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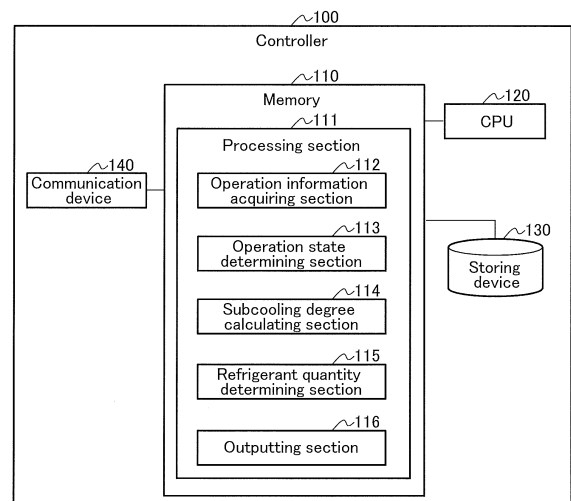
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(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle device, provided with: a compressor (14); a condenser (11); an evaporator (21); a pressure reducer (23); a subcooler (16) performing subcooling on a refrigerant passing through the condenser (11); a subcooling degree calculation unit (114) estimating a suitable subcooling degree of the refrigerant of an outlet of the subcooler (16) on the basis of a refrigerant cycle amount of a portion from the compressor (14) via the condenser (11) and the subcooler (16), and calculating, on the basis of the estimated suitable subcooling degree, a determination threshold value used for determining a refrigeration measurement; a refrigerant determination unit (115) comparing a measured subcooling degree and the determination threshold value, and thereby determining a refrigerant amount.

FIG.2



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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a technology of a refrigeration cycle device.

BACKGROUND ART

10 **[0002]** For example, Patent Document 1 discloses, in claims, an air conditioning device (1) which includes a heat source unit (2) having a compressor (21), a heat source-side heat exchanger (23) and a cooling heat source adjusting means (27) capable of adjusting a cooling function of the a cooling heat source for the heat source-side heat exchanger (23), a utilizing unit (4) having a utilization-side heat exchanger (41), an expansion mechanism (33), a refrigerant circuit (10) capable of performing at least a cooling operation for functioning the utilization-side heat exchanger as a condenser for the refrigerant compressed by the compressor and as an evaporator for the refrigerant condensed by the compressor, 15 a mode switching means for switch the utilization-side heat exchanger to a refrigerant quantity determining operation mode to make a degree of superheat of the refrigerant at an outlet of the utilization-side heat exchanger from a normal operation mode for controlling respective devices in the utilizing unit, a detecting means for detecting a subcooling degree of the refrigerant at the outlet of the utilization -side heat exchanger in the refrigerant quantity determining operation mode, a subcooling degree correcting means for deriving as subcooling degree correction value a value 20 derived by dividing the degree of subcooling by a value obtained by subtracting outdoor temperature from condensation temperature, and a refrigerant quantity propriety or impropriety of the amount of the refrigerant charged in a refrigerant circuit.

PRIOR ART

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PATENT DOCUMENT

[0003] PATENT DOCUMENT 1: JP5505477

30 SUMMARY OF INVENTION

PROBLEM TO BE SOLVED BY INVENTION

35 **[0004]** In the air conditioning device disclosed in the PATENT DOCUMENT 1, at first, shifts to a refrigerant determination operation mode for controlling a refrigerant superheating degree at an outlet of the evaporator in cooling operation to have a positive value. Next, the air conditioning device detects the refrigerant subcooling degree at the outlet of the condenser and derives a relative subcooling degree obtained by dividing the degree of subcooling by a value obtained by subtracting outdoor temperature from condensation temperature as a subcooling degree correction value. After that, the air conditioning device performs the refrigerant quantity propriety and impropriety in the refrigerant circuit on the 40 basis of the subcooling degree correction value (relative supercharging value).

[0005] The air conditioning device according to PATENT DOCUMENT 1, a refrigerant quantity propriety and impropriety determination at a high accuracy without influence of external disturbance such as an outdoor temperature, and external disturbance such as an outdoor temperature, soil of the outdoor heat exchanger.

45 **[0006]** In the refrigerant quantity propriety and impropriety determining method in the air conditioning device disclosed in PATENT DOCUMENT 1, a detection accuracy cannot be obtained if the subcooling degree of the condenser is made greater than a constant value (for example, 6 to 10 in consideration of the error in the temperature sensor and the pressure sensor which are detection means for subcooling value. However, when the subcooling degree is increased to keep the detection accuracy, this results in increase in a discharging pressure at the compressor, so that there is a problem in that a high efficient operation is impossible because the increase in the subcooling degree result in increase 50 in the discharge pressure. More specifically, it is difficult to determine whether determination of leakage of the refrigerant on the basis of the subcooling degree at the outlet of the condenser.

[0007] Further, in the refrigerant quantity determination mode in the technology described in PATENT DOCUMENT 1, it is impossible to perform the refrigerant quantity propriety and impropriety determination with the condenser subcooling degree as long as the superheating degree of the evaporator is kept constant. Accordingly, it is impossible to use for 55 the refrigerant quantity determination for the conditioning unit, etc. in which the superheating degree of the evaporator cannot be controlled from the heat source side.

[0008] Further, PATENT DOCUMENT 1 disclosed it is possible to increase the determination accuracy by using the subcooling degree corrected by the outdoor temperature and a condensing temperature. However, there is a problem

in that the determination accuracy is insufficient for responding to an operation state of the refrigerator, etc. in which the operation condition in the refrigerating cycle has a wider range (extremely varies).

[0009] The present invention is developed in consideration of the background describe above and has a problem in that the refrigerant quantity is determined at a high accuracy.

MEANS FOR SOLVING PROBLEM

[0010] An aspect of the invention provides a refrigeration cycle device comprising:

a compressor for compressing a gaseous refrigerant;
 a condenser for condensing the compressed refrigerant;
 a decompressor for decompressing the condensed refrigerant;
 an evaporator for evaporating the decompressed refrigerant;
 a subcooling device for subcooling the refrigerant condensed by the condenser;
 an appropriate subcooling degree estimation section for estimating a value related to an appropriate subcooling degree of the refrigerant at an outlet of the subcooling device based on a value related to a refrigerant circulation quantity of the refrigerant circulating from a discharging side of the compressor through the condenser, and the subcooling device;
 a determination threshold calculating section for calculating a determination threshold for determination of a refrigerant quantity based on a value related to the estimated appropriate subcooling degree; and
 a determining process section for determining a quantity of the refrigerant by comparing the value related to the measured subcooling degree and the determination threshold.

[0011] Other solving means is disclosed in the embodiments

ADVANTAGEOUS EFFECT OF INVENTION

[0012] According to the present invention, it is possible to determine the refrigerant quantity at a high accuracy.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1 is a drawing showing a configuration example of an air conditioning device according to a first embodiment.
 Fig. 2 is a drawing showing a configuration example of a controller according to the first embodiment.
 Fig. 3 is a Mollier chart (P-h chart) of the air conditioning device according to the first embodiment.
 Fig. 4 is a characteristic chart showing a refrigerant circulation quantity Gr and subcooling degrees at respective sections.
 Fig. 5 is a graph showing a relation between an estimation value of the refrigerant circulation quantity and actual measurement values of the refrigerant circulation quantity.
 Fig. 6 is a flowchart showing a process of refrigerant leakage determination process according to the first embodiment.
 Fig. 7 is a characteristic chart showing a relation between the refrigerant circulation quantity and a subcooling degree at an outlet of the subcooling device while a rotation speed of an outdoor fan is variously changed.
 Fig. 8 is a characteristic chart showing a relation between a value (Grr/For) acquired by dividing a refrigerant circulation ratio Grr by an outdoor fan rotation speed ratio For and the subcooling degree at the outlet of the subcooling device while a rotation speed of an outdoor fan is variously changed.
 Fig. 9 is a characteristic chart showing a relation between a value (Grr/For) acquired by dividing a refrigerant circulation ratio Grr by an outdoor fan rotation speed ratio For and the subcooling degree efficiency at the outlet of the subcooling device while a rotation speed of an outdoor fan is variously changed.
 Fig. 10 is a characteristic chart showing a relation between the refrigerant circulation quantity and the subcooling degree efficient at the outlet of the subcooling device while the outdoor fan rotation speed is variously changed.
 Fig. 11 is a drawing showing a configuration example of the air conditioning device according to a second embodiment.
 Fig. 12 is a Mollier chart (P-h chart) of the air conditioning device according to the second embodiment.
 Fig. 13 is a characteristic chart showing a relation between the refrigerant circulation quantity and a subcooling degree at an outlet of the economizer.
 Fig. 14 is a flowchart showing process of a refrigerant leakage determination process according to a third embodiment.

MODES FOR CARRYING OUT INVENTION

[0014] Next, embodiments for carrying out the invention are described in detail below referring to drawings. In the embodiments, a case where an interior of a room is cooled is described.

[First embodiment]

[0015] A first embodiment is described below.

(Configuration of an air conditioning device 1)

[0016] Fig. 1 is a drawing showing a configuration example of an air conditioning device according to a first embodiment.

[0017] The airconditioning device 1 according to the first embodiment is configured including an outdoor unit 10, an indoor unit 20, a controller 100, and a display device 200. The display device 200 can be omitted. The outdoor unit 10 is configured including an outdoor heat exchanger 11 operating as condenser, a receiver (excess refrigerant storage) 13, a subcooling device 16, an outdoor fan 12, a liquid injection valve 17, a compressor 14, an accumulator 15, the gas stop valve 18a, and a liquid stop valve 18b. On the other hand, the indoor unit 20 is configured including an indoor heat exchanger 21 operating as an evaporator, an indoor fan 22, and an indoor expansion valve (decompressor) 23.

[0018] The outdoor unit 10 and the indoor unit 20 are connected with pipes 30 and 31 through which refrigerant flow. The outdoor unit 10 is connected to the pipe 31 through a gas stop valve 18a and the pipe 30 through a liquid stop valve 18b.

[0019] The airconditioning device 1 according to the first embodiment makes a refrigerating cycle with a compressor 14, the outdoor heat exchanger 11, the receiver 13, the subcooling device 16, a liquid injection valve 17, the indoor heat exchanger 21, and the expansion valve 23.

[0020] The controller 100 controls the outdoor unit 10 by starting and stopping the outdoor fan 12 in the outdoor unit 10, adjusting an open degree of the liquid injection valve 17, adjusting a rotation speed F_r of the compressor 14 in the outdoor unit 10. Further, the controller 100 controls the indoor unit 20 by, in the indoor unit 20, starting and stopping the indoor fan 22, adjusting an open degree of the expansion valve 23, etc. Further, control lines for these controls are omitted in Fig. 1.

[0021] The refrigerant (gas, gaseous state) compressed by the compressor 14 flows into the outdoor heat exchanger 11 as a condenser where the refrigerant is condensed as a result of cooling by heat exchange with the outdoor air blown by the outdoor fan 12. The refrigerant (liquid) condensed by the outdoor heat exchanger 11 passes through the receiver 13 while an excess refrigerant is stored in the receiver 13 and subcooled by the subcooling device 16, and then introduced into the indoor unit 20 flowing through the pipe 30. A part of the refrigerant after passing through the subcooling device 16 (first passage) is adjusted by the liquid injection valve 17 to have a predetermined flow rate and injected to an intermediate section of the compressing chamber of the compressor 14. This controls a discharging temperature T_d of the compressor 14 to an appropriate value.

[0022] The refrigerant not flowing into the liquid injection valve 17, but is introduced into the indoor unit 20 (liquid: a second passage) is decompressed by the indoor expansion valve 23, and flows into the indoor heat exchanger 21 as the evaporator. The refrigerant (gas and liquid two phase state or liquid) flowing into the indoor heat exchanger 21 vaporizes (evaporates) by heat exchange with indoor air blown by the indoor fan 22. During this, the refrigerant (liquid) which is evaporated in the indoor heat exchanger 21 removes heat of evaporation from the indoor air, which cools the indoor air.

[0023] The refrigerant (gas, gaseous state) which is evaporated in the indoor heat exchanger 21 is introduced into the outdoor unit 10, flowing through the pipe 31 and flows into an accumulator 15. The accumulator 15 functions as a buffer tank for storing the refrigerant (liquid) when the liquid refrigerant transiently excessively flowing thereinto, which prevents the compressor 14 from compressing the liquid. Accordingly the accumulator 15 adjusts dryness of the refrigerant, so that the refrigerant having an appropriate dryness flows into the compressor 14, which prevents liquid-compression, etc., so that reliability is secured.

[0024] Further, the outdoor unit 10 includes a discharging temperature sensor 10ta for measuring a temperature (discharging temperature T_d) of the refrigerant discharged by the compressor 14, the discharging pressure sensor 10pa for measuring a pressure (discharging pressure P_d) of the refrigerant on an outlet side of the compressor 14 and an inlet pressure sensor 10pb for measuring a pressure (an inlet pressure P_s) of the refrigerant on an inlet side of the compressor 14.

[0025] Further, the outdoor unit 10 includes a temperature sensor 10tb for measuring a condensation temperature T_c of the refrigerant at the outdoor heat exchanger 11 and a temperature sensor 10tc for measuring an outlet temperature T_{sc} of the subcooling device 16. Further, the outdoor unit 10 includes a temperature sensor 10td for measuring a outlet temperature T_s of the gas stop valve 18a (an inlet temperature of the accumulator 15). Further, the outdoor unit 10 includes a temperature sensor 10te for measuring a temperature of the refrigerant at an outlet of a condenser (the

outdoor heat exchanger 11) and an outdoor air temperature sensor 10tf for measuring an outdoor temperature. Further, the outdoor unit 10 includes a temperature sensor 10tg installed to the pipe at the gas and liquid two phase state part of the outdoor heat exchanger 11 for measuring a temperature at a gas and liquid two phase state part.

[0026] The indoor unit 20 includes a temperature sensor 20ta for measuring an evaporation temperature T_e of the refrigerant at the indoor heat exchanger 21. Further, the indoor unit 20 includes a temperature sensor 20tb for measuring an inlet temperature of the indoor heat exchanger 21 and a temperature sensor 20tc for measuring an outlet temperature of the indoor heat exchanger 21.

[0027] Moreover, there may be a configuration measuring an upper part temperature of the chamber of the compressor 14 in place of the discharging temperature T_d .

[0028] The controller 100 calculates a subcooling degree at an outlet of the subcooling device 16 and determines a quantity of the refrigerant in the refrigerating cycle by comparing the subcooling degree with a determination threshold calculated by a method which will be described later on the basis of the information acquired from various sensors, i.e., the discharging temperature sensor 10ta, the temperature sensor 10tb, the temperature sensor 10tc, the temperature sensor 10td, the temperature sensor 10te, the outdoor air temperature sensor 10tf, the temperature sensor 10tg, a temperature sensor 10pa, the inlet pressure sensor 10pb, a temperature sensor temperature sensor 20ta, a temperature sensor 20tb, and the temperature sensor 20tc, the liquid injection valve 17, the indoor expansion valve 23, etc. The determination of the quantity of the refrigerant will be described later. The controller 100 displays the determination result of the quantity of the refrigerant on the display device 200, etc.

(Configuration of the controller 100)

[0029] Fig. 2 is a block diagram of a configuration example of the controller according to the first embodiment.

[0030] The controller 100 includes a memory 110, a CPU (Central Processing Unit) 120, a storing device 130 such as a HD (Hard Disk), and a communication device 140.

[0031] A program is loaded in the memory 110 and executed by the CPU 120, so that a processing section 111, an operation information acquiring section 112, an operation state determining section 113, a subcooling degree calculating section 114 (an appropriate subcooling degree estimation section, determination threshold calculating section), a refrigerant quantity determination section (determining process section) 115, and the an outputting section 116 are embodied.

[0032] The operation information acquiring section 112 acquires information from the discharging temperature sensor 10ta, the temperature sensor 10tb, the temperature sensor 10tc, the temperature sensor 10td, the temperature sensor 10te, the outdoor air temperature sensor 10tf, the temperature sensor 10tg, a temperature sensor 10pa, the inlet pressure sensor 10pb, a temperature sensor temperature sensor 20ta, a temperature sensor 20tb, and the temperature sensor 20tc, etc. in Fig. 1 and information of the open degrees of the liquid injection valve 17 and the indoor expansion valve 23.

[0033] The operation state determining section 113 determines whether a state of the airconditioning device 1 is in a state suitable for a refrigerant leakage state or not.

[0034] The subcooling degree calculating section 114 calculates a determination threshold described later and an actual measurement subcooling degree at an outlet of the subcooling device 16.

