Once the second valve hole 105 is closed, only the first valve body 103 adjusts the pressure in the crank chamber 202.

[0014] As described above, the first valve body 103 and the second valve body 106 operate separately. However, the first valve hole 102 and the second valve hole 105 are never open at the same time. That is, while the first valve body 103 is operating, the second valve hole 105 is closed by the second valve body 106. Therefore, the pressure in the second valve chamber 104, or discharge pressure, acting on the second valve body 106 does not affect the operation of the first valve body 103. This structure enables the target suction pressure to be determined only by the force produced by the coil 116 of the solenoid 115, regardless of the discharge pressure. Specifically, the discharge pressure varies according to the performance of a condenser provided in the air conditioning system. The condenser performance varies as a function of factors including the atomospheric temperature. Accordingly, in this displacement control valve, the target suction pressure is determined accurately as a function of the electric current supplied to the coil 116 of the solenoid 115, regardless of external factors such as the atmospheric temperature.

[0015] However, in the above displacement control valve, the first rod 108 slides with respect to the first valve body 103 such that the first valve hole 102 and the second valve hole 105 are never open simultaneously. That is, a clearance is defined between the inner surface of the first valve body 103 and the outer surface of the first rod 18. Thus, even though the first valve body 103 closes the first valve hole 102, the clearance allows compressed refrigerant gas to leak through the first valve hole 102 to the first valve chamber 101. The leakage makes it difficult to adjust the pressure in the crank chamber 202 to a desired value. The compressor displacement is thus not controlled optimally.

[0016] If the axial dimension of the first valve body 103 increases, the surface area of the inner side of the first valve body 103 contacting the first rod 108 is increased. The clearance between the inner side of the first valve body 103 and the first rod 108 is thus sealed more effectively. However, this structure causes the first valve body 103 to become relatively large and heavy. That is, the first valve body 103 does not operate as smoothly, and the displacement control valve is not as responsive.

SUMMARY OF THE INVENTION

[0017] Accordingly, it is an objective of the present invention to provide a displacement control valve used in a variable displacement type compressor for controlling the compressor displacement with greater accuracy and responsiveness.

[0018] To achieve the above objective, the present invention provides a control valve used in a variable displacement type compressor. The control valve adjusts the pressure in a crank chamber of the compressor to vary the compressor displacement. The compressor includes a suction pressure zone, the pressure of which is a suction pressure, a discharge pressure zone, the pressure of which is a discharge pressure, a bleed passage communicating the crank chamber with the suction pressure zone, and a supply passage communicating the crank chamber with the discharge pressure zone. The control valve comprises a housing, a first valve hole forming part of the bleed passage, a first valve body for adjusting an opening size of the first valve hole, a pressure sensitive member for moving the first valve body according to the suction pressure such that the suction pressure is maintained at a target value, an actuator for actuating the first valve body such that the target value of the suction pressure varies as a function of an external instruction, a second valve hole extending in the housing, wherein the second valve hole forms part of the supply passage, and a second valve body for adjusting an opening size of the second valve hole. A movable body is supported by the housing such that the movable body moves in the housing. The first valve hole extending in the movable body. The first valve body abuts against the movable body to close the first valve hole. A positioning member positions the movable body at a predetermined initial position. The second valve body is movable integrally with the movable body. The second valve body closes the second valve hole when the movable body is located at the initial position. The second valve body moves to open the second valve hole when the first valve body separates the movable body from the initial position while abutting against the movable body.

[0019] Other aspects and advantages of the 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

[0020] 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 type compressor of a first embodiment according to the present invention;

Fig. 2 is an enlarged cross-sectional view showing a displacement control valve located in the compressor of Fig. 1;

Fig. 3 is an enlarged cross-sectional view showing the displacement control valve of Fig. 2 in a different operational state;

Fig. 4 is a graph illustrating the operational characteristics of the displacement control valve illustrated in Figs. 2 and 3;

Fig. 5 is an enlarged cross-sectional view showing a major section of a displacement control valve of a second embodiment according to the present invention;

Fig. 6 is a cross-sectional view showing a prior art displacement control valve;

Fig. 6A is an enlarged view of the area indicated by circle 6A of Fig. 6;

Fig. 7 is a cross-sectional view showing the displacement control valve of Fig. 6 in a different operational state; and

Fig. 7A is an enlarged view of the area indicated by circle 7A of Fig. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] A first embodiment of the present invention, which is a displacement control valve used in an variable displacement type compressor for automobile air conditioning systems, will now be described with reference to Figs. 1 to 4.

[0022] As shown in Fig. 1, the variable displacement type compressor has a front housing member 11 joined with a front end (to the left as viewed in Fig. 1) of a cylinder block 12. The compressor further has a rear housing member 13 joined with a rear end (to the right as viewed in Fig. 1) of the cylinder block 12. A valve plate 14 is arranged between the cylinder block 12 and the rear housing member 13. A crank chamber 15 is defined by the front housing member 11 and the cylinder block 12.

[0023] A drive shaft 16 extends in the crank chamber 15 and is rotationally supported by the front housing member 11 and the cylinder block 12. The drive shaft 16 is connected to an automobile engine Eg through a clutch mechanism C, which is, for example, an electromagnetic clutch. When the engine Eg is operating, the clutch mechanism C connects the compressor with the engine Eg such that the drive shaft 16 rotates.

[0024] A rotor 17 is secured to the drive shaft 16 in the crank chamber 15 and supports a swash plate 18. The swash plate 18 is arranged in the crank chamber 15 and is fitted around the drive shaft 16. The swash plate 18 is capable of sliding along the drive shaft 16 in the direction of the axis L of the drive shaft 16. The swash plate 18 also inclines relative to the drive shaft 16. A hinge mechanism 19 connects the rotor 17 with the swash plate 18. The hinge mechanism 19 permits the swash plate 18 to incline relative to the axis L of the drive shaft 16 and causes the swash plate 18 to rotate integrally with the drive shaft 16. When the swash plate 18 moves toward the rotor 17, the inclination angle of the swash plate 18 increases. When the swash plate 18 separates from the rotor 17, the inclination angle of the swash plate 18 decreases.

[0025] A plurality of cylinder bores 21 (only one is illustrated in Fig. 1) are formed in the cylinder block 12. Each cylinder bore 21 accommodates a single-headed piston 22. Each piston 22 is connected with the periphery of the swash plate 18 by a pair of shoes 23. The swash plate 18 converts the rotation of the drive shaft 18 to reciprocal movement of the pistons 22 in the associated cylinder bores 21.

