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(71) Applicant:
Kabushiki Kaisha
Toyota Jidoshokki Seisakusho
Aichi-ken (JP)

(72) Inventors:
• Kawaguchi, Masahiro
Kariya-shi, Aichi-ken (JP)

• Sonobe, Masanori
Kariya-shi, Aichi-ken (JP)
• Fukanuma, Tetsuhiko
Kariya-shi, Aichi-ken (JP)
• Nagai, Hiroyuki
Kariya-shi, Aichi-ken (JP)

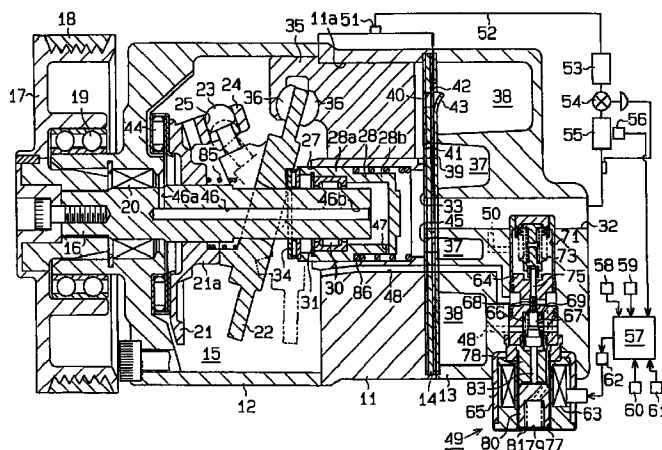
(74) Representative:
Pellmann, Hans-Bernd, Dipl.-Ing. et al
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4
80336 München (DE)

(54) Variable displacement compressor

(57) An improved variable displacement compressor is disclosed. A compressor has a cam plate (22) that is mounted on a drive shaft (16) for integral rotation therewith. At least one piston (35) is coupled to the cam plate (22). The cam plate (22) is tiltable between its maximum inclining position and its minimum inclining position with respect to an axis of the drive shaft (16). The piston (35) reciprocates in a cylinder bore by a stroke based on an inclined angle of the cam plate (22) and compresses gas that is supplied to the cylinder

bore (11a) from an external gas circuit (52) and discharge the compressed gas to the external gas circuit (52) that is connected to the interior of compressor by way of a gas passage (32). The shutter body (28) is urged by a first spring (85, 91) and a second spring (86) in opposite directions. The urging force of the first spring (85, 92) is greater than that of the second spring (86). A shutter body (28) that is biased to disconnect the gas passage (32) from the external gas circuit (52).

Fig.1



Description

The present invention generally relates to a variable displacement compressor. More particularly, the present invention pertains to a variable displacement compressor that lubricates moving parts of the compressor by misted lubricant oil contained in refrigerant gas.

A typical variable displacement compressor includes a cylinder block that constitutes a part of the compressor housing. A crank chamber is defined in the cylinder block. A discharge chamber and a suction chamber are also defined in a compressor. A through hole is defined at the center portion of the cylinder block. A plurality of cylinder bores extend through the cylinder block and are located about the through hole. The cylinder bores are spaced apart at equal intervals. The through hole is connected to an external refrigerant circuit. Refrigerant gas in the circuit is drawn into the suction chamber via a suction passage and the through hole.

A rotary shaft is rotatably supported in the crank chamber. A cam plate is supported by the rotary shaft in the crank chamber. The inclination of the cam plate is varied in accordance with the difference between the pressure in the crank chamber and the pressure in the cylinder bores. The stroke of each piston is varied in accordance with the inclination of the cam plate. When the inclination of the cam plate is increased, the displacement of the compressor is increased, accordingly. A decreased inclination of the plate lowers the compressor's displacement.

The compressor is provided with a discharge chamber that is connected to the crank chamber by a supply passage. A displacement control valve is located in the supply passage. The control valve controls the flow rate of refrigerant gas from the discharge chamber to the crank chamber thereby controlling the pressure in the crank chamber.

A spool-like shutter is accommodated in the through hole in the cylinder block. The shutter slides in accordance with changes in the inclination of the cam plate. As the inclination decreases, the shutter narrows the passage between the suction passage and the suction chamber. If the cam plate reaches the minimum inclination, the shutter disconnects the suction chamber from the suction passage.

The control valve increases the pressure in the crank chamber for re-increasing the inclination of the cam plate. At the same time, the shutter opens the suction passage thereby communicating the passage with the suction passage again.

Refrigerant condensed in the external refrigerant circuit may be liquefied by a change in the ambient temperature. If the shutter does not completely close the suction passage when the compressor is not operating, the liquefied refrigerant in the circuit may flow into the compressor. The liquefied refrigerant is then mixed with the lubricant in the compressor. When operation of the

compressor is resumed, the liquefied refrigerant in the compressor may foam up and quickly flows back to the refrigerant circuit. This also removes lubricant mixed with the liquefied refrigerant from the compressor. Thus, lubrication of the compressor may become insufficient.

Accordingly, it is an objective of the present invention to provide a construction for lubricating each moving part in a compressor when the compressor starts operating from a stationary state.

To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a compressor having a cam plate mounted on a drive shaft for integral rotation therewith and a piston coupled to the cam plate is provided. The cam plate is tiltable between its maximum inclining position and its minimum inclining position with respect to an axis of the drive shaft. The piston reciprocates in a cylinder bore by a stroke based on an inclined angle of the cam plate to compress gas supplied to the cylinder bore from an external gas circuit and to discharge the compressed gas to the external gas circuit. The compressor includes a gas passage connecting the external gas circuit to the interior of compressor and a shutter body biased to disconnect the gas passage from the external gas circuit when the compressor is in an in operative state.

The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. 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 illustrating a variable displacement compressor according to a first embodiment of the present invention;

Fig. 2 is a cross-sectional view illustrating the compressor of Fig. 1 when the inclination of the swash plate is minimum;

Fig. 3 is a cross sectional view illustrating a compressor according to a second embodiment of the present invention; and

Fig. 4 is a cross sectional view illustrating a compressor according to a third embodiment of the present invention.

A variable displacement compressor according to a first embodiment of the present invention will now be described with reference to Figs. 1 and 2.

A cylinder block 11 constitutes a part of the compressor housing. A front housing 12 is secured to the front end face of a cylinder block 11. A rear housing 13 is secured to the rear end face of the cylinder block 11 with a valve plate 14 in between. A crank chamber 15 is defined by the inner walls of the front housing 12 and the front end face of the cylinder block 11.

