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

(11) EP 3 483 531 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.05.2019 Bulletin 2019/20

(51) Int Cl.:
F25B 49/02 *(2006.01)*

(21) Application number: **18205477.5**

(22) Date of filing: **09.11.2018**

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

(30) Priority: **13.11.2017 JP 2017218055**

(71) Applicant: **MITSUBISHI HEAVY INDUSTRIES THERMAL SYSTEMS, LTD.**
108-8215 Tokyo (JP)

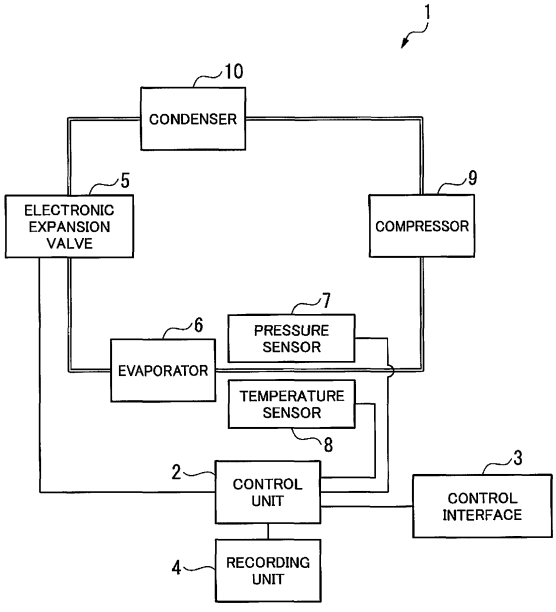
(72) Inventors:
- **KADOSHIMA, Yuta**
  TOKYO, 108-8215 (JP)
- **KAI, Masakazu**
  TOKYO, 108-8215 (JP)
- **HACHISUKA, Katsumi**
  TOKYO, 108-8215 (JP)
- **OSADA, Kazumi**
  TOKYO, 108-8215 (JP)

(74) Representative: **Cabinet Beau de Loménie**
158, rue de l'Université
75340 Paris Cedex 07 (FR)

(54) CONTROL DEVICE, REFRIGERATING MACHINE, CONTROL METHOD, AND PROGRAM

(57) A control device includes: a pressure acquisition section which is configured to acquire an outlet pressure of an evaporator from a pressure sensor for detecting a pressure of the refrigerant at an outlet of the evaporator in the refrigeration unit; a temperature acquisition section which is configured to acquire an outlet temperature of the evaporator from a temperature sensor for detecting a temperature of the refrigerant at the outlet of the evaporator; a saturation temperature table acquisition section which is configured to acquire one of a plurality of saturation temperature tables recorded in a recording unit in the refrigeration unit, the plurality of saturation temperature tables corresponding to each of the different refrigerants, the saturation temperature table designating the gas side saturation temperature at each pressure for a corresponding refrigerant; and an expansion valve control section which is configured to control an expansion valve opening degree of an electronic expansion valve in the refrigeration unit to obtain a predetermined degree of superheat, based on the obtained saturation temperature table, the acquired outlet pressure, and the acquired outlet temperature.

FIG. 1



EP 3 483 531 A2

Description

[Technical Field]

[0001] The present invention relates to a control device, a refrigeration unit, a control method, and a program.

[0002] Priority is claimed on Japanese Patent Application No. 2017-218055 filed November 13, 2017, the contents of which are incorporated herein by reference.

[Background Art]

[0003] Controlling a degree of superheat of a refrigerant in a refrigeration unit is an important technique from the perspective of protecting a compressor and maximizing refrigeration efficiency. On the other hand, when producing refrigeration units corresponding to a plurality of different refrigerants, different designs for the refrigeration units are usually required since a saturation temperature at each pressure is different for each refrigerant. As a technique for controlling a degree of superheat in accordance with different refrigerants, Patent Literature 1 below discloses setting an initial valve opening degree of an electronic valve suitable for characteristics of a refrigerant before a freezing operation is started.

[Citation List]

[Patent Literature]

[0004] [Patent Literature 1] Japanese Unexamined Patent Application, First Publication No. S61-036671

[Summary of Invention]

[Technical Problem]

[0005] Currently, R404A is widely used as a refrigerant of a vapor compression refrigeration unit. On the other hand, the global warming potential (GWP) value of R404A is 3922 (the Fourth Assessment Report of the Intergovernmental Panel on the Climate Change (IPCC AR4)), which is a high value. Since the situation urgently requires switching to low GWP refrigerants, many low GWP mixed refrigerants (such as R448A, R449, and R452A) having physical properties close to those of R404A have been proposed by individual refrigerant manufacturers. Under such circumstances, when designing a refrigeration unit that operates with a certain alternative refrigerant, there is no guarantee that the employed alternative refrigerant will be stably supplied in the future. In the worst case, there is concern that the refrigerant may be unobtainable and after-sales service will not be able to be provided.

[0006] In addition, since situations for supplying refrigerants are different in each country depending on various circumstances, it is not always possible to obtain necessary refrigerants. Therefore, there is also a problem that a desired refrigerant cannot always be obtained in a refrigeration unit for transportation which moves multilaterally, in particular, when refrigerant exchange becomes necessary due to various circumstances such as leakage of the refrigerant or the like.

[0007] The present invention has been made in view of the above problems, and it is an object of the present invention to provide a control device for a refrigeration unit, a refrigeration unit, a control method, and a program, which are capable of controlling the degree of superheat suitable for refrigerants even when different refrigerants are used in the refrigeration unit. In an embodiment of the present invention, a recording unit has saturation temperature tables corresponding to a plurality of types of refrigerants, and the control device of the refrigeration unit selects a suitable one from the plurality of recorded saturation temperature tables, thereby making it possible to deal with different refrigerants.

[Solution to Problem]

[0008] According to a first aspect of the present invention, a control device which is configured to perform control of a refrigeration unit in response to different refrigerants includes: a pressure acquisition section which is configured to acquire an outlet pressure of an evaporator from a pressure sensor for detecting a pressure of the refrigerant at an outlet of the evaporator in the refrigeration unit; a temperature acquisition section which is configured to acquire an outlet temperature of the evaporator from a temperature sensor for detecting a temperature of the refrigerant at the outlet of the evaporator; and an expansion valve control section which is configured to control an expansion valve opening degree of an electronic expansion valve in the refrigeration unit to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure, and the acquired outlet temperature.

[0009] According to a second aspect of the present invention, the control device according to the first aspect further includes a saturation temperature table acquisition section which is configured to acquire one of a plurality of saturation temperature tables recorded in a recording unit in the refrigeration unit, the plurality of saturation temperature tables corresponding to each of the different refrigerants, the saturation temperature table designating the gas side saturation temperature at each pressure for a corresponding refrigerant, in which the expansion valve control section is configured to determine the gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure based on the acquired saturation temperature table.

[0010] Also, according to a third aspect of the present invention, the control device according to the first aspect further includes a refrigerant selection signal acquisition section which is configured to acquire a signal indicating

selection of a specific refrigerant from a control interface of the refrigeration unit, in which the saturation temperature table acquisition section is configured to select a saturation temperature table corresponding to the specific refrigerant from the plurality of saturation temperature tables based on the signal indicating selection of the specific refrigerant.

[0011] Also, according to a fourth aspect of the present invention, the recording unit is configured to record information on an allowable pressure of the refrigeration unit, and the control device according to the first aspect further includes a compatible refrigerant determination section which is configured to determine a refrigerant suitable for the refrigeration unit among the refrigerants corresponding to the plurality of saturation temperature tables recorded in the recording unit, based on the allowable pressure, and a compatible refrigerant information providing section which is configured to provide the determined refrigerant information to a control interface of the refrigeration unit.

[0012] Also, according to a fifth aspect of the present invention, the recording unit is configured to record information on a lubricating oil to be used for the refrigeration unit, and the control device according to the first aspect further includes a compatible refrigerant determination section which is configured to determine a refrigerant suitable for the refrigeration unit among the refrigerants corresponding to the plurality of saturation temperature tables recorded in the recording unit, based on information of the lubricating oil, and a compatible refrigerant information providing section which is configured to provide the determined refrigerant information to a control interface of the refrigeration unit.

[0013] Also, according to a sixth aspect of the present invention, the control device according to the fourth or fifth aspect further includes a refrigerant selection signal acquisition section which is configured to acquire a signal indicating selection of a specific refrigerant from the control interface of the refrigeration unit, and a warning information providing section which is configured to provide warning information to the control interface of the refrigeration unit when the signal indicating the selection of the specific refrigerant indicates selection of a refrigerant other than the refrigerant suitable for the refrigeration unit.

