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

(11) EP 4 488 597 A1

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

(43) Date of publication:
08.01.2025 Bulletin 2025/02

(21) Application number: **22929868.2**

(22) Date of filing: **04.03.2022**

(51) International Patent Classification (IPC):
F25B 1/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25B 1/00

(86) International application number:
PCT/JP2022/009494

(87) International publication number:
WO 2023/166724 (07.09.2023 Gazette 2023/36)

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

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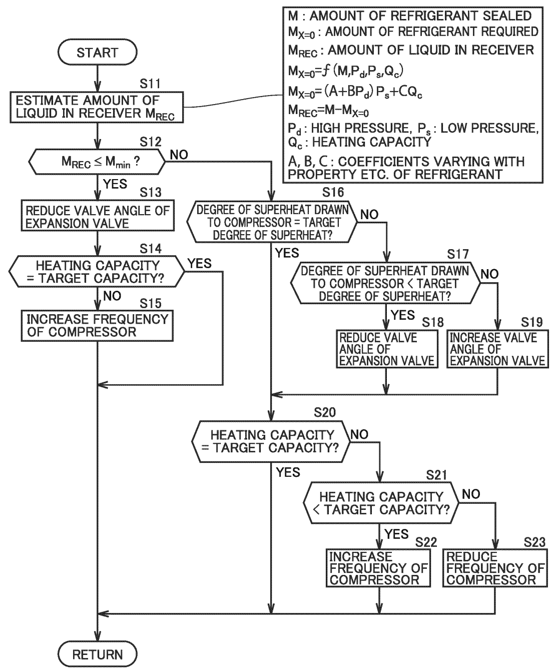
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus (100) comprises a refrigerant circuit (110) and a controller (10) configured to control the refrigerant circuit (110). The refrigerant circuit (110) comprises a compressor (1) configured to compress refrigerant, a condenser (3), a receiver (4) configured to reserve excess refrigerant, an expansion valve (5) configured to decompress refrigerant, and an evaporator (6). The refrigerant circuit (110) is configured such that refrigerant circulates through the compressor (1), the condenser (3), the receiver (4), the expansion valve (5), and the evaporator (6) in this order during the heating operation. The controller (10) controls the refrigerant circuit (110) to increase an amount of liquid in the receiver (4) (M_{REC}) by reducing the pressure of the evaporator (6) when the amount of liquid in the receiver (4) (M_{REC}) is below a predetermined defined value (M_{min}).

FIG.6



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] In recent years, using refrigerant having a small global warming potential (GWP) is desired. A GWP numerically represents, with reference to carbon dioxide, how much warming potential other greenhouse gases have. However, many refrigerants with small GWPs are combustible (e.g., propane etc.). In addition, for such combustible refrigerants, an upper limit for an amount of refrigerant to be sealed is determined according to standards such as the ISO (the International Organization for Standardization), the IEC (the International Electrotechnical Commission) and the like. Accordingly, there is a demand for a technology for a refrigeration cycle apparatus to implement a desired operation even with a limited amount of refrigerant.

[0003] An amount of refrigerant required to provide the refrigerant as a saturated liquid at an outlet of a condenser is defined as a required amount of refrigerant. The required amount of refrigerant varies depending on outside air temperature, water temperature and other similar environmental conditions or capacities (a heating capacity, a condensing capacity, etc.). For example, for higher outside air temperature, refrigerant attains higher temperature and hence higher pressure than for lower outside air temperature. As the refrigerant attains higher pressure, the refrigerant increases in density. Density is represented as mass per unit volume. A condenser has a fixed volume and so does an evaporator, and the refrigerant having a high density will have an increased mass occupying the volume. When the refrigerant has an increased mass, the amount of refrigerant required to provide the refrigerant as a saturated liquid at the outlet of the condenser would also increase.

[0004] In contrast, for lower outside air temperature, refrigerant has lower temperature and hence lower pressure than for higher outside air temperature. As the refrigerant has lower pressure, the refrigerant decreases in density. The refrigerant having a low density will have a decreased mass occupying the volume. As a result, the required amount of refrigerant decreases, and an amount of refrigerant sealed in the refrigeration cycle apparatus minus the required amount of refrigerant, that is, excess refrigerant, increases. The excess refrigerant is reserved in a refrigerant adjustment reservoir such as a receiver provided in the refrigeration cycle apparatus.

[0005] When the refrigeration cycle apparatus has refrigerant sealed in a small amount as defined for an upper limit for an amount of refrigerant to be sealed, it will provide a subcooling-short operation in an operation state requiring a large amount of refrigerant. Subcooling-short operation is to operate a refrigeration cycle apparatus while refrigerant before an expansion valve is insufficiently cooled and a degree of supercooling is not ensured. In the subcooling-short operation, the refrigerant is insufficiently condensed by the condenser and thus with gas mixed therein flows into the expansion valve, and this causes an abnormal noise in the expansion valve. Further, in the subcooling-short operation, it is difficult to estimate the refrigerant's state at the outlet of the condenser when the refrigerant is a single refrigerant or a pseudo-azeotropic refrigerant having no temperature gradient.

[0006] Japanese Patent Application Laying-Open No. 2004-053191 (PTL 1) discloses a refrigeration cycle apparatus configured to adjust excess refrigerant in a refrigerant adjustment reservoir.

CITATION LIST

PATENT LITERATURE

[0007] PTL 1: Japanese Patent Laying-Open No. 2004-053191

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0008] The refrigeration cycle apparatus of PTL 1 is an adjustment mechanism depending on outside air temperature. For this reason, the refrigeration cycle apparatus of PTL 1 may require a larger amount of refrigerant in a heating operation with high outside air temperature or the like than that with low outside air temperature, and may provide a subcooling-short operation when a small amount of refrigerant is sealed.

[0009] It is an object of the present disclosure to provide a refrigeration cycle apparatus that does not provide a subcooling-short operation even when a reduced amount of refrigerant is sealed.

SOLUTION TO PROBLEM

[0010] The presently disclosed refrigeration cycle apparatus comprises a refrigerant circuit and a controller configured to control the refrigerant circuit. The refrigerant circuit comprises a compressor configured to compress refrigerant, a condenser, a receiver configured to reserve excess refrigerant, an expansion valve configured to decompress the refrigerant, and an evaporator. The refrigerant circuit is configured such that during a heating operation the refrigerant circulates through the compressor, the condenser, the receiver, the expansion valve, and the evaporator in this order. The controller controls the refrigerant circuit to increase an amount of liquid in the receiver by reducing the pressure of the evaporator when the amount of liquid in the receiver is below a predetermined defined value.

ADVANTAGEOUS EFFECTS OF INVENTION

[0011] According to the present disclosure, when the amount of liquid in the receiver is below a predetermined defined value during the heating operation, the pressure of the evaporator is reduced to suppress elevation in pressure of the refrigerant in the evaporator. This can reduce a maximum value for an amount of refrigerant required. As a result, according to the present disclosure, even when a reduced amount of refrigerant is sealed, an amount of refrigerant required can also be reduced, and a subcooling-short operation can be avoided.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 is a diagram showing a circuit configuration of a refrigeration cycle apparatus according to a first embodiment.
Fig. 2 is a p-h diagram with isopycnic lines indicated together.
Fig. 3 is a graph representing a relationship between pressure and an amount of refrigerant required.
Fig. 4 is a graph representing a relationship between pressure and an amount of liquid in a receiver in a comparative example.
Fig. 5 is a graph representing a relationship between pressure and an amount of liquid in a receiver in the first embodiment.
Fig. 6 is a flowchart of control by a controller according to the first embodiment.
Fig. 7 is a flowchart of control by the controller according to a second embodiment.

DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. In the embodiments described below, when a number, an amount, or the like is referred to, the scope of the present disclosure is not necessarily limited to the number, the amount, or the like unless otherwise specified. Identical and equivalent components are identically denoted and may not be described redundantly. Using the configurations in the embodiments in combination, as appropriate, is originally planned.

