(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 951 288 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
09.02.2022 Bulletin 2022/06

(21) Application number: **19922100.3**

(22) Date of filing: **26.03.2019**

(51) International Patent Classification (IPC):
F25B 49/02 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25B 49/02

(86) International application number:
PCT/JP2019/012745

(87) International publication number:
WO 2020/194490 (01.10.2020 Gazette 2020/40)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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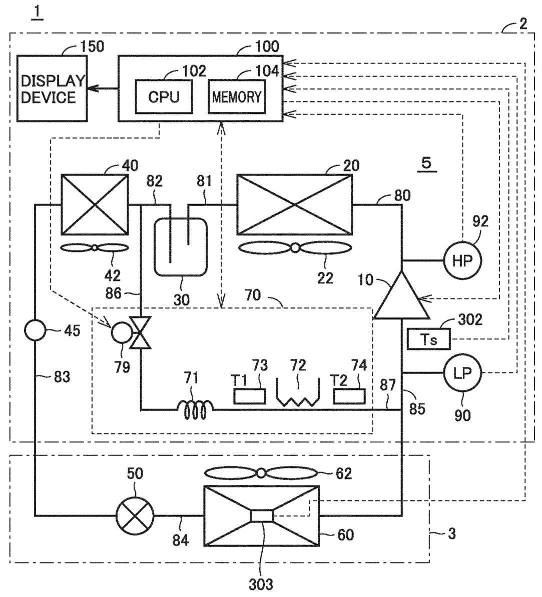
(54) OUTDOOR UNIT AND REFRIGERATION CYCLE DEVICE EQUIPPED WITH SAME

(57) An outdoor unit (2) is connected with an indoor unit (3) to form a refrigeration cycle apparatus (1). The outdoor unit (2) includes a compressor (10), a condenser (20), and a control device (100). The compressor (10) and the condenser (20) form a refrigerant circuit (5) through which refrigerant circulates, together with an expansion mechanism (50) and an evaporator (60) included in the indoor unit (3). The control device (100) determines whether or not the refrigerant circulating through the refrigerant circuit (5) is insufficient, and when the control device (100) determines that the refrigerant is insufficient, the control device (100) gives notice of one of liquid back operation, operation in which an evaporation temperature of the refrigerant is high, and leakage of the refrigerant from the refrigerant circuit, as a factor in determining that the refrigerant is insufficient.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an outdoor unit and a refrigeration cycle apparatus including the same.

BACKGROUND ART

[0002] Japanese Patent Laying-Open No. 2012-132639 (PTL 1) discloses a refrigeration cycle apparatus. An outdoor unit of the refrigeration cycle apparatus includes a compressor, an oil separator, a condenser, a liquid receiver, a supercooling heat exchanger, and an accumulator. An indoor unit thereof includes an expansion valve and an evaporator. In this refrigeration cycle apparatus, suitability of the amount of refrigerant charged into a refrigerant circuit is determined based on the temperature efficiency of the supercooling heat exchanger. The temperature efficiency is a value obtained by dividing a supercooling degree of the refrigerant at an outlet of the supercooling heat exchanger by a maximum temperature difference in the supercooling heat exchanger. With this refrigeration cycle apparatus, it is possible to determine shortage of the refrigerant circulating through the refrigerant circuit.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2012-132639

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] When it is determined that refrigerant circulating through a refrigerant circuit is insufficient, there are various causes, including leakage of the refrigerant. However, the refrigeration cycle apparatus of PTL 1 cannot give notice of a factor determined as shortage of the refrigerant circulating through the refrigerant circuit. As a result, an on-site operator cannot take measures corresponding to the factor determined as shortage of the refrigerant circulating through the refrigerant circuit.

[0005] The present disclosure has been made to solve such a problem, and an object of the present disclosure is to provide an outdoor unit that can determine shortage of refrigerant circulating through a refrigerant circuit and can also give notice of a factor in the shortage of the refrigerant, and a refrigeration cycle apparatus including the same.

SOLUTION TO PROBLEM

[0006] An outdoor unit of the present disclosure is an outdoor unit connected with an indoor unit to form a refrigeration cycle apparatus, the outdoor unit including a compressor to compress refrigerant, and a condenser to condense the refrigerant outputted from the compressor. The compressor and the condenser form a refrigerant circuit through which the refrigerant circulates, together with an expansion mechanism and an evaporator included in the indoor unit. The outdoor unit further includes a control device to determine whether or not the refrigerant circulating through the refrigerant circuit is insufficient, and when the control device determines that the refrigerant is insufficient, to give notice of one of liquid back operation, operation in which an evaporation temperature of the refrigerant is high, and leakage of the refrigerant from the refrigerant circuit, as a factor in determining that the refrigerant is insufficient.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] According to the outdoor unit of the present disclosure and the refrigeration cycle apparatus including the same, it is possible to determine shortage of refrigerant circulating through a refrigerant circuit, and also to give notice of a factor in the shortage of the refrigerant.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a first embodiment is used.
Fig. 2 is a diagram conceptually showing the state of refrigerant in the vicinity of a heater in a normal condition where shortage of the refrigerant does not occur.
Fig. 3 is a diagram showing an example of a change in refrigerant temperature caused by the heater in the normal condition.
Fig. 4 is a diagram conceptually showing the state of the refrigerant in the vicinity of the heater when the refrigerant is insufficient.
Fig. 5 is a diagram showing an example of a change in refrigerant temperature caused by the heater when the refrigerant is insufficient.
Fig. 6 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by a control device in the first embodiment.
Fig. 7 is a diagram schematically showing a structure of the outdoor unit.
Fig. 8 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a second embodiment is used.
Fig. 9 is a flowchart showing an example of a

processing procedure for determining shortage of the refrigerant performed by a control device 100A in the second embodiment.

Fig. 10 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a third embodiment is used.

Fig. 11 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by a control device 100C in the third embodiment.

Fig. 12 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a fourth embodiment is used.

Fig. 13 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by a control device 100D in the fourth embodiment.

Fig. 14 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a fifth embodiment is used.

Fig. 15 is a diagram for describing processing for determining shortage of the refrigerant performed by a control device in the fifth embodiment.

Fig. 16 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by a control device 100B in the fifth embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the drawings. Although a plurality of embodiments will be described below, it is originally intended from the time of filing the present application to combine features described in the embodiments as appropriate. It should be noted that identical or corresponding parts in the drawings will be designated by the same reference characters, and the description thereof will not be repeated.

First Embodiment

[0010] Fig. 1 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a first embodiment is used. Fig. 1 functionally shows the connection relation and the arrangement configuration of devices in the refrigeration cycle apparatus, and does not necessarily show an arrangement in a physical space.

[0011] Referring to Fig. 1, a refrigeration cycle apparatus 1 includes an outdoor unit 2 and an indoor unit 3. Outdoor unit 2 includes a compressor 10, a condenser 20, a fan 22, a liquid reservoir 30, a supercooling heat exchanger 40, a fan 42, a sight glass 45, and pipes 80 to 83 and 85. Outdoor unit 2 further includes pipes 86 and 87, a refrigerant amount detection unit 70, a suction pressure sensor 90, a discharge pressure sensor 92, a control device 100, and a display device 150. Indoor unit 3 includes an expansion mechanism 50, an evaporator 60, a fan 62, and a pipe 84. Indoor unit 3 is connected to outdoor unit 2 through pipes 83 and 85.

[0012] Pipe 80 connects a discharge port of compressor 10 and condenser 20. Pipe 81 connects condenser 20 and liquid reservoir 30. Pipe 82 connects liquid reservoir 30 and supercooling heat exchanger 40. Pipe 83 connects supercooling heat exchanger 40 and expansion mechanism 50. Pipe 84 connects expansion mechanism 50 and evaporator 60. Pipe 85 connects evaporator 60 and a suction port of compressor 10. Pipe 86 connects pipe 82 and refrigerant amount detection unit 70. Pipe 87 connects refrigerant amount detection unit 70 and pipe 85.

[0013] Compressor 10 compresses refrigerant suctioned from pipe 85, and outputs the compressed refrigerant to pipe 80. Compressor 10 is configured to adjust the number of revolutions according to a control signal from control device 100. By adjusting the number of revolutions of compressor 10, a circulation amount of the refrigerant is adjusted, and the capability of refrigeration cycle apparatus 1 can be adjusted. As compressor 10, various types of compressors can be employed, and for example, a compressor of scroll type, rotary type, screw type, or the like can be employed.

[0014] Condenser 20 condenses the refrigerant outputted from compressor 10 to pipe 80, and outputs the condensed refrigerant to pipe 81. Condenser 20 is configured such that the high-temperature, high-pressure gas refrigerant outputted from compressor 10 performs heat exchange with outside air (heat dissipation). By this heat exchange, the refrigerant is condensed and transforms into a liquid phase. Fan 22 supplies the outside air with which the refrigerant performs heat exchange in condenser 20, to condenser 20. By adjusting the number of revolutions of fan 22, a refrigerant pressure on a discharge side of compressor 10 (a high pressure-side pressure) can be adjusted.

[0015] Liquid reservoir 30 stores the high-pressure liquid refrigerant condensed by condenser 20. Supercooling heat exchanger 40 is configured such that the liquid refrigerant outputted from liquid reservoir 30 to pipe 82 further performs heat exchange with the outside air (heat dissipation). The refrigerant passes through supercooling heat exchanger 40 and thereby becomes the supercooled liquid refrigerant. Fan 42 supplies the outside air with which the refrigerant performs heat exchange in supercooling heat exchanger 40, to supercooling heat exchanger 40. Sight glass 45 is a window for visually checking for air bubbles (flash gas) in the refrigerant flowing through pipe 83.

[0016] Expansion mechanism 50 decompresses the refrigerant outputted from supercooling heat exchanger 40 to pipe 83, and outputs the decompressed refrigerant to pipe 84. As expansion mechanism 50, an expansion valve can be used, for example. When the degree of opening of the expansion valve is changed in a closing direction, a refrigerant pressure on a discharge side of the expansion valve decreases, and the degree of dryness of the refrigerant increases. When the degree of opening of the expansion valve is changed in an opening direction, the refrigerant pressure on the discharge side of the expansion valve increases, and the degree of dryness of the refrigerant decreases. As expansion mechanism 50, a capillary tube may be used instead of the expansion valve.

[0017] Evaporator 60 evaporates the refrigerant outputted from expansion mechanism 50 to pipe 84, and outputs the evaporated refrigerant to pipe 85. Evaporator 60 is configured such that the refrigerant decompressed by expansion mechanism 50 performs heat exchange with air within indoor unit 3 (heat absorption). The refrigerant is evaporated by passing through evaporator 60, and becomes superheated steam. Fan 62 supplies the outside air with which the refrigerant performs heat exchange in evaporator 60, to evaporator 60.

[0018] Compressor 10, pipe 82, condenser 20, pipe 81, liquid reservoir 30, pipe 82, supercooling heat exchanger 40, pipe 83, expansion mechanism 50, pipe 84, evaporator 60, and pipe 85 form a refrigerant circuit 5 through which the refrigerant circulates.

[0019] Refrigerant amount detection unit 70 is provided between pipe 86 branched from pipe 82 and pipe 87 connected to pipe 85. Pipe 86, refrigerant amount detection unit 70, and pipe 87 constitute a "bypass circuit" that returns a portion of the refrigerant on a discharge side of condenser 20 to compressor 10 without passing through indoor unit 3.

[0020] Refrigerant amount detection unit 70 includes a capillary tube (decompression device) 71, a heater 72, and temperature sensors 73 and 74. Capillary tube 71 is connected between pipe 86 and pipe 87 to reduce the pressure of the refrigerant flowing to the bypass circuit. Capillary tube 71 is designed as appropriate, also in consideration of a heating amount of heater 72, such that, even when the liquid refrigerant is supplied from pipe 86 and the refrigerant that has passed through capillary tube 71 is heated by heater 72, the refrigerant is in a gas-liquid two-phase state without entering a gas single-phase state. It should be noted that an expansion valve may be used instead of capillary tube 71.

[0021] Heater 72 and temperature sensors 73 and 74 are provided at pipe 87. Heater 72 heats the refrigerant that has passed through capillary tube 71. The refrigerant heated by heater 72 has an increased enthalpy. The heating amount of heater 72 is set together with the specification of capillary tube 71, such that, even when the refrigerant that has passed through capillary tube 71 is heated by heater 72, the refrigerant is in the gas-liquid two-phase state without entering the gas single-phase state, as described above. Heater 72 may heat the refrigerant from the outside of pipe 87, or may be placed inside pipe 87 to further ensure heat transfer from heater 72 to the refrigerant. Heater 72 may always be set to an ON state when refrigeration cycle apparatus 1 is ON. Alternatively, heater 72 may be set to an ON state only during processing for determining shortage of the refrigerant. Alternatively, heater 72 may be set to an ON state only when compressor 10 is activated. The first embodiment describes a case where heater 72 is set to an ON state only during the processing for determining shortage of the refrigerant.

[0022] Further, refrigerant amount detection unit 70 further includes a solenoid valve 79. Solenoid valve 79 is provided at pipe 86 upstream of capillary tube 71, and is opened/closed according to an instruction from control device 100. When solenoid valve 79 is opened, the refrigerant flows to capillary tube 71 and pipe 87, and it becomes possible to detect shortage of the refrigerant. When solenoid valve 79 is closed, the flow of the refrigerant to capillary tube 71 and pipe 87 is blocked, and thus it is not possible to detect shortage of the refrigerant.

[0023] Solenoid valve 79 may always be set to an ON state when refrigeration cycle apparatus 1 is ON. Alternatively, solenoid valve 79 may be set to an ON state only during the processing for determining shortage of the refrigerant. The first embodiment describes a case where solenoid valve 79 is set to an ON state only during the processing for determining shortage of the refrigerant.