[0014] Also, according to a seventh aspect of the present invention, the refrigeration unit is a refrigeration unit for transportation.

[0015] Also, according to an eighth aspect of the present invention, the expansion valve control section is configured to determine a current degree of superheat by subtracting the gas side saturation temperature of the refrigerant from the acquired outlet temperature, and control the expansion valve opening degree of the electronic expansion valve in the refrigeration unit so that the current degree of superheat is brought close to the predetermined degree of superheat.

[0016] Also, according to a ninth aspect of the present invention, at least one of the refrigerants corresponding to the plurality of saturation temperature tables is a refrigerant having a temperature glide characteristic.

[0017] Also, according to a tenth aspect of the present invention, a refrigeration unit which is configured to operate in response to different refrigerants includes: an electronic expansion valve which is capable of freely changing an expansion valve opening degree; an evaporator which is configured to evaporate a refrigerant expanded by the electronic expansion valve; a pressure sensor which is configured to detect a pressure of the refrigerant at an outlet of the evaporator; and a temperature sensor which is configured to detect a temperature of the refrigerant at the outlet of the evaporator, in which the control unit is configured to control the expansion valve opening degree of the electronic expansion valve to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the pressure detected by the pressure sensor, and the temperature detected by the temperature sensor.

[0018] Also, according to an eleventh aspect of the present invention, a method of controlling a refrigeration unit in response to different refrigerants includes steps of: obtaining an outlet pressure of an evaporator from a pressure sensor which is configured to detect a pressure of a refrigerant at an outlet of the evaporator in the refrigeration unit; obtaining an outlet temperature of the evaporator from a temperature sensor which is configured to detect a temperature of the refrigerant at the outlet of the evaporator; and controlling an expansion valve opening degree of an electronic expansion valve in the refrigeration unit to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure, and the acquired outlet temperature.

[0019] Also, according to a twelfth aspect of the present invention, a program is configured to cause a computer of a refrigeration unit to execute the method according to the tenth aspect.

[Advantageous Effects of Invention]

[0020] According to the control device for the refrigeration unit, the refrigeration unit, the control method for the refrigeration unit, and the program, controlling the degree of superheat suitable for refrigerants can be performed even when different refrigerants are used in the refrigeration unit. Accordingly, even in a situation where a refrigerant changing time and directivity are different in each country, refrigerants to be used can be selected while keeping the same design for machines. Thus, it is possible to cope with a plurality of refrigerants without hampering a cost reduction effect due to a mass production effect of the machines. Also, even when selection and concentration of alternative cooling progresses in the future, a drop-in use of refrigerants available at that time can be easily made.

[Brief Description of Drawings]

[0021]

FIG. 1 is a diagram showing the entire configuration of a refrigeration unit according to a first embodiment.
FIG. 2 is a diagram showing a functional configuration of a control unit according to the first embodiment.
FIG. 3 is a diagram showing a phase change of a refrigerant R404A in a p-h diagram.
FIG. 4 is a diagram showing a phase change of a refrigerant R452A in a p-h diagram.
FIG. 5 is a diagram showing an example of a saturation temperature table recorded in a recording unit of the refrigeration unit according to the first embodiment.
FIG 6 is a diagram showing a processing flow of the control unit according to the first embodiment.
FIG. 7 is a diagram showing a functional configuration of a control unit according to a second embodiment.
FIG. 8 is a diagram showing a processing flow of the control unit according to the second embodiment.

[Description of Embodiments]

<First embodiment>

[0022] Hereinafter, a refrigeration unit according to a first embodiment will be described with reference to FIGS. 1 to 6.

(Configuration of a refrigeration unit)

[0023] FIG. 1 is a diagram showing a configuration of a refrigeration unit according to a first embodiment.

[0024] The refrigeration unit 1 according to the first embodiment may be used as a refrigeration unit for transportation which is mounted on a truck, a train, an aircraft, or the like. On the other hand, in other embodiments, the refrigeration unit 1 is not limited to the aspects described above, and may be used as a general refrigeration unit.

[0025] The refrigeration unit 1 according to the first embodiment includes a control unit 2, a control interface 3, a recording unit 4, an electronic expansion valve 5, an evaporator 6, a pressure sensor 7, a temperature sensor 8, a compressor 9, and a condenser 10. As shown in FIG. 1, the electronic expansion valve 5, the evaporator 6, the compressor 9, and the condenser 10 are connected sequentially in a loop shape using pipes through which a refrigerant passes to form a refrigeration cycle.

[0026] The control unit 2 acquires one of a plurality of saturation temperature tables corresponding to different refrigerants from the recording unit 4, and controls an expansion valve opening degree of the electronic expansion valve in the refrigeration unit so that a predetermined degree of superheat can be obtained based on the acquired saturation temperature table. Also, a functional configuration of the control unit 2 will be described in more detail below with reference to FIG. 2.

[0027] The control interface 3 is a means for an operator to set the refrigeration unit, and provides the operator with a means for selecting the refrigerant. The control interface 3 may be implemented with an arbitrary user interface for communicating the intention of the operator to the control unit 2. For example, the control interface 3 may be implemented as a physical switch such as a dip switch on a board, or as a touch sensor provided on a touch display. The operator can select any of available refrigerants on the control interface 3. In response to the operator's selection of the refrigerant, the control unit 2 acquires a saturation temperature table corresponding to the selected refrigerant from the plurality of saturation temperature tables recorded in the recording unit 4.

[0028] The recording unit 4 records a plurality of saturation temperature tables corresponding to different refrigerants. The saturation temperature table represents the gas side saturation temperature of the refrigerant with respect to each pressure. The control unit 2 acquires one from the plurality of saturation temperature tables recorded in the recording unit 4, and performs control of a degree of superheat based on the acquired saturation temperature table. Details of the saturation temperature table will be described in more detail below with reference to FIGS. 2 to 7.

[0029] The electronic expansion valve 5 is connected between the condenser 10 and the evaporator 6, and a high-pressure liquid refrigerant flows thereinto from the condenser 10. The electronic expansion valve 5 adjusts a flow rate or the like of the refrigerant to make the refrigerant passing in accordance with an opening degree thereof, thereby adjusting the pressure of the refrigerant after passing, and discharges a low pressure gas-liquid mixed refrigerant to the evaporator 6. The opening degree of the electronic expansion valve 5 is dynamically adjustable and is controlled by the control unit 2.

[0030] The evaporator 6 is connected between the electronic expansion valve 5 and the compressor 9, and a low pressure refrigerant flows thereinto from the electronic expansion valve 5. The evaporator 6 has a function of evaporating the refrigerant expanded by the electronic expansion valve. Therefore, since all the refrigerant which was in a mixed state of a liquid phase and a gas phase is vaporized in the evaporator 6, heat exchange with the air is carried out due to heat absorption of the refrigerant. As a result, the air in a storage in which the refrigeration unit is installed is cooled. From the viewpoint of refrigeration efficiency and compressor protection, it is desirable that the refrigerant in which the liquid phase and gas phase are mixed becomes a completely vaporized refrigerant at an outlet of the evaporator 6. Therefore, in order to ensure that the refrigerant is discharged in a completely vaporized state, the evaporator 6 makes the refrigerant into superheated steam at a temperature

higher than the gas side saturation temperature and then discharges it to the compressor 9 side. An ascending temperature of the superheated steam with respect to the gas side saturation temperature is generally called a "degree of superheat."

[0031] The pressure sensor 7 may be provided in a pipe or the like extending from the evaporator 6 to the compressor 9, and detects the pressure of the refrigerant at the outlet of the evaporator 6 (hereinafter referred to as the "outlet pressure"). The pressure sensor 7 outputs the detected pressure to the control unit 2, and the control unit 2 uses the pressure detected by the pressure sensor 7 to calculate the degree of superheat.

[0032] Further, the temperature sensor 8 may be provided in a pipe or the like similarly extending from the evaporator 6 to the compressor 9, and detects the temperature of the refrigerant at the outlet of the evaporator 6 (hereinafter referred to as the "outlet temperature"). The temperature sensor 8 outputs the detected pressure to the control unit 2, and the control unit 2 uses the temperature detected by the temperature sensor 8 in addition to the pressure to calculate the degree of superheat.

[0033] The compressor 9 is connected between the evaporator 6 and the condenser 10, and a low-pressure gas refrigerant flows thereinto from the evaporator 6. The compressor 9 compresses the inflowing refrigerant to produce a high pressure gas refrigerant, and then discharges it to the condenser 10.

[0034] The condenser 10 is connected between the compressor 9 and the electronic expansion valve 5, and a high-pressure gas refrigerant flows thereinto from the compressor 9. The condenser 10 releases heat from the high pressure gas refrigerant and discharges a high pressure liquid refrigerant to the electronic expansion valve 5.

