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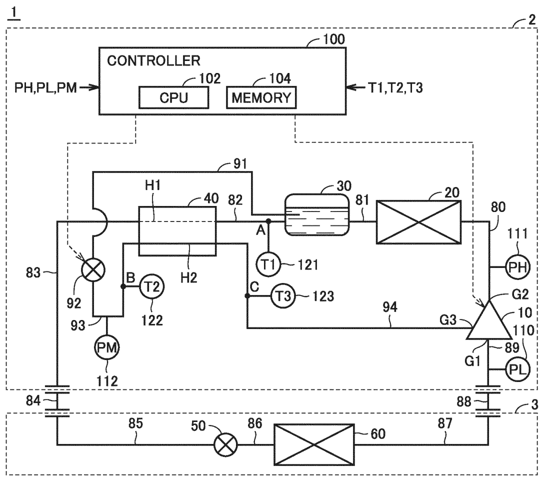
(54) OUTDOOR UNIT, REFRIGERATION CYCLE DEVICE, AND REFRIGERATOR

(57) An outdoor unit (2) includes: a heat exchanger (40); and a receiver (30). The heat exchanger (40) exchanges heat between refrigerant flowing in a first passage (HI) and the refrigerant flowing in a second passage (H2). The receiver (30) is disposed between a condenser (20) and the first passage (HI) of the heat exchanger (40), and stores the refrigerant. A load device (3) and a flow path from a compressor (10) to the first passage (HI) of the heat exchanger (40) via the condenser (20) and the receiver (30) form a circulation flow path through which the refrigerant circulates. The outdoor unit (2) further includes: a first refrigerant flow path (91); a second expansion valve (92); and a second refrigerant flow path (94). The first refrigerant flow path (91) causes the refrigerant to flow from the receiver (30) or an outlet pipe of the receiver (30) on the circulation flow path to an inlet of the second passage (H2). The second refrigerant flow path (94) causes the refrigerant to flow from an outlet of the second passage (H2) to the compressor (10).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to an outdoor unit, a refrigeration cycle apparatus and a refrigerator.

BACKGROUND ART

[0002] Japanese Patent No. 5505477 discloses an air conditioning apparatus that can make refrigerant amount appropriateness determination at proper operation, at low cost and with a small determination error, even under the influence of disturbances such as dirt of an outdoor heat exchanger, a placement situation of an outdoor unit, and wind and rain.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent No. 5505477

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] Japanese Patent No. 5505477 describes the air conditioning apparatus. However, there is a refrigeration cycle apparatus such as a refrigerator that is generally configured such that a receiver is provided between a condenser and an expansion valve. In the refrigeration cycle apparatus including the receiver, at the stage where an amount of refrigerant in the receiver is decreasing, a degree of supercooling at the outlet of the condenser does not change so much, even when the amount of refrigerant decreases. Therefore, the decrease in amount of refrigerant cannot be detected by using the method described in Japanese Patent No. 5505477, unless an amount of leakage of the refrigerant is large.

[0005] Furthermore, in recent years, there has been a demand to suppress emission of CFCs. A refrigerator has been demanded to enclose refrigerant having a global warming potential (GWP) lower than 1500, and a facility manager has been required to report an amount of leakage of the refrigerant equal to or larger than a certain amount.

[0006] In order to achieve flexible refrigerant shift in the market, development of a multiple-refrigerant-using apparatus is under consideration. The multiple-refrigerant-using apparatus is an apparatus in which existing pseudo-azeotropic refrigerant and next-generation non-azeotropic refrigerant having a GWP lower than 1500 can be both used in one housing. In the case of the multiple-refrigerant-using apparatus, an operator needs to set a type of enclosed refrigerant in the apparatus. However, the operator may erroneously set a type of refrigerant different from the enclosed refrigerant in the apparatus, which may raise concerns about performance degradation of a refrigeration cycle apparatus.

[0007] The present invention has been made to solve the above-described problem, and an object of the present invention is to provide an outdoor unit of a refrigeration cycle apparatus, a refrigeration cycle apparatus, and a refrigerator, which make it possible to prevent performance degradation caused by erroneous setting of a type of refrigerant, and to detect refrigerant leakage at a small amount of leakage, even when a receiver is provided.

SOLUTION TO PROBLEM

[0008] The present disclosure relates to an outdoor unit of a refrigeration cycle apparatus, the outdoor unit being connectable to a load device including a first expansion valve and an evaporator. The outdoor unit includes: a heat exchanger; and a receiver. The heat exchanger includes: a compressor having a suction port and a discharge port; and a condenser, has a first passage and a second passage, and the heat exchanger is configured to exchange heat between refrigerant flowing in the first passage and the refrigerant flowing in the second passage. The receiver is disposed between the condenser and the first passage of the heat exchanger, and the receiver is configured to store the refrigerant. The load device and a flow path from the compressor to the first passage of the heat exchanger via the condenser and the receiver form a circulation flow path through which the refrigerant circulates. The outdoor unit further includes: a first refrigerant flow path configured to cause the refrigerant to flow from the receiver or an outlet pipe of the receiver on the circulation flow path to an inlet of the second passage; a second expansion valve disposed on the first refrigerant flow path; and a second refrigerant flow path configured to cause the refrigerant to flow from an outlet of the second passage to the compressor.

ADVANTAGEOUS EFFECTS OF INVENTION

[0009] According to the outdoor unit, the refrigeration cycle apparatus and the refrigerator of the present disclosure, it is possible to reduce the possibility of performance degradation caused by erroneous setting of a type of refrigerant, and to detect refrigerant leakage at a small amount of leakage, even when a receiver is provided.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

Fig. 1 is an overall configuration diagram of a refrigeration cycle apparatus 1 according to a first embodiment.

Fig. 2 is a diagram for illustrating a configuration of a receiver in the first embodiment.

Fig. 3 is a flowchart for illustrating a process related to refrigerant, which is performed by a controller 100.

Fig. 4 is a flowchart showing details of a refrigerant amount determination process performed in step S1 in Fig. 3.

Fig. 5 shows, in an overlapping manner, a p-h diagram when the amount of the refrigerant is appropriate and a p-h diagram when the amount of the refrigerant is insufficient.

Fig. 6 is a diagram for illustrating a change in temperature of the refrigerant in an injection flow path.

Fig. 7 is a flowchart showing details of a refrigerant type determination process performed in step S2.

Fig. 8 is a p-h diagram when R410A, which is pseudo-azeotropic refrigerant, is used.

Fig. 9 is a p-h diagram when R463A, which is non-azeotropic refrigerant, is used.

Fig. 10 is a flowchart showing details of compressor control performed in step S3.

Fig. 11 is a diagram for illustrating detection of a composition of the refrigerant in step S35.

Fig. 12 is a diagram for illustrating a relationship between a composition and an evaporation temperature.

Fig. 13 shows a configuration of a refrigeration cycle apparatus 101 according to a second embodiment.

Fig. 14 shows a configuration of a refrigeration cycle apparatus 201 according to a third embodiment.

DESCRIPTION OF EMBODIMENTS

[0011] Embodiments of the present invention will be described in detail hereinafter with reference to the drawings. Although a plurality of embodiments will be described below, it is originally intended to combine as appropriate the features described in the embodiments. In the drawings, the same or corresponding portions are denoted by the same reference characters, and description thereof will not be repeated.

First Embodiment

[0012] Fig. 1 is an overall configuration diagram of a refrigeration cycle apparatus 1 according to a first embodiment. Fig. 1 functionally shows connection relationships and arrangement configurations of the devices in the refrigeration cycle apparatus, and does not necessarily show arrangement in a physical space.

[0013] Referring to Fig. 1, refrigeration cycle apparatus 1 includes an outdoor unit 2, a load device 3, and extension pipes 84 and 88.

[0014] Outdoor unit 2 of refrigeration cycle apparatus 1 is connectable to load device 3 by extension pipes 84 and 88.

[0015] Outdoor unit 2 includes a compressor 10, a condenser 20, a heat exchanger 40, a receiver 30, and pipes 80 to 83 and 89. Heat exchanger 40 has a first passage H1 and a second passage H2, and is configured to exchange heat between refrigerant flowing in first passage H1 and the refrigerant flowing in second passage H2. Receiver 30 is disposed between first passage H1 of heat exchanger 40 and condenser 20, and is configured to store the refrigerant.

[0016] Load device 3 and a flow path from compressor 10 to first passage H1 of heat exchanger 40 via condenser 20 and receiver 30 form a circulation flow path through which the refrigerant circulates. Hereinafter, this circulation flow path will also be referred to as "main circuit" of a refrigeration cycle.

[0017] Outdoor unit 2 further includes a first refrigerant flow path 91, a second expansion valve 92 disposed on first refrigerant flow path 91, and a second refrigerant flow path 94. First refrigerant flow path 91 is configured to cause the refrigerant to flow from receiver 30 or an outlet pipe of receiver 30 of the circulation flow path to an inlet of second passage H2. Second refrigerant flow path 94 is configured to cause the refrigerant to flow from an outlet of second passage H2 to compressor 10. Hereinafter, this flow path that branches off from the main circuit and delivers the refrigerant to compressor 10 via second passage H2 will be referred to as "injection flow path".

[0018] Load device 3 includes a first expansion valve 50, an evaporator 60 and pipes 85, 86 and 87. First expansion valve 50 is implemented by, for example, a temperature expansion valve controlled independently of outdoor unit 2.

[0019] Compressor 10 compresses the refrigerant suctioned from pipes 89 and 94, and discharges the compressed refrigerant to pipe 80. Compressor 10 has a suction port G1, a discharge port G2 and an intermediate pressure port G3. Compressor 10 is configured to suction the refrigerant having passed through evaporator 60 from suction port G1, and discharge the refrigerant from discharge port G2 toward condenser 20.

[0020] Second refrigerant flow path 94 is configured to cause the refrigerant to flow from the outlet of second passage H2 to intermediate pressure port G3 of compressor 10.

[0021] Compressor 10 is configured to adjust a rotation speed in accordance with a control signal from a controller 100. By adjusting the rotation speed of compressor 10, an amount of circulation of the refrigerant is adjusted, and thus, a refrigeration capacity of refrigeration cycle apparatus 1 can be adjusted. Various types of compressors can be used as compressor 10, and a scroll-type compressor, a rotary-type compressor, a screw-type compressor or the like can, for example, be used.

