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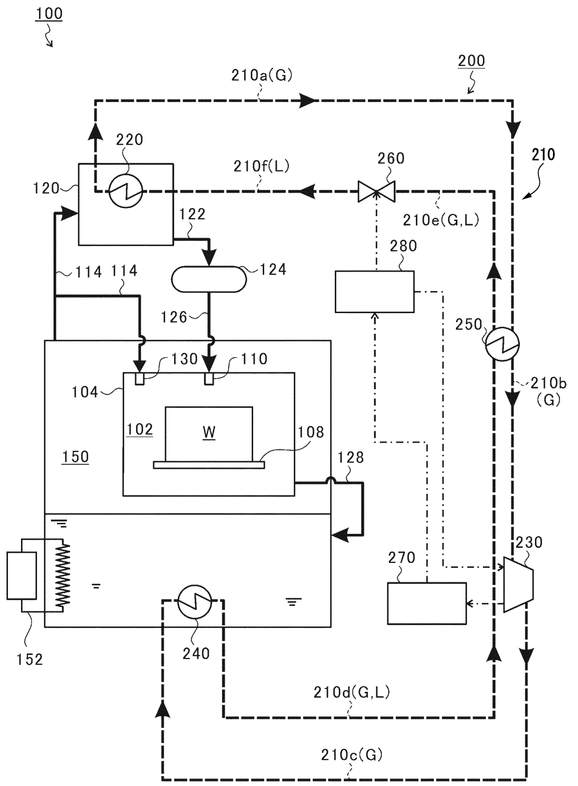
(54) ## HEAT PUMP UNIT AND HEAT PUMP UNIT OPERATION METHOD

(57) A heat pump unit (200) includes: a circulation passageway (210) through which a heat medium circulates; a compressor (230) which includes an accommodation space (R) accommodating lubricating oil to be supplied to a compression mechanism (232, 234) and which increases the temperature of the heat medium by adiabatically compressing the heat medium; a condenser (240) which condenses the heat medium; an expansion valve (260) which decompresses and expands the heat medium; an evaporator (220) which evaporates the heat medium; and a controller (280) which controls drive of the compressor and the opening degree of the expansion valve. The controller is adapted to decrease the opening degree of the expansion valve so that the height of the liquid surface of the lubricating oil accommodated in the accommodation space is maintained to be greater than or equal to a preset threshold, and to stop operation of the compressor after completely closing the expansion valve, when receiving instructions to stop compression operation of the compressor.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a heat pump unit and a heat pump unit operation method.

[0002] Priority is claimed on Japanese Patent Application No. 2013-082117, filed April 10, 2013, the content of which is incorporated herein by reference.

Background Art

[0003] In the related art, a heat pump unit is known including a compressor which heats a heat medium by adiabatically compressing the heat medium circulating through a circulation passageway, a condenser which condenses the heat medium by cooling the heat medium heated by the compressor, an expansion valve which cools the heat medium by decompressing and expanding the heat medium condensed by the condenser, and an evaporator which evaporates the heat medium by heating the heat medium cooled by the expansion valve. The heat pump unit is utilized for various fields such as a refrigerator, a freezer, an air conditioner, and a water heater.

[0004] When the operation of the heat pump unit is stopped, for example, if the drive of the compressor is stopped without closing the expansion valve, a liquid heat medium remains in the evaporator. In this case, at the time the operation of the heat pump unit is started next time, the liquid heat medium remaining in the evaporator is imported into the compressor while keeping the liquid state, and thus a malfunction of the compressor may occur.

[0005] Accordingly, a technology is disclosed in which when the operation of a heat pump unit including an expansion valve capable of being controlled so as to be opened or closed is stopped, the expansion valve is completely closed at one time before the drive of a compressor is stopped (for example, refer to Patent Document 1).

Document of Related Art

Patent Document

[0006] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2001-165511

Summary of Invention

Technical Problem

[0007] A compression mechanism included in the compressor is supplied with lubricating oil, and in the heat pump unit, at the time the compressor adiabatically compresses a heat medium, the heat medium may dissolve in the lubricating oil. In this case, if the technology of Patent Document 1 is used and the expansion valve is completely closed at one time in a state where the compressor is being driven, the pressure inside the compressor suddenly decreases, and the heat medium dissolving in the lubricating oil may bubble.

[0008] If the heat medium bubbles, the seeming viscosity of the lubricating oil decreases, an oil film of the lubricating oil may not be sufficiently formed in the compression mechanism, wear of the compression mechanism may be advanced, and thus the compressor may be damaged.

[0009] An object of the present invention is to provide a heat pump unit and a heat pump unit operation method which can limit the generation of bubbles of a heat medium contained in lubricating oil at the time the compressor is stopped and thus can prevent damage to the compressor.

Solution to Problem

[0010] In order to solve the above problems, a first aspect of the present invention is a heat pump unit including: a circulation passageway through which a heat medium circulates; a compressor which includes a compression mechanism and an accommodation space accommodating lubricating oil to be supplied to the compression mechanism, and which increases the temperature of the heat medium by adiabatically compressing the heat medium circulating through the circulation passageway; a condenser which is provided on a downstream side of the compressor in the circulation passageway, and which condenses the heat medium by cooling the heat medium whose temperature has been increased by the compressor; an expansion valve which is provided on a downstream side of the condenser in the circulation passageway, and which cools the heat medium by decompressing and expanding the heat medium condensed by the condenser; an evaporator which is provided on a downstream side of the expansion valve in the circulation passageway, and which evaporates the heat medium by heating the heat medium cooled by the expansion valve; and a controller which controls drive of the compressor and the opening degree of the expansion valve, and which controls the circulating amount of the heat medium in the circulation passageway. In addition, the controller is adapted to decrease the opening degree of the expansion valve so that the height of the liquid surface of the lubricating oil accommodated in the accommodation space is maintained to be greater than or equal to a threshold preset for the compressor, and to stop compression operation on the heat medium by the compressor after blocking inflow of the heat medium into the compressor through the expansion valve by completely closing the expansion valve, when the controller receives instructions to stop the compression operation on the heat medium by the compressor.

[0011] A second aspect of the present invention is that in the heat pump unit of the first aspect, the controller is adapted to maintain the height of the liquid surface of the lubricating oil accommodated in the accommodation space to be greater than or equal to the threshold by decreasing the opening degree of the expansion valve so that the changing rate of the opening degree of the expansion valve is maintained to be a predetermined first value.

[0012] A third aspect of the present invention is that in the heat pump unit of the first aspect, the controller is adapted to maintain the height of the liquid surface of the lubricating oil accommodated in the accommodation space to be greater than or equal to the threshold by decreasing the opening degree of the expansion valve so that the decreasing rate of the pressure of the accommodation space is maintained to be a predetermined second value.