[0035] The refrigeration unit 1 cools, for example, an interior of a refrigerating storage mounted on a truck, train, aircraft, or the like using the above-described refrigeration cycle. In the refrigeration unit 1 according to the first embodiment, it is possible for the recording unit 4 to record a plurality of saturation temperature tables corresponding to different refrigerants, and for the control unit 2 to acquire an appropriate one from among the plurality of saturation temperature tables, thereby performing appropriate control of the degree of superheat for different refrigerants. A more detailed functional configuration of the control unit 2 will be described below.

(Functional configuration of the control unit)

[0036] FIG. 2 is a diagram showing a functional configuration of the control unit 2 according to the first embodiment.

[0037] As shown in FIG. 2, the control unit 2 includes a pressure acquisition section 21, a temperature acquisition section 22, a saturation temperature table acquisition section 23, an expansion valve control section 24, and a refrigerant selection signal acquisition section 25. The control unit 2 is a processor (a microcomputer) that takes charge of controlling the entire refrigeration unit 1, and operates in accordance with a program prepared in advance. The control unit 2 is also electrically coupled to the recording unit 4, the electronic expansion valve 5, the pressure sensor 7, and the temperature sensor 8.

[0038] Also, as shown in FIG. 2, the recording unit 4 records saturation temperature tables corresponding to a plurality of refrigerants. As described above, the saturation temperature table represents the gas side saturation temperature for each pressure of the refrigerant. In general, different refrigerants have different gas side saturation temperatures for each pressure. For example, boundaries of phase changes in the p-h diagram (Mollier diagram) of the refrigerants R404A and R452A are shown in FIGS. 3 and 4. The saturation temperature table expresses the relationship between the pressure and the gas side saturation temperature in the graph as a table.

[0039] Further, in FIG. 3, the refrigeration cycle of the refrigeration unit on the p-h diagram is shown as a dotted line. The bottom side portion of a reverse trapezoidal shape in the refrigeration cycle shows the state change of the refrigerant in the evaporator. When the refrigerant passes through the electronic expansion valve 5, it flows into the evaporator in a low pressure and low temperature state. In the evaporator, under substantially isobaric conditions, the refrigerant changes from a mixed state of the liquid phase and the gas phase to a gas phase. On the other hand, in order to ensure complete evaporation of the refrigerant as described above, the refrigerant is heated as much as the degree of superheat higher than the gas side saturation temperature and is discharged to the compressor 9 side. In FIG. 3, the arrow (1) shows the state of the evaporator outlet and the arrow (2) shows the state at the gas side saturation temperature. In the present invention, the degree of superheat is calculated as a value obtained by subtracting the gas side saturation temperature from the evaporator outlet temperature.

[0040] The saturation temperature table is recorded in the recording unit 4 as a table as shown in FIG. 5, for example. Although FIG. 5 illustrates, as examples, saturation temperature tables for three refrigerants, saturation temperature tables for any number of refrigerants may be recorded in the recording unit 4. For example, in the saturation temperature table for the refrigerant A, the gas side saturation temperatures (T_{A1}, T_{A2}, and T_{A3}) of the refrigerant are associated with respective pressures (P_1, P_2, and P_3). In the saturation temperature table for the refrigerant B, the gas side saturation temperatures (T_{B1}, T_{B2}, and T_{B3}) of the refrigerant are associated with respective pressures (P_1, P_2, and P_3). Similarly for the refrigerant C, the gas side saturation temperatures (T_{C1}, T_{C2}, and T_{C3}) of the refrigerant are associated with respective pressures (P_1, P_2, and P_3). Although the gas side saturation temperatures are explicitly associated only with three pressures in FIG. 5, this is merely an example and the gas side saturation temperatures can be associated with any number of pressures at any intervals.

[0041] Further, the saturation temperature table is as-

sumed to be recorded in advance in the recording unit 4 at the time of manufacture. However, it may be recorded and updated at any time by acquiring data from a network via wireless or wired communication, or from another external recording medium as necessary.

[0042] Returning to FIG. 2, the pressure acquisition section 21 acquires the outlet pressure from the pressure sensor 7 that detects the pressure of the refrigerant at the outlet of the evaporator 6. Also, the temperature acquisition section 22 acquires the outlet temperature from the temperature sensor 8 that detects the temperature of the refrigerant at the outlet of the evaporator 6. The pressure acquisition section 21 and the temperature acquisition section 22 can acquire measured values of the respective sensors continuously or at predetermined time intervals. The obtained outlet pressure and outlet temperature of the evaporator 6 are used by the expansion valve control section 24 to determine and control the degree of superheat.

[0043] The refrigerant selection signal acquisition section 25 acquires a signal corresponding to the refrigerant selected by the operator in the control interface 3 from the control interface 3. As described above, the control interface 3 may be implemented in any form such as a physical switch on a board or a touch sensor on a touch display. The operator can select an intended refrigerant at the control interface 3, and the refrigerant selection signal acquisition section 25 acquires a signal reflecting the refrigerant selection of the operator.

[0044] The saturation temperature table acquisition section 23 acquires one of the plurality of saturation temperature tables recorded in the recording unit 4. The saturation temperature table acquisition section 23 can select a corresponding one from the plurality of saturation temperature tables based on an initial setting or signals acquired by the refrigerant selection signal acquisition section.

[0045] The expansion valve control section 24 controls the expansion valve opening degree of the electronic expansion valve 5 in the refrigeration unit to obtain a predetermined degree of superheat based on the saturation temperature table acquired by the saturation temperature table acquisition section 23, the outlet pressure acquired by the pressure acquisition section 21, and the outlet temperature acquired by the temperature acquisition section 22. This control of the degree of superheat will be described in more detail below.

[0046] In the first embodiment, the refrigerant selection signal acquisition section 25 acquires the refrigerant selection signal from the control interface 3, and an appropriate saturation temperature table is selected based on the refrigerant selection signal. However, in another embodiment, the control unit 2 may automatically determine a refrigerant to be used, and select an appropriate saturation temperature table based on the determination. In such an embodiment, the control unit 2 may include a refrigerant determination section 26 (not shown) that determines a refrigerant to be used for the refrigeration unit 1, instead of the refrigerant selection signal acquisition section 25. The saturation temperature table acquisition section 23 can select a corresponding one of the plurality of saturation temperature tables based on the determined refrigerant.

[0047] FIG. 6 is a diagram showing a processing flow of the control unit 2 according to the first embodiment.

[0048] Before the processing flow in FIG. 6 starts, the operator can select a refrigerant to be used through the control interface 3. For example, a situation in which a currently used refrigerant cannot be used when replacement of the refrigerant is required due to a failure or the like is assumed. In such a case, the operator selects settings corresponding to a newly replaced refrigerant on the control interface 3. As described above, the control interface 3 may be implemented into a user interface in any type that allows the operator to select a refrigerant. After such settings are made, the following processing flow may be started. It should be noted that the order of the processing steps described below is merely illustrated for ease of explanation, and the order of some processing steps may be changed or they may be executed in parallel.

[0049] In step S101, the control unit 2 acquires the outlet pressure of the evaporator 6 from the pressure sensor that detects the outlet pressure of the evaporator 6 in the refrigeration unit 1. Further, in step S102, the control unit 2 acquires the outlet temperature of the evaporator 6 from the temperature sensor that detects the outlet temperature of the evaporator 6. In order to control the degree of superheat of the refrigeration unit 1, acquisition of the outlet pressure and the outlet temperature may be performed continuously as long as the operation of the refrigeration unit 1 continues.

[0050] In step S103, the control unit 2 acquires a corresponding one from the plurality of saturation temperature tables recorded in the recording unit 4 in the refrigeration unit 1. The plurality of saturation temperature tables include saturation temperature tables corresponding to different refrigerants, and each saturation temperature table specifies the gas side saturation temperature for each pressure for a particular refrigerant. Specifically, in step S103, the control unit 2 may perform acquisition of the saturation temperature table by executing the steps of acquiring a signal indicating the refrigerant selected by the operator from the control interface 3 of the refrigeration unit 1 and selecting a corresponding saturation temperature table from the plurality of saturation temperature tables recorded in the recording unit 4 based on a signal indicating the selected refrigerant. Unlike steps S101 and S102, acquisition of the saturation temperature table is sufficient if performed once in the operation of the refrigeration unit 1. The acquired saturation temperature table may be stored in a memory or the like in the processor constituting the control unit 2 and may be referred to at any time by the control unit 2.