[0022] Condenser 20 condenses the refrigerant discharged from compressor 10 to pipe 80, and causes the condensed refrigerant to flow to pipe 81. Condenser 20 is configured to exchange heat between the high-temperature and high-pressure gas refrigerant discharged from compressor 10 and the outdoor air. As a result of this heat exchange, the refrigerant having dissipated heat condenses to a liquid phase. A notshown fan supplies, to condenser 20, the outdoor air for heat exchange with the refrigerant in condenser 20. By adjusting the rotation speed of the fan, a refrigerant pressure on the discharge side of compressor 10 can be adjusted.

[0023] Outdoor unit 2 further includes pressure sensors 110, 111 and 112, temperature sensors 121, 122 and 123, and controller 100 that controls outdoor unit 2.

[0024] Pressure sensor 110 detects a pressure PL of the refrigerant suctioned into compressor 10, and outputs a detection value to controller 100. Pressure sensor 111 detects a pressure PH of the refrigerant discharged from compressor 10, and outputs a detection value to controller 100. Pressure sensor 112 detects a pressure PM in pipe 93 at an outlet of second expansion valve 92, and outputs a detection value to controller 100.

[0025] Temperature sensor 121 detects a temperature T1 of the refrigerant in pipe 82 at an outlet of receiver 30, and outputs a detection value to controller 100. Temperature sensor 122 detects a temperature T2 of the refrigerant at the inlet of second passage H2 on the cooling side of heat exchanger 40, and outputs a detection value to controller 100. Temperature sensor 123 detects a temperature T3 of the refrigerant at the outlet of second passage H2 on the cooling side of heat exchanger 40, and outputs a detection value to controller 100.

[0026] Controller 100 includes a central processing unit (CPU) 102, a memory 104 (a read only memory (ROM) and a random access memory (RAM)), an input/output buffer (not shown) for inputting/outputting various signals, and the like. CPU 102 loads programs stored in the ROM to the RAM or the like and performs the programs. The programs stored in the ROM are programs describing a process procedure of controller 100. In accordance with these programs, controller 100 performs control of the devices in outdoor unit 2. This control is not limited to processing by software, and may be performed by processing by dedicated hardware (electronic circuit).

[0027] In the present embodiment, controller 100 is configured to a) determine an amount of the refrigerant enclosed in refrigeration cycle apparatus 1, b) determine a type of the refrigerant enclosed in refrigeration cycle apparatus 1, and c) perform control of outdoor unit 2 corresponding to the type of the refrigerant enclosed in refrigeration cycle apparatus 1.

[0028] Fig. 2 is a diagram for illustrating a configuration of the receiver in the first embodiment.

[0029] Referring to Fig. 2, receiver 30 includes a housing 31 that stores the liquid refrigerant, an inlet pipe IP1, a first outlet pipe OP1, and a second outlet pipe OP2.

[0030] The outlet of receiver 30 to the circulation flow path, which is the main circuit, is first outlet pipe OP1. Second outlet pipe OP2 is an outlet of receiver 30 different from first outlet pipe OP1. First refrigerant flow path 91 is configured to cause the refrigerant to flow from second outlet pipe OP2 to the inlet of second passage H2 of heat exchanger 40. In receiver 30, an inlet port of second outlet pipe OP2 is disposed at a position higher than an inlet port of first outlet pipe OP1.

[0031] Specifically, a height L1 of the inlet port of first outlet pipe OP1 and a height L2 of the inlet port of second outlet pipe OP2 are lower than a liquid level height L0 when the amount of the refrigerant is appropriate. However, height L2 of the inlet port of second outlet pipe OP2 is between height L1 and height L0, and a position in a height direction is determined in accordance with the sensitivity of detection of a refrigerant shortage. When height L2 is brought closer to height L0, the gas refrigerant is suctioned due to only a little drop of the liquid level of the refrigerant, and thus, the sensitivity of detection of a refrigerant shortage becomes higher. In contrast, when height L2 is brought closer to height L1, the gas refrigerant is not suctioned due to a little drop of the liquid level of the refrigerant, and thus, the sensitivity of detection becomes lower although a refrigerant shortage can be detected.

[0032] As for a standard injection flow path for controlling a discharge temperature of a refrigerator, a branch portion is in many cases provided at an outlet of first passage H1 of heat exchanger 40. Although a refrigerant shortage can be detected even when the branch portion is provided at the outlet of first passage H1 of heat exchanger 40, the sensitivity of detection decreases. In the present embodiment, the branch portion is provided at a portion of receiver 30 that stores the liquid refrigerant. With such a configuration, controller 100 can perform a refrigerant amount determination process for detecting in an early stage a refrigerant shortage caused by refrigerant leakage, a refrigerant type determination process for identifying pseudo-azeotropic refrigerant and non-azeotropic refrigerant, and a process for controlling compressor 10 to maintain the refrigeration capacity in accordance with a change in composition of the non-azeotropic refrigerant.

[0033] Fig. 3 is a flowchart for illustrating a process related to the refrigerant, which is performed by controller 100. The process in this flowchart is performed at the time of initial startup after refrigeration cycle apparatus 1 is placed, or every time refrigeration cycle apparatus 1 is powered on after refrigeration cycle apparatus 1 is placed. Referring to Fig. 3, in step S1, controller 100 performs the refrigerant amount determination process for finding refrigerant leakage in an early stage. Next, in step S2, controller 100 performs the refrigerant type determination process for determining whether the refrigerant enclosed in refrigeration cycle apparatus 1 is pseudo-azeotropic refrigerant or non-azeotropic refrigerant. Next, in step S3, controller 100 performs the process for controlling the compressor to maintain the refrigeration capacity in accordance with a change in composition of the non-azeotropic refrigerant.

[0034] Fig. 4 is a flowchart showing details of the refrigerant amount determination process performed in step S1 in Fig. 3.

[0035] As a precondition for performing the refrigerant amount determination process, the position of second outlet pipe OP2 that introduces the liquid refrigerant into the injection flow path as shown in Fig. 2 needs to be appropriate. By appropriately setting height L2, the liquid refrigerant is delivered from receiver 30 to the injection flow path when the amount of the refrigerant is appropriate, and the gas refrigerant is delivered from receiver 30 to the injection flow path when the amount of the liquid refrigerant is insufficient.

[0036] First, in step S11, on the assumption that the amount of the refrigerant would be appropriate, controller 100 adjusts a degree of opening of second expansion valve 92 such that a degree of dryness X at a point B on the intermediate pressure side of heat exchanger 40 becomes less than 1. Controller 100 determines a target degree of opening of second expansion valve 92 based on pressure PH of a high-pressure portion, intermediate pressure PM, and an operation frequency of compressor 10. As a result, the refrigerant in a two-phase state flows through second passage H2 of heat exchanger 40. The refrigerant is heated by heat exchange with the liquid refrigerant on the high pressure side flowing through first passage H1.

[0037] Next, in step S12, controller 100 detects temperature T2 of the refrigerant at the inlet of the second passage of heat exchanger 40 and temperature T3 of the refrigerant at the outlet of the second passage of heat exchanger 40 by using temperature sensors 122 and 123. Then, in step S13, controller 100 determines whether or not a difference between temperature T2 and temperature T3 of the refrigerant is larger than a threshold value.

[0038] When the amount of the refrigerant is appropriate and the refrigerant in a two-phase state flows through second passage H2 of heat exchanger 40, the temperature difference is equal to or smaller than the threshold value (NO in S13). In contrast, when the amount of the refrigerant is smaller than the appropriate amount, the refrigerant flowing through second passage H2 changes to the refrigerant in a gas state in midway, and thus, all of the heat provided by heating is sensible heat, which makes the temperature difference larger than the threshold value (YES in S 13). This temperature difference will be described in detail with reference to Figs. 5 and 6.

[0039] Fig. 5 shows, in an overlapping manner, a p-h diagram when the amount of the refrigerant is appropriate and a p-h diagram when the amount of the refrigerant is insufficient. When the amount of the refrigerant is appropriate, a state of the refrigerant on the p-h diagram moves from a point A to a point B. Fig. 1 shows positions of point A and point B before and after second expansion valve 92. In contrast, when the amount of the refrigerant is insufficient, the positions indicating the state of the refrigerant on the p-h diagram moves from point A and point B to a point A' and a point B', respectively, before and after second expansion valve 92.

[0040] Fig. 6 is a diagram for illustrating a change in temperature of the refrigerant in the injection flow path. Referring to Figs. 5 and 6, when the amount of the refrigerant is appropriate, point A is in a liquid region and point B is in a two-phase region, and thus, the refrigerant flowing into second passage H2 of heat exchanger 40 is in a two-phase state. Therefore, the temperature changes gently with respect to a change in enthalpy. In this case, although the temperature of the refrigerant having passed through second passage H2 of heat exchanger 40 changes from point B to a point C in Fig. 6, an amount of the temperature change is small. In contrast, when the amount of the refrigerant is insufficient, point B' and a point C' are in a gas region, and thus, the refrigerant flowing into second passage H2 of heat exchanger 40 is in a gas state. All of the heat provided in heat exchanger 40 in midway from point B' to point C' is sensible heat without latent heat of the refrigerant, and thus, the temperature changes directly with respect to a change in enthalpy. Therefore, the temperature changes from point B' to point C' in Fig. 6, and an amount of the temperature change is larger than the amount of the temperature change from point B to point C. Determination as to whether or not the amount of the temperature change before and after the second passage of heat exchanger 40 exceeds the threshold value is made in step S13 in Fig. 4.

[0041] Referring again to Fig. 4, when the temperature difference is larger than the threshold value (YES in S13), controller 100 determines that there is a refrigerant shortage, and notifies a user or a maintenance person of the refrigerant shortage in step S14. The notification is provided by, for example, a display on an LED mounted on a substrate or a remote controller, an alarm sound or the like. In addition to the notification, controller 100 may stop the operation of the refrigeration cycle apparatus in step S15. In contrast, when the temperature difference is equal to or smaller than the threshold value (NO in S13), the control is returned to the main routine in Fig. 3 in step S16. In this case, the refrigerant type determination process in step S2 is then performed.

[0042] Fig. 7 is a flowchart showing details of the refrigerant type determination process performed in step S2. When an apparatus that can be used for both of two types of refrigerant is developed, the user generally sets, in the apparatus, which refrigerant is enclosed in the apparatus. However, in the present embodiment, the apparatus automatically determines a type of the refrigerant.

[0043] First, in step S21, on the assumption that the amount of the refrigerant would be appropriate, controller 100 adjusts the degree of opening of second expansion valve 92 such that degree of dryness X at the point B on the intermediate pressure side of heat exchanger 40 becomes less than 1. Controller 100 determines the target degree of opening of second expansion valve 92 based on pressure PH of the high pressure portion, intermediate pressure PM, and the operation frequency of compressor 10. As a result, the refrigerant in a two-phase state flows through second passage H2 of heat exchanger 40. The refrigerant is heated by heat exchange with the liquid refrigerant on the high pressure side flowing through first passage H1.

