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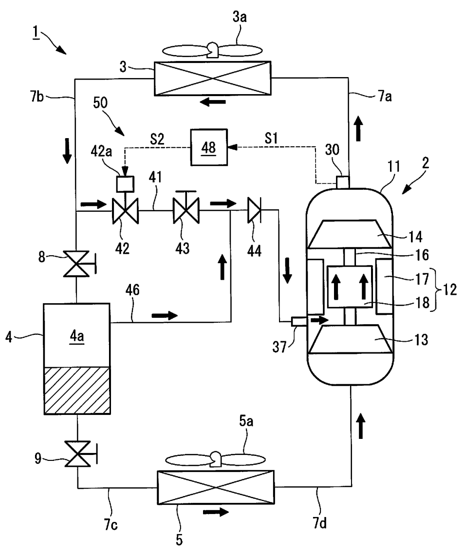
(54) **MULTI-STAGE COMPRESSOR AND REFRIGERATION SYSTEM EQUIPPED WITH SAME**

(57) It is an object of the present invention to prevent liquid compression in a high-stage side compression mechanism of a multi-stage compressor, and to effectively cool an electric motor at all times by means of an injection refrigerant thus expanding an operable range. A multi-stage compressor (2) according to the present invention includes: a housing (11) having a sealed container shape; a low-stage side compression mechanism (13) and a high-stage side compression mechanism (14) which are installed in the housing (11); an electric motor (12) which drives the low-stage side compression mechanism (13) and the high-stage side compression mechanism (14), the electric motor (12) being installed in an intermediate pressure zone in the housing (11); an injection nozzle (37) installed into the housing (11) in a penetrating manner so as to face the electric motor (12); and a refrigerant supply part (50) which extracts a gas phase portion and a liquid phase portion of a compressed refrigerant discharged from the high-stage side compression mechanism (14), and selectively supplies the gas phase portion and the liquid phase portion to the injection nozzle (37) as an injection refrigerant.

FIG. 1



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Description

[Technical Field]

[0001] The present invention relates to a multi-stage compressor and a chilling system provided with the multi-stage compressor.

[Background Art]

[0002] For a compressor which compresses a gas refrigerant in an air conditioner or a chilling device, there is a multi-stage compressor where a low-stage side compression mechanism, a high-stage side compression mechanism, and an electric motor for driving these compressors are accommodated inside of a housing formed into a sealed container shape.

[0003] For example, a multi-stage (two-stage) compressor described in PTL 1 is configured such that an electric motor is installed at a center portion in the axial direction in the substantially cylindrical housing, a main shaft is driven by the electric motor, a low-stage side compression mechanism is installed below the electric motor, a high-stage side compression mechanism is installed above the electric motor, and the low-stage side compression mechanism and the high-stage side compression mechanism are coaxially driven by the main shaft.

[0004] The multi-stage compressor described in PTL 1 includes an injection circuit. The injection circuit injects a gas refrigerant at an intermediate pressure which is extracted from a refrigerant circuit into the housing as an injection refrigerant.

[0005] The injection circuit includes a first circuit, a second circuit, and a switching mechanism. The first circuit is communicably connected to a space in the housing on the same side as the high-stage side compression mechanism with respect to the electric motor. The second circuit is communicably connected to a space in the housing on the side opposite to the high-stage side compression mechanism with the electric motor therebetween. The switching mechanism selectively makes the first circuit or the second circuit communicate with the inside of the housing corresponding to a degree of dryness of the injection refrigerant.

[0006] The switching mechanism changes over the injection circuit to the first circuit when a degree of dryness of the injection refrigerant is equal to or more than a set value. An injection refrigerant having a high degree of dryness, that is, a dried injection refrigerant, is injected into the inside of the housing from an opening portion of the first circuit. With such injection, while a possibility of liquid compression in the high-stage side compression mechanism is eliminated, a gas refrigerant at an intermediate pressure is supplied to the high-stage side compression mechanism. Accordingly, the lowering of suction efficiency of the high-stage side compression mechanism is prevented and hence, compression efficiency can be increased.

[0007] When a degree of dryness of the injection refrigerant is equal to or less than a set value, the switching mechanism changes over the injection circuit to the second circuit. An injection refrigerant having a low degree of dryness, that is, a wet injection refrigerant, is injected into the inside of the housing from an opening portion of the second circuit. When the wet injection refrigerant passes through an area in the vicinity of the electric motor, the wet injection refrigerant is heated by working heat of the electric motor so that a liquid portion is vaporized thus becoming a dried gas refrigerant. The gas refrigerant is sucked into the high-stage side compression mechanism. With such a configuration, it is possible to eliminate a possibility of liquid compression in the high-stage side compression mechanism.

[Citation List]

[Patent Literature]

[0008] [PTL 1] Japanese Unexamined Patent Application, Publication No. 2009-30484

[Summary of Invention]

[Technical Problem]

[0009] As described above, in the multi-stage compressor disclosed in PTL 1, a degree of dryness of an injection refrigerant is detected. When the degree of dryness is lower than a predetermined value, the injection refrigerant is made to pass through the electric motor so as to dry the injection refrigerant with the working heat of the electric motor. Accordingly, it is possible to prevent the liquid refrigerant from being sucked into the high-stage side compression mechanism.

[0010] In the electric motor, a temperature of a coil increases under operation conditions such as a condition where a circulation amount of refrigerant is lowered or a condition where motor efficiency is lowered. When the temperature of the coil reaches a stipulated upper limit temperature, the electric motor is forced to stop operation for safety. In the case of the multi-stage compressor disclosed in PTL 1, when the injection refrigerant is injected into the inside of the housing from the first circuit of the multi-stage compressor, the injection refrigerant does not pass through the electric motor. Accordingly, when the electric motor is overheated as described above at such timing, there is a concern that an operable range is restricted.

[0011] The present invention has been made under such circumstances, and it is an object of the present invention to provide a multi-stage compressor and a chilling system provided with the multi-stage compressor where system efficiency is enhanced by the injection and, at the same time, while liquid compression is prevented in the high-stage side compression mechanism, the electric motor is at all times effectively cooled by means of the injection refrigerant so that an operable range can be expanded.

[Solution to Problem]

[0012] To solve the above-mentioned problem, the present invention adopts the following solutions.

[0013] That is, a multi-stage compressor according to the present invention includes: a housing having a sealed container shape; a low-stage side compression mechanism and a high-stage side compression mechanism which are installed in the housing; an electric motor configured to drive the low-stage side compression mechanism and the high-stage side compression mechanism, the electric motor being installed in an intermediate pressure zone in the housing; an injection nozzle installed into the housing in a penetrating manner so as to face the electric motor; and a refrigerant supply part configured to extract a gas phase portion and a liquid phase portion of a compressed refrigerant discharged from the high-stage side compression mechanism, and to selectively supply the gas phase portion and the liquid phase portion to the injection nozzle as an injection refrigerant.