[0024] Although solenoid valve 79 is provided at pipe 86 in Fig. 1, solenoid valve 79 may be provided at pipe 87 downstream of capillary tube 71. However, it is preferable to provide solenoid valve 79 at pipe 86, because providing solenoid valve 79 on an upstream side in the bypass circuit can more reduce the amount of the liquid refrigerant staying in the bypass circuit in a normal condition. Further, it is more preferable to provide solenoid valve 79 at a position that is as close as possible to a branch portion where pipe 86 is branched from pipe 82.

[0025] Temperature sensor 73 detects a refrigerant temperature before heating the refrigerant by heater 72, that is, a temperature T1 of the refrigerant between capillary tube 71 and heater 72, and outputs a detection value thereof to control device 100. On the other hand, temperature sensor 74 detects a refrigerant temperature after heating the refrigerant by heater 72, that is, a temperature T2 of the refrigerant downstream of heater 72 and before merging into pipe 85, and outputs a detection value thereof to control device 100. Temperature sensors 73 and 74 may be placed outside pipe 87, or may be placed inside pipe 87 to more reliably detect the temperature of the refrigerant. The principle and the method of determining shortage of the refrigerant by refrigerant amount detection unit 70 will be described in detail later.

[0026] Suction pressure sensor 90 detects a suction pressure LP of the refrigerant within pipe 85, and outputs a detection value thereof to control device 100. That is, suction pressure sensor 90 detects refrigerant pressure (low pressure-side pressure) LP on a suction side of compressor 10. Discharge pressure sensor 92 detects a discharge pressure HP of the refrigerant within pipe 80, and outputs a detection value thereof to control device 100. That is, discharge pressure sensor 92 detects refrigerant pressure (high pressure-side pressure) HP on the discharge side of compressor 10.

[0027] A suction temperature sensor 302 is placed in the vicinity of a suction port of compressor 10. Suction temperature sensor 302 detects a suction temperature Ts of the refrigerant to be suctioned into compressor 10.

[0028] An evaporation temperature sensor 303 detects a temperature of the refrigerant flowing through evaporator 60 as an evaporation temperature Te of the refrigerant.

[0029] Control device 100 includes a CPU (Central Processing Unit) 102, a memory 104 (a ROM (Read Only Memory) and a RAM (Random Access Memory)), input/output buffers (not shown) for inputting/outputting various signals, and the like. CPU 102 expands programs stored in the ROM onto the RAM or the like and executes the programs. The programs stored in the ROM are programs describing processing procedures of control device 100. According to these programs, control device 100 performs control of the devices in outdoor unit 2. This control can be processed not only by software but also by dedicated hardware (electronic circuitry).

[0030] Display device 150 displays information such as the state of refrigeration cycle apparatus 1 transmitted from control device 100, in order to give notice to a user or an operator.

<Description of Determination of Shortage of Refrigerant>

[0031] In the following, a method of determining shortage of the refrigerant using refrigerant amount detection unit 70 will be described. It should be noted that shortage of the refrigerant occurs when an initial charging amount of the refrigerant into the refrigerant circuit is insufficient, or when leakage of the refrigerant occurs after the beginning of usage, or the like.

[0032] Fig. 2 is a diagram conceptually showing the state of the refrigerant in the vicinity of heater 72 in a normal condition where shortage of the refrigerant does not occur. It should be noted that, in the following, a condition where shortage of the refrigerant does not occur and a refrigerant amount is within an appropriate range may be simply referred to as a "normal condition".

[0033] Referring to Fig. 1 together with Fig. 2, in the normal condition where the refrigerant amount is appropriate, the refrigerant is substantially in a liquid-phase state at an outlet of condenser 20, and the liquid refrigerant is stored in liquid reservoir 30. Thereby, the liquid refrigerant flows to pipe 86, and the refrigerant that has passed through capillary tube 71 contains a liquid component in a large amount. Then, the refrigerant that has passed through capillary tube 71 is heated by heater 72, and the degree of dryness thereof increases.

[0034] Fig. 3 is a diagram showing an example of a change in refrigerant temperature caused by heater 72 in the normal condition. In Fig. 3, the axis of abscissas represents a position in a direction in which pipe 87 extends, and P1 and P2 represent positions where temperature sensors 73 and 74 are placed, respectively. The axis of ordinates represents a refrigerant temperature at each position in pipe 87. It should be noted that Fig. 3 shows a case where the refrigerant is an azeotropic refrigerant (i.e., a refrigerant having no temperature gradient; for example, a refrigerant such as R410a).

[0035] Referring to Fig. 3, in the normal condition, since the refrigerant that has passed through capillary tube 71 contains a liquid component in a large amount, the temperature of the refrigerant basically does not change even though the refrigerant is heated by heater 72 (heating energy is utilized to change the latent heat of the refrigerant). Therefore, temperature T2 of the refrigerant after heating the refrigerant by heater 72 is substantially equal to temperature T1 of the refrigerant before heating the refrigerant by heater 72.

[0036] It should be noted that, although not particularly shown, when the refrigerant is a non-azeotropic refrigerant (i.e., a refrigerant having a temperature gradient; for example, a refrigerant such as R407a, R448a, R449a, or R463a), the temperature of the refrigerant slightly increases (about 10 degrees at most) by heating by heater 72.

[0037] Fig. 4 is a diagram conceptually showing the state of the refrigerant in the vicinity of heater 72 when the refrigerant is insufficient. Referring to Fig. 1 together with Fig. 4, when the refrigerant is insufficient, the refrigerant is in the gas-liquid two-phase state at the outlet of condenser 20, and no or little liquid refrigerant is stored in liquid reservoir 30. Thereby, the gas-liquid two-phase refrigerant flows to pipe 86, and the refrigerant that has passed through capillary tube 71 contains a gas component in a large amount, when compared with the normal condition. Therefore, the refrigerant that has passed through capillary tube 71 is heated by heater 72 and is evaporated, and the temperature (superheating degree) thereof increases.

[0038] Fig. 5 is a diagram showing an example of a change in refrigerant temperature caused by heater 72 when the refrigerant is insufficient. Also in Fig. 5, the axis of abscissas represents a position in the direction in which pipe 87 extends, and P1 and P2 represent positions where temperature sensors 73 and 74 are placed, respectively. The axis of ordinates represents a refrigerant temperature at each position in pipe 87.

[0039] Referring to Fig. 5, when the refrigerant is insufficient, since the refrigerant that has passed through capillary tube 71 contains a gas component in a large amount, the refrigerant is evaporated and the temperature of the refrigerant increases (superheating degree > 0) when the refrigerant is heated by heater 72. Therefore, temperature T2 of the refrigerant after heating the refrigerant by heater 72 becomes higher than temperature T1 of the refrigerant before heating the refrigerant by heater 72.

[0040] It should be noted that, when the refrigerant is a non-azeotropic refrigerant, the heating amount of heater 72 is set as appropriate such that temperature increase of the refrigerant caused by heater 72 when the refrigerant is insufficient can be distinguished from temperature increase of the refrigerant caused by heater 72 in the normal condition (temperature increase based on the temperature gradient of the refrigerant).

[0041] In this manner, it is possible to determine whether or not shortage of the refrigerant occurs in the refrigerant circuit, based on a temperature increase amount of the refrigerant when the refrigerant is heated by heater 72 in refrigerant amount detection unit 70.

[0042] Control device 100 acquires suction temperature Ts of compressor 10 detected by suction temperature sensor 302. Control device 100 acquires suction pressure LP of compressor 10 detected by suction pressure sensor 90. Control device 100 calculates a saturation temperature ST(LP) of suction pressure LP. Control device 100 calculates a suction superheating degree SH of compressor 10 by subtracting saturation temperature ST(LP) of suction pressure LP of compressor 10 from suction temperature Ts of compressor 10.

[0043] Control device 100 acquires evaporation temperature Te of the refrigerant detected by evaporation temperature sensor 303. It should be noted that control device 100 may calculate evaporation temperature Te of the refrigerant by converting suction pressure LP detected by suction pressure sensor 90 into a refrigerant saturated gas temperature.

[0044] Control device 100 determines whether or not the refrigerant circulating through refrigerant circuit 5 is insufficient, and when it determines that the refrigerant is insufficient, it gives notice of a factor in the shortage of the refrigerant, as described below.

[0045] When a difference (T2-T1) between temperature T1 detected by temperature sensor 73 and temperature T2 detected by temperature sensor 74 of refrigerant amount detection unit 70 is more than or equal to a threshold value Th1, control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is insufficient.

[0046] In liquid back operation, the refrigerant containing the liquid refrigerant flows from evaporator 60 to compressor 10, and thus suction superheating degree SH of compressor 10 decreases. During the liquid back operation, a large amount of the refrigerant moves toward the suction side of compressor 10, and thus the amount of the refrigerant supplied to refrigerant amount detection unit 70 decreases. As a result, it is determined that the refrigerant circulating through refrigerant circuit 5 is insufficient. Therefore, when control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and suction superheating degree SH of compressor 10 is lower than a threshold value Th2, control device 100 gives notice of the liquid back operation as the factor.

[0047] When operation in which evaporation temperature Te is high is performed, the amount of the refrigerant on a low-pressure side of refrigerant circuit 5 is large, and thus the amount of the refrigerant supplied to refrigerant amount detection unit 70 decreases. As a result, it is determined that the refrigerant circulating through refrigerant circuit 5 is insufficient. Therefore, when control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and evaporation temperature Te of the refrigerant is more than or equal to a threshold value Th3, control device 100 gives notice of the operation in which the evaporation temperature of the refrigerant is high, as the factor.

[0048] When it is determined that the refrigerant circulating through refrigerant circuit 5 is insufficient in a case where the liquid back operation is not performed and operation in which the evaporation temperature of the refrigerant is low is performed, it is highly likely that the refrigerant may leak from refrigerant circuit 5. Therefore, when control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 and evaporation temperature Te of the refrigerant is less than threshold value Th3, control device 100 gives notice of leakage of the refrigerant from refrigerant circuit 5 to the outside, as the factor.

[0049] Fig. 6 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by the control device in the first embodiment. A series of processing shown in this flowchart is repeatedly performed while refrigeration cycle apparatus 1 performs steady operation.

[0050] Referring to Fig. 6, in step S101, control device 100 determines whether or not control for determining shortage of the refrigerant is performed. The control for determining shortage of the refrigerant is performed for several minutes, at once per hour, for example. When the control for determining shortage of the refrigerant is not performed (NO in step S101), control device 100 advances the processing to RETURN without performing a series of subsequent processing. When it is determined that the control for determining shortage of the refrigerant is performed (YES in step S101), the processing advances to step S102.

[0051] In step S102, control device 100 turns on (opens) solenoid valve 79, and turns on heater 72.

[0052] In step S103, control device 100 acquires the detection values of temperatures T1 and T2 from temperature sensors 73 and 74, respectively, of refrigerant amount detection unit 70.

[0053] In step S104, control device 100 determines whether or not the difference (T2-T1) between acquired temperature T2 and temperature T1, that is, the temperature increase amount of the refrigerant caused by heater 72, is more than or equal to threshold value Th1. When control device 100 determines that the temperature increase amount of the refrigerant caused by heater 72 is more than or equal to threshold value Th1 (S104: YES), control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and the processing advances to step S105. When control device 100 determines that the temperature increase amount of the refrigerant caused by heater 72 is less than threshold value Th1 (S104: NO), control device 100 determines that the refrigerant circulating through refrigerant circuit 5 is not insufficient, and the processing advances to step S110.

[0054] In step S105, control device 100 determines whether or not suction superheating degree SH of compressor 10 is less than threshold value Th2. When control device 100 determines that suction superheating degree SH of compressor 10 is less than threshold value Th2 (S105: YES), the processing advances to step S107. When control device 100 determines that suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 (S105: NO), the processing advances to step S106.

[0055] In step S106, control device 100 determines whether or not evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3. When control device 100 determines that evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3 (S106: YES), the processing advances to step S108. When control device 100 determines that evaporation temperature Te of the refrigerant is less than threshold value Th3 (S106: NO), the processing advances to step S109.

[0056] In step S107, control device 100 displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the liquid back operation.

[0057] In step S108, control device 100 displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the operation in which the evaporation temperature of the refrigerant is high.

[0058] In step S109, control device 100 displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the leakage of the refrigerant enclosed within refrigerant circuit 5 to the outside.

[0059] In step S110, control device 100 turns off (closes) solenoid valve 79, and turns off heater 72.

[0060] It should be noted that, as described above, in the case where a non-azeotropic refrigerant is used, when the refrigerant is heated by heater 72, the temperature of the refrigerant increases even though the refrigerant amount is appropriate. Accordingly, threshold value Th1 in step S104 is set as appropriate based on the type of the refrigerant used and the heating amount of heater 72, such that a temperature increase amount of the refrigerant caused by heater 72 in the normal condition can be distinguished from a temperature increase amount of the refrigerant caused by heater 72 when the refrigerant is insufficient.

[0061] As described above, in the first embodiment, it is possible to determine whether or not shortage of the refrigerant occurs, based on the temperature increase amount of the refrigerant caused by heater 72. Therefore, the accuracy of determining shortage of the refrigerant depends on the accuracy of detecting the temperature increase amount of the refrigerant caused by heater 72. Thus, in outdoor unit 2 according to the first embodiment, refrigerant amount detection unit 70 is provided at a position where it is less likely to be influenced by wind serving as a disturbance in detecting the temperature increase amount. Specifically, refrigerant amount detection unit 70 is provided at a position where it is less influenced by air flow, when compared with condenser 20. The wind whose influence on refrigerant amount detection unit 70 should be reduced includes wind after passing through condenser 20, wind before passing through condenser 20, and natural wind. This can suppress the temperature increase amount described above from having an error due to the influence of the wind on refrigerant amount detection unit 70.