[0044] Next, in step S22, controller 100 detects temperature T2 of the refrigerant at the inlet of the second passage of heat exchanger 40 and temperature T3 of the refrigerant at the outlet of the second passage of heat exchanger 40 by using temperature sensors 122 and 123.

[0045] The processing in steps S21 and S22 described above may be omitted when the result of the processing performed in steps S11 and S12 in Fig. 4 is used as it is.

[0046] Next, in step S23, controller 100 determines whether or not a temperature difference between temperature T2 and temperature T3 of the refrigerant is larger than a threshold value. The threshold value is a threshold value set to determine the type of the refrigerant.

[0047] The temperature difference between temperature T2 and temperature T3 of the refrigerant varies depending on whether the refrigerant is non-azeotropic mixed refrigerant or pseudo-azeotropic refrigerant. This temperature difference will be described in detail with reference to Figs. 8 and 9.

[0048] Fig. 8 is a p-h diagram when R410A, which is pseudo-azeotropic refrigerant, is used. In the case of the pseudo-azeotropic refrigerant, isothermal lines in a two-phase region sandwiched between a saturated liquid line and a saturated gas line are substantially horizontal. That is, there is no temperature gradient with respect to a change in enthalpy in the two-phase region. Therefore, there is almost no temperature difference between a temperature at the point B before heating and a temperature at the point C after heating in second passage H2 of heat exchanger 40.

[0049] Fig. 9 is a p-h diagram when R463A, which is non-azeotropic refrigerant, is used. In the case of the non-azeotropic refrigerant, isothermal lines in a two-phase region sandwiched between a saturated liquid line and a saturated gas line are downward to the right. That is, there is a temperature gradient with respect to a change in enthalpy in the two-phase region. Therefore, a temperature difference occurs between a temperature at a point B before heating and a temperature at a point C after heating in second passage H2 of heat exchanger 40. When a spacing between the isothermal lines is reduced, the point B is on the isothermal line of 10°C or lower, although it is difficult to see in Fig. 9 because the spacing between the isothermal lines is wide. In contrast, the point C is on the isothermal line of around 10°C. That is, temperature T3 of the two-phase refrigerant in the state of the point C is higher than temperature T2 of the two-phase refrigerant in the state of the point B.

[0050] Therefore, the threshold value in step S23 in Fig. 4 is set at a value that allows identification between the refrigerant in Fig. 8 and the refrigerant in Fig. 9.

[0051] When T3-T2>threshold value is satisfied (YES in S23), controller 100 determines in step S24 that the enclosed refrigerant is non-azeotropic refrigerant. In contrast, when T3-T2>threshold value is not satisfied (NO in S23), controller 100 determines in step S25 that the enclosed refrigerant is pseudo-azeotropic refrigerant.

[0052] When the type of the refrigerant is determined in step S24 or step S25, the process proceeds to step S26, and then, the compressor control in step S3 in Fig. 3 is performed.

[0053] Fig. 10 is a flowchart showing details of the compressor control performed in step S3. First, in step S31, controller 100 determines whether or not the refrigerant is non-azeotropic refrigerant, based on the result of the determination in step S2.

[0054] When the refrigerant is non-azeotropic refrigerant (YES in S31), the processing in steps S32 to S38 is performed. In contrast, when the refrigerant is pseudo-azeotropic refrigerant (NO in S31), the processing in steps S39 to S41 is performed.

[0055] When the refrigerant is pseudo-azeotropic refrigerant, controller 100 associates a conversion equation between the pressure and the evaporation temperature with the pseudo-azeotropic refrigerant in step S39. Then, in step S40, controller 100 determines a suction pressure for controlling the evaporation temperature. Furthermore, in step S41, controller 100 changes the operation frequency of compressor 10.

[0056] In contrast, when the refrigerant is non-azeotropic refrigerant, a composition of the refrigerant circulating in the refrigeration cycle apparatus is determined by a ratio of a gas refrigerant mass in receiver 30 to a total enclosed refrigerant mass. For example, when receiver 30 is filled with the liquid and there is no gas refrigerant, a composition of the circulating refrigerant is the same as a composition when the refrigerant is enclosed. However, when there is gas refrigerant in receiver 30, the gas refrigerant stays in receiver 30 and does not circulate in the refrigeration cycle apparatus. Therefore, a composition of the refrigerant circulating in the refrigeration cycle apparatus is a composition of the refrigerant excluding the gas refrigerant in receiver 30.

[0057] When the refrigerant is non-azeotropic refrigerant (YES in S31), controller 100 first obtains temperature T1 at the inlet of second expansion valve 92 from temperature sensor 121 in step S32. Then, in step S33, controller 100 converts temperature T1 into enthalpy. In parallel with these steps, controller 100 obtains pressure PM and temperature T2 at the inlet of second passage H2 of heat exchanger 40 from pressure sensor 112 and temperature sensor 122, respectively, in step S34.

[0058] Next, in step S35, controller 100 detects a composition of the refrigerant based on the enthalpy, pressure PM and temperature T2.

[0059] When the composition can be specified, a saturation temperature can be obtained based on the pressure and the enthalpy. Conversely, when the pressure, the enthalpy and the saturation temperature can be known, the composition can be specified.

[0060] More specifically, on the premise that the composition is known, when two of the pressure, the enthalpy and the temperature of the refrigerant are known, the other one is known. When all of the pressure, the enthalpy and the temperature are known, the composition is known.

[0061] This principle is applied, and based on pressure PM and temperature T2 measured by pressure sensor 112 and temperature sensor 122 in the two-phase portion, and the enthalpy calculated from temperature T1 measured by temperature sensor 121 in the liquid portion, controller 100 specifies the composition of the refrigerant by using a preliminarily created function or conversion map.

[0062] Fig. 11 is a diagram for illustrating detection of the composition of the refrigerant in step S35. Fig. 11 shows a relationship between the composition and the temperature in a state where the pressure and the enthalpy are fixed. Fig. 11 shows the relationship between the composition and the temperature in a portion that detects the composition of the refrigerant, i.e., in an intermediate pressure portion in the refrigeration cycle apparatus. In Fig. 11, the vertical axis represents temperature T2 of the refrigerant at an inlet of heat exchanger 40, and the horizontal axis represents a weight ratio between an amount of the gas refrigerant and an amount of the enclosed refrigerant in receiver 30 in terms of percent. In Fig. 11, the enthalpy converted from temperature T1 and pressure PM are fixed at certain values. Under this condition, temperature T2 corresponds to the weight ratio between the amount of the gas refrigerant and the amount of the enclosed refrigerant in a one-to-one relationship. Let us assume, for example, that temperature T2 when receiver 30 is filled with the liquid and the composition of the circulating refrigerant is a pure composition of the non-azeotropic refrigerant is -6.8°C, and actual temperature T2 is -5°C. Therefore, a temperature deviation ΔT from the temperature in the case of the pure composition corresponds to 0.25 of the weight ratio (%) between the amount of the gas refrigerant and the amount of the enclosed refrigerant indicated by the horizontal axis.

[0063] The weight ratio between the amount of the gas refrigerant and the amount of the enclosed refrigerant corresponds to the composition of the circulating refrigerant. Therefore, when temperature T2 is known, the composition of the circulating refrigerant can be determined. Such a relationship shown in the graph is present for each pressure and for each enthalpy. Therefore, a map for determining the composition of the refrigerant can be created based on pressure PM, temperature T2 and temperature T1.

[0064] The process for determining the composition of the circulating refrigerant described above is performed in step S35. Next, in step S36, controller 100 associates the conversion equation between the pressure and the evaporation temperature with the detected composition. The evaporation temperature herein refers to an average evaporation temperature of a dew point and a boiling point.

[0065] Fig. 12 is a diagram for illustrating a relationship between the composition and the evaporation temperature. Fig. 12 shows the relationship between the composition and the temperature in a state where the pressure and the enthalpy are fixed. Fig. 12 shows the relationship between the composition and the temperature in a portion reflected in the control of the refrigeration cycle apparatus, i.e., in a low pressure portion in the refrigeration cycle apparatus. In Fig. 12, the vertical axis represents the average evaporation temperature of evaporator 60, and the horizontal axis represents the weight ratio between the amount of the gas refrigerant and the amount of the enclosed refrigerant in receiver 30 in terms of percent.

[0066] The graph shown in Fig. 12 corresponds to a map for reflecting the detected composition in the control. For example, when 0.25 of the weight ratio (%) between the amount of the gas refrigerant and the amount of the enclosed refrigerant corresponding to the composition is applied to the map shown in Fig. 12, assuming that the average evaporation temperature when receiver 30 is filled with the liquid and the composition of the circulating refrigerant is a pure composition of the non-azeotropic refrigerant is -40°C, the average evaporation temperature is -38.5°C.

[0067] Next, in step S37, controller 100 determines, as a suction pressure, pressure PL for controlling the refrigeration cycle apparatus to achieve the average evaporation temperature obtained in step S36. Then, in step S38, controller 100 changes the operation frequency of compressor 10 to achieve pressure PL.

[0068] That is, controller 100 controls compressor 10 by using a pressure corresponding to a saturation temperature suitable for the detected composition as a target value of pressure PL on the inlet side of compressor 10.

[0069] When the processing in step S38 or step S41 is completed, the control returns to the flowchart in Fig. 3 in step S42. In the case of the non-azeotropic refrigerant, the flowchart in Fig. 3 is repeatedly performed, and thus, the control of compressor 10 is performed in accordance with the composition of the circulating refrigerant, when an amount of the liquid in receiver 30 changes. As described above, controller 100 is configured to reflect a change in composition of the refrigerant in the control and maintain the refrigeration capacity of the refrigeration cycle apparatus when the non-azeotropic refrigerant is used as the refrigerant.

[0070] In the refrigeration cycle apparatus according to the first embodiment described above, a refrigerant shortage can be detected before the receiver becomes empty, i.e., when an amount of leakage of the refrigerant is small.

[0071] In addition, a reduction in refrigeration capacity caused by erroneous setting of the type of the refrigerant in the multiple-refrigerant-using apparatus can be prevented.

