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

(72) Inventors:
- **Fujii, Toshiro**
  2-1, Toyoda-cho, Kariya-shi, Aichi-ken (JP)
- **Okabe, Takanori**
  2-1, Toyoda-cho, Kariya-shi, Aichi-ken (JP)
- **Murakami, Kazuo**
  2-1, Toyoda-cho, Kariya-shi, Aichi-ken (JP)
- **Nakane, Yoshiyuki**
  2-1, Toyoda-cho, Kariya-shi, Aichi-ken (JP)

(74) Representative:
Pellmann, Hans-Bernd, Dipl.-Ing. et al
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4-6
80336 München (DE)

(54) Air conditioning systems

(57) The air conditioning system 100 may include a compressor 101, a heating circuit 152, and a capacity controller 181. The compressor 101 has a suction port 115, a discharge port 120, a driving unit 130 provided within a driving chamber 110, a first passage 201 and a second passage 202. The driving unit 130 may decrease compressor output discharge capacity when the pressure within the driving chamber 110 increases. The first passage 201 may connect the discharge port 120 to the driving chamber 110 and the second passage 202 may connect the driving chamber 110 to the suction port 115. The capacity controller 181, 185 may open the first passage 201 when the refrigerant discharge pressure results predetermined pressure. Further, the capacity controller 181, 185 may narrow the second passage 202 in response to the opening of the first passage 201. By opening the first passage 201, the high-pressure refrigerant may be released from the discharge port 120 to the driving chamber 110 through the first passage 201. By narrowing the second passage 202, the high-pressure refrigerant released from the discharge port is difficult to be released from the driving chamber 110 to the suction port 116. Thus, the pressure within the driving chamber 110 may quickly increase, the compressor output discharge capacity can be quickly reduced, the abnormally high discharge pressure of the compressor 101 can be quickly alleviated by the reduction in the compressor output discharge capacity.

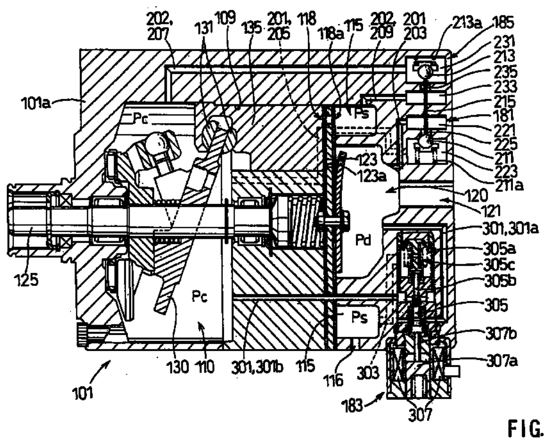

FIG. 3

EP 1 014 016 A2

Description

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates to air conditioning systems that utilize refrigerants and a compressor, and particularly to air conditioning systems capable of effectively alleviating excessive increases in refrigerant discharge pressure within a heating circuit.

DESCRIPTION OF THE RELATED ART

[0002] A known air conditioning system is disclosed in Japanese Unexamined Patent Publication No. 7-19630 and includes a compressor 1, a cooling circuit 51, a heating circuit 52 and a controller 83, as shown in FIG. 1.

[0003] The cooling circuit 51 includes a condenser 55, a first expansion valve 57, and a heat exchanger 59 provided on a passage connecting a discharge port D to a suction port S of the compressor 1. High-pressure refrigerant discharged from the discharge port of the compressor 1 is drawn through the above respective devices and back to the compressor 1.

[0004] The heating circuit 52 includes a bypass passage 52a that extends from the discharge port D of the compressor 1 to the heat exchanger 59. A second expansion valve 63 is provided within the bypass passage 52a between the discharge port D and the heat exchanger 59. The high pressure refrigerant discharged from the compressor 1 is not directed to the condenser 55, but rather is drawn by the compressor 1 through the second expansion valve 63 and the heat exchanger 59 and this cycle is repeated. Such a heating circuit 52 is generally known as a hot-gas bypass heater.

[0005] The operation of the cooling circuit 51 and the heating circuit 52 is changeably selected by opening and closing selector valves 53a and 53b, which opening and closing operations are performed by the controller 83.

[0006] Because the air conditioning system is used in a state in which the refrigerant discharge pressure is higher when the heating circuit 52 is used than when the cooling circuit 51 is used, abnormally high pressure is likely to be applied during operation of the heating circuit 52. For example, the abnormally high-pressure state is likely to occur when a rotation speed of the compressor 1 is increased temporarily during operation of the heating circuit 52. Therefore, the air conditioning system is further provided with a refrigerant releasing passage 91 having a pressure relief valve 93. The refrigerant releasing passage 91 is connected to the heating circuit 52 and the cooling circuit 51 and the pressure relief valve 93 can be opened to release the refrigerant from the heating circuit 52 to the cooling circuit 51 when the refrigerant discharge pressure abnormally increases during the operation of the heating circuit 52.

[0007] Because the cooling circuit 51 and the heating circuit 52 are alternatively selected by the selector valves 53a and 53b, the refrigerant is released toward the cooling circuit 51 which is not used when the discharge pressure is increased abnormally during operation of the heating circuit 52, thereby preventing the discharge pressure at the heating circuit 52 from increasing abnormally.

[0008] Because the refrigerant is released from the operating heating circuit 52 to the cooling circuit 51 which is not used, the abnormally high-pressure state of the discharge pressure during operation of the heating circuit 52 can be alleviated. However, because the refrigerant in the heating circuit 52 is released into the cooling circuit 51 whenever the discharge pressure increases, the amount of the refrigerant in the heating circuit 52 is reduced and heating performance may be reduced. Moreover, because the high- pressure refrigerant is wastefully released from the heating circuit by working the compressor 1, energy efficiency is reduced.

SUMMARY OF THE INVENTION

[0009] It is, therefore, an object of the present invention to provide an air conditioning system that can effectively alleviate abnormally high-pressure state.

[0010] An air conditioning system may preferably include a compressor, a heating circuit, and a compressor output discharge capacity controller.

[0011] The compressor may have a suction port for drawing refrigerant, a discharge port for discharging compressed refrigerant, a driving unit provided within the compressor driving chamber, a first passage that connects the discharge port to the driving chamber, and a second passage that connects the driving chamber to the suction port. The driving unit may decrease compressor output discharge capacity when pressure within the driving chamber increases. The heating circuit may have a passage that extends from the discharge port to the suction port through a heat exchanger.

[0012] The capacity controller may open the first passage when the refrigerant discharge pressure results predetermined pressure state and the capacity controller may narrow the second passage in response to the opening of the first passage. By opening the first passage, the refrigerant is released from the discharge port into the driving chamber and the pressure within the driving chamber increases. Because the second passage is narrowed in response to the opening of the first passage, the necessary amount of refrigerant released from the discharge port into the driving chamber for increasing the pressure within the driving chamber can be reduced. Moreover, by narrowing the second passage in response to the opening of the first passage, the pressure within the driving chamber can be quickly increased and the high-pressure state within the driving chamber can be maintained relatively for long time. Thus, when compressor discharge pressure results abnormally high pressure state, the compressor output discharge capacity can be decreased thereby alleviating the high discharge pressure quickly and effectively.

[0013] Other objects, features and advantages of the present invention will be readily understood after reading the following detailed description together with the accompanying drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1 shows a known air conditioning system.