[0051] In S104, the control unit 2 controls the expansion valve opening degree of the electronic expansion

valve 5 in the refrigeration unit 1 to be able to obtain a predetermined degree of superheat based on the acquired saturation temperature table, the acquired outlet pressure, and the acquired outlet temperature.

[0052] In detail, the control unit 2 may first calculate the current degree of superheat. That is, the control unit 2 can determine what degree is the gas side saturation temperature with respect to the currently acquired outlet pressure of the evaporator 6 with reference to the acquired saturation temperature table. Also, the control unit 2 can determine the current degree of superheat by subtracting the determined gas side saturation temperature of the refrigerant from the acquired outlet temperature. In addition, the control unit 2 can control the expansion valve opening degree of the electronic expansion valve 5 so that the current degree of superheat is brought close to the predetermined degree of superheat. For example, by increasing the opening degree of the electronic expansion valve 5 above the present state, the pressure in the evaporator 6 can be lowered. As is apparent from FIGS. 3 to 6, since the gas side saturation temperature also changes accordingly, the degree of superheat also changes. The expansion valve control section 24 controls the electronic expansion valve 5 to obtain an appropriate degree of superheat by using such a process. Also, step S104 may be performed continuously as long as the operation of the refrigeration unit 1 continues.

[0053] As described above, in the present invention, the degree of superheat is determined by determining the gas side saturation temperature from the saturation temperature table and measuring the outlet temperature of the evaporator 6. On the other hand, such a configuration makes it possible to control the degree of superheat more accurately as compared with the method of measuring an inlet temperature of the evaporator 6 as the gas side saturation temperature and calculating the degree of superheat from the difference between the inlet temperature and the outlet temperature. For example, as shown with the refrigerant R452A in FIG. 4, there is a case in which a temperature changes even in an isobaric state in a mixed region of a gas phase and a liquid phase, and such a characteristic is called a "temperature glide characteristic." The refrigerant having the temperature glide characteristic has a problem that the inlet temperature of the evaporator 6 is different from the gas side saturation temperature of the refrigerant. Therefore, by calculating the gas side saturation temperature directly from the saturation temperature table as in the present invention, a more accurate degree of superheat can be obtained, and the control of the degree of superheat can be performed more accurately.

(Operation and effects of the first embodiment)

[0054] As described above, according to the refrigeration unit 1 of the first embodiment, since the recording unit 4 of the refrigeration unit 1 has saturation temperature tables corresponding to the plurality of types of refrigerants even when different refrigerants are used for the refrigeration unit 1, the saturation temperature table corresponding to the refrigerant to be used can be selected, thereby making it possible to perform optimal controlling of the degree of superheat.

<Second embodiment>

[0055] In a second embodiment of the present application, such a function of enabling the operator to select only a suitable refrigerant is provided in addition to the configuration of the control unit 2 of the first embodiment. Therefore, the second embodiment of the present application discloses an additional configuration arbitrarily applicable to the first embodiment.

[0056] Generally, the refrigeration unit has an allowable pressure, and this allowable pressure is derived from an allowable pressure of a refrigerant container or the like. Therefore, it is practically impossible for a refrigeration unit to be compatible with all refrigerants, and a refrigeration unit is compatible with a refrigerant having a predetermined pressure characteristic. Also, although a lubricating oil such as polyol ester (POE) oil is used for a refrigeration unit, a suitable refrigerant for each lubricating oil also exists.

[0057] In the second embodiment of the present application, in view of the above points, a refrigeration unit is configured such that an operator can select a suitable refrigerant under predetermined conditions of the refrigeration unit.

[0058] FIG. 7 is a diagram showing a further functional configuration of the control unit 2 and the recording unit 4, in addition to the functional configuration of the control unit 2 and the recording unit 4 shown in FIG. 2. For ease of explanation, descriptions of each component of the control unit 2 shown in FIG. 2 are omitted in FIG. 7.

[0059] In addition to the saturation temperature table, the recording unit 4 further records information on the allowable pressure of the refrigeration unit 1 (hereinafter referred to as "allowable pressure information") and information on the lubricating oil to be used for the refrigeration unit 1 (hereinafter referred to as "lubricating oil information"). The allowable pressure of the refrigeration unit 1 is determined in advance based on a design of the refrigerant container of the refrigeration unit 1 and other designs of the refrigeration unit 1.

[0060] In addition to each constituent element (not shown) shown in FIG. 2, the control unit 2 further includes a compatible refrigerant determination section 26, a compatible refrigerant information providing section 27, and a warning information providing section 28.

[0061] The compatible refrigerant determination section 26 determines the refrigerant (hereinafter referred to as the "compatible refrigerant") suitable for the allowable pressure of the refrigeration unit 1 and the lubricating oil to be used for the refrigeration unit 1, among the refrigerants corresponding to the saturation temperature tables recorded in the recording unit 4, based on the al-

lowable pressure information and the lubricant information recorded in the recording unit 4. Although the compatible refrigerant is determined based on both the allowable pressure information and the lubricant information in the present embodiment, the compatible refrigerant may be determined based on either information in other embodiments.

[0062] The compatible refrigerant information providing section 27 provides information on the compatible refrigerant determined by the compatible refrigerant determination section 26 to the control interface 3. In the case where the control interface 3 includes a display, by displaying the compatible refrigerant on the display, only the compatible refrigerant can be selected by the operator. Also, even when the control interface 3 is implemented with physical switches, it is possible to explicitly indicate a switch corresponding to the compatible refrigerant by turning on a lamp or the like, thereby informing the operator of the compatible refrigerant. On the other hand, the present invention is not limited to such an embodiment, and the control interface 3 may be configured to notify the operator of a compatible refrigerant in an arbitrary form by using the information on the compatible refrigerant.

[0063] The warning information providing section 28 provides warning information to the control interface 3 when an incompatible refrigerant is selected in the control interface 3. Specifically, the refrigerant selection signal acquisition section 25 shown in FIG. 2 acquires a signal indicating the refrigerant selected by the operator from the control interface 3. The warning information providing section 28 provides warning information to the control interface 3 when the selected refrigerant is other than the compatible refrigerant determined by the compatible refrigerant determination section 26. This configuration is particularly useful when the control interface 3 includes a physical switch such as a dip switch or the like provided on a substrate.

[0064] Further, in addition to the above configuration, the control unit 2 can control not to execute controlling of the refrigeration unit 1 when an incompatible refrigerant is selected. In yet another embodiment, the recording unit 4 may also record information on which refrigerant is ASHRAE safety grade A1 (non-toxic, noncombustible), and the control unit 2 may control the control interface 3 such that the operator can select only the refrigerant which is ASHRAE safety grade A1 (non-toxic, non-combustible).

[0065] FIG. 8 is a diagram showing a processing flow of the control unit according to the second embodiment.

[0066] The processing flow of FIG. 8 may be executed before the processing flow shown in FIG. 6 is started.

[0067] In step S201, the control unit 2 determines the compatible refrigerant of the refrigeration unit 1 among the refrigerants corresponding to the saturation temperature tables recorded in the recording unit 4 based on the allowable pressure information and the lubricant information recorded in the recording unit 4.

[0068] In step S202, the control unit 2 provides information on the determined compatible refrigerant to the control interface 3. The control interface 3 can notify the operator of the compatible refrigerant in an arbitrary manner using the received information on the compatible refrigerant. When the control interface 3 includes a display, only the compatible refrigerant may be selectively displayed. In this case, since the operator can select only the compatible refrigerant, the following step S203 may be omitted and the process described in FIG. 6 may be continued.

[0069] In step S203, the control unit 2 receives a signal indicating the selection of the refrigerant from the control interface 3, and determines whether the selected refrigerant is included in the determined compatible refrigerant or not.

[0070] In the case of YES in step S203, that is, when the compatible refrigerant is selected in the control interface 3, the processing in the control unit 2 continues to the processing flow in step S101 shown in FIG. 6.

[0071] In the case of NO in step S203, that is, when an incompatible refrigerant is selected in the control interface 3, warning information is provided to the control interface 3 in step S204 to urge a provider to select a compatible refrigerant. In this case, returning to step S203, it may be determined whether or not the selected refrigerant is included in the determined compatible refrigerant.

(Operation and effects)

[0072] As described above, according to the refrigeration unit 1 of the second embodiment, the operator can reliably select the refrigerant suitable for the refrigeration unit without knowing the allowable pressure and the lubricating oil for the refrigeration unit, or other conditions concerning refrigerants. Therefore, it is possible to prevent the refrigeration unit from malfunctioning or the like resulting from using incompatible refrigerant.

[0073] In each of the above-described embodiments, the processes of the control unit 2 described above are stored in a computer-readable recording medium in the form of a program. The above-described various processes are performed by reading and executing this program by the computer. Also, the computer-readable recording medium refers to a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like. Alternatively, the computer program may be distributed to a computer via a communication line, and the computer receiving the distribution may run the program.