[0072] Furthermore, when the non-azeotropic refrigerant is used, a change in composition of the refrigerant can be reflected in the control and the refrigeration capacity of the refrigeration cycle apparatus can be maintained. In addition, the injection flow path, which is a standard circuit for controlling a discharge temperature of a refrigerator, and heat exchanger 40 are used during detection of the composition of the refrigerant, and thus, a low-cost and space-saving refrigerator can be achieved without adding a special composition detection circuit.

Second Embodiment

[0073] Fig. 13 shows a configuration of a refrigeration cycle apparatus 101 according to a second embodiment. Referring to Fig. 13, refrigeration cycle apparatus 101 includes an outdoor unit 102, load device 3, and extension pipes 84 and 88. Load device 3 is configured similarly to that in the first embodiment.

[0074] Outdoor unit 102 of refrigeration cycle apparatus 101 is connectable to load device 3 by extension pipes 84 and 88.

[0075] Outdoor unit 102 includes compressor 10, condenser 20, heat exchanger 40, receiver 30, and pipes 80 to 83 and 89. Load device 3 and a flow path from compressor 10 to first passage H1 of heat exchanger 40 via condenser 20 and receiver 30 form a circulation flow path through which refrigerant circulates. The circulation flow path, i.e., "main circuit" is configured similarly to that of refrigeration cycle apparatus 1 according to the first embodiment.

[0076] Outdoor unit 102 further includes first refrigerant flow path 91, second expansion valve 92 disposed on first refrigerant flow path 91, and second refrigerant flow path 94. In refrigeration cycle apparatus 1 according to the first embodiment shown in Fig. 1, "injection flow path", which is a flow path that branches off from the main circuit and delivers the refrigerant to compressor 10 via second passage H2, is connected to the intermediate pressure port of compressor 10. In contrast, in refrigeration cycle apparatus 101 according to the second embodiment, the injection flow path is connected to a suction port of compressor 10. In this case, controller 100 can perform detection of a refrigerant shortage, identification of the refrigerant, and detection of the composition of the refrigerant by using pressure PL detected by pressure sensor 110, instead of pressure PM detected by pressure sensor 112 in Fig. 1.

[0077] In outdoor unit 102 of refrigeration cycle apparatus 101 shown in Fig. 13, second refrigerant flow path 94 is configured to cause the refrigerant to flow from the outlet of second passage H2 to suction port G1 of compressor 10.

[0078] With such a configuration, similarly to the first embodiment, it is possible to omit pressure sensor 112 in the first embodiment, while achieving detection of a refrigerant shortage for finding refrigerant leakage in an early stage, automatic identification between pseudo-azeotropic refrigerant and non-azeotropic refrigerant, and detection of the composition for maintaining the capacity when the composition changes.

Third Embodiment

[0079] In the second embodiment, description has been given of the example in which the injection flow path is connected to the suction port instead of the intermediate pressure port of the compressor. In a third embodiment, description will be given of an example in which a branch portion b of the injection flow path is changed from the receiver to an outlet pipe portion of the receiver.

[0080] Fig. 14 shows a configuration of a refrigeration cycle apparatus 201 according to the third embodiment. Referring to Fig. 14, refrigeration cycle apparatus 201 includes an outdoor unit 202, load device 3, and extension pipes 84 and 88. Load device 3 is configured similarly to that in each of the first and second embodiments.

[0081] Outdoor unit 202 of refrigeration cycle apparatus 201 is connectable to load device 3 by extension pipes 84 and 88.

[0082] Outdoor unit 202 includes compressor 10, condenser 20, heat exchanger 40, receiver 30, and pipes 80 to 83 and 89. Load device 3 and a flow path from compressor 10 to first passage H1 of heat exchanger 40 via condenser 20 and receiver 30 form a circulation flow path through which refrigerant circulates. The circulation flow path, i.e., "main circuit" is configured similarly to that of each of refrigeration cycle apparatus 1 according to the first embodiment and refrigeration cycle apparatus 101 according to the second embodiment.

[0083] Outdoor unit 102 further includes first refrigerant flow path 91, second expansion valve 92 disposed on first refrigerant flow path 91, and second refrigerant flow path 94. In refrigeration cycle apparatus 1 according to the first embodiment shown in Fig. 1, "injection flow path", which is a flow path that branches off from the main circuit and delivers the refrigerant to compressor 10 via second passage H2, branches off from receiver 30. In contrast, in refrigeration cycle apparatus 201 according to the third embodiment, the injection flow path branches off from a portion where a rising pipe 95 is connected to pipe 82 connected to the outlet of receiver 30.

[0084] In refrigeration cycle apparatus 201 shown in Fig. 14, outdoor unit 202 further includes rising pipe 95 configured to branch off from the outlet pipe of receiver 30. First refrigerant flow path 91 is configured to cause the refrigerant to flow from rising pipe 95 to the inlet of second passage H2.

[0085] Because of branching by rising pipe 95, when the refrigerant leaks and a refrigerant shortage occurs, the two-phase refrigerant mixed with the gas refrigerant is introduced into first refrigerant flow path 91, similarly to the case of branching from receiver 30. Therefore, detection of a refrigerant shortage, identification of the refrigerant, and detection of the composition of the refrigerant can be performed by the control similar to that in the first embodiment.

[0086] In addition, since the configuration in which receiver 30 is provided with the two outlet pipes as in the first embodiment is expensive to process, the refrigeration cycle apparatus can be implemented more inexpensively in the case of the configuration in which rising pipe 95 is provided.

[0087] Similarly to the second embodiment, the injection flow path may be connected to the suction port of compressor 10 instead of the intermediate pressure port of compressor 10.

[0088] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims, rather than the description of the embodiments above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0089] 1, 101, 201 refrigeration cycle apparatus; 2, 102, 202 outdoor unit; 3 load device; 10 compressor; 20 condenser; 30 receiver; 31 housing; 40 heat exchanger; 50 first expansion valve; 60 evaporator; 80, 81, 82, 83, 85, 86, 87, 89, 93 pipe; 84, 88 extension pipe; 91, 94 flow path; 92 second expansion valve; 95 rising pipe; 100 controller; 104 memory; 110, 111, 112 pressure sensor; 121, 122, 123 temperature sensor; G1 suction port; G2 discharge port; G3 intermediate pressure port; H1 first passage; H2 second passage; IP1 inlet pipe; OP1 first outlet pipe; OP2 second outlet pipe.

Claims

1. An outdoor unit of a refrigeration cycle apparatus, the outdoor unit being connectable to a load device including a first expansion valve and an evaporator, the outdoor unit comprising:

a compressor;
a condenser;
a heat exchanger having a first passage and a second passage, the heat exchanger being configured to exchange heat between refrigerant flowing in the first passage and the refrigerant flowing in the second passage; and
a receiver disposed between the condenser and the first passage of the heat exchanger, the receiver being configured to store the refrigerant, wherein
the load device and a flow path from the compressor to the first passage of the heat exchanger via the condenser and the receiver form a circulation flow path through which the refrigerant circulates,
the outdoor unit further comprising:

a first refrigerant flow path configured to cause the refrigerant to flow from the receiver or an outlet pipe of the receiver on the circulation flow path to an inlet of the second passage;
a second expansion valve disposed on the first refrigerant flow path; and
a second refrigerant flow path configured to cause the refrigerant to flow from an outlet of the second passage to the compressor.

2. The outdoor unit according to claim 1, wherein

the outlet pipe is a first outlet pipe,
the receiver has a second outlet pipe different from the first outlet pipe,
the first refrigerant flow path is configured to cause the refrigerant to flow from the second outlet pipe to the inlet of the second passage, and
in the receiver, an inlet port of the second outlet pipe is disposed at a position higher than an inlet port of the first outlet pipe.

3. The outdoor unit according to claim 1, wherein

the compressor has a suction port, a discharge port and an intermediate pressure port,
the compressor is configured to suction from the suction port the refrigerant having passed through the evaporator and discharge the refrigerant from the discharge port toward the condenser, and
the second refrigerant flow path is configured to cause the refrigerant to flow from the outlet of the second passage to the intermediate pressure port of the compressor.

4. The outdoor unit according to claim 1, wherein
the second refrigerant flow path is configured to cause the refrigerant to flow from the outlet of the second passage to a suction port of the compressor.

5. The outdoor unit according to claim 1, further comprising

a rising pipe configured to branch off from the outlet pipe of the receiver, wherein
the first refrigerant flow path is configured to cause the refrigerant to flow from the rising pipe to the inlet of the second passage.

6. The outdoor unit according to claim 1, further comprising a controller configured to control the outdoor unit, wherein
the controller is configured to:

a) determine an amount of the refrigerant enclosed in the refrigeration cycle apparatus;
b) determine a type of the refrigerant enclosed in the refrigeration cycle apparatus; and

c) perform control of the outdoor unit corresponding to the type of the refrigerant enclosed in the refrigeration cycle apparatus.

7. The outdoor unit according to claim 6, wherein the controller is configured to reflect a change in composition of the refrigerant in the control and maintain a refrigeration capacity of the refrigeration cycle apparatus, when non-azeotropic refrigerant is used as the refrigerant.

8. A refrigeration cycle apparatus comprising:

the outdoor unit as recited in any one of claims 1 to 7; and
the load device.