[0035] The refrigerant quantity determination section 115 determines whether the quantity of the refrigerant is appropriate on the basis of the determination threshold calculated by the subcooling degree calculating section 114 and the actual measurement subcooling degree.

[0036] The outputting section 116 outputs information indicating that the quantity of the refrigerant is improper when the quantity of the refrigerant is improper (erroneous) on the basis of the refrigerant quantity determination section 115.

[0037] Detailed processes performed by respective sections, i.e., the processing section 111 to the outputting section 116 will be described later.

(Mollier chart)

[0038] Fig. 3 is a Mollier chart (P-h chart) of the air conditioning device according to the first embodiment. Occasionally, Fig. 1 is referred.

[0039] When the airconditioning device 1 cools a room, the refrigerant (gas, or a gaseous state) in a state 301 is compressed by the compressor 14, so that a temperature (specific enthalpy) and a pressure of the refrigerant increase and the state shifts to a state 302 at an intermediate pressure point of the compressor 14. The refrigerant in a state 307 having a low specific enthalpy is injected from the liquid injection valve 17, so that the refrigerant shifts to a state 303.

[0040] Further, the refrigerant is brought into a state 304 because the refrigerant in the state 303 is compressed by the compressor 14 to a high pressure P_d .

[0041] After this, the refrigerant is introduced into the outdoor heat exchanger 11 operating as a condenser during a cooling operation, so that the refrigerant is cooled by the outdoor air blown by the outdoor fan 12 and condensed and the state shift to a state 305 (liquid) and the liquid is introduced into the receiver 13. Since the receiver 13 is kept in a

saturated state because there is a liquid level in the receiver 13, the refrigerant is discharged from a bottom part thereof and introduced into the subcooling device 16 and brought into a state 306 which is a subcooled state by the outdoor air blown by the outdoor fan 12.

[0042] A part (broken line) of the refrigerant in the state 306 is decompressed to the state 307 by the liquid injection valve 17. Only a predetermined quantity of the refrigerant in the state 307 is injected to the intermediate pressure of the compressor 14 becoming the state 303 to perform the control of the discharging temperature T_d .

[0043] In the remaining main circuit (solid line), a liquid refrigerant is sent through the pipe 30 to the indoor unit 20 where the liquid refrigerant is decompressed by the indoor expansion valve 23. The refrigerant becomes in the state indicated by a point 308, i.e., in the gas and liquid two phase state at a low temperature and is introduced into the indoor heat exchanger 21. There, heat exchange is performed between the refrigerant and the room air blown by the indoor fan 22, so that the refrigerant evaporates and becomes a gaseous refrigerant, which provides a cooling function for the room air.

[0044] The gaseous refrigerant evaporating in the indoor heat exchanger 21 is brought into the state 301 and returned to the outdoor unit 10 through the pipe 31 on a gaseous side where the refrigerant is returned to the compressor 14 through the accumulator 15, which forms a sequential refrigerating cycle.

[0045] In this operation, an appropriate quantity of the refrigerant is charged into the refrigerant cycle, so that a subcooling degree Sc at the outlet of the outdoor unit 10 indicated with the state 306 shown in Fig. 3 has an appropriate value. According to this, a difference in the specific enthalpies (from the state 308 to the state 301) is sufficiently large, which secures the cooling capacity.

[0046] The operation state in the case where the quantity of the refrigerant is appropriate can be explained because there is a state in which there is the liquid level in the receiver 13. When the liquid level decreases down to a lower end, this means a lack of the refrigerant. On the other hand, when the liquid level is fully filled in the receiver 13, this means that the receiver 13 is in an excess state of the refrigerant.

[0047] For example, when the receiver 13 is in an excess state of the refrigerant, the receiver 13 is fully filled with subcooled refrigerant therein, and a state of an outlet of the outdoor heat exchanger 11 as a condenser, located upstream from the receiver 13, shifts to a subcooled state. In this state, the inside of the outdoor heat exchanger 11 is filled with the liquid refrigerant, so that a condensation pressure increases by a subcooled degree.

[0048] When the pressure increase is too excessive, a compression drive force at the compressor 14 increases due to increase in the discharging pressure P_d of the compressor 14, which causes a problem in that a coefficient of performance decreases.

[0049] Further, in a lack state of the refrigerant due to a leakage of the refrigerant, the liquid level decreases in the receiver 13 down to a lower end. As a result, the outlet of the condenser is brought into the gas and liquid two phase state, so that the point indicated with a state 305 in Fig. 3 is inside the saturated line, and the specific enthalpy increases. As a result, a difference in the specific enthalpies in the evaporator (the indoor heat exchanger 21) is made smaller (the state 308 to the state 301), which results in decrease in the cooling performance and the performance coefficient.

[0050] More specifically, when the quantity of the refrigerant is appropriate because the receiver 13 is in a state that there is a liquid level in the receiver 13, this contributes to a high efficient cooling operation. Further, in other words, if it is possible to determine whether the refrigerant in the receiver 13 changes to an under quantity side from progress of operation, it becomes possible to determine whether the refrigerant leaks. This contributes to prevention of global warming due to the leakage of the refrigerant and fire accidents due to a slightly flammable refrigerant. This provides a useful function.

[0051] According to this, in the first embodiment, as a method of determining whether the refrigerant is lack or excess, a determination is made using a characteristic of subcooling degree at the outlet of the subcooling device 16 with respect to a quantity of circulation refrigerant shown in Fig. 4. In addition, in the embodiments of the present invention, a quantity of the refrigerant in the entire refrigeration cycle is called a refrigerant quantity and a quantity of the refrigerant flowing per a unit interval is called a refrigerant circulation quantity (mass flow rate).

[0052] Fig. 4 is a characteristic diagram showing a refrigerant circulation quantity Gr and subcooling degrees at respective parts. A refrigerant circulation quantity Gr in Fig. 4 indicates a refrigerant circulating from a discharging side of the compressor 14, via the outdoor heat exchanger 11, the receiver 13, and the subcooling device 16. A point indicated with "□" represents a subcooling degree (the state 304 in Fig. 3) at an outlet of the condenser (the outdoor heat exchanger 11); a point indicated with "◇" is a subcooling degree (the state 306 in Fig. 3) at the outlet of the subcooling device 16. "Δ" in Fig. 4 will be described later.

[0053] Further, the points shown in Fig. 4 indicate the state in which there is a liquid level in the receiver 13, i.e., the operation state at an appropriate refrigerant quantity, i.e., various states in which operation state such as the evaporation temperature T_e , the outdoor air temperature, an outdoor fan rotation speed, a compressor rotation speed, etc vary. More specifically, in the state that there is an excess refrigerant in the receiver 13, various states are shown in ranges of the evaporation temperature T_e from -40 to 0°C , the compressor rotation speed from 40 to 85 rps, the outdoor air temperature from 16 to 36°C , and the outdoor fan rotation speed from 60 to 100%.

[0054] From the graph in Fig. 4, it is substantially shown that both the subcooling degree ("□") at the outlet of the condenser (the outdoor heat exchanger 11) and the subcooling degree "◇" at the outlet of the subcooling device 16 have tendency of increase in accordance with increases in the refrigerant circulation quantity.

[0055] However, since the subcooling degree ("□") at the outlet of the condenser has a small value not greater than 2 [K], an accuracy of the detecting means is considered to be insufficient. More specifically, the subcooling degree is calculated from a difference between an outlet temperature of the condenser (outdoor heat exchanger 11) and the condensation temperature Tc. Accordingly, detection errors of two sensors, i.e., the temperature sensor 10te for measuring an outlet temperature of the condenser and the temperature sensor 10tb for measuring the condensation temperature Tc are added, so that it is difficult to determine whether the refrigerant is excessive and insufficient at a temperature not greater than 2 [K].

[0056] On the contrary, the subcooling degree of "◇" at the outlet of the subcooling device 16 indicates a subcooling degree of downstream of the receiver 13, where the refrigerant passes there while the subcooling degree is in a substantially saturation state. Accordingly, this indicates the subcooling degree having values from 5 to 10 [K], and the inventor found that the values are usable and appropriate for determining whether the quantity of the refrigerant is excessive or insufficient though there may be a detection error in the temperature sensor 10tc.

[0057] When it is assumed that a line 401 which is derived by approximating points "◇" represents a subcooling degree which is appropriate (appropriate subcooling degree), the appropriate subcooling degree with respect to the refrigerant circulation quantity is defined by Eq.(1) representing the line 401.

$$Sc1s = A1 \cdot \ln(Gr) - A2 \quad \text{--- (1)}$$

[0058] A1 and A2 are values acquired from the line 401 in Fig. 4. More specifically, A1 and A2 are values acquired as a result of fitting the subcooling degree at the outlet of the subcooling device 16 with respect to the refrigerant circulation quantity. Particularly, A2 is an appropriate subcooling degree when the refrigerant circulation quantity is a rated circulation quantity. Gr is a refrigerant circulation quantity.

[0059] In the example shown in Fig. 4, A1 = 5.83 and A2 = 24.54. The values of A1 and A2 are variable in accordance with simulation conditions. However, it is desirable that A1 have a value in a range from 5 to 7.

[0060] If the subcooling degree when refrigerant leakage rate is 15% is represented by a line 402 represents a state that the subcooling degree decreased to about 60%. Using this, a determination threshold Sc1th for the refrigerant leakage can be represented by Eq. (2).

$$Sc1th = Sc1s \times A3 \quad \text{--- (2)}$$

[0061] A3 is a decrease rate of the subcooling degree when leakage of the refrigerant occurs and A3 = 0.6 because the subcooling degree decreases to about 60% if the refrigerant leakage rate is 15%. Accordingly, A3 is a positive integral lower than 1. Here, A3 = 0.6 is an example, and the value of A3 is not limited to 0.6 as long as the value of A3 is suitable value for refrigerant leakage determination.

[0062] Since, to directly measure the refrigerant circulation quantity Gr is not practical regarding a cost, it is desirable to acquire an estimated refrigerant circulation quantity using the approximation represented by Eq. (3).

$$Grp = (a1 \cdot Fr + a2)(b1 \cdot Ps + b2)(c1 \cdot MV + c2) \quad \text{--- (3)}$$

[0063] Grp represents an estimated value [kg/h] of the refrigerant circulation quantity, Fr represents compressor rotation speed [rps], Ps represents an inlet pressure Ps [MPa] of the compressor 14, and MV is an opening degree of the liquid injection valve 17. Further, a1, a2, b1, b2, c1, c2 are coefficients respectively acquired by experiments, simulation, etc.

[0064] Fig. 5 is a graphic chart showing a relation between an estimated value of the refrigerant circulation quantity acquired by Eq. (3) and measurement values of the refrigerant circulation quantity.

[0065] In Fig. 5, an axis of abscissa represents the measured refrigerant circulation quantity Gr and an axis of ordinates represents the refrigerant circulation quantity estimation value Grp of the estimated values. In Fig. 5, a solid line 501 is a line representing that the measured refrigerant circulation quantity Gr agrees with a estimated refrigerant circulation quantity value Grp. A broken line 502 is a line representing that the estimated refrigerant circulation quantity value Grp has a deviation of +5% to the measured refrigerant circulation quantity Gr. A broken line 503 is a line representing that the estimated refrigerant circulation quantity value Grp has a deviation of -5% to the measured refrigerant circulation

quantity Gr. In Fig. 5, plotted points "□" are made by plotting the estimated refrigerant circulation quantity values Grp calculated using Eq. (2) in the condition when the measured refrigerant circulation quantities Gr are acquired.

[0066] As shown in Fig. 5, the estimated refrigerant circulation quantity values Grp (an axis of ordinates) have accuracy not greater than $\pm 5\%$ with respect to the measured refrigerant circulation quantities Gr (axis of abscissa). Accordingly, it can be considered that the subcooling degree at the outlet of the subcooling device 16 calculated by substituting the estimated refrigerant circulation quantity value Grp estimated using Eq. (3) for the refrigerant circulation quantity Gr in Eq. (1), is substantially accurate. Accordingly, it is supposed that the determination threshold calculated in accordance with Eq. (2) using the estimated refrigerant circulation quantity value Grp of the refrigerant circulation quantity is likely useful.

(Flowchart)

[0067] Fig. 6 is a flow chart showing a flow of refrigerant leakage determination process according to the first embodiment. Occasionally, Figs. 1 and 2 are referred.

[0068] The process shown in Fig. 6 can be performed in a general operation without transition to a special mode such as a refrigerant determination mode in which the subcooling degree is increased for determination, etc.

[0069] First, when the processing section 111 in the controller 100 starts the refrigerant leakage detection, the operation information acquiring section 112 acquires information (regarding operation states) of respective components in the air conditioning device 1 (operation state information)(S101). The operation state information includes information outputted by the various types of sensors (10ta, 10tb, 10tc, 10td, 10te, 10tf, 10tg, 10pa, 10pb, 20ta, 20tb, 20tc, etc., an opening degree information of a valve acquired from the liquid injection valve 17 and the indoor expansion valve 23, the compressor rotation speed Fr, etc. acquired from the compressor 14.

[0070] Next, the operation state determining section 113 determines whether it is in such a state that the refrigerant leakage determination is possible on the basis of the operation state information (S102). A state, in which the refrigerant leakage state can be determined, depends on whether variations of respective states are stable within constant values or not. For example, it depends on whether the inlet pressure Ps acquired from the inlet pressure sensor 10pb is appropriate or not, whether an inlet superheat degree SH in the compressor 14 acquired from the outlet temperature Ts of the gas stop valve 18a measured by the temperature sensor 10td is appropriate or not (for example, the suction superheat degree SH is not smaller than 5K and the outlet temperature Ts of the gas stop valve 18a measured by the temperature sensor 10td is not greater than 20°C), whether the outdoor temperature measured by the outdoor air temperature sensor 10tf is appropriate or not (for example, the outdoor temperature is 0 to 35°C), whether a compressor rotation speed Fr is appropriate or not (for example, not smaller than 50% of the rated rotation speed), etc. More specifically, the operation state determining section 113 determines in a step S102 whether a value related to the operation state is in a state capable of determining the refrigerant state. Further, an inlet temperature of the compressor 14 can be used in place of the outlet temperature Ts of the gas stop valve 18a.

[0071] It is also possible that the operation state determining section 113 can determine that the determination of the refrigerant leakage when the refrigerant circulation quantity Gr (or the estimated value Grp of the refrigerant circulation quantity) is within a predetermined range (for example, between 150kg/h to 550kg/h). This prevents performing determination of the refrigerant leakage when the operation state is extremely different from the general operation condition.

[0072] As a result of the step S102, the state is not a state in which the refrigerant leakage determination is possible (No in S102), the processing section 111 returns the processing to a step S101.

[0073] As a result of the step S102, when the refrigerant leakage determination is possible (YES in S102), the operation state determining section 113 determines whether a predetermined period has elapsed (for example, about fifteen minutes) (a step S103).

[0074] Here, the determination is made based on the operation state information whether the refrigerant leakage determination is possible every hour. However, it is also possible that the operation state determining section 113 stores information regarding the operation state of the airconditioning device 1 for a predetermined period and determines whether the refrigerant leakage determination is possible on the basis of the stored information regarding the operation state.

[0075] As a result of the step S103, when the predetermined period has not elapsed (NO in S103), the processing section 111 returns the processing to the step S101.

[0076] As a result of the step S103, when the predetermined period has elapsed (YES in S103), the subcooling degree calculating section 114 calculates the determination threshold Sc1th using Eqs. (1) to (3) (S111).

[0077] The subcooling degree calculating section 114 calculates a measured subcooling degree Sc1 at the outlet of the subcooling device 16 (S112).

[0078] The subcooling degree calculating section 114 calculates the condensation temperature Tc from the discharging pressure Pd detected by the discharging pressure sensor 10pa on the basis of the characteristic information of the refrigerant physical property previously stored in the storing device 130. The subcooling degree calculating section 114

calculates the measured subcooling degree Sc1 at the outlet of the subcooling device 16 by Eq. (4) providing a difference between the outlet temperature Tsc of the subcooling device 16 acquired by the temperature sensor 10tc installed at the outlet of the subcooling device 16 and the condensation temperature Tc.

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$$Sc1 = Tc - Tsc \text{ --- (4)}$$

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[0079] In place of the condensation temperature Tc acquired on the basis of the discharging pressure Pd, a pipe temperature at a gas and liquid two phase state portion of the outdoor heat exchanger 11 is measured by the temperature sensor 10tg or the temperature sensor 10te at the outlet of the condenser at the condenser (the outdoor heat exchanger 11), and the temperature is usable as the condensation temperature Tc to calculate the measured subcooling degree Sc1 at the outlet of the subcooling device 16 similarly.