First Embodiment

<Circuit configuration of refrigeration cycle apparatus 100>

[0014] Fig. 1 is a diagram showing a circuit configuration of a refrigeration cycle apparatus 100 according to a first embodiment. Refrigeration cycle apparatus 100 comprises a refrigerant circuit 110 and a load circuit 120. Refrigerant flowing through refrigerant circuit 110 and a heating medium flowing through load circuit 120 exchange heat via a condenser 3.

[0015] Refrigerant circuit 110 has a compressor 1, a four-way valve 2, condenser 3, a receiver 4, an expansion valve 5, and an evaporator 6 connected by a pipe. In refrigerant circuit 110, the refrigerant circulates through the pipe. The refrigerant is, for example, a combustible refrigerant such as propane. The refrigerant may be a different refrigerant with a low GWP.

[0016] Compressor 1 draws, compresses, and discharges the refrigerant. Four-way valve 2 switches a direction in which the refrigerant circulates. Condenser 3 allows the refrigerant to exchange heat with the heating medium, and functions as a load-side heat exchanger. Receiver 4 reserves a liquid refrigerant of an amount, which is obtained by subtracting from an amount of refrigerant sealed in refrigerant circuit 110 an amount of refrigerant required to provide the refrigerant as a saturated liquid at the outlet of condenser 3.

[0017] Expansion valve 5 expands and decompresses the refrigerant. Expansion valve 5 is, for example, a device capable of controlling the valve angle of an electronic expansion valve or the like, as desired. Evaporator 6 allows the refrigerant to exchange heat with air, and functions as a heat exchanger on the side of a heat source. A fan 7 configured to blow air is provided along with evaporator 6.

[0018] Load circuit 120 has pump 8, condenser 3, and a load device (not shown) connected by a pipe. Load circuit 120 has the heating medium circulating through the pipe. The heating medium is, for example, water. The heating medium may be other than water. The load device is, for example, a water heater. The load device may be a different device.

[0019] Refrigeration cycle apparatus 100 further comprises a controller 10 configured to collectively control compressor 1, four-way valve 2, expansion valve 5, fan 7, pump 8 and other components to be driven.

[0020] Controller 10 includes a CPU (a Central Processing Unit) 11, a memory 12 (a ROM (a Read Only Memory) and a RAM (a Random Access Memory)), an input/output device (not shown) configured to input/output a variety of signals, and the like. CPU 11 loads a program stored in the ROM into the RAM or the like and executes the program. The program stored in the ROM is a program describing a procedure of a process to be performed by controller 10. Controller 10 controls each device in accordance with these programs. This control is not limited to processing by software, and may be processed by dedicated hardware (or electronic circuitry).

[0021] Refrigeration cycle apparatus 100 comprises a plurality of sensors. Refrigeration cycle apparatus 100 comprises pressure sensors 21, 22 and 23 and a temperature sensor 24 in refrigerant circuit 110. Pressure sensor 21 senses pressure at the outlet of expansion valve 5. Pressure sensor 22 senses pressure on the drawing side of compressor 1 (or pressure on a low pressure side). Pressure sensor 23 senses pressure on the discharging side of compressor 1 (or pressure on a high pressure side). Temperature sensor 24 senses the refrigerant's temperature on the drawing side of compressor 1.

[0022] Refrigeration cycle apparatus 100 comprises in load circuit 120 a temperature sensor 31 configured to sense at the inlet of condenser 3 the temperature of the heating medium flowing through condenser 3, and a temperature sensor 32 configured to sense at the outlet of condenser 3 the temperature of the heating medium flowing through condenser 3. Controller 10 obtains a value sensed by each of the plurality of sensors. Controller 10 calculates a degree of superheat of the refrigerant drawn into compressor 1 (hereinafter also referred to as a "degree of drawn superheat"). A degree of drawn superheat is a degree of superheat of gaseous refrigerant represented by a difference in temperature between the temperature of the refrigerant drawn by compressor 1 (hereinafter also referred to as "drawn temperature") and a saturated gas temperature corresponding to the pressure of the refrigerant drawn by the compressor (hereinafter also referred to as "drawn pressure"). Controller 10 refers to a graph stored in memory 12 and indicating a relationship between the drawn pressure and the saturated gas temperature to calculate a saturated gas temperature. Controller 10 calculates a degree of superheat drawn to compressor 1 by subtracting the saturated gas temperature for the pressure drawn to compressor 1 from the temperature drawn to compressor 1.

[0023] Fig. 2 is a p-h diagram with isopycnic lines indicated together. The pressure of the refrigerant on the side of evaporator 6 (hereinafter also simply referred to as a low pressure side) is on a low pressure side of the graph. The pressure of the refrigerant on the side of condenser 3 (hereinafter also simply referred to as a high pressure side) is on a high pressure side of the graph. Fig. 2 illustrates how pressure on the low pressure side changes when the high pressure side has a heating capacity and a pressure Pd fixed. The heating capacity on the high pressure side is an ability to warm the heating medium, or water, by heat exchange with the refrigerant in condenser 3.

[0024] S1, S2 and S3 represents refrigeration cycles when the low pressure side has pressures Ps1, Ps2 and Ps3, respectively. The graph shows a plurality of obliquely inclined dashed lines, which indicate isopycnic lines of the refrigerant. As shown in Fig. 2, as the pressure on the low pressure side increases, the refrigerant's density in evaporator 6 increases accordingly. When the refrigerant's density increases, the amount of refrigerant required will increase.

[0025] That is, in Fig. 2, when the pressure on the low pressure side is increased from Ps1 to Ps3 and the state of the refrigerant is changed from refrigeration cycles S1 to S3, the refrigerant is required in a larger amount than when the pressure on the low pressure side is increased from Ps1 to Ps2 and the state of the refrigerant is changed from refrigeration cycles S1 to S2. In the first embodiment, an increase in pressure on the low pressure side is suppressed up to Ps2 to suppress an increase in density of the refrigerant. Thus, a difference between amounts of the refrigerant required when the refrigerant's state changes is reduced to avoid a subcooling-short operation even when the refrigerant is sealed in a reduced amount.

[0026] Fig. 3 is a graph representing a relationship between pressure and an amount of refrigerant required. The abscissa represents pressure on the low pressure side, and the ordinate represents the amount of refrigerant required. A solid line in the graph represents an amount of refrigerant required during a maximum capacity operation of compressor 1. A dot-dashed line in the graph represents an amount of refrigerant required during a minimum capacity operation of compressor 1. The maximum capacity operation is an operation state in which compressor 1 is maximized in frequency (or rotation speed) to allow the refrigerant to flow at a high flow rate (or circulate in a large amount). In contrast, the minimum capacity operation is an operation state in which compressor 1 is minimized in frequency (or rotation speed) to allow the refrigerant to flow at a low flow rate (or circulate in a small amount).

[0027] A line connecting points A, B, and C in the graph represents a state of a highest high pressure during the maximum capacity operation, and a line connecting points D, E, and F in the graph represents a state of a lowest high pressure during the maximum capacity operation. A line connecting points a and c in the graph represents a state of a highest high pressure during the minimum capacity operation, and a line connecting points d and f in the graph represents a state of a lowest high pressure during the minimum capacity operation. Highest high pressure is, for example, a pressure in a state in which water is circulated at a water temperature of 70°C, which is a highest warm water discharging temperature at condenser 3 on the high pressure side. Lowest high pressure is, for example, a pressure in a state in which water is circulated at a water temperature of 25°C, which is a lowest warm water discharging temperature at condenser 3 on the high pressure side.

[0028] As shown in Fig. 3, an amount of refrigerant required $M_{x=0}$ is larger in the maximum capacity operation than in the minimum capacity operation. The amount of refrigerant required $M_{x=0}$ during the maximum capacity operation will now be discussed. When the pressure on the low pressure side is Ps1, the amount of refrigerant required $M_{x=0}$ is higher at the highest high pressure at point A than at the lowest high pressure at point D. When the pressure on the low pressure side is Ps2, the amount of refrigerant required $M_{x=0}$ is higher at the highest high pressure at point B than at the lowest high pressure at point E. When the pressure on the low pressure side is Ps3, the amount of refrigerant required $M_{x=0}$ is higher at the highest high pressure at point C than at the lowest high pressure at point F.