A rotary shaft 16 is rotatably supported in the front housing 12 and the cylinder block 11. The front end of the rotary shaft 16 protrudes from the crank chamber 15

and is secured to a pulley 17. The pulley 17 is directly coupled to an external drive source (a vehicle engine E in this embodiment) by a belt 18. The compressor of this embodiment is a clutchless type variable displacement compressor having no clutch between the rotary shaft 16 and the drive source. The pulley 17 is supported by the front housing 12 with an angular bearing 19. The angular bearing 19 transfers thrust and radial loads that act on the pulley 17 to the housing 12.

A lip seal 20 is located between the rotary shaft 16 and the front housing 12 for sealing the crank chamber 15. The lip seal 20 prevents the pressure in the crank chamber 15 from leaking.

A substantially disk-like swash plate 22 is supported by the rotary shaft 16 in the crank chamber 15 to be slidable along and tiltable with respect to the axis of the shaft 16. The swash plate 22 is provided with a pair of guiding pins 23, each having a guide ball at its distal end. A rotor 21 is fixed to the rotary shaft 16 in the crank chamber 15. The rotor 21 rotates integrally with the rotary shaft 16. The rotor 21 has a support arm 24 protruding toward the swash plate 22. A pair of guide holes 25 are formed in the support arm 24. Each guide pin 23 is slidably fitted into the corresponding guide hole 25. The cooperation of the arm 24 and the guide pins 23 permits the swash plate 22 to rotate together with the rotary shaft 16. The cooperation also guides the tilting of the swash plate 22 and the movement of the swash plate 22 along the axis of the rotary shaft 16. As the swash plate 22 slides rearward toward the cylinder block 11, the inclination of the swash plate 22 decreases.

A first coil spring 85 is located between the rotor 21 and the swash plate 22. The first spring 85 urges the swash plate 22 rearward, or in a direction decreasing the inclination of the swash plate 22. The rotor 21 is provided with a projection 21a on its rear end face. The abutment of the swash plate 22 against the projection 21a prevents the inclination of the swash plate 22 beyond the predetermined maximum inclination.

A shutter chamber 27 is defined at the center portion of the cylinder block 11 and extends along the axis of the rotary shaft 16. A hollow cylindrical shutter 28 with a closed end is accommodated in the shutter chamber 27. The shutter 28 slides along the axis of the rotary shaft 16. The shutter 28 has a large diameter portion 28a and a small diameter portion 28b. A second coil spring 86 is located between a step, which is defined by the large diameter portion 28a and the small diameter portion 28b, and a wall of the shutter chamber 27. The second coil spring 86 urges the shutter 28 toward the swash plate 22. The urging force of the first spring 85 is greater than the force of the second spring 86.

The rear end of the rotary shaft 16 is inserted in the shutter 28. A radial bearing 30 is fixed to the inner wall of the large diameter portion 28a of the shutter 30 by a snap ring 31. Therefore, the radial bearing 30 moves with the shutter 28 along the axis of the rotary shaft 16. The rear end of the rotary shaft 16 is supported by the

inner wall of the shutter chamber 27 with the radial bearing 30 and the shutter 28 in between.

A suction passage 32 is defined at the center portion of the rear housing 13 and the valve plate 14. The passage 32 is aligned with the axis of the rotary shaft 16 and is communicated with the shutter chamber 27. The suction passage 32 functions as a suction pressure area. A positioning surface 33 is formed on the valve plate 14 about the inner opening of the suction passage 32. The rear end of the shutter 28 abuts against the positioning surface 33. Abutment of the shutter 28 against the positioning surface 33 prevents the shutter 28 from moving further rearward away from the swash plate 22. The abutment also disconnects the suction passage 32 from the shutter chamber 27.

A thrust bearing 34 is supported on the rotary shaft 16 and is located between the swash plate 22 and the shutter 28. The thrust bearing 34 slides along the axis of the rotary shaft 16 and is constantly retained between the swash plate 22 and the shutter 28 by the force of the second spring 86. The thrust bearing 34 prevents the rotation of the swash plate 22 from being transmitted to the shutter 28.

The swash plate 22 moves rearward as its inclination decreases. As it moves rearward, the swash plate 22 pushes the shutter 28 rearward through the thrust bearing 34. Accordingly, the shutter 28 moves toward the positioning surface 33 against the force of the second spring 86. As illustrated by a dashed line and a continuous line in Figs. 1 and 2, the rear end of the shutter 28 abuts against the positioning surface 33 when the swash plate 22 reaches the minimum inclination. In this state, the shutter 28 is located at the closed position for disconnecting the shutter chamber 27 from the suction passage 32.

A plurality of cylinder bores 11a extend through the cylinder block 11 and are located about the axis of the rotary shaft 16. The cylinder bores 11a are spaced apart at equal intervals. A single-headed piston 35 is accommodated in each cylinder bore 11a. A pair of semispherical shoes 36 are fitted between each piston 35 and the swash plate 22. A semispherical portion and a flat portion are defined on each shoe 36. The semispherical portion slidably contacts the piston 35 while the flat portion slidably contacts the swash plate 22. The swash plate 22 is rotated by the rotary shaft 16 through the rotor 21. The rotating movement of the swash plate 22 is transmitted to each piston 35 through the shoes 36 and is converted to linear reciprocating movement of each piston 35 in the associated cylinder bore 11a.

A suction chamber 37 is defined in the center portion of the rear housing 13. The suction chamber 37 is communicated with the shutter chamber 27 via a communication hole 45. A discharge chamber 38 is defined about the suction chamber 37 in the rear housing 13. Suction ports 39 and discharge ports 40 are formed in the valve plate 14. Each suction port 39 and each discharge port 40 correspond to one of the cylinder bores 11a. Suction valve flaps 41 are formed on the valve

plate 14. Each suction valve flap 41 corresponds to one of the suction ports 39. Discharge valve flaps 42 are formed on one valve plate 14. Each discharge valve flap 42 corresponds to one of the discharge ports 40.