[0074] The above program may be provided for executing a part of the functions described above. Further, it may be a so-called difference file (a difference program) which can realize the above-mentioned functions based on combinations with programs already recorded in a computer system. Furthermore, in another embodiment, the control unit 2 of the refrigeration unit 1 may be con-

figured with one computer or a plurality of computers communicably connected.

[0075] As such, while several embodiments of the present invention have been described, these embodiments have been presented by way of example and are not intended to limit the scope of the invention. These embodiments can be implemented in various other aspects, and various omissions, substitutions, and changes can be made without departing from the gist of the invention. These embodiments and modifications thereof are included in the scope and gist of the invention as well as within the invention described in the claims and the equivalent scope thereof.

[Industrial Applicability]

[0076] According to the control device for the refrigeration unit, the refrigeration unit, the control method for the refrigeration unit, and the program, controlling the degree of superheat suitable for refrigerants can be performed even when different refrigerants are used in the refrigeration unit. Accordingly, even in a situation where a refrigerant changing time and directivity are different in each country, refrigerants to be used can be selected while keeping the same design for machines. Thus, it is possible to cope with a plurality of refrigerants without hampering a cost reduction effect due to a mass production effect of the machines. Also, even when selection and concentration of alternative cooling progresses in the future, a drop-in use of refrigerants available at that time can be easily made.

[Reference Signs List]

[0077]

1	Refrigeration unit
2	Control unit
3	Control interface
4	Recording unit
5	Electronic expansion valve
6	Evaporator
7	Pressure sensor
8	Temperature sensor
9	Compressor
10	Condenser
21	Pressure acquisition section
22	Temperature acquisition section
23	Saturation temperature table acquisition section
24	Expansion valve control section
25	Refrigerant selection signal acquisition section
26	Compatible refrigerant determination section
27	Compatible refrigerant information providing section
28	Warning information providing section

Claims

1. A control device which is configured to perform control of a refrigeration unit in response to different refrigerants, comprising:

   a pressure acquisition section which is configured to acquire an outlet pressure of an evaporator from a pressure sensor for detecting a pressure of the refrigerant at an outlet of the evaporator in the refrigeration unit;
   a temperature acquisition section which is configured to acquire an outlet temperature of the evaporator from a temperature sensor for detecting a temperature of the refrigerant at the outlet of the evaporator; and
   an expansion valve control section which is configured to control an expansion valve opening degree of an electronic expansion valve in the refrigeration unit to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure, and the acquired outlet temperature.

2. The control device according to claim 1, further comprising:

   a saturation temperature table acquisition section which is configured to acquire one of a plurality of saturation temperature tables recorded in a recording unit in the refrigeration unit, the plurality of saturation temperature tables corresponding to each of the different refrigerants, the saturation temperature table designating the gas side saturation temperature at each pressure for a corresponding refrigerant,
   wherein the expansion valve control section is configured to determine the gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure based on the acquired saturation temperature table.

3. The control device according to claim 2, further comprising:

   a refrigerant selection signal acquisition section which is configured to acquire a signal indicating selection of a specific refrigerant from a control interface of the refrigeration unit,
   wherein the saturation temperature table acquisition section is configured to select a saturation temperature table corresponding to the specific refrigerant from the plurality of saturation temperature tables based on the signal indicating selection of the specific refrigerant.

4. The control device according to claim 2,

wherein the recording unit is configured to record information on an allowable pressure of the refrigeration unit, and
the control device further comprises:

a compatible refrigerant determination section which is configured to determine a refrigerant suitable for the refrigeration unit among the refrigerants corresponding to the plurality of saturation temperature tables recorded in the recording unit, based on the information of the allowable pressure; and
a compatible refrigerant information providing section which is configured to provide the determined refrigerant information to a control interface of the refrigeration unit.

5. The control device according to claim 2,
wherein the recording unit is configured to record information on a lubricating oil to be used for the refrigeration unit, and
the control device further comprises:

a compatible refrigerant determination section which is configured to determine a refrigerant suitable for the refrigeration unit among the refrigerants corresponding to the plurality of saturation temperature tables recorded in the recording unit, based on information of the lubricating oil; and
a compatible refrigerant information providing section which is configured to provide the determined refrigerant information to a control interface of the refrigeration unit.

6. The control device according to claim 4 or 5, further comprising:

a refrigerant selection signal acquisition section which is configured to acquire a signal indicating selection of a specific refrigerant from the control interface of the refrigeration unit; and
a warning information providing section which is configured to provide warning information to the control interface of the refrigeration unit when the signal indicating the selection of the specific refrigerant indicates selection of a refrigerant other than the refrigerant suitable for the refrigeration unit.

7. The control device according to claim 2, wherein the refrigeration unit is a refrigeration unit for transportation.

8. The control device according to claim 2,
wherein the expansion valve control section is configured to determine a current degree of superheat by subtracting the gas side saturation temperature of the refrigerant from the acquired outlet temperature, and control the expansion valve opening degree of the electronic expansion valve in the refrigeration unit so that the current degree of superheat is brought close to the predetermined degree of superheat.

9. The control device according to claim 2, wherein at least one of the refrigerants corresponding to the plurality of saturation temperature tables is a refrigerant having a temperature glide characteristic.

10. A refrigeration unit which is configured to operate in response to different refrigerants, comprising:

an electronic expansion valve which is capable of freely changing an expansion valve opening degree;
an evaporator which is configured to evaporate a refrigerant expanded by the electronic expansion valve;
a pressure sensor which is configured to detect a pressure of the refrigerant at an outlet of the evaporator;
a temperature sensor which is configured to detect a temperature of the refrigerant at the outlet of the evaporator; and
a control unit which is configured to control the expansion valve opening degree,
wherein the control unit is configured to control the expansion valve opening degree of the electronic expansion valve to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the pressure detected by the pressure sensor, and the temperature detected by the temperature sensor.

11. A method of controlling a refrigeration unit in response to different refrigerants, comprising steps of:

obtaining an outlet pressure of an evaporator from a pressure sensor which is configured to detect a pressure of a refrigerant at an outlet of the evaporator in the refrigeration unit;
obtaining an outlet temperature of the evaporator from a temperature sensor which is configured to detect a temperature of the refrigerant at the outlet of the evaporator; and
controlling an expansion valve opening degree of an electronic expansion valve in the refrigeration unit to obtain a predetermined degree of superheat, based on a gas side saturation temperature of the refrigerant corresponding to the acquired outlet pressure, and the acquired outlet temperature.

12. A program which is configured to cause a computer

of a refrigeration unit to execute the method according to claim 11.