[0013] A fourth aspect of the present invention is that in the heat pump unit of any one of the first to third aspects, the controller is adapted to continue the compression operation on the heat medium by the compressor until the pressure of the accommodation space is less than a pressure corresponding to a predetermined density of the heat medium contained in the lubricating oil after completely closing the expansion valve, and to stop the compression operation on the heat medium by the compressor when the pressure of the accommodation space is less than the pressure corresponding to the predetermined density of the heat medium contained in the lubricating oil.

[0014] In order to solve the above problems, a fifth aspect of the present invention is a heat pump unit operation method used for a heat pump unit, the heat pump unit including: a circulation passageway through which a heat medium circulates; a compressor which includes a compression mechanism and an accommodation space accommodating lubricating oil to be supplied to the compression mechanism, and which increases the temperature of the heat medium by adiabatically compressing the heat medium circulating through the circulation passageway; a condenser which is provided on a downstream side of the compressor in the circulation passageway, and which condenses the heat medium by cooling the heat medium whose temperature has been increased by the compressor; an expansion valve which is provided on a downstream side of the condenser in the circulation passageway, and which cools the heat medium by decompressing and expanding the heat medium condensed by the condenser; and an evaporator which is provided on a downstream side of the expansion valve in the circulation passageway, and which evaporates the heat medium by heating the heat medium cooled by the expansion valve. The operation method includes a step of decreasing the opening degree of the expansion valve so that the height of the liquid surface of the lubricating oil accommodated in the accommodation space is maintained to be greater than or equal to a threshold preset for the compressor, and of stopping compression operation on the heat medium by the compressor after blocking inflow of the heat medium into the compressor through the expansion valve by completely closing the expansion valve, based on instructions to stop the compression operation on the heat medium by the compressor.

Effects of Invention

[0015] According to the present invention, it is possible to limit the generation of bubbles of a heat medium contained in lubricating oil at the time the compressor is stopped, and thus to prevent damage to the compressor.

Brief Description of Drawings

[0016]

FIG. 1 is a conceptual diagram showing a vacuum cleaning apparatus.

FIG. 2 is a diagram showing the structure of a compressor.

FIG. 3 is a flowchart showing the flow of processing of a heat pump unit operation method.

Description of Embodiments

[0017] Hereinafter, preferable embodiments of the present invention are described in detail with reference to the attached drawings. Dimensions, materials, other specific numerical values and the like shown in the embodiments are merely examples which facilitate understanding of the present invention and do not limit the present invention other than a case where a special description limiting it is provided. Additionally, in the specification and drawings, components having substantially the same function and structure are represented by the same reference sign, and a duplicate description thereof is omitted. Furthermore, the illustrations of components not directly relating to the present invention are omitted.

[0018] In the related art, a heat pump unit is provided in various kinds of electrical equipment such as a refrigerator, a freezer, an air conditioner, and a water heater. Additionally, in recent years, a vacuum cleaning apparatus, which cleans a work (processing object) under decreased pressure using vapor of a hydrocarbon-based cleaning agent, has been developed, and the heat pump unit is also utilized for the vacuum cleaning apparatus. The work denotes, for example, an industrial product, and the vacuum cleaning apparatus cleans the work and removes contamination adhering to the work. In this embodiment, a vacuum cleaning apparatus being an example of the apparatus including a heat pump unit is described.

(Vacuum Cleaning Apparatus 100)

[0019] FIG. 1 is a conceptual diagram (block diagram) showing a vacuum cleaning apparatus 100. In FIG. 1, the flow of a hydrocarbon-based cleaning agent is shown by arrows of solid lines, the flow of a heat medium is shown by arrows of dashed lines, and the flow of signals is shown by arrows of dashed-dotted lines. As shown in FIG. 1, the vacuum cleaning apparatus 100 includes a vacuum vessel 104 inside which a cleaning chamber 102 is provided. The vacuum vessel 104 is provided with an opening (not shown), and the opening is capable of being opened and closed by an opening and closing door (not shown). Thus, when a work W is cleaned, the opening and closing door is opened, the work W is carried into the cleaning chamber 102 through the opening and is mounted on a mounting table 108, the opening and closing door is closed, and the work W is cleaned. Thereafter, the opening and closing door is opened again, and the work W is carried out of the opening.

[0020] The cleaning chamber 102 is provided with a shower unit 110. In addition, a vapor chamber 150 is communicated with the shower unit 110 via a vapor supply pipe 114, a condensing chamber 120, a condensed cleaning agent supply pipe 122, a cleaning agent reservoir 124, and a condensed cleaning agent supply pipe 126 in sequence.

[0021] The cleaning chamber 102 is provided with a vapor supply unit 130. The vapor supply unit 130 is communicated with the vapor chamber 150 via a vapor supply pipe 114.

[0022] The vapor chamber 150 is provided with a heater 152 and a condenser 240, and generates vapor of a hydrocarbon-based cleaning agent (hereinafter, merely referred to as the "vapor") by heating the hydrocarbon-based cleaning agent (solvent) to, for example, a temperature between about 80 and 140 °C, preferably to about 120 °C. The vapor generated in the vapor chamber 150 is imported into the condensing chamber 120 via the vapor supply pipe 114 or is supplied into the cleaning chamber 102 through the vapor supply unit 130. The vapor supplied into the cleaning chamber 102 by the vapor supply unit 130 contacts the work W and thereby is condensed. A heating mechanism by the condenser 240 is described in detail later.

[0023] Although the kind of hydrocarbon-based cleaning agent has no special limitation, it is preferable to use a cleaning agent of third petroleum from the viewpoint of safety. The hydrocarbon-based cleaning agent includes, for example, normal paraffinic, isoparaffinic, napthenic, and aromatic cleaning agents. Specifically, as a cleaning agent of third petroleum, it is preferable to use Teclean N-20, Clean Sol G, Daphne® Solvent or the like, called a "cleaning solvent".

[0024] The condensing chamber 120 includes an evaporator 220. The vapor imported into the condensing chamber 120 is cooled by the evaporator 220 and is condensed into the liquid hydrocarbon-based cleaning agent (hereinafter, merely referred to as the "condensed cleaning agent"). The condensed cleaning agent is stored in the cleaning agent reservoir 124 through the condensed cleaning agent supply pipe 122, and thereafter is supplied into the cleaning chamber 102 through the condensed cleaning agent supply pipe 126 and the shower unit 110. A cooling mechanism by the evaporator 220 is described in detail later.

[0025] The condensed cleaning agent which has cleaned the work W after being supplied from the shower unit 110, or the condensed cleaning agent generated by condensing at the work W, vapor supplied from the vapor supply unit 130, is again imported into the vapor chamber 150 through a used cleaning agent import pipe 128. The used cleaning agent imported into the vapor chamber 150 is again heated by the heater 152 or by the condenser 240 described above and thereby becomes vapor. In this way, the cleaning agent circulates through the vapor chamber 150, the vapor supply pipe 114, the condensing chamber 120, the condensed cleaning agent supply pipe 122, the cleaning agent reservoir 124, the condensed cleaning agent supply pipe 126, the shower unit 110, the cleaning chamber 102, and the used cleaning agent import pipe 128.