[0062] Fig. 7 is a diagram schematically showing a structure of outdoor unit 2 of refrigeration cycle apparatus 1. Referring to Fig. 7, the inside of outdoor unit 2 is partitioned by a partition plate (wall) 206 into a heat exchange chamber 202 and a machine chamber 204. Heat exchange chamber 202 accommodates condenser 20, liquid reservoir 30, and supercooling heat exchanger 40 (all not shown), and fans 22 and 42. Condenser 20 and supercooling heat exchanger 40 (hereinafter may be collectively referred to as a "heat exchange unit") and fans 22 and 42 are provided on side surfaces of a case of outdoor unit. In this example, the heat exchange unit is provided on a back surface side and fans 22 and 42 are provided on a front surface side, and exhaust heat wind of the heat exchange unit flows from the back surface side toward the front surface side of heat exchange chamber 202. Machine chamber 204 accommodates compressor 10, the pipes, suction pressure sensor 90, discharge pressure sensor 92, and control device 100.

[0063] In outdoor unit 2 according to the first embodiment, refrigerant amount detection unit 70 is accommodated in machine chamber 204. Wind caused by the operation of fans 22 and 42 flows through heat exchange chamber 202, or when the fans are stopped, natural wind flows through heat exchange chamber 202. When refrigerant amount detection unit 70 is placed within heat exchange chamber 202 through which such wind flows, an error may be caused in measuring the temperature increase amount of the refrigerant caused by heater 72 due to the influence of the wind on refrigerant amount detection unit 70 (in particular, temperature sensors 73 and 74). In this example, since refrigerant amount detection unit 70 is accommodated in machine chamber 204 partitioned from heat exchange chamber 202 by partition plate 206, refrigerant amount detection unit 70 is not influenced by the wind. Therefore, with this outdoor unit 2, the temperature increase amount of the refrigerant caused by heater 72 can be measured with high accuracy.

[0064] It should be noted that, although it is described above that liquid reservoir 30 is provided in heat exchange chamber 202, liquid reservoir 30 may be provided in machine chamber 204.

[0065] As described above, according to the first embodiment, it is possible to determine shortage of the refrigerant based on the temperature increase amount of the refrigerant that has passed through heater 72, irrespective of the magnitude of the supercooling degree of the refrigerant, or whether or not a non-azeotropic refrigerant is used.

[0066] According to the first embodiment, the operator or the user can be notified of a factor determined as shortage of the refrigerant. Thereby, it is possible to take measures corresponding to the factor determined as shortage of the refrigerant.

[0067] In the first embodiment, refrigerant amount detection unit 70 is provided in machine chamber 204 that is not influenced by the wind, which can avoid the temperature increase amount described above from having an error due to the influence of the wind on refrigerant amount detection unit 70. As a result, according to the first embodiment, shortage of the refrigerant in refrigerant circuit 5 can be determined with high accuracy.

Second Embodiment

[0068] In a second embodiment, as a heat source in the refrigerant amount detection unit, the high-temperature, high-pressure refrigerant on the discharge side of compressor 10 is used instead of heater 72. Thereby, the refrigerant amount detection unit can be configured without separately providing heater 72.

[0069] Fig. 8 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to the second embodiment is used. Referring to Fig. 8, a refrigeration cycle apparatus 1A includes an outdoor unit 2A and indoor unit 3. Outdoor unit 2A includes a refrigerant amount detection unit 70A and a control device 100A, instead of refrigerant amount detection unit 70 and control device 100, respectively, in outdoor unit 2 of the first embodiment shown in Fig. 1.

[0070] Refrigerant amount detection unit 70A includes a heat exchange unit 78, instead of heater 72 in refrigerant amount detection unit 70 of the first embodiment shown in Fig. 1, and further includes temperature sensors 75 to 77. Heat exchange unit 78 is configured to perform heat exchange between the high-temperature, high-pressure refrigerant outputted from compressor 10 and the refrigerant that has passed through capillary tube 71. Then, temperature sensor 73 detects a refrigerant temperature upstream of heat exchange unit 78, that is, temperature T1 of the refrigerant between capillary tube 71 and heat exchange unit 78. On the other hand, temperature sensor 74 detects a refrigerant temperature downstream of heat exchange unit 78, that is, temperature T2 of the refrigerant downstream of heat exchange unit 78 and before merging into pipe 85.

[0071] Temperature sensor 75 detects a temperature T3 of the high temperature, high pressure refrigerant outputted from compressor 10, and outputs a detection value thereof to control device 100A. Temperature sensor 76 detects a temperature T4 of the refrigerant outputted from compressor 10 and having passed through heat exchange unit 78, and outputs a detection value thereof to control device 100A. That is, for the refrigerant supplied from compressor 10 to condenser 20, temperature sensors 75 and 76 detect a temperature of the refrigerant before passing through heat exchange unit 78, and a temperature of the refrigerant after passing through heat exchange unit 78, respectively. Temperature sensor 77 detects a temperature T5 of the refrigerant to be suctioned into compressor 10, and outputs a detection value thereof to control device 100A.

[0072] Control device 100A determines whether or not shortage of the refrigerant occurs in refrigerant circuit 5A, based on a temperature increase amount of the refrigerant when the refrigerant flowing through pipe 87 is heated by heat exchange unit 78. More specifically, when the temperature increase amount of the refrigerant caused by heat exchange unit 78 is more than or equal to a threshold value, control device 100A determines that shortage of the refrigerant occurs.

[0073] Here, since a heating amount of heat exchange unit 78 changes depending on the operation state of refrigeration cycle apparatus 1A, the temperature increase amount of the refrigerant within pipe 87 at heat exchange unit 78 also changes depending on the operation state of refrigeration cycle apparatus 1A. In particular, in the case where the refrigerant is a non-azeotropic refrigerant, when the gas-liquid two-phase refrigerant flowing through pipe 87 is heated at heat exchange unit 78, the temperature thereof increases even though shortage of the refrigerant does not occur, and the temperature increase amount thereof depends on the heating amount. Further, even in the case where the refrigerant is an azeotropic refrigerant, when the heating amount of heat exchange unit 78 is large, the temperature of the refrigerant may increase.

[0074] Thus, in the second embodiment, the heating amount of heat exchange unit 78 is calculated, and a threshold value for determining whether or not shortage of the refrigerant occurs (a threshold value of the temperature increase amount of the refrigerant at heat exchange unit 78) is set based on the heating amount. Thereby, shortage of the refrigerant can be determined with high accuracy, even when the heating amount of heat exchange unit 78 changes depending on the operation state of refrigeration cycle apparatus 1A.

[0075] The heating amount of heat exchange unit 78 can be calculated for example as described below. The heating amount (W = J/s) of heat exchange unit 78 is calculated by the following equation.

$$\text{Heating Amount} = G \times H \ldots (1),$$

where G is a flow rate of the refrigerant flowing from compressor 10 to heat exchange unit 78, and H is an enthalpy difference between enthalpies before and after heat exchange unit 78, of the refrigerant flowing from compressor 10 to heat exchange unit 78.

[0076] Refrigerant flow rate G (kg/hr) can be calculated by the following equation.

$$\text{Refrigerant Flow Rate } G = V \times R \times D \ldots (2),$$

where V is a displacement (m^3) of compressor 10, that is, a refrigerant suction amount per revolution of compressor 10, R is the number of revolutions (1/hr or 1/s) of compressor 10, and D is a density (kg/m^3) of the refrigerant. Density D is an amount determined by the refrigerant temperature and pressure on the suction side of compressor 10, and can be calculated from temperature T5 detected by temperature sensor 77 and suction pressure LP detected by suction pressure sensor 90.

[0077] In addition, enthalpy difference H (kJ/kg) can be calculated by the following equation.

$$\text{Enthalpy Difference } H = H3 - H4 \ldots (3),$$

where H3 is an enthalpy of the refrigerant supplied from compressor 10 to heat exchange unit 78, and H4 is an enthalpy of the refrigerant after passing through heat exchange unit 78. It should be noted that enthalpy H3 is an amount determined by discharge pressure HP of compressor 10 and the temperature of the refrigerant before passing through heat exchange unit 78, and can be obtained from discharge pressure HP detected by discharge pressure sensor 92 and temperature T3 detected by temperature sensor 75. Further, enthalpy H4 is an amount determined by discharge pressure HP of compressor 10 and the temperature of the refrigerant after passing through heat exchange unit 78, and can be obtained from discharge pressure HP and temperature T4 detected by temperature sensor 76.

[0078] Fig. 9 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by control device 100A in the second embodiment. A series of processing shown in this flowchart is repeatedly performed while refrigeration cycle apparatus 1A performs steady operation.

[0079] Referring to Fig. 9, in step S201, control device 100A determines whether or not control for determining shortage of the refrigerant is performed. The control for determining shortage of the refrigerant is performed for several minutes, at once per hour, for example. When the control for determining shortage of the refrigerant is not performed (NO in step S201), control device 100A advances the processing to RETURN without performing a series of subsequent processing. When it is determined that the control for determining shortage of the refrigerant is performed (YES in step S201), the processing advances to step S202.

[0080] In step S202, control device 100A acquires the detection values of temperatures T1 to T5 from temperature sensors 73 to 77, respectively, acquires the number of revolutions R of compressor 10, and further acquires the detection values of suction pressure LP and discharge pressure HP from suction pressure sensor 90 and discharge pressure sensor 92, respectively.

[0081] In step S203, control device 100A calculates refrigerant flow rate G using the equation (2) described above, and calculates enthalpy difference H using the equation (3) described above.

[0082] In step S204, control device 100A calculates the heating amount (G×H) of heat exchange unit 78 by multiplying calculated refrigerant flow rate G by enthalpy difference H.

[0083] In step S205, control device 100A sets a threshold value Th4 for determining whether or not shortage of the refrigerant occurs (a threshold value of the temperature increase amount of the refrigerant flowing through pipe 87 at heat exchange unit 78), based on the calculated heating amount of heat exchange unit 78.

[0084] The relation between the heating amount and threshold value Th4 is predetermined by prior evaluation, simulation, or the like depending on the type of refrigerant used, and is stored in the ROM of control device 100A. Qualitatively, as the heating amount is larger, threshold value Th4 is higher. In addition, when the heating amount is the same, the threshold value of a non-azeotropic refrigerant is higher than the threshold value of an azeotropic refrigerant.

[0085] In step S206, control device 100A determines whether or not the difference (T2-T1) between temperature T2 and temperature T1 acquired in step S202, that is, the temperature increase amount of the refrigerant flowing through pipe 87 at heat exchange unit 78, is more than or equal to threshold value Th4. When control device 100A determines that the temperature increase amount of the refrigerant is more than or equal to threshold value Th4 (S206: YES), control device 100A determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and the processing advances to step S207. When control device 100A determines that the temperature increase amount of the refrigerant is less than threshold value Th4 (S206: NO), control device 100A determines that the refrigerant circulating through refrigerant circuit 5 is not insufficient, and advances the processing to RETURN.

[0086] In step S207, control device 100A determines whether or not suction superheating degree SH of compressor 10 is less than threshold value Th2. When control device 100A determines that suction superheating degree SH of compressor 10 is less than threshold value Th2 (S207: YES), the processing advances to step S209. When control device 100A determines that suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 (S207: NO), the processing advances to step S208.

[0087] In step S208, control device 100A determines whether or not evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3. When control device 100A determines that evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3 (S1208: YES), the processing advances to step S210. When control device 100A determines that evaporation temperature Te of the refrigerant is less than threshold value Th3 (S208: NO), the processing advances to step S211.

[0088] In step S209, control device 100A displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the liquid back operation.

[0089] In step S210, control device 100A displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the operation in which the evaporation temperature of the refrigerant is high.

[0090] In step S211, control device 100A displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the leakage of the refrigerant enclosed within refrigerant circuit 5 to the outside.

[0091] As described above, according to the second embodiment, as a heat source in refrigerant amount detection unit 70A, heat exchange unit 78 using the high-temperature, high-pressure refrigerant on the discharge side of compressor 10 is provided instead of heater 72. Thereby, the refrigerant amount detection unit can be configured without providing heater 72.

[0092] Further, although the heating amount of heat exchange unit 78 changes depending on the operation state of refrigeration cycle apparatus 1A, according to the second embodiment, threshold value Th4 of the temperature increase amount of the refrigerant flowing through pipe 87 at heat exchange unit 78 is set based on the heating amount of heat exchange unit 78. Thus, shortage of the refrigerant can be determined with high accuracy, even when the operation state of refrigeration cycle apparatus 1A changes.

[0093] According to the second embodiment, the operator or the user can be notified of a factor determined as shortage of the refrigerant, as in the first embodiment. Thereby, it is possible to take measures corresponding to the factor determined as shortage of the refrigerant.

Third Embodiment

[0094] Fig. 10 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a third embodiment is used. Referring to Fig. 10, a refrigeration cycle apparatus 1C includes an outdoor unit 2C and indoor unit 3. Outdoor unit 2C includes a control device 100C, instead of control device 100 in outdoor unit 2 of the first embodiment shown in Fig. 1. Outdoor unit 2C further includes a condensation temperature sensor 305 and a liquid refrigerant temperature sensor 304.

[0095] Condensation temperature sensor 305 is provided at an inlet of supercooling heat exchanger 40. Condensation temperature sensor 305 detects a temperature of the refrigerant as a condensation temperature Tx.

[0096] Liquid refrigerant temperature sensor 304 is provided at an outlet of supercooling heat exchanger 40. Liquid refrigerant temperature sensor 304 detects a temperature of the refrigerant as a liquid refrigerant temperature Ty.