9. A refrigerator comprising the refrigeration cycle apparatus as recited in claim 8.

FIG.1

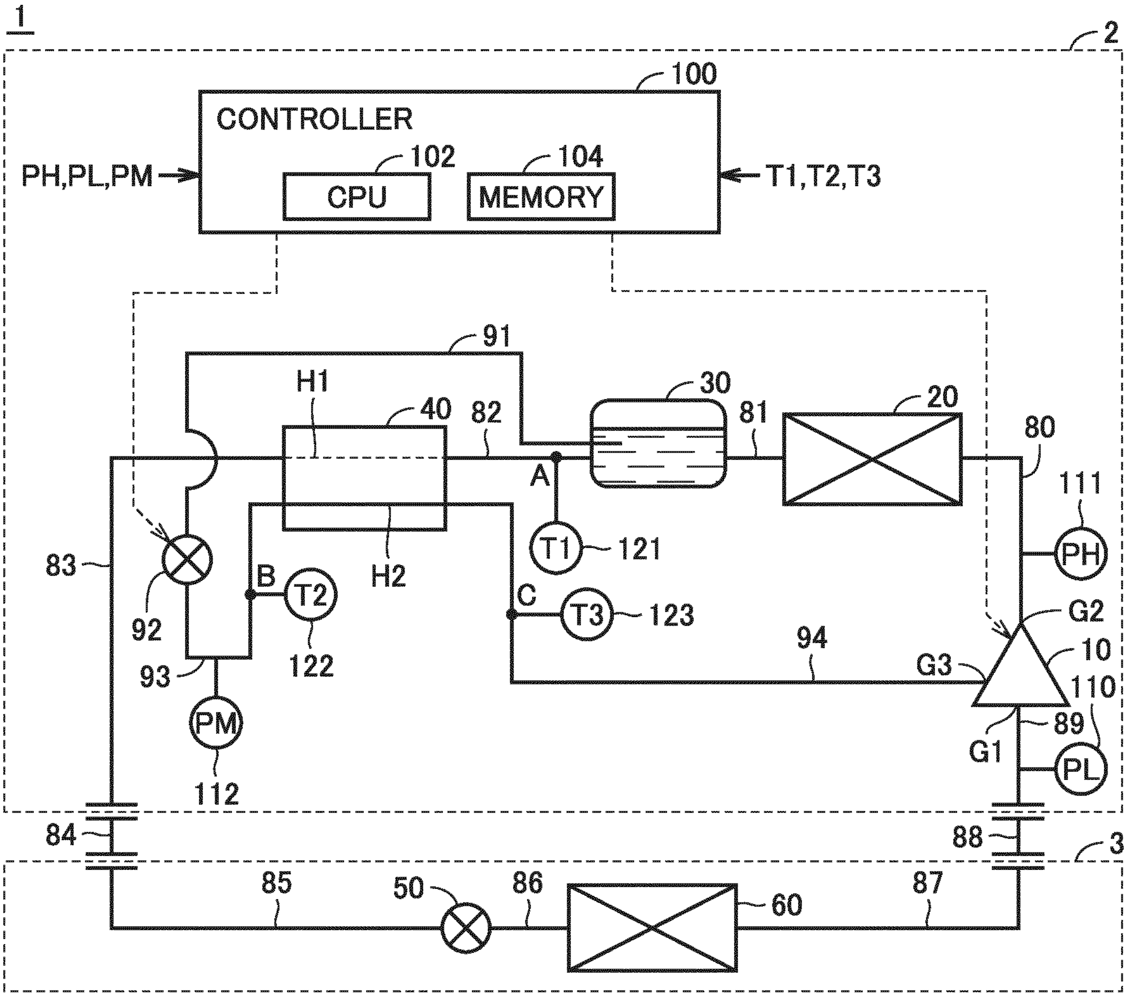

1
2
100
CONTROLLER
102
104
CPU
MEMORY
PH,PL,PM
T1,T2,T3
91
H1
40
82
30
81
20
80
111
A
T1
121
PH
83
92
B
T2
H2
C
T3
123
G2
10
94
G3
110
93
122
89
PM
G1
PL
112
84
88
3
85
50
86
87
60

FIG.2

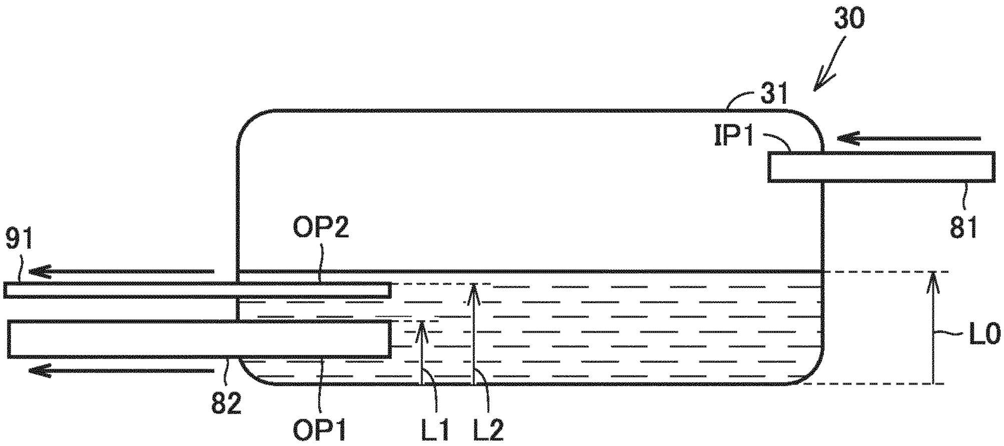

30
31
IP1
81
91
OP2
L0
82
OP1
L1
L2

FIG.3

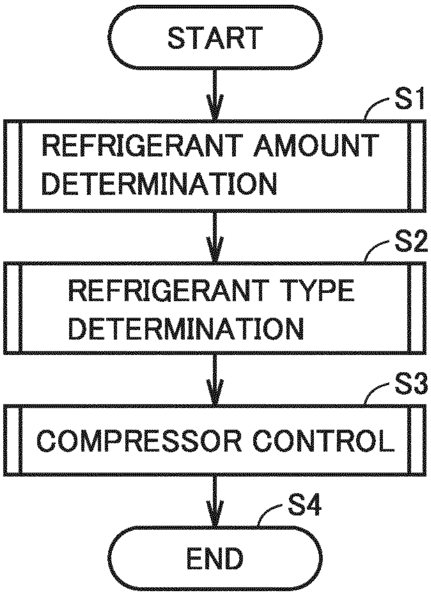

START
S1
REFRIGERANT AMOUNT DETERMINATION
S2
REFRIGERANT TYPE DETERMINATION
S3
COMPRESSOR CONTROL
S4
END

FIG.4

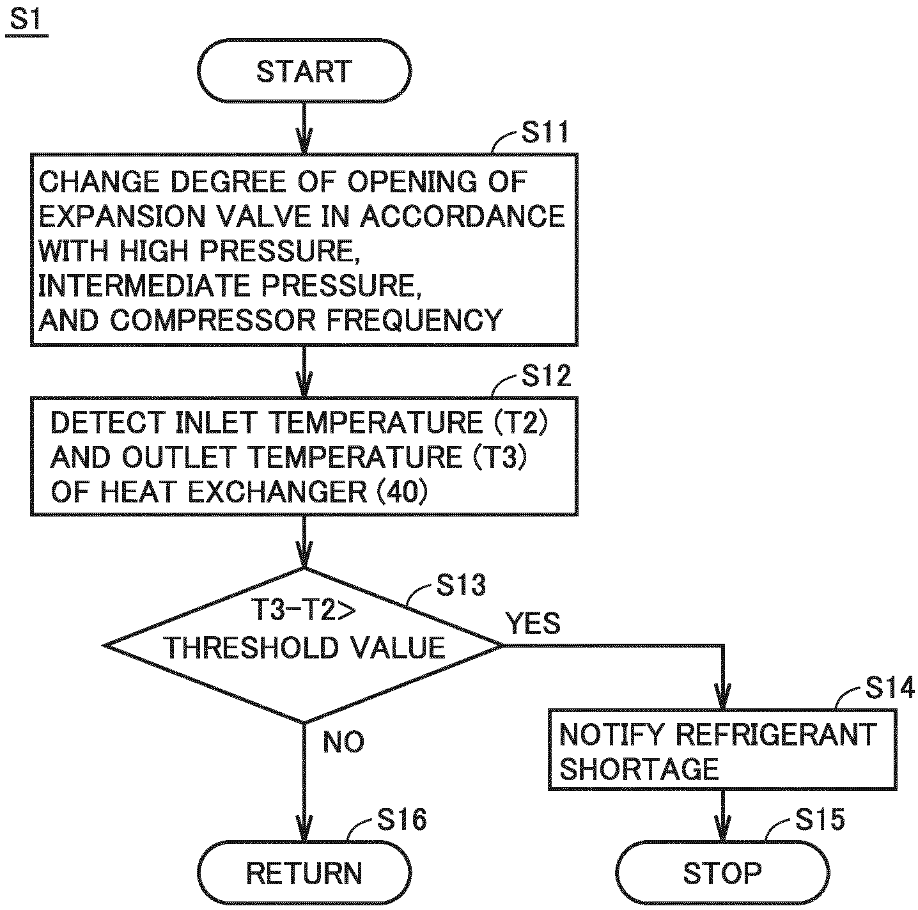

S1
START
S11
CHANGE DEGREE OF OPENING OF EXPANSION VALVE IN ACCORDANCE WITH HIGH PRESSURE, INTERMEDIATE PRESSURE, AND COMPRESSOR FREQUENCY
S12
DETECT INLET TEMPERATURE (T2) AND OUTLET TEMPERATURE (T3) OF HEAT EXCHANGER (40)
S13
T3−T2> THRESHOLD VALUE
YES
NO
S14
NOTIFY REFRIGERANT SHORTAGE
S15
STOP
S16
RETURN

FIG.5

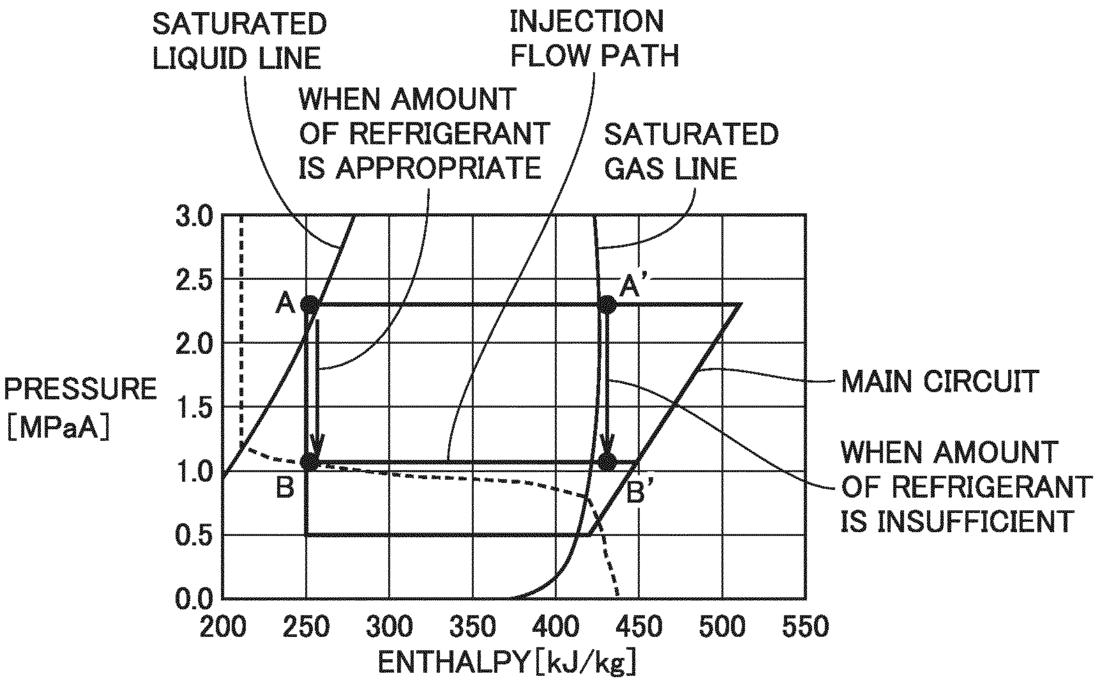

SATURATED
LIQUID LINE
WHEN AMOUNT
OF REFRIGERANT
IS APPROPRIATE
INJECTION
FLOW PATH
SATURATED
GAS LINE
3.0
2.5
2.0
1.5
1.0
0.5
0.0
A
A'
B
B'
PRESSURE
[MPaA]
MAIN CIRCUIT
WHEN AMOUNT
OF REFRIGERANT
IS INSUFFICIENT
200
250
300
350
400
450
500
550
ENTHALPY[kJ/kg]