FIG. 2 shows an air conditioning system according to a first representative embodiment.

FIG. 3 shows a variable displacement compressor and a capacity controller according to the first representative embodiment.

FIG. 4 shows a variable displacement compressor and a capacity controller according to a second representative embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Preferably, an air conditioning system may include a compressor, a heating circuit, and a compressor output discharge capacity controller. The compressor may have a suction port, a discharge port, a driving unit, a first passage and a second passage. The suction port may draw the refrigerant into the compressor. The discharge port may discharge compressed high-pressure refrigerant. The driving unit may be provided within a compressor driving chamber. The driving unit may decrease compressor output discharge capacity when the pressure within the driving chamber increases. The first passage may connect the discharge port to the driving chamber. The second passage may connect the driving chamber to the suction port.

[0016] The heating circuit may have a passage that extends from the discharge port to the suction port through the heat exchanger. Such type of the heating circuit is generally known as a hot gas bypass heater. Preferably, a decompressor such as an expansion valve may be provided within the passage from the discharge port to the heat exchanger.

[0017] The capacity controller may close the first passage when the refrigerant discharge pressure does not result predetermined pressure state. By closing the first passage, the high-pressure refrigerant can not be released from the discharge port to the driving chamber, the pressure within the driving chamber does not increase and the compressor output discharge capacity can not be decreased thereby maintaining high circuit operation performance. To the contrary, the capacity controller may open the first passage when the refrigerant discharge pressure results predetermined pressure. By opening the first passage, the high pressure refrigerant may be released from the discharge port to the driving chamber through the first passage. Further, the capacity controller may narrow the second passage in response to the opening of the first passage. By narrowing the second passage, pressure within the driving chamber can be quickly increased and the necessary amount of refrigerant to be released from the discharge port into the driving chamber can be reduced, because high-pressure refrigerant released from the discharge port into the driving chamber is difficult to be released into the suction port through the narrowed second passage. As the result, pressure within the driving chamber can be quickly increased to decrease the compressor output discharge capacity quickly. Therefore, even if the refrigerant discharge pressure increases sharply, the alleviation of the abnormally high discharge pressure can be started at an early stage of such increase of the discharge pressure. Furthermore, the high-pressure state within the driving chamber can be maintained relatively for long time, because the second passage narrowed by the capacity controller prevents the refrigerant within the driving chamber from being released quickly into the suction port. This is, the necessary amount of high-pressure refrigerant for increasing the pressure within the driving chamber can be reduced and the reduction of energy efficiency can be minimized. The second passage may preferably be narrowed by throttling the second passage. Thus, when compressor discharge pressure results abnormally high, the compressor output discharge capacity can be quickly and effectively decreased thereby alleviating the high discharge pressure quickly and effectively.

[0018] As another example, when the refrigerant discharge pressure results predetermined pressure state, the second passage may be closed, instead of being narrowed, in response to the opening of the first passage. In this example, the refrigerant released from the discharge port into the driving chamber can be fully retained within the driving chamber. Therefore, the necessary time and the necessary amount of refrigerant for increasing the pressure within the driving chamber can be minimized.

[0019] In both examples, the capacity controller may preferably have a first valve disposed within the first passage and a second valve disposed within the second passage. The first valve may open the first passage when the refrigerant discharge pressure results predetermined pressure state. The second valve may narrow or close the second passage in response to the opening of the first valve. By narrowing the second passage, the necessary amount of high-pressure refrigerant to be released from the discharge port into the driving chamber can be decreased, thereby increasing the pressure within the driving chamber quickly and maintaining the high-pressure state within the driving chamber relatively for long time. By closing the second passage, the high-pressure refrigerant within the driving chamber can not be released into the suction port. Thus, the pressure within the driving chamber can be increased extremely quickly and the high-pressure state within the driving chamber can be maintained until the second passage is again opened. Therefore, the abnormally high discharge pressure can be quickly and effectively alleviated. The first valve and the second valve are one of the features that corresponds to the capacity controller or the capacity control means.

[0020] In closing or narrowing the second passage, driving chamber decompression means may preferably be provided in the air conditioning system. When the high-pressure refrigerant is released from the discharge port into the driving chamber by opening the first passage, the driving chamber tends to be brought into an abnormally high pressure state because the second passage is narrowed or closed in order to increase the pressure within the driving chamber for decreasing the compressor output discharge capacity. If the pressure within the driving chamber exceeds the upper tolerance level of the driving chamber, the airtight seal of the driving chamber will be degraded. Therefore, the driving chamber decompression means may release the refrigerant from the driving chamber into the suction port separately from the second passage when the pressure within the driving chamber results predetermined high-pressure state. The driving chamber decompression means may preferably have a driving chamber decompression passage that connects the driving chamber to the suction port separately from the second passage and a driving chamber decompression valve that is provided within the driving chamber decompression passage. When the pressure within the driving chamber results abnormally high-pressure state, the driving chamber decompression valve opens the driving chamber decompression passage thereby releasing the high-pressure refrigerant from the driving chamber into the suction port in order to decrease the pressure within the driving chamber. The driving chamber decompression valve may open the driving chamber decompression passage based on the difference between the pressure within the driving chamber and lower pressure than the pressure within the driving chamber. For example, compressor suction pressure, atmospheric pressure or vacuum pressure may be utilized. Otherwise, the driving chamber decompression valve may open the driving chamber decompression passage by utilizing a valve-opening signals generated on the basis of the pressure within the driving chamber.

[0021] After the alleviation of abnormally high discharge pressure, the capacity controller may close the first passage and open the second passage. By closing the first passage, the refrigerant can not be released from the discharge port to the driving chamber. By opening the second passage, the high-pressure refrigerant within the driving chamber is released into the suction port.

[0022] The refrigerant released from the driving chamber into the suction port through the second passage is drawn by the suction port and again compressed and discharged.

[0023] Although a slight reduction of energy efficiency is inevitable according to the air conditioning system because the refrigerant is released from the discharge port to the driving chamber by working the compressor, problems such as an extreme reduction in energy efficiency and a reduction in circuit operating performance due to wasteful release of the high-pressure refrigerant from the circuit to the outside will not occur.

[0024] Each of the additional features and method steps disclosed above and below may be utilized separately or in conjunction with other features and method steps to provide improved air conditioning systems and methods for designing and using such air conditioning systems. Representative examples of the present invention, which examples utilize many of these additional features and method steps in conjunction, will now be described in detail with reference to the drawings. This detailed description is merely intended to teach a person of skilled in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detail description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly described some representative examples of the invention, which detailed description will now be given with reference to the accompanying drawings.

First Detailed Representative Embodiment

[0025] Referring to Fig. 2, a representative air conditioning system 100 may include a cooling circuit 151, a heating circuit 152 and a variable displacement compressor 101 as a driving source for both the heating and cooling circuits. A representative capacity controller is shown in FIG. 3, but is not shown in FIG. 2 for the sake of convenience and will be described below in further detail. Such the air conditioning system 100 may be utilized in a vehicle-mounted air conditioning system. In such case, a driving shaft 125 of the compressor 100 may be coupled to and driven by an automobile engine 170.