[0014] With the multi-stage compressor having the above-mentioned configuration, a compressed refrigerant is discharged from the high-stage side compression mechanism. A gas phase portion and a liquid phase portion of the compressed refrigerant are selectively supplied to the injection nozzle by the refrigerant supply part, and are injected to the electric motor from the injection nozzle. That is, a gas refrigerant or a liquid refrigerant can be selectively injected to the electric motor. Alternatively, a mixture of the gas refrigerant and the liquid refrigerant can be injected to the electric motor.

[0015] With such a configuration, corresponding to a degree of temperature increase of the electric motor, cooling may be performed by the injection of only a gas refrigerant which enhances efficiency of a chilling system. Alternatively, cooling may be performed by the injection of a liquid refrigerant or a gas-liquid mixed refrigerant which is effective in cooling the electric motor. Accordingly, the electric motor can be at all times effectively cooled by means of the injection refrigerant so that an operable range can be expanded.

[0016] In the multi-stage compressor having the above-mentioned configuration, the refrigerant supply part may include: a first refrigerant supply passage branching from a condensed refrigerant passage and connected to the injection nozzle, the compressed refrigerant, discharged from the high-stage side compression mechanism thus being condensed and cooled, flowing in the condensed refrigerant passage; a second refrigerant supply passage extending from a space above a liquid surface in a gas-liquid separator, and connected to the injection nozzle, the gas-liquid separator separating the compressed refrigerant, discharged from the high-stage side compression mechanism, into a gas and a liquid; an on-off valve configured to open and close the first refrigerant supply passage; a control part configured to control opening and closing of the on-off valve; and a temperature detection part configured to detect a working temperature of the electric motor, and to input the working temperature into the control part, wherein the control part may open the on-off valve upon the working temperature of the electric motor reaching a predetermined threshold temperature.

[0017] With the above-mentioned configuration, the control part maintains the on-off valve in a closed state until a working temperature of the electric motor reaches a predetermined threshold temperature, and a gas phase portion of a compressed refrigerant, which is separated into a gas and a liquid by the gas-liquid separator, that is, only a gas refrigerant, is supplied to the electric motor from the injection nozzle through the second refrigerant supply passage. With such a configuration, cooling is performed by the injection of only a gas refrigerant which enhances efficiency of the chilling system.

[0018] When a working temperature of the electric motor reaches the predetermined threshold temperature, the on-off valve is opened by the control part. Accordingly, the condensed refrigerant containing a liquid phase portion is supplied to the electric motor from the injection nozzle through the first refrigerant supply passage. Therefore, cooling is performed by the injection of a liquid refrigerant or a gas-liquid mixed refrigerant which is effective in cooling the electric motor.

[0019] In the multi-stage compressor having the above-mentioned configuration, the temperature detection part may be a refrigerant temperature sensor configured to detect a temperature of the compressed refrigerant discharged from the high-stage side compression mechanism.

[0020] To directly detect an actual working temperature of the electric motor, it is necessary to provide a temperature sensor inside of the housing and, at the same time, to make wiring extending from the temperature sensor penetrate the housing. Such a configuration has difficulty with regards to structure. With the configuration of the present invention, a working temperature of the electric motor can be easily detected based on a temperature of a compressed refrigerant detected by the refrigerant temperature sensor.

[0021] In the multi-stage compressor having the above-mentioned configuration, a position of an inner opening portion of the injection nozzle on an inner side of the housing is preferably disposed in a vicinity of an end portion of the electric motor disposed on an upstream side in a flow direction of the refrigerant in the housing.

[0022] With the above-mentioned configuration, an injection refrigerant injected from the injection nozzle to the end portion of the electric motor flows toward an end portion of the electric motor on the opposite joining the flow of the intermediate pressure refrigerant flowing inside of the housing. Therefore, the electric motor can be uniformly cooled.

[0023] When a liquid refrigerant is injected from the injection nozzle, the liquid refrigerant flows along the axial direction of the electric motor, and is vaporized by working heat of the electric motor. Accordingly, it is possible to prevent that a liquid refrigerant which is not vaporized is sucked into the high-stage side compression mechanism installed on the downstream side of the electric motor, and liquid compression is performed. Accordingly, soundness of the high-stage side compression mechanism can be maintained.

[0024] In the multi-stage compressor having the above-mentioned configuration, the position of the inner opening portion of the injection nozzle on the inner side of the housing may be disposed in a vicinity of a lower portion of the electric motor in the housing.

[0025] With the above-mentioned configuration, when a liquid refrigerant is injected from the injection nozzle, the liquid refrigerant tends to stay in an area around the electric motor due to gravity and hence, vaporization of the liquid refrigerant can be facilitated by working heat of the electric motor. Accordingly, there is no possibility that the liquid refrigerant is blown upwards due to the rotation of the electric motor, and is directly sucked into the high-stage side compression mechanism. Therefore, it is possible to prevent the liquid refrigerant from being compressed in the high-stage side compression mechanism.

[0026] In the multi-stage compressor having the above-mentioned configuration, a height of the inner opening portion of the injection nozzle on the inner side of the housing is preferably set higher than an oil surface level in working-state of a lubricant oil filled in the housing.

[0027] With the above-mentioned configuration, when a refrigerant is injected into the housing from the injection nozzle, it is possible to suppress that the lubricant oil filled in the housing is blown up. Therefore, it is possible to prevent that the lubricant oil is blown up in the housing, and is directly sucked into the high-stage side compression mechanism and, as a result, the lubricant oil is discharged to the outside of the multi-stage compressor.

[0028] In the multi-stage compressor having the above-mentioned configuration, a height of an outer opening portion of the injection nozzle on an outer side of the housing is preferably set higher than an oil surface level in stopped-state of the lubricant oil filled in the housing.

[0029] With the above-mentioned configuration, at the time of shipping, fixing or the like of the multi-stage compressor, it is possible to prevent the lubricant oil from flowing out from the outer opening portion of the injection nozzle.

[0030] In the multi-stage compressor having the above-mentioned configuration, a position of the injection nozzle in a circumferential direction with respect to the housing is preferably set to a position displaced from a position where the lubricant oil flows down from an upper portion to a lower portion in the housing as viewed in a plan view of the housing.

[0031] With the above-mentioned configuration, during a working state of the multi-stage compressor, the lubricant oil flowing down from the upper portion in the housing does not impinge on the flow of an injection refrigerant injected into the housing from the injection nozzle. Accordingly, it is possible to prevent a lubricant oil from being blown up in the housing. Therefore, it is possible to prevent that the lubricant oil which is blown up is directly sucked into the high-stage side compression mechanism, and is discharged to the outside of the multi-stage compressor.

[0032] A chilling system according to the present invention includes any one of the above-mentioned multi-stage compressors.

[0033] With the chilling system of the present invention, corresponding to a degree of temperature increase of the electric motor, cooling may be performed by the injection of only a gas refrigerant which enhances efficiency of the chilling system. Alternatively, cooling may be performed by the injection of a liquid refrigerant or a gas-liquid mixed refrigerant which is effective in cooling the electric motor. Accordingly, the electric motor can be at all times effectively cooled by means of the injection refrigerant so that an operable range can be expanded.