[0026] A suction chamber 24 and a discharge chamber 25 are defined in the rear housing member 13. The pressure in the suction chamber 24 is referred to as the suction pressure, while the pressure in the discharge chamber 25 is referred to as the discharge pressure. A suction port 26, a suction valve 27, a discharge port 28, and a discharge valve 29 correspond to each cylinder bore 21. The suction ports 26 and the discharge ports 28 extend through the valve plate 14. The suction valves 27 and the discharge valves 29 are formed in the valve plate 14. When each piston 22 moves from the top dead center position to the bottom dead center position, refrigerant gas in the suction chamber 24 is supplied to the associated cylinder bore 21 through the corresponding suction port 26, which is opened by the associated suction valve 27. When the piston 22 moves from the bottom dead center position to the top dead center position, refrigerant gas in the cylinder bore 24 is compressed to a predetermined pressure. The compressed refrigerant gas is then discharged to the discharge chamber 25 through the corresponding discharge port 28, which is opened by the associated discharge valve 29.

[0027] A bleed passage 30 communicates the crank chamber 15 with the suction chamber 24. A supply passage 31 communicates the discharge chamber 25 with the crank chamber 15. The bleed passage 30 and the supply passage 31 each extend through a displacement control valve 32. The bleed passage 30 and the supply passage 31 share a common passage 61 between the displacement control valve 32 and the crank chamber 15.

[0028] The compressor further includes a temperature selector 33 for selecting a target value of the passenger compartment temperature, a temperature sensor 34 for detecting the same, and a driver 35 for sending current to the displacement control valve 32. The temperature selector 33, the temperature sensor 34, the driver 35, and the clutch mechanism C are connected to a controller X.

[0029] The configuration of the displacement control valve 32 will hereafter be described. As shown in Figs. 2 and 3, the displacement control valve 32 includes a valve housing 38 joined with a solenoid 39. A first valve chamber 40, which also serves as a pressure sensitive chamber, is defined by the valve housing 38 near an end of the housing 38 that is adjacent to the solenoid 39. The first valve chamber 40 communicates with the suction chamber 24 via a downstream section of the bleed passage 30. The pressure in the suction chamber 24, or suction pressure, is applied to the first valve chamber 40. The first valve chamber 40 accommodates a first valve body 41 such that the first valve body 41 moves in the first valve chamber 40.

[0030] The valve housing 38 further has an accommodating recess 42 located adjacent to the first valve chamber 40. The recess 42 is farther from the solenoid 39 than the first valve chamber 40 and accommodates a cylindrical movable body 43. The movable body 43 moves in the axial direction of the valve housing 38. A first valve hole 46 extends axially through the movable body 43. A valve seat 43a is formed at an end of the movable body 43 that is adjacent to the first valve chamber 40. The first valve body 41 is received by the valve seat 43a. A step 43b is formed along the outer wall of the movable body 43.

[0031] The movable body 43 includes a contact surface extending from the step 43b to the upper end of the movable body 43 as viewed in the drawings. The movable body 43 contacts the wall of the accommodating recess 42 along this contact surface. The axial dimension of the contact surface is selected such that the space defined between the movable body 43 and the wall of the recess 42 is substantially sealed.

[0032] A positioning ring 44, or positioning member, is fitted in an annular groove formed in the wall of the accommodating recess 42. The step 43b of the movable body 43 engages with the positioning ring 44 for stopping the movable body 43 from moving further toward the first valve chamber 40. In this manner, the movable body 43 is arranged at a predetermined initial position. A recess spring 45, which is a coil spring in this embodiment, is located in the accommodating recess 42. The recess spring 45, or an urging member, urges the movable body 43 toward the first valve chamber 40.

[0033] The valve housing 38 further includes a second valve chamber 47 near the upper end of the valve housing 38 as illustrated. The second valve chamber 47 communicates with the discharge chamber 25 via an upstream section of the supply passage 31. The pressure in the discharge chamber 25, or discharge pressure, is applied to the second valve chamber 47. The second valve chamber 47 accommodates a second valve body 48 such that the second valve body 48 moves in the second valve chamber 47. A second valve hole 49 is opposed to the second valve body 48 and opens to the second valve chamber 47. The second valve hole 49 communicates with the accommodating recess 42. The second valve chamber 47 houses a closing spring 50 that urges the second valve body 48 to close the second valve hole 49.

[0034] The solenoid 39, or actuator, has a fixed core 52 located substantially in the middle of the solenoid 39. A plunger chamber 51 is defined in the solenoid 39 at a position adjacent to the fixed core 52 as illustrated. The plunger chamber 51 is located between the valve housing 38 and the fixed core 52. A plunger 53 is located in the plunger chamber 51 such that the plunger 53 moves in the plunger chamber 51. The plunger 53 opposes the fixed core 52. A cylindrical coil 54 is arranged around the fixed core 52 and the plunger 53. The driver 35 is connected with the coil 54.

[0035] A partition 55 separates the first valve chamber 40 from the plunger chamber 51. A guide hole 55a extends though the partition 55 for accommodating a first rod 56. One end of the first rod 56 is secured to the plunger 53, and the other end of the first rod 56 extends into the first valve chamber 40. The first valve chamber 40 accommodates a bellows 57, or a pressure sensitive member. The bellows 57 extends and contracts in the axial direction of the valve housing 38. A bellows spring 58 is located in the bellows 57 to define the initial dimension of the bellows 57. One end of the bellows 57 is secured to the first valve body 41, and the other end of the bellows 57 is secured to the first rod 56. That is, the first rod 56 and the bellows 57 connect the plunger 53 with the first valve body 41.

[0036] The first valve hole 46 and the second valve hole 49 are aligned coaxially and communicate with each other through the accommodating recess 42. A second rod 59 extends through the first valve hole 46 and the second valve hole 49. The diameter of the second rod 59 is smaller than that of the first valve hole 46 and that of the second valve hole 49. A lower end of the second rod 59 is secured to the first valve body 41.

[0037] The axial dimension of the second rod 59 is selected such that the second rod 59 abuts against the second valve body 48 when the first valve body 41 contacts the valve seat 43a, the movable body 43 contacts the positioning ring 44, and the second valve body 48 closes the second valve hole 49. That is, when the movable body 43 is located at its initial position, the second valve body 48 closes the second valve hole 49 regardless of the position of the first valve body 41.

[0038] However, when the first valve body 41, which is contacting the valve seat 43a, moves further toward the second valve body 48 while pushing the movable body 43 in the same direction, the second rod 59 pushes the second valve body 48 to open the second valve hole 49. Specifically, once the movable body 43 separates from the positioning ring 44, the first valve body 41 and the second rod 59 transmit the movement of the movable body 43 to the second valve body 48. The second valve body 48 thus opens the second valve hole 49. That is, the first valve body 41 and the second rod 59 serve as a transmission member for transmitting the movement of the movable body 43 to the second valve body 48.

[0039] A port 60 is formed in the valve housing 38 between the accommodating recess 42 and the second valve chamber 47. The port 60 communicates the second valve hole 49 and the recess 42 with the crank chamber 15 via the common passage 61. The pressure in the crank chamber 15, or crank pressure, is applied to the second valve hole 49, the recess 42, and the first valve hole 46 via the common passage 61. The first valve chamber 40, the first valve hole 46, the accommodating recess 42, and the port 60 form part of the bleed passage 30. The second valve chamber 47, the second valve hole 49, and the port 60 form part of the supply passage 31.