FIG. 1

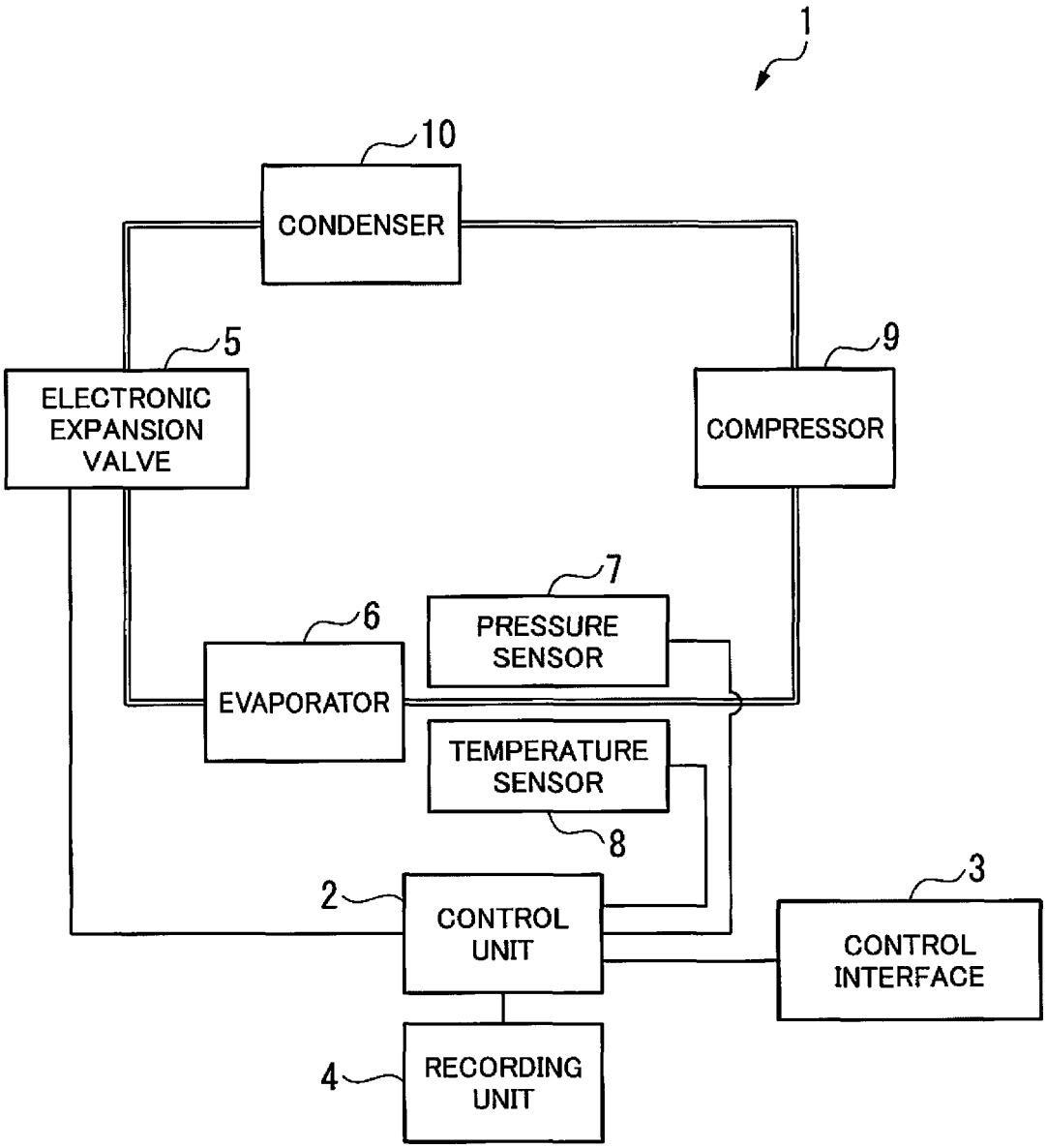

1
10
CONDENSER
5
ELECTRONIC EXPANSION VALVE
9
COMPRESSOR
7
PRESSURE SENSOR
6
EVAPORATOR
TEMPERATURE SENSOR
8
2
CONTROL UNIT
3
CONTROL INTERFACE
4
RECORDING UNIT

FIG. 2

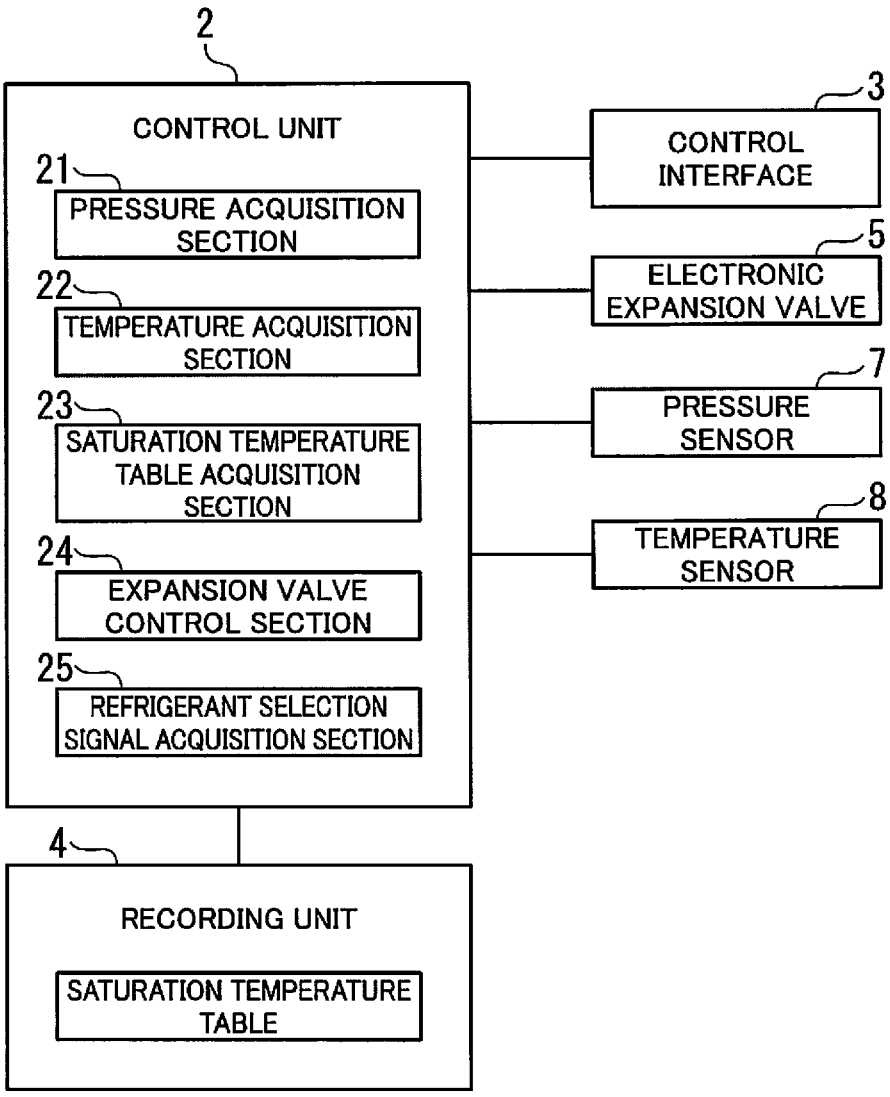

2
CONTROL UNIT
21
PRESSURE ACQUISITION SECTION
22
TEMPERATURE ACQUISITION SECTION
23
SATURATION TEMPERATURE TABLE ACQUISITION SECTION
24
EXPANSION VALVE CONTROL SECTION
25
REFRIGERANT SELECTION SIGNAL ACQUISITION SECTION
4
RECORDING UNIT
SATURATION TEMPERATURE TABLE
3
CONTROL INTERFACE
5
ELECTRONIC EXPANSION VALVE
7
PRESSURE SENSOR
8
TEMPERATURE SENSOR