[0026] The cooling circuit 151 may be driven by high-pressure refrigerant, which is compressed by the compressor 101, and may include a condenser 155, a first expansion valve 157, a heat exchanger 159 and an accumulator 161. These devices may be disposed within a path 151a that extends from a discharge port D to a suction port S of the compressor 101. The heat exchanger 159 is also generally known as an evaporator. The heat exchanger 159 may be arranged side by side with a hot-water heater 171, which circulates hot coolant from the engine 170 through a pipe 173.

[0027] The heating circuit 152 is driven by high-temperature and high-pressure refrigerant, which is also compressed by the compressor 101, and may include a second expansion valve 163, the heat exchanger 159 and the accumulator 161. These devices may be disposed on a bypass passage 152a for introducing the refrigerant discharged from the discharge port D to the heat exchanger 159. In other words, the heating circuit 152 partially overlaps with the cooling circuit 151. Such a heating circuit 152 is also generally known as a hot-gas bypass heater.

[0028] In FIG. 2, a first open/close valve 153a and a second open/close valve 153b may be utilized as switch valves for alternatively actuating the cooling circuit 151 and the heating circuit 152.

[0029] During operation of the cooling circuit 151, the refrigerant is compressed by the compressor 101 to attain a high temperature and high pressure state. The compressed refrigerant is sent to the condenser 155, where heat from the high-temperature refrigerant is dissipated to the outside environment and the refrigerant is liquefied. The refrigerant is decompressed by the first expansion valve 157 and sent to the heat exchanger 159 where the refrigerant absorbs outside heat and is gasified. The gasified refrigerant is returned to the compressor 101 again through the accumulator 161 for recirculation throughout the system 100.

[0030] During operation of the heating circuit 152, the refrigerant is compressed by the compressor 101 to attain a high temperature and high pressure state. The compressed refrigerant is then decompressed by the second expansion valve 163 and sent to the heat exchanger 159, where beat from the compressed refrigerant is dissipated to the outside environment. In the heating circuit cycle, the refrigerant is constantly in a gaseous state while circulating through the heating circuit 152.

[0031] The heating circuit 152 may be used as an auxiliary heater. Heat generated by the heat exchanger 159 during operation of the heating circuit 152 may be used as an auxiliary heating source for the hot water heater 171. The heating circuit 152 also may be used to assist the coolant from the engine 170 when the coolant can not provide sufficient heat to start the engine 170 in a low-temperature environment, such as an outside air temperature of - 20 °C or so.

[0032] Referring to FIG. 3, a representative compressor 101 is shown that may include a driving chamber 110 defined within a housing 101a of the compressor 101 and a swash plate 130 that is rotatably supported by the driving shaft 125 in the driving chamber 110. The swash plate 130 may be supported by the driving shaft 125 and may rotate together with the driving shaft 125. The swash plate 130 is inclined with respect to the driving shaft 125 when the driving shaft 125 rotates and the inclination angle of the swash plate 130 with respect to a plane perpendicular to the axis of rotation of the driving shaft 125 is changeable.

[0033] The peripheral edge portion of the swash plate 130 may be connected to the head portions of the pistons 135 by means of movable shoes 131. Six pistons 135 in total may be disposed around the driving shaft 125 (however, only one piston is shown in FIG. 3 for the sake of convenience) and may be laterally slide within six cylinder bores 109. The circumferential positions of the six cylinder bores 109 are fixed by the compressor housing 101a.

[0034] When the swash plate 130 rotates together with the driving shaft 125 while being inclined as shown in FIG. 3, the peripheral edge of the swash plate 130 slides with respect to the piston 135 fixed in the circumferential direction. When the peripheral edge of the swash plate 130 is inclined to a position closest to the cylinder bores 109 (as shown in FIG. 3), the piston 135 reaches its deepest insertion into the cylinder bores 109. When the peripheral edge of the swash plate 130 (the peripheral edge shown in a lower part of FIG. 3) is inclined to a position furthest away from the cylinder bores 109 (i.e., when the driving shaft 125 rotates 180° from the state shown in FIG. 3), the piston 135 is substantially withdrawn from the cylinder bore 109. Each 360° rotation of the driving shaft 125 results in each piston 135 laterally reciprocating one time.

[0035] A suction port 118a and a discharge port 123a are defined in a bottom portion of each the cylinder bore 109. A suction valve 118 is positioned to correspond to the suction port 118a and a discharge valve 123 is positioned to correspond to the discharge port 123a. Each suction port 118a communicates with a suction chamber 115 and each the discharge port 123a communicates with a discharge chamber 120.

[0036] When the piston 135 moves to the left in FIG. 3, as a result of rotation of the swash plate 130, refrigerant is introduced from the suction opening 116 through the suction chamber 115, suction port 118a and suction valve 118 into the cylinder bore 109. When the piston 135 moves to the right in FIG. 3, as a result of further rotation of the swash plate 130, the refrigerant is compressed into a high-pressure state and discharged from a discharge opening 121 through the discharge port 123a, discharge valve 123 and discharge chamber 120.

[0037] The output discharge capacity of the compressor 101 is determined by the stroke length of the piston 135, which is determined by the degree of change in inclination angle of the swash plate 130 during each cycle. That is, the further the swash plate 130 is withdrawn from the cylinder bore 109 during each cycle, the longer the stroke length of the piston 135 will be. As the stroke length decreases, the output discharge capacity of the compressor 101 also decreases.

[0038] The inclination angle of the swash plate 130 is determined, in part, by the difference in pressure on the opposite sides of the piston 135, i.e., the pressure difference between driving chamber pressure and the cylinder bore pressure. Increasing or decreasing the driving chamber pressure can adjust this pressure difference. When the pressure within the driving chamber 110 is increased, the swash plate 130 does not move as much in the lateral direction and the stroke length of the piston 135 decreases. Therefore, the output discharge capacity also will decrease. When the output discharge capacity decreases, the refrigerant discharge pressure decreases and the suction pressure increases. When the pressure within the driving chamber 110 is decreased, the swash plate 130 will move further in the lateral direction, the stroke length of the piston 135 increases. In this case, the output discharge capacity will increase. When the output discharge capacity increases, the refrigerant discharge pressure increases and the suction pressure decreases.

[0039] In order to decrease the output discharge capacity, the high-pressure refrigerant in the discharge chamber 120 is released into the driving chamber 110 to increase the pressure within the driving chamber 110. In order to increase the output discharge capacity instead, the refrigerant in the discharge chamber 120 is prevented from being released into the driving chamber 110.

[0040] In the representative compressor 101, as shown in FIG. 3, the discharge chamber 120 is connected to the driving chamber 110 by a heating circuit capacity control passage 201 and also by a cooling circuit capacity control passage 301.

[0041] A heating circuit capacity control valve 181 is provided within the heating circuit capacity control passage 201. The heating circuit capacity control valve 181 includes a valve body 211 provided between a first capacity control chamber 221 and a second capacity control chamber 223. The first capacity control chamber 221 and the second capacity control chamber 223 can communicate with each other through a connecting passage 225 when the valve body 211 opens the connecting passage 225. However, in a normal condition of operating the heating circuit, the valve body is biased by a spring 211a such that the valve body 211 closes the connecting passage 225.

[0042] The discharge chamber 120 is connected with the first capacity control chamber 221 by a first heating circuit capacity control passage 203. Therefore, pressure in the first heating circuit capacity control passage 203 and the pressure in the first capacity control chamber 221 are equal to the discharge pressure Pd. The driving chamber 110 is connected with the second capacity control chamber 223 by a second heating circuit capacity control passage 205. Therefore, pressure in the second heating circuit capacity control passage 205 and the pressure in the second capacity control chamber 223 are equal to the pressure Pc within the driving chamber 110.