[0040] An adjusting chamber 62 is defined near the fixed core 52 in the solenoid 39. The adjusting chamber 62 is at the opposite end of the fixed core 52 from the plunger 53. The adjusting chamber 62 accommodates an adjusting plunger 63. A guide hole 52a extends through the fixed core 52. A third rod 64 is fitted in the guide hole 52a such that the third rod 64 slides in the guide hole 52a. While one end of the third rod 64 is located in the plunger chamber 51, the other end of the third rod 64 extends into the adjusting chamber 62. The adjusting chamber 62 accommodates an adjusting spring 65, which urges the adjusting plunger 63 toward the fixed core 52. That is, the adjusting spring 65 urges the first valve body 41 in the direction to close the first valve hole 46, by means of the adjusting plunger 63, the third rod 64, the plunger 53, the first rod 56, and the bellows 57. The force of the adjusting spring 65 is adjusted by axially moving an adjusting screw 66 fitted in the end of the adjusting chamber 62.

[0041] The operation of the displacement control valve 32 will now be described.

[0042] If the temperature detected by the temperature sensor 34 is greater than a target value selected by the temperature selector 33 after the engine Eg is started and an air-conditioner activating switch (not shown) is turned on, the controller X causes the clutch mechanism C to engage the engine Eg with the compressor, thus starting the compressor. The bellows 57 of the displacement control valve 32 extends or contracts in accordance with the pressure in the first valve chamber 40, or the suction pressure. As a result, the first valve body 41 determines the opening size of the first valve hole 46.

[0043] Meanwhile, the controller X determines the level of electric current supplied to the coil 54 of the displacement control valve 32 in relation to external information, which includes the target temperature selected by the temperature selector 33 and the temperature detected by the temperature sensor 34. The controller X then signals the determined level to the driver 35. The driver 35 then supplies the coil 54 of the displacement control valve 32 with the determined electric current. The coil 54 generates electromagnetic force acting to move the plunger 53 toward the fixed core 52 in accordance with the supplied electric current. The force is opposite to the direction in which the adjusting spring 65 urges the first valve body 41 (for closing the first valve hole 46). Thus, the force acting on the first valve body 41 from the solenoid 39 is determined by balance between the electromagnetic force of the coil 54 and the force of the adjusting spring 65. The force of the solenoid 39, or the electric current supplied to the coil 54, represents a target value of the suction pressure, or target suction pressure.

[0044] The position of the first valve body 41, or the opening size of the first valve hole 46, is determined by the force of the bellows 51 and the force of the solenoid 39 acting on the first valve body 41.

[0045] For example, when an increasing cooling load is applied to the compressor, or when the difference between the temperature detected by the temperature sensor 34 and the target temperature selected by the temperature selector 33 is relatively large, the controller X increases the electric current supplied to the coil 54 such that the target suction pressure is lowered. The electromagnetic force acting to move the plunger 53 toward the fixed core 52 thus increases. Accordingly, the force of the solenoid 39 urging the first valve body 41 in the direction to close the first valve hole 46 is decreased. As a result, the bellows 57 operates the first valve body 41 to maintain the suction pressure at a lower level.

[0046] When the electric current supplied to the coil 54 increases or when the suction pressure increases, the first valve body 41 increases the opening size of the first valve hole 46. The amount of refrigerant gas flowing from the crank chamber 15 to the suction chamber 24 via the bleed passage 30 thus increases. Accordingly, the pressure in the crank chamber 15 falls such that the inclination angle of the swash plate 18 increases. As a result, the compressor displacement increases. Furthermore, when the first valve body 41 fully opens the first valve hole 46, the pressure in the crank chamber 15 is substantially equal to the pressure in the suction chamber 24. In this state, the inclination angle of the swash plate 18 is maximized and the compressor displacement is maximized. As a result, the suction pressure is lowered to the target suction pressure.

[0047] When the cooling load applied to the compressor decreases, or when the difference between the temperature detected by the temperature sensor 34 and the target temperature selected by the temperature selector 33 is relatively small, the controller X decreases the electric current supplied to the coil 54 such that the target suction pressure is increased. The electromagnetic force acting to move the plunger 53 toward the fixed core 52 thus decreases. Accordingly, the force of the solenoid 39 urging the first valve body 41 to close the first valve hole 46 is increased. As a result, the bellows 57 operates the first valve body 41 such that the suction pressure is maintained at a higher level.

[0048] When the electric current supplied to the coil 54 decreases or when the suction pressure decreases, the first valve body 41 reduces the opening size of the first valve hole 46. The amount of the refrigerant gas flowing from the crank chamber 15 to the suction chamber 24 via the bleed passage 30 thus decreases. Accordingly, the pressure in the crank chamber 15 rises such that the inclination angle of the swash plate 18 decreases. As a result, the compressor displacement decreases. Furthermore, when the first valve body 41 fully closes the first valve hole 46, no refrigerant gas flows from the crank chamber 15 to the suction chamber 24. The pressure in the crank chamber 15 thus becomes relatively high. Accordingly, the inclination angle of the swash plate 18 is minimized and the compressor displacement is minimized. As a result, the suction pressure is raised to the target suction pressure.

[0049] The electromagnetic force generated by the coil 54 when electric current is supplied to the coil 54 for moving the plunger 53 toward the fixed core 52 is opposite to the direction in which the adjusting spring 65 urges the first valve body 41. In other words, the force of the adjusting spring 65 is countered when electric current is supplied to the coil 54. In this state, even if the suction pressure falls below the target pressure such that the first valve body 41 fully closes the first valve hole 46, the first valve body 41 does not further move against the force applied by the recess spring 45 and the closing spring 50. That is, as long as electric current is supplied to the coil 54, the first valve body 41 cannot push the movable body 43 away from its initial position. Accordingly, if electric current is supplied to the coil 54, the second valve body 48 always closes the second valve hole 49, regardless whether the first valve hole 46 is opened.

[0050] When substantially no cooling load is applied to the compressor, or when there is substantially no difference between the temperature detected by the temperature sensor 34 and the target temperature selected by the temperature selector 33, the controller X causes no electric current to be supplied to the coil 54 such that the target suction pressure is maximized. The coil 54 thus no longer produces electromagnetic force acting to move the plunger 53 toward the fixed core 52. Accordingly, the adjusting spring 62 urges the first valve body 41 to close the first valve hole 46. The first valve body 41 thus contacts the valve seat 43a and closes the first valve hole 46. The first valve body 41 further moves against the force of the closing spring 50 and that of the recess spring 45. In this manner, the first valve body 41 separates the movable body 43 from its initial position. Accordingly, as shown in Fig. 3, the second rod 59 pushes the second valve body 48 to open the second valve hole 49. As a result, an increased amount of compressed refrigerant gas flows from the discharge chamber 25 to the crank chamber 15. The pressure in the crank chamber 15 thus rapidly rises and the compressor displacement quickly decreases.