[0097] Control device 100C calculates a supercooling degree SC of the refrigerant at the outlet of supercooling heat exchanger 40 by subtracting liquid refrigerant temperature Ty from condensation temperature Tx.

$$SC = Tx - Ty \ldots (4).$$

[0098] When supercooling degree SC is less than or equal to a threshold value Th5, control device 100C determines that the refrigerant circulating through refrigerant circuit 5 is insufficient.

[0099] Fig. 11 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by control device 100C in the third embodiment. A series of processing shown in this flowchart is repeatedly performed while refrigeration cycle apparatus 1C performs steady operation.

[0100] Referring to Fig. 11, in step S301, control device 100C determines whether or not control for determining shortage of the refrigerant is performed. The control for determining shortage of the refrigerant is performed for several minutes, at once per hour, for example. When the control for determining shortage of the refrigerant is not performed (NO in step S301), control device 100C advances the processing to RETURN without performing a series of subsequent processing. When it is determined that the control for determining shortage of the refrigerant is performed (YES in step S301), the processing advances to step S302.

[0101] In step S302, control device 100C acquires condensation temperature Tx from condensation temperature sensor 305, and acquires liquid refrigerant temperature Ty from liquid refrigerant temperature sensor 304.

[0102] In step S303, control device 100C calculates supercooling degree SC of the refrigerant at the outlet of supercooling heat exchanger 40, based on condensation temperature Tx and liquid refrigerant temperature Ty.

[0103] In step S304, control device 100C determines whether or not supercooling degree SC is less than or equal to threshold value Th5. When control device 100C determines that supercooling degree SC is less than or equal to threshold value Th5 (S304: YES), control device 100C determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and the processing advances to step S305. When control device 100C determines that supercooling degree SC is more than threshold value Th5 (S304: NO), control device 100C determines that the refrigerant circulating through refrigerant circuit 5 is not insufficient, and advances the processing to RETURN.

[0104] In step S305, control device 100C determines whether or not suction superheating degree SH of compressor 10 is less than threshold value Th2. When control device 100C determines that suction superheating degree SH of compressor 10 is less than threshold value Th2 (S305: YES), the processing advances to step S307. When control device 100C determines that suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 (S305: NO), the processing advances to step S306.

[0105] In step S306, control device 100C determines whether or not evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3. When control device 100C determines that evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3 (S306: YES), the processing advances to step S308. When control device 100C determines that evaporation temperature Te of the refrigerant is less than threshold value Th3 (S306: NO), the processing advances to step S309.

[0106] In step S307, control device 100C displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the liquid back operation.

[0107] In step S308, control device 100C displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the operation in which the evaporation temperature of the refrigerant is high.

[0108] In step S309, control device 100C displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the leakage of the refrigerant enclosed within refrigerant circuit 5 to the outside.

[0109] As described above, according to the third embodiment, it is possible to determine whether or not the refrigerant is insufficient, based on supercooling degree SC of the refrigerant at the outlet of supercooling heat exchanger 40.

[0110] According to the third embodiment, the operator or the user can be notified of a factor determined as shortage of the refrigerant, as in the first and second embodiments. Thereby, it is possible to take measures corresponding to the factor determined as shortage of the refrigerant.

Fourth Embodiment

[0111] Fig. 12 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a fourth embodiment is used. Referring to Fig. 12, a refrigeration cycle apparatus 1D includes an outdoor unit 2D and indoor unit 3. Outdoor unit 2D includes a control device 100D, instead of control device 100 in outdoor unit 2 of the first embodiment shown in Fig. 1. Outdoor unit 2D further includes condensation temperature sensor 305, liquid refrigerant temperature sensor 304, and an outside air temperature sensor 301.

[0112] Outside air temperature sensor 301 is provided in the vicinity of condenser 20. Outside air temperature sensor 301 detects an outside air temperature To.

[0113] Condensation temperature sensor 305 is provided at the inlet of supercooling heat exchanger 40. Condensation temperature sensor 305 detects the temperature of the refrigerant as condensation temperature Tx.

[0114] Liquid refrigerant temperature sensor 304 is provided at the outlet of supercooling heat exchanger 40. Liquid refrigerant temperature sensor 304 detects the temperature of the refrigerant as liquid refrigerant temperature Ty.

[0115] Control device 100D calculates supercooling degree SC of the refrigerant at the outlet of supercooling heat exchanger 40 by subtracting liquid refrigerant temperature Ty from condensation temperature Tx.

[0116] Control device 100D calculates a temperature efficiency ε of supercooling heat exchanger 40 by dividing the supercooling degree (condensation temperature Tx - liquid refrigerant temperature Ty) of the refrigerant at the outlet of supercooling heat exchanger 40 by a maximum temperature difference (condensation temperature Tx - outside air temperature To) in supercooling heat exchanger 40.

$$\varepsilon = (Tx - Ty)/(Tx - To) \ldots (5).$$

When temperature efficiency ε is less than or equal to a threshold value Th6, control device 100D determines that the refrigerant circulating through refrigerant circuit 5 is insufficient.

[0117] Fig. 13 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by control device 100D in the fourth embodiment. A series of processing shown in this flowchart is repeatedly performed while refrigeration cycle apparatus 1D performs steady operation.

[0118] Referring to Fig. 13, in step S401, control device 100D determines whether or not control for determining shortage of the refrigerant is performed. The control for determining shortage of the refrigerant is performed for several minutes, at once per hour, for example. When the control for determining shortage of the refrigerant is not performed (NO in step S401), control device 100D advances the processing to RETURN without performing a series of subsequent processing. When it is determined that the control for determining shortage of the refrigerant is performed (YES in step S401), the processing advances to step S402.

[0119] In step S402, control device 100D acquires condensation temperature Tx from condensation temperature sensor 305, acquires liquid refrigerant temperature Ty from liquid refrigerant temperature sensor 304, and acquires outside air temperature To from outside air temperature sensor 301.

[0120] In step S403, control device 100D calculates temperature efficiency ε of supercooling heat exchanger 40, based on outside air temperature To, condensation temperature Tx, and liquid refrigerant temperature Ty.

[0121] In step S404, control device 100D determines whether or not temperature efficiency ε of supercooling heat exchanger 40 is less than or equal to threshold value Th6. When control device 100D determines that temperature efficiency ε of supercooling heat exchanger 40 is less than or equal to threshold value Th6 (S404: YES), control device 100D determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and the processing advances to step S405. When control device 100D determines that temperature efficiency ε of supercooling heat exchanger 40 is more than threshold value Th6 (S404: NO), control device 100D determines that the refrigerant circulating through refrigerant circuit 5 is not insufficient, and advances the processing to RETURN

[0122] In step S405, control device 100D determines whether or not suction superheating degree SH of compressor 10 is less than threshold value Th2. When control device 100D determines that suction superheating degree SH of compressor 10 is less than threshold value Th2 (S405: YES), the processing advances to step S407. When control device 100D determines that suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 (S405: NO), the processing advances to step S406.

[0123] In step S406, control device 100D determines whether or not evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3. When control device 100D determines that evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3 (S406: YES), the processing advances to step S408. When control device 100D determines that evaporation temperature Te of the refrigerant is less than threshold value Th3 (S406: NO), the processing advances to step S409.

[0124] In step S407, control device 100D displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the liquid back operation.

[0125] In step S408, control device 100D displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the operation in which the evaporation temperature of the refrigerant is high.

[0126] In step S409, control device 100D displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the leakage of the refrigerant enclosed within refrigerant circuit 5 to the outside.

[0127] As described above, according to the fourth embodiment, it is possible to determine whether or not the refrigerant is insufficient, based on temperature efficiency ε of supercooling heat exchanger 0.

[0128] According to the fourth embodiment, the operator or the user can be notified of a factor determined as shortage of the refrigerant, as in the first to third embodiments. Thereby, it is possible to take measures corresponding to the factor determined as shortage of the refrigerant.

Fifth Embodiment

[0129] Fig. 14 is an overall configuration diagram of a refrigeration cycle apparatus in which an outdoor unit according to a fifth embodiment is used. Referring to Fig. 14, a refrigeration cycle apparatus 1B includes an outdoor unit 2B and indoor unit 3. Outdoor unit 2B includes a control device 100B, instead of control device 100 in outdoor unit 2 of the first embodiment shown in Fig. 1.

[0130] Fig. 15 is a diagram for describing processing for determining shortage of the refrigerant performed by the control device in the fifth embodiment. As shown in Fig. 15, control device 100B calculates the temperature increase amount (T2-T1) of the refrigerant caused by heater 72, at intervals of A seconds (t1, t2, t3 ...). Control device 100B calculates an average value M of the latest three temperature increase amounts of the refrigerant. At a time point when average value M becomes equal to or more than threshold value Th1, control device 100B determines that the refrigerant is insufficient. When average value M is continuously less than threshold value Th1 for B minutes, control device 100B determines that the refrigerant is not insufficient.

[0131] Fig. 16 is a flowchart showing an example of a processing procedure for determining shortage of the refrigerant performed by control device 100B in the fifth embodiment. A series of processing shown in this flowchart is repeatedly performed while refrigeration cycle apparatus 1B performs steady operation.

[0132] Referring to Fig. 16, in step S501, control device 100B determines whether or not control for determining shortage of the refrigerant is performed. The control for determining shortage of the refrigerant is performed for several minutes, at once per hour, for example. When the control for determining shortage of the refrigerant is not performed (NO in step S501), control device 100B advances the processing to RETURN without performing a series of subsequent processing. When it is determined that the control for determining shortage of the refrigerant is performed (YES in step S501), the processing advances to step S102.

[0133] In step S502, control device 100B turns on (opens) solenoid valve 79, and turns on heater 72.

[0134] In step S503, when A seconds have passed since a time when solenoid valve 79 was turned on and heater 72 was turned on, or a time when previous detection values of temperatures T1 and T2 were acquired, the processing advances to step S504.

[0135] In step S504, control device 100B acquires the detection values of temperatures T1 and T2 from temperature sensors 73 and 74, respectively, of refrigerant amount detection unit 70.

[0136] In step S505, an average value of the latest three differences (T2-T1) between temperature T2 and temperature T1, that is, average value M of the latest three temperature increase amounts of the refrigerant caused by heater 72, is calculated.

[0137] In step S506, control device 100B determines whether or not average value M is more than or equal to threshold value Th1. When control device 100B determines that average value M is more than or equal to threshold value Th1 (S506: YES), control device 100B determines that the refrigerant circulating through refrigerant circuit 5 is insufficient, and the processing advances to step S508. When control device 100B determines that average value M is less than threshold value Th1 (S506: NO), control device 100B determines that the refrigerant circulating through refrigerant circuit 5 is not insufficient, and the processing advances to step S507.

[0138] In step S507, when B minutes have passed since the time when solenoid valve 79 was turned on and heater 72 was turned on (S507: YES), the processing advances to step S513. When B minutes have not passed since the time when solenoid valve 79 was turned on and heater 72 was turned on (S507: NO), the processing returns to step S503.

[0139] In step S508, control device 100B determines whether or not suction superheating degree SH of compressor 10 is less than threshold value Th2. When control device 100B determines that suction superheating degree SH of compressor 10 is less than threshold value Th2 (S508: YES), the processing advances to step S510. When control device 100B determines that suction superheating degree SH of compressor 10 is more than or equal to threshold value Th2 (S510: NO), the processing advances to step S511.

[0140] In step S509, control device 100B determines whether or not evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3. When control device 100B determines that evaporation temperature Te of the refrigerant is more than or equal to threshold value Th3 (S109: YES), the processing advances to step S511. When control device 100B determines that evaporation temperature Te of the refrigerant is less than threshold value Th3 (S509: NO), the processing advances to step S512.

[0141] In step S510, control device 100B displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the liquid back operation.

[0142] In step S511, control device 100B displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the operation in which the evaporation temperature of the refrigerant is high.

[0143] In step S512, control device 100B displays on display device 150 that it has determined that the refrigerant circulating through refrigerant circuit 5 is insufficient due to the leakage of the refrigerant enclosed within refrigerant circuit 5 to the outside.

[0144] In step S513, control device 100B turns off (closes) solenoid valve 79, and turns off heater 72.

[0145] As described above, according to the fifth embodiment, it is possible to prevent making a mistake in determining whether or not the refrigerant is insufficient, when detected temperatures T1 and T2 have variations.

[0146] It should be noted that, although the control device in the embodiment described above determines shortage of the refrigerant using an average value of a plurality of temperature increase amounts in the first embodiment, the present disclosure is not limited thereto.

[0147] The control device may determine shortage of the refrigerant using an average value of a plurality of temperature increase amounts in the second embodiment. The control device may determine shortage of the refrigerant using an average value of a plurality of supercooling degrees at the outlet of the supercooling heat exchanger in the third embodiment. The control device may determine shortage of the refrigerant using an average value of a plurality of temperature efficiencies of the supercooling heat exchanger in the fourth embodiment.

[0148] It is intended that the embodiments disclosed herein may also be implemented by being combined as appropriate within the scope in which no technical inconsistency arises. In addition, 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 scope of the claims, rather than the description of the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the scope of the claims.

REFERENCE SIGNS LIST

[0149] 1, 1A, 1B, 1C, 1D: refrigeration cycle apparatus; 2, 2A, 2B, 2C, 2D: outdoor unit; 3: indoor unit; 10: compressor; 20: condenser; 22, 42, 62: fan; 30: liquid reservoir; 40: supercooling heat exchanger; 45: sight glass; 50: expansion valve; 60: evaporator; 70, 70A: refrigerant amount detection unit; 71: capillary tube; 72: heater; 73 to 77, 301, 302, 304, 305: temperature sensor; 78: heat exchange unit; 79: solenoid valve; 80 to 87: pipe; 90, 92: pressure sensor; 100, 100A, 100B, 100C, 100D: control device; 102: CPU; 104: memory; 150: display device; 201: temperature sensor; 202: heat exchange chamber; 204: machine chamber; 206: partition plate; 208: box.