[0043] The driving chamber 110 is connected to the suction chamber 115 by a refrigerant bleeding passage 202. A refrigerant bleeding valve 185 is provided onto the refrigerant bleeding passage 202. The refrigerant bleeding valve 185 includes a valve body 213 provided between a first refrigerant bleeding chamber 231 and a second refrigerant bleeding chamber 233. The valve body 213 is biased by a spring 213a. As shown in FIG.3, the first refrigerant bleeding chamber 231 and the second refrigerant bleeding chamber 233 are communicated with each other through a connecting passage 235 during a normal operation of the heating circuit. The first refrigerant bleeding chamber 231 is connected with the driving chamber 110 by a first refrigerant bleeding passage 207. Therefore, pressure in the first refrigerant bleeding passage 207 and the first refrigerant bleeding chamber 231 are equal to the pressure Pc within the driving chamber 110. The second refrigerant bleeding chamber 233 is connected with the suction chamber 115 by a second refrigerant bleeding passage 209. Therefore, pressure in the second refrigerant bleeding passage 209 and the second refrigerant bleeding chamber 233 are equal to the suction pressure Ps.

[0044] The heating circuit capacity control valve 181 and the refrigerant bleeding valve 185 are integrally provided within the compressor housing 101a. The valve body 213 for opening /closing the refrigerant bleeding passage 202 is coupled to the valve body 211 for opening/closing the heating circuit capacity control passage 201 by a connecting member 215. When the valve body 211 of the heating circuit capacity control valve 181 is located to close the heating circuit capacity control passage 201, the valve body 213 of the refrigerant bleeding valve 185 is located to narrow the refrigerant bleeding passage 202. In this representative embodiment, locations of both valve bodies 211, 213 are adjusted by controlling the biasing force of the springs 211a and 213a or by disposing a spacer between the valve body 213 and the connecting passage 235 such that the valve body 213 is spaced with respect to the connecting passage 235 even when the valve body 213 is to move towards the connecting passage 235.

[0045] As shown in FIG. 3 and described above, the discharge chamber 120 is connected to the driving chamber 110 by the cooling circuit capacity control passage 301 as well as the heating circuit capacity control passage 201. A cooling circuit capacity control valve 183 is provided within the cooling circuit capacity control passage 301. The discharge chamber 120 is connected with the cooling circuit capacity control valve 183 by a first cooling circuit capacity control passage 301a. Therefore, pressure in the first cooling circuit capacity control passage 301a is equal to the discharge pressure Pd. The cooling circuit capacity control valve 183 is connected with the driving chamber 110 by a second cooling circuit capacity control passage 301b. Therefore, pressure in the second cooling circuit capacity control passage 301b is equal to the pressure Pc in the driving chamber 110. The cooling circuit capacity control valve 183 includes a valve body 305, an actuating member

307a actuated by a solenoid 307, a connecting member 307b for connecting the actuating member 307a to the valve body 305 and a bellows 305a. The bellows 305a can expand and contract to move the valve body 305 in accordance with the suction pressure Ps. The suction pressure Ps for expanding or contracting the bellows 305a may be detected through a suction pressure detecting passage 303 that is connected to the suction chamber 115. The bellows 305a opens the valve body 305 to communicate the first cooling circuit capacity control passage 301a with the second cooling circuit capacity control passage 301b when the suction pressure Ps satisfies the condition of opening the valve body 305. Such condition may be changed by exciting or not exciting the solenoid 307. A controller (not particularly shown in the drawings) generates a control signal for exciting the solenoid 307. This is because the force exerted onto the actuating member 307a by the solenoid 307 is utilized as a biasing force against the movement of the bellows 305a. During operation of the heating circuit, the solenoid 307 is excited to close the cooling circuit capacity control valve 183, because the output discharge capacity is to be controlled exclusively by utilizing the heating circuit capacity control valve 181 during operation of the heating circuit.

[0046] When the compressor discharge pressure results predetermined high-pressure state during the operation of the heating circuit, a difference between the discharge pressure Pd in the first capacity control chamber 221 and the pressure Pc in the second capacity control chamber 223 increases. The high discharge pressure prevails over the biasing force of the springs 211a, 213a and the pressure within the second capacity control chamber 223. Thus, the valve body 211 moves to open the heating circuit capacity control valve 181 (The valve body 211 moves downward in FIG.3). As described above, a condition for opening the heating circuit capacity control valve 181 can be determined by properly adjusting the biasing force of the springs 211a, 213a. As the result of opening the heating circuit capacity control valve 181, the valve body 213 of the refrigerant bleeding valve 185 is moved downward in FIG.3 in response to the downward movement of the valve body 211 of the capacity control valve 181. Thus, the refrigerant bleeding passage 202 is narrowed by the refrigerant bleeding valve 185 in response to the opening of the capacity control valve 181. By opening the capacity control valve 181, the discharge chamber 120 is communicated with the driving chamber 110 through the heating circuit capacity control passage 201. The high-pressure refrigerant is released from the discharge chamber 120 into the driving chamber 110. However, the refrigerant released into the driving chamber 110 is difficult to be released into the suction chamber 115 because the refrigerant bleeding passage 202 is narrowed. As the result, the pressure within the driving chamber 110 is quickly increased and the high pressure state in the driving chamber 110 is maintained relatively for long time. Thus, the swash plate 130 stands to decrease the stroke length of the pistons 135, the compressor output discharge capacity is decreased and the compressor discharge pressure is decreased thereby alleviating the abnormally high discharge pressure quickly. The necessary amount of the refrigerant for increasing the pressure within the driving chamber 110 can be reduced, because the refrigerant bleeding passage 202 is narrowed in response to the opening of the capacity control passage 201 and therefore, the pressure within the driving chamber 110 can be quickly and sufficiently increased by releasing only small amount of the high-pressure refrigerant into the driving chamber 110. Therefore, extreme reduction of the energy efficiency does not occur.

[0047] When the discharge pressure does not result predetermined high-pressure state during operation of the heating circuit 152, the difference between the discharge pressure Pd and the pressure Pc within the driving chamber 110 does not increase. Therefore, pressure within the first capacity control chamber 221 (equal to the discharge pressure) does not prevail over the biasing force of the springs 211a, 213a and the pressure within the second capacity control chamber 223. Thus, the valve body 211 does not move to open the heating circuit capacity control passage 201 and the refrigerant bleeding valve 185 does not narrow the refrigerant bleeding passage 202. As the result, the capacity control passage 201 is not opened and the refrigerant bleeding passage 202 is not narrowed. The high-pressure refrigerant can not be released from the discharge chamber 120 into the driving chamber. The pressure within the driving chamber 110 is not increased, the compressor output discharge capacity is not decreased and the compressor discharge pressure is not decreased thereby maintaining the high operating performance of the heating circuit.

[0048] During operation of the cooling circuit, when the refrigerant suction pressure Ps does not result predetermined low pressure, the cooling circuit capacity control valve 183 is closed. As the result, the discharge chamber 120 does not communicate with the driving chamber 110. The high-pressure refrigerant is not released from the discharge chamber 120 into the driving chamber 110. Thus, the pressure within the driving chamber 110 does not increase, the inclination angle of the swash plate 130 does not increase, the output discharge capacity does not decrease, thereby maintaining high cooling performance.