[0026] A vacuum pump (not shown) is connected to the cleaning chamber 102 and to the vapor chamber 150. In a decompression step before the cleaning of the work W is started, the vacuum pump vacuums (initially vacuums) the inside of the vacuum vessel 104 (the cleaning chamber 102) and thereby decreases the pressure of the inside to a predetermined pressure (for example, 6 kPa). Furthermore, the cleaning chamber 102 is connected with a pipe (not shown) used to open the cleaning chamber 102 to the atmosphere. The pipe is provided with an atmosphere-opening valve capable of blocking the communication between the atmosphere and the cleaning chamber 102. In a unloading step after a cleaning step and a drying step of the work W are finished, the atmosphere-opening valve opens the cleaning chamber 102 to the atmosphere and thus returns the internal pressure of the cleaning chamber 102 to the atmospheric pressure.

(Heat Pump Unit 200)

[0027] A heat pump unit 200 includes a circulation passageway 210 (shown by reference numerals 210a to 210f in FIG. 1), the evaporator 220, a compressor 230, the condenser 240, an intermediate heat exchanger 250, an expansion valve 260, a pressure measurement unit 270, and a controller 280. In the heat pump unit 200, a heat medium circulates through the circulation passageway 210 as shown by arrows of dashed lines in FIG. 1, and is again imported into the evaporator 220 from the evaporator 220 through the intermediate heat exchanger 250, the compressor 230, the condenser 240, the intermediate heat exchanger 250, the expansion valve 260, which are provided in the circulation passageway 210. In addition, although the kind of heat medium has no special limitation, it is preferable to use a chlorofluorocarbon-based heat medium (for example, R-245fa (1,1,1,3,3-Pentafluoropropane)) which is liquid at normal temperature under the atmospheric pressure and whose latent heat can be used at the evaporator 220. The normal temperature is, for example, 25 °C.

[0028] The evaporator 220 is disposed on the downstream side of the expansion valve 260 in the circulation passageway 210. The evaporator 220 performs in the condensing chamber 120, heat exchange between a heat medium and vapor of a hydrocarbon-based cleaning agent imported from the vapor chamber 150, and thereby condenses (cools) the vapor into a condensed cleaning agent, and heats and vaporizes the heat medium. That is, the heat medium is heated by the evaporator 220, and thereby becomes gas (shown by reference signs G in FIG. 1). The heat medium heated by the evaporator 220 is further heated by the intermediate heat exchanger 250. A heating mechanism by the intermediate heat exchanger 250 is described in detail later.

[0029] The compressor 230 is configured of, for example, a reciprocating compressor, and includes a compression mechanism and an accommodation space accommodating lubricating oil which is supplied to the compression mechanism. The compressor 230 adiabatically compresses the heat medium heated by the intermediate heat exchanger 250, and thus further heats the heat medium. That is, the compressor 230 increases the temperature of the heat medium by adiabatically compressing the heat medium. The specific configuration of the compressor 230 is described in detail later.

[0030] The condenser 240 is disposed on the downstream side of the compressor 230 in the circulation passageway 210. The condenser 240 performs in the vapor chamber 150, heat exchange between the heat medium heated (the temperature of the heat medium has been increased) by the compressor 230 and a liquid hydrocarbon-based cleaning agent, and thereby heats the hydrocarbon-based cleaning agent and generates vapor of the hydrocarbon-based cleaning agent, and at the same time, cools and condenses the heat medium. The heat medium is cooled by the condenser 240, and thereby becomes a gas-liquid mixed state (shown by reference signs G, L in FIG. 1).

[0031] The intermediate heat exchanger 250 performs heat exchange between the heat medium flowing through the circulation passageways 210a and 210b (passageway between the evaporator 220 and the compressor 230) and the heat medium flowing through the circulation passageways 210d and 210e (passageway between the condenser 240 and the expansion valve 260). The heat medium, which has been heated by the evaporator 220 and flows through the circulation passageway 210a, may not be completely vaporized and may be a gas-liquid mixed state. In this case, if the liquid heat medium is imported into the compressor 230, a malfunction of the compressor 230 may occur.

[0032] Therefore, in a configuration including the intermediate heat exchanger 250, the heat medium flowing through the circulation passageway 210a is heated and the temperature of the heat medium is set to be higher than the saturation temperature thereof, and thereby the heat medium imported into the compressor 230 (the heat medium flowing through the circulation passageway 210b) can be reliably made to be only gas. Accordingly, it is possible to avoid a situation where a malfunction of the compressor 230 occurs.

[0033] The expansion valve 260 is a valve which causes pressure reduction of a fluid, and is provided on the downstream side of the condenser 240. The expansion valve 260 further cools the heat medium by decompressing and expanding the heat medium condensed (cooled) by the condenser 240. The heat medium is cooled by the expansion valve 260, and thereby becomes liquid (shown by a reference sign L in FIG. 1). The heat medium cooled at the expansion valve 260 is again imported into the evaporator 220 through the circulation passageway 210f.

[0034] The pressure measurement unit 270 measures the pressure of gas inside the accommodation space (described later) of the compressor 230.

[0035] The controller 280 is configured of a semiconductor integrated circuit including a CPU (central processing unit), reads out a program, parameters or the like, which are used to operate the CPU, from a ROM, and manages and controls the entire heat pump unit 200 while working together with a RAM being a work area or with another electronic circuit. In this embodiment, the controller 280 controls the drive level (drive) of the compressor 230 and the opening degree of the expansion valve 260 based on the pressure measured by the pressure measurement unit 270, and thereby controls the circulating amount of the heat medium in the circulation passageway 210.

[0036] As described above, the heat medium may dissolve in the lubricating oil accommodated in the compressor 230. Hereinafter, with reference to FIG. 2, the operation is described that the heat medium dissolves in the lubricating oil accommodated in the compressor 230.

[0037] FIG. 2 is a diagram showing the structure of the compressor 230. In FIG. 2, the flow of the heat medium is shown by arrows of solid lines, the flow of the lubricating oil is shown by white arrows, and the lubricating oil is shown by the area filled with gray. As shown in FIG. 2, pistons (compression mechanism) 232 of the compressor 230 are connected to a drive shaft (compression mechanism) 234, and when the drive shaft 234 is rotationally driven by a motor (not shown), the pistons 232 reciprocate relative to compression chambers 236 (cylinders). In addition, a drive unit other than the motor may be used in order to rotationally drive the drive shaft 234. At the time the piston 232 is positioned in the vicinity of the bottom dead center thereof, the heat medium is imported into the compression chamber 236 from the circulation passageway 210b through an inlet 238a of the compressor 230. The heat medium imported into the compression chamber 236 is compressed through the compression operation of the piston 232, and thereafter is sent to the circulation passageway 210c from an outlet 238b at the time the piston 232 is positioned in the vicinity of the top dead center thereof.