[0051] The pressure in the first valve chamber 40, or the suction pressure, rises as the compressor displacement decreases. The bellows 57 thus contracts. As a result, while keeping the first valve hole 46 closed, the first valve body 41, the movable body 43, and the second rod 59 are integrally pulled by the bellows 58 in the downward direction in the drawing. This is the direction in which the second valve body 48 closes the second valve hole 49. In this manner, the second valve body 48 decreases the opening size of the second valve hole 49. When the suction pressure reaches the target suction pressure, the movable body 43 engages with the positioning ring 44 and the second valve body 48 fully closes the second valve hole 49. Once the second valve hole 49 is fully closed by the second valve body 48, the pressure in the crank chamber 15 is controlled only by the first valve body 41.

[0052] As described above, the second valve body 48 operates only when no electric current is supplied to the coil 54, or when the target suction pressure need to be maximized.

[0053] Fig. 4 is a graph showing the operational characteristics of the displacement control valve 32 illustrated in Figs. 2 and 3. As shown in Fig. 4, the first valve body 41 opens the first valve hole 46 only while the movable body 43 remains engaged with the positioning ring 44. On the other hand, the second valve body 48 opens the second valve hole 49 only when the movable body 43 is disengaged from the positioning ring 44. That is, the first valve hole 46 and the second valve hole 49 are never open at the same time. Thus, the second valve body 48 always closes the second valve hole 49 while the first valve body 41 is operating. In this state, the pressure in the second valve chamber 47 acting on the second valve body 48, or the discharge pressure, does not affect the first valve body 41. Accordingly, the target suction pressure is determined exclusively by the force of the solenoid 39, regardless of the discharge pressure. The discharge pressure is a function of the performance of a condenser (not shown), which varies as a function of factors such as the atmospheric temperature. Therefore, in the first embodiment, the target suction pressure is accurately selected as a function of the electric current supplied to the coil 54 of the solenoid 39, regardless of factors such as the atmospheric temperature.

[0054] The first embodiment has the following advantages.

[0055] In the first embodiment, the movable body 43 is employed for preventing the second valve hole 49 from opening when the first valve hole 46 is opened. Specifically, the movable body 43 has the first valve hole 46 and the valve seat 43a. Thus, while the second valve body 48 operates only when the first valve hole 46 is closed, the first valve body 41 operates only when the second valve hole 49 is closed.

[0056] The axial dimension of the movable body 43 is relatively large such that the space defined between the contact surface of the movable body 43 and the wall of the accommodating recess 42 is sufficiently sealed. Thus, when the first valve body 41 closes the first valve hole 46, refrigerant gas does not leak from the crank chamber 15 to the suction chamber 24 through the space between the movable body 43 and the wall of the recess 42.

[0057] The movable body 43 operates only when the target suction pressure is selected to be the maximum value. In other words, the movable body 43 does not operate often. Thus, even if the movable body 43 is relatively large (relatively heavy), the operation of the first valve body 41 is not affected by the movable body 43. That is, regardless of the movable body 43, the first valve body 41 moves smoothly. This structure enables the compressor displacement to be controlled with high accuracy and responsiveness.

[0058] When no electric current is supplied to the coil 54, the target suction pressure is maximized such that the compressor displacement is substantially minimized. Thus, if the current supply to the coil 54 fails due to, for example, disconnection of the coil 54, the target suction pressure is maintained as the maximum value. Accordingly, the compressor displacement is substantially minimized. As a result, the compressor applies a minimum load to the engine. That is, even if the engine Eg is driven at high speed, the load applied to the compressor is not excessive. Furthermore, a minimum cooling capability of the air-conditioning system is ensured.

[0059] The common passage 61 serves as a section of the bleed passage 30 between the crank chamber 15 and the first valve body 41. The common passage 61 serves also as a section of the supply passage 31 between the second valve body 48 and the crank chamber 15. In other words, the upstream section of the bleed passage 30 and the downstream section of the supply passage 31 share the common passage 61. This structure saves space in the compressor and simplifies production, as compared to a compressor in which the bleed passage 30 and the supply passage 31 are separate.

[0060] Furthermore, the present invention may be embodied as follows without departing from the scope of the invention.

[0061] As shown in Fig. 5, in a second embodiment of the present invention, the second rod 59 is secured to the movable body 43, unlike the first embodiment in which the second rod 59 is secured to the first valve body 41. In this case, the second rod 59 transmits the movement of the movable body 43 to the second valve body 48. This structure enables the first valve body 41 to operate more smoothly, as compared to the first embodiment illustrated in Figs. 2 and 3. The compressor displacement is thus controlled with improved responsiveness.

[0062] As indicated by the broken line in Fig. 5, a seal 71 constituted by, for example, an O ring, may be located in the space between the wall of the accommodating recess 42 and the movable body 43. In this case, the space is sealed sufficiently such that the axial dimension of the movable body 43 is reduced.

[0063] In the first and second embodiments, the bellows 57 is employed as a pressure sensitive member. However, the bellows 57 may be replaced by a diaphragm.

[0064] Unlike the first or second embodiment, the bleed passage 30 and the supply passage 31 may be completely separate.

[0065] The structure of the displacement control valve 32 may be altered such that the target suction pressure rises as the electric current supplied to the coil 54 increases. In this case, if the current supply to the coil 54 fails due to, for example, disconnection of the coil 54, the compressor displacement is maintained as a maximum value. Thus, the compressor operates optimally even when an increased cooling load is applied to the air conditioning system.

[0066] Although the solenoid 39 is employed in the first and second embodiments, other actuators such as fluid pressure actuators may replace the solenoid 39. In this case, the target suction pressure is altered by varying the fluid pressure, for example, oil pressure or gas pressure, acting on the plunger 53.

[0067] 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.

[0068] A control valve for a variable displacement type compressor includes a movable body (43) supported by the housing (38) such that the movable body (43) moves in the housing (38). The movable body (43) includes a first valve hole (46) that forms part of a bleed passage (30). A first valve body (41) adjusts the opening of the first valve hole (46). The first valve body (41) abuts against the movable body (43) such that the first valve hole (46) is closed. A second valve hole (49) extends in the housing (38) and forms part of a supply passage (31). A second valve body (48) adjusts the opening of the second valve hole (49). The second valve body (48) is movable integrally with the movable body (43). When the movable body (43) is located at an initial position, the second valve body (48) closes the second valve hole (49). However, when the first valve body (41) separates the movable body (43) from the initial position while abutting against the movable body (43), the second valve body (48) is moved to open the second valve hole (49). In this control valve, the first valve hole (46) and the second valve hole (49) are never open at the same time. Furthermore, the control valve controls the compressor displacement with high accuracy and an responsiveness.