[0029] Thus, the amount of refrigerant required $M_{x=0}$

increases as the pressure on the low pressure side increases, and the amount of refrigerant required $M_{x=0}$ increases more for the state of the highest high pressure than that of the lowest high pressure.

[0030] Fig. 4 is a graph representing a relationship between pressure and an amount of liquid in the receiver in a comparative example. The abscissa represents the pressure on the low pressure side, and the ordinate represents the amount of liquid in receiver 4. A solid line in the graph represents the maximum capacity operation of compressor 1. A dot-dashed line in the graph represents the minimum capacity operation of compressor 1.

[0031] A line connecting points A, B, and C in the graph represents a state of the highest high pressure during the maximum capacity operation, and a line connecting points D, E, and F in the graph represents a state of the lowest high pressure during the maximum capacity operation. A line connecting points a and c in the graph represents a state of the highest high pressure during the minimum capacity operation, and a line connecting points d and f in the graph represents a state of the lowest high pressure during the minimum capacity operation.

[0032] As shown in Fig. 4, an amount of liquid in the receiver M_{REC} is smaller during the maximum capacity operation than during the minimum capacity operation. The amount of liquid in the receiver M_{REC} during maximum capacity operation will now be discussed. When the pressure on the low pressure side is Ps1, the amount of liquid in the receiver M_{REC} is smaller at the highest high pressure at point A than at the lowest high pressure at point D. When the pressure on the low pressure side is Ps2, the amount of liquid in the receiver M_{REC} is smaller at the highest high pressure at point B than at the lowest high pressure at point E. When the pressure on the low pressure side is Ps3, the amount of liquid in the receiver M_{REC} is smaller at the maximum high pressure at point C than at the minimum high pressure at point F.

[0033] Thus, the amount of liquid in the receiver M_{REC} decreases as the pressure on the low pressure side increases, and the amount of liquid in the receiver M_{REC} decreases more for the state of the highest high pressure than for that of the lowest high pressure. The amount of liquid in the receiver M_{REC} is a value obtained by subtracting the amount of refrigerant required $M_{x=0}$ from an amount of refrigerant sealed M, and accordingly, the graph of Fig. 4 shows a gradient opposite to that in the graph of Fig. 3.

[0034] The comparative example performs an operation with the refrigerant's pressure on the low pressure side between Ps1 and Ps3. Therefore, when a minimum value for the amount of liquid in the receiver M_{REC} required for the operation is represented as M_{min}, M_{min} is exceeded in all of the states. However, in such a case, the amount of refrigerant required $M_{x=0}$ for Ps3 increases, and accordingly, the amount of refrigerant sealed M would increase. Thus, it is difficult to reduce the amount of refrigerant sealed M.

[0035] Fig. 5 is a graph representing a relationship between pressure and an amount of liquid in the receiver in the first embodiment. The abscissa represents the pressure on the low pressure side, and the ordinate represents the amount of liquid in receiver 4. A solid line in the graph represents the maximum capacity operation of compressor 1. A dot-dashed line in the graph represents the minimum capacity operation of compressor 1.

[0036] In Fig. 5, the minimum value M_{min} for the amount of liquid in the receiver M_{REC} is set at a position overlapping point B of Ps2. In the first embodiment, operation is controlled so that the amount of liquid in the receiver M_{REC} is not smaller than the minimum value M_{min} that is a defined value. Herein, the defined value is a minimum value for the amount of liquid in the receiver M_{REC} that allows the maximum capacity operation in the state of the highest high pressure during the heating operation to be performed. The first embodiment provides an operation performed with the refrigerant's pressure on the low pressure side between Ps1 and Ps2.

[0037] The first embodiment provides the operation within a range in which the pressure on the low pressure side is not improved as compared with the comparative example. That is, the first embodiment provides the operation in a range in which the amount of liquid in the receiver M_{REC} has a maximum value and a minimum value with a difference smaller than the comparative example does. Thus, the first embodiment allows the operation to be performed in a range requiring a smaller amount of refrigerant than the comparative example does, and can avoid the subcooling-short operation even when the refrigerant is sealed in a reduced amount.

[0038] Controller 10 performs a process, as will be described below. Fig. 6 is a flowchart of control by controller 10 according to the first embodiment. The process of the flowchart of Fig. 6 is repeatedly invoked and executed as a subroutine from a main routine in controlling refrigeration cycle apparatus 100. Controller 10 initially estimates an amount of liquid in the receiver M_{REC} in step (hereinafter simply referred to as "S") 11.

[0039] M represents an amount of refrigerant sealed, $M_{x=0}$ represents an amount of refrigerant required, M_{REC} represents an amount of liquid in the receiver, Pd represents the refrigerant's pressure on the high pressure side (or on the side of the condenser), Ps represents the refrigerant's pressure on the low pressure side (or on the side of the evaporator), Qc represents a heating capacity, and A, B and C represent coefficients varying with a property or the like of the refrigerant. In this case, $M_{x=0}$ can be expressed as a function of ?(M, Pd, Ps, Qc). When this is expressed using the coefficients A, B, and C, it will be $M_{x=0} = (A + BPd)Ps + CQc$. Since $M_{REC} = M - M_{x=0}$, it can be expressed as $M_{REC} = M - (A + BPd)Ps + CQc$. Thus, the amount of liquid in the receiver M_{REC} can be estimated from a function indicating the pressure of the refrigerant in evaporator 6, the pressure of the refrigerant in condenser 3, and the heating capacity of refrigeration cycle apparatus 100.

[0040] Subsequently, controller 10 determines whether the M_{REC} estimated in S12 is equal to or smaller than the minimum value M_{min} for the amount of liquid in the receiver as a predetermined defined value. When controller 10 determines that the M_{REC} is equal to or smaller than the M_{min} (YES in S12), controller 10 controls expansion valve 5 to reduce the valve angle (S13). Reducing the valve angle of expansion valve 5 results in the refrigerant flowing to evaporator 6 at a reduced flow rate. This reduces the evaporation capacity of evaporator 6 and reduces the pressure of the refrigerant in evaporator 6. As the side of evaporator 6 (or the low pressure side) is reduced in pressure, evaporator 6 has refrigerant therein with a reduced density, which can reduce the amount of refrigerant required.

[0041] Subsequently, controller 10 determines whether the heating capacity of refrigeration cycle apparatus 100 attains a target capacity (S14). The heating capacity attaining the target capacity means, for example, that the water temperature attains a target water temperature of 45°C. When the heating capacity attains the target capacity (YES in S14), controller 10 fixes compressor 1 in frequency to circulate the refrigerant in a fixed amount, and returns the process from the subroutine to the main routine. When the heating capacity is not the target capacity (NO in S14), controller 10 increases the frequency of compressor 1 (S15), and returns the process from the subroutine to the main routine. Increasing the frequency of compressor 1 can increase the flow rate of the refrigerant to improve the heating capacity at condenser 3.

[0042] When controller 10 determines in S12 that the M_{REC} is larger than the M_{min} (NO in S12), controller 10 determines whether the refrigerant drawn to compressor 1 has a target degree of superheat (S16). When the drawn refrigerant has the target degree of superheat, this ensures a degree of superheat of the refrigerant on the drawing side of compressor 1 and can prevent liquid compression in compressor 1. When controller 10 determines in S16 that compressor 1 draws the target degree of superheat (YES in S16), controller 10 determines whether the heating capacity of refrigeration cycle apparatus 100 attains the target capacity (S20). When controller 10 determines that the heating capacity attains the target capacity (YES in S20), controller 10 fixes compressor 1 in frequency to circulate the refrigerant in a fixed amount, and returns the process from the subroutine to the main routine.