[0049] On the other hand, during operation of the cooling circuit, when the suction pressure Ps results predetermined low-pressure state, the bellows 305a of the cooling circuit capacity control valve 183 moves the valve 305 to communicate the first cooling circuit capacity control passage 301a with the second cooling circuit capacity control passage 301b. Thus, the high-pressure refrigerant is released from the discharge chamber 120 into the driving chamber 110 through the cooling circuit capacity control passage 301. Thus, the pressure within the driving chamber 110 increases and the compressor output discharge capacity decreases. By decreasing the compressor output discharge capacity, the suction pressure Ps increases and the heat exchanger 159 (shown in FIG.2) is prevented from being frosted.

[0050] During operation of the heating circuit, the cooling circuit capacity control valve 183 is necessarily to be closed because the discharge pressure is to be controlled exclusively by the heating circuit capacity control valve 181. Therefore, when the heating circuit is operated, the solenoid 307 in the cooling circuit capacity control valve 183 is not excited. Thus, the cooling circuit capacity control passage 301 is closed during the operation of the heating circuit.

[0051] To the contrary, during operation of the cooling circuit, the heating circuit capacity control valve 181 is necessarily to be closed because the suction pressure is to be controlled exclusively by utilizing the cooling circuit capacity control valve 183. However, the heating circuit capacity control valve 181 utilizes the difference between the discharge pressure Pd and the pressure within the driving chamber 110. Therefore, during operation of the cooling circuit, the heating circuit capacity control valve 181 may possibly be opened when the discharge pressure Pd particularly increases with respect to the pressure within the driving chamber 110. However, the pressure necessary for opening the heating circuit capacity control valve 181 is set to be higher than the discharge pressure utilized during the operation of the cooling circuit. Therefore, the heating circuit capacity control valve 181 is unlikely opened during operation of the cooling circuit. Moreover, even if the heating circuit capacity control valve 181 is opened during the operation of the cooling circuit, the compressor output discharge capacity decreases and the discharge pressure soon decreases. Therefore, the heating circuit capacity control valve 181 is swiftly closed causing no practical damage onto the air conditioning system.

[0052] In the first representative embodiment, when the capacity control valve 181 opens the heating circuit capacity control passage 201, the refrigerant bleeding valve 185 narrows the refrigerant bleeding passage 202 in response to the opening of the capacity control valve 181. As the result of narrowing the refrigerant bleeding passage 202, the refrigerant in the driving chamber 110 is difficult to be released into the suction chamber 115 and the pressure within the driving chamber 110 can be quickly increased for alleviating the abnormally high discharge pressure. As a modification of how to alleviate the abnormally high discharge pressure quickly, the biasing force of each spring 211a, 213a may preferably be adjusted such that the valve body 213 of the refrigerant bleeding valve 185 closes the refrigerant bleeding passage 202 when the valve body 212 in the capacity control valve 181 opens the heating circuit capacity control passage 201. This is, the refrigerant bleeding passage 202 is closed in response to the opening of the capacity control passage 201 when the compressor discharge pressure results predetermined high pressure state. As the result, when the discharge pressure results abnormally high pressure state, the refrigerant is released from the discharge chamber 120 into the driving chamber 110 through the heating circuit capacity control passage 201. However, the refrigerant released into the driving chamber 110 can not be released into the suction chamber 115 because the refrigerant bleeding passage is closed by the refrigerant bleeding valve 185. Thus, the necessary steps for alleviating the abnormally high discharge pressure, i.e., to increase the pressure within the driving chamber 110, to decrease the stroke length of the pistons 135, to decrease the compressor output discharge capacity and to decrease the compressor discharge pressure, can be taken extremely quickly. Moreover, by closing the refrigerant bleeding passage 202, the high-pressure refrigerant can be fully retained within the driving chamber. Therefore, the necessary amount of the refrigerant to increase the pressure within the driving chamber can be extremely reduced thereby minimizing the reduction of energy efficiency in operating the air conditioning system.

Second Detailed Representative Embodiment

[0053] A second representative embodiment is shown in FIG.4 and includes a driving chamber decompression passage 403 and a driving chamber decompression valve 409. The driving chamber decompression passage 403 connects the driving chamber 110 to the suction chamber 115 separately from the refrigerant bleeding passage 202. The driving chamber decompression valve 409 is provided within the driving chamber decompression passage 403. The driving chamber 110 is connected with a first chamber 413 provided within the driving chamber decompression valve 409 through a first driving chamber decompression passage 405. Therefore, pressure within the first chamber 413 is equal to the pressure Pc within the driving chamber 110. The suction chamber 115 is connected with a second chamber 415 provided within the driving chamber decompression valve 409 through a second driving chamber decompression passage 407. Therefore, the pressure within the second chamber 415 is equal to the suction pressure Ps. The first chamber 413 and the second chamber 415 can be communicated with each other. However, in a normal operation of the air conditioning system, a valve body 411 biased by a spring 417 cuts the communication between the first and second chambers 413, 415.

[0054] When the pressure Pc within the driving chamber 110 is increased and results the predetermined pressure by the release of the high-pressure refrigerant from the discharge chamber to the driving chamber 110, the pressure within the first chamber 413 is also increased. Such high pressure within the first chamber prevails over the biasing force of the spring 417 and the pressure Ps within the second chamber 415. The valve body 411 moves to open the driving chamber decompression passage 403 (the valve body 411 moves upward in FIG.4). Thus, the high-pressure refrigerant within the driving chamber 110 is released into the suction chamber 115 through the driving chamber decompression passage 403 and the pressure Pc within the driving chamber 110 is decreased thereby preventing the airtight seal of the driving chamber from being degraded.

[0055] The driving chamber decompression passage 403 and the driving chamber decompression valve 409 may be provided to the air conditioning system in association with the refrigerant bleeding valve that narrows or closes the refrigerant bleeding passage 202. Especially, the driving chamber decompression passage 403 and the driving chamber decompression valve 409 may be provided, as an emergent means, to the air conditioning system in association with the refrigerant bleeding valve that closes the refrigerant bleeding passage 202, because the driving chamber 110 is likely brought into the extremely high pressure state when the refrigerant bleeding passage 202 is closed.

[0056] Because the refrigerant released from the discharge chamber 120 into the driving chamber 110 is to be utilized to increase the pressure within the driving chamber 110 for alleviating the abnormally high discharge pressure, the refrigerant within the driving chamber 110 is to be released into the suction chamber 115 through the driving chamber decompression passage 403 only when the pressure within the driving chamber 110 results abnormally high pressure state as to degrade the driving chamber airtight seal. In this connection, the condition for opening the driving chamber decompression valve 409 is set by adjusting the biasing force of the spring 417 such that only high pressure that exceeds the upper tolerance level of the driving chamber 110 moves the valve body 411 to open the driving chamber decompression valve 409.

[0057] Although the suction pressure Ps is utilized as one of the differential pressure to open or close the driving chamber decompression valve 409, another pressure such like atmospheric pressure or vacuum pressure may preferably be utilized in combination with the pressure Pc within the driving chamber.

[0058] Although the air conditioning system has the cooling circuit and the heating circuit, the cooling circuit may be omitted because it is mainly during operation of the heating circuit that the measure against the abnormally high discharge pressure is necessary.