[Advantageous Effects of Invention]

[0034] As has been described above, with the multi-stage compressor and the chilling system provided with the multi-stage compressor according to the present invention, system efficiency is enhanced by the injection and, at the same time, liquid compression is prevented in the high-stage side compression mechanism, and the electric motor is at all times effectively cooled by means of the injection refrigerant so that an operable range can be expanded.

[Brief Description of Drawings]

[0035]

[Fig. 1] Fig. 1 is a schematic configuration diagram showing an embodiment of a chilling system according to the present invention.

[Fig. 2] Fig. 2 is a longitudinal cross-sectional view showing the embodiment of a multi-stage compressor according to the present invention.

[Fig. 3] Fig. 3 is a transverse cross-sectional view of the multi-stage compressor taken along line III-III in Fig. 2.

[Fig. 4] Fig. 4 is a longitudinal cross-sectional view showing another example of a shape of an injection nozzle.

[Description of Embodiments]

[0036] Hereinafter, one embodiment of the present invention is described with reference to drawings.

[0037] Fig. 1 is a schematic configuration diagram of a chilling system according to the embodiment of the present invention. A chilling system 1 is a chilling system for a shop showcase, for example. However, the chilling system 1 may be a chilling system for other uses.

[0038] The chilling system 1 is configured such that a multi-stage compressor 2, a condenser 3, a gas-liquid separator 4, and an evaporator 5 are respectively connected to refrigerant passages 7a, 7b, 7c, 7d in this order so as to perform chilling and refrigerating operations. Expansion valves 8, 9 for automatically adjusting a pressure and a flow rate of a refrigerant are respectively provided to the refrigerant passages 7b, 7c.

[0039] Fig. 2 is a longitudinal cross-sectional view of the multi-stage compressor 2. The multi-stage compressor 2 has the known basic structure. As shown in Fig. 1 and Fig. 2, the multi-stage compressor 2 includes a housing 11 disposed with the axial direction thereof extending in the vertical direction. The housing 11 has a substantially cylindrical shape, and a sealed container shape. An electric motor 12 is disposed at a center portion in the axial direction inside of the housing 11. A rotary compressor 13 (low-stage side compression mechanism) is installed below the electric motor 12, that is, at a lower portion of the housing 11. A scroll compressor 14 (high-stage side compression mechanism) is installed above the electric motor 12, that is, at an upper portion of the housing 11. The rotary compressor 13 and the scroll compressor 14 are coaxially driven by a main shaft 16 pivotally supported along a center axis of the housing 11.

[0040] The electric motor 12 includes a stator 17 (stator) fixed to an inner peripheral surface of the housing 11 and a rotor 18 (rotor) positioned on the inner peripheral side of the stator 17 and rotating integrally with the main shaft 16. A coil 17a is wound around the stator 17. When the electric motor 12 starts, the main shaft 16 rotates so that both compressors 13, 14 are coaxially driven.

[0041] That is, crank portions 16a, 16b are respectively formed at both end portions of the main shaft 16 in an eccentric manner. The crank portions 16a, 16b are respectively inserted into a rotor 20 of the rotary compressor 13 and an orbiting scroll 22 of the scroll compressor 14 in an eccentric manner. When the electric motor 12 works thus rotating the main shaft 16, the rotor 20 of the rotary compressor 13 rotates in an eccentric manner inside of an eccentric cylinder 21, and the orbiting scroll 22 of the scroll compressor 14 performs an orbital revolving motion with respect to a fixed scroll 23.

[0042] A refrigerant suction pipe 26 is mounted on a side surface of a lower portion of the housing 11, and the refrigerant suction pipe 26 communicates with a suction port 25 of the rotary compressor 13. A refrigerant discharge pipe 29 is mounted at the upper portion of the housing 11, and the refrigerant discharge pipe 29 communicates with a discharge port 27 of the scroll compressor 14 and a discharge chamber 28. A refrigerant passage 7d shown in Fig. 1 is connected to the refrigerant suction pipe 26. A refrigerant passage 7a shown in Fig. 1 is connected to the refrigerant discharge pipe 29. A refrigerant temperature sensor 30 is mounted on the refrigerant discharge pipe 29. The refrigerant temperature sensor 30 detects a temperature of a compressed refrigerant discharged from the scroll compressor 14 thus indirectly detecting a working temperature of the electric motor 12.

[0043] A place where the electric motor 12 is installed in the housing 11 is an intermediate pressure zone M. The intermediate pressure zone M is filled with a refrigerant at an intermediate pressure, which is initially compressed by the rotary compressor 13, during the working of the multi-stage compressor 2.

[0044] A predetermined amount of lubricant oil O is sealed in a bottom portion of the housing 11. An oil supply pump 33 is installed at the bottom portion of the housing 11 so as to be disposed below an oil surface of the lubricant oil O. The oil supply pump 33 is rotationally driven by a lower end portion of the main shaft 16. When the oil supply pump 33 is driven, the lubricant oil O is supplied to desired lubricated portions of the rotary compressor 13 and the scroll compressor 14 through oil supply passages not shown in the drawing formed inside of the main shaft 16 along the axial direction.

[0045] When the electric motor 12 is in a stopped state, an oil surface level of the lubricant oil O is at an oil surface level H1. However, when the electric motor 12 works thus allowing a refrigerant to flow through the housing 11, the refrigerant is mixed into the lubricant oil O so that the oil surface level of the lubricant oil O is elevated to an oil surface level H2. As shown in Fig. 2 and Fig. 3, one or a plurality of oil return passages (stator cuts) 34 are formed between the stator 17 of the electric motor 12 and the housing 11. The lubricant oil O supplied to the scroll compressor 14 disposed at the upper portion of the housing 11 flows down to the lower portion of the housing 11 through the oil return passages 34.

[0046] An injection nozzle 37 having a horizontal linear pipe shape is installed into the housing 11 of the multi-stage compressor 2 in a penetrating manner so as to face the electric motor 12. To be more specific, a position (height) of an inner opening portion 37a of the injection nozzle 37 on the inner side of the housing 11 is set substantially equal to a height of an end portion of the electric motor 12, that is, an area in the vicinity of a lower end portion of the electric motor 12. An intermediate pressure refrigerant flows inside of the housing 11 from the lower side to the upper side during a working state of the multi-stage compressor 2. The electric motor 12 is disposed on the upstream side in the flow direction of the intermediate pressure refrigerant.

[0047] As shown in Fig. 3, a position of the injection nozzle 37 in the circumferential direction with respect to the housing 11 is set to a position displaced from a position of the oil return passage 34 when the housing 11 is viewed in a plan view. The lubricant oil O flows down through the oil return passage 34 from the upper portion to the lower portion in the housing 11. For example, when only one oil return passage 34 is provided, it is desirable to dispose the injection nozzle 37 on the side 180 degrees opposite to the position of the oil return passage 34 in the circumferential direction.