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[0080] When the temperature sensor 10te at the outlet of the condenser (the outdoor heat exchanger 11) is used, this enables to calculate the actual condensation temperature excluding influence of pressure loss quantity in the refrigerant flow passage from the compressor 14 to the outdoor heat exchanger 11. This can increase a calculation accuracy of the measured subcooling degree Sc1 at the outlet of the subcooling device 16.

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[0081] Further, when the temperature measured by the temperature sensor 10te at the outlet of the condenser (the outdoor heat exchanger 11) is used, and as a kind of the refrigerant, if a non-azeotropic refrigerant mixture is used, the temperature on a side of boiling point can be measured correctly, though composition changes occurs in the refrigerant. Accordingly, the subcooling degree at the subcooling device 16 can be accurately calculated.

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[0082] The refrigerant quantity determining section 115 determines whether the refrigerant leakage (a quantity of the refrigerant is insufficient) occurs by determining whether the measured subcooling degree Sc1 at the outlet of the subcooling device 16 calculated in a step S112 is equal to or smaller than the determination threshold Sc1th or not (S113).

[0083] As a result of a step S113, the measured subcooling degree Sc1 at the outlet of the subcooling device 16 is not smaller than a determination threshold Sc1th (NO in S113), the refrigerant quantity determining section 115 determines that there is no refrigerant leakage (the quantity of the refrigerant is not insufficient), the processing section returns the processing to the step S101.

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[0084] As a result of the step S113, when the measured subcooling degree Sc1 at the outlet of the subcooling device 16 is smaller than the determination threshold Sc1th (YES in S113), the refrigerant quantity determining section 115 determines whether a predetermined period has elapsed (S114). In other words, the refrigerant quantity determining section 115 determines whether a state in which the measured subcooling degree Sc1 is smaller than the Sc1th continues for a long time or not.

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[0085] As a result of a step S114, when the predetermined period has not elapsed (NO in S114), the processing section 111 returns the processing to the step S112. Further, when the predetermined period has not elapsed, the processing section 111 can return the processing also to the step S111.

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[0086] As a result of the step S114, when the predetermined period has elapsed (YES in S114), the refrigerant quantity determining section 115 determines that the refrigerant leakage occurs (the quantity of the refrigerant is insufficient) (S121). As described above, determination that the leakage occurs (the refrigerant quantity is insufficient) is made after the predetermined period has elapsed in the state in which the measured subcooling degree Sc1 at the outlet of the subcooling device 16 is smaller than the determination threshold Sc1th. This prevents determination made in response to detection of temporary noise, etc.

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[0087] Next, the outputting section 116 sends a refrigerant leakage determination flag to the display device 200, an alarming device, a concentrated monitoring device (not shown), etc. (S122). For example, the display device 200 makes an alarming indication such as "Refrigerant leakage may occur", etc.

[0088] The above-description is for the control method of determining whether refrigerant leakage occurs. When the refrigerant leakage is detected by this process, a countermeasure changes and depends on the kind or use of the airconditioning device 1.

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[0089] For example, when a cooling subject of the airconditioning device 1 is a food, a drink, or the like, decrease in quality due to stop of operation becomes a problem.

[0090] In such application, the operation of the airconditioning device 1 is not immediately stopped, but makes an emergency communication with a service center, etc. (not shown) to prompt to send a service man to that place. This provides a quick countermeasure.

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[0091] On the other hand, though the cooling object is food, when the used refrigerant is a slightly flammable refrigerant, the controller 100 stops the operation of the airconditioning device 1 and ensure safety with the highest priority such as making an alarm for the surrounding, shutting off shut-off valves, and driving a ventilation device.

[0092] Further, when use of the airconditioning device 1 is for human beings, the controller 100 prevents the refrigerant from leaking to a room by shutting off the indoor expansion valve 23, the gas stop valve 18a, the liquid stop valve 18b,

etc. in addition to stopping the operation of the airconditioning device 1.

[0093] In the embodiments, an appropriate subcooling degree $Sc1s$ is calculated using Eq. (1). However, the embodiments are not limited to this, and it is possible to hold as a map a relation between the refrigerant circulation quantity in Fig. 5 and the subcooling degree of the refrigerant at the outlet of the subcooling device 16 and calculate the appropriate subcooling degree $Sc1s$ on the basis of the map.

[0094] The map may be made through simulation and made on the basis of the measured values.

[0095] The controller 100 of the airconditioning device 1 according to the embodiment calculates the appropriate subcooling degree at the outlet of the subcooling device 16 on the basis of the refrigerant circulation quantity. When the controller 100 calculates the determination threshold on the basis of the appropriate subcooling degree, the controller 100 makes determination of the quantity of the refrigerant, more specifically, makes the determination of whether the quantity of the refrigerant is insufficient due to the leakage of the refrigerant by comparing the measured subcooling degree with the determination threshold. According to this operation, the quantity of the refrigerant can be determined at a high accuracy without increase in the subcooling degree.

[0096] More specifically, as described referring to Fig. 4, the relation between the refrigerant circulation quantity of the refrigerant and the subcooling degree at the outlet of the subcooling device 16 is stable though the operation state such as the evaporation temperature T_e , the outdoor temperature, an outdoor fan rotation speed, a compressor rotation speed changes in various manner. Accordingly, the airconditioning device 1 of the present embodiment can determine the quantity of the refrigerant stable even though various operation states (disturbance, error factor) occur. In other words, the airconditioning device 1 according to the present embodiment can increase authenticity and accuracy in determination of the quantity of the refrigerant.

[0097] Further, the determination of the quantity of the refrigerant has been made in only in a special mode by fixing the operation state to increase the subcooling degree. On the other hand, according to the method of the embodiment, the refrigerant quantity determination can be made also in the general operation. This eliminates, in the airconditioning device 1 according to the present embodiment, influence on the cooling temperature on a side of the load, which enables to make determination of the quantity of the refrigerant generally, more specifically, determination of insufficiency of the quantity of the refrigerant (leakage of the refrigerant) can be made.

[0098] Further, in the airconditioning device 1 according to the present embodiment, since it is possible to make determination of the insufficiency of the quantity of the refrigerant in a high accuracy (leakage of the refrigerant) even in various operation states, which enables a rapid countermeasure when the quantity of the refrigerant is insufficient (occurrence of leakage), so that labor saving in inspection, cost reduction, a efficient countermeasure against.

[0099] In addition, the airconditioning device 1 according to the present embodiment includes the receiver 13 upstream from the subcooling device 16. As described above, the receiver 13 is provided, which stabilizes the subcooling degree at the outlet of the subcooling device 16, so that accuracy of determining the quantity of the refrigerant can be increased.

[0100] Further, the airconditioning device 1 according to the embodiment determines that insufficiency in the quantity of the refrigerant (leakage of the refrigerant) occurs when a state that the actual subcooling degree is smaller than the determination threshold continues for the predetermined period. This can prevent an erroneous determination that the quantity of the refrigerant is insufficient when the measured subcooling degree temporary decreases due to noise etc.

[0101] Further, the airconditioning device 1 according to the present embodiment calculates the appropriate subcooling degree on the basis of Eq. (1). This can make, in the airconditioning device 1 according to the present embodiment, a memory region necessary for calculating the appropriate subcooling degree.

[0102] Further, the airconditioning device 1 calculates the determination threshold on the basis of Eq. (2). This can make, in the airconditioning device 1 according to the present embodiment, a memory region necessary for calculating the determination threshold small.

[0103] Further, the airconditioning device 1 according to the present embodiment estimates a refrigerant circulation quantity using Eq. (3). This can realize the airconditioning device 1 according to the present embodiment from view point of cost of calculating the refrigerant circulation quantity.

[0104] In addition, the airconditioning device 1 according to the present embodiment performs calculation, etc. of the appropriate subcooling degree when operation state information is in a state in which determination of the refrigerant state is possible. This can improve the determination accuracy of the refrigerant state.

[0105] Further, when in place of the refrigerant circulation quantity Gr , a value (Grr/For) derived by dividing the refrigerant circulation quantity ratio Grr by the outdoor fan rotation speed ratio For is used, this provides a further accurate determination. Here, the refrigerant circulation quantity ratio Grr and the outdoor fan rotation speed ratio For are calculated by Eqs. (5) and (6).

$$Grr = Gr/Grc \quad \text{--- (5)}$$

[0106] Here, G_{rc} is a rated refrigerant circulation quantity [kg/h]. The rated refrigerant circulation quantity is, for example, a refrigerant circulation quantity when the compressor operates at the maximum rotation speed at an evaporating temperature of -10°C .

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$$F_{or} = F_o / F_{oc} \quad \text{--- (6)}$$

[0107] Here, F_o is a current rotation speed [rpm] of the outdoor fan 12. F_{oc} is a rated outdoor fan rotation speed [rpm] of the outdoor fan 12. The rated fan rotation speed is, for example, a maximum rotation speed of the outdoor fan 12.

10 **[0108]** Next, a method of determining occurrence of the refrigerant leakage while the outdoor fan rotation speed is changed in various manners is described referring to Figs. 7 to 9.

[0109] Fig. 7 is a characteristic diagram indicating a relation between the refrigerant circulation quantity and the subcooling degree at the outlet of the subcooling device while the outdoor fan rotation speed is changed in the various manners.

15 **[0110]** Here, Fig. 7 indicates the subcooling degree $Sc1$ on the axis of ordinates and the refrigerant circulation quantity Gr on the axis of abscissa under conditions of various outdoor rotation speeds. Further, in Fig. 7, a point indicated with "▲" indicates a refrigerant leakage rate of 0%. Further, a point indicated with "●" indicates a refrigerant leakage rate of 10%. Still further, a point indicated with "◆" indicates a refrigerant leakage rate of 15%.

20 **[0111]** Fig. 4 shows the case in which the outdoor fan rotation speed is a standard rotation speed. On the other hand, Fig. 7 shows the relation between the refrigerant circulation quantity and the subcooling degree in various rotation speeds of the outdoor fan 12 in a save energy mode, a standard mode, a low noise mode, etc.

[0112] In Fig. 7, a line 601 is a regression line of "▲", a line 602 is a regression line of "●", and a line 603 is a regression line of "◆". The line 601 is also a line indicating the appropriate subcooling degree.

25 **[0113]** The leakage rate has a reference (0%) when a liquid level of the receiver 13 is at the lower end to remove influence of the operation state on the load side and variation in the necessary quantity of the refrigerant due to outdoor temperature. More specifically, the leakage rate of the refrigerant is calculated from a critical state before a state at the inlet of the subcooling device 16 becomes the gas and liquid two phase state.

[0114] Though Fig. 7 does not show a line indicating the determination threshold, the determination threshold can be calculated only by calculation in accordance with Eq. (2) described above.

30 **[0115]** According to this method, it can be understood that determination whether there is leakage or not cannot be done because though the leakage rate is 0%, a condition in which the subcooling degree is small like the subcooling degree when the leakage rate is about 10%. In other words, there is a region where the points of "▲" and "●" are overlapping.

35 **[0116]** This is because there is a condition in which the rotation speed of the outdoor fan is extremely large or a condition in which the rotation speed of the outdoor fan is extremely small. More specifically, though the rotation speed of the outdoor fan is controlled so as to make the condensing pressure appropriate, the rotation speed is controlled in accordance with a change of condensing pressure target value according to an installation state in addition to the refrigerant circulation quantity and the outdoor temperature. More specifically, when a mode can be changed among an energy saving mode, a standard mode, a silent mode, etc, a change width of, particularly, the rotation speed of the outdoor fan becomes large.

40 **[0117]** Accordingly, it becomes difficult to make the refrigerant leakage determination with the subcooling degree $SC1$ based on only the refrigerant circulation quantity.

[0118] Therefore, the measured subcooling degree $Sc1$ when the above-described index G_{rr}/F_{or} is used in place of the refrigerant circulation quantity, is shown in the chart in Fig. 8.

45 **[0119]** Fig. 8 is a characteristic chart showing a relation between a value (G_{rr}/F_{or}) acquired by dividing a refrigerant circulation ratio G_{rr} by an outdoor fan rotation speed ratio F_{or} and the subcooling degree at the outlet of the subcooling device, while the outdoor fan rotation speed is changed variously. The value acquired by dividing a refrigerant circulation ratio G_{rr} by the outdoor fan rotation speed ratio F_{or} (G_{rr}/F_{or}) is calculated by, for example, the step S112 in Fig. 6.

50 **[0120]** In Fig. 8, the subcooling degree $SC1$ is represented by the axis of ordinates under various conditions, and the value (G_{rr}/F_{or}) which is acquired by dividing the refrigerant circulation quantity ratio G_{rr} by the outdoor fan rotation speed ratio F_{or} is shown by the axis of abscissa.

[0121] Also in Fig. 8, the points indicated with "▲" indicate that the refrigerant leakage rate is 0%. Further, the points indicated with "●" indicate that the refrigerant leakage rate is 10%. Further, the points indicated with "◆" indicate that the refrigerant leakage rate is 15%.

55 **[0122]** In addition, a line 611 in Fig. 8 is a regression line of the points of "▲", a line 612 is a regression line of the points of "●", and a line 613 is a regression line of the points of "◆". Further, the line 611 is also a line indicating the appropriate subcooling degree.

[0123] A appropriate subcooling degree Sc3 indicated by the line 611 is represented by the Eq. (11) below.

$$Sc3 = A4 \cdot (Grr/For) + A5 \quad \text{--- (11)}$$

[0124] Here, A4 and A5 are values acquired as a result of fitting of points "▲" at the refrigerant leakage rate of 0%, and variable in accordance with specifications of the outdoor heat exchanger 11, the outdoor fan 12, the indoor heat exchanger 21, the indoor fan 22, etc.

[0125] A line 701 indicating the determination threshold is a line of a determination threshold Sc3th, which is represented by Eq. (12) below.

$$Sc3th = Sc3 \times A6 \quad \text{--- (12)}$$

[0126] Here, A6 is a decrease rate of the subcooling degree when refrigerant leakage occurs.

[0127] When the value obtained by dividing the refrigerant circulation ratio Grr by the outdoor fan rotation speed ratio For (Grr/For) is used, this provides easy distinction among the leakage rates of 0%, 10%, and 15%.

[0128] Introducing this method provides accurate determination of the quantity of the refrigeration though there is wide variation in mode setting of the outdoor fan 12, the outdoor temperature, the evaporating temperature, the compressor rotation speed, etc.

[0129] Here, a chart in which the axis of ordinates of Fig. 8 is changed to the subcooling degree efficiency is shown in Fig. 9.

[0130] Fig. 9 is a characteristic chart showing a relation between the value obtained by dividing the refrigerant circulation ratio Grr by the outdoor fan rotation speed ratio For (Grr/For) and the subcooling degree efficiency in the case where the outdoor fan rotation speed is change variously.

[0131] Here, the subcooling degree efficiency is a value obtained by dividing the subcooling degree Sc1 at the outlet of the subcooling device 16 by a difference between the condensation temperature and the outdoor temperature.

[0132] Further, in Fig. 9, a subcooling degree efficiency SCef is represented by the axis of ordinates and Grr/For is represented by the axis of abscissa.

[0133] In Fig. 9, the points indicated by "▲" indicate that the refrigerant leakage rate is 0%. Further, the points indicated by "●" indicate that the refrigerant leakage rate is 10%. The points indicated by "◆" indicate that the refrigerant leakage rate is 15%.

[0134] In Fig. 9, a line 621 is a regression line of "▲", a line 622 is a regression line of "●", and a line 623 is a regression line of "◆". Further, the line 621 is also a line representing the appropriate subcooling degree.

[0135] Regarding this, the appropriate subcooling degree efficiency Scef represented by the line 621 is represented by Eq. (21) below.

$$Scef = A7 \cdot (Grr/For) + A8 \quad \text{--- (21)}$$

[0136] Here, A7 and A8 are values obtained as a result of fitting of points "▲" at the refrigerant leakage rate of 0%, and variable in accordance with specifications of the outdoor heat exchanger 11, the outdoor fan 12, the indoor heat exchanger 21, the indoor fan 22, etc.

[0137] A line 711 indicating the determination threshold is a line of a determination threshold Scefth, which is represented by Eq. (22) below.

$$Scefth = Scef \times A9 \quad \text{--- (22)}$$

[0138] Here, A9 is a decrease rate of the subcooling degree when there is refrigerant leakage.

[0139] The chart in Fig. 9 also provides easy distinction among the leakage rates of 0%, 10%, and 15%.