[0059] Although a one-sided swash plate type of variable displacement compressor, i.e., a variable displacement compressor of a type in which the pistons 135 are disposed only on one side of the swash plate 130 in FIGS. 3 and 4 is used in both of the first and second embodiments, a double-ended piston type of compressor in which pistons are connected to opposite sides of the swash plate for reciprocation can be used.

[0060] Although the capacity controller is provided inside the compressor (within the housing) in both of the first and second embodiments, the capacity controller can be provided outside the compressor.

[0061] The air conditioning system 100 may include a compressor 101, a heating circuit 152, and a capacity controller 181. The compressor 101 has a suction port 115, a discharge port 120, a driving unit 130 provided within a driving chamber 110, a first passage 201 and a second passage 202. The driving unit 130 may decrease compressor output discharge capacity when the pressure within the driving chamber 110 increases. The first passage 201 may connect the discharge port 120 to the driving chamber 110 and the second passage 202 may connect the driving chamber 110 to the suction port 115. The capacity controller 181, 185 may open the first passage 201 when the refrigerant discharge pressure results predetermined pressure. Further, the capacity controller 181, 185 may narrow the second passage 202 in response to the opening of the first passage 201. By opening the first passage 201, the high-pressure refrigerant may be released from the discharge port 120 to the driving chamber 110 through the first passage 201. By narrowing the second passage 202, the high-pressure refrigerant released from the discharge port is difficult to be released from the driving chamber 110 to the suction port 116. Thus, the pressure within the driving chamber 110 may quickly increase, the compressor output discharge capacity can be quickly reduced, the abnormally high discharge pressure of the compressor 101 can be quickly alleviated by the reduction in the compressor output discharge capacity.

Claims

1. An air conditioning system comprising:

a compressor having a suction port, a discharge port, a driving unit provided within a compressor driving chamber, the driving unit decreasing compressor output discharge capacity when pressure within the driving chamber increases, a first passage that connects the discharge port to the driving chamber, a second passage that connects the driving chamber to the suction port,

a heating circuit having a passage that extends from the discharge port to the suction port through a heat exchanger,

a capacity controller that opens the first passage when the refrigerant discharge pressure results predetermined pressure state

characterized in that the capacity controller narrows the second passage in response to the opening of the first passage.

2. An air conditioning system comprising:

a compressor having a suction port, a discharge port, a driving unit provided within a compressor driving chamber, the driving unit decreasing compressor output discharge capacity when pressure within the driving chamber increases, a first passage that connects the discharge port to the driving chamber, a second passage that connects the driving chamber to the suction port,
a heating circuit having a passage that extends from the discharge port to the suction port through a heat exchanger,
a capacity controller that opens the first passage when the refrigerant discharge pressure results predetermined pressure state
characterized in that the capacity controller closes the second passage in response to the opening of the first passage.

3. An air conditioning system according to claim 1 or 2, further comprising:

a cooling circuit having a condenser disposed on a passage extending from the discharge port to the suction port and a heat exchanger disposed downstream from the condenser.

4. An air conditioning system according to any one of claims 1 to 3, wherein the driving unit further comprises:

a swash plate connected to a driving shaft disposed within the driving chamber, the swash plate rotating together with the driving shaft at an inclination angle with respect to a plane perpendicular to the driving shaft and
a piston disposed in a cylinder bore, an end portion of the piston connected to a peripheral edge of the swash plate by means of a shoe, the piston reciprocating in the cylinder bore to compress the refrigerant in response to rotation of the swash plate in the driving chamber.

5. An air conditioning system according to any one of claims 1 to 4 further comprising:

a third passage that connects the driving chamber to the suction port separately from the second passage, the third passage being opened when the pressure within the driving chamber results predetermined pressure state.

6. An air conditioning system according to claim 5 wherein a driving chamber decompression valve is provided within the third passage, the driving chamber decompression valve opening the third passage when the pressure within the driving chamber results predetermined pressure state

7. An air conditioning system according to claim 1, wherein the capacity controller comprises a first valve disposed within the first passage and a second valve disposed within the second passage, the first valve opening the first passage when the refrigerant discharge pressure results predetermined pressure state, the second valve narrowing the second passage in response to the opening of the first valve.

8. An air conditioning system according to claim 7, wherein the first valve and the second valve are integrally constructed.

9. An air conditioning system according to claim 8, wherein the first valve and the second valve are integrally connected by a connecting member.

10. An air conditioning system according to claim 7, wherein the first valve and/or the second valve are (is) provided within the compressor housing.

11. An air conditioning system according to claim 2, wherein the capacity controller comprises a first valve disposed within the first passage and a second valve disposed within the second passage, the first valve opening the first passage when the refrigerant discharge pressure results predetermined pressure state, the second valve closing the second passage in response to the opening of the first valve.

12. An air conditioning system according to claim 11, wherein the first valve and the second valve are integrally constructed.

13. An air conditioning system according to claim 12, wherein the first valve and the second valve are integrally connected by a connecting member.

14. An air conditioning system according to claim 11, wherein the first valve and/or the second valve are (is) provided within the compressor housing.

15. A vehicle comprising an air conditioning system according to any one of claims 1 to 14 and an engine for driving the compressor.

16. An air conditioning system comprising:

a compressor having a suction port, a discharge port, a driving unit provided within a compressor driving chamber, the driving unit that decreases compressor output discharge capacity when pressure within the driving

chamber increases, a first passage that connects the discharge port to the driving chamber, a second passage that connects the driving chamber to the suction port,
a heating circuit having a passage that extends from the discharge port to the suction port through a heat exchanger,
capacity control means for opening the first passage when the refrigerant discharge pressure results predetermined pressure state characterized in that capacity control means narrows the second passage in response to the opening of the first passage.

17. An air conditioning system comprising:

a compressor having a suction port, a discharge port, a driving unit provided within a compressor driving chamber, the driving unit that decreases compressor output discharge capacity when pressure within the driving chamber increases, a first passage that connects the discharge port to the driving chamber, a second passage that connects the driving chamber to the suction port,
a heating circuit having a passage that extends from the discharge port to the suction port through a heat exchanger,
capacity control means for opening the first passage when the refrigerant discharge pressure results predetermined pressure state characterized in that capacity control means closes the second passage in response to the opening of the first passage.

18. A method of using the air conditioning system according to claim 1 characterized by the steps of:

opening the first passage when the refrigerant discharge pressure results predetermined pressure state and
narrowing the second passage in response to the opening of the first passage.

19. A method of using the air conditioning system according to claim 2 characterized by the steps of:

opening the first passage when the refrigerant discharge pressure results predetermined pressure state and
closing the second passage in response to the opening of the first passage.

20. A method for controlling refrigerant discharge pressure in an air conditioning system characterized by the steps of:

opening a first passage that connects the compressor discharge port to the compressor driving chamber when the refrigerant discharge pressure results predetermined pressure state and
narrowing a second passage that connects the compressor driving chamber to the compressor suction port in response to the opening of the first passage.

21. A method for controlling refrigerant discharge pressure in an air conditioning system characterized by the steps of:

opening a first passage that connects the compressor discharge port to the compressor driving chamber when the refrigerant discharge pressure results predetermined pressure state and
closing a second passage that connects the compressor driving chamber to the compressor suction port in response to the opening of the first passage.

22. A method according to claim 18 or 19, wherein the air conditioning system further comprising:

a cooling circuit having a condenser disposed on a passage extending from the discharge port to the suction port and a heat exchanger disposed downstream from the condenser.