[0048] It is preferable to set a height of the inner opening portion 37a of the injection nozzle 37 higher than the oil surface level in working-state H2 of the lubricant oil O filled in the housing 11. It is preferable to set a height of an outer opening portion 37b of the injection nozzle 37 higher than at least the oil surface level in stopped-state H1 of the lubricant oil O. It is more preferable to set the height of the outer opening portion 37b higher than the oil surface level in working-state H2. However, when the height of the inner opening portion 37a of the injection nozzle 37 approaches the oil surface level in working-state H2 of the lubricant oil O in layout irrespective of any change, as shown in Fig. 4, the injection nozzle 37 may have a bent (curved) shape or the like such that the outer opening portion 37b is disposed at a position higher than the inner opening portion 37a disposed further inward than the outer opening portion 37b.

[0049] As shown in Fig. 1, a first refrigerant supply passage 41 branching from the refrigerant passage 7b (condensed refrigerant passage) is connected to the injection nozzle 37. The refrigerant passage 7b from which the first refrigerant supply passage 41 branches is a passage through which a part of a compressed refrigerant which is condensed and cooled in the condenser 3 flows to the gas-liquid separator 4 as described later.

[0050] A solenoid valve 42 (on-off valve), an expansion valve 43, and a check valve 44 are installed in the first refrigerant supply passage 41 in this order from the refrigerant passage 7b side. The solenoid valve 42 opens and closes the first refrigerant supply passage 41. The expansion valve 43 automatically adjusts a pressure and a flow rate of a refrigerant. The check valve 44 prevents a backflow of the refrigerant toward the refrigerant passage 7b side.

[0051] A second refrigerant supply passage 46 extends from a space 4a above a liquid surface in the gas-liquid separator 4. The second refrigerant supply passage 46 is connected to an intermediate portion of the first refrigerant supply passage 41 between the expansion valve 43 and the check valve 44. That is, the second refrigerant supply passage 46 extends from the space 4a above the liquid surface in the gas-liquid separator 4, and is connected to the injection nozzle 37 through the first refrigerant supply passage 41. An on-off valve, a flow rate adjusting valve or the like may be provided to the second refrigerant supply passage 46.

[0052] A control part 48 for controlling opening and closing of the solenoid valve 42 is also provided. The control part 48 opens the solenoid valve 42 when a working temperature of the electric motor 12 of the multi-stage compressor 2 reaches a predetermined threshold temperature (for example, 120°C). The working temperature of the electric motor 12 is indirectly detected by the refrigerant temperature sensor 30 mounted on the refrigerant discharge pipe 29 of the multi-stage compressor 2. That is, the refrigerant temperature sensor 30 detects a temperature of a compressed refrigerant discharged from the scroll compressor 14, and inputs a temperature signal S1 of the compressed refrigerant into the control part 48 as a working temperature signal of the electric motor 12. The control part 48 transmits an opening and closing signal S2 to a solenoid 42a of the solenoid valve 42 so as to control opening and closing of the solenoid valve 42.

[0053] A refrigerant supply part 50 includes: the first refrigerant supply passage 41; the second refrigerant supply passage 46; the solenoid valve 42; the control part 48; and the refrigerant temperature sensor 30. The refrigerant supply part 50 extracts a gas phase portion and a liquid phase portion of a compressed refrigerant discharged from the scroll compressor 14 of the multi-stage compressor 2, and selectively supplies these portions to the injection nozzle 37 of the multi-stage compressor 2 as an injection refrigerant. The injection refrigerant injected from the injection nozzle 37 is injected to an area in the vicinity of a lower end of the coil 17a of the stator 17 of the electric motor 12.

[0054] The chilling system 1 and the multi-stage compressor 2 configured as described above work as described below.

[0055] When the electric motor 12 starts thus causing the main shaft 16 to rotate, the rotor 20 of the rotary compressor 13 rotates in an eccentric manner inside of the eccentric cylinder 21. Accordingly, a gas refrigerant is sucked from the refrigerant passage 7d shown in Fig. 1 through the refrigerant suction pipe 26 (see Fig. 2) mounted on the side surface of the lower portion of the housing 11. The gas refrigerant is initially compressed by the rotary compressor 13, and is discharged to the intermediate pressure zone M where the electric motor 12 is installed.

[0056] In the scroll compressor 14, the orbiting scroll 22 performs an orbital revolving motion with respect to the fixed scroll 23 with the rotation of the main shaft 16 so that a refrigerant at an intermediate pressure which is filled in the intermediate pressure zone M is sucked from a suction port not shown in the drawing thus being secondarily compressed. With such secondary compression, a compressed refrigerant having a high temperature and a high pressure is generated. The compressed refrigerant is discharged from the refrigerant discharge pipe 29 mounted at the upper portion of the housing 11, and is fed to the refrigerant passage 7a shown in Fig. 1.

[0057] A refrigerant is compressed at two stages by the multi-stage compressor 2 as described above thus forming the compressed refrigerant having a high temperature and a high pressure. The compressed refrigerant flows to the condenser 3 through the refrigerant passage 7a. The compressed refrigerant performs heat exchange with air which is blown by a condenser fan 3a in the condenser 3. With such heat exchange, the compressed refrigerant is cooled and condensed thus being brought into a gas-liquid mixed state where a refrigerant in a gas phase (gas refrigerant) and a refrigerant in a liquid phase (liquid refrigerant) are mixed with each other. When the compressed refrigerant passes through the refrigerant passage 7b, a flow rate and a pressure of the compressed refrigerant are automatically adjusted by the expansion valve 8, and the compressed refrigerant flows to the gas-liquid separator 4.

[0058] The compressed refrigerant in the gas-liquid mixed state flowing to the gas-liquid separator 4 is separated into a gas refrigerant and a liquid refrigerant. When the liquid refrigerant of the compressed refrigerant passes through the refrigerant passage 7c, a flow rate and a pressure of the liquid refrigerant is automatically adjusted by the expansion valve 9, and the liquid refrigerant flows to the evaporator 5. The liquid refrigerant performs heat exchange with air blown by an evaporator fan 5a in the evaporator 5. With such heat exchange, the liquid refrigerant is evaporated (vaporized) thus becoming a gas refrigerant. The gas refrigerant passes through the refrigerant passage 7d and is again sucked into and compressed by the multi-stage compressor 2, and is made to circulate through the refrigerant passages 7a to 7d in the same manner. The evaporator 5 is cooled by heat of vaporization of the liquid refrigerant. Cold air is blown by the evaporator fan 5a and performs heat exchange with the evaporator 5 having a low temperature. The cold air which is subjected to heat exchange is used for chilling and refrigerating.

[0059] Assume a case where the chilling system 1 and the multi-stage compressor 2 are in a working state as described above. In such a state, a gas phase portion of a compressed refrigerant, which is separated into a gas and a liquid by the gas-liquid separator 4, that is, only a gas refrigerant, is supplied to the electric motor 12 from the injection nozzle 37 through the second refrigerant supply passage 46 and the first refrigerant supply passage 41. The second refrigerant supply passage 46 extends from the space 4a above the liquid surface in the gas-liquid separator 4. With such a configuration, the working heat of the electric motor 12 is cooled by the injection of only a gas refrigerant which enhances efficiency of the chilling system 1.