As each piston 35 moves from the top dead center to the bottom dead center in the associated cylinder bore 11a, refrigerant gas in the suction chamber 37 is drawn into each cylinder bore 11a through the associated suction port 39 while causing the associated suction valve flap 41 to flex to an open position. As each piston 35 moves from the bottom dead center to the top dead center in the associated cylinder bore 11a, refrigerant gas is compressed in the cylinder bore 11a and discharged to the discharge chamber 38 through the associated discharge port 40 while causing the associated discharge valve flap 42 to flex to an open position. Retainers 43 are formed on the valve plate 14. Each retainer 43 corresponds to one of the discharge valve flaps 42. The opening amount of each discharge valve flap 42 is defined by contact between the valve flap 42 and the associated retainer 43.

A thrust bearing 44 is located between the front housing 12 and the rotor 21. The thrust bearing 44 carries the reactive force of gas compression acting on the rotor 21 through the pistons 35 and the swash plate 22.

A pressure release passage 46 is defined at the center portion of the rotary shaft 16. The pressure release passage 46 has an inlet 46a, which opens to the crank chamber 15 in the vicinity of the lip seal 20, and an outlet 46b, which opens to the interior of the shutter 28. A pressure release hole 47 is formed in the peripheral wall near the rear end of the shutter 28. The hole 47 communicates the interior of the shutter 28 with the shutter chamber 27.

A supply passage 48 is defined in the rear housing 13, the valve plate 14 and the cylinder block 11 for communicating the discharge chamber 38 with the crank chamber 15. A displacement control valve 49 is accommodated in the rear housing 13 midway in the supply passage 48. A pressure introduction passage 50 is defined in the rear housing 13 for communicating the control valve 49 with the suction passage 32. Thus, the suction pressure P_s is communicated with the control valve 49.

An outlet port 51 is formed in the cylinder block 11 and is communicated with the discharge chamber 38. The outlet port 51 is connected to the suction passage 32 by an external refrigerant circuit 52. The refrigerant circuit 52 includes a condenser 53, an expansion valve 54 and an evaporator 55. A temperature sensor 56 is located in the vicinity of the evaporator 55. The temperature sensor 56 detects the temperature of the evaporator 55 and issues signals relating to the detected temperature to a computer 57. The computer 57 is connected to various devices including a temperature adjuster 58, a passenger compartment temperature sensor 59, an air conditioner starting switch 60 and an engine speed sensor 61. A passenger sets a desirable compartment temperature by the temperature adjuster

58.

The computer 57 computes a current value for the control valve 49 based on various conditions including, for example, a target temperature set by the temperature adjuster 58, the temperature detected by the temperature sensor 56, the passenger compartment temperature detected by the temperature sensor 59, the engine speed detected by the engine speed sensor 61 and an ON/OFF signal from the starting switch 60. The computer 57 transmits the computed current value to a driver 62. The driver 62 sends a current having the value transmitted from the computer 57 to a coil 63 of a solenoid 65 in the valve 49. The coil 63 and the solenoid 65 will be described later. The conditions for determining the current value for the valve 49 may include data other than those listed above, for example, the data may include the temperature outside of the vehicle.

The control valve 49 includes a housing 64 and the solenoid 65, which are secured to each other. A valve chamber 66 is defined between the housing 64 and the solenoid 65. The valve chamber 66 is connected to the discharge chamber 38 by the supply passage 48. A valve body 67 is arranged in the valve chamber 66. The area about the opening of the valve hole 68 functions as a valve seat, against which a top end of the valve body 67 abuts. A coil spring 69 extends between the valve body 67 and a wall of the valve chamber 66.

A pressure sensing chamber 71 is defined at the upper portion of the housing 64. The chamber 71 is provided with a bellows 73 and is connected to the suction passage 32 by the pressure introduction passage 50. Suction pressure P_s in the suction passage 32 is introduced to the chamber 71 via the passage 50 and is detected by the bellows 73. The bellows 73 is connected to the valve body 67 by a first rod 75. The valve hole 68 is connected to the crank chamber 15 by the supply passage 48.

An accommodating hole 77 is defined in the center portion of the solenoid 65. A fixed steel core 78 is fitted in the upper portion of the hole 77. A plunger chamber 79 is defined by the fixed core 78 and inner walls of the hole 77 at the lower portion of the hole 77. A plunger 80 is slidably accommodated in the chamber 79. A coil spring 81 extends between the plunger 80 and the bottom of the hole 77. The urging force of the spring 81 is smaller than that of the coil spring 69. The spring 69 urges the valve body 67 downward, while the spring 81 urges the plunger 80 upward. This allows the lower end of the second rod 83 to constantly contact the plunger 80. In other words, the valve body 67 moves integrally with the plunger 80 with the second rod 83 in between.

A cylindrical coil 63 is wound about the core 78 and the plunger 80. The driver 62 supplies coil 63 with a current having a value computed by the computer 57.

When the switch 60 is turned on, if the compartment temperature detected by the temperature sensor 59 is equal to or greater than a target temperature, the computer 57 commands the driver 62 to excite solenoid 65. A current is supplied to the coil 63, accordingly. This

generates a magnetic attractive force between the core 78 and the plunger 80. The attractive force urges the valve body 67 in a direction closing the valve hole 68. On the other hand, the length of the bellows 73 changes in accordance with the suction pressure P_s in the suction passage 32, which is introduced to the pressure sensing chamber 71 via the passage 50. The changes in the length of the bellows 73 are transmitted to the valve body 67. The higher the suction pressure P_s is, the shorter the bellows 73 becomes. As the bellows 73 becomes shorter, the bellows 73 pulls the valve body 67 in a direction closing the valve hole 68.

The opening area between the valve body 67 and the valve hole 68 is determined by the equilibrium of forces acting on the valve body 67. Specifically, the opening area is determined by the equilibrium position of the body 67, which is affected by the force of the solenoid 65 transmitted through the second rod 83, the force of the bellows 73 and the force of the spring 69.

Suppose the cooling load is great, the temperature in the vehicle compartment detected by the sensor 59 is significantly higher than a target temperature set by the temperature adjuster 58 and the suction pressure P_s is high. The computer 57 sets a higher target current value when the difference between the detected temperature and the target temperature is great. This increases the magnitude of the attractive force between the core 78 and the plunger 80 thereby increasing the resultant force urging the valve body 67 in a direction closing the valve hole 68. This lowers the value of pressure P_s required for opening of the valve hole 68. Increasing the value of the current to the valve 49 causes the valve 49 to maintain a lower suction pressure P_s .