23. A method according to claim 18, wherein the first passage is opened by utilizing a first valve disposed within the first passage and the second passage is narrowed by utilizing a second valve disposed within the second passage, the first valve opening the first passage when the refrigerant discharge pressure results predetermined pressure state and the second valve narrowing the second passage in response to the opening of the first valve.

24. A method according to claim 19, wherein the first passage is opened by utilizing a first valve disposed within the first passage and the second passage is closed by utilizing a second valve disposed within the second passage, the first valve opening the first passage when the refrigerant discharge pressure results predetermined pressure state and the second valve closing the second passage in response to the opening of the first valve.

25. A method according to claim 18 or 19, wherein the driving chamber is connected to the suction port when the pressure within the driving chamber results predetermined pressure.

26. A method according to claim 25, wherein the driving chamber is connected to the suction port by a third passage, the third passage being opened by utilizing a driving chamber decompression valve disposed within the third chamber.

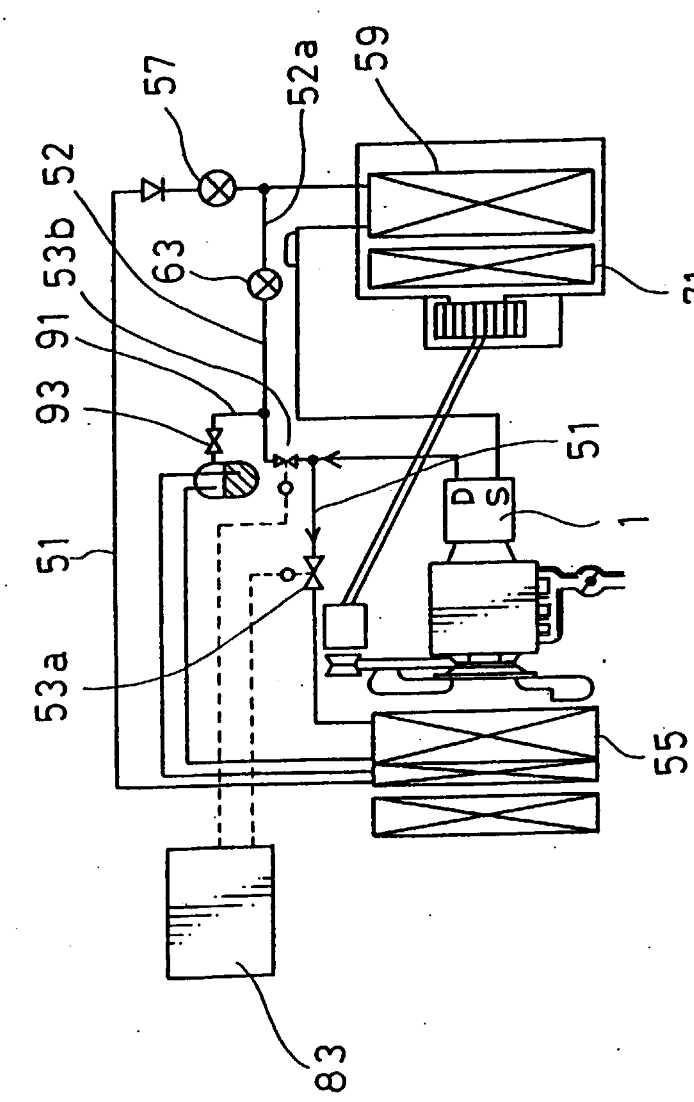

FIG. 1

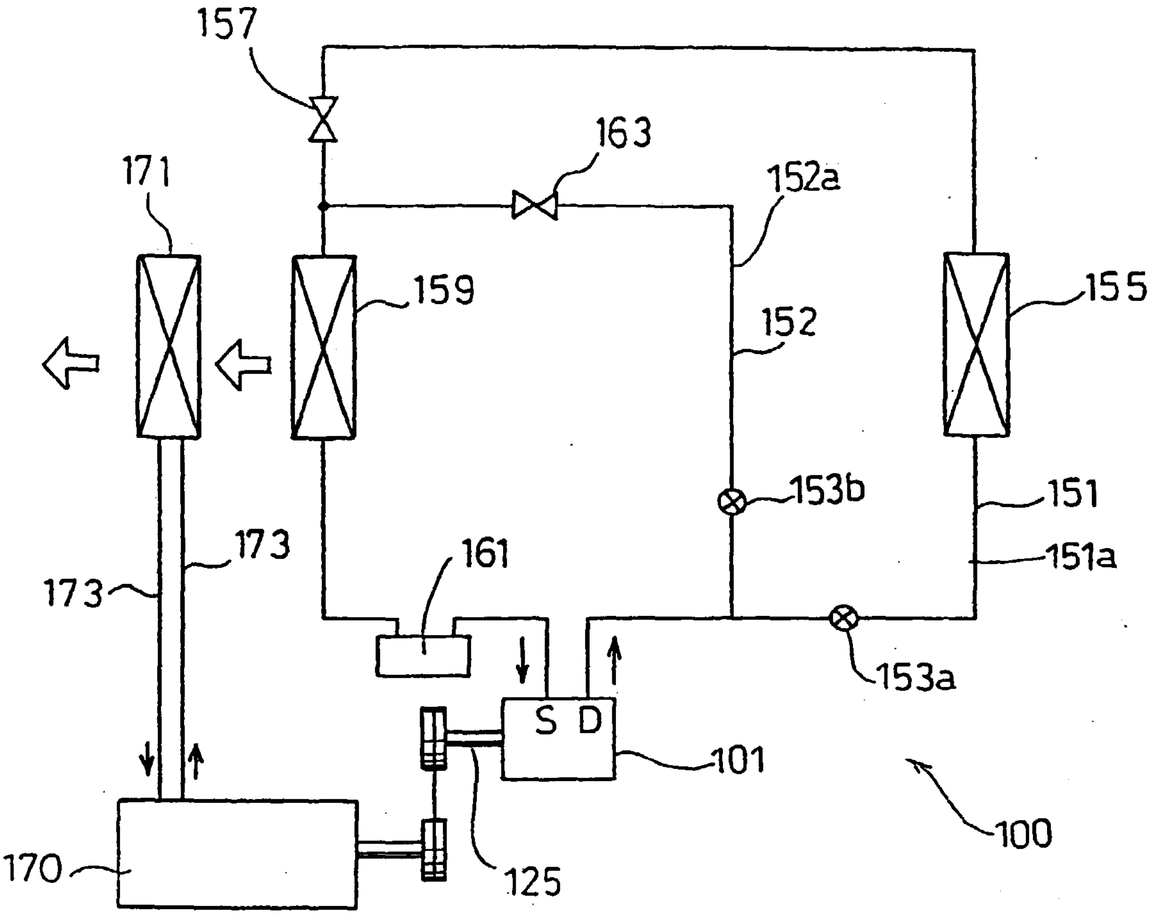
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FIG. 2