Claims

1. A control valve used in a variable displacement type compressor, wherein the control valve adjusts the pressure in a crank chamber (15) of the compressor to vary the compressor displacement, wherein the compressor includes a suction pressure zone (24), the pressure of which is a suction pressure, a discharge pressure zone (25), the pressure of which is a discharge pressure, a bleed passage (30) communicating the crank chamber (15) with the suction pressure zone (24), and a supply passage (31) communicating the crank chamber (15) with the discharge pressure zone (25), the control valve comprising:

a housing (38);
a first valve hole (46) forming part of the bleed passage (30);
a first valve body (41) for adjusting an opening size of the first valve hole (46);
a pressure sensitive member (57) for moving the first valve body (41) according to the suction pressure such that the suction pressure is maintained at a target value;
an actuator (39) for actuating the first valve body (41) such that the target value of the suction pressure varies as a function of an external instruction;
a second valve hole (49) extending in the housing (38), wherein the second valve hole (49) forms part of the supply passage (31); and
a second valve body (48) for adjusting an opening size of the second valve hole (49), the control valve being

characterized in that:

a movable body (43) is supported by the housing (38) such that the movable body (43) moves in the housing (38), the first valve hole (46) extending in the movable body (43), wherein the first valve body (41) abuts against the movable body (43) to close the first valve hole (46), wherein a positioning member (44) positions the movable body (43) at a predetermined initial position, wherein the second valve body (48) is movable integrally with the movable body (43), and the second valve body (48) closes the second valve hole (49) when the movable body (43) is located at the initial position, and wherein the second valve body (48) moves to open the second valve hole (49) when the first valve body (41) separates the movable body (43) from the initial position while abutting against the movable body (43).

2. The control valve as set forth in claim 1 **characterized by** an urging member (45) for urging the movable body (43) toward the initial position.

3. The control valve as set forth in claims 1 or 2 **characterized in that** the first valve body (41) separates the movable body (43) from the initial position when a force urging the first valve body (41) toward the movable body (43) becomes greater than a predetermined value.

4. The control valve as set forth in claim 3 **characterized in that** the force urging the first valve body (41) toward the movable body (43) includes a force produced by the actuator (39).

5. The control valve as set forth in claim 4 **characterized in that** the actuator (39) is a solenoid, and the solenoid (39) has a coil (54) and a plunger (53), the plunger (53) being connected with the first valve body (41), wherein an electric current supplied to the coil (54) produces an electromagnetic force for actuating the plunger (53).

6. The control valve as set forth in claim 5 **characterized in that** the target value of the suction pressure increases as the electric current supplied to the coil (54) decreases, and the target value of the suction pressure is maximized when no electric current is supplied to the coil (54).

7. The control valve as set forth in claims 5 or 6 **characterized in that** the solenoid (39) includes a spring (65) for urging the plunger (53) in a first direction to move the first valve body (41) toward the movable body (43), wherein the electromagnetic force urges the plunger (53) in a second direction, which is opposite to the first direction, and the force generated by the solenoid (39) for urging the first valve body (41) toward the movable body (43) increases as the electric current supplied to the coil (54) decreases.

8. The control valve as set forth in any one of claims 1 to 7 **characterized by** a transmission member (59) for transmitting movement of the movable body (43) to the second valve body (48).

9. The control valve as set forth in claim 8 **characterized in that** the transmission member includes a rod (59) extending from the first valve body (41) toward the second valve body (48), and the rod (59) abuts against the second valve body (48) when the first valve body (41) abuts against the movable body (43).

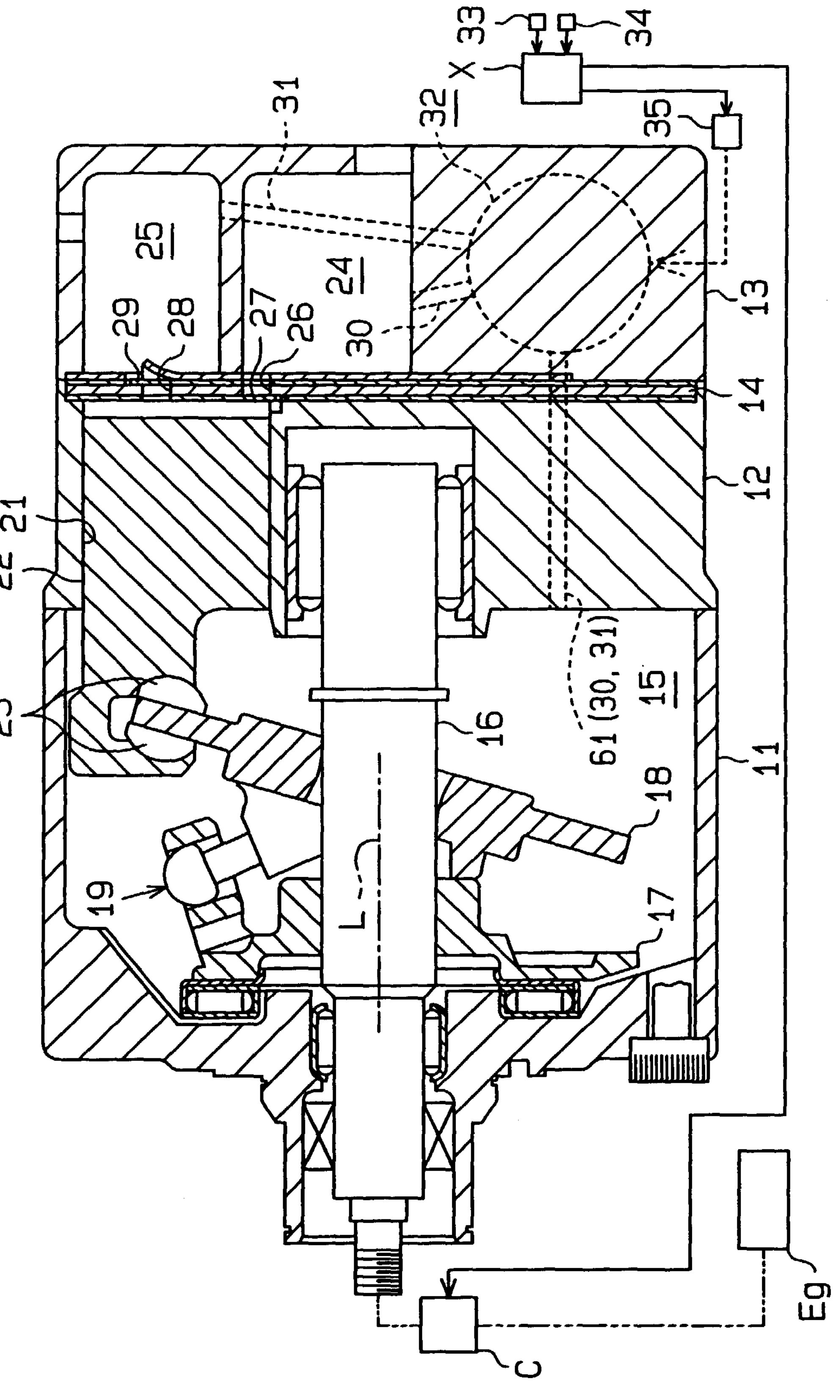
10. The control valve as set forth in claim 8 **characterized in that** the transmission member is a rod (59) extending from the movable body (43) toward the second valve body (48).