[0043] When controller 10 determines in S16 that the refrigerant drawn to compressor 1 does not have the target degree of superheat (NO in S16), controller 10 determines whether the refrigerant drawn to compressor 1 has a degree of superheat lower than the target degree of superheat (S17). When controller 10 determines that the refrigerant drawn to compressor 1 has a degree of superheat lower than the target degree of superheat (YES in S17), controller 10 reduces the valve angle of expansion valve 5 (S18) and proceeds to the step of S20. In S18, the valve angle of expansion valve 5 is reduced to reduce the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100. This can increase the degree of superheat of the refrigerant drawn to compressor 1.

[0044] When controller 10 determines that the refrigerant drawn to compressor 1 has a degree of superheat higher than the target degree of superheat (NO in S17), controller 10 increases the valve angle of expansion valve 5 (S19) and proceeds to the step of S20. In S19, the valve angle of expansion valve 5 is increased to increase the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100. This can reduce the degree of superheat of the refrigerant drawn to compressor 1. Controller 10 increases/decreases the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100 to adjust the degree of superheat that is drawn to compressor 1 to be the target degree of superheat.

[0045] When controller 10 determines in S20 that the heating capacity is not the target capacity (NO in S20), controller 10 determines whether the heating capacity is smaller than the target capacity (S21). When controller 10 determines that the heating capacity is smaller than the target capacity (YES in S21), controller 10 increases the frequency of compressor 1 (S22) to increase the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100 to improve the heating capacity, and returns the process from the subroutine to the main routine. When controller 10 determines that the heating capacity is larger than the target capacity (NO in S21), controller 10 reduces the frequency of compressor 1 (S23) to reduce the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100 to reduce the heating capacity, and returns the process from the subroutine to the main routine.

[0046] As shown in Fig. 6, controller 10 reduces the valve angle of expansion valve 5 in S 13 to reduce the pressure of the refrigerant in evaporator 6 and thus suppress an increase in pressure of the refrigerant in evaporator 6. This can reduce the maximum value for the amount of refrigerant required $M_{x=0}$. As a result, even if the amount of refrigerant sealed M is reduced, the amount of refrigerant required $M_{x=0}$ can also be reduced, and the subcooling-short operation can be avoided.

Second Embodiment

[0047] In the second embodiment will be described a case in which, rather than controlling the valve angle of expansion valve 5, as described in the first embodiment, fan 7 blows air in a controlled volume. Fig. 7 is a flowchart of control by controller 10 according to the second embodiment. Controller 10 initially estimates an amount of liquid in the receiver M_{REC} in step S51. How the amount of liquid in the receiver M_{REC} is estimated is the same as in the first embodiment.

[0048] Subsequently, controller 10 determines whether the M_{REC} estimated in S12 is equal to or smaller than the minimum value M_{min} for the amount of liquid in the receiver as a predetermined defined value. When controller 10 determines that the M_{REC} is equal to or smaller than the M_{min} (YES in S52), controller 10 controls fan 7 to blow air in a reduced volume (S53). The air volume of fan 7 is reduced by reducing the rotational speed of a motor (not shown). Reducing the air volume of fan 7 reduces a heat transfer coefficient between air and the refrigerant, and hence the heat exchange capacity of evaporator 6. This brings the refrigerant to a state in which the refrigerant exchanges heat with outside air while the refrigerant's evaporation temperature is lowered, and thus reduces the pressure of the refrigerant in evaporator 6. As the side of evaporator 6 (or the low pressure side) is reduced in pressure, evaporator 6 has refrigerant therein with a reduced density, which can reduce the amount of refrigerant required.

[0049] Subsequently, controller 10 determines whether the heating capacity of refrigeration cycle apparatus 100 attains the target capacity (S54). The heating capacity attaining the target capacity means, for example, that the heating capacity attains a target water temperature of 45°C. When controller 10 determines that the heating capacity attains the target capacity (YES in S54), controller 10 fixes compressor 1 in frequency to circulate the refrigerant in a fixed amount, and returns the process from the subroutine to the main routine. When the heating capacity is not the target capacity (NO in S54), controller 10 increases the frequency of compressor 1 (S55), and returns the process from the subroutine to the main routine. Increasing the frequency of compressor 1 can increase the flow rate of the refrigerant to improve the heating capacity at condenser 3.

[0050] When controller 10 determines in S52 that the M_{REC} is larger than the M_{min} (NO in S52), controller 10 determines whether the refrigerant drawn to compressor 1 has a target pressure (S56). When the drawn refrigerant has the target pressure, this ensures a pressure of the refrigerant on the drawing side of compressor 1 and can prevent liquid compression in compressor 1. When controller 10 determines in S56 that the refrigerant drawn to compressor 1 has the target pressure (YES in S56), controller 10 determines whether the heating capacity of refrigeration cycle apparatus 100 attains the target capacity (S60). When controller 10 determines that the heating capacity attains the target capacity (YES in S60), controller 10 fixes compressor 1 in frequency to circulate the refrigerant in a fixed amount, and returns the process from the subroutine to the main routine.

[0051] When controller 10 determines in S56 that the refrigerant drawn to compressor 1 does not have the target pressure (NO in S56), controller 10 determines whether the refrigerant drawn to compressor 1 has a pressure lower than the target pressure (S57). When controller 10 determines that the refrigerant drawn to compressor 1 has a pressure lower than the target pressure (YES in S57), controller 10 increases the air volume of fan 7 (S58), and proceeds to the step of S60. In S58, the air volume of fan 7 is increased to improve the heat exchange capacity of evaporator 6. This increases the pressure of the refrigerant in evaporator 6, and can thus increase the pressure drawn to compressor 1.

[0052] When controller 10 determines that the refrigerant drawn to compressor 1 has a pressure higher than the target pressure (NO in S57), controller 10 reduces the air volume of fan 7 (S59) and proceeds to the step of S60. In S59, the air volume of fan 7 is reduced to reduce the heat exchange capacity of evaporator 6. This reduces the pressure of the refrigerant in evaporator 6, and can thus reduce the pressure drawn to compressor 1. Controller 10 increases/decreases the air volume of fan 7 to adjust the pressure that is drawn to compressor 1 to be the target pressure.

[0053] When controller 10 determines in S60 that the heating capacity is not the target capacity (NO in S60), controller 10 determines whether the heating capacity is smaller than the target capacity (S61). When controller 10 determines that the heating capacity is smaller than the target capacity (YES in S61), controller 10 increases the frequency of compressor 1 (S62) to increase the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100 to improve the heating capacity, and returns the process from the subroutine to the main routine. When controller 10 determines that the heating capacity is larger than the target capacity (NO in S61), controller 10 reduces the frequency of compressor 1 (S63) to reduce the amount of the refrigerant flowing and thus circulating through refrigeration cycle apparatus 100 to reduce the heating capacity, and returns the process from the subroutine to the main routine.

[0054] As shown in Fig. 7, controller 10 reduces the air volume of fan 7 in S53 to reduce the pressure of the refrigerant in evaporator 6 to suppress an increase in pressure of the refrigerant in evaporator 6. This can reduce the maximum value for the amount of refrigerant required $M_{x=0}$. As a result, even if the amount of refrigerant sealed M is reduced, the amount of refrigerant required $M_{x=0}$ can also be reduced, and the subcooling-short operation can be avoided.

<Summary>

[0055] Refrigeration cycle apparatus 100 of the present disclosure comprises refrigerant circuit 110 and controller 10 configured to control refrigerant circuit 110. Refrigerant circuit 110 comprises compressor 1 configured to compress refrigerant, condenser 3, receiver 4 configured to reserve excess refrigerant, expansion valve 5 configured to decompress refrigerant, and evaporator 6. Refrigerant circuit 110 is configured such that refrigerant circulates through compressor 1, condenser 3, receiver 4, expansion valve 5, and evaporator 6 in this order during a heating operation. Controller 10 controls refrigerant circuit 110 to increase an amount of liquid in receiver 4 M_{REC} by reducing the pressure of evaporator 6 when the amount of liquid in receiver 4 M_{REC} is below a predetermined defined value M_{min}.