FIG.6

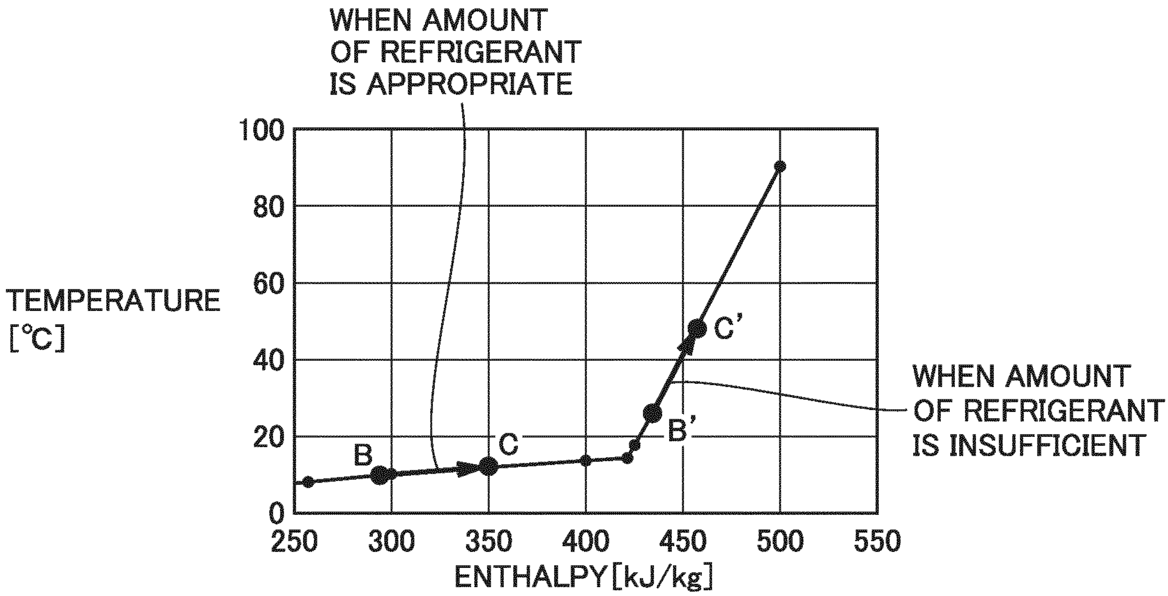

WHEN AMOUNT
OF REFRIGERANT
IS APPROPRIATE
100
80
60
40
20
0
TEMPERATURE
[℃]
B
C
B'
C'
WHEN AMOUNT
OF REFRIGERANT
IS INSUFFICIENT
250
300
350
400
450
500
550
ENTHALPY[kJ/kg]

FIG.7

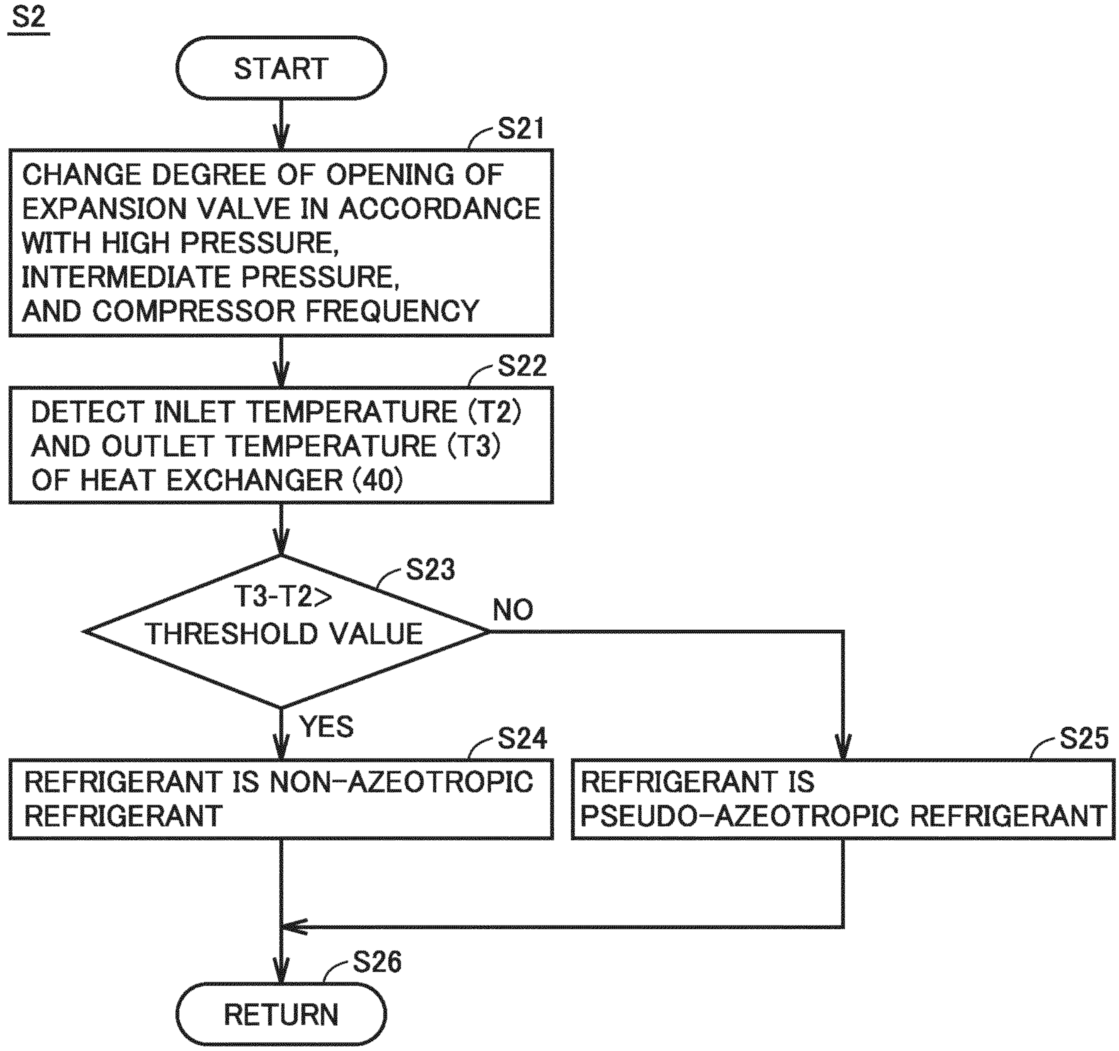

S2
START
S21
CHANGE DEGREE OF OPENING OF EXPANSION VALVE IN ACCORDANCE WITH HIGH PRESSURE, INTERMEDIATE PRESSURE, AND COMPRESSOR FREQUENCY
S22
DETECT INLET TEMPERATURE (T2) AND OUTLET TEMPERATURE (T3) OF HEAT EXCHANGER (40)
S23
T3-T2> THRESHOLD VALUE
NO
YES
S24
REFRIGERANT IS NON-AZEOTROPIC REFRIGERANT
S25
REFRIGERANT IS PSEUDO-AZEOTROPIC REFRIGERANT
S26
RETURN

FIG.8

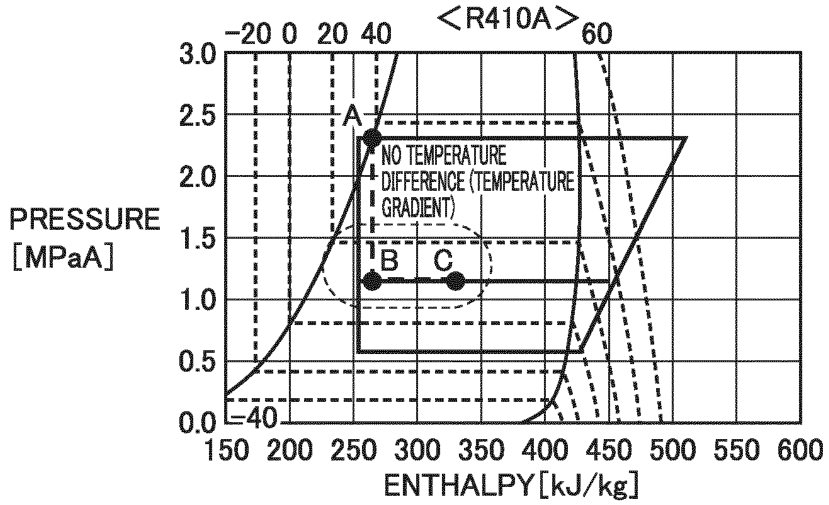

<R410A>
-20 0 20 40
60
-40
A
B
C
NO TEMPERATURE DIFFERENCE (TEMPERATURE GRADIENT)
PRESSURE [MPaA]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
150 200 250 300 350 400 450 500 550 600
ENTHALPY [kJ/kg]