[0038] As shown in FIG. 2, the inside of the compressor

230 is provided with the accommodation space R which accommodates the lubricating oil (for example, POE (polyol ester)), and the lubricating oil accommodated in the accommodation space R is supplied into an oil passageway 312 of the drive shaft 234 by a lubricating oil pump 310. The lubricating oil supplied into the oil passageway 312 is supplied to the outer circumferential surface of the piston 232 through an oil passageway (not shown) of the piston 232. In addition, the lubricating oil accommodated in the accommodation space R is supplied by a spraying portion 320 to the joint between the piston 232 and the drive shaft 234, or to the outer circumferential surface of the piston 232 and to the inner circumferential surface of the compression chamber 236 (cylinder). In this way, the lubricating oil is supplied to the outer circumferential surface of the piston 232 and to the inner circumferential surface of the compression chamber 236, and thereby the friction coefficient between the piston 232 and the compression chamber 236 is decreased, and wear of the piston 232 and the compression chamber 236 is reduced.

[0039] In this way, since the heat medium is imported into the compression chamber 236 of the heat pump unit 200, and the lubricating oil is supplied to the inner circumferential surface of the compression chamber 236, the heat medium may dissolve in the lubricating oil at the compression chamber 236. In this case, the lubricating oil, in which the heat medium has dissolved, circulates through the circulation passageway 210. That is, the compression operation of the compressor 230 is continued in a state where the heat medium dissolves in the lubricating oil.

[0040] As described above, when the operation of the heat pump unit 200 is stopped, if the drive of the compressor 230 is stopped without closing the expansion valve 260, the liquid heat medium may remain in the evaporator 220. In this state, when the operation of the heat pump unit 200 is started next time, the liquid heat medium remaining in the evaporator 220 is imported into the compressor 230 while keeping the liquid state, and thus a malfunction of the compressor 230 may occur. On the other hand, when the heat pump unit 200 is stopped, if the expansion valve 260 is completely closed at one time in a state where the compressor 230 is driven in order to prevent the liquid heat medium from remaining in the evaporator 220, the pressure inside the accommodation space R of the compressor 230 suddenly decreases, the heat medium dissolving in the lubricating oil of the compressor 230 may bubble, and thus the compressor 230 may be damaged. For example, bubbles of the heat medium may reach the compression chamber 236.

[0041] Particularly, a heat medium used for the heat pump unit 200 of the vacuum cleaning apparatus 100 has a characteristic of more easily dissolving in lubricating oil than another heat medium used for a heat pump unit of a refrigerator, a freezer, an air conditioner, a water heater or the like (hereinafter, referred to as the "household electrical appliances"). Specifically, in order to generate vapor of a hydrocarbon-based cleaning agent in the vacuum cleaning apparatus 100, it is necessary to heat the hydrocarbon-based cleaning agent to a high temperature between, for example, about 80 to 140 °C. Thus, the boiling point of the heat medium used for the heat pump unit 200 of the vacuum cleaning apparatus 100 is higher than that of the heat medium used for a heat pump unit of the household electrical appliances or for a heat pump unit for general industry. For example, the temperature at a compressor inlet of a heat medium used for a heat pump unit of the household electrical appliances is about 30 °C, and the temperature at a compressor outlet thereof is about 60 °C. The temperature at a compressor inlet of a heat medium used for a heat pump unit for general industry is about 90 °C, and the temperature at a compressor outlet thereof is about 110 °C. In contrast, the temperature at the inlet 238a of the heat medium (the heat medium passing through the circulation passageway 210b) used for the heat pump unit 200 of the vacuum cleaning apparatus 100 is about 100 to 110 °C, and the temperature at the outlet 238b of the compressor 230 (the temperature of the heat medium passing through the circulation passageway 210c) is about 140 °C.

[0042] The heat medium having a comparatively high boiling point generally has greater solubility in the lubricating oil of the compressor 230 included in the heat pump unit 200 than that of the heat medium having a comparatively low boiling point. Specifically, in the heat medium used for a heat pump unit of the household electrical appliances, only a few percentages thereof dissolves in the lubricating oil of the compressor. In contrast, in the heat medium used for the heat pump unit 200 of the vacuum cleaning apparatus 100, about 20 percentages thereof may dissolve in the lubricating oil of the compressor 230. Thus, in the compressor 230 of the heat pump unit 200 of the vacuum cleaning apparatus 100, the generation of bubbles of the heat medium thereof may become remarkable compared to the compressor of a heat pump unit of the household electrical appliances, and there is a high possibility that the compressor 230 is damaged due to a decrease in height of the liquid surface LH of the lubricating oil. In addition, since the generation of bubbles of the heat medium is caused by evaporation of the liquid heat medium, if the heat medium in the lubricating oil evaporates, the height of the liquid surface LH of the lubricating oil decreases. If the height of the liquid surface LH decreases, and the amount of the lubricating oil cannot be secured which is required for lubrication of the joint between the piston 232 and the drive shaft 234 or for lubrication between the outer circumferential surface of the piston 232 and the inner circumferential surface of the compression chamber 236, wear of components may be advanced, and the compressor 230 may be damaged.

[0043] Accordingly, the controller 280 adjusts the opening degree of the expansion valve 260 when stopping the compressor 230, and thus limits the generation of bubbles of the heat medium inside the accommodation space R of the compressor 230. Hereinafter, stopping control of the compressor 230 by the controller 280 is described.

(Stopping Control of Compressor 230)

[0044] When the controller 280 receives instructions to stop the heat pump unit 200, namely instructions to stop the compression operation on the heat medium by the compressor 230, the controller 280 decreases the opening degree of the expansion valve 260 so that the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R of the compressor 230 is not less than a threshold preset for the compressor 230. That is, the controller 280 decreases the opening of the expansion valve 260 so that the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R is maintained to be greater than or equal to the threshold preset for the compressor 230. The threshold preset for the compressor 230 is the lower limit for the height of the liquid surface of the lubricating oil required for lubrication of the joint between the piston 232 and the drive shaft 234 or for lubrication between the outer circumferential surface of the piston 232 and the inner circumferential surface of the compression chamber 236. Therefore, if the height of the liquid surface LH of the lubricating oil is maintained to be greater than or equal to the threshold, it is possible to maintain appropriate lubrication on components of the compressor 230. In addition, the instructions to stop the heat pump unit 200 may be input into the controller 280 by an operator through an input device or the like, or may be received from another control device or the like.

[0045] When the controller 280 decreases the opening degree of the expansion valve 260 so that the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R of the compressor 230 is not less than the threshold preset for the compressor 230, for example, one of the following four methods is used.

(Opening Adjustment 1 of Expansion Valve 260 by Controller 280)

[0046] The controller 280 decreases the opening degree of the expansion valve 260 so that the changing rate of the opening degree of the expansion valve 260 is maintained to be a predetermined first value, and thereby the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R does not become less than the threshold. In a case where the opening degree at the time the expansion valve 260 completely opens is 100%, the first value is, for example, 3% / min.