[0140] Further, use of Eqs. (11), (12), (21), and (22) provides calculation of the appropriate subcooling degree and the appropriate subcooling degree efficiency based on the value (Grr/For) acquired by dividing the refrigerant circulation ratio Grr by the outdoor fan rotation speed ratio For (Grr/For) and the determination threshold on the basis of the values quantitatively.

[0141] Further, from comparison between Figs. 8 and 9 it is understood that when Grr/For is large, this makes it easy to have distinction in Fig. 8 and when Grr/For is small, this makes it easy to have distinction in Fig. 9. In other words,

the determination accuracy increases as increase in difference between 0% and 10% in the leakage rate. Accordingly, when the value of Grr/For is, for example, equal to or larger than 1, the method shown in Fig. 8 is used, and when the value is smaller than 1, the method shown in Fig. 9 is used, this provides a high accuracy determination.

[0142] In addition, when the refrigerant circulation quantity ratio Grr is obtained using Eq. (7) below, this reduces an operation load, which makes it easy to apply this method to products with a practical use accuracy.

$$Grr = (Ft/Ftmax)(Ps/Psc) \quad \text{--- (7)}$$

[0143] Here, Ft represents a current compressor rotation speed [rps].

[0144] $Ftmax$ is a compressor rotation speed upper limit [rps]. Ps represents a current inlet pressure of the compressor 14 or an inlet pressure [MPaA] of the entire of the outdoor unit 10. Further, Psc is Ps at the evaporation temperature as a reference (for example, -10°C).

[0145] Here, Fig. 10 is shown in which the axis of ordinates in Fig. 7 is changed to the subcooling degree efficiency.

[0146] Fig. 10 is a characteristic chart representing a relation between the refrigerant circulation quantity when the outdoor rotation speed is variably changed and the subcooling degree efficiency at the outlet of the subcooling device 16.

[0147] Here, the subcooling degree efficiency at the outlet of the subcooling device 16 is, as described above, a value acquired by dividing the subcooling degree $Sc1$ at the outlet of the subcooling device 16 by the difference between the condensation temperature and the outdoor temperature.

[0148] Fig. 10 shows a case where the subcooling degree efficiency $Scef$ under a condition of various outdoor fan rotation speed is represented on the axis of ordinates, and the refrigerant circulation quantity Gr on the axis of abscissa. Further, in Fig. 10, points indicated with " $\blacktriangle$ " represent that the refrigerant leakage rate is 0%. Further, points indicated with " $\bullet$ " represent the refrigerant leakage of 10%. Further, points indicated with " $\blacklozenge$ " represent the refrigerant leakage of 15%.

[0149] In Fig. 10, a line 631 is a regression line of " $\blacktriangle$ ", and a line 632 is a regression line of " $\bullet$ ", and a line 633 is a regression line of " $\blacklozenge$ ". The line 631 is also a line representing the appropriate subcooling degree.

[0150] In Fig. 10, though a line the determination threshold is not shown, the determination threshold can be calculated such that the subcooling degree $Sc1s$ in Eq. (2) is regarded as the appropriate subcooling degree efficient (the line 631).

[0151] As shown in Fig. 10, the airconditioning device 1 calculates the appropriate subcooling degree efficiency on the basis of the refrigerant circulation quantity and makes determination of the refrigerant leakage on the basis of the appropriate subcooling degree efficiency, so that an effect is provided which is the same as that provided by determination of the refrigerant leakage determination made on the basis of the appropriate subcooling degree which is calculated on the basis of the refrigerant circulation quantity.

[0152] Further, from comparison between Figs. 7 and 10, it is easily understood that when the refrigerant circulation quantity is large, this makes it easy to have distinction in Fig. 7 and when the refrigerant circulation quantity is small, this makes it easy to have distinction in Fig. 10. In other words, the determination accuracy increases as increase in difference between 0% and 10% in the leakage rate. Accordingly, when the value of the refrigerant circulation quantity is, for example, equal to or larger than 100 (kg/h), the method shown in Fig. 7 is used, and when the value is smaller than 100 (kg/h), the method shown in Fig. 10 is used, this provides a further higher accurate determination.

[0153] Further, when the subcooling degree efficiency is used in place of the subcooling degree, in the step S112, a measured subcooling degree efficiency obtained by dividing the measured subcooling degree by a difference between the condensation temperature and the outdoor temperature is calculated.

[Second embodiment]

[0154] Next, a second embodiment is described below. In the airconditioning device 1 according to the first embodiment is not provided with an economizer. On the other hand, in the second embodiment, an airconditioning device including the economizer is targeted.

(Configuration of an air conditioning device 1a)

[0155] Fig. 11 shows an example of configuration of the airconditioning device according to the second embodiment.

[0156] In Fig. 11, the same or corresponding elements are designated with the same or like references and a detailed description is omitted.

[0157] An outdoor unit 10a of the air conditioning device 1a in Fig. 11 is further provided with an economizer 41, a economizer valve (economizer decompressor) 42 for allowing a low temperature and low pressure refrigerant to flow through the economizer 41, and a temperature sensor 10th for measuring a refrigerant (liquid refrigerant) temperature

at an outlet of the economizer 41, which is difference from the airconditioning device 1 in Fig. 1.

[0158] A subcooling liquid (subcooled refrigerant) flowing out from the subcooling device 16 on an upstream side of the economizer 41 is divided into a first passage in which the subcooled liquid flows into the liquid injection valve 17, a third passage (main passage) in which the subcooled liquid flows into the economizer 41, and a fourth passage (bypass passage) in which the subcooled liquid flows into the economizer valve 42. In other words, the second passage in the first embodiment is divided into the third passage and the fourth passage.

[0159] The subcooling liquid in the fourth passage (bypass passage) flows into the economizer valve 42 and decompressed by the economizer valve 42 with temperature decrease, and then flows into the economizer 41.

[0160] The subcooling liquid in the third passage (main passage) is further subcooled by thermal exchange with the subcooling liquid in the fourth passage which is decompressed by the economizer valve 42 with a low temperature. The refrigerant in the third passage subcooled by the economizer 41 is supplied to the indoor heat exchanger 21 as a evaporator in the indoor unit 20 through the pipe 30.

[0161] On the other hand, the subcooling liquid in the fourth passage (bypass passage) is evaporated by the economizer 41, and then flows out from the economizer 41 and joins with the refrigerant in the first passage flowing from the liquid injection valve 17. The joined refrigerant flows into an intermediate pressure section of the compressor 14 which compresses the refrigerant up to the discharge pressure P_d .

[0162] Fig. 12 is a Mollier chart (P-h diagram) of the airconditioning device according to the second embodiment. Occasionally Fig. 11 is referred. The elements in Fig. 12 which is same or like elements in Fig. 3 are designated with the same or like references and the detailed description is omitted.

[0163] In the refrigerating cycle operation state with the economizer 41 shown in Fig. 12, as a result of the subcooling by the economizer 41, the subcooling degree increases from the state 306 to a state 311 as compared with the Mollier chart shown in Fig. 3. In the air conditioning device 1a, increase in the refrigerating power by increase in the subcooling degree from the state 306 to the state 311 (a state 312 to the state 301) can be provided without power increase between the inlet pressure P_s and the intermediate pressure. This increases the performance coefficient.

[0164] In the air conditioning device 1a as described above, it can be considered that the subcooling degree at the outlet of the economizer 41 is used in place of the subcooling degree at the outlet of the subcooling device 16.

[0165] Next, referring to Fig. 4, the subcooling degree at the outlet of the economizer 41 is described.

[0166] Further, in Fig. 4, the mark of " Δ " indicates the subcooling degree at the outlet of the economizer 41. Points shown in Fig. 4 have values when the outdoor temperature and the evaporation temperature T_e , etc. change variously under the above-described condition. Regarding this, an opening degree of the economizer valve 42 is controlled by the discharging temperature T_d of the compressor 14. More specifically, under a high pressure rate condition in which the discharging temperature T_d becomes high, controlling such as increasing the opening degree of the economizer valve 42, etc. is made. This changes the flow rate of the bypass passage to the economizer 41 in accordance with the discharging temperature T_d .

[0167] As a result, the subcooling degree for the refrigerant circulation quantity at the outlet on the main side of the economizer 41 disperses as shown in Fig. 4. Accordingly, the determination of the refrigerant leakage cannot be made by only the refrigerant circulation quantity. In other words, there is a region where " Δ " and " $\diamond$ " are overlapping. Accordingly, it is difficult that the subcooling degree at the outlet on the main passage of the economizer 41 is used as a simple determination index using the refrigerant circulation quantity as described in the first embodiment.

[0168] Accordingly, it is useful to use the subcooling degree at the outlet of the subcooling device 16 as described in the first embodiment.

[0169] However, in the air conditioning device 1a according to the second embodiment, because the flow of the refrigerant is divided between the subcooling device 16 and the liquid injection valve 17, it is not possible to use the opening degree MV of the liquid injection valve 17 in Eq. (3) described above as it is.

[0170] Then, in the second embodiment, when the refrigerant circulation quantity is acquired by Eq. (3), MV is calculated as an opening degree acquired by summing the opening degree of the economizer valve 42 and the opening degree of the liquid injection valve 17 and the refrigerant circulation quantity is estimated. More specifically, MV in Eq. (3) is calculated as $MV = \text{opening degree MV1 of the economizer valve 42} + \text{opening degree MV2 of the liquid injection valve 17}$. This MV is substituted in Eq. (3) to calculate an estimation value of the refrigerant circulation quantity.

[0171] As described above, the controller 100 can determine whether the refrigerant quantity is appropriate or not using the determination threshold for the subcooling degree at the outlet of the subcooling device 16 calculated from Eqs. (1) to (3) similar to the first embodiment. According to this, the controller 100 can make refrigerant leakage determination stable even under various operation conditions.

[0172] Further, in the cycle including the economizer 41, it is possible to use determination using the subcooling degree (hereinafter, referred to as economizer outlet subcooling degree) at the liquid stop valve 18b subcooled by the economizer 41.

[0173] Fig. 13 is a characteristic chart indicating a relation between the refrigerant circulation quantity and an economizer outlet subcooling degree.

[0174] In Fig. 13, an economizer outlet subcooling degree SCeco is represented on the axis of ordinates, and the refrigerant circulation quantity Gr is represented on the axis of abscissa.

[0175] In Fig. 13, points indicated with "▲" represent the refrigerant leakage of 0%. Further, points indicated with "●" represent the refrigerant leakage of 10%. Points indicated with "◆" represent the refrigerant leakage of 15%.

[0176] In Fig. 13, a line 641 is a regression line of "▲", and a line 642 is a regression line of "●", and a line 643 is a regression line of "◆". The line 641 is also a line representing the appropriate subcooling degree.

[0177] Further, the line 641 is also a line representing an appropriate economizer outlet subcooling degree. Further, the line representing the determination threshold is not limited to the line 641.

[0178] In addition, in Fig. 13, though a line of the determination threshold is not shown, it is sufficient that the appropriate subcooling degree Sc1s in Eq. (2) is calculated as the appropriate economizer outlet subcooling degree (line 641).

[0179] The appropriate economizer outlet subcooling degree S can be calculated by Eq. (31) below.

$$SCeco = A10 \cdot Gr + A11 \quad \text{--- (31)}$$

[0180] Here, A10 and A11 are, for example, coefficients determined by the line 641 having a refrigerant leakage rate of 0%. In addition A10 and A11 are variable in accordance with specifications of the outdoor heat exchanger 11, the outdoor fan 12, the indoor heat exchanger 21, the indoor fan 22, etc.

[0181] As shown in Fig. 13, as increase in the refrigerant leakage rate from 0%, via 10%, to 15%, the economizer outlet subcooling degree SCeco tends to decrease. However, there is also a state in which a clear refrigerant leakage determination cannot be made. This is because the flow rate of the refrigerant flowing through the liquid stop valve 18b becomes small because a flow rate in the bypass passage running in the economizer 41 becomes relatively high in a state in which the refrigerant circulation quantity is small. In other words, even when the refrigerant is insufficient, there is a case where the liquid refrigerant flowing through the main passage running in the liquid stop valve 18b can be sufficiently subcooled.

[0182] Accordingly, it is desirable that determination using the subcooling degree of the subcooling device 16 in the first embodiment is made as a main determination and the subcooling degree of the economizer 41 according to the second embodiment is used as an auxiliary determination. A process for using the subcooling degree of the economizer 41 is used as auxiliary determination is described below. The determination process is carried out in the step S113 in Fig. 6.

<Process 1>

[0183] The refrigerant quantity determining section 115 determines whether the quantity of the refrigerant is insufficient (leakage) or not using the subcooling degree of the subcooling device 16 (Fig. 4) or the subcooling degree efficiency (Fig. 9) (first embodiment).

<Process 2>

[0184] The refrigerant quantity determining section 115 determines whether the refrigerant is insufficient (leakage) with the economizer outlet subcooling degree SCeco (second embodiment).

<Process 3>

[0185] When the refrigerant is determined to be insufficient (leakage) in Process 1 and the refrigerant is determined to be insufficient (leakage) in Process 2, the refrigerant quantity determining section 115 determines "Yes" in the step S113. When the refrigerant is not determined to be insufficient (leakage) in either of Process 1 or Process 2, the refrigerant quantity determining section 115 determines "No" in the step S113.

[0186] Performing Processes 1 to 3 prevents an erroneous determination due to influence of sensor error and variation in operation state.

[0187] More specifically, the air conditioning device 1a can acquire the determination threshold for increasing accuracy in refrigerant leakage determination using the economizer outlet subcooling degree.

[Third embodiment]

[0188] Next, a third embodiment of the present invention is described below referring to Fig. 14. The controllers 100 according to the first and second embodiments determine whether the refrigerant leaks or not. However, this can be used for determining whether the refrigerant quantity is appropriate or not when the refrigerant is charged. In the third

embodiment, a method of determining whether the refrigerant quantity is appropriate or not is described below. Further, the third embodiment is applicable to both the airconditioning device 1 according to the first embodiment and the air conditioning device 1a according to the second embodiment.

[0189] Fig. 14 is a flowchart showing process of refrigerant leakage determination process according to the third embodiment. In Fig. 14, the processes which are same as those in Fig. 6 are designated with the same step reference, and the detailed description is omitted.

[0190] When determination whether the quantity of the refrigerant is appropriate or not is made, it is desirable that A3 in Eq. (2) is set to be larger than 0.6 used in the first embodiment. For example, A3 is set to about 0.8, i.e., $A3 = 0.8$, which is nearly sufficient. This enables a substantially appropriate determination of the necessary refrigerant quantity.

[0191] Further, $A3 = 0.8$ is an example, and the value of A3 is not limited to 0.8 as long as the value for A3 is suitable for determining an appropriate quantity of the refrigerant.

[0192] Regarding this, it is possible that the coefficient A3 in Eq. (2) is set to 1.2, etc. which is equal to or higher than 1 and the determination threshold Sc1th to have a value exceeding the ideal appropriate subcooling degree Sc1s (appropriate subcooling degree). In such a case, when determination is made that the measured subcooling degree exceeds the determination threshold Sc1th, the refrigerant quantity determining section 115 determines that the receiver 13 is in a full state (refrigerant excess). This operation provides detection of the full state (excessive refrigerant) of the receiver 13.

[0193] Next, in a step S113a corresponding to the step S113 in Fig. 6, the refrigerant quantity determining section 115 determines whether the refrigerant quantity is appropriate or not by determining whether the measured subcooling degree Sc1 at the outlet of the subcooling device 16, calculated in the step S112 is equal to or greater than the determination threshold Sc1th.

[0194] As a result of the step S113a, when the measured subcooling degree Sc1 at the outlet of the subcooling device 16 is equal to or greater than the determination threshold Sc1th (YES in S113), the refrigerant quantity determining section 115 determines that the refrigerant quantity is appropriate, and the processing section 111 returns the processing to the step S101.

[0195] As a result of the step S113a, the measured subcooling degree Sc1 at the outlet of the subcooling device 16 is smaller than the determination threshold Sc1th (NO in the step S113a), the refrigerant quantity determining section 115 determines whether a predetermined period has elapsed or not (S114).

[0196] As a result of the step S114, when the predetermined period has not elapsed (NO in the step S114), the processing section 111 returns the processing to the step S112. When the predetermined period has not elapsed, it is also possible that the processing section 111 returns the processing to a step S111.