FIG. 3

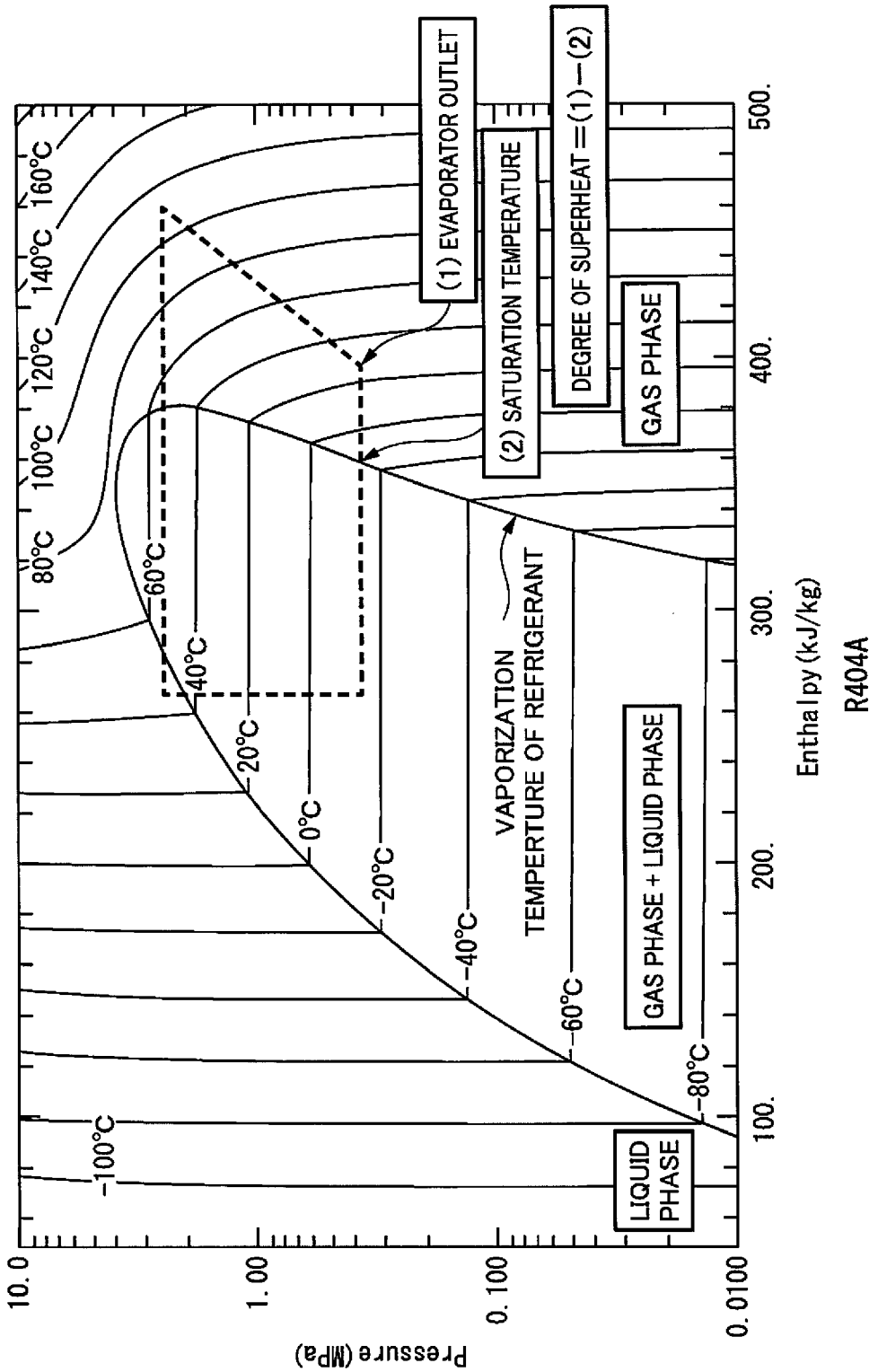

(1) EVAPORATOR OUTLET
(2) SATURATION TEMPERATURE
DEGREE OF SUPERHEAT=(1)−(2)
GAS PHASE
VAPORIZATION TEMPERTURE OF REFRIGERANT
GAS PHASE + LIQUID PHASE
LIQUID PHASE
160°C
140°C
120°C
100°C
80°C
60°C
40°C
20°C
0°C
−20°C
−40°C
−60°C
−80°C
−100°C
10.0
1.00
0.100
0.0100
Pressure (MPa)
100.
200.
300.
400.
500.
Enthalpy (kJ/kg)
R404A

FIG. 4

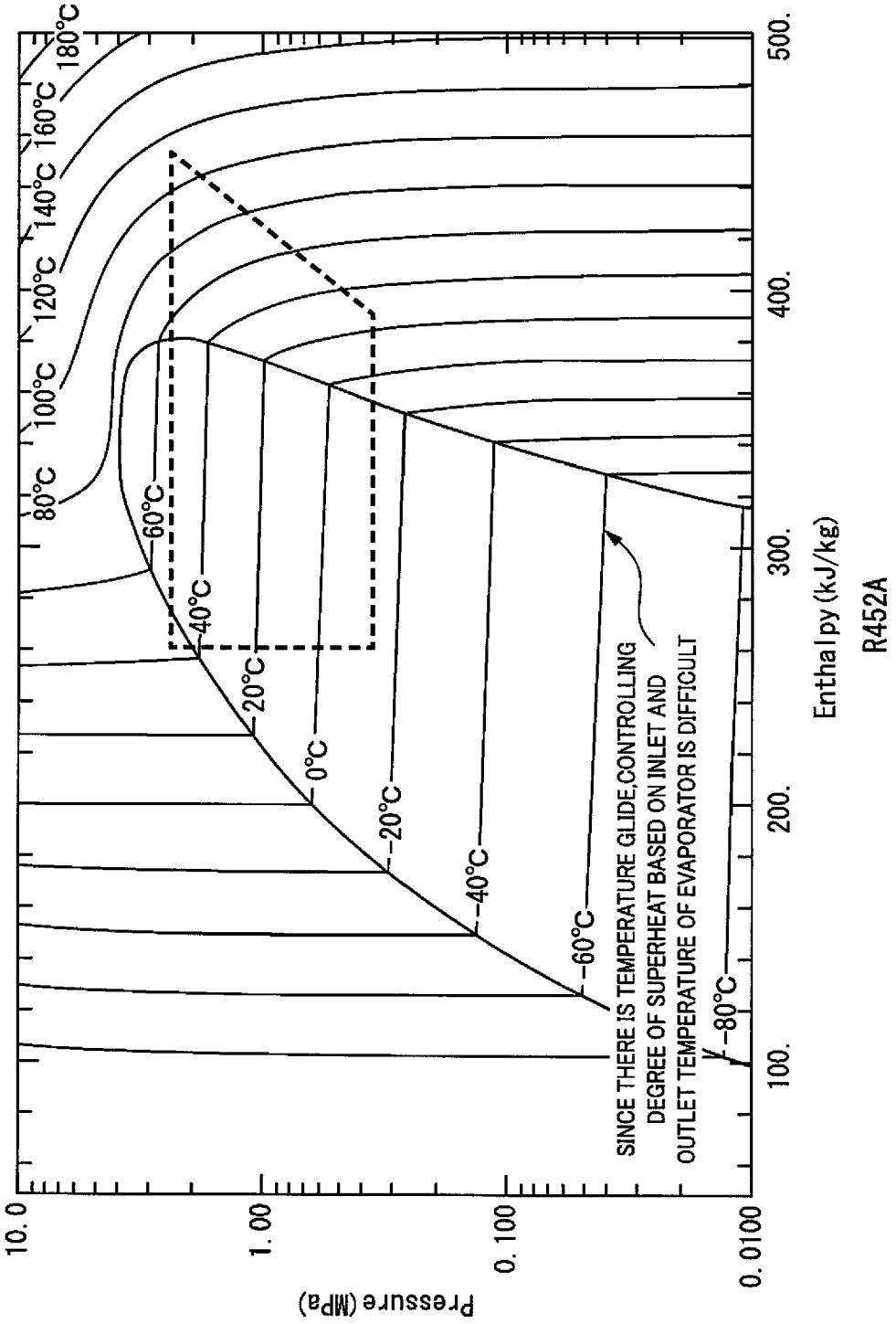

180°C
160°C
140°C
120°C
100°C
80°C
60°C
40°C
20°C
0°C
-20°C
-40°C
-60°C
-80°C
SINCE THERE IS TEMPERATURE GLIDE,CONTROLLING DEGREE OF SUPERHEAT BASED ON INLET AND OUTLET TEMPERATURE OF EVAPORATOR IS DIFFICULT
10.0
1.00
0.100
0.0100
Pressure (MPa)
100.
200.
300.
400.
500.
Enthalpy (kJ/kg)
R452A