(Opening Adjustment 2 of Expansion Valve 260 by Controller 280)

[0047] The controller 280 decreases the opening degree of the expansion valve 260 so that the decreasing rate of the pressure of the accommodation space R measured by the pressure measurement unit 270 is maintained to be a predetermined second value, and thereby the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R does not become less than the threshold. The second value is, for example, a decreasing rate of (10% of the pressure at the normal operation of the compressor 230) / min or less. Thus, in a case where the pressure at the normal operation of the compressor 230 is, for example, 500 kPa, the second value is 50 kPa / min.

(Opening Adjustment 3 of Expansion Valve 260 by Controller 280)

[0048] The compressor 230 is provided with a liquid level gauge, and the controller 280 decreases the opening degree of the expansion valve 260 so that the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R of the compressor 230 is not less than a preset threshold for the compressor 230. The liquid level gauge can be configured of existing technologies such as an optical sensor and an image-processing device.

(Opening Adjustment 4 of Expansion Valve 260 by Controller 280)

[0049] The compressor 230 is provided with a device used to measure a bubble amount (the amount of bubbles generated through bubbling of the heat medium), and the controller 280 decreases the opening degree of the expansion valve 260 so that the amount of bubbles generated in the accommodation space R of the compressor 230 is not greater than or equal to a predetermined amount. The predetermined amount is the upper limit for the bubble amount capable of maintaining lubrication (lubrication using lubricating oil) of the joint between the piston 232 and the drive shaft 234 or lubrication between the outer circumferential surface of the piston 232 and the inner circumferential surface of the compression chamber 236. The device used to measure the bubble amount can be configured of existing technologies such as a void fraction meter, an optical sensor, and an image-processing device.

[0050] The opening degree of the expansion valve 260 is decreased based on the value described in the above opening adjustments 1 to 4, and thereby it is possible to prevent the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R of the compressor 230 from becoming less than a preset threshold for the compressor 230. In addition, as described above, if the bubbling amount (evaporation amount) of the heat medium increases, the liquid surface LH of the lubricating oil declines, and thus they have a correlation. Therefore, if the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R is maintained to be greater than or equal to the preset threshold, the bubbling amount (the bubbling amount per unit time) of the heat medium can be limited to be less than or equal to a constant value, and thus it is possible to prevent sudden generation of bubbles of the heat medium.

[0051] The pressure in the accommodation space R can be gradually decreased before the drive of the compressor 230 is stopped, and it is possible to limit the generation of bubbles of the heat medium dissolving in the lubricating oil. Thus, it is possible to avoid a situation where the seeming viscosity of the lubricating oil decreases, and to sufficiently form oil films of the lubricating oil on slide members such as the piston 232, the drive shaft 234, and the compression chamber 236. Therefore, it is possible to avoid a situation where the slide members are worn and thereby the compressor 230 is damaged.

[0052] The controller 280 continues the compression operation on the heat medium using the compressor 230 until the pressure of the accommodation space R measured by the pressure measurement unit 270 becomes less than a pressure (hereinafter, referred to as the "corresponding pressure") corresponding to a predetermined density of the heat medium contained in the lubricating oil after completely closing the expansion valve 260 and thereby blocking the inflow of the heat medium into the compressor 230 through the expansion valve 260. In addition, the corresponding pressure is, for example, 40 kPa (Abs).

[0053] In this way, since the controller 280 stops the drive of the compressor 230 after completely closing the expansion valve 260, it is possible to prevent the liquid heat medium from remaining in the evaporator 220. Therefore, when the controller 280 starts the operation of the heat pump unit 200 next time, no liquid heat medium is imported into the compressor 230, and thus damage to the compressor 230 can be prevented.

[0054] The controller 280 maintains (continues) the compression operation on the heat medium using the compressor 230 until the pressure of the accommodation space R measured by the pressure measurement unit 270 becomes less than the corresponding pressure after completely closing the expansion valve 260, and thereby it is possible to evaporate the heat medium dissolving in the lubricating oil. Thus, the heat medium can be removed from the lubricating oil, and when the operation of the heat pump unit 200 is started next time, it is possible to limit the generation of bubbles of the heat medium in the lubricating oil, that is, to limit the decline amount of the liquid surface LH of the lubricating oil.

(Operation Method of Heat Pump Unit 200)

[0055] Next, an operation method of the heat pump unit 200, particularly a stopping method thereof, is described. FIG. 3 is a flowchart showing the flow of processing of the operation method of the heat pump unit 200. In addition, the stopping control of the heat pump unit 200 is performed during operation of the heat pump unit 200.

[0056] When the controller 280 receives instructions to stop the compression operation on the heat medium using the compressor 230 in accordance with operation and input by an operator ("YES" at step S410), the controller 280 decreases the opening degree of the expansion valve 260 so that the height of the liquid surface LH of the lubricating oil accommodated in the accommodation space R of the compressor 230 is not less than a threshold A preset for the compressor 230 (step S412).

[0057] Subsequently, the controller 280 determines whether or not the expansion valve 260 is completely closed (step S414), and if the expansion valve 260 is not completely closed ("NO" at step S414), the controller 280 continues processing of the step S412. In addition, the step S414 is performed again.

[0058] On the other hand, if the expansion valve 260 is completely closed ("YES" at step S414), the controller 280 determines whether or not the pressure of the accommodation space R of the compressor 230 measured by the pressure measurement unit 270 is less than the corresponding pressure (step S416). If the pressure of the accommodation space R is not less than the corresponding pressure ("NO" at step S416), the controller 280 continues the drive of the compressor 230, and performs the step S416 again. When the pressure of the accommodation space R becomes less than the corresponding pressure ("YES" at step S416), the controller 280 stops the drive of the compressor 230 (step S418).

[0059] As described above, according to the heat pump unit 200 of this embodiment and to the operation method of the heat pump unit 200 of this embodiment, it is possible to limit the generation of bubbles of the heat medium contained in the lubricating oil when the compressor 230 is stopped, and thus to prevent damage to the compressor 230.

[0060] Hereinbefore, although the preferable embodiment of the present invention is described with reference to the attached drawings, the present invention is not limited to this embodiment. A person having ordinary skill in the art can make various modifications within the scope shown by the attached claims, and these modifications are naturally included in the technical scope of the present invention.

[0061] Although the heat pump unit 200 included in the vacuum cleaning apparatus 100 is described in the above embodiment as an example, an apparatus, on which the heat pump unit 200 is mounted, is not limited thereto. For example, in a heat pump unit mounted on various kinds of electrical equipment such as a refrigerator, a freezer, an air conditioner, and a water heater, a heat medium may also dissolve in lubricating oil of a compressor. Therefore, the heat pump unit 200 and the operation method of the heat pump unit 200 of the present invention can be applied to the above electrical equipment or the like.