FIG.9

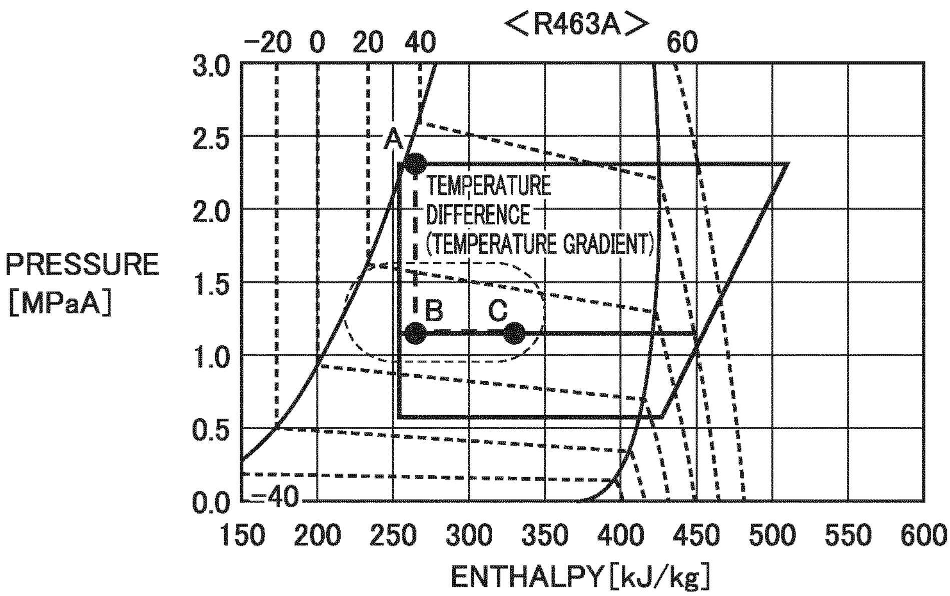

<R463A>
-20
0
20
40
60
-40
3.0
2.5
2.0
1.5
1.0
0.5
0.0
PRESSURE [MPaA]
150
200
250
300
350
400
450
500
550
600
ENTHALPY[kJ/kg]
A
B
C
TEMPERATURE DIFFERENCE (TEMPERATURE GRADIENT)

FIG.10

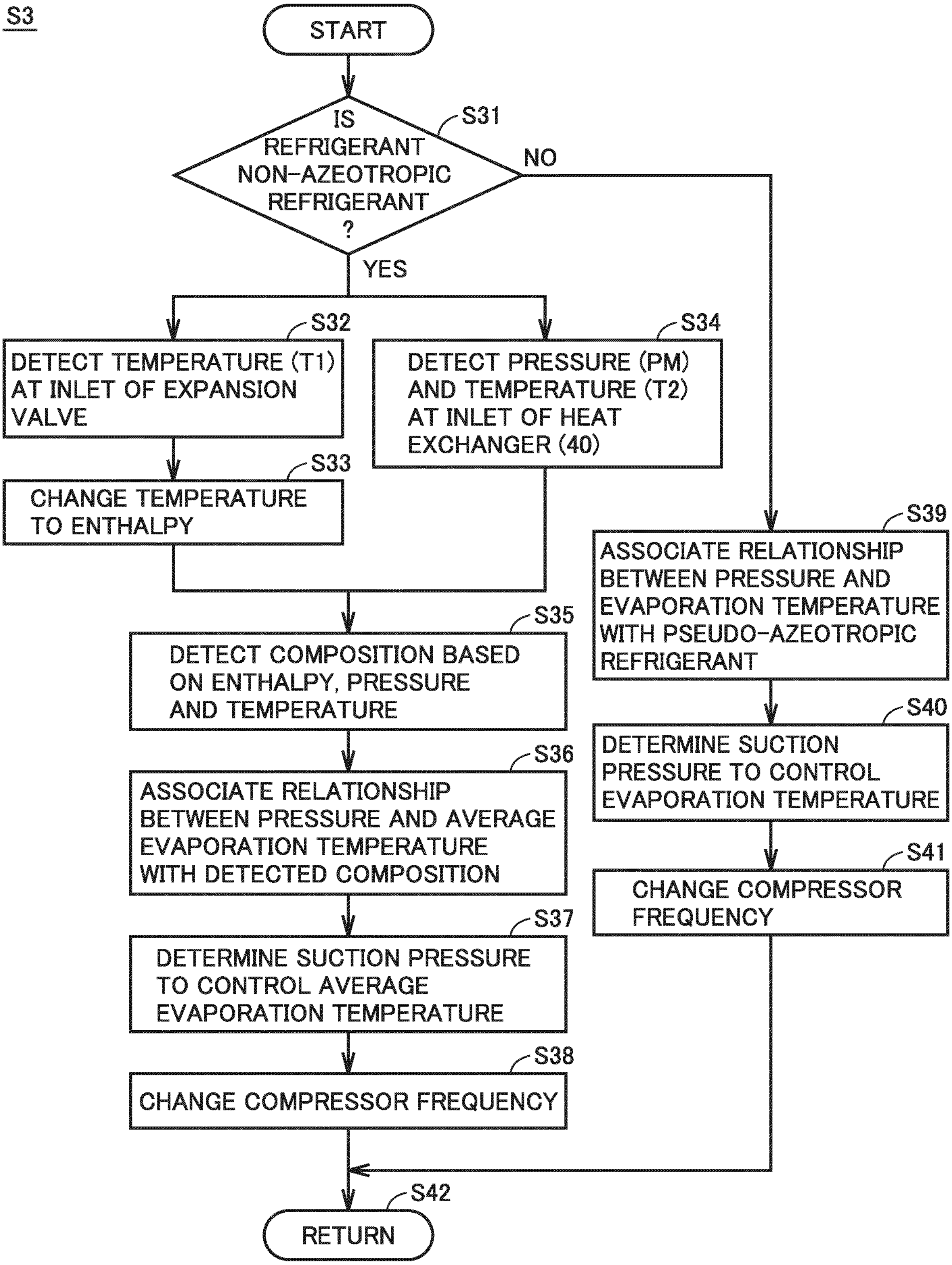

S3
START
IS REFRIGERANT NON-AZEOTROPIC REFRIGERANT ?
S31
NO
YES
S32
DETECT TEMPERATURE (T1) AT INLET OF EXPANSION VALVE
S33
CHANGE TEMPERATURE TO ENTHALPY
S34
DETECT PRESSURE (PM) AND TEMPERATURE (T2) AT INLET OF HEAT EXCHANGER (40)
S35
DETECT COMPOSITION BASED ON ENTHALPY, PRESSURE AND TEMPERATURE
S36
ASSOCIATE RELATIONSHIP BETWEEN PRESSURE AND AVERAGE EVAPORATION TEMPERATURE WITH DETECTED COMPOSITION
S37
DETERMINE SUCTION PRESSURE TO CONTROL AVERAGE EVAPORATION TEMPERATURE
S38
CHANGE COMPRESSOR FREQUENCY
S39
ASSOCIATE RELATIONSHIP BETWEEN PRESSURE AND EVAPORATION TEMPERATURE WITH PSEUDO-AZEOTROPIC REFRIGERANT
S40
DETERMINE SUCTION PRESSURE TO CONTROL EVAPORATION TEMPERATURE
S41
CHANGE COMPRESSOR FREQUENCY
S42
RETURN

FIG.11

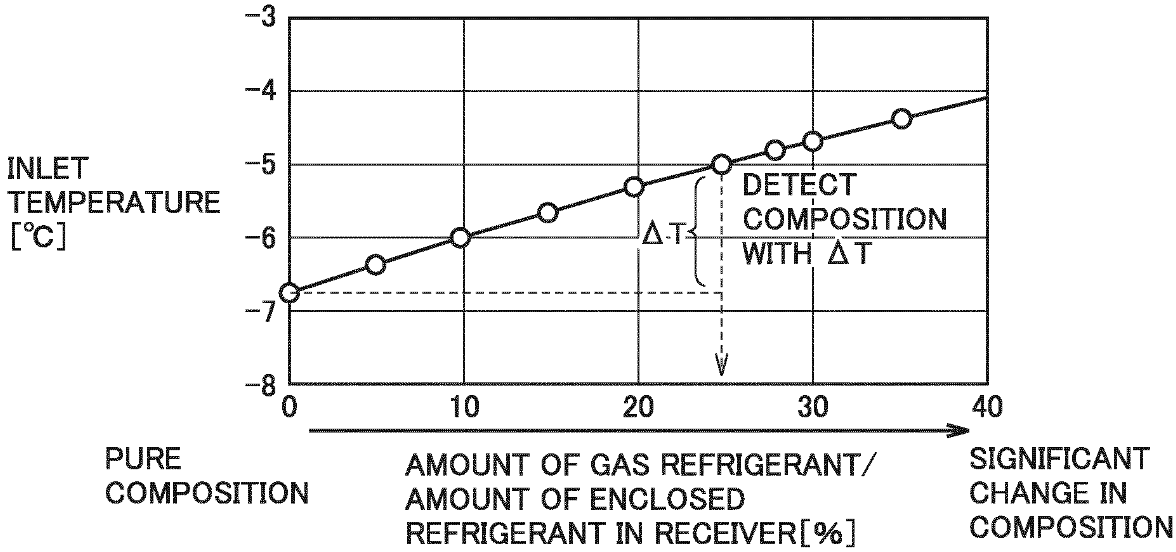

INLET
TEMPERATURE
[°C]
-3
-4
-5
-6
-7
-8
0
10
20
30
40
ΔT
DETECT
COMPOSITION
WITH ΔT
PURE
COMPOSITION
AMOUNT OF GAS REFRIGERANT/
AMOUNT OF ENCLOSED
REFRIGERANT IN RECEIVER[%]
SIGNIFICANT
CHANGE IN
COMPOSITION

FIG.12

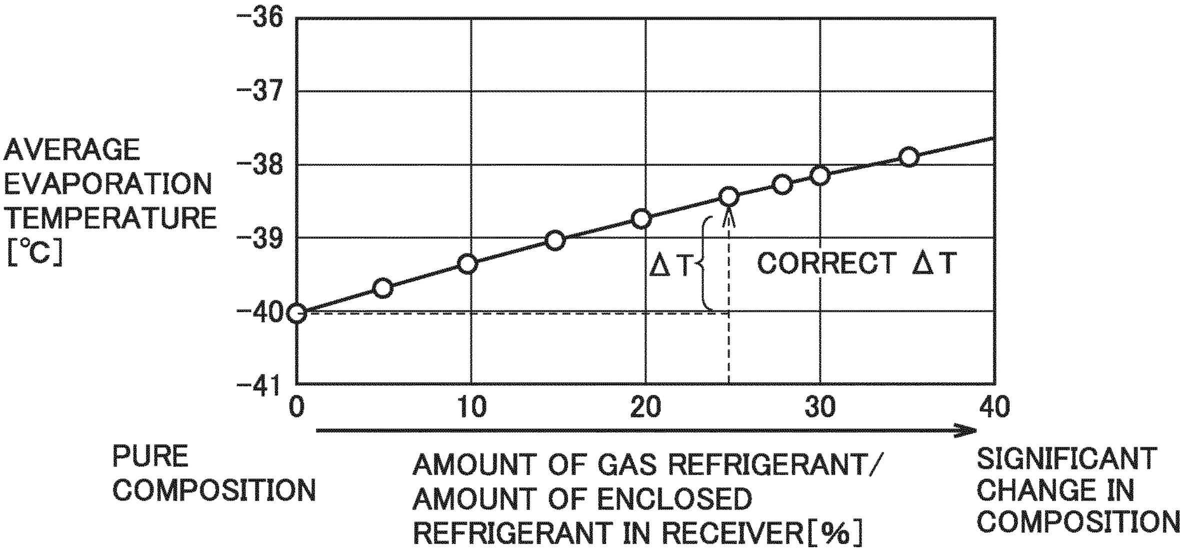

AVERAGE
EVAPORATION
TEMPERATURE
[°C]
-36
-37
-38
-39
-40
-41
0
10
20
30
40
ΔT
CORRECT ΔT
PURE
COMPOSITION
AMOUNT OF GAS REFRIGERANT/
AMOUNT OF ENCLOSED
REFRIGERANT IN RECEIVER[%]
SIGNIFICANT
CHANGE IN
COMPOSITION