[0060] The control part 48 of the refrigerant supply part 50 refers to the compressed refrigerant temperature signal S1 which is inputted from the refrigerant temperature sensor 30. The control part 48 maintains the solenoid valve 42 in a closed state until a temperature of the compressed refrigerant, that is, an indirect working temperature of the electric motor 12, reaches a predetermined threshold temperature (for example, 120°C), and causes the electric motor 12 to be cooled by the injection of only a gas refrigerant as described above.

[0061] When a temperature of the compressed refrigerant reaches the predetermined threshold temperature, the control part 48 outputs the opening and closing signal S2 so as to open the solenoid valve 42. With the opening of the solenoid valve 42, a portion of the compressed refrigerant (condensed refrigerant) which flows through the refrigerant passage 7a and contains a large amount of liquid phase portion is extracted from the first refrigerant supply passage 41, and is supplied to the electric motor 12 from the injection nozzle 37 as an injection refrigerant. A pressure and a flow rate of the injection refrigerant are automatically adjusted by the expansion valve 43. Accordingly, the electric motor 12 is cooled by the injection of a liquid refrigerant or a gas-liquid mixed refrigerant which is effective in cooling the electric motor 12.

[0062] As described above, a compressed refrigerant is discharged from the scroll compressor 14 of the multistage compressor 2. A gas phase portion and a liquid phase portion of the compressed refrigerant are selectively supplied to the injection nozzle 37 by the refrigerant supply part 50, and are injected to the electric motor 12 from the injection nozzle 37. That is, a gas refrigerant or a liquid refrigerant can be selectively injected to the electric motor 12. Alternatively, a mixture of the gas refrigerant and the liquid refrigerant can be injected to the electric motor 12.

[0063] With such a configuration, corresponding to a degree of temperature increase of the electric motor 12, cooling may be performed by the injection of only a gas refrigerant which enhances efficiency (coefficient of performance (COP) or the like) of the chilling system 1. Alternatively, cooling may be performed by the injection of a liquid refrigerant or a gas-liquid mixed refrigerant which is effective in cooling the electric motor 12.

[0064] Accordingly, the electric motor 12 can be at all times effectively cooled by means of an injection refrigerant. Even under adverse conditions such as a condition where a circulation amount of refrigerant is reduced or a condition where motor efficiency is lowered, it is possible to prevent interruption of the operation of the electric motor 12 caused by overheating of the coil 17a so that an operable range can be expanded.

[0065] The refrigerant supply part 50 indirectly detects a temperature of a compressed refrigerant discharged from the multi-stage compressor 2 by the refrigerant temperature sensor 30. The refrigerant supply part 50 inputs the refrigerant temperature into the control part 48 as a temperature of the electric motor 12 (coil 17a) so as to control opening and closing of the solenoid valve 42.

[0066] To directly detect an actual working temperature of the electric motor 12 (coil 17a), it is necessary to provide a temperature sensor inside of the housing 11 and, at the same time, to make wiring extending from the temperature sensor penetrate the housing 11 in an airtight manner. Such a configuration has difficulty with regards to structure.

[0067] With a configuration of this embodiment, a working temperature of the electric motor 12 can be easily detected based on a temperature of a compressed refrigerant detected by the refrigerant temperature sensor 30.

[0068] In the multi-stage compressor 2, with respect to the injection nozzle 37 mounted on the housing 11, a position (height) of the inner opening portion 37a on the inner side of the housing 11 is disposed in the vicinity of the end portion of the electric motor 12. The electric motor 12 is disposed on the upstream side in the flow direction of the intermediate pressure refrigerant inside of the housing 11. That is, in this embodiment, the position of the inner opening portion 37a is disposed in the vicinity of the lower portion of the electric motor 12.

[0069] Accordingly, an injection refrigerant injected from the injection nozzle 37 to an area in the vicinity of the lower end portion of the electric motor 12 flows toward an end portion (upper end side) of the electric motor 12 on the opposite joining the flow of the intermediate pressure refrigerant flowing inside of the housing 11 through the intermediate pressure zone M. Therefore, the electric motor 12 can be uniformly cooled.

[0070] When an injection refrigerant injected from the injection nozzle 37 contains a large amount of liquid refrigerant, the liquid refrigerant flows along the axial direction of the electric motor 12, and is vaporized by working heat of the electric motor 12. Accordingly, it is possible to prevent that a liquid refrigerant which is not vaporized is sucked into the scroll compressor 14, and liquid compression is performed. Accordingly, soundness of the scroll compressor 14 can be maintained.

[0071] The inner opening portion 37a of the injection nozzle 37 is disposed at a position in the vicinity of the lower portion of the electric motor 12. With such a configuration, an injection refrigerant in the form of a liquid refrigerant which is injected from the injection nozzle 37 tends to stay in an area around the electric motor 12 due to gravity. The injection refrigerant joins the flow of the intermediate pressure refrigerant thus reducing a speed of the intermediate pressure refrigerant elevating in the housing 11. Accordingly, the liquid refrigerant can be favorably vaporized by working heat of the electric motor 12 and hence, there is no possibility that the liquid refrigerant is blown upwards due to the rotation of the electric motor 12, and is directly sucked into the scroll compressor 14. Therefore, it is possible to prevent the liquid refrigerant from being compressed in the scroll compressor 14.

[0072] A height of the inner opening portion 37a of the injection nozzle 37 is set higher than the oil surface level in working-state H2 of the lubricant oil O filled in the housing 11. Accordingly, when an injection refrigerant is injected into the housing 11 from the injection nozzle 37, it is possible to suppress that the lubricant oil O filled in the housing 11 is blown up. Therefore, it is possible to prevent that the lubricant oil O is blown up in the housing 11, and is directly sucked into the scroll compressor 14 and, as a result, the lubricant oil O is discharged to the outside of the multi-stage compressor 2.

[0073] On the other hand, a height of the outer opening portion 37b of the injection nozzle 37 on the outside of the housing 11 is set higher than the oil surface level in stopped-state H1 of the lubricant oil O. Accordingly, at the time of shipping, fixing or the like of the multi-stage compressor 2, it is possible to prevent the lubricant oil O from flowing out from the outer opening portion 37b.

[0074] Further, a position of the injection nozzle 37 in the circumferential direction with respect to the housing 11 is set to a position displaced from the oil return passage 34 through which the lubricant oil O flows down from the upper portion to the lower portion in the housing 11 when the housing 11 is viewed in a plan view (see Fig. 3).

[0075] Accordingly, during a working state of the multi-stage compressor 2, the lubricant oil O flowing down from the upper portion in the housing 11 does not impinge on the flow of the injection refrigerant injected into the housing 11 from the injection nozzle 37.

[0076] As a result, it is possible to prevent the lubricant oil O from being blown up in the housing 11. Therefore, it is possible to prevent that the lubricant oil O which is blown up is directly sucked into the scroll compressor 14, and is discharged to the outside of the multi-stage compressor 2. Accordingly, the scroll compressor 14 can be protected.

[0077] As has been described heretofore, with the multi-stage compressor 2 and the chilling system 1 provided with the multi-stage compressor 2 according to the above-mentioned embodiment, while liquid compression is prevented in the scroll compressor 14 forming the high-stage side compression mechanism, the electric motor 12 is at all times effectively cooled by means of the injection refrigerant so that an operable range can be expanded.