[0062] The above embodiment discloses a configuration in which the controller 280 continues the compression operation on the heat medium using the compressor 230 until the pressure of the accommodation space R measured by the pressure measurement unit 270 becomes less than the corresponding pressure after completely closing the expansion valve 260. However, the compression operation on the heat medium using the compressor 230 may be continued for the time estimated to be taken before the pressure becomes less than the corresponding pressure after the expansion valve 260 is completely closed. The time may be preset through experiment or the like.

[0063] Although the above embodiment discloses a configuration in which the heat pump unit 200 includes the intermediate heat exchanger 250, the intermediate heat exchanger 250 may not be provided therein. Even if the intermediate heat exchanger 250 is not provided, it is possible to limit the generation of bubbles of the heat medium contained in lubricating oil when the compressor 230 is stopped, and thus to prevent damage to the compressor 230.

[0064] The above embodiment discloses the vacuum cleaning apparatus 100 in which the cleaning using the condensed cleaning agent supplied from the shower unit 110 and the cleaning using vapor supplied from the vapor supply unit 130 are performed. However, for example, an immersion room may be provided under the cleaning chamber 102 inside the vacuum vessel 104, and a work W may be cleaned by immersing the work W in the immersion room.

[0065] Specifically, a hydrocarbon-based cleaning agent (liquid) is stored in the immersion room, the amount of the hydrocarbon-based cleaning agent is sufficient to completely immerse the work W therein, and a heater used to heat the hydrocarbon-based cleaning agent is provided in the immersion room. In addition, an intermediate door is provided between the cleaning chamber 102 and the immersion room, and is configured to communicate the cleaning chamber 102 and the immersion room with each other and to block the communication. The hydrocarbon-based cleaning agent stored in the immersion room is one of or both of the condensed cleaning agent supplied from the shower unit 110 and the condensed cleaning agent supplied from the cleaning agent reservoir 124 through the condensed cleaning agent supply pipe 126. In this case, the mounting table 108 is provided with a lifting device, and thus is configured to be capable of vertically moving. Thus, the lifting device is driven in a state where the cleaning chamber 102 and the immersion room communicate with each other by opening the intermediate door, and thereby the work W is moved from the cleaning chamber 102 into the immersion room or from the immersion room into the cleaning chamber 102, and thus is cleaned.

[0066] It is not necessary to always perform the steps of the heat pump unit operation method of this specification in the order described in the flowchart, and the method may include a parallel or subroutine process.

Industrial Applicability

[0067] The present invention can be used for a heat pump unit and for a heat pump unit operation method.

Description of Reference Signs

[0068]

200	heat pump unit
210	circulation passageway
220	evaporator
230	compressor
232	piston (compression mechanism)
234	drive shaft (compression mechanism)
240	condenser
260	expansion valve
270	pressure measurement unit
280	controller
R	accommodation space

Claims

1. A heat pump unit comprising:

a circulation passageway through which a heat medium circulates;
a compressor which includes a compression mechanism and an accommodation space accommodating lubricating oil to be supplied to the compression mechanism, and which increases the temperature of the heat medium by adiabatically compressing the heat medium circulating through the circulation passageway;
a condenser which is provided on a downstream side of the compressor in the circulation passageway, and which condenses the heat medium by cooling the heat medium whose temperature has been increased by the compressor;
an expansion valve which is provided on a downstream side of the condenser in the circulation passageway, and which cools the heat medium by decompressing and expanding the heat medium condensed by the condenser;
an evaporator which is provided on a downstream side of the expansion valve in the circulation passageway, and which evaporates the heat medium by heating the heat medium cooled by the expansion valve; and
a controller which controls drive of the compressor and the opening degree of the expansion valve, and which controls the circulating amount

of the heat medium in the circulation passageway,
wherein the controller is adapted to decrease the opening degree of the expansion valve so that the height of a liquid surface of the lubricating oil accommodated in the accommodation space is maintained to be greater than or equal to a threshold preset for the compressor, and to stop compression operation on the heat medium by the compressor after blocking inflow of the heat medium into the compressor through the expansion valve by completely closing the expansion valve, when the controller receives instructions to stop the compression operation on the heat medium by the compressor.

2. The heat pump unit according to claim 1,
wherein the controller is adapted to maintain the height of the liquid surface of the lubricating oil accommodated in the accommodation space to be greater than or equal to the threshold by decreasing the opening degree of the expansion valve so that the changing rate of the opening degree of the expansion valve is maintained to be a predetermined first value.

3. The heat pump unit according to claim 1,
wherein the controller is adapted to maintain the height of the liquid surface of the lubricating oil accommodated in the accommodation space to be greater than or equal to the threshold by decreasing the opening degree of the expansion valve so that the decreasing rate of the pressure of the accommodation space is maintained to be a predetermined second value.

4. The heat pump unit according to claim 1,
wherein the controller is adapted to continue the compression operation on the heat medium by the compressor until the pressure of the accommodation space is less than a pressure corresponding to a predetermined density of the heat medium contained in the lubricating oil after completely closing the expansion valve, and to stop the compression operation on the heat medium by the compressor when the pressure of the accommodation space is less than the pressure corresponding to the predetermined density of the heat medium contained in the lubricating oil.

5. The heat pump unit according to claim 2,
wherein the controller is adapted to continue the compression operation on the heat medium by the compressor until the pressure of the accommodation space is less than a pressure corresponding to a predetermined density of the heat medium contained in the lubricating oil after completely closing the expansion valve, and to stop the compression operation on the heat medium by the compressor when the pressure of the accommodation space is less than the pressure corresponding to the predetermined density of the heat medium contained in the lubricating oil.

6. The heat pump unit according to claim 3,
wherein the controller is adapted to continue the compression operation on the heat medium by the compressor until the pressure of the accommodation space is less than a pressure corresponding to a predetermined density of the heat medium contained in the lubricating oil after completely closing the expansion valve, and to stop the compression operation on the heat medium by the compressor when the pressure of the accommodation space is less than the pressure corresponding to the predetermined density of the heat medium contained in the lubricating oil.

7. A heat pump unit operation method, a heat pump unit including:

a circulation passageway through which a heat medium circulates;
a compressor which includes a compression mechanism and an accommodation space accommodating lubricating oil to be supplied to the compression mechanism, and which increases the temperature of the heat medium by adiabatically compressing the heat medium circulating through the circulation passageway;
a condenser which is provided on a downstream side of the compressor in the circulation passageway, and which condenses the heat medium by cooling the heat medium whose temperature has been increased by the compressor;
an expansion valve which is provided on a downstream side of the condenser in the circulation passageway, and which cools the heat medium by decompressing and expanding the heat medium condensed by the condenser; and
an evaporator which is provided on a downstream side of the expansion valve in the circulation passageway, and which evaporates the heat medium by heating the heat medium cooled by the expansion valve;
the heat pump unit operation method comprising:

a step of decreasing the opening degree of the expansion valve so that the height of a liquid surface of the lubricating oil accommodated in the accommodation space is maintained to be greater than or equal to a threshold preset for the compressor, and of stopping compression operation on the heat medium by the compressor after blocking inflow of the heat medium into the compressor through the expansion valve by completely closing the expansion valve, based on instructions to stop the compression operation on the heat medium by the compressor.