Claims

1. An outdoor unit connected with an indoor unit to form a refrigeration cycle apparatus, the outdoor unit comprising:

   a compressor to compress refrigerant;

a condenser to condense the refrigerant outputted from the compressor,
the compressor and the condenser forming a refrigerant circuit through which the refrigerant circulates, together with an expansion mechanism and an evaporator included in the indoor unit; and
a control device to determine whether or not the refrigerant circulating through the refrigerant circuit is insufficient, and when the control device determines that the refrigerant is insufficient, to give notice of one of liquid back operation, operation in which an evaporation temperature of the refrigerant is high, and leakage of the refrigerant from the refrigerant circuit, as a factor in determining that the refrigerant is insufficient.

2. The outdoor unit according to claim 1, wherein, when the control device determines that the refrigerant is insufficient, and a suction superheating degree of the compressor is lower than a first threshold value, the control device gives notice of the liquid back operation as the factor.

3. The outdoor unit according to claim 1, wherein, when the control device determines that the refrigerant is insufficient, and the evaporation temperature of the refrigerant is more than or equal to a second threshold value, the control device gives notice of the operation in which the evaporation temperature of the refrigerant is high, as the factor.

4. The outdoor unit according to claim 1, wherein, when the control device determines that the refrigerant is insufficient, and a suction superheating degree of the compressor is more than or equal to a first threshold value and the evaporation temperature of the refrigerant is less than a second threshold value, the control device gives notice of the leakage of the refrigerant from the refrigerant circuit, as the factor.

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

a bypass circuit to return a portion of the refrigerant on a discharge side of the condenser to the compressor without passing through the indoor unit; and
a refrigerant amount detection unit including a heating unit to heat the refrigerant flowing to the bypass circuit, a pre-heating temperature sensor to detect a temperature of the refrigerant before being heated by the heating unit, and a post-heating temperature sensor to detect a temperature of the refrigerant heated by the heating unit, wherein
the control device determines whether or not the refrigerant circulating through the refrigerant circuit is insufficient, using a temperature increase amount calculated from the temperature detected by the post-heating temperature sensor and the temperature detected by the pre-heating temperature sensor.

6. The outdoor unit according to claim 5, wherein, when the temperature increase amount is more than or equal to a third threshold value, the control device determines that the refrigerant circulating through the refrigerant circuit is insufficient.

7. The outdoor unit according to claim 5, wherein, when an average value of the temperature increase amounts at a plurality of times is more than or equal to a third threshold value, the control device determines that the refrigerant circulating through the refrigerant circuit is insufficient.

8. The outdoor unit according to claim 5, wherein the refrigerant amount detection unit is provided at a position where the refrigerant amount detection unit is less influenced by air flow, when compared with the condenser.

9. The outdoor unit according to claim 5, wherein the heating unit is a heater.

10. The outdoor unit according to claim 5, wherein the heating unit is a refrigerant pipe on a discharge side of the compressor.

11. The outdoor unit according to claim 5, further comprising a valve provided in the bypass circuit to switch between flowing and blocking of the refrigerant in the bypass circuit, wherein
the control device

controls the valve to be opened, when determination control for determining whether or not the refrigerant circulating through the refrigerant circuit is insufficient is performed, and
controls the valve to be closed, when the determination control is not performed.

12. The outdoor unit according to claim 5, further comprising a decompression device provided in the bypass circuit to reduce a pressure of the refrigerant flowing to the bypass circuit.

13. The outdoor unit according to claim 1, comprising a supercooling heat exchanger to supercool the refrigerant flowing out of the condenser, wherein
when a supercooling degree in the supercooling heat exchanger is less than or equal to a fourth threshold value, the control device determines that the refrigerant circulating through the refrigerant circuit is insufficient.

14. The outdoor unit according to claim 1, comprising a supercooling heat exchanger to supercool the refrigerant flowing out of the condenser, wherein
when a temperature efficiency of the supercooling heat exchanger is less than or equal to a fifth threshold value, the control device determines that the refrigerant circulating through the refrigerant circuit is insufficient.

15. A refrigeration cycle apparatus comprising:

an outdoor unit according to any one of claims 1 to 14; and
the indoor unit connected to the outdoor unit.

FIG.1

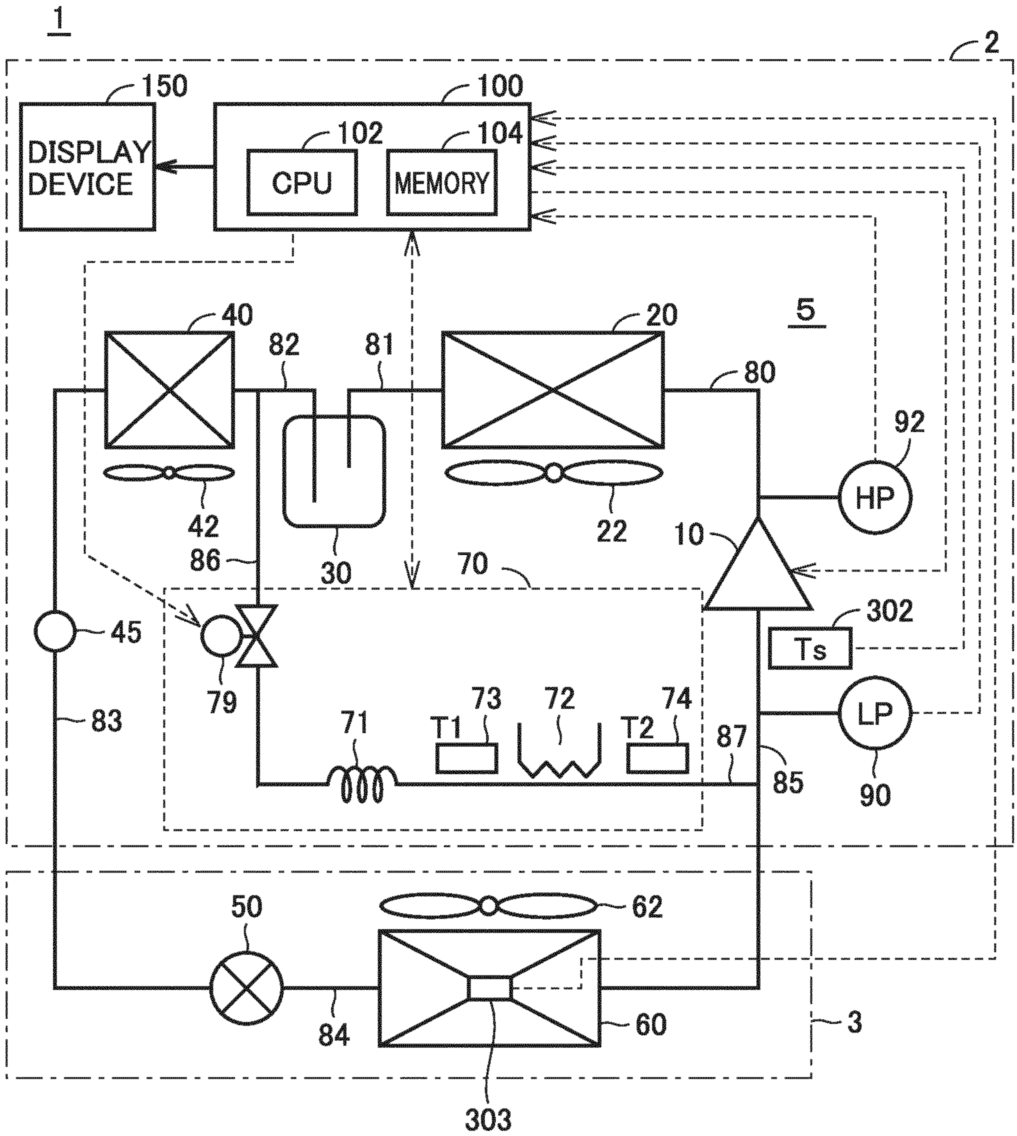

1
2
150
DISPLAY DEVICE
100
102
CPU
104
MEMORY
40
82
81
20
5
80
92
HP
42
22
10
86
30
70
45
79
302
Ts
83
71
73
72
74
T1
T2
87
LP
85
90
50
62
84
60
3
303

FIG.2

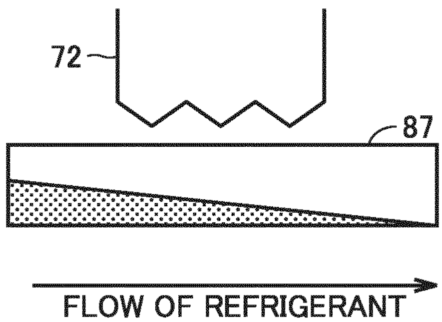

72
87
FLOW OF REFRIGERANT

FIG.3

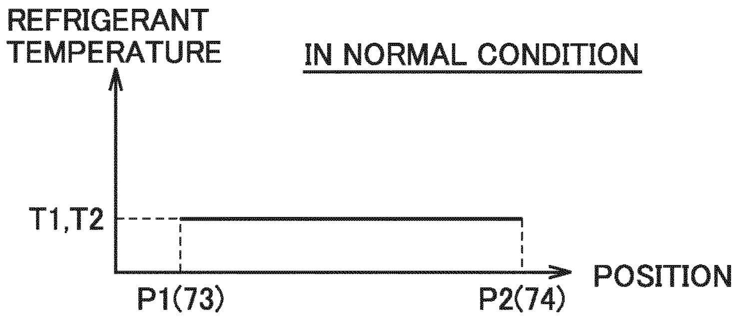


FIG.4

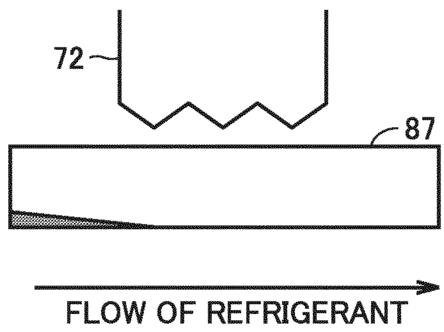


FIG.5

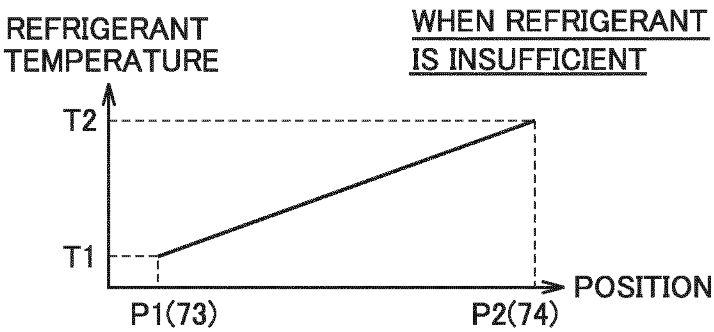


FIG.6

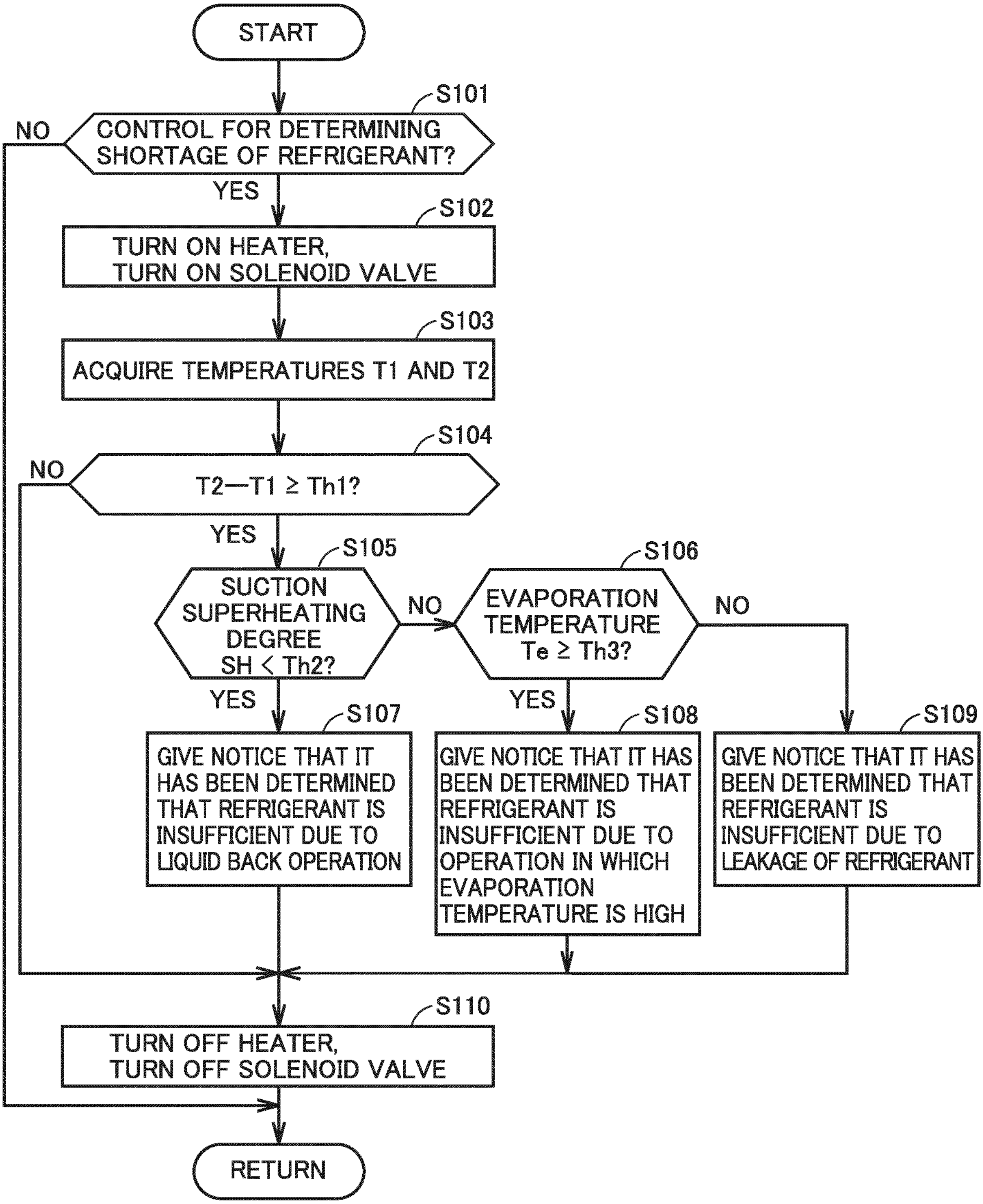

START
S101
NO
CONTROL FOR DETERMINING SHORTAGE OF REFRIGERANT?
YES
S102
TURN ON HEATER, TURN ON SOLENOID VALVE
S103
ACQUIRE TEMPERATURES T1 AND T2
S104
NO
T2—T1 ≥ Th1?
YES
S105
SUCTION SUPERHEATING DEGREE SH < Th2?
NO
S106
EVAPORATION TEMPERATURE Te ≥ Th3?
NO
YES
YES
S107
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LIQUID BACK OPERATION
S108
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO OPERATION IN WHICH EVAPORATION TEMPERATURE IS HIGH
S109
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LEAKAGE OF REFRIGERANT
S110
TURN OFF HEATER, TURN OFF SOLENOID VALVE
RETURN