[0197] As a result of the step S114, when the predetermined period has elapsed (YES in the step S114), the refrigerant quantity determining section 115 determines that the refrigerant quantity is abnormal (S121a). The outputting section 116 sends a refrigerant abnormality flag to the display device 200, an alarm (not shown), and a concentrated monitoring device (not shown). For example, the display device 200 makes an alarming indication of "There may be abnormality in refrigerant quantity", etc. After this, the refrigerant having a predetermined quantity according to the capacity of the receiver 13 or a quantity calculated as an additional charging quantity is added (calculation of charging quantity and addition: S122a). Further, the calculation of the additional quantity and addition of the refrigerant may be done when determination is made that the refrigerant leakage occurs in Fig. 6. A process in a step S122a may be omitted.

[0198] According to this operation, the airconditioning device 1 in the third embodiment can determine whether the refrigerant quantity is appropriate or not in addition to the determination that the refrigerant quantity is insufficient (leakage).

[About refrigerant]

[0199] As the refrigerant circulating in the airconditioning devices 1, 1a according to the first to third embodiment, for example, inflammable refrigerants having a GWP (Global Warming Potential) not smaller than 1000 such as R404A, R407C, R407F, R407E, R410A, R134a, R507A, R448A, R449A, R450A, R452A, and R513A are used.

Coefficient Of Performance

[0200] Further, when the refrigerant having the Global Warming Potential GWP having a value not smaller than 1000 is used, the performance coefficient COP (Coefficient Of Performance) can be made high, so that a running cost can be reduced and influence on global warming associated with power consumption in operation can be made small. In addition, there is an advantageous effect in initial cost which is reduced because a cost of safety measure against leakage of the refrigerant can be reduced due to inflammable refrigerant. However, since the GWP is not smaller than 1000, which is relatively large, it is important to earlier detection of the refrigerant leakage from point view of prevention of global warming. Therefore, the refrigerant leakage determination according to the embodiments of the invention has

a high usefulness.

[0201] As another refrigerant, if a refrigerant having a low GWP (for example, GWP is not larger 750) but a refrigerant having a low flammability is used, though the influence on global warming can be made small, but it is desirable to make earlier determination of the refrigerant leakage because of the low flammability. Accordingly, when the latter, i.e., the refrigerant having a low flammability, is used, the technology according to the present embodiments providing the refrigerant leakage determination has a high usefulness.

[0202] Therefore, the refrigerant used in the airconditioning device 1 may be a refrigerant having the GWP not larger than 750 such as R32, R1123, R1234yf, R1234ze(E), R454A, R454B, R444B.

[0203] The present invention is not limited to the above-described embodiments. For example, the embodiments described above are made in detail to have easy understanding the present invention, and not limited to the configuration including all described configurations.

[0204] Further, a part of the configuration in an embodiment can be replaced with a part of another embodiment or added to another configuration.

[0205] For example, the above-described explanations are made such that the airconditioning devices 1, 1a perform cooling. However, when the airconditioning device 1 perform room heating, the receiver 13 and the subcooling device 16 are installed on the side of the condenser (the indoor heat exchanger 21) operated for heating and an expansion valve is installed at the inlet of the outdoor heat exchanger 11. This provides the airconditioning device 1, 1a according to the embodiments for room heating. In this case, the receiver 13 may be installed on a side of the indoor unit 20.

[0206] Further, the receiver 13 may not be installed on the sides of the outdoor unit 10 and the indoor unit 20.

[0207] Further, the airconditioning devices 1, 1a can be applied to a package air conditioner, a room air conditioner, etc.

[0208] When the airconditioning devices 1, 1a according to the embodiments are used as a refrigerator, if the section corresponding to the indoor unit 20 is a unit cooler, the airconditioning devices 1, 1a can be used for cooling a freezing storage room, if the airconditioning devices 1, 1a are used as a show case, the airconditioning devices 1, 1a are used for cooling displayed foods or drinks. However, the cooling target is not limited to these.

[0209] Here, the controller 100 may be installed in the outdoor unit 10 or the indoor unit 20 and may be as a separated device from the outdoor unit 10 and the indoor unit 20.

[0210] The present invention is not limited to the embodiments, but may be variously modified. For example, the embodiments are described to easily understand the invention, but not limited to the configuration including all described elements. Further a part of the configuration in each of the embodiments can be added to another configuration, deleted in another configuration or replaced with another element in another configuration.

[0211] Further all or partial configurations, functions, respective sections 111 to 116, the storing device 130, etc. described above are realized by hardware by designing an integrated circuit. Further, as shown in Fig. 5, the configurations and functions, etc. described above may be realized by software, i.e., a processor such as the CPU 120 interprets programs and execute the program to provide respective functions. The programs, tables, files for realizing respective function may be stored in a recording device such as a memory, or in a recording medium such as an SSD (Solid State Drive), an IC (Integrated Circuit) card, a SD (Secure Digital)card, a DVD(Digital Versatile Disc) in addition to recording in a HD.

[0212] Further, in each of the embodiments, the control line and a data line are shown which are considered to be necessary, and not all control lines and data lines are shown.

Actually, all elements are connected to each other.

DESCRIPTION OF REFERENCE SYMBOLS

[0213]

1, 1a airconditioning device (refrigeration cycle device)

10, 10a outdoor unit

10ta discharging temperature sensor

10tb to 10th temperature sensor

10pa discharging pressure sensor

10pb inlet pressure sensor

11 outdoor heat exchanger (condenser)

12 outdoor fan

13 receiver (excess refrigerant storage)

14 compressor

15 accumulator

16 subcooling device

17 liquid injection valve

18a gas stop valve
 18b liquid stop valve
 20 indoor unit
 21 indoor heat exchanger (evaporator)
 5 22 indoor fan
 23 indoor expansion valve (decompressor)
 41 economizer
 42 economizer valve (economizer decompressor)
 111 processing section
 10 112 operation information acquiring section
 113 operation state determining section
 114 subcooling degree calculating section (appropriate subcooling degree estimation section, determination threshold calculating section)
 115 refrigerant quantity determining section (determining process section)
 15 116 outputting section

Claims

20 1. A refrigeration cycle device comprising:

a compressor for compressing a gaseous refrigerant;
 a condenser for condensing the compressed refrigerant;
 a decompressor for decompressing the condensed refrigerant;
 25 an evaporator for evaporating the decompressed refrigerant;
 a subcooling device for subcooling the refrigerant condensed by the condenser;
 an appropriate subcooling degree estimation section for estimating a value related to an appropriate subcooling degree of the refrigerant at an outlet of the subcooling device based on a value related to a refrigerant circulation quantity of the refrigerant circulating from a discharging side of the compressor through the condenser, and the
 30 subcooling device;
 a determination threshold calculating section for calculating a determination threshold for determination of a refrigerant quantity based on a value related to the estimated appropriate subcooling degree; and
 a determining process section for determining a quantity of the refrigerant by comparing the value related to the measured subcooling degree and the determination threshold.

35 2. The refrigeration cycle device as claimed in claim 1, wherein the value related to the refrigerant circulation quantity is the refrigerant circulation quantity.

40 3. The refrigeration cycle device as claimed in claim 2,
 wherein the passage of the refrigerant flowing out from the subcooling device is divided into first and second passages;
 wherein the refrigerant in the first passage is decompressed by a liquid injection decompressor, and then, injected into an intermediate pressure of the compressor;
 wherein the refrigerant in the second passage is supplied to the decompressor,
 wherein the appropriate subcooling degree estimation section defines, as a value of the refrigerant circulation quantity, an estimated refrigerant circulation quantity estimated based on Formula (2): $Gr = (a1 \cdot Fr + a2)(b1 \cdot Ps + b2)(c1 \cdot MV + c2)$ ---(2),
 45 where Gr is an estimation value of the refrigerant circulation quantity, Fr is a compressor rotation speed, Ps is an inlet pressure Ps, and MV is an opening degree of the liquid injection decompressor, and
 where a1, a2, b1, b2, c1, and c2 are coefficients acquired by experiment or simulation, respectively.

50 4. The refrigeration cycle device as claimed in claim 3, further comprising an economizer and an economizer decompressor which are installed between the subcooling device and the decompressor,
 wherein the second passage is divided into a third passage allowing the refrigerant to flow into the economizer and a fourth passage allowing the refrigerant to flow into the economizer decompressor;
 55 wherein the refrigerant flowing into the fourth passage is decompressed by the economizer decompressor and then, flows into the economizer, and then flows out from the economizer, and then is joined with the refrigerant in the first passage, and the joined refrigerant is injected into an intermediate pressure of the compressor;
 wherein the refrigerant flowing into the third passage is subcooled by heat exchanging with the refrigerant in the

fourth passage in the economizer and supplied to the decompressor,
 wherein the appropriate subcooling degree estimation section sets the opening degree of the liquid injection de-
 compressor in Formula (2) to a sum of the opening degree of the liquid injection decompressor and an opening
 degree of the economizer decompressor.

- 5 5. The refrigeration cycle device as claimed in claim 2,
 wherein a value related to the appropriate subcooling degree is the appropriate subcooling degree and the value
 related to the measured subcooling degree is the measured subcooling degree.
- 10 6. The refrigeration cycle device as claimed in claim 2,
 wherein the value related to the appropriate subcooling degree is an appropriate subcooling degree efficiency
 acquired by dividing an appropriate subcooling degree of the refrigerant at an outlet of the subcooling device by a
 difference between the outdoor temperature and a condensation temperature; and
 wherein the value related to the measured subcooling degree is a measured subcooling degree efficiency acquired
 15 by dividing the measured appropriate subcooling degree of the refrigerant at an outlet of the subcooling device by
 a difference between an outdoor temperature and a condensation temperature.
- 20 7. The refrigeration cycle device as claimed in claim 2,
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an
 appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant
 at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation tem-
 perature;
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an
 appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant
 25 at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation tem-
 perature;
 wherein the values related to the measured subcooling degree are the measured appropriate subcooling degree of
 the refrigerant measured at an outlet of the subcooling device and a measured subcooling degree efficiency acquired
 by dividing the measured appropriate subcooling degree by the difference between the outdoor temperature and
 30 the condensation temperature;
 wherein when the refrigerant circulation quantity is equal to or greater than a predetermined value, the determining
 process section makes determination of the refrigerant quantity using a determination threshold based on the ap-
 propriate subcooling degree and when the refrigerant circulation quantity is smaller than the predetermined value,
 the determining process section makes determination of the refrigerant quantity using a determination threshold
 35 based on the appropriate subcooling degree efficiency.
- 40 8. The refrigeration cycle device as claimed in claim 2,
 further comprising an economizer and an economizer decompressor installed between the subcooling device and
 the decompressor,
 wherein the value related to the appropriate subcooling degree is a measured economizer outlet subcooling degree
 which is an appropriate subcooling degree at the outlet of the economizer, and
 wherein the value related to the measured subcooling degree is a measured economizer outlet subcooling degree
 which is a measured subcooling degree at the outlet of the economizer.
- 45 9. The refrigeration cycle device as claimed in claim 2,
 wherein the appropriate subcooling degree estimation section calculates the appropriate subcooling degree based
 on Formula (1): $Sc1s = A1 \cdot \ln(Gr) - A2$ --- (1),
 where Sc1s is the appropriate subcooling degree, Gr is the refrigerant circulation quantity, A1 and A2 are predeter-
 mined coefficients acquired from a relation between the refrigerant circulation quantity and the appropriate subcooling
 50 degree.
- 55 10. The refrigeration cycle device as claimed in claim 1, further comprising an outdoor fan, wherein the value related
 to the refrigerant circulation quantity is a value acquired by dividing a rated ratio of the refrigerant circulation quantity
 by a rated ratio of a rotation speed of the outdoor fan.,
11. The refrigeration cycle device as claimed in claim 10,
 wherein the value related to the appropriate subcooling degree is the appropriate subcooling degree, and
 wherein the value related to the measured subcooling degree is the measured appropriate subcooling degree.

12. The refrigeration cycle device as claimed in claim 10,
 wherein the value related to the appropriate subcooling degree is an appropriate subcooling degree efficiency
 acquired by dividing the appropriate subcooling degree of the refrigerant at the outlet of the subcooling device by
 a difference between the outdoor temperature and the condensation temperature, and
 wherein the value related to the measured subcooling degree is a measured subcooling degree efficiency acquired
 by dividing a measured appropriate subcooling degree at the outlet of the subcooling device by a difference between
 the outdoor temperature and the condensation temperature.
13. The refrigeration cycle device as claimed in claim 10,
 wherein the appropriate subcooling degree estimation section calculates the appropriate subcooling degree of the
 refrigerant based on Formula (2): $Sc2c = A3 \cdot (Grr/For) + A4$ --- (2),
 where Sc2c is an appropriate subcooling degree; Grr is a refrigerant circulation quantity rated ratio Grr; For is a
 rated ratio of the rotation speed of the outdoor fan; A3 and A4 are predetermined coefficients acquired from a relation
 between a value acquired by dividing a refrigerant circulation rated ratio by a rated ratio of the rotation speed of the
 outdoor fan and the appropriate subcooling degree.
14. The refrigeration cycle device as claimed in claim 10,
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an
 appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant
 at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation tem-
 perature;
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an
 appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant
 at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation tem-
 perature;
 wherein the value related to the measured subcooling degree are the measured appropriate subcooling degree of
 the refrigerant measured at an outlet of the subcooling device and a measured subcooling degree efficiency acquired
 by dividing the measured appropriate subcooling degree by the difference between the outdoor temperature and
 the condensation temperature;
 wherein when a value acquired by dividing a rated ratio of the refrigerant circulation quantity by a rated ratio of
 rotation speed of the outdoor fan is equal to or greater than a predetermined value, the determining process section
 makes determination using a determination threshold based on the appropriate subcooling degree and when the
 value is smaller than the predetermined value, the determining process section makes determination using a de-
 termination threshold based on the appropriate subcooling degree efficiency.
15. The refrigeration cycle device as claimed in claim 1, further comprising an excess refrigerant storage between the
 condenser and the subcooling device, wherein the excess refrigerant storage stores the refrigerant condensed by
 the condenser.
16. The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that the refrigerant quantity is insufficient when the measured
 subcooling degree is smaller than the determination threshold.
17. The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that insufficient in the refrigerant quantity occurs when a state
 that the value related to the measured subcooling degree is smaller than the determination threshold is kept for a
 predetermined period.
18. The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that the refrigerant quantity is appropriate when the measured
 subcooling degree is greater than the determination threshold.
19. The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section calculates an additional charging quantity of the refrigerant when the value
 related to the measured subcooling degree is smaller than the determination threshold, and makes a determination
 that the refrigerant quantity which is the additional charging quantity of the refrigerant added, has a certain ratio to
 the appropriate refrigerant quantity, and then, calculated a remaining additionally charging quantity and makes an
 instruction.

20. The refrigeration cycle device as claimed in claim 1, wherein the refrigerant has a Global Warming Potential which is equal to or greater than 1000.

21. The refrigeration cycle device as claimed in claim 1, wherein the refrigerant has a Global Warming Potential which is equal to or smaller than 750.

Amended claims under Art. 19.1 PCT

1. A refrigeration cycle device comprising:

a compressor for compressing a gaseous refrigerant;
 a condenser for condensing the compressed refrigerant;
 a decompressor for decompressing the condensed refrigerant;
 an evaporator for evaporating the decompressed refrigerant;
 a subcooling device for subcooling the refrigerant condensed by the condenser;
 an appropriate subcooling degree estimation section for estimating a value related to an appropriate subcooling degree of the refrigerant at an outlet of the subcooling device based on a value related to a refrigerant circulation quantity of the refrigerant circulating from a discharging side of the compressor through the condenser, and the subcooling device;
 a determination threshold calculating section for calculating a determination threshold for determination of a refrigerant quantity based on a value related to the estimated appropriate subcooling degree; and
 a determining process section for determining a quantity of the refrigerant by comparing the value related to the measured subcooling degree and the determination threshold.

2. The refrigeration cycle device as claimed in claim 1, wherein the value related to the refrigerant circulation quantity is the refrigerant circulation quantity.

3. The refrigeration cycle device as claimed in claim 2,
 wherein the passage of the refrigerant flowing out from the subcooling device is divided into first and second passages;
 wherein the refrigerant in the first passage is decompressed by a liquid injection decompressor, and then, injected into an intermediate pressure of the compressor;
 wherein the refrigerant in the second passage is supplied to the decompressor,
 wherein the appropriate subcooling degree estimation section defines, as a value of the refrigerant circulation quantity, an estimated refrigerant circulation quantity estimated based on Formula (1): $Gr = (a1 \cdot Fr + a2)(b1 \cdot Ps + b2)(c1 \cdot MV + c2) \text{ --- (1)}$,
 where Gr is an estimation value of the refrigerant circulation quantity, Fr is a compressor rotation speed, Ps is an inlet pressure, and MV is an opening degree of the liquid injection decompressor, and where a1, a2, b1, b2, c1, and c2 are coefficients acquired by experiment or simulation, respectively.