FIG. 1

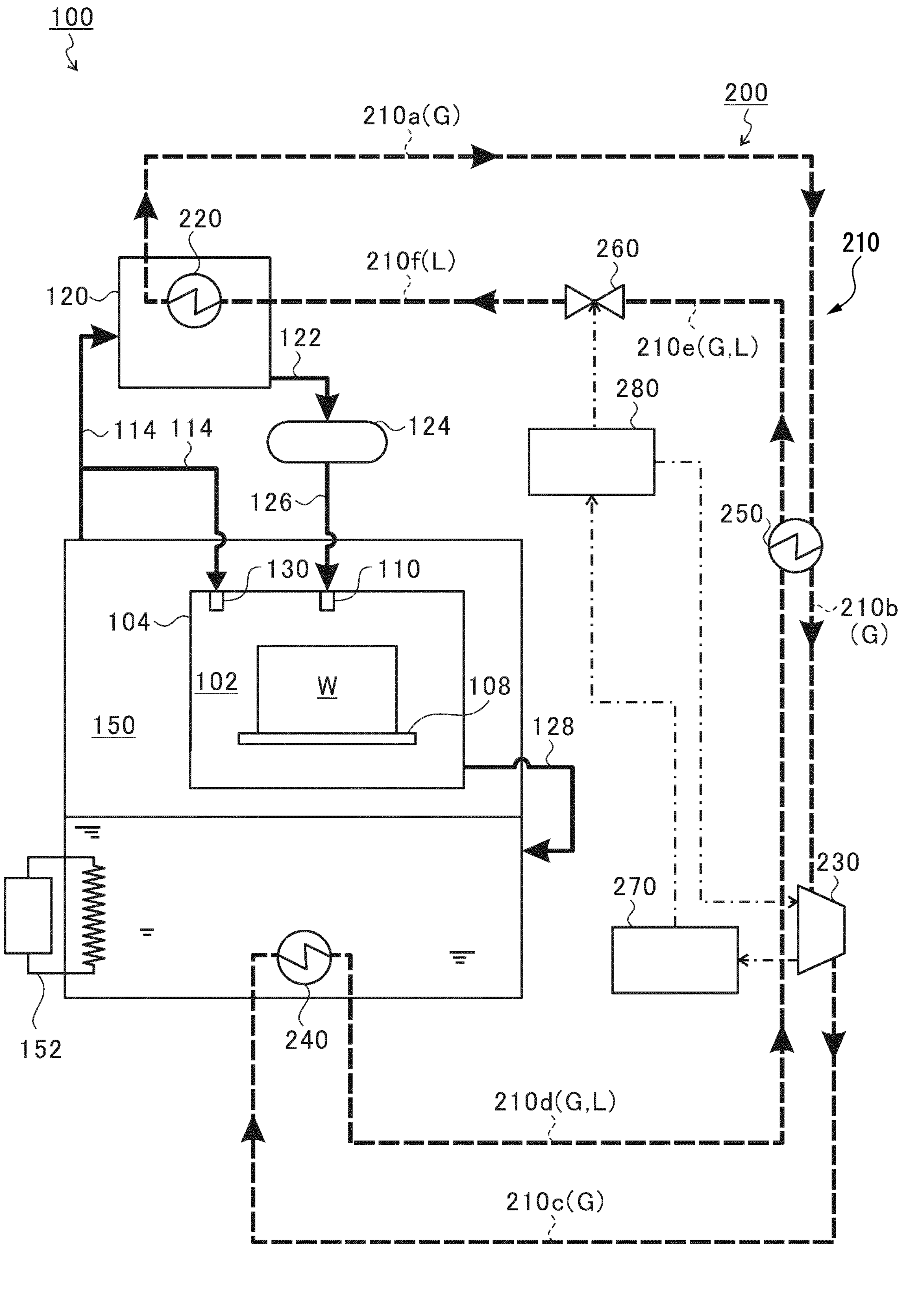

100
200
210a(G)
210
220
260
120
210f(L)
210e(G,L)
122
280
114 114
124
126
250
130
110
210b
(G)
104
102
W
108
150
128
230
270
152
240
210d(G,L)
210c(G)