[0078] The present invention is not limited to the configuration of the above-mentioned embodiment, and a change or a modification can be suitably applied to the embodiment. Such embodiments to which a change or a modification is applied also fall within the scope of rights of the present invention.

[0079] For example, in the above-mentioned embodiment, the rotary compressor 13 is used as the low-stage side compression mechanism, and the scroll compressor 14 is used as the high-stage side compression mechanism. However, a compression mechanism of another type may be used, or compression mechanisms of the same type may be continuously provided.

[0080] Further, in the above-mentioned embodiment, the multi-stage compressor 2 is disposed with the axial direction thereof extending in the vertical direction. However, it is not always necessary for the multi-stage compressor 2 to adopt such a posture or an arrangement layout.

[0081] Further, in the above-mentioned embodiment, the solenoid valve 42 is provided only to the first refrigerant supply passage 41. However, it may be possible to adopt the configuration where a solenoid valve may be provided also to the second refrigerant supply passage 46, and the second refrigerant supply passage 46 is closed when the injection of a gas refrigerant is unnecessary.

[Reference Signs List]

[0082]

1	chilling system
2	multi-stage compressor
3	condenser
4	gas-liquid separator
4a	space above liquid surface in gas-liquid separator
5	evaporator
7b	refrigerant passage (condensed refrigerant passage)
11	housing
12	electric motor
13	rotary compressor (low-stage side compression mechanism)
14	scroll compressor (high-stage side compression mechanism)
16	main shaft
17	stator
18	rotor
30	refrigerant temperature sensor (temperature detection part)
34	oil return passage
37	injection nozzle
37a	inner opening portion of injection nozzle
37b	outer opening portion of injection nozzle
41	first refrigerant supply passage
42	solenoid valve (on-off valve)
46	second refrigerant supply passage
48	control part
50	refrigerant supply part
H1	oil surface level in stopped-state of lubricant oil
H2	oil surface level in working-state of lubricant oil
M	intermediate pressure zone
O	lubricant oil

Claims

1. A multi-stage compressor comprising:

a housing having a sealed container shape;
a low-stage side compression mechanism and a high-stage side compression mechanism which are installed in the housing;
an electric motor configured to drive the low-stage side compression mechanism and the high-stage side compression mechanism, the electric motor being installed in an intermediate pressure zone in the housing;
an injection nozzle installed into the housing in a penetrating manner so as to face the electric motor; and
a refrigerant supply part configured to extract a gas phase portion and a liquid phase portion of a compressed refrigerant discharged from the high-stage side compression mechanism, and to selectively supply the gas phase portion and the liquid phase portion to the injection nozzle as an injection refrigerant.

2. The multi-stage compressor according to claim 1, wherein
the refrigerant supply part includes:

a first refrigerant supply passage branching from a condensed refrigerant passage and connected to the injection nozzle, the compressed refrigerant, discharged from the high-stage side compression mechanism thus being condensed and cooled, flowing in the condensed refrigerant passage;
a second refrigerant supply passage extending from a space above a liquid surface in a gas-liquid separator, and connected to the injection nozzle, the gas-liquid separator separating the compressed refrigerant, discharged from the high-stage side compression mechanism, into a gas and a liquid;
an on-off valve configured to open and close the first refrigerant supply passage;
a control part configured to control opening and closing of the on-offvalve; and
a temperature detection part configured to detect a working temperature of the electric motor, and to input the working temperature into the control part, wherein
the control part opens the on-off valve upon the working temperature of the electric motor reaching a predetermined threshold temperature.

3. The multi-stage compressor according to claim 2, wherein the temperature detection part is a refrigerant temperature sensor configured to detect a temperature of the compressed refrigerant discharged from the high-stage side compression mechanism.

4. The multi-stage compressor according to any one of claims 1 to 3, wherein a position of an inner opening portion of the injection nozzle on an inner side of the housing is disposed in a vicinity of an end portion of the electric motor disposed on an upstream side in a flow direction of the refrigerant in the housing.

5. The multi-stage compressor according to any one of claims 1 to 4, wherein the position of an inner opening portion of the injection nozzle on an inner side of the housing is disposed in a vicinity of a lower portion of the electric motor in the housing.

6. The multi-stage compressor according to any one of claims 1 to 5, wherein a height of an inner opening portion of the injection nozzle on an inner side of the housing is set higher than an oil surface level in working-state of the lubricant oil filled in the housing.

7. The multi-stage compressor according to any one of claims 1 to 6, wherein a height of an outer opening portion of the injection nozzle on an outer side of the housing is set higher than an oil surface level in stopped-state of the lubricant oil filled in the housing.

8. The multi-stage compressor according to any one of claims 1 to 7, wherein a position of the injection nozzle in a circumferential direction with respect to the housing is set to a position displaced from a position where the lubricant oil flows down from an upper portion to a lower portion in the housing as viewed in a plan view of the housing.

9. A chilling system comprising the multi-stage compressor according to any one of claims 1 to 8.

Amended claims under Art. 19.1 PCT

1. A multi-stage compressor comprising:

a housing having a sealed container shape;
a low-stage side compression mechanism and a high-stage side compression mechanism which are installed in the housing;
an electric motor configured to drive the low-stage side compression mechanism and the high-stage side compression mechanism, the electric motor being installed in an intermediate pressure zone in the housing;
an injection nozzle installed into the housing in a penetrating manner so as to face the electric motor; and
a refrigerant supply part configured to extract a gas phase portion and a liquid phase portion of a compressed refrigerant discharged from the high-stage side compression mechanism, and to selectively supply the gas phase portion and the liquid phase portion to the injection nozzle as an injection refrigerant, wherein
the refrigerant supply part includes:

a first refrigerant supply passage branching from a condensed refrigerant passage and connected to the injection nozzle, the compressed refrigerant, discharged from the high-stage side compression mechanism thus being condensed and cooled, flowing in the condensed refrigerant passage;
a second refrigerant supply passage extending from a space above a liquid surface in a gas-liquid separator, and connected to the injection nozzle, the gas-liquid separator separating the compressed refrigerant, discharged from the high-stage side compression mechanism, into a gas and a liquid;
an on-off valve configured to open and close the first refrigerant supply passage;
a control part configured to control opening and closing of the on-off valve; and
a temperature detection part configured to detect a working temperature of the electric motor, and to input the working temperature into the control part, wherein

the control part opens the on-off valve upon the working temperature of the electric motor reaching a predetermined threshold temperature.

2. The multi-stage compressor according to claim 1, wherein the temperature detection part is a refrigerant temperature sensor configured to detect a temperature of the compressed refrigerant discharged from the high-stage side compression mechanism.

3. The multi-stage compressor according to claim 1 or 2, wherein a position of an inner opening portion of the injection nozzle on an inner side of the housing is disposed in a vicinity of an end portion of the electric motor disposed on an upstream side in a flow direction of a refrigerant in the housing.