11. The control valve as set forth in any one of claims 1 to 10 **characterized in that** the housing (38) has a recess (42) for accommodating the movable body (43), and the movable body (43) has an axial dimension selected such that a space defined between the outer surface of the movable body (43) and the inner surface of the recess (42) is substantially sealed.

12. The control valve as set forth in any one of claims 1 to 10 **characterized in that** the housing (38) has a recess (42) for accommodating the movable body (43), and wherein a seal (71) is provided between the outer surface of the movable body (43) and the inner surface of the recess (42).

13. The control valve as set forth in any one of claims 1 to 12 **characterized in that** a common passage (61) functions as an upstream section of the bleed passage (30) and a downstream section of the supply passage (31).

Fig.1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23
24
25
26
27
28
29
30
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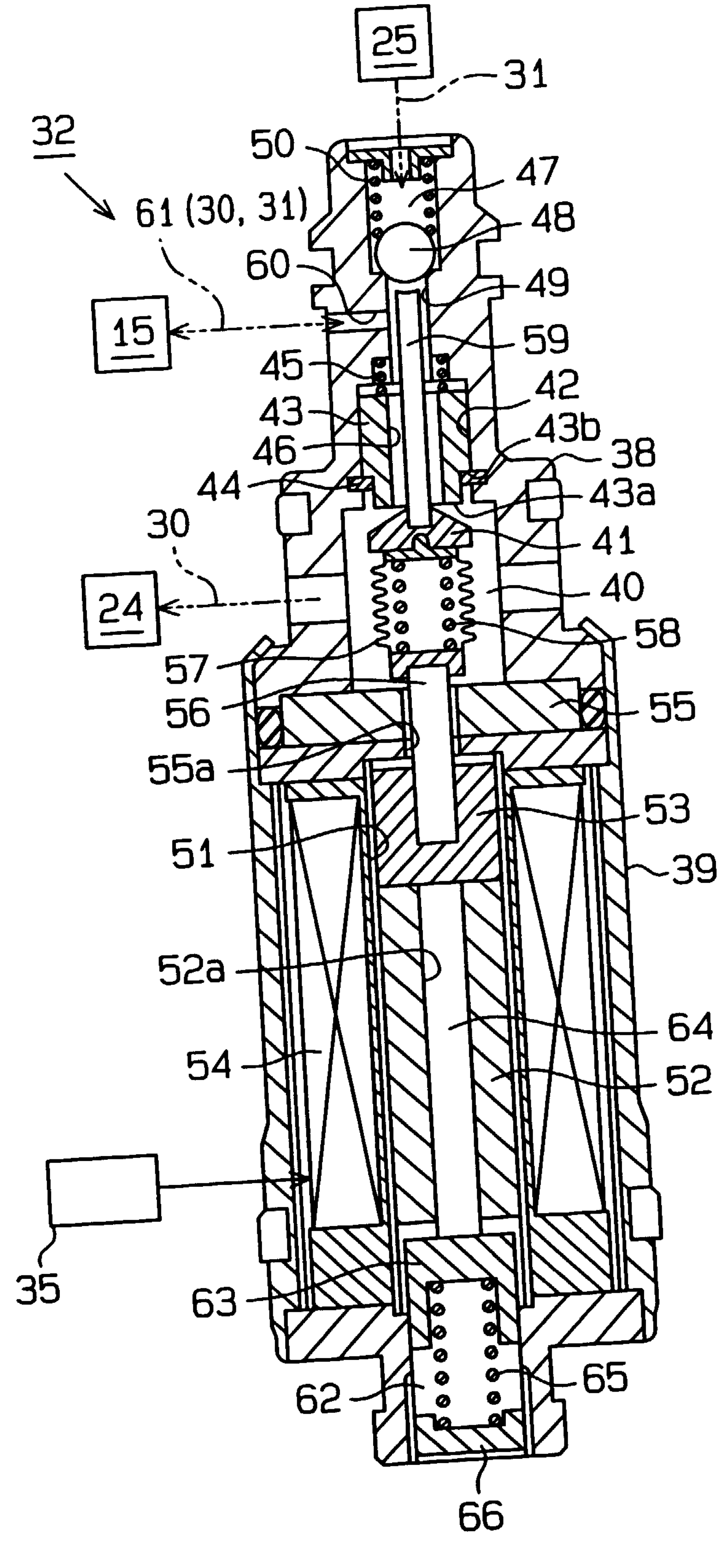
32
33
34
35
X
L
61 (30, 31)
C
Eg

Fig.2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43a
30
41
40
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51
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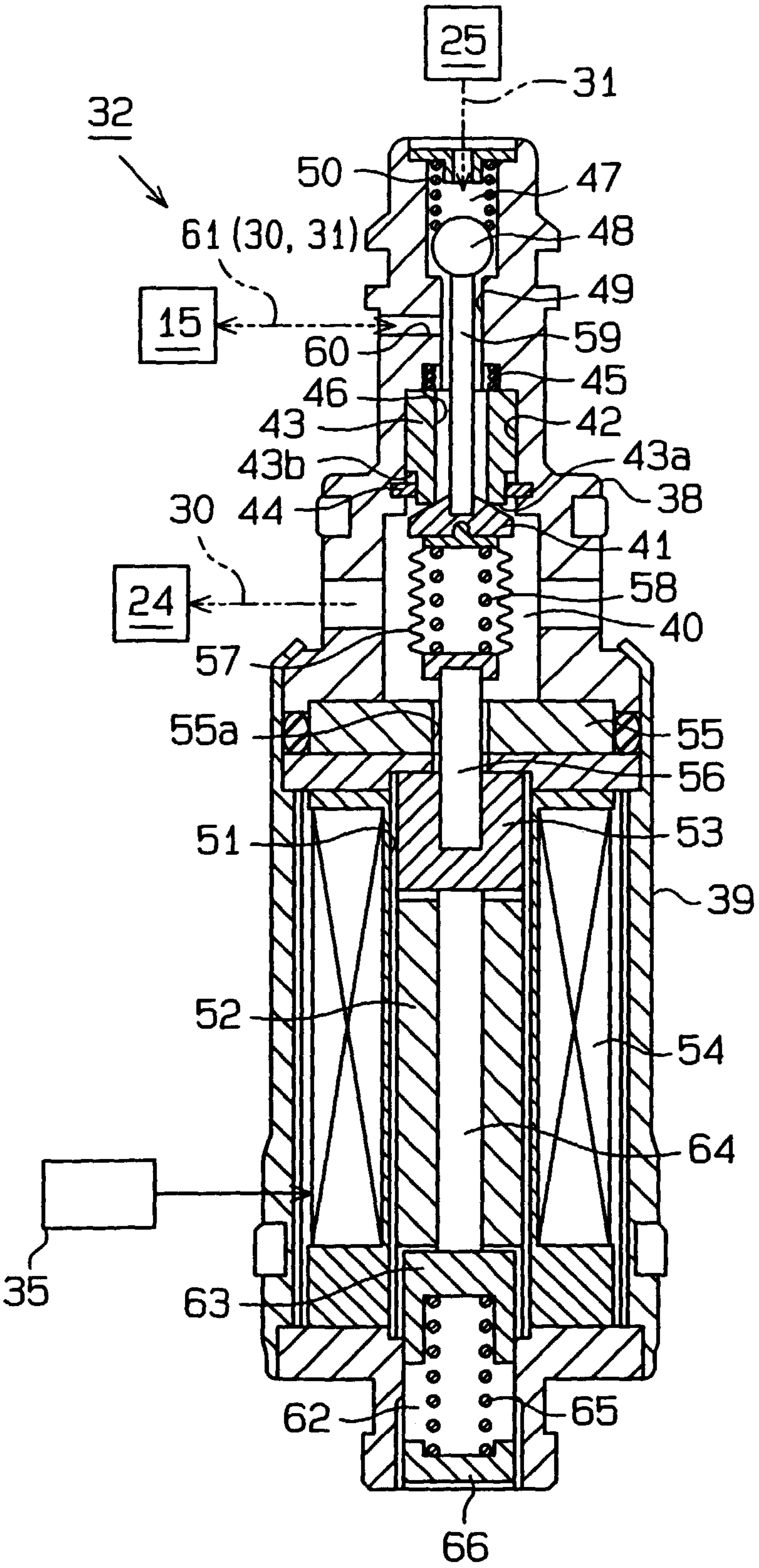
52a
64
54
52
35
63
65
62
66