A smaller opening area between the valve body 67 and the valve hole 68 decreases the refrigerant gas flow from the discharge chamber 38 to the crank chamber 15 via the passage 48. The refrigerant gas in the crank chamber 15 flows into the suction chamber 37 via the pressure release passage 46 and the pressure release hole 47. This lowers the pressure P_c in the crank chamber 15. Further, when the cooling load is great, the suction pressure P_s is high. Accordingly, the pressure in each cylinder bore 11a is high. Therefore, the difference between the pressure P_c in the crank chamber 15 and the pressure in each cylinder 11a is small. This increases the inclination of the swash plate 22, thereby allowing the compressor to operate at a large displacement.

When the valve hole 68 in the valve 49 is completely closed by the valve body 67, the supply passage 48 is closed. This stops the supply of the highly pressurized refrigerant gas in the discharge chamber 38 to the crank chamber 15. Therefore, the pressure P_c in the crank chamber 15 becomes substantially the same as the low pressure P_s in the suction chamber 37. The inclination of the swash plate 22 thus becomes maximum as shown in Fig. 1, and the compressor operates at the maximum displacement. The abutment of the swash plate 22 and the projection 21a of the rotor 21

prevents the swash plate 22 from inclining beyond the predetermined maximum inclination.

Suppose the cooling load is small, the difference between the compartment temperature detected by the sensor 59 and the target temperature set by the temperature adjuster 58 is small and the suction pressure P_s is low. The computer 57 commands the driver 62 to decrease the current value to the coil 63 of the valve 49 for a smaller difference between the detected temperature and the target temperature. This decreases the magnitude of the attractive force between the core 78 and the plunger 80 thereby decreasing the resultant force urging the valve body 67 in a direction closing the valve hole 68. This increases the value of the pressure P_s that will open the valve hole 68. Decreasing the value of the current to the valve 49 causes the valve 49 to maintain a higher suction pressure P_s .

A larger opening area between the valve body 67 and the valve hole 68 increases the refrigerant gas flow from the discharge chamber 38 to the crank chamber 15. This increases the pressure P_c in the crank chamber 15. Further, when the cooling load is small, the suction pressure P_s is low and the pressure in each cylinder bore 11a is low. Therefore, the difference between the pressure P_c in the crank chamber 15 and the pressure in each cylinder 11a is great. This decreases the inclination of the swash plate 22 thereby allowing the compressor to operate at a small displacement.

As cooling load approaches zero, the temperature of the evaporator 55 in the refrigerant circuit 52 drops to a frost forming temperature. When the temperature sensor 56 detects a temperature that is lower than the frost forming temperature, the computer 57 commands the driver 62 to de-excite the solenoid 65. The driver 62 stops sending current to the coil 63, accordingly. This eliminates the magnetic attractive force between the core 78 and the plunger 80. The valve body 67 is then moved by the force of the spring 69 against the force of the spring 81 transmitted by the plunger 80 and the second rod 83. The valve body 67 is moved in a direction opening the valve hole 68. This maximizes the opening area between the valve body 67 and the valve hole 68. Accordingly, the gas flow from the discharge chamber 38 to the crank chamber 15 is increased. This further raises the pressure P_c in the crank chamber 15 thereby minimizing the inclination of the swash plate 22. The compressor thus operates at the minimum displacement.

When the switch 60 is turned off, the computer 57 commands the driver 62 to de-excite the solenoid 65. This also minimizes the inclination of the swash plate 22.

As described above, when the value of the current to the coil 63 is increased, the valve body 67 of the valve 49 allows the opening area of the valve hole 68 to be controlled by a lower suction pressure P_s . When the value of the current to the coil 63 is decreased, on the other hand, the valve body 67 allows the opening area

of the valve hole 68 to be controlled by a higher suction pressure P_s . The compressor controls the inclination of the swash plate 22 to adjust its displacement thereby maintaining a target suction pressure P_s . That is, the valve 49 changes the target value of the suction pressure P_s in accordance with the value of the current supplied thereto. Also, the valve, 49 causes the compressor to operate at the minimum displacement for any given suction pressure P_s . A compressor equipped with the control valve 49 varies the cooling ability of the air conditioner.

The shutter 28 slides in accordance with the tilting motion of the swash plate 22. As the inclination of the swash plate 22 decreases, the shutter 28 gradually reduces the cross-sectional area of the passage between the suction passage 32 and the suction chamber 37. This gradually reduces the amount of refrigerant gas that enters the suction chamber 37 from the suction passage 32. The amount of refrigerant gas that is drawn into the cylinder bores 11a from the suction chamber 37 gradually decreases, accordingly. As a result, the displacement of the compressor gradually decreases. This gradually lowers the discharge pressure P_d of the compressor. The load torque of the compressor thus gradually decreases. In this manner, the load torque for operating the compressor does not change dramatically in a short time when the displacement decreases from the maximum to the minimum. The shock that accompanies load torque fluctuations is therefore lessened.

When the inclination of the swash plate 22 is minimum, the shutter 28 abuts against the positioning surface 33. The abutment of the shutter 28 against the positioning surface 33 prevents the inclination of the swash plate 22 from being smaller than the predetermined minimum inclination. The abutment also disconnects the suction passage 32 from the suction chamber 37. This stops the gas flow from the refrigerant circuit 52 to the suction chamber 37 thereby stopping the circulation of refrigerant gas between the circuit 52 and the compressor.

The minimum inclination of the swash plate 22 is slightly larger than zero degrees. Zero degrees refers to the angle of the swash plate's inclination when it is perpendicular to the axis of the rotary shaft 16. Therefore, even if the inclination of the swash plate 22 is minimum, refrigerant gas in the cylinder bores 11a is discharged to the discharge chamber 38 and the compressor operates at the minimum displacement. The refrigerant gas discharged to the discharge chamber 38 from the cylinder bores 11a is drawn into the crank chamber 15 through the supply passage 48. The refrigerant gas in the crank chamber 15 is drawn back into the cylinder bores 11a through the pressure release passage 46, a pressure release hole 47 and the suction chamber 37. That is, when the inclination of the swash plate 22 is minimum, refrigerant gas circulates within the compressor traveling through the discharge chamber 38, the supply passage 48, the crank chamber 15, the pressure release passage 46, the pressure release hole 47, the

suction chamber 37 and the cylinder bores 11a. This circulation of refrigerant gas allows the lubricant oil contained in the gas to lubricate the moving parts of the compressor.