FIG. 5

REFRIGERANT A

PRESSURE(MPa)	TEMPERATURE(°C)
P_1	T_{A1}
P_2	T_{A2}
P_3	T_{A3}
⋮	⋮

REFRIGERANT B

PRESSURE(MPa)	TEMPERATURE(°C)
P_1	T_{B1}
P_2	T_{B2}
P_3	T_{B3}
⋮	⋮

REFRIGERANT C

PRESSURE(MPa)	TEMPERATURE(°C)
P_1	T_{C1}
P_2	T_{C2}
P_3	T_{C3}
⋮	⋮

FIG. 6

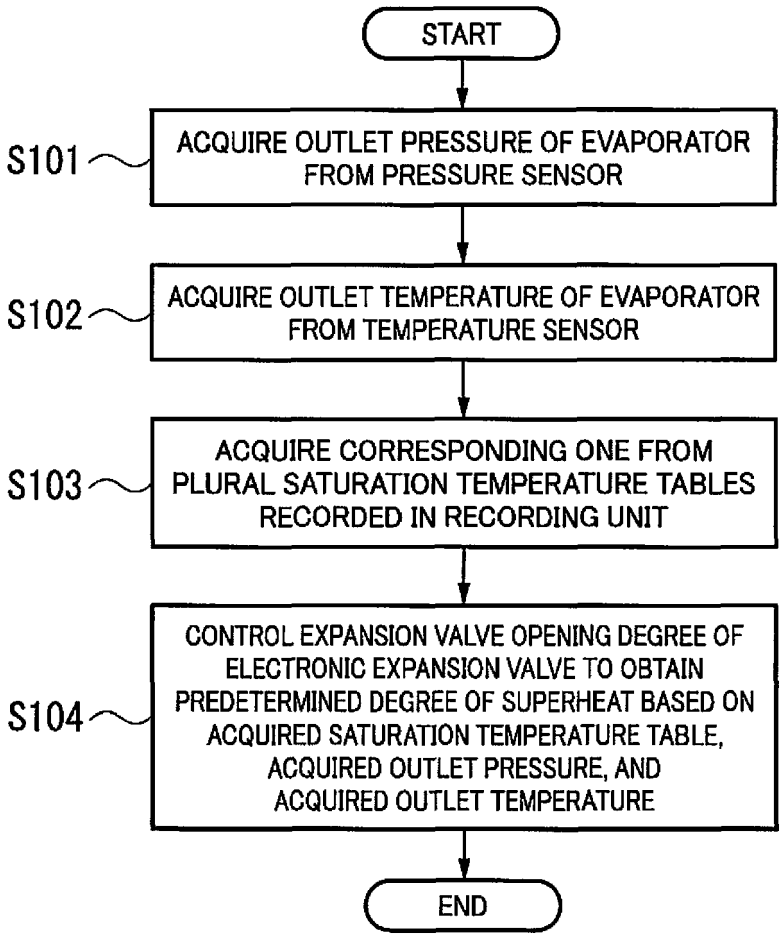

START
S101
ACQUIRE OUTLET PRESSURE OF EVAPORATOR FROM PRESSURE SENSOR
S102
ACQUIRE OUTLET TEMPERATURE OF EVAPORATOR FROM TEMPERATURE SENSOR
S103
ACQUIRE CORRESPONDING ONE FROM PLURAL SATURATION TEMPERATURE TABLES RECORDED IN RECORDING UNIT
S104
CONTROL EXPANSION VALVE OPENING DEGREE OF ELECTRONIC EXPANSION VALVE TO OBTAIN PREDETERMINED DEGREE OF SUPERHEAT BASED ON ACQUIRED SATURATION TEMPERATURE TABLE, ACQUIRED OUTLET PRESSURE, AND ACQUIRED OUTLET TEMPERATURE
END

FIG. 7

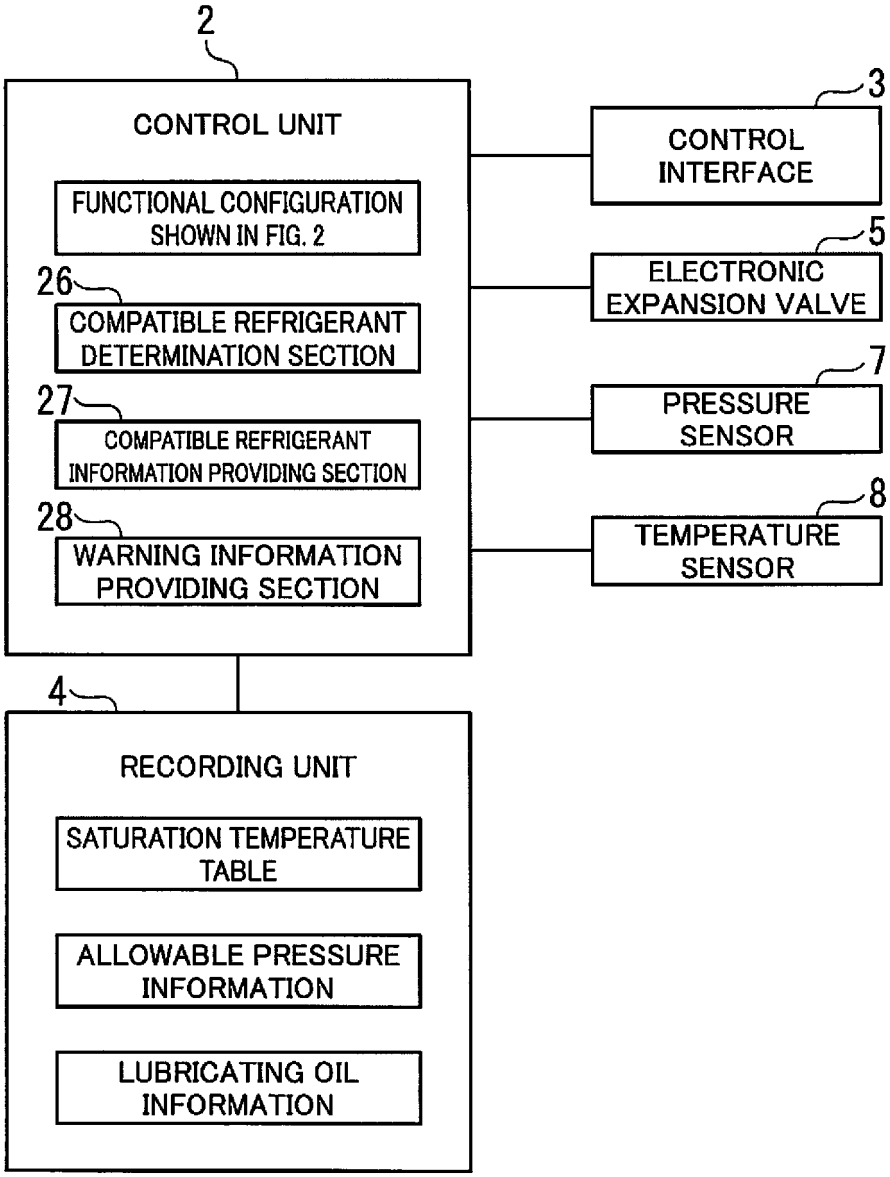
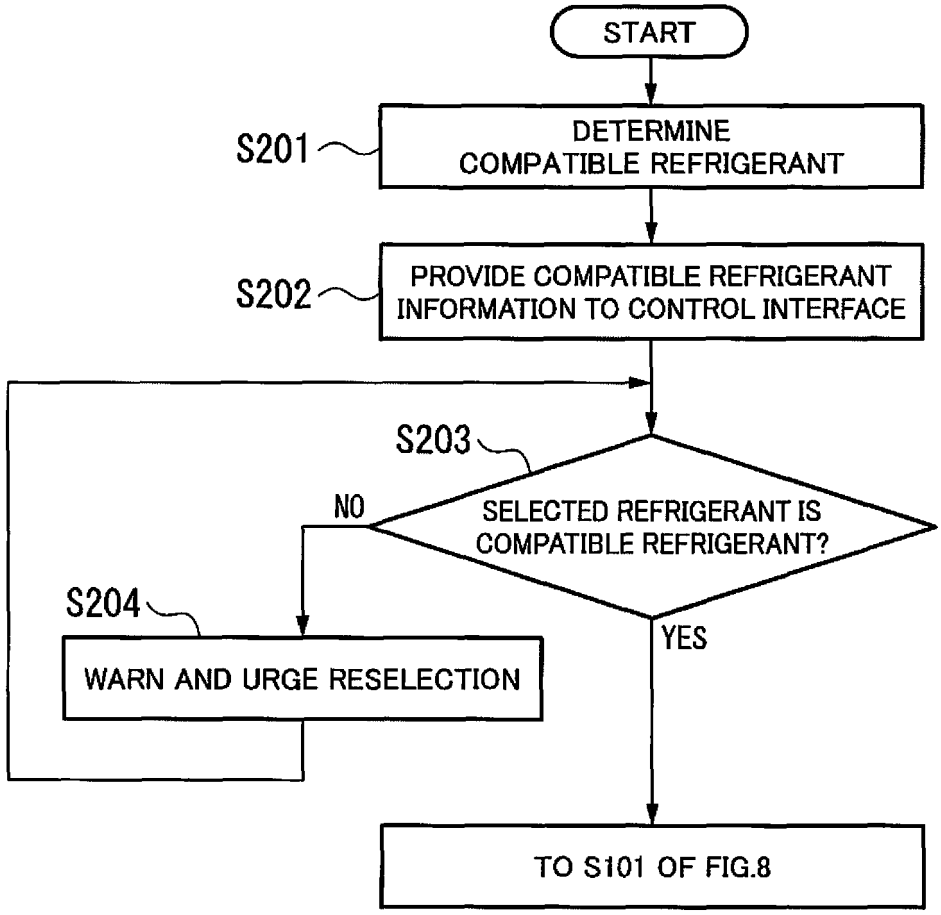

2
CONTROL UNIT
FUNCTIONAL CONFIGURATION SHOWN IN FIG. 2
26
COMPATIBLE REFRIGERANT DETERMINATION SECTION
27
COMPATIBLE REFRIGERANT INFORMATION PROVIDING SECTION
28
WARNING INFORMATION PROVIDING SECTION
3
CONTROL INTERFACE
5
ELECTRONIC EXPANSION VALVE
7
PRESSURE SENSOR
8
TEMPERATURE SENSOR
4
RECORDING UNIT
SATURATION TEMPERATURE TABLE
ALLOWABLE PRESSURE INFORMATION
LUBRICATING OIL INFORMATION

FIG. 8


START
S201
DETERMINE COMPATIBLE REFRIGERANT
S202
PROVIDE COMPATIBLE REFRIGERANT INFORMATION TO CONTROL INTERFACE
S203
SELECTED REFRIGERANT IS COMPATIBLE REFRIGERANT?
NO
YES
S204
WARN AND URGE RESELECTION
TO S101 OF FIG.8

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2017218055 A **[0002]**
- JP S61036671 B **[0004]**