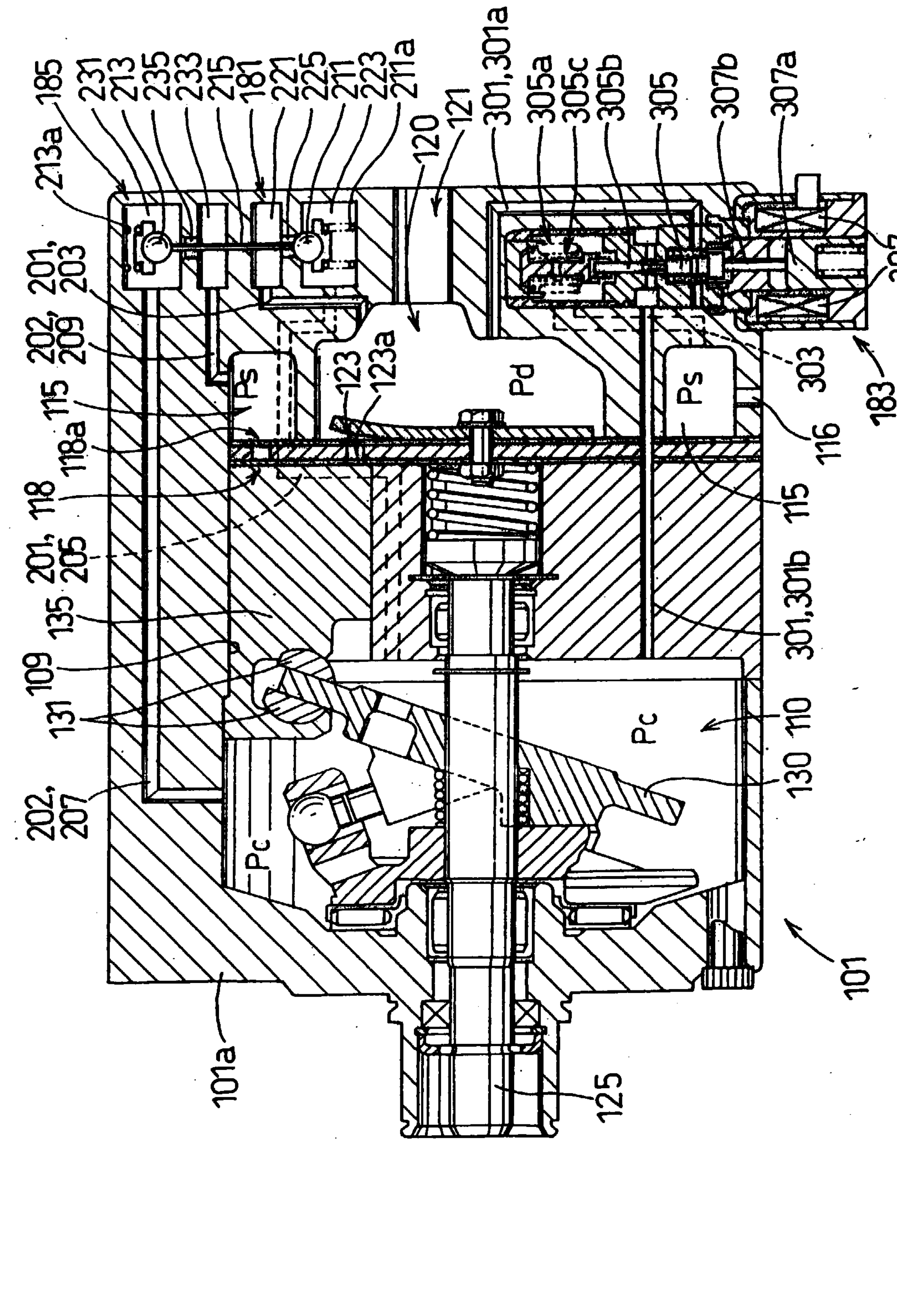

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FIG. 3

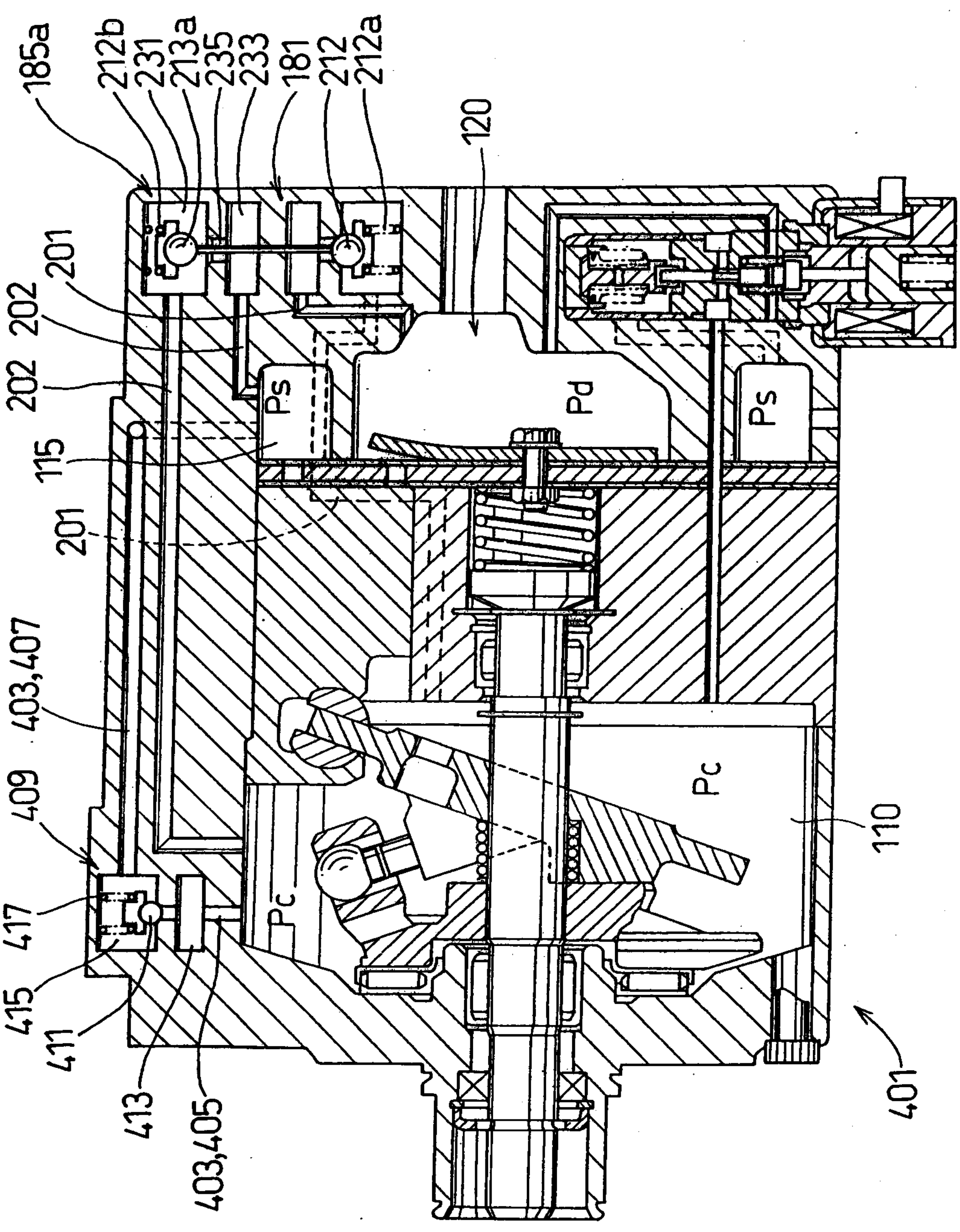
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FIG. 4