If the switch 60 is turned on and the inclination of the swash plate 22 is minimum, an increase in the compartment temperature increases the cooling load. This causes the compartment temperature detected by the sensor 59 to be higher than a target temperature set by the temperature adjuster 58. The computer 57 commands the driver 62 to excite the solenoid 65 in accordance with the detected temperature increase. Exciting the solenoid 65 closes the supply passage 48. This stops the flow of refrigerant gas from the discharge chamber 38 into the crank chamber 15. The refrigerant gas in the crank chamber 15 flows into the suction chamber 37 via the pressure release passage 46. This gradually lowers the pressure P_c in the crank chamber 15 thereby moving the swash plate 22 from the minimum inclination to the maximum inclination.

As the swash plate's inclination increases, the force of the second spring 86 gradually pushes the shutter 28 away from the positioning surface 33. This gradually increases the amount of refrigerant gas flow from the suction passage 32 into the suction chamber 37. Therefore, the amount of refrigerant gas drawn into the cylinder bores 11a from the suction chamber 37 gradually increases. This allows the displacement of the compressor to gradually increase. Thus, the discharge pressure P_d of the compressor gradually increases and the torque needed for operating the compressor also gradually increases accordingly. In this manner, the load torque of the compressor does not change dramatically in a short time when the displacement increases from the minimum to the maximum. The shock that accompanies load torque fluctuations is therefore lessened.

If the engine E is stopped, the compressor is also stopped (that is, the rotation of the swash plate 22 is stopped). Also, the supply of current to the coil 63 in the valve 49 is stopped. This de-excites the solenoid 65 thereby opening the supply passage 48. The inclination of the swash plate 22 is thus minimum. If the nonoperational state of the compressor continues, the pressures in the chambers of the compressor become equalized and the swash plate 22 is kept at the minimum inclination by the force of first spring 85. Therefore, when the compressor is not operating, the interior of the compressor is completely disconnected from the refrigerant circuit 52. Thus, even if the nonoperational state of the compressor continues over a relatively long period of time, liquefied refrigerant in the circuit 52 is prevented from entering the compressor.

As described in the background section, when the compressor is re-started by the engine E, a small amount of liquefied refrigerant may exist in the compressor. Foaming of the liquefied refrigerant is prevented since liquefied refrigerant is prevented from entering the compressor. Thus, lubricant stored in the compressor is prevented from being mixed with the liq-

uefied refrigerant and from being removed to the refrigerant circuit 52. Lubrication of the moving parts in the compressor is improved, accordingly.

Fig. 3 shows a second embodiment of the present invention. In this embodiment, an end of the guide hole 25 in the arm 21 is closed by a wall 92. The hole 25 has a U-shaped cross section. A spring 91 extends between the wall 92 and the guide pin 23. The spring 91 urges the swash plate 22 in a direction decreasing the inclination of the plate 22. The urging force of the spring 91 is greater than that of the spring 86, which opens the shutter 28.

If the compressor is not operating and the pressures in the chambers of the compressor are equalized, the swash plate 22 reaches the minimum inclination. This causes the shutter to close the suction passage 32. In this state, liquefied refrigerant in the refrigerant circuit 52 is prevented from entering the compressor. Therefore, when the compressor starts operating again, lubricant in the compressor is not removed to the circuit 52 by foaming of the liquefied refrigerant.

If the pressure in the crank chamber 15 is lowered, highly pressurized heated gas from the discharge chamber 38 is drawn into the crank chamber 15 via the passage 48. Thus, parts in the crank chamber 15 are exposed to the heated gas. However, the spring 91 is located in the arm 24 having a U-shaped cross-section and is not directly exposed to the gas flow. The spring 91 is thus not affected by the heated gas flowing in the crank chamber 15. This improves the durability of the spring 91.

A third embodiment of the present invention will now be described with reference to Fig. 4. The differences from the first embodiment will mainly be discussed below, and like or the same reference numerals are given to those components that are like or the same as the corresponding components of the first embodiment.

A second suction passage 101, defined in the cylinder block 11, communicates the shutter chamber 27 with the crank chamber 15. Refrigerant gas supplied to the shutter chamber 27 from the suction passage 32 is drawn into the crank chamber 15 via the second suction passage 101.

An introduction passage 102 communicates the crank chamber 15 with the suction chamber 37. Refrigerant gas in the crank chamber 15 is drawn into the suction chamber 37 via the introduction passage 102. The passage 102 includes a first passage 146, through holes 104, a second passage 103, a valve chamber 105 and a hole 105a. The first passage 146 is defined at the center portion of the rotary shaft 16 along the axis of the shaft 16. The first passage 146 has an inlet 146a, which opens to the crank chamber 15 in the vicinity of the lip seal 20, and an outlet 146b, which opens in the interior of the shutter 28. A plurality of through holes 104 are formed in the peripheral wall near the rear end of the shutter 28, which communicate the interior of the shutter 28 with the second passage 103, which is defined in

the cylinder block 11 and the valve plate 14. The valve chamber 105 is defined in the rear housing 13 and is communicated with the second passage 103. The hole 105a communicates the valve chamber 105 with the suction chamber 37.

A tapered outlet 106 is defined in the downstream end of the second passage 103, which opens to the valve chamber 105. A valve body 107, which functions as a spool valve, is slidably housed in the valve chamber 105. A tapered restrictor 108 is defined on an end of the valve body 107 facing the tapered outlet 106 of the passage 103. A spring 109 extends between the valve body 107 and the wall of the valve chamber 105 and urges the valve body 107 away from the outlet 106 of the passage 103.

A pressure control chamber 111 is defined by the rear end face of the valve body 107 and the valve chamber 105. A pressure supply passage 110 is defined in the rear housing 13 and communicates the discharge chamber 38 with the chamber 111. The displacement control valve 49 is accommodated in the rear housing 13 and is located in the passage 110. A pressure release passage 112 is defined in the rear housing 13, the valve plate 14 and the cylinder block 11 and communicates the chamber 111 with the crank chamber 15.

When the compressor is operating, refrigerant gas in the external refrigerant circuit 52 is drawn into the crank chamber 15 via the suction passage 32, the shutter chamber 27 and the second suction passage 101. Refrigerant gas in the crank chamber 15 is then drawn into the suction chamber 37 via the introduction passage 102, which includes the first passage 146, the through hole 104, the second passage 103, the valve chamber 105 and the hole 105a. The crank chamber 15 constitutes a part of the passage between the refrigerant circuit 52 and the suction chamber 37.