[0056] Preferably, controller 10 estimates the amount of liquid in receiver 4 from a formula of a function indicating a relationship between the pressure of evaporator 6, the pressure of condenser 3, and the heating capacity of refrigeration cycle apparatus 100 during the heating operation.

[0057] Preferably, the amount of liquid in receiver 4 M_{REC} is a value obtained by subtracting from an amount of refrigerant sealed M in refrigerant circuit 110 an amount of refrigerant required $M_{x = 0}$ to provide the refrigerant as a saturated liquid at the outlet of condenser 3 during the heating operation.

[0058] Preferably, controller 10 reduces the valve angle of expansion valve 5 during the heating operation to reduce the pressure of evaporator 6.

[0059] Preferably, refrigerant circuit 110 further comprises fan 7 configured to blow air to evaporator 6. Controller 10 reduces the air volume of fan 7 during the heating operation to reduce the pressure of evaporator 6.

[0060] Preferably, controller 10 increases the frequency of compressor 1 when during the heating operation the pressure of evaporator 6 decreases and accordingly the refrigerant circulates in a reduced amount and refrigeration cycle apparatus 100 thus has a heating capacity below a target capacity.

[0061] Preferably, refrigeration cycle apparatus 100 further comprises load circuit 120 connected to condenser 3 and circulating a heating medium.

[0062] Preferably, the heating medium is water. Refrigeration cycle apparatus 100 of the present embodiment that has the above-described configuration suppresses an increase in pressure of the refrigerant in evaporator 6 by reducing the pressure of evaporator 6 when the amount of liquid in receiver 4 M_{REC} is below the predetermined defined value M_{min} during the heating operation. This can reduce the maximum value for the amount of refrigerant required $M_{x = 0}$. As a result, even if the amount of refrigerant sealed M is reduced, the amount of refrigerant required $M_{x = 0}$ can also be reduced, and the subcooling-short operation can be avoided.

<Modification>

[0063] Controlling expansion valve 5 according to the first embodiment and controlling fan 7 according to the second embodiment may be done in the same flow. In such a case, the control that is less likely to reduce the heating capacity may be given priority. This can suppress a control load increasing the frequency of compressor 1.

[0064] When the load device connected to load circuit 120 is other than a water heater, the heating medium may be other than water. In such a case, the heating medium may be brine.

[0065] It should be understood that the embodiments disclosed herein have been described for the purpose of illustration only and in a non-restrictive manner in any respect. The scope of the present disclosure is defined by the terms of the claims, rather than the embodiments description above, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0066] 1 compressor, 2 four-way valve, 3 condenser, 4 receiver, 5 expansion valve, 6 evaporator, 7 fan, 8 pump, 10 controller, 11 CPU, 12 memory, 21, 22, 23 pressure sensor, 24, 31, 32 temperature sensor, 100 refrigeration cycle apparatus, 110 refrigerant circuit, 120 load circuit.

Claims

1. A refrigeration cycle apparatus comprising a refrigerant circuit and a controller configured to control the refrigerant circuit,

   the refrigerant circuit comprising
   a compressor configured to compress refrigerant,
   a condenser,
   a receiver configured to reserve excess refrigerant,
   an expansion valve configured to decompress refrigerant, and
   an evaporator,
   the refrigerant circuit being configured such that refrigerant circulates through the compressor, the condenser, the receiver, the expansion valve, and the evaporator in this order during a heating operation,
   the controller being configured to control the refrigerant circuit to increase an amount of liquid in the receiver by reducing a pressure of the evaporator when the amount of liquid in the receiver is below a predetermined defined value.

2. The refrigeration cycle apparatus according to claim 1, wherein the controller estimates the amount of liquid in the receiver from a formula of a function indicating a relationship between the pressure of the evaporator, a pressure of the condenser, and a heating capacity of the refrigeration cycle apparatus during the heating operation.

3. The refrigeration cycle apparatus according to claim 2, wherein the amount of liquid in the receiver is a value obtained by subtracting from an amount of refrigerant sealed in the refrigerant circuit an amount of refrigerant required to provide the refrigerant as a

saturated liquid at an outlet of the condenser during the heating operation.

4. The refrigeration cycle apparatus according to any one of claims 1 to 3, wherein the controller reduces a valve angle of the expansion valve during the heating operation to reduce the pressure of the evaporator.

5. The refrigeration cycle apparatus according to any one of claims 1 to 4, wherein

   the refrigerant circuit further comprises a fan configured to blow air to the evaporator, and
   the controller reduces an air volume of the fan during the heating operation to reduce the pressure of the evaporator.

6. The refrigeration cycle apparatus according to any one of claims 1 to 5, wherein the controller increases a frequency of the compressor when during the heating operation the pressure of the evaporator decreases and accordingly the refrigerant circulates in a reduced amount and the refrigeration cycle apparatus thus has a heating capacity below a target capacity.

7. The refrigeration cycle apparatus according to any one of claims 1 to 6, further comprising a load circuit connected to the condenser and circulating a heating medium.