4. The multi-stage compressor according to any one of claims 1 to 3, wherein the position of an inner opening portion of the injection nozzle on an inner side of the housing is disposed in a vicinity of a lower portion of the electric motor in the housing.

5. The multi-stage compressor according to any one of claims 1 to 4, wherein a height of an inner opening portion of the injection nozzle on an inner side of the housing is set higher than an oil surface level in working-state of a lubricant oil filled in the housing.

6. The multi-stage compressor according to any one of claims 1 to 5, wherein a height of an outer opening portion of the injection nozzle on an outer side of the housing is set higher than an oil surface level in stopped-state of the lubricant oil filled in the housing.

7. The multi-stage compressor according to any one of claims 1 to 6, wherein a position of the injection nozzle in a circumferential direction with respect to the housing is set to a position displaced from a position where the lubricant oil flows down from an upper portion to a lower portion in the housing as viewed in a plan view of the housing.

8. A chilling system comprising the multi-stage compressor according to any one of claims 1 to 7.

9. Deleted)

FIG. 1

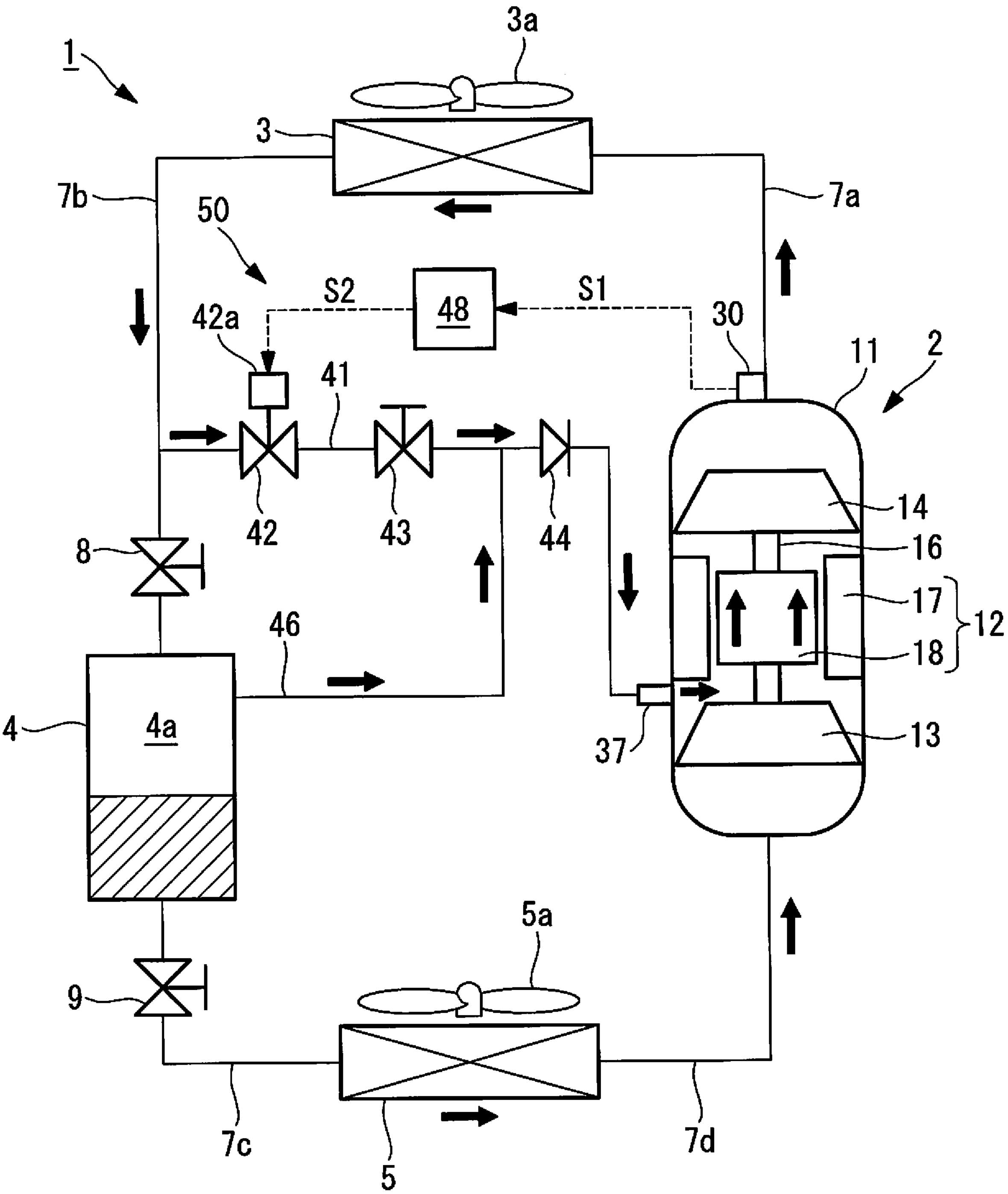
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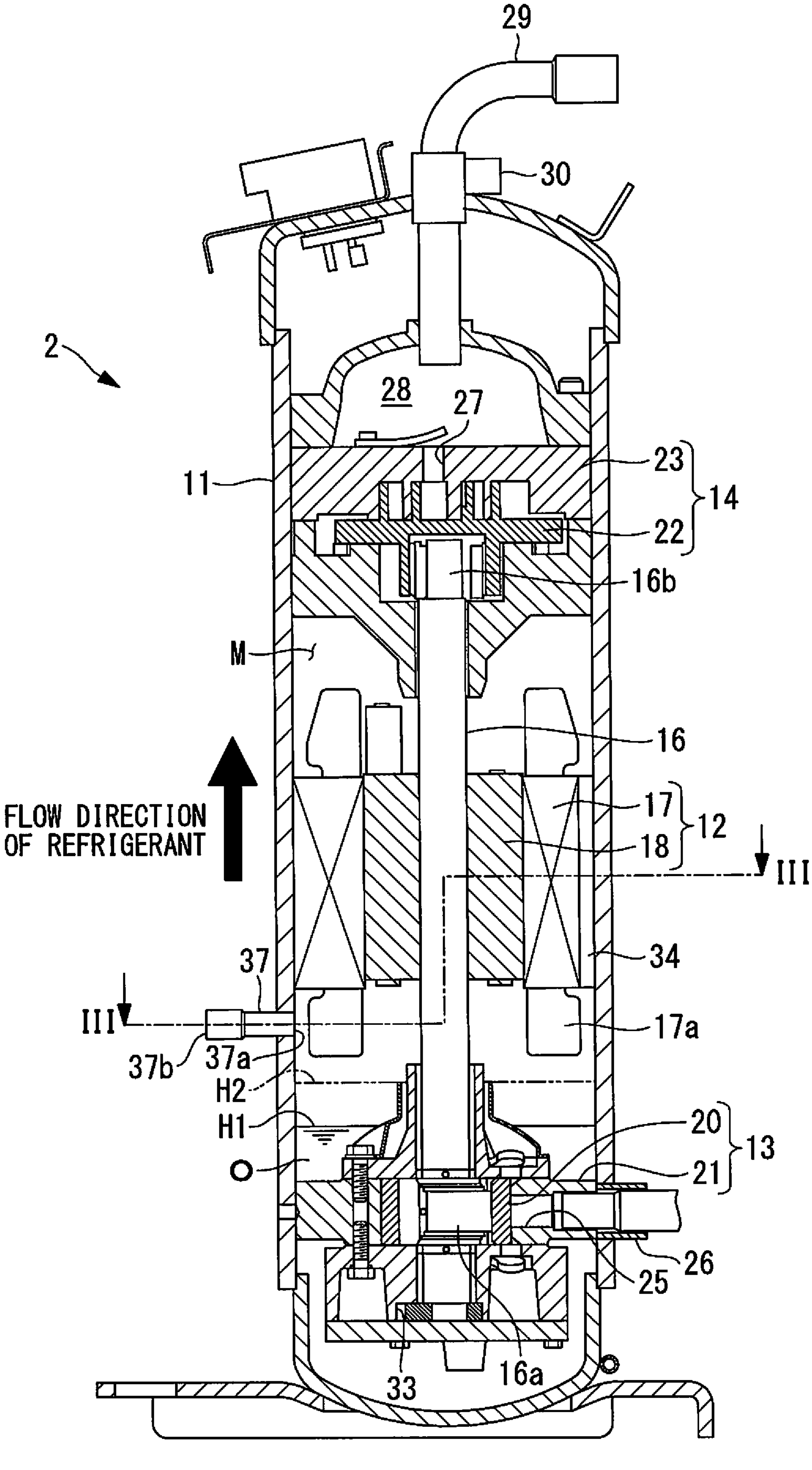
FIG. 2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FLOW DIRECTION
OF REFRIGERANT
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III
34
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37b
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H2
H1
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16a