If the cooling load is great, the current value to the coil 63 in the valve 49 is increased. This increases the magnitude of the attractive force between the core 78 and the plunger 80 thereby increasing the resultant force urging the valve body 67 in a direction closing the valve hole 68. Decreasing the opening between the valve hole 68 and the valve body 67 reduces the amount of gas flow from the discharge chamber 38 to the pressure control chamber 111 via the supply passage 110. Refrigerant gas in the chamber 111, on the other hand, flows into the crank chamber 15 via the passage 112. This lowers the pressure in the chamber 111 thereby moving the valve body 107 rearward, or away from the tapered outlet 106. Accordingly, the restriction of the outlet 106 by the restrictor 108 of the valve body 107 is decreased. Decreasing the restriction, or increasing the opening of the outlet 106, increases the amount of gas flow from the crank chamber 15 into the suction chamber 37 via the passage 102. This increases the pressure in the suction chamber 37. Therefore, the difference between the pressure P_c in the crank chamber 15 and the pressure in each cylinder bore 11a is small. This increases the inclination of the

swash plate 22, thereby allowing the compressor to operate at a large displacement.

When the valve hole 68 in the valve 49 is completely closed by the valve body 67, the supply passage 110 is closed. This stops the supply of refrigerant gas from the discharge chamber 38 to the pressure control chamber 111. This further lowers the pressure in the pressure control chamber 111 thereby maximizing the opening between the outlet 106 and the valve body 107. Thus, the pressure in the suction chamber 37 is substantially equal to the pressure P_c in the crank chamber 15. The inclination of the swash plate 22 thus becomes maximum, and the compressor operates at the maximum displacement. When the supply passage 110 is closed by the valve 49, refrigerant gas in the discharge chamber 38 is supplied to the refrigerant circuit 52 and is not supplied to the crank chamber 15 via the passages 110 and 112.

Suppose the cooling load is small, the current value to the coil 63 in the valve 49 is lowered. This decreases the magnitude of the attractive force between the core 78 and the plunger 80 thereby decreasing the resultant force that urges the valve body 67 in a direction closing the valve hole 68. Increasing the opening between valve hole 68 and the valve body 67 increases the amount of gas flow from the discharge chamber 38 to the pressure control chamber 111 via the supply passage 110. This increases the pressure in the chamber 111 thereby moving the valve body 107 forward, or toward the tapered outlet 106. Accordingly, the restriction between the restrictor 108 and the outlet 106 is increased. Increasing the restriction, or decreasing the opening of the outlet 106, decreases the amount gas flow from the crank chamber 15 into the suction chamber 37 via the passage 102. This lowers the pressure in the suction chamber 37. Therefore, the difference between the pressure P_c in the crank chamber 15 and the pressure in each cylinder bore 11a is great. This decreases the inclination of the swash plate 22 thereby allowing the compressor to operate at a small displacement.

If the cooling load becomes zero, current supply to the coil 63 of the valve 49 is stopped. This eliminates the magnetic attractive force between the core 78 and the plunger 80. The valve body 67 is moved to a position that maximizes the opening of the valve hole 68. Accordingly, the supply passage 110 is fully opened. This further increases the gas flow from the discharge chamber 38 to the pressure control chamber 111 thereby increasing the pressure in the chamber 111. The pressure moves the valve body 107 forward and maximizing the restriction between the outlet 106 and the valve body 107. The maximum restriction minimizes gas flow from the crank chamber 15 to the suction chamber 37 and lowers the pressure in the suction chamber 37. This minimizes the inclination of the swash plate 22 thereby allowing the compressor to operate at the minimum displacement.

The minimum inclination of the swash plate 22 causes the shutter 28 to close the supply passage 32.

This stops gas flow from the refrigerant circuit 52 into the suction chamber 37. In this state, refrigerant gas circulates within the compressor traveling through the discharge chamber 38, the supply passage 110, the pressure control chamber 111, the pressure release passage 112, the crank chamber 15, the introduction passage 102, the suction chamber 37 and the cylinder bores 11a.

When the compressor is not operating, the pressures in the chambers of the compressor are equalized. Thus, the swash plate 22 returns to the minimum inclination position. This causes the shutter to close the suction passage 32. In this state, a small amount of liquefied refrigerant is stored in the compressor. Therefore, when the compressor starts operating again, lubricant in the compressor is not removed to the circuit 52 by foaming of the liquefied refrigerant.

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 of the appended claims.

An improved variable displacement compressor is disclosed. A compressor has a cam plate (22) that is mounted on a drive shaft (16) for integral rotation therewith. At least one piston (35) is coupled to the cam plate (22). The cam plate (22) is tiltable between its maximum inclining position and its minimum inclining position with respect to an axis of the drive shaft (16). The piston (35) reciprocates in a cylinder bore by a stroke based on an inclined angle of the cam plate (22) and compresses gas that is supplied to the cylinder bore (11a) from an external gas circuit (52) and discharge the compressed gas to the external gas circuit (52) that is connected to the interior of compressor by way of a gas passage (32). The shutter body (28) is urged by a first spring (85, 91) and a second spring (86) in opposite directions. The urging force of the first spring (85, 92) is greater than that of the second spring (86). A shutter body (28) that is biased to disconnect the gas passage (32) from the external gas circuit (52).

Claims

1. A compressor having a cam plate (22) mounted on a drive shaft (16) for integral rotation therewith and at least one piston (35) coupled to the cam plate (22), said cam plate (22) being tiltable between its maximum inclining position and its minimum inclining position with respect to an axis of the drive shaft (16), wherein said piston (35) reciprocates in a cylinder bore (11a) by a stroke based on an inclined angle of the cam plate (22) to compress gas supplied to the cylinder bore (11a) from an external gas circuit (52) and discharge the compressed gas to the external gas circuit (52), and wherein said external gas circuit (52) has a downstream side, in which the pressure is lower than the pressure of the rest of the external gas circuit (52), and the down-

stream side is connected to the interior of the compressor by way of a gas passage (32), said compressor being characterized by a shutter body (28) that is biased to disconnect the gas passage (32) from the external gas circuit (52).