FIG.13

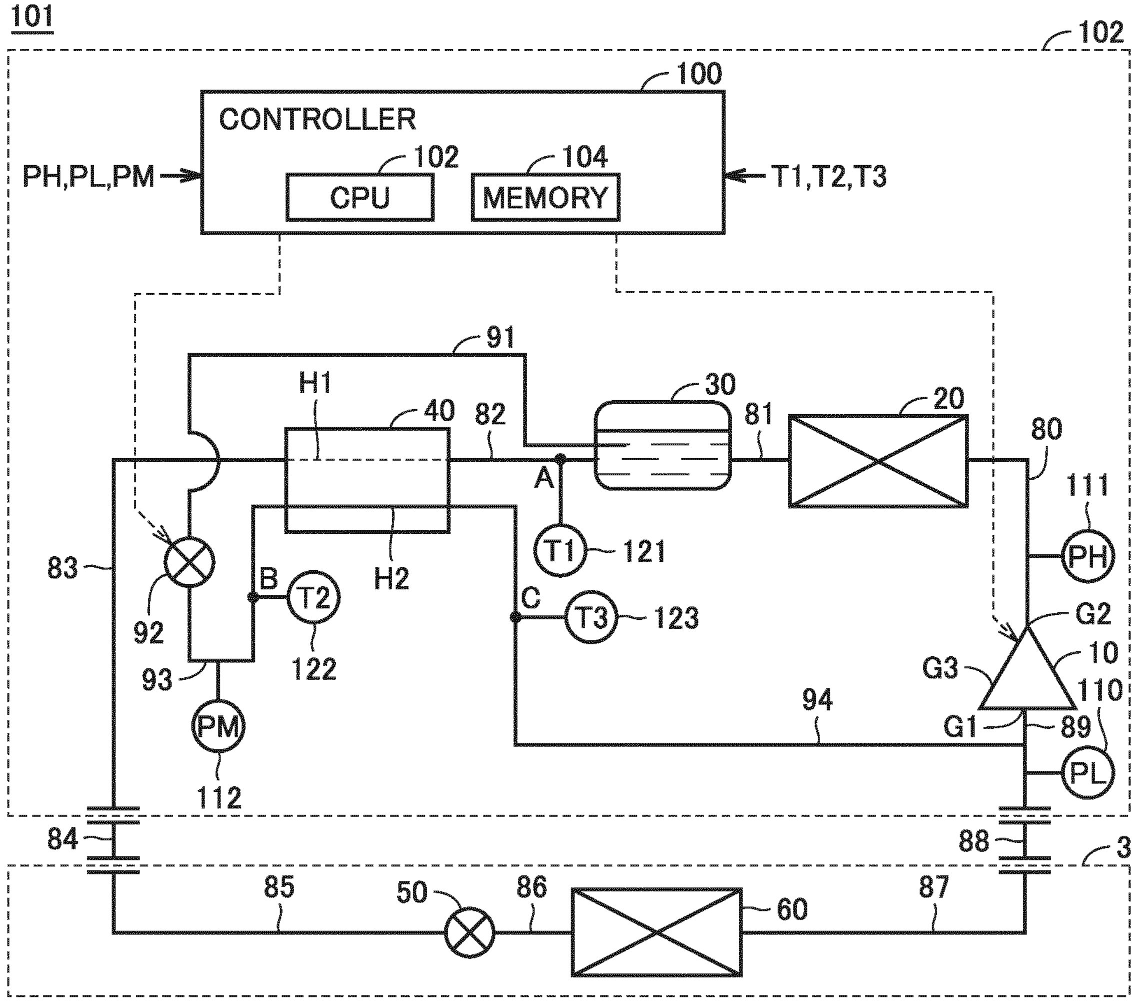
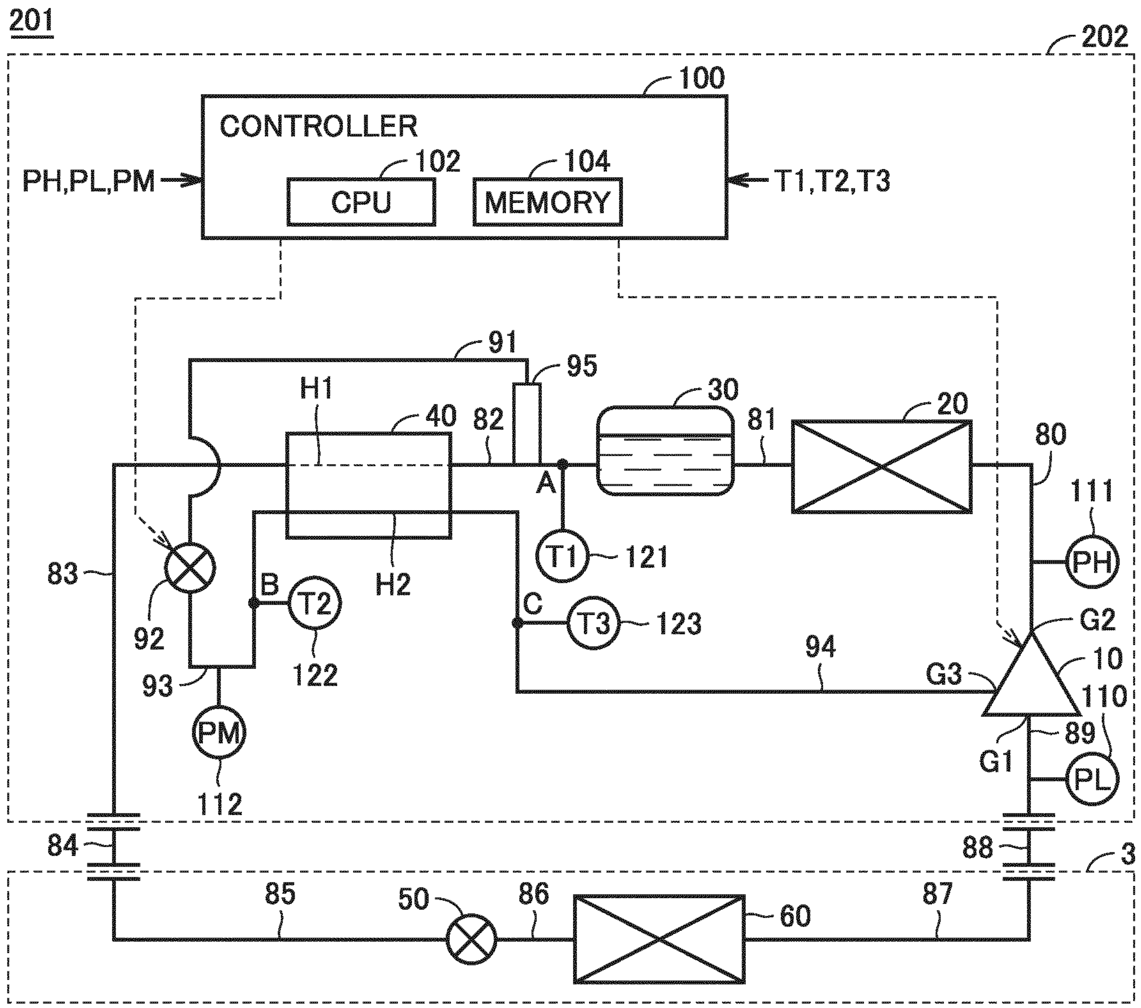

101
102
100
CONTROLLER
102
104
PH,PL,PM
CPU
MEMORY
T1,T2,T3
91
30
20
H1
40
82
81
80
A
111
PH
83
92
B
T2
H2
C
T3
123
T1
121
G2
10
G3
110
94
G1
89
93
122
PM
112
PL
84
88
3
85
50
86
60
87

FIG.14


201
202
100
CONTROLLER
102
CPU
104
MEMORY
PH,PL,PM
T1,T2,T3
91
95
30
20
H1
40
82
81
80
A
111
PH
T1
121
83
B
T2
H2
C
T3
123
G2
92
94
10
93
122
G3
110
PM
89
G1
PL
112
84
88
3
85
50
86
87
60

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/024585

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F25B43/00(2006.01)i, F25B1/00(2006.01)i, F25B49/02(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)
Int. Cl. F25B43/00, F25B1/00, F25B49/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

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 A	JP 4864110 B2 (MITSUBISHI ELECTRIC CORP.) 01 February 2012, paragraphs [0001]-[0168], fig. 1-17 (Family: none)	1, 3, 8-9 2, 4-5 6-7
Y A	JP 2005-308393 A (DAIKIN INDUSTRIES, LTD.) 04 November 2005, paragraphs [0001]-[0057], fig. 1-15 (Family: none)	2, 4 1, 3, 5-9
Y A	JP 2007-139244 A (FUJITSU GENERAL LTD.) 07 June 2007, paragraphs [0001]-[0069], fig. 1-7 (Family: none)	2 1, 3-9
Y	JP 2015-34736 A (AZBIL CORP.) 19 February 2015, paragraphs [0025], [0026], [0044]-[0047] & WO 2015/020023 A1	5

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

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"O" document referring to an oral disclosure, use, exhibition or other means
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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
05.08.2019	20.08.2019

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

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/024585

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-2801 A (PANASONIC CORP.) 07 January 2013, paragraphs [0001]-[0059], fig. 1-6 (Family: none)	1-9
A	JP 7-63430 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 10 March 1995, paragraphs [0001]-[0038], fig. 1-12 (Family: none)	1-9
A	US 2009/0235675 A1 (LG ELECTRONICS INC.) 24 September 2009, paragraphs [0002]-[0063], fig. 1-5 & EP 2103889 A2 & KR 10-2009-0100859 A & CN 101539316 A	1-9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5505477 B **[0002] [0003] [0004]**