4. The refrigeration cycle device as claimed in claim 3, further comprising an economizer and an economizer decompressor which are installed between the subcooling device and the decompressor,
 wherein the second passage is divided into a third passage allowing the refrigerant to flow into the economizer and a fourth passage allowing the refrigerant to flow into the economizer decompressor;
 wherein the refrigerant flowing into the fourth passage is decompressed by the economizer decompressor and then, flows into the economizer, and then flows out from the economizer, and then is joined with the refrigerant in the first passage, and the joined refrigerant is injected into an intermediate pressure of the compressor;
 wherein the refrigerant flowing into the third passage is subcooled by heat exchanging with the refrigerant in the fourth passage in the economizer and supplied to the decompressor,
 wherein the appropriate subcooling degree estimation section sets the opening degree of the liquid injection decompressor in Formula (1) to a sum of the opening degree of the liquid injection decompressor and an opening degree of the economizer decompressor.

5. The refrigeration cycle device as claimed in claim 2,
 wherein a value related to the appropriate subcooling degree is the appropriate subcooling degree and the value related to the measured subcooling degree is the measured subcooling degree.

6. The refrigeration cycle device as claimed in claim 2,

wherein the value related to the appropriate subcooling degree is an appropriate subcooling degree efficiency acquired by dividing an appropriate subcooling degree of the refrigerant at an outlet of the subcooling device by a difference between the outdoor temperature and a condensation temperature; and
 wherein the value related to the measured subcooling degree is a measured subcooling degree efficiency acquired by dividing the measured appropriate subcooling degree of the refrigerant by a difference between an outdoor temperature and a condensation temperature.

7. The refrigeration cycle device as claimed in claim 2,
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation temperature;
 wherein the values related to the measured subcooling degree are the measured appropriate subcooling degree of the refrigerant measured at an outlet of the subcooling device and a measured subcooling degree efficiency acquired by dividing the measured appropriate subcooling degree by the difference between the outdoor temperature and the condensation temperature;
 wherein when the refrigerant circulation quantity is equal to or greater than a predetermined value, the determining process section makes determination of the refrigerant quantity using a determination threshold based on the appropriate subcooling degree and when the refrigerant circulation quantity is smaller than the predetermined value, the determining process section makes determination of the refrigerant quantity using a determination threshold based on the appropriate subcooling degree efficiency.
8. The refrigeration cycle device as claimed in claim 2,
 further comprising an economizer and an economizer decompressor installed between the subcooling device and the decompressor,
 wherein the value related to the appropriate subcooling degree is a measured economizer outlet subcooling degree which is an appropriate subcooling degree at the outlet of the economizer,
 wherein the value related to the measured subcooling degree is a measured economizer outlet subcooling degree which is a measured subcooling degree at the outlet of the economizer.
9. The refrigeration cycle device as claimed in claim 2,
 wherein the appropriate subcooling degree estimation section calculates the appropriate subcooling degree based on Formula (2): $Sc1s = A1 \cdot \ln(Gr) - A2$ --- (2),
 where Sc1s is the appropriate subcooling degree, Gr is the refrigerant circulation quantity, A1 and A2 are predetermined coefficients acquired from a relation between the refrigerant circulation quantity and the appropriate subcooling degree.
10. The refrigeration cycle device as claimed in claim 1, further comprising an outdoor fan, wherein the value related to the refrigerant circulation quantity is a value acquired by dividing a rated ratio of the refrigerant circulation quantity by a rated ratio of a rotation speed of the outdoor fan.,
11. The refrigeration cycle device as claimed in claim 10,
 wherein the value related to the appropriate subcooling degree is the appropriate subcooling degree, and
 wherein the value related to the measured subcooling degree is the measured appropriate subcooling degree.
12. The refrigeration cycle device as claimed in claim 10,
 wherein the value related to the appropriate subcooling degree is an appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant at the outlet of the subcooling device by a difference between the outdoor temperature and the condensation temperature, and
 wherein the value related to the measured subcooling degree is a measured subcooling degree efficiency acquired by dividing a measured appropriate subcooling degree by a difference between the outdoor temperature and the condensation temperature.
13. The refrigeration cycle device as claimed in claim 10,
 wherein the appropriate subcooling degree estimation section calculate the appropriate subcooling degree of the refrigerant based on Formula (3): $Sc2c = A3 \cdot (Grr/For) + A4$ --- (3),
 where Sc2c is an appropriate subcooling degree; Grr is a refrigerant circulation quantity rated ratio Grr; For is a rated ratio of the rotation speed of the outdoor fan; A3 and A4 are predetermined coefficients acquired from a relation

between a value acquired by dividing a refrigerant circulation rated ratio by a rated ratio of the rotation speed of the outdoor fan and the appropriate subcooling degree.

- 5 **14.** The refrigeration cycle device as claimed in claim 10,
 wherein the values related to the appropriate subcooling degree are the appropriate subcooling degree and an
 appropriate subcooling degree efficiency acquired by dividing the appropriate subcooling degree of the refrigerant
 at an outlet of the subcooling device by a difference between the outdoor temperature and the condensation tem-
 perature;
 wherein the value related to the measured subcooling degree are the measured appropriate subcooling degree of
 10 the refrigerant measured at an outlet of the subcooling device and a measured subcooling degree efficiency acquired
 by dividing the measured appropriate subcooling degree by the difference between the outdoor temperature and
 the condensation temperature;
 wherein when a value acquired by dividing a rated ratio of the refrigerant circulation quantity by a rated ratio of
 rotation speed of the outdoor fan is equal to or greater than a predetermined value, the determining process section
 15 makes determination using a determination threshold based on the appropriate subcooling degree and when the
 value is smaller than the predetermined value, the determining process section makes determination using a de-
 termination threshold based on the appropriate subcooling degree efficiency.
- 20 **15.** The refrigeration cycle device as claimed in claim 1, further comprising an excess refrigerant storage between the
 condenser and the subcooling device, wherein the excess refrigerant storage stores the refrigerant condensed by
 the condenser.
- 25 **16.** The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that the refrigerant quantity is insufficient when the measured
 subcooling degree is smaller than the determination threshold.
- 30 **17.** The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that insufficient in the refrigerant quantity occurs when a state
 that the value related to the measured subcooling degree is smaller than the determination threshold is kept for a
 predetermined period.
- 35 **18.** The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section determines that the refrigerant quantity is appropriate when the measured
 subcooling degree is greater than the determination threshold.
- 40 **19.** The refrigeration cycle device as claimed in claim 1,
 wherein the determining process section calculates an additional charging quantity of the refrigerant when the value
 related to the measured subcooling degree is smaller than the determination threshold, and makes a determination
 that the refrigerant quantity which is the additional charging quantity of the refrigerant added, has a certain ratio to
 the appropriate refrigerant quantity, and then, calculated a remaining additionally charging quantity and makes an
 instruction.
- 45 **20.** The refrigeration cycle device as claimed in claim 1, wherein the refrigerant has a Global Warming Potential which
 is equal to or greater than 1000.
- 50 **21.** The refrigeration cycle device as claimed in claim 1, wherein the refrigerant has a Global Warming Potential which
 is equal to or smaller than 750.