8. The refrigeration cycle apparatus according to claim 7, wherein the heating medium is water.

FIG.1

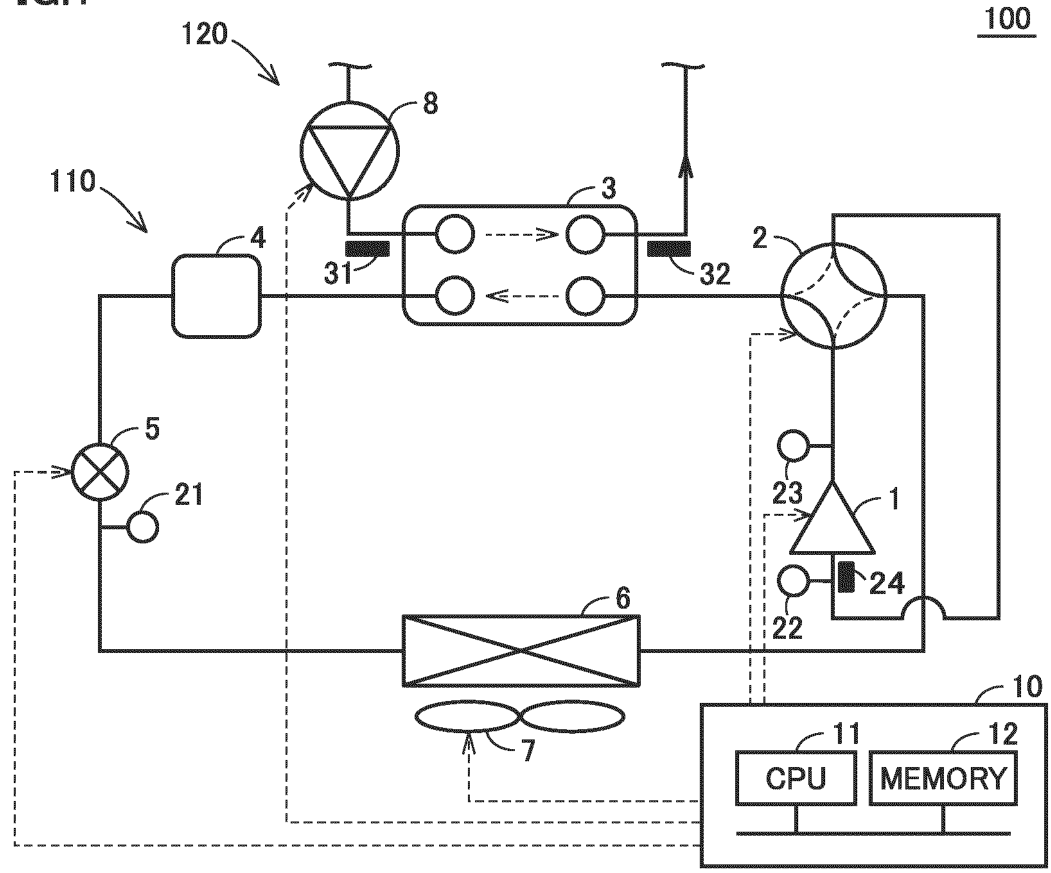

100
120
110
8
3
4
2
31
32
5
21
23
1
24
22
6
7
10
11
12
CPU
MEMORY

FIG.2

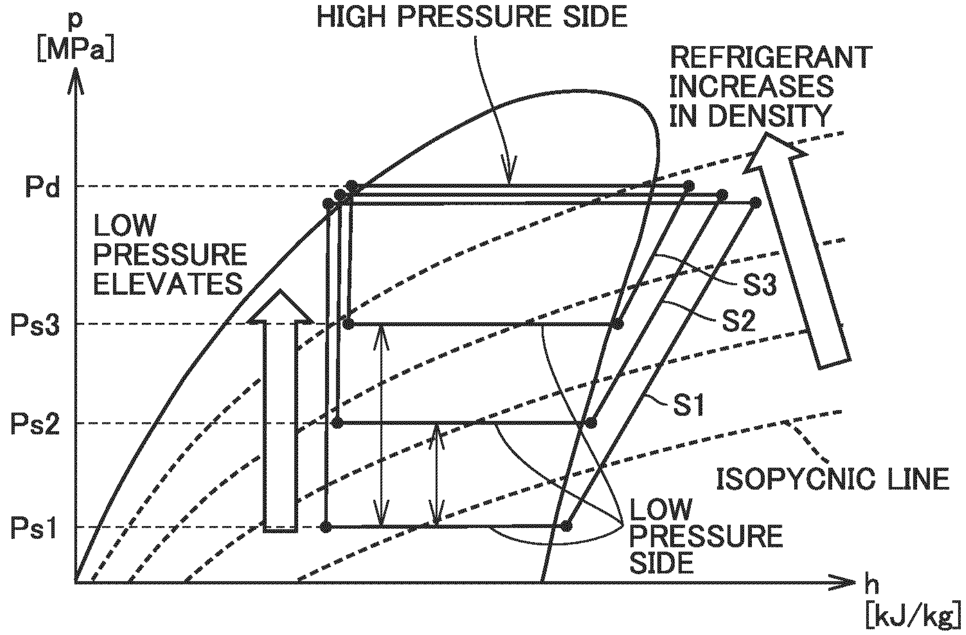

p
[MPa]
HIGH PRESSURE SIDE
REFRIGERANT
INCREASES
IN DENSITY
Pd
LOW
PRESSURE
ELEVATES
S3
S2
Ps3
Ps2
S1
ISOPYCNIC LINE
Ps1
LOW
PRESSURE
SIDE
h
[kJ/kg]

FIG.3

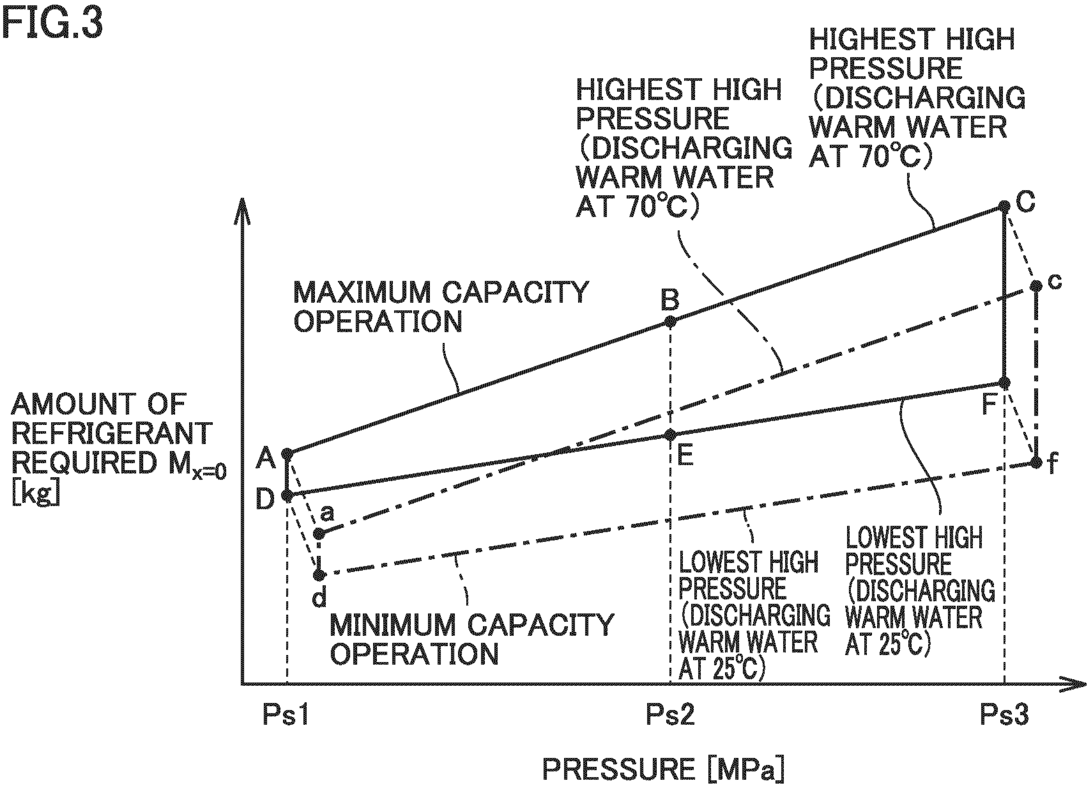

HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)
HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)
MAXIMUM CAPACITY OPERATION
AMOUNT OF REFRIGERANT REQUIRED $M_{x=0}$ [kg]
A
B
C
c
D
E
F
f
a
d
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
MINIMUM CAPACITY OPERATION
Ps1
Ps2
Ps3
PRESSURE [MPa]

FIG.4

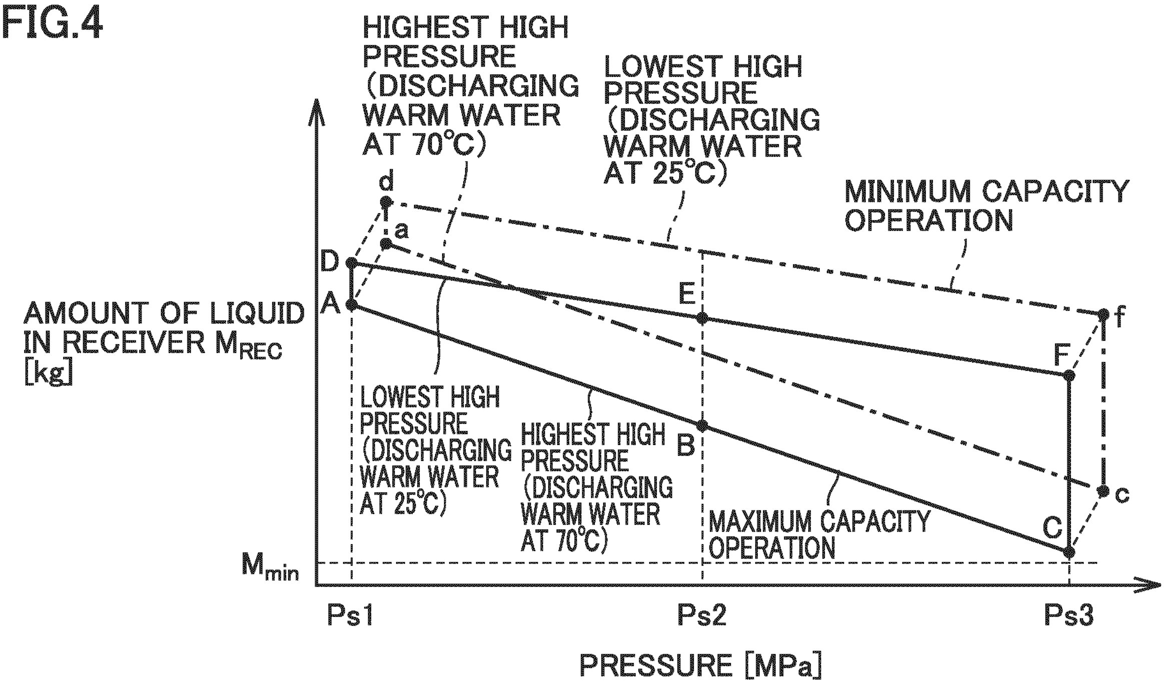

HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
MINIMUM CAPACITY OPERATION
d
a
D
A
E
f
F
AMOUNT OF LIQUID IN RECEIVER M_{REC} [kg]
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)
B
c
C
MAXIMUM CAPACITY OPERATION
M_{min}
Ps1
Ps2
Ps3
PRESSURE [MPa]