FIG. 2

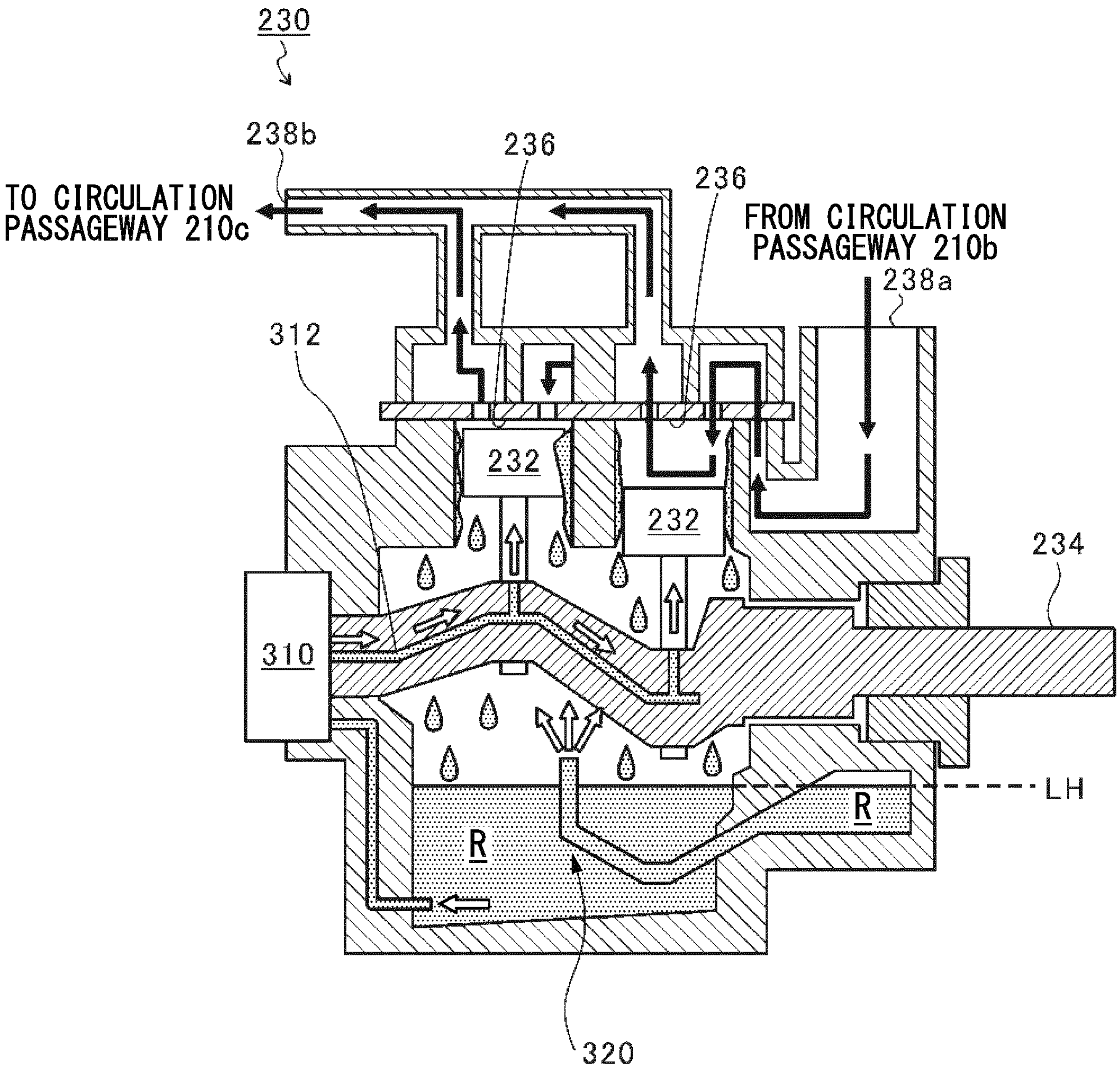
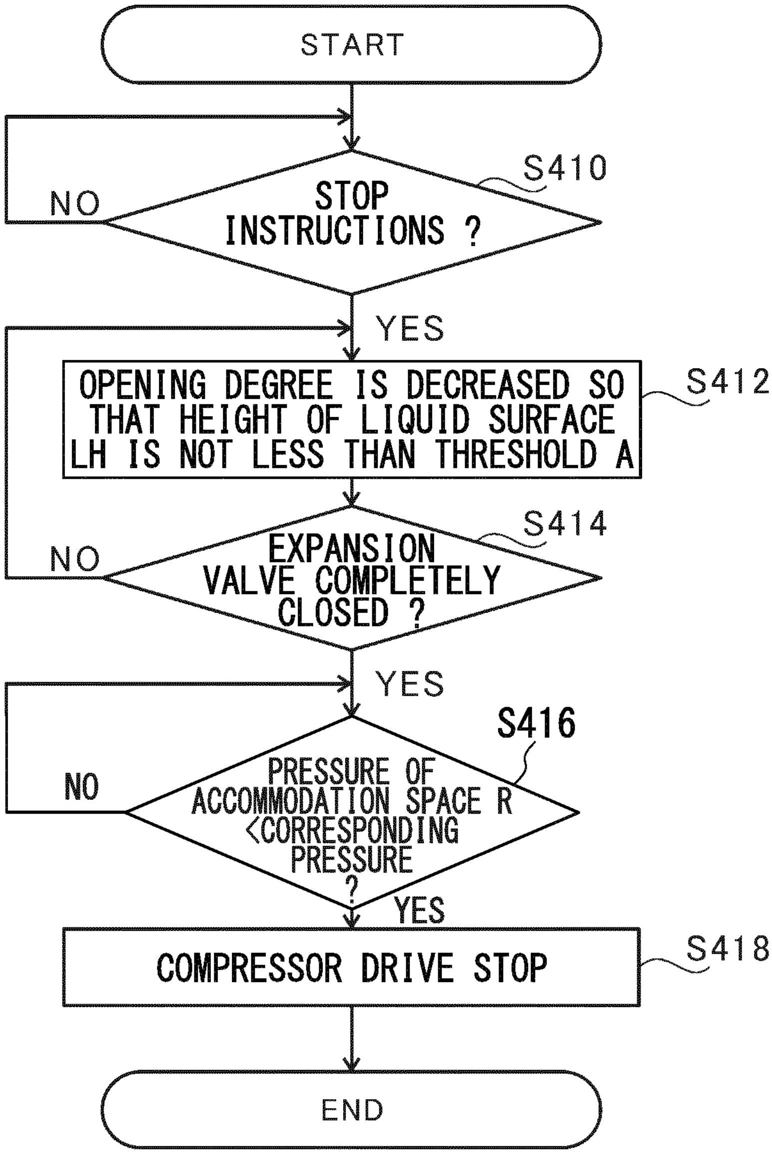

230
238b
236
236
TO CIRCULATION
PASSAGEWAY 210c
FROM CIRCULATION
PASSAGEWAY 210b
238a
312
232
232
234
310
LH
R
R
320

FIG. 3


START
S410
NO
STOP INSTRUCTIONS ?
YES
S412
OPENING DEGREE IS DECREASED SO THAT HEIGHT OF LIQUID SURFACE LH IS NOT LESS THAN THRESHOLD A
S414
NO
EXPANSION VALVE COMPLETELY CLOSED ?
YES
S416
NO
PRESSURE OF ACCOMMODATION SPACE R <CORRESPONDING PRESSURE ?
YES
S418
COMPRESSOR DRIVE STOP
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/060105

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(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)
F25B1/00

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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.
Y A	JP 6-026716 A (Daikin Industries, Ltd.), 04 February 1994 (04.02.1994), paragraphs [0005] to [0006], [0056] to [0065], [0094], [0098]; fig. 1, 4 (Family: none)	1,4,7 2-3,5-6
Y A	JP 2000-039237 A (Mitsubishi Electric Corp.), 08 February 2000 (08.02.2000), paragraph [0116]; fig. 1 & US 6220041 B1 & US 2001/0000050 A1	1,4,7 2-3,5-6
Y A	JP 11-083205 A (Daikin Industries, Ltd.), 26 March 1999 (26.03.1999), paragraph [0029]; fig. 1 to 2 (Family: none)	1,4,7 2-3,5-6

☒ 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
11 June, 2014 (11.06.14)	24 June, 2014 (24.06.14)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/060105

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 63-290353 A (Matsushita Refrigeration Co.), 28 November 1988 (28.11.1988), claims (Family: none)	1,4,7 2-3,5-6
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 148586/1983(Laid-open No. 055959/1985) (Toshiba Corp.), 19 April 1985 (19.04.1985), claims (Family: none)	1,4,7 2-3,5-6
Y A	JP 2012-13349 A (Panasonic Corp.), 19 January 2012 (19.01.2012), paragraph [0045]; fig. 2 (Family: none)	4 2-3,5-6
Y A	JP 2009-250482 A (Ebara Refrigeration Equipment & Systems Co., Ltd.), 29 October 2009 (29.10.2009), paragraph [0028]; fig. 2 (Family: none)	4 2-3,5-6

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REFERENCES CITED IN THE DESCRIPTION

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