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2. The compressor as set forth in claim 1, characterized in that said shutter body (28) moves in association with an inclination of the cam plate (22), wherein said shutter body (28) disconnects the gas passage (32) from the external gas circuit (52) when the cam plate (22) is in the minimum inclining position. 10
3. The compressor as set forth in claims 1 or 2, characterized in that said cam plate (22) is biased to the minimum inclining position and the maximum inclining position by a first spring (85; 91) and a second spring (86), respectively, wherein said first spring (85; 91) has biasing force greater than that of the second spring (86). 15 20
4. The compressor as set forth in Claim 3, characterized in that gas flow is supplied to the crank chamber (15) from the discharge chamber (38) when pressure in the crank chamber (15) decreases, wherein the gas flow circulated in the crank chamber (15), and wherein the first spring (91) is located away from a path of the gas flow. 25 30
5. The compressor as set forth in Claim 4, characterized in that a rotor (21) is mounted on the drive shaft (16) for integral rotation therewith and said rotor has a guide groove (25) with an end being closed, wherein said cam plate (22) has a portion (23) guided in the guide groove (25) to couple the cam plate (22) to the rotor (21) in much a manner that the cam plate (22) integrally rotates and tiltably with respect to the rotor (21), and wherein said first spring (91) is located in the guide groove (25) and biases the cam plate (22) to the minimum inclining position. 35 40 45 50 55