Fig.3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38
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63
62
65
66

Fig.4

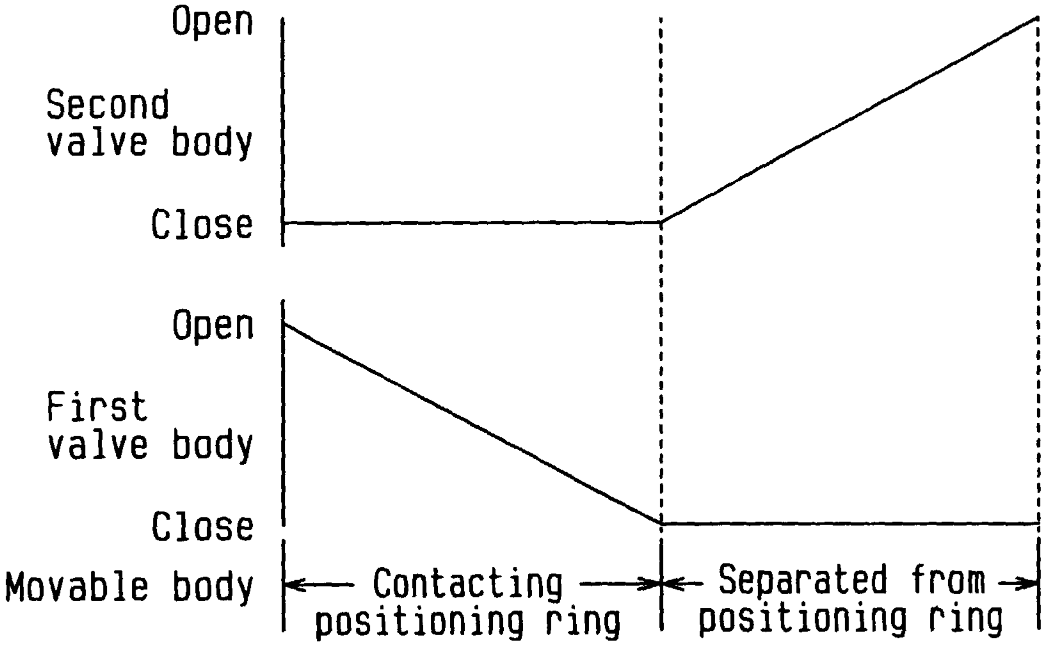
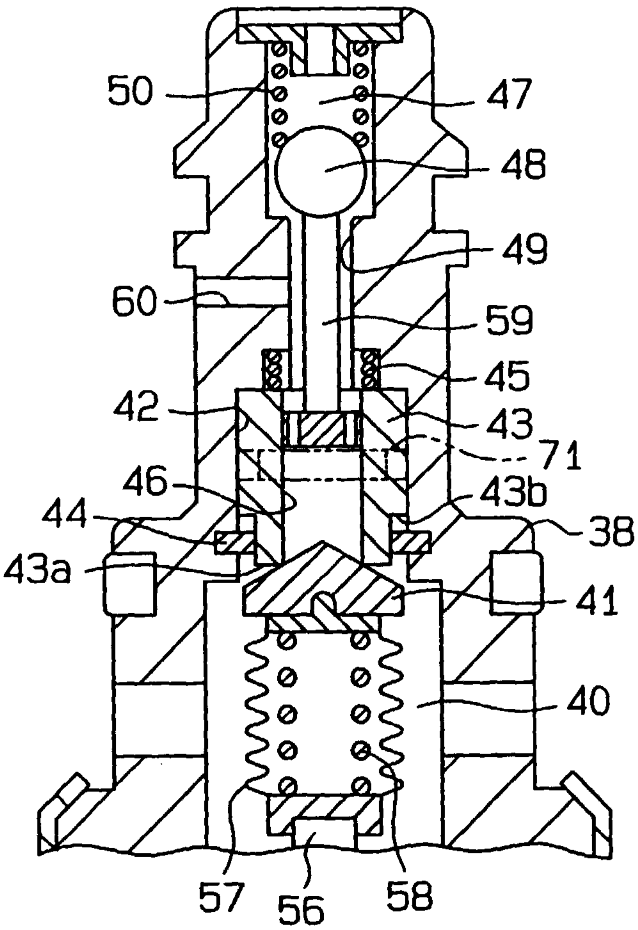

Open
Second
valve body
Close
Open
First
valve body
Close
Movable body
Contacting
positioning ring
Separated from
positioning ring

Fig.5


50
47
48
49
60
59
45
42
43
71
46
43b
44
38
43a
41
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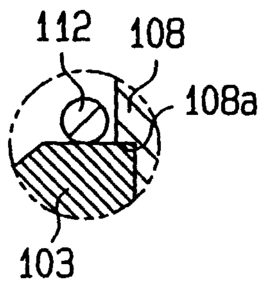
57
56
58