FIG.5

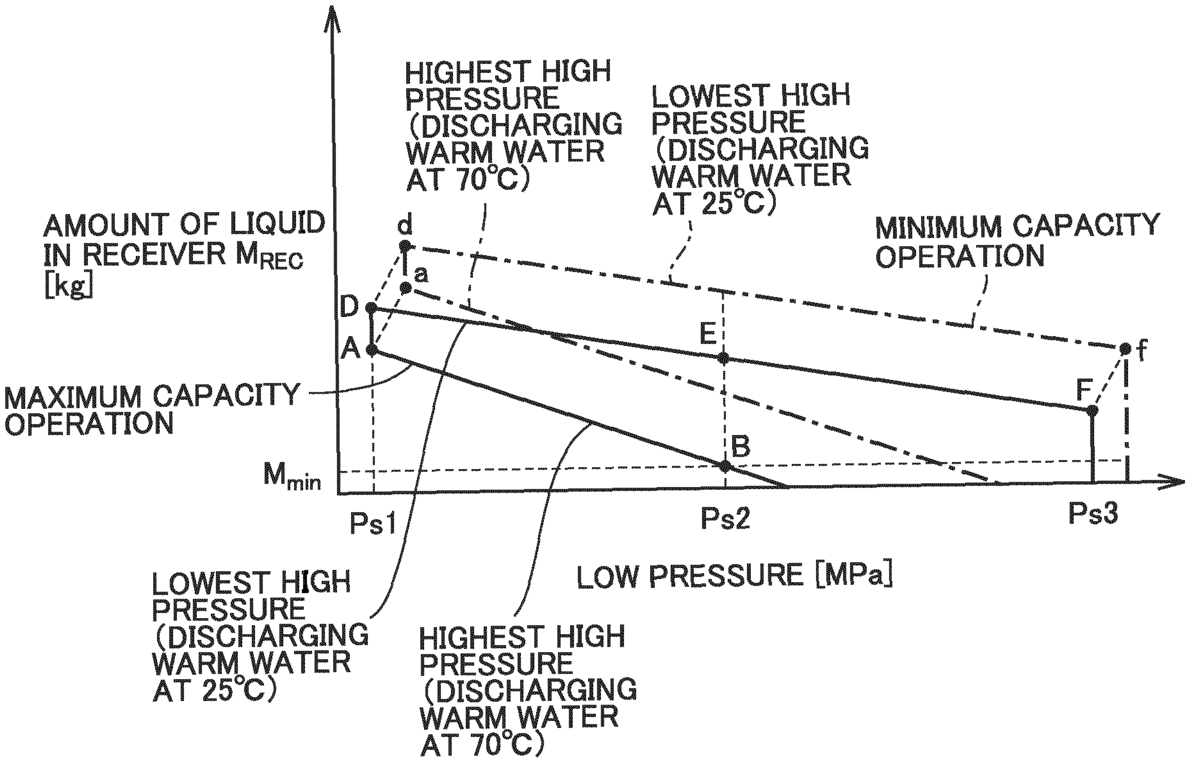

HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
AMOUNT OF LIQUID IN RECEIVER MREC [kg]
MINIMUM CAPACITY OPERATION
d
a
D
A
E
f
F
B
MAXIMUM CAPACITY OPERATION
Mmin
Ps1
Ps2
Ps3
LOW PRESSURE [MPa]
LOWEST HIGH PRESSURE (DISCHARGING WARM WATER AT 25°C)
HIGHEST HIGH PRESSURE (DISCHARGING WARM WATER AT 70°C)