FIG.1

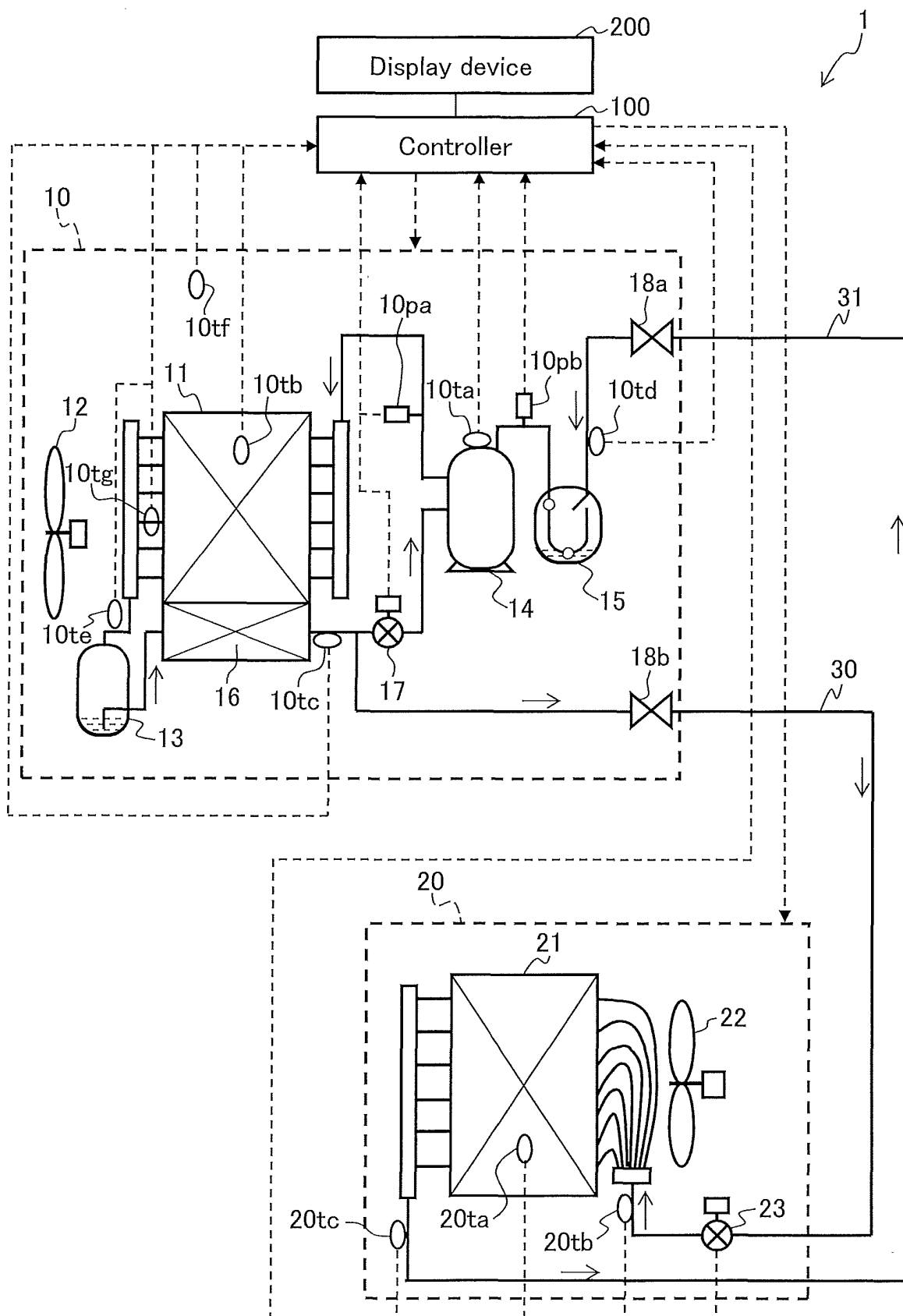


FIG.2

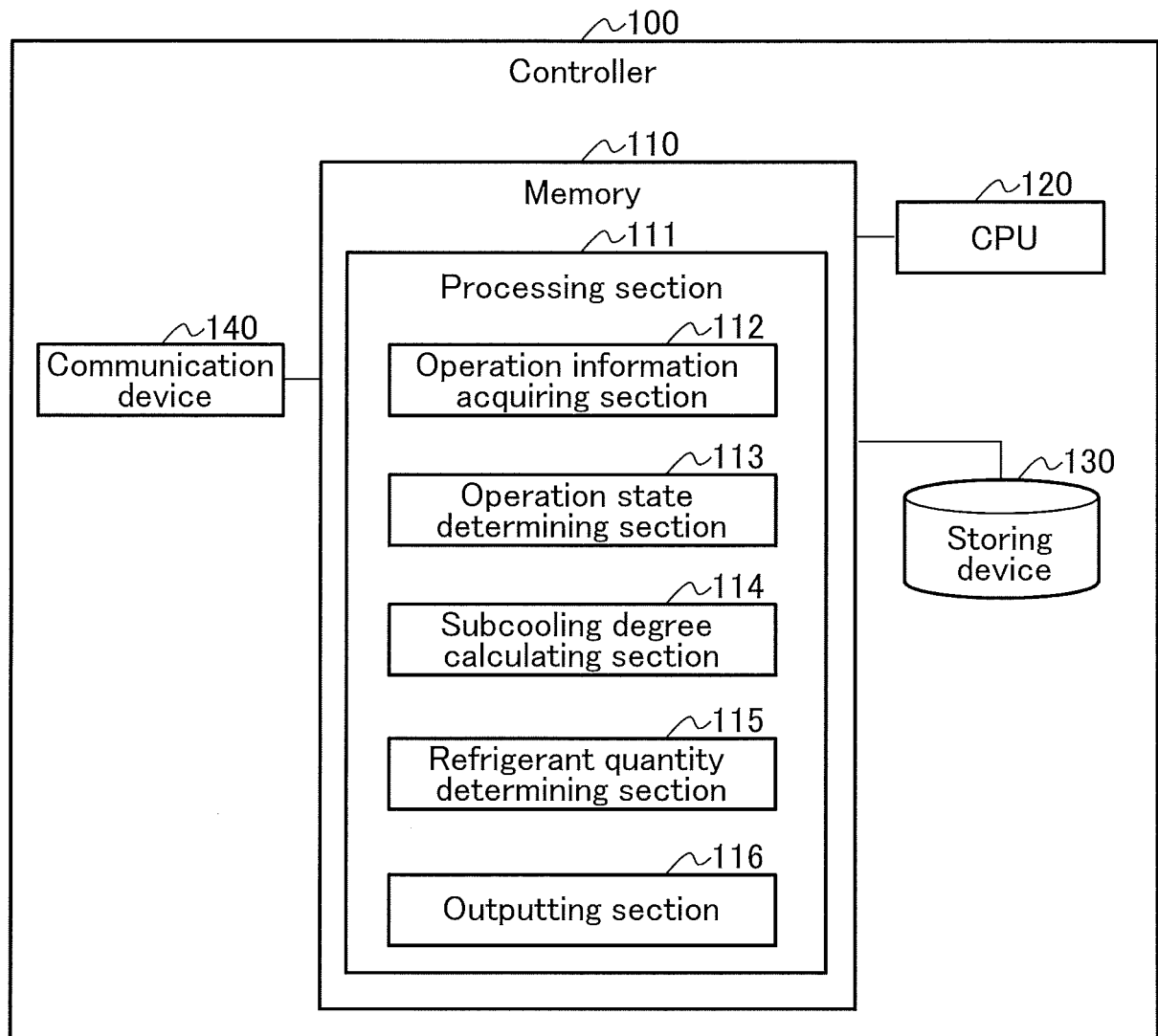


FIG.3

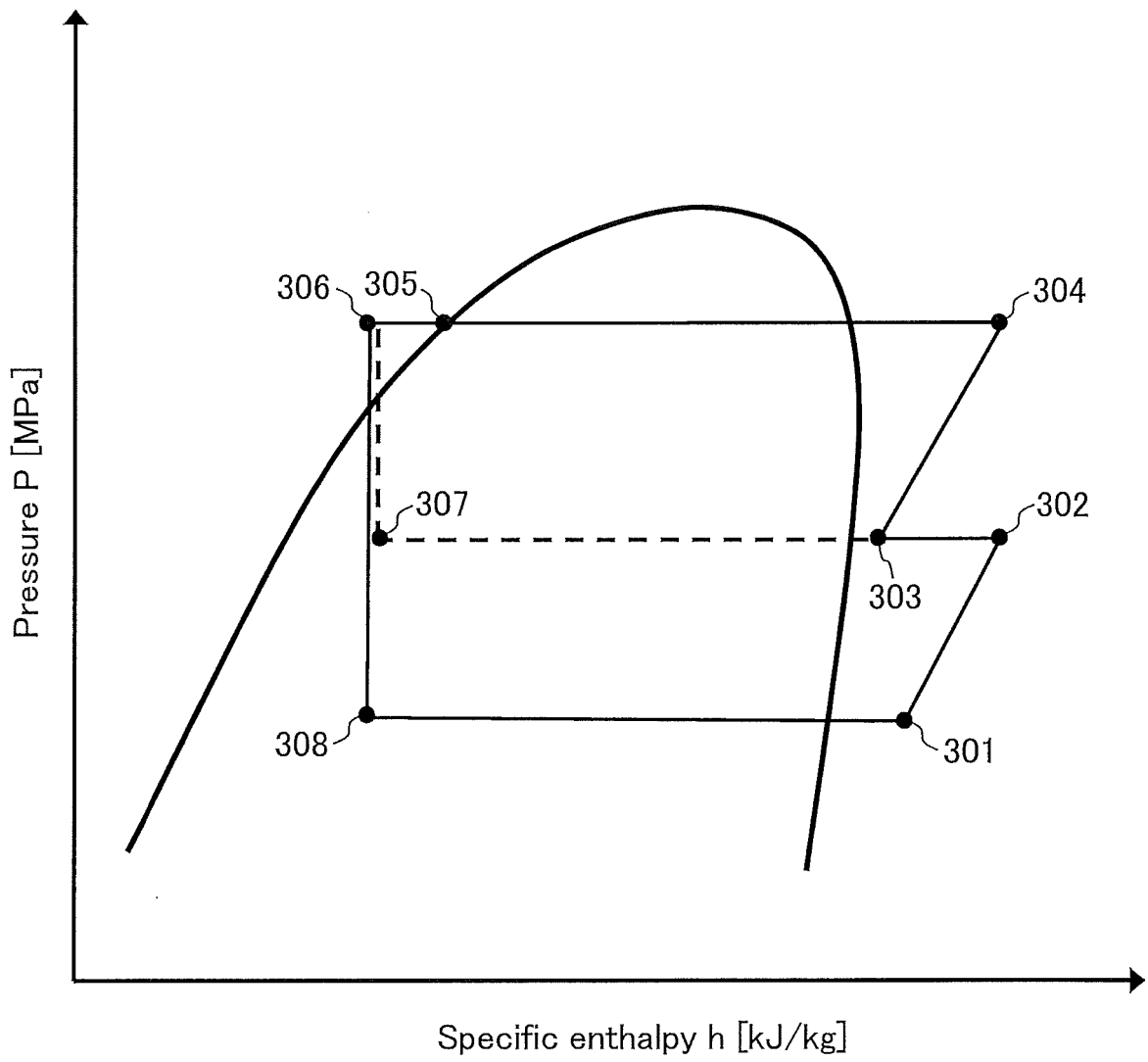


FIG.4

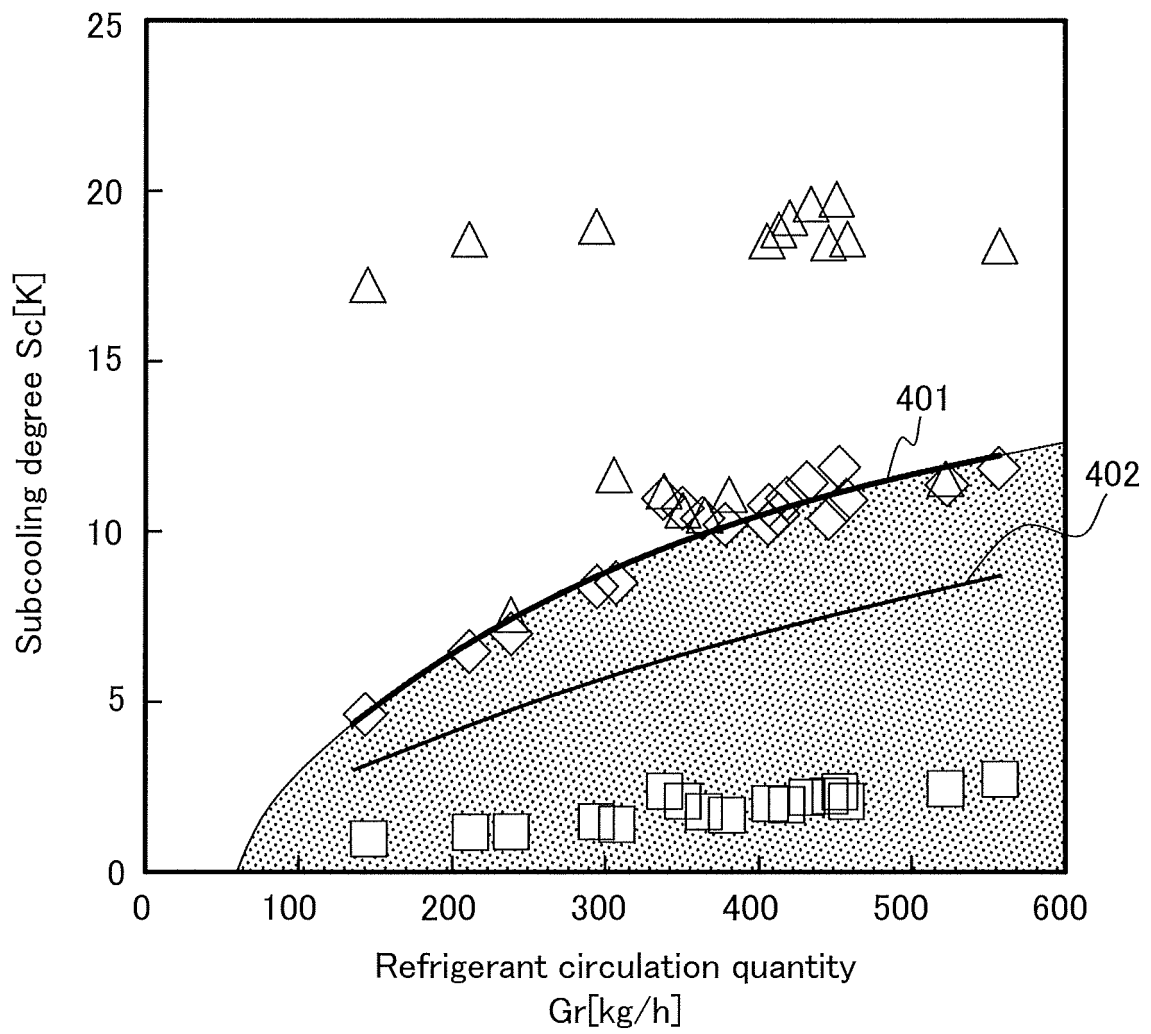


FIG.5

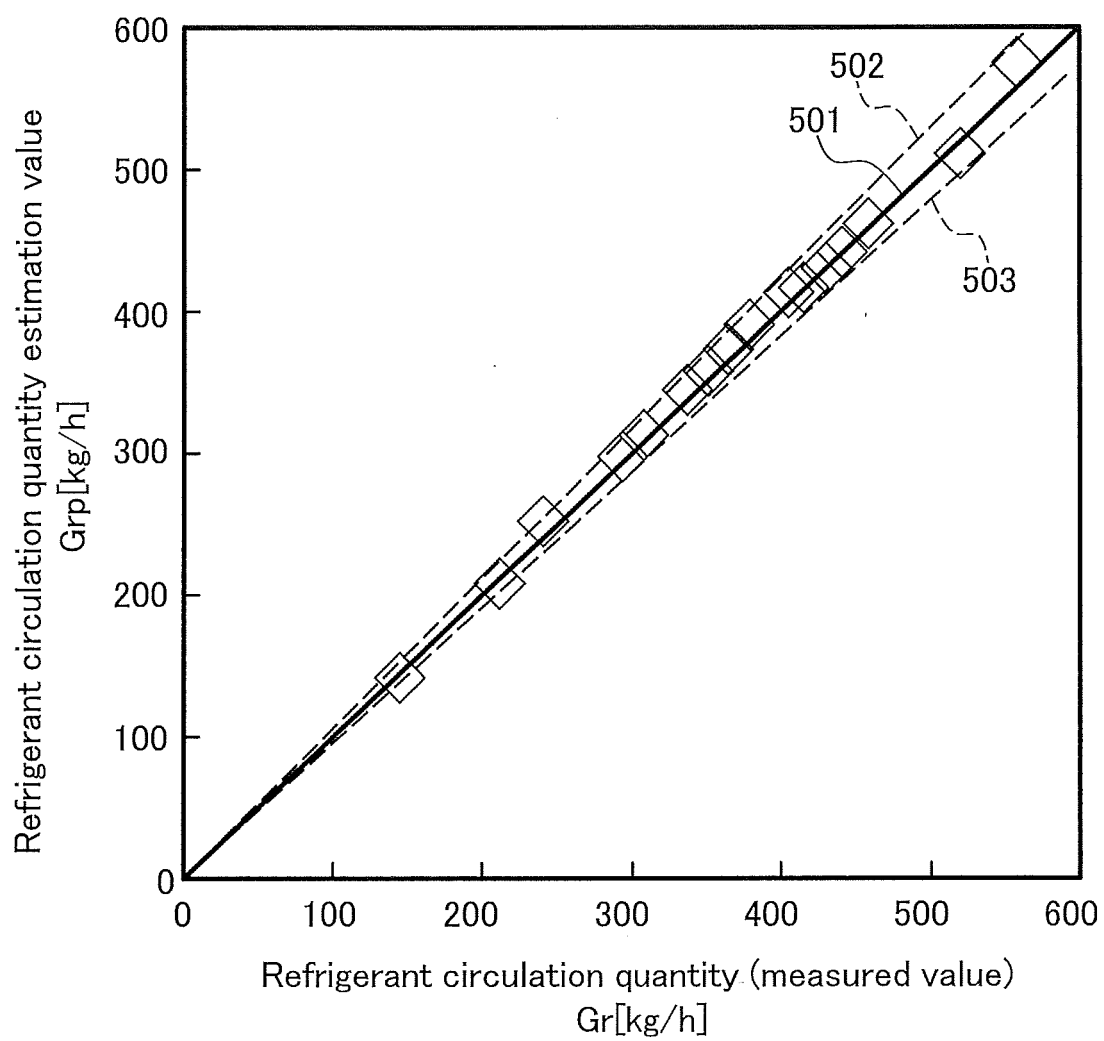


FIG.6

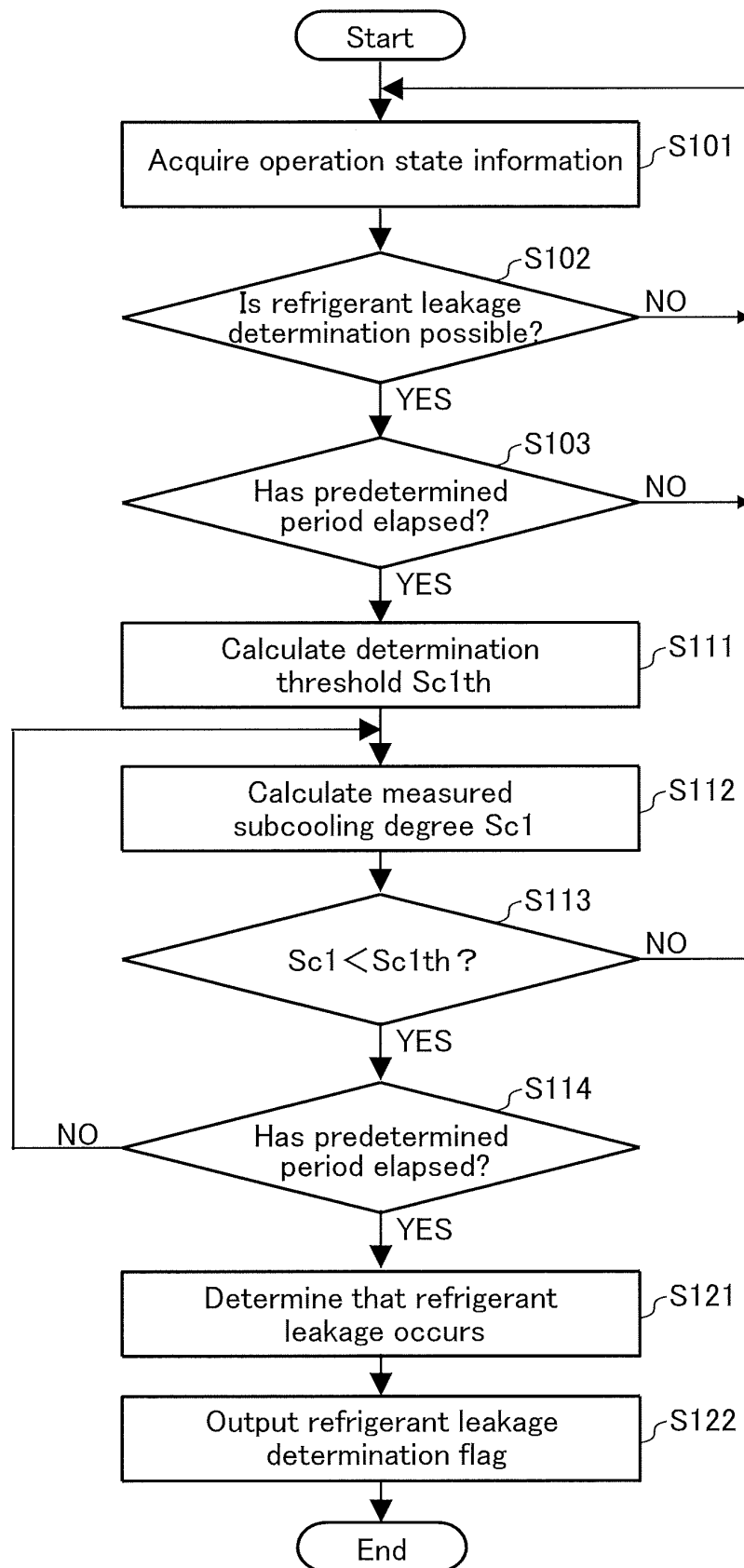


FIG.7

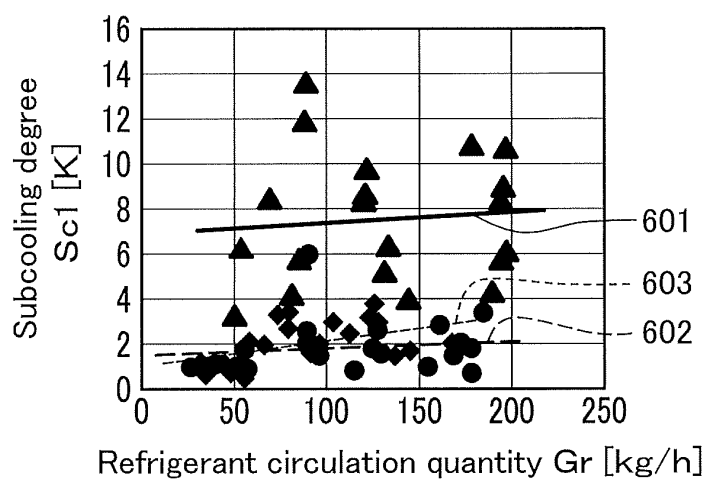


FIG.8

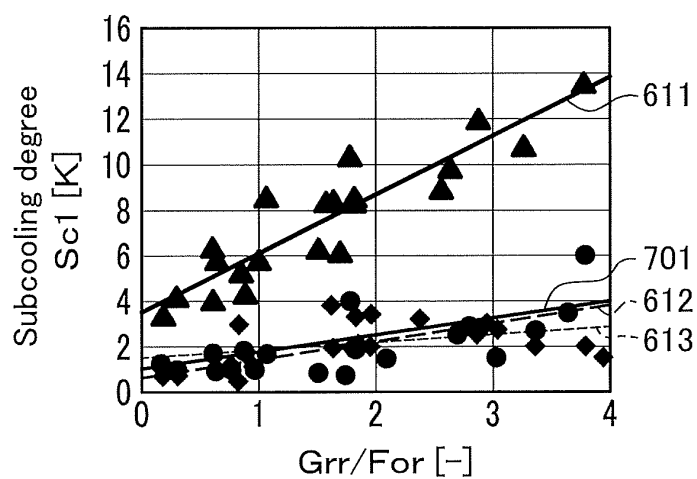


FIG.9

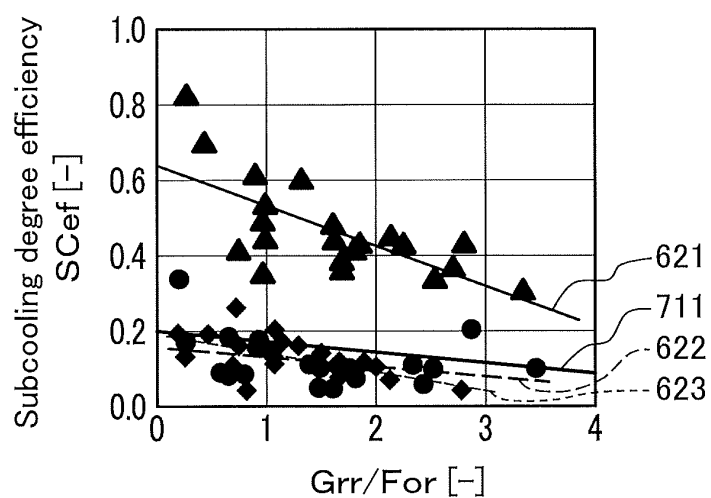


FIG.10

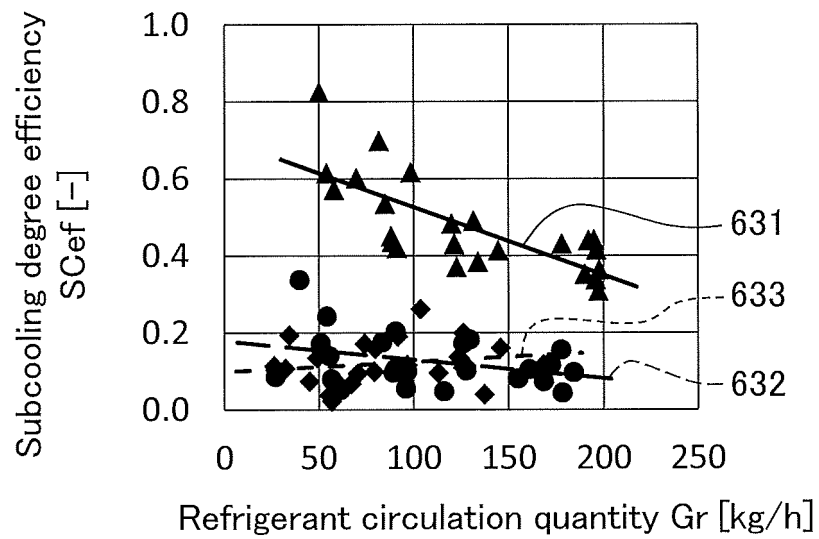


FIG.11

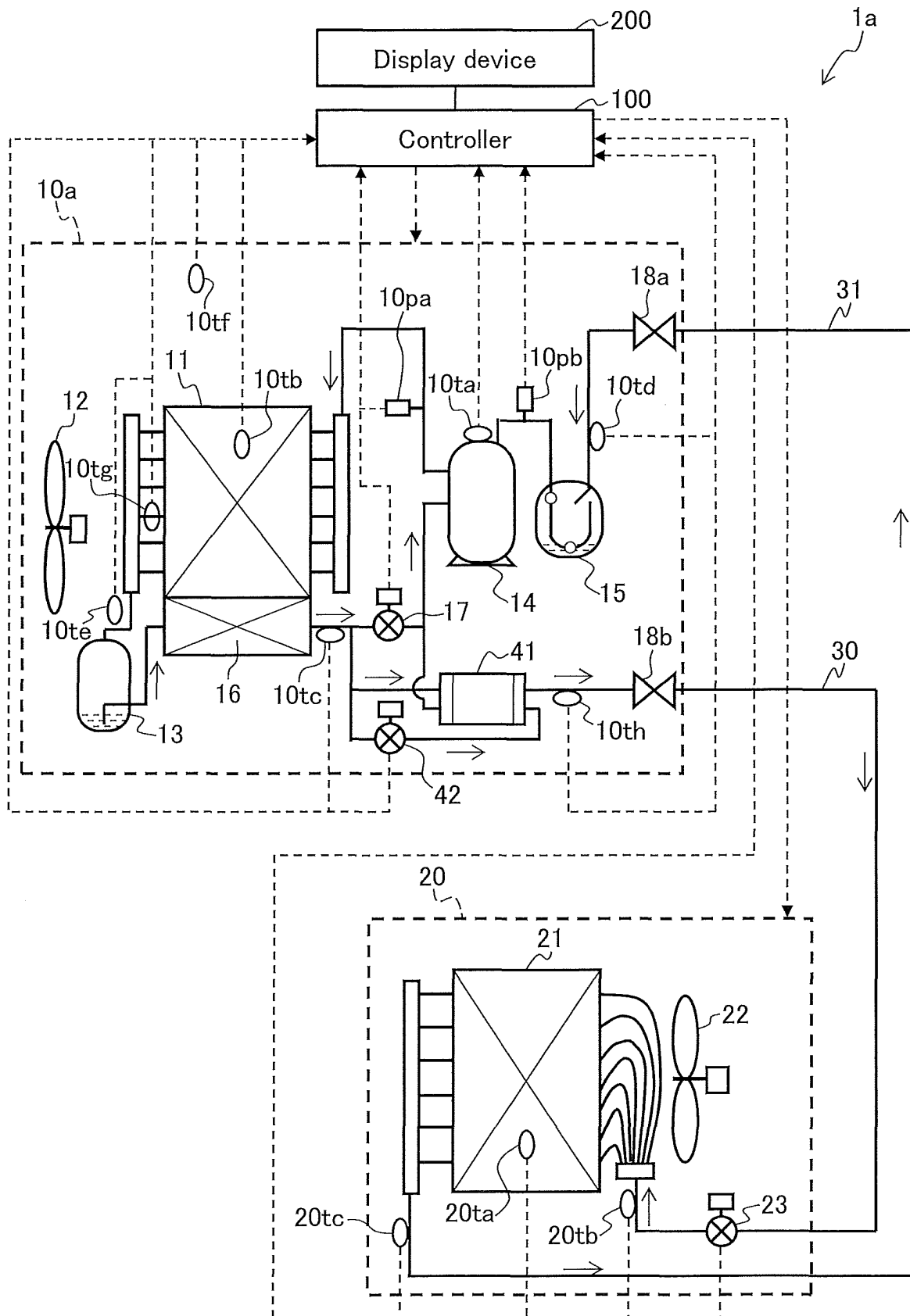


FIG.12

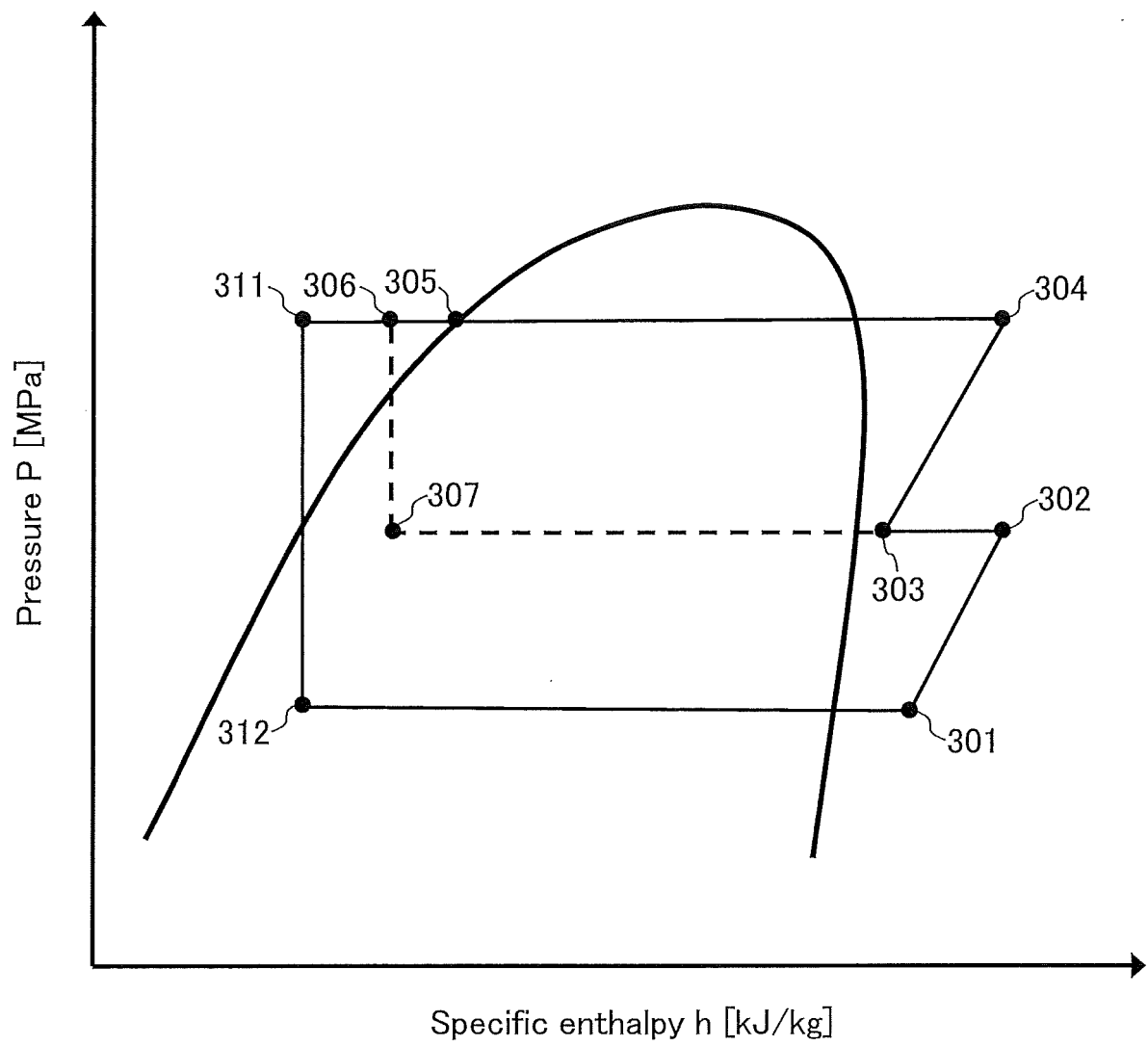


FIG.13

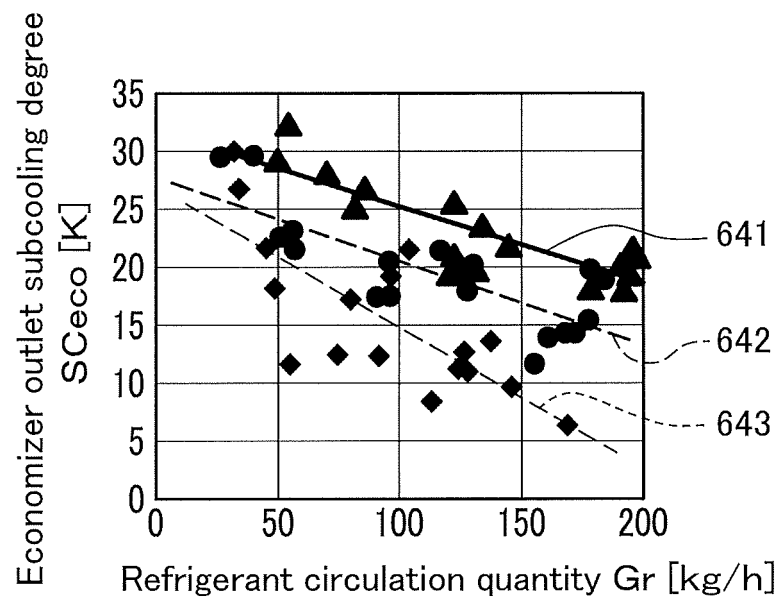
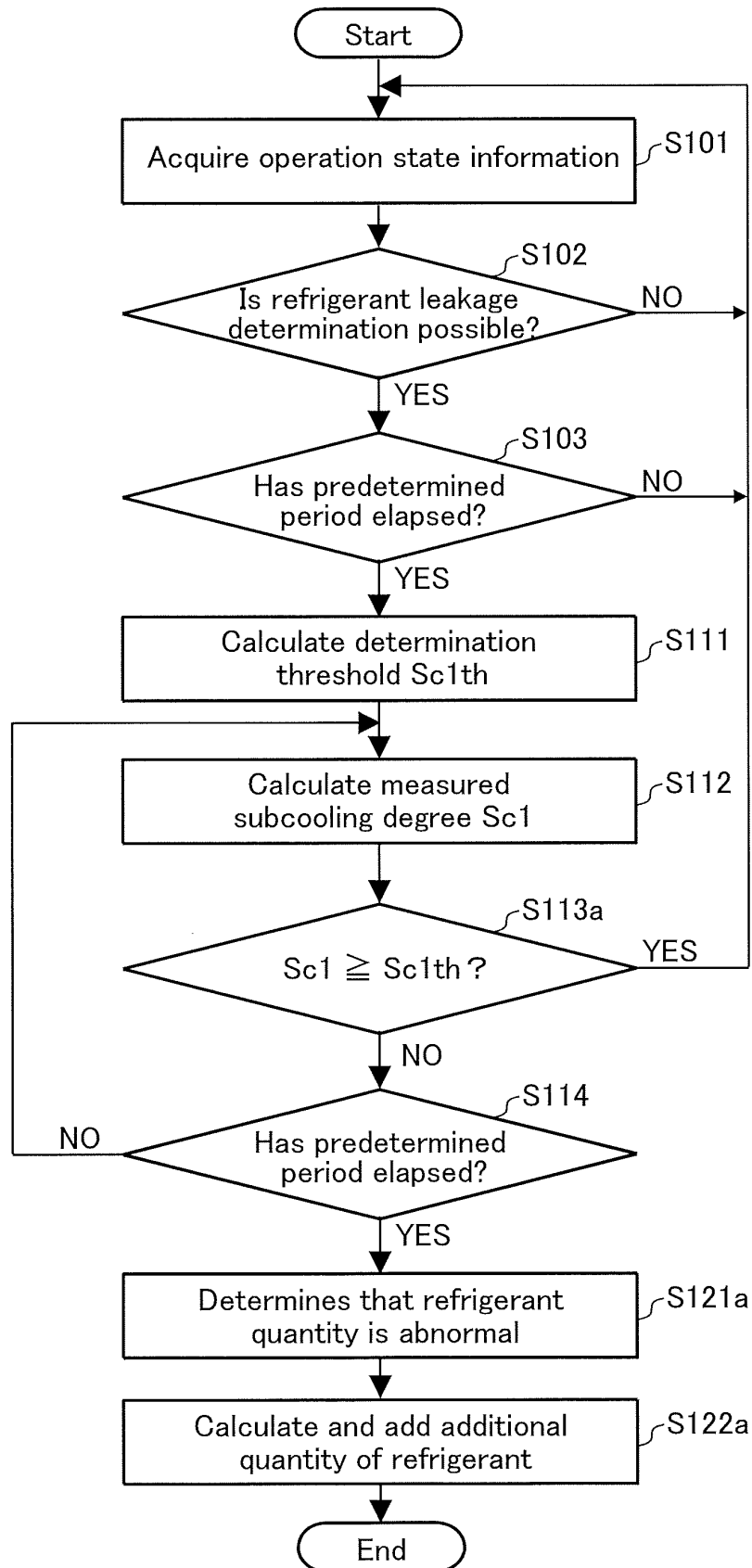


FIG.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2016/054799

A. CLASSIFICATION OF SUBJECT MATTER

F25B 49/02 (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)

F25B

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

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

CNPAT, CNKI, WPI, EPODOC: air condition, degree of supercooling, air, condition, refrigerant, quantity, amount, measure, judge, supercooling, subcooling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102077042 A (DAIKIN INDUSTRIES LTD.), 25 May 2011 (25.05.2011), description, paragraphs [0008]-[0135], and figures 1-8	1-21
A	CN 102077041 A (DAIKIN INDUSTRIES LTD.), 25 May 2011 (25.05.2011), the whole document	1-21
A	JP 2008164265 A (HITACHI APPLIANCES INC.), 17 July 2008 (17.07.2008), the whole document	1-21

☐ 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	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
30 November 2016 (30.11.2016)Date of mailing of the international search report
19 December 2016 (19.12.2016)Name and mailing address of the ISA/CN:
State Intellectual Property Office of the P. R. China
No. 6, Xitucheng Road, Jimenqiao
Haidian District, Beijing 100088, China
Facsimile No.: (86-10) 62019451Authorized officer
WANG, Meifang
Telephone No.: (86-10) 62084949

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INTERNATIONAL SEARCH REPORT
 Information on patent family members

International application No.

PCT/IB2016/054799

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102077042 A	25 May 2011	CN 102077042 B	17 April 2013
		EP 2314958 A4	26 November 2014
		JP 2010007995 A	14 January 2010
		WO 2009157200 A1	30 December 2009
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		EP 2314958 A1	27 April 2011
		AU 2009263640 A1	30 December 2009
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		EP 2320169 A4	26 November 2014
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		JP 2010007994 A	14 January 2010
		AU 2009263631 A8	28 February 2013
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REFERENCES CITED IN THE DESCRIPTION

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- JP 5505477 B [0003]