Fig.6

Fig.6A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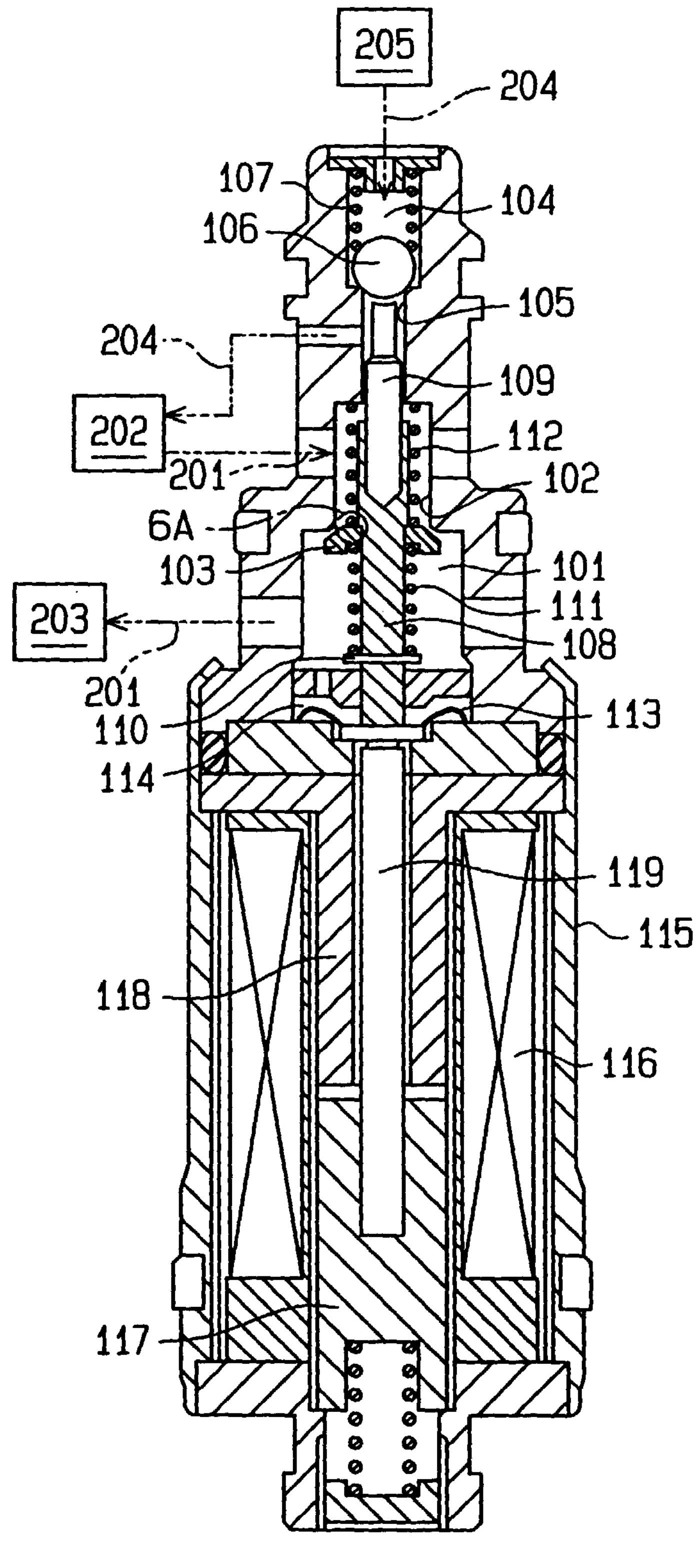
108a
103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106
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204
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202
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Fig.7A

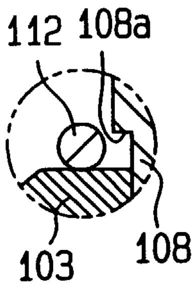
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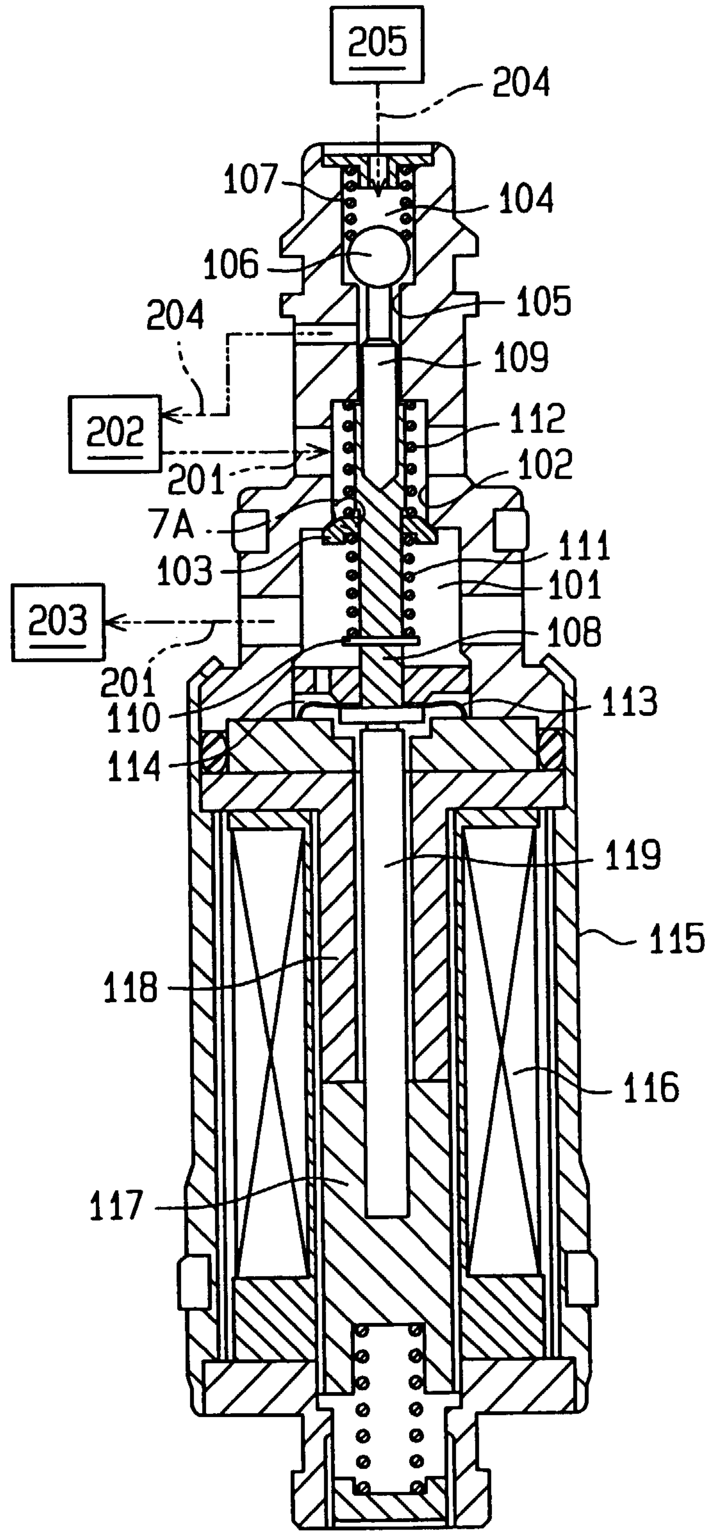
Fig.7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7A
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