FIG.7

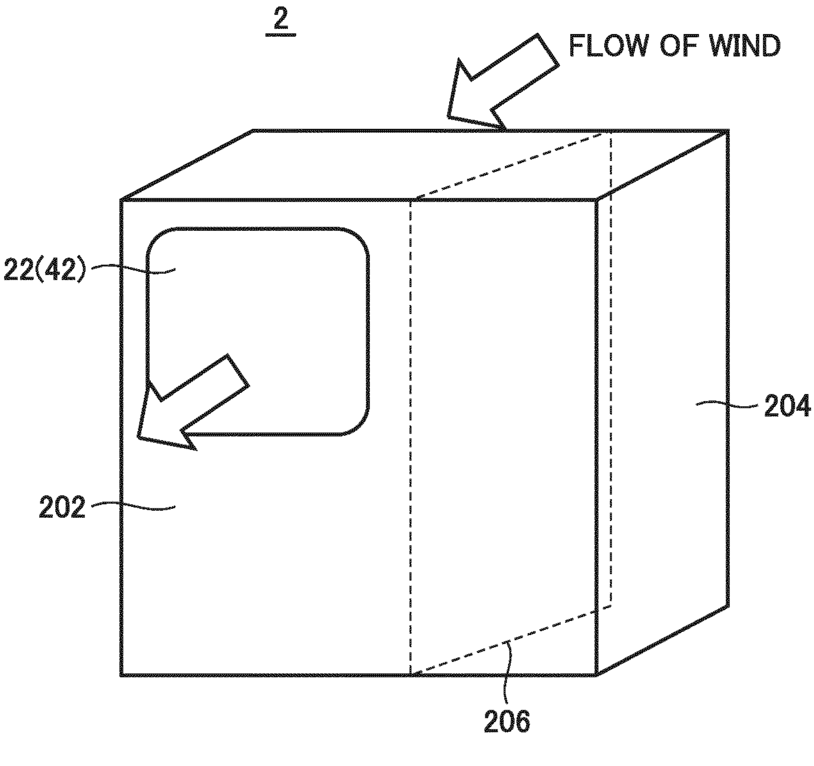


FIG.8

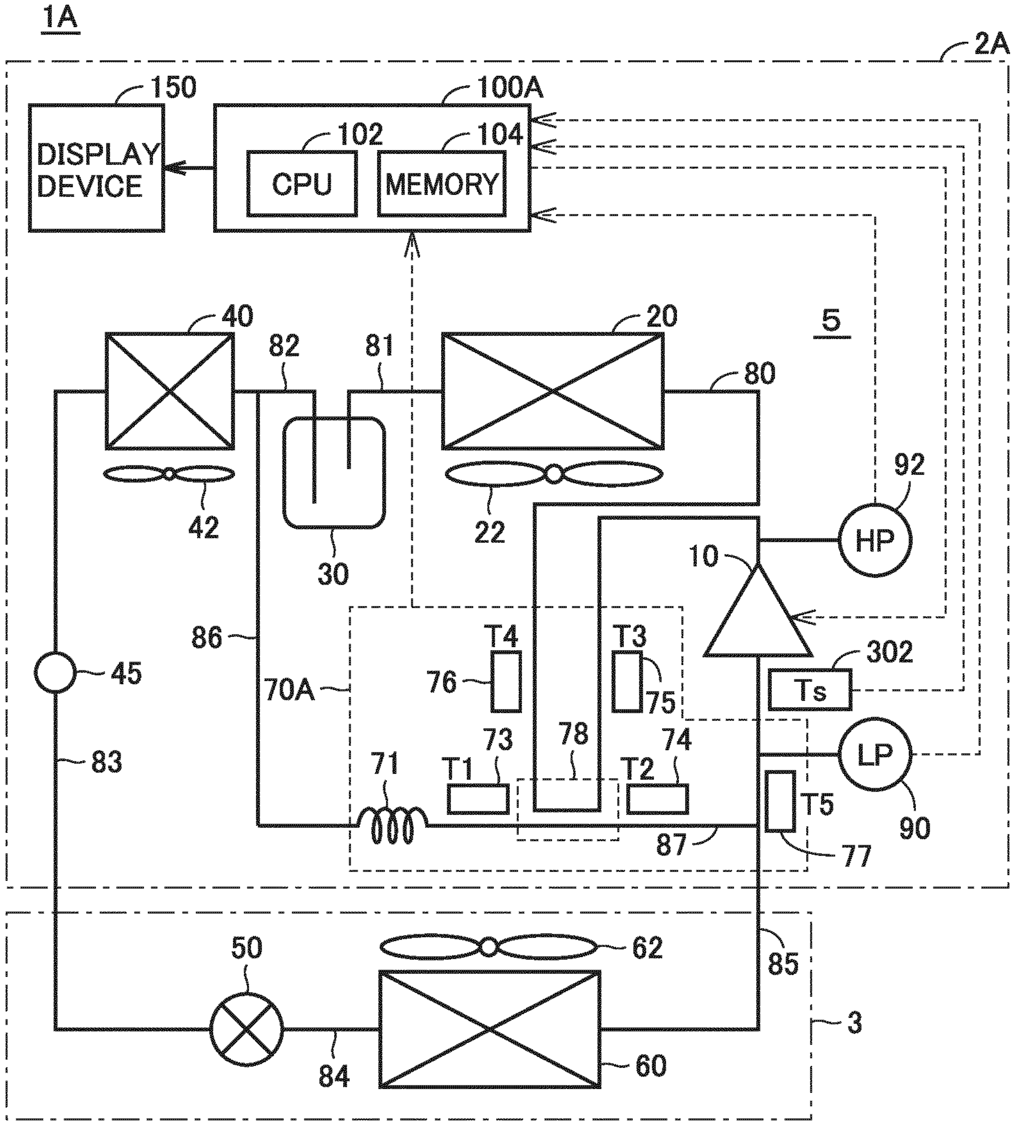

1A
2A
150
DISPLAY DEVICE
100A
102
CPU
104
MEMORY
40
82
81
20
5
80
42
30
22
92
HP
10
86
T4
T3
302
76
75
Ts
45
70A
73
78
74
LP
83
71
T1
T2
T5
87
77
90
50
62
85
3
84
60

FIG.9

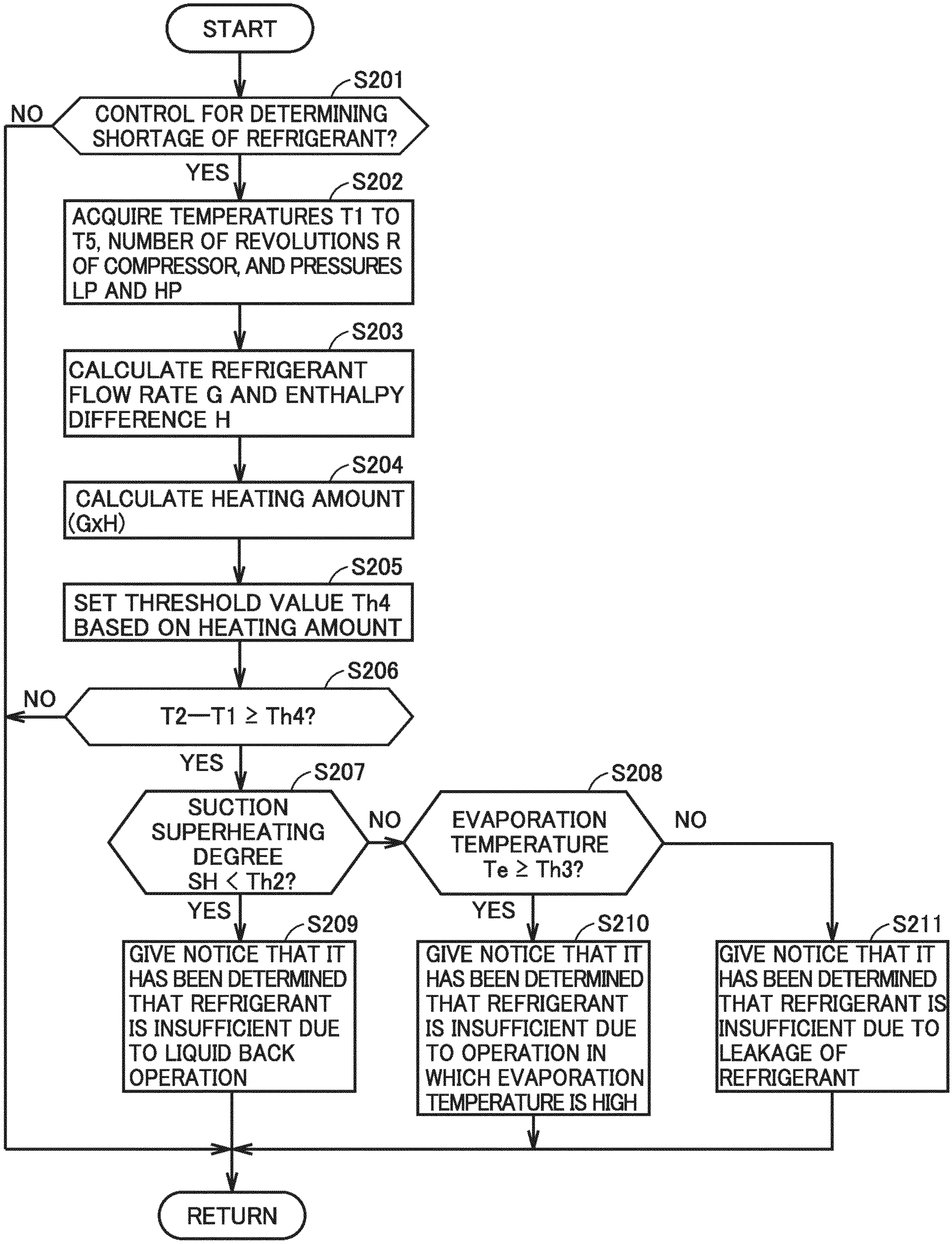

START
S201
CONTROL FOR DETERMINING SHORTAGE OF REFRIGERANT?
NO
YES
S202
ACQUIRE TEMPERATURES T1 TO T5, NUMBER OF REVOLUTIONS R OF COMPRESSOR, AND PRESSURES LP AND HP
S203
CALCULATE REFRIGERANT FLOW RATE G AND ENTHALPY DIFFERENCE H
S204
CALCULATE HEATING AMOUNT (GxH)
S205
SET THRESHOLD VALUE Th4 BASED ON HEATING AMOUNT
S206
T2—T1 ≥ Th4?
NO
YES
S207
SUCTION SUPERHEATING DEGREE SH < Th2?
NO
S208
EVAPORATION TEMPERATURE Te ≥ Th3?
NO
YES
S209
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LIQUID BACK OPERATION
YES
S210
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO OPERATION IN WHICH EVAPORATION TEMPERATURE IS HIGH
S211
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LEAKAGE OF REFRIGERANT
RETURN