FIG. 3

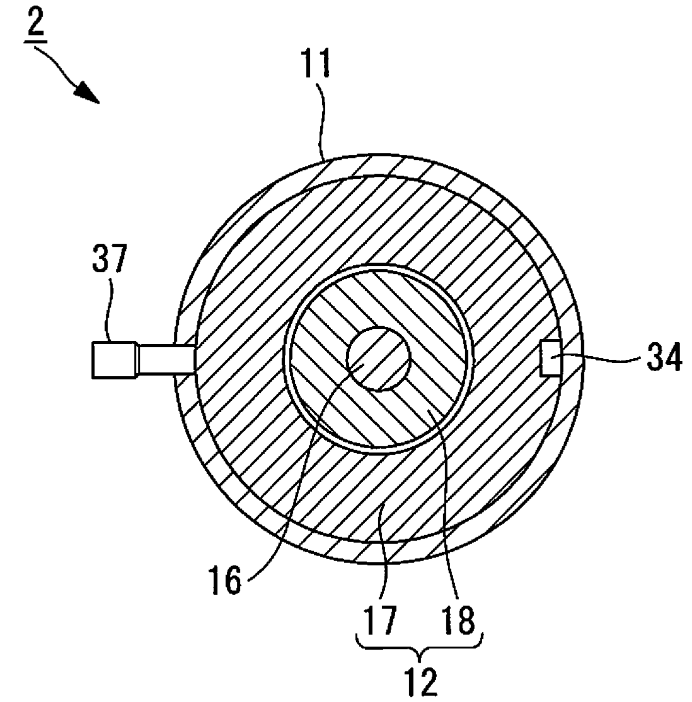
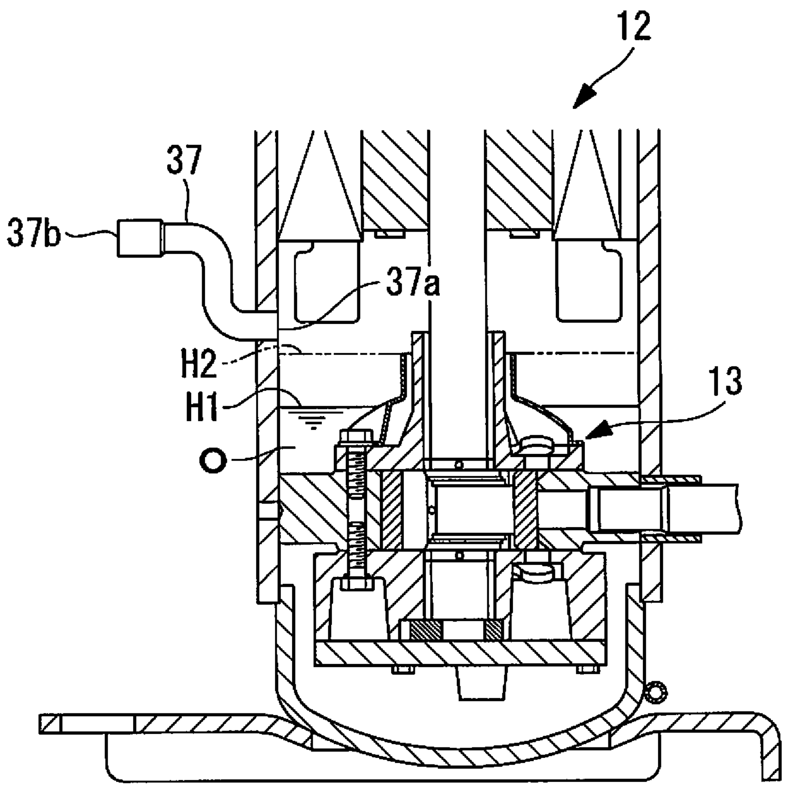


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/072994

A. CLASSIFICATION OF SUBJECT MATTER
F04C23/00(2006.01)i, *F04B39/06*(2006.01)i, *F04C28/02*(2006.01)i, *F04C29/04*(2006.01)i, *F25B1/00*(2006.01)i, *F25B1/10*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C23/00, F04B39/06, F04C28/02, F04C29/04, F25B1/00, F25B1/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2008-286037 A (Fujitsu General Ltd.), 27 November 2008 (27.11.2008), paragraphs [0007] to [0063]; fig. 1 to 6 (Family: none)	1,4,6-7,9 1-9
Y	JP 2009-30484 A (Mitsubishi Heavy Industries, Ltd.), 12 February 2009 (12.02.2009), paragraphs [0008] to [0053]; fig. 1 to 2 & US 2010/0064707 A1 paragraphs [0010] to [0079]; fig. 1 to 2	1-9
Y	JP 2015-14195 A (Hitachi Appliances, Inc.), 22 January 2015 (22.01.2015), paragraphs [0037] to [0050]; fig. 9 to 10 & CN 104279783 A paragraphs [0087] to [0101]; fig. 9 to 10	1-9

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 October 2016 (18.10.16)	25 October 2016 (25.10.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/072994

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 3-67958 A (Daikin Industries, Ltd.), 22 March 1991 (22.03.1991), page 6, upper right column, line 18 to lower right column, line 9; fig. 8 (Family: none)	2-3
A	JP 2008-163894 A (Mitsubishi Heavy Industries, Ltd.), 17 July 2008 (17.07.2008), entire text; all drawings & US 2010/0143172 A1 entire text; all drawings	1-9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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