Fig.1

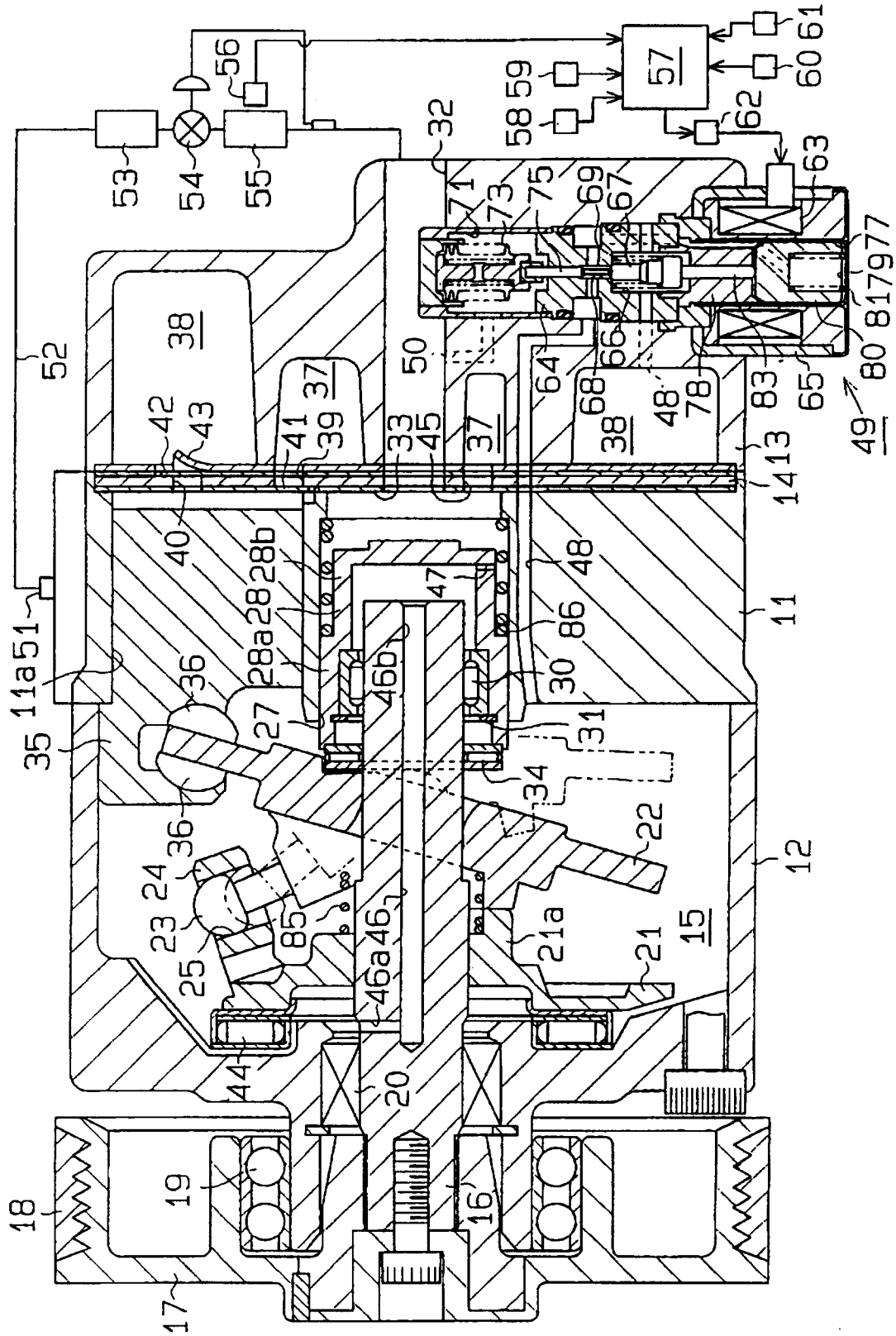


Fig. 2

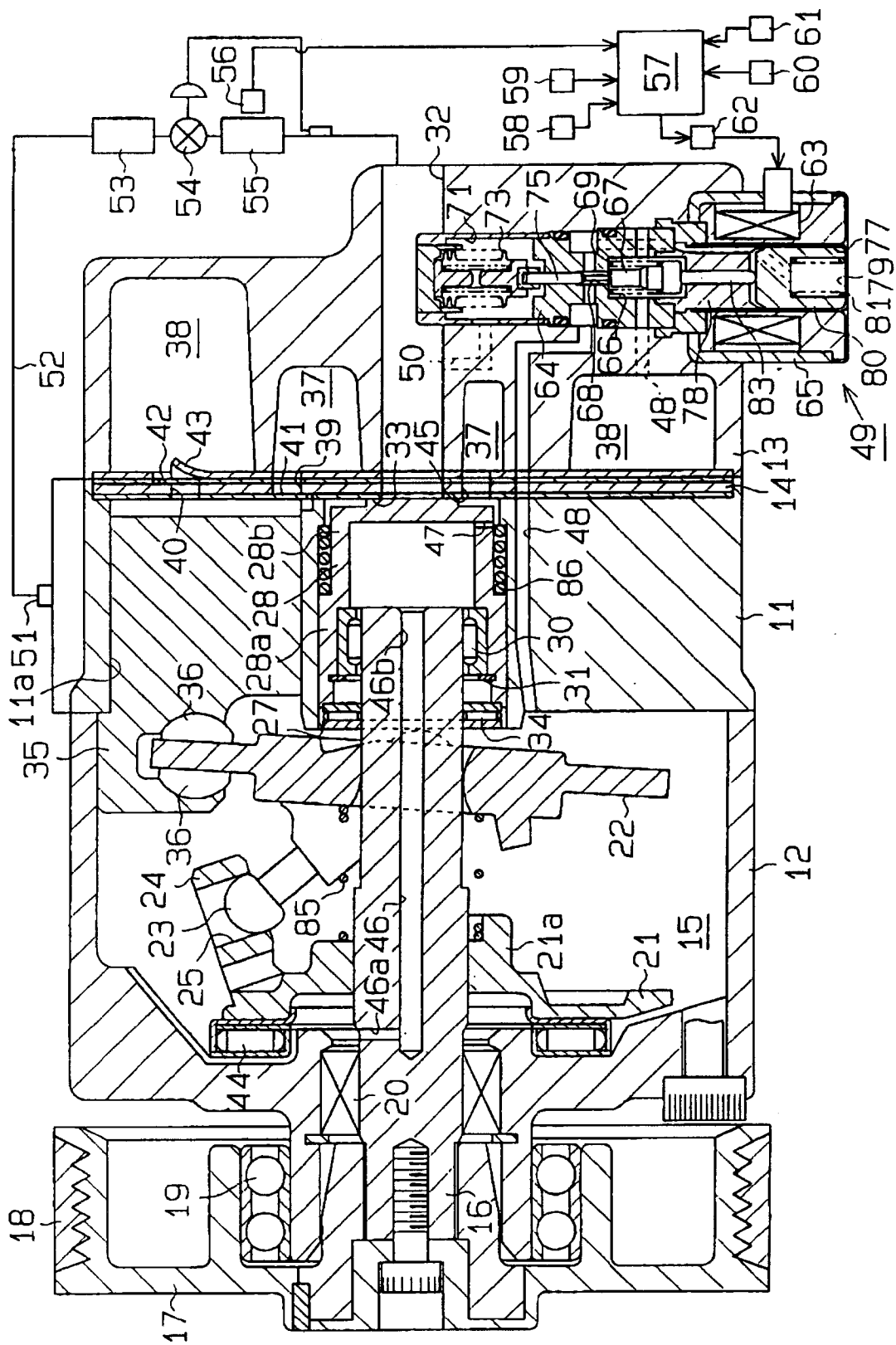


Fig. 3

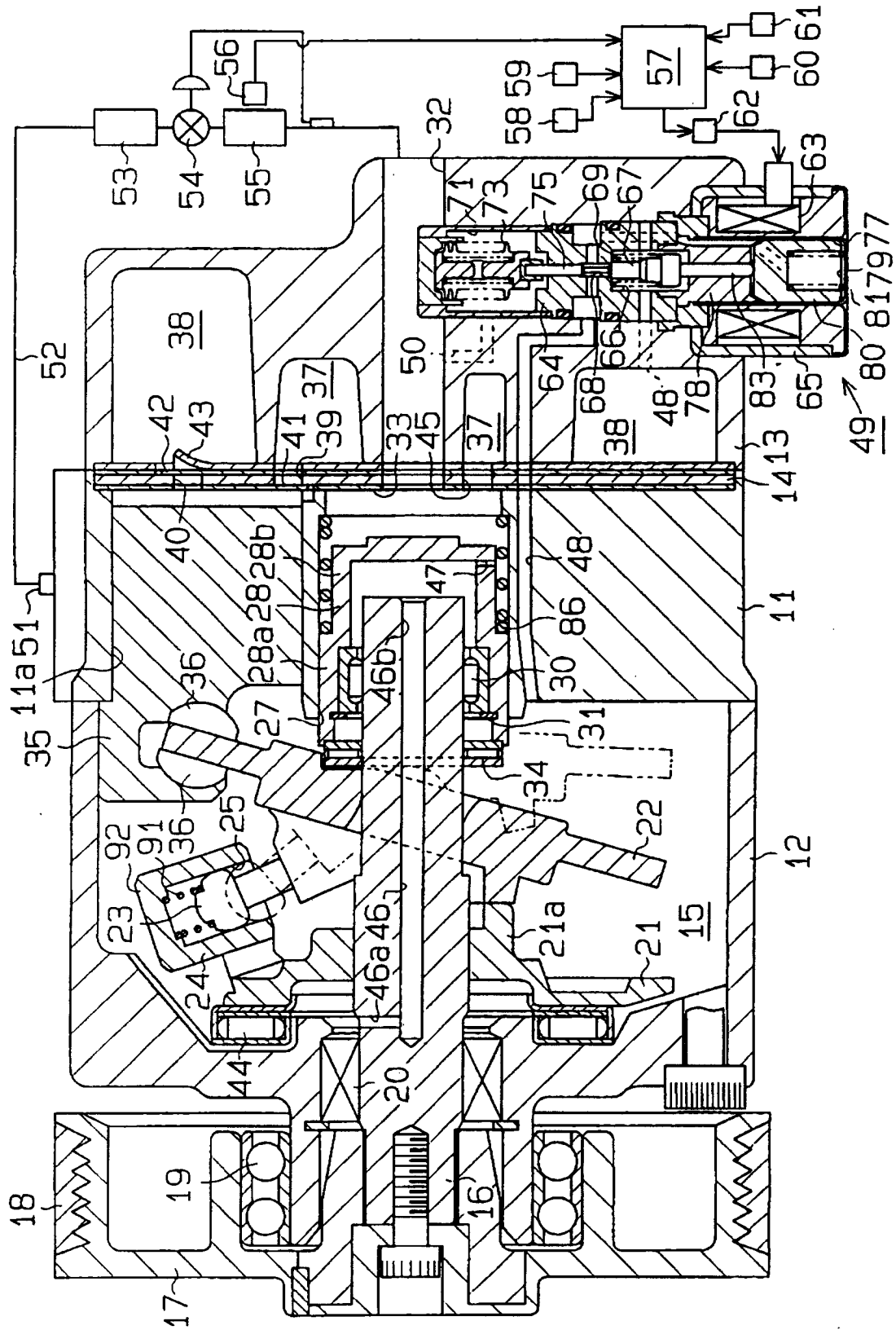


Fig. 4