FIG.10

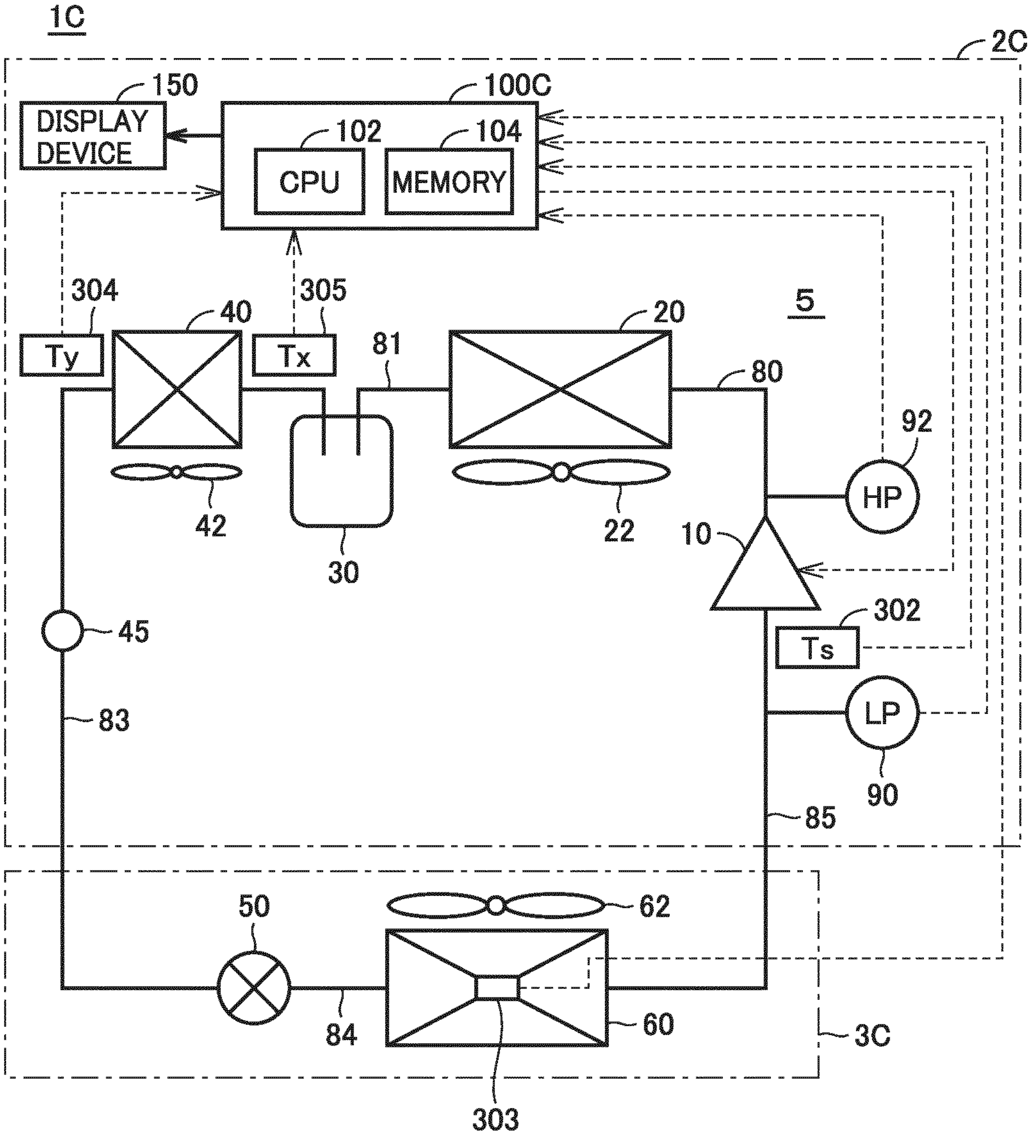

1C
2C
150
DISPLAY DEVICE
100C
102
CPU
104
MEMORY
304
40
305
20
5
Ty
Tx
81
80
92
HP
42
30
22
10
45
302
Ts
83
LP
90
85
50
62
84
60
3C
303

FIG.11

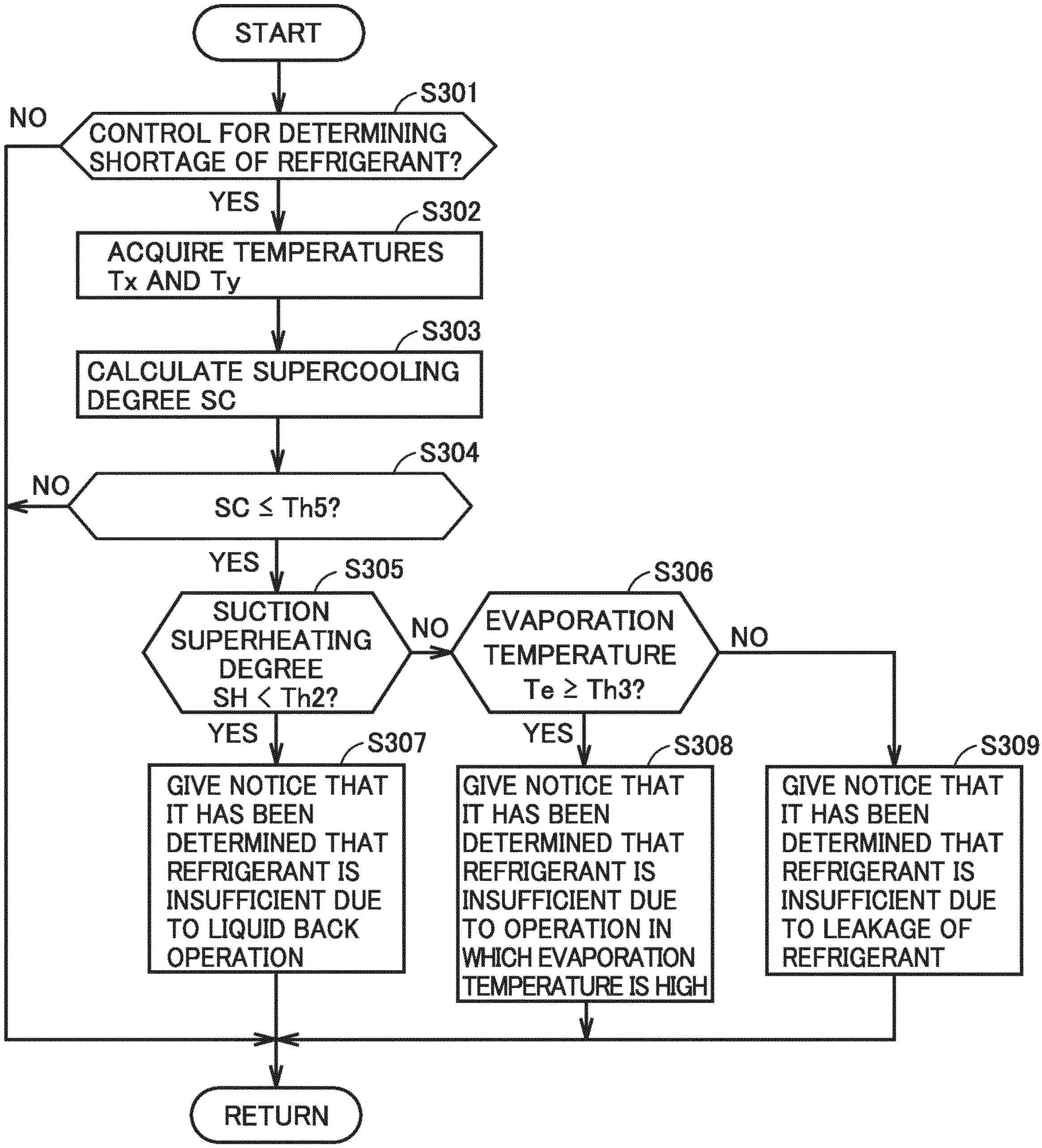

START
S301
CONTROL FOR DETERMINING SHORTAGE OF REFRIGERANT?
NO
YES
S302
ACQUIRE TEMPERATURES Tx AND Ty
S303
CALCULATE SUPERCOOLING DEGREE SC
S304
SC ≤ Th5?
NO
YES
S305
SUCTION SUPERHEATING DEGREE SH < Th2?
NO
S306
EVAPORATION TEMPERATURE Te ≥ Th3?
NO
YES
S307
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LIQUID BACK OPERATION
YES
S308
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO OPERATION IN WHICH EVAPORATION TEMPERATURE IS HIGH
S309
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LEAKAGE OF REFRIGERANT
RETURN

FIG.12

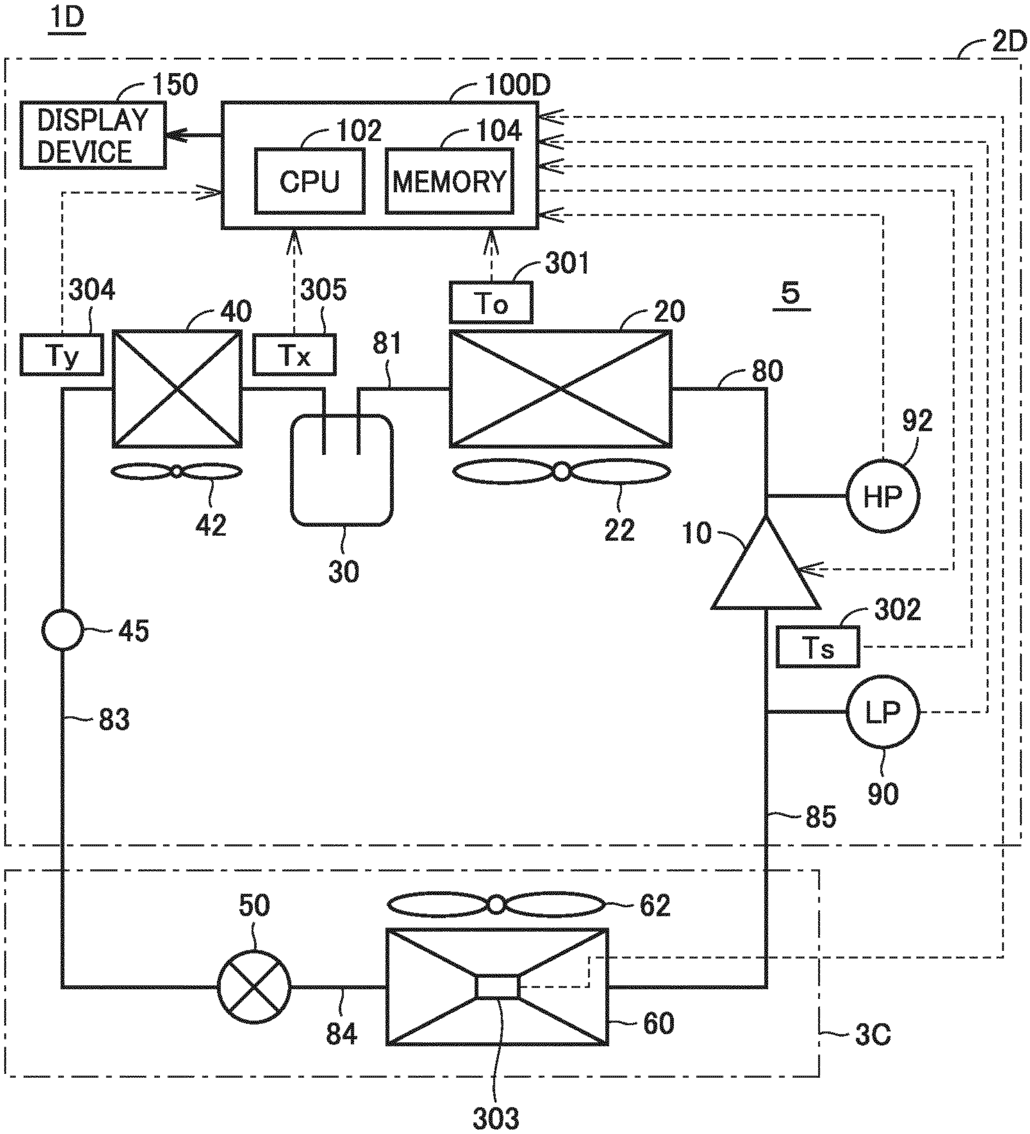

1D
2D
150
DISPLAY DEVICE
100D
102
104
CPU
MEMORY
301
304
305
To
5
40
20
Ty
Tx
81
80
92
HP
42
22
30
10
45
302
Ts
LP
83
90
85
50
62
84
60
3C
303

FIG.13

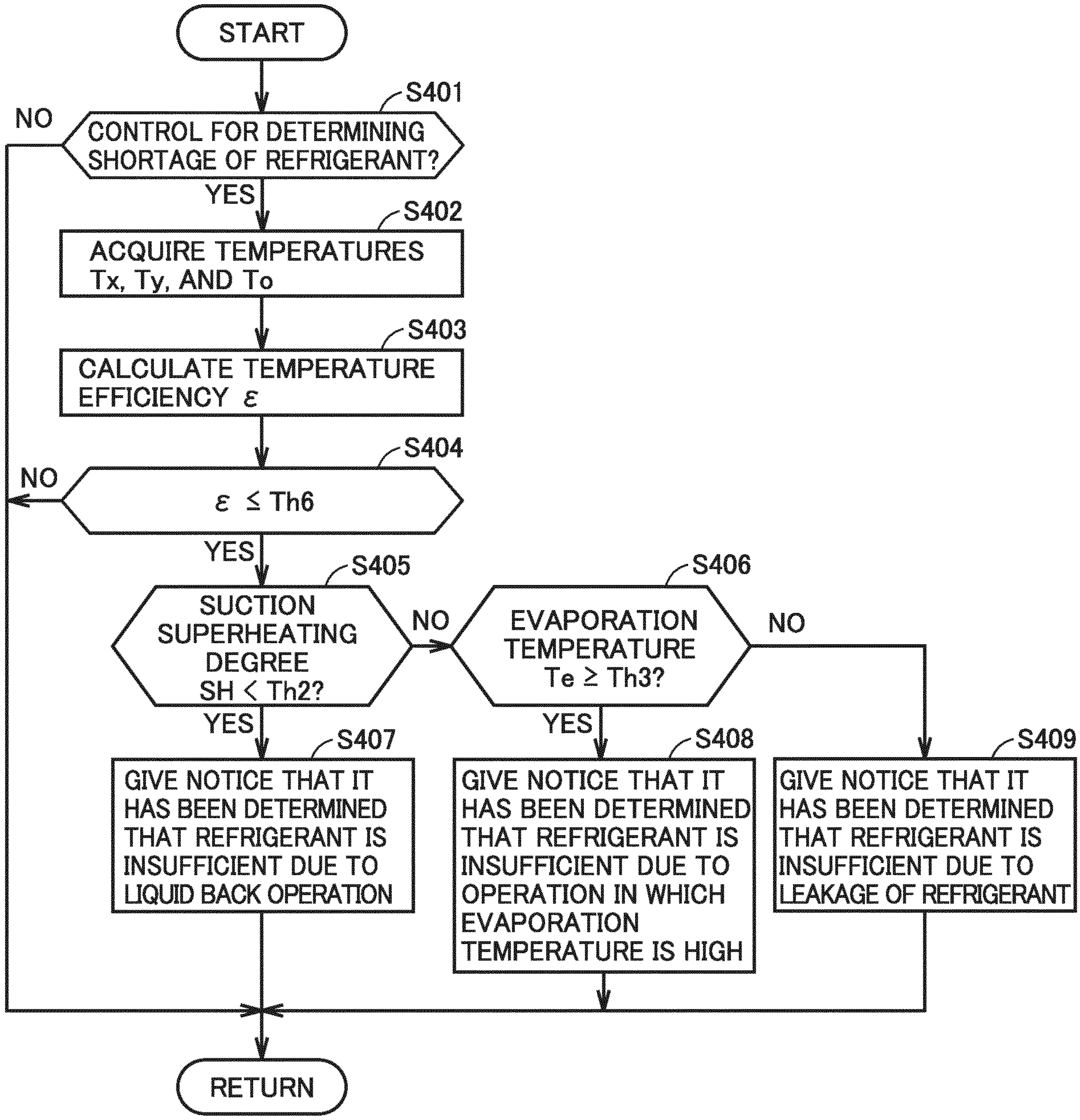

START
S401
CONTROL FOR DETERMINING SHORTAGE OF REFRIGERANT?
NO
YES
S402
ACQUIRE TEMPERATURES Tx, Ty, AND To
S403
CALCULATE TEMPERATURE EFFICIENCY ε
S404
ε ≤ Th6
NO
YES
S405
SUCTION SUPERHEATING DEGREE SH < Th2?
NO
S406
EVAPORATION TEMPERATURE Te ≥ Th3?
NO
YES
YES
S407
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LIQUID BACK OPERATION
S408
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO OPERATION IN WHICH EVAPORATION TEMPERATURE IS HIGH
S409
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LEAKAGE OF REFRIGERANT
RETURN

FIG.14

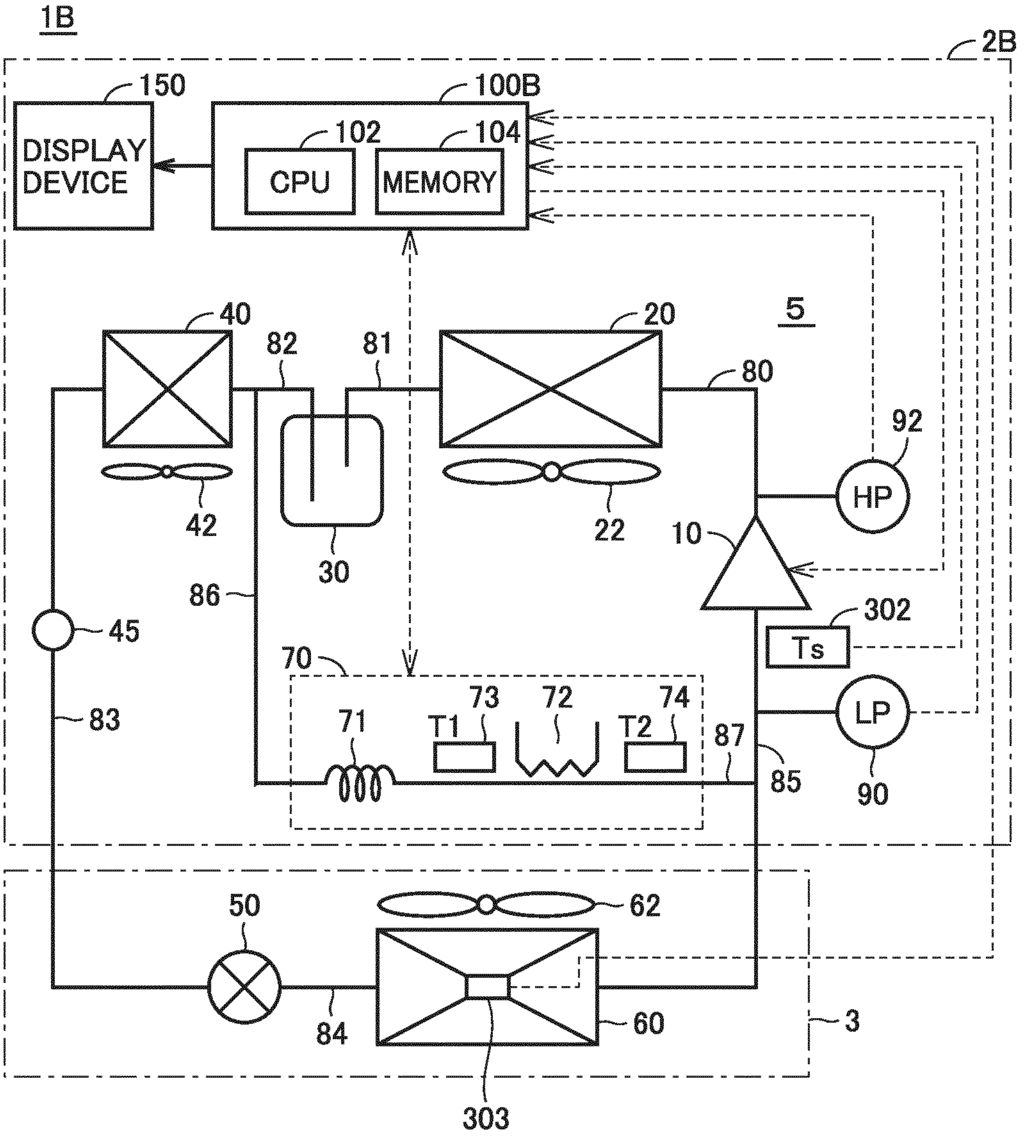

1B
2B
150
DISPLAY DEVICE
100B
102
CPU
104
MEMORY
40
82
81
20
5
80
92
HP
42
22
10
30
86
45
302
Ts
70
73
72
74
T1
T2
LP
83
71
87
85
90
50
62
84
60
3
303

FIG.15

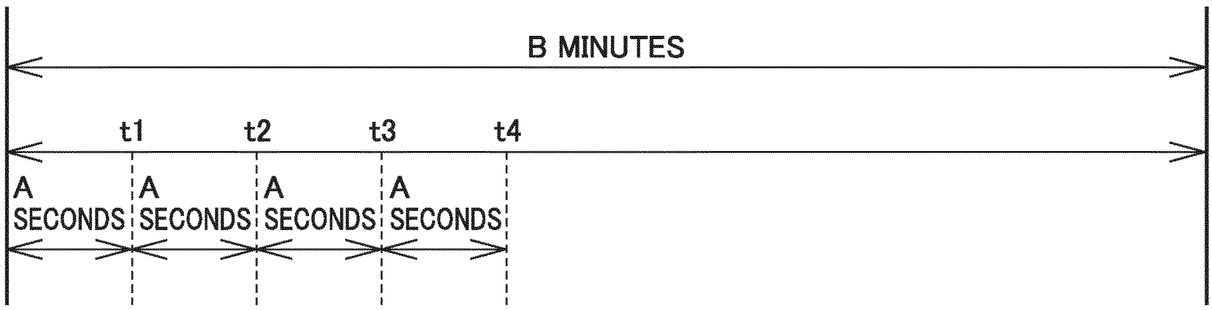
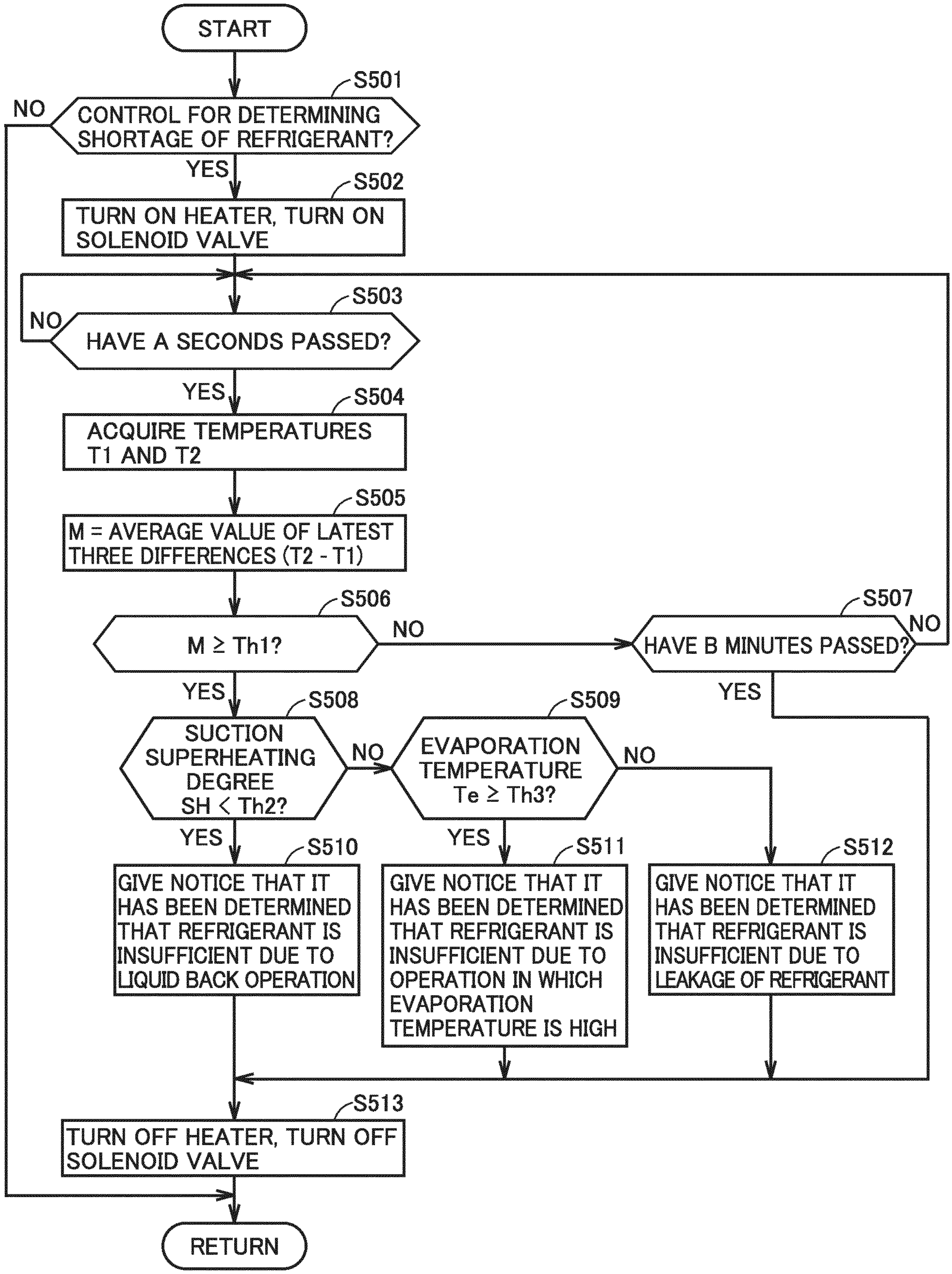


FIG.16


START
S501
CONTROL FOR DETERMINING SHORTAGE OF REFRIGERANT?
NO
YES
S502
TURN ON HEATER, TURN ON SOLENOID VALVE
S503
HAVE A SECONDS PASSED?
NO
YES
S504
ACQUIRE TEMPERATURES T1 AND T2
S505
M = AVERAGE VALUE OF LATEST THREE DIFFERENCES (T2 - T1)
S506
M ≥ Th1?
NO
YES
S507
HAVE B MINUTES PASSED?
NO
YES
S508
SUCTION SUPERHEATING DEGREE SH < Th2?
NO
YES
S509
EVAPORATION TEMPERATURE Te ≥ Th3?
NO
YES
S510
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LIQUID BACK OPERATION
S511
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO OPERATION IN WHICH EVAPORATION TEMPERATURE IS HIGH
S512
GIVE NOTICE THAT IT HAS BEEN DETERMINED THAT REFRIGERANT IS INSUFFICIENT DUE TO LEAKAGE OF REFRIGERANT
S513
TURN OFF HEATER, TURN OFF SOLENOID VALVE
RETURN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/012745

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. 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. 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.
Y A	US 2017/0198953 A1 (BERGSTROM, INC.) 13 July 2017, paragraphs [0001]-[0072], fig. 1-5 & CN 107042747 A	1-4, 13-15 5-12
Y A	US 2007/0089438 A1 (SINGH, A.) 26 April 2007, paragraphs [0001]-[0124], fig. 1-40 & WO 2007/047886 A1	1-4, 13-15 5-12
Y A	JP 2011-226704 A (MITSUBISHI ELECTRIC CORPORATION) 10 November 2011, paragraphs [0001]-[0140], fig. 1-14 (Family: none)	1-4, 13-15 5-12

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09.05.2019	21.05.2019

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/012745

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2015/0059373 A1 (BECKETT PERFORMANCE PRODUCTS, LLC) 05 March 2015, paragraphs [0002]-[0033], fig. 1-3 (Family: none)	1-15
A	US 2012/0143528 A1 (KATES, L.) 07 June 2012, paragraphs [0002]-[0253], fig. 1-18 & WO 2009/017851 A1	1-15
A	US 4576011 A (ELECTRIC POWER RESEARCH INSTITUTE) 18 March 1986, column 1, line 10 to column 5, line 22, fig. 1 & GB 2188136 A & DE 3607038 A & FR 2595797 A	1-2
A	JP 7-63430 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 10 March 1995, paragraphs [0001]-[0038], fig. 1-12 (Family: none)	5-12

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2012132639 A **[0002] [0003]**