FIG.6

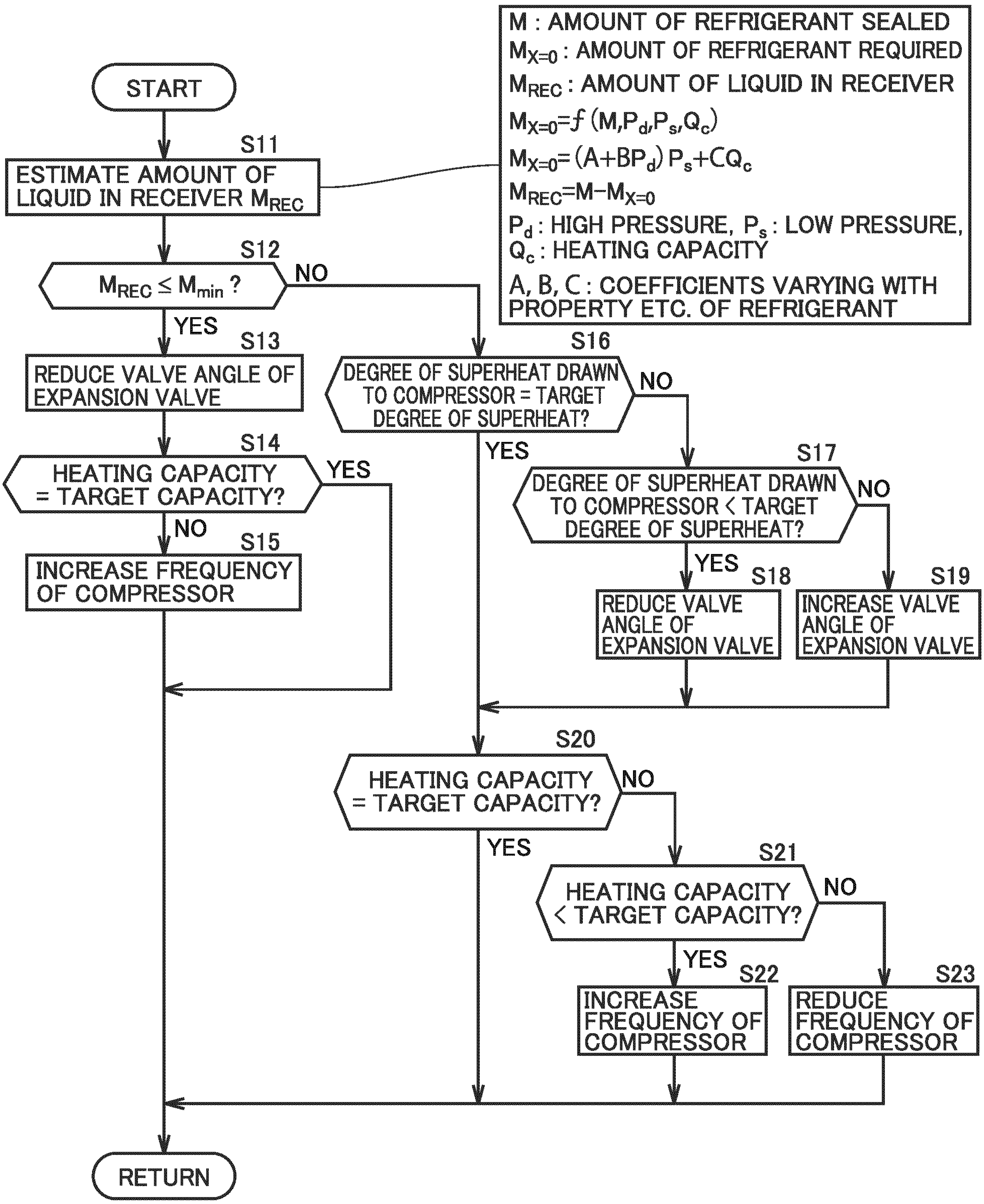
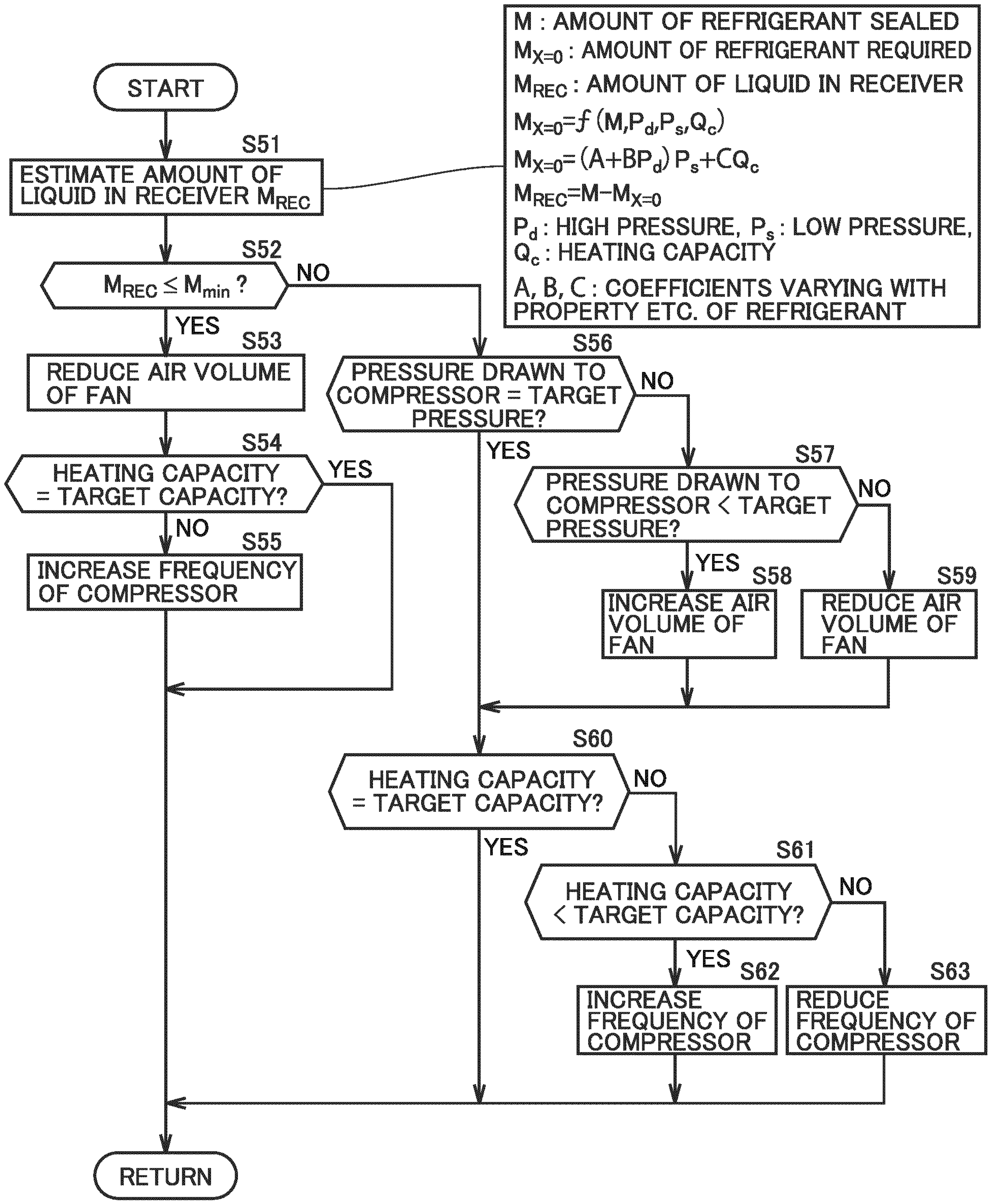

START
S11
ESTIMATE AMOUNT OF LIQUID IN RECEIVER M_{REC}
M : AMOUNT OF REFRIGERANT SEALED
$M_{X=0}$: AMOUNT OF REFRIGERANT REQUIRED
M_{REC} : AMOUNT OF LIQUID IN RECEIVER
$M_{X=0}=f(M,P_d,P_s,Q_c)$
$M_{X=0}=(A+BP_d)P_s+CQ_c$
$M_{REC}=M-M_{X=0}$
P_d : HIGH PRESSURE, P_s : LOW PRESSURE, Q_c : HEATING CAPACITY
A, B, C : COEFFICIENTS VARYING WITH PROPERTY ETC. OF REFRIGERANT
S12
$M_{REC} \leq M_{min}$?
NO
YES
S13
REDUCE VALVE ANGLE OF EXPANSION VALVE
S14
HEATING CAPACITY = TARGET CAPACITY?
YES
NO
S15
INCREASE FREQUENCY OF COMPRESSOR
S16
DEGREE OF SUPERHEAT DRAWN TO COMPRESSOR = TARGET DEGREE OF SUPERHEAT?
NO
YES
S17
DEGREE OF SUPERHEAT DRAWN TO COMPRESSOR < TARGET DEGREE OF SUPERHEAT?
NO
YES
S18
REDUCE VALVE ANGLE OF EXPANSION VALVE
S19
INCREASE VALVE ANGLE OF EXPANSION VALVE
S20
HEATING CAPACITY = TARGET CAPACITY?
NO
YES
S21
HEATING CAPACITY < TARGET CAPACITY?
NO
YES
S22
INCREASE FREQUENCY OF COMPRESSOR
S23
REDUCE FREQUENCY OF COMPRESSOR
RETURN

FIG.7


M : AMOUNT OF REFRIGERANT SEALED
$M_{X=0}$: AMOUNT OF REFRIGERANT REQUIRED
M_{REC} : AMOUNT OF LIQUID IN RECEIVER
$M_{X=0}=f(M, P_d, P_s, Q_c)$
$M_{X=0}=(A+BP_d)P_s+CQ_c$
$M_{REC}=M-M_{X=0}$
P_d : HIGH PRESSURE, P_s : LOW PRESSURE,
Q_c : HEATING CAPACITY
A, B, C : COEFFICIENTS VARYING WITH PROPERTY ETC. OF REFRIGERANT
START
S51
ESTIMATE AMOUNT OF LIQUID IN RECEIVER M_{REC}
S52
$M_{REC} \leq M_{min}$?
NO
YES
S53
REDUCE AIR VOLUME OF FAN
S54
HEATING CAPACITY = TARGET CAPACITY?
YES
NO
S55
INCREASE FREQUENCY OF COMPRESSOR
S56
PRESSURE DRAWN TO COMPRESSOR = TARGET PRESSURE?
NO
YES
S57
PRESSURE DRAWN TO COMPRESSOR < TARGET PRESSURE?
NO
YES
S58
INCREASE AIR VOLUME OF FAN
S59
REDUCE AIR VOLUME OF FAN
S60
HEATING CAPACITY = TARGET CAPACITY?
NO
YES
S61
HEATING CAPACITY < TARGET CAPACITY?
NO
YES
S62
INCREASE FREQUENCY OF COMPRESSOR
S63
REDUCE FREQUENCY OF COMPRESSOR
RETURN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/009494

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i
FI: F25B1/00 385Z

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 7-218008 A (HITACHI LTD) 18 August 1995 (1995-08-18) paragraphs [0012]-[0022], fig. 1-2	1, 4
Y		2-3, 5-8
Y	JP 2011-247504 A (MITSUBISHI ELECTRIC CORP) 08 December 2011 (2011-12-08) paragraphs [0020]-[0029]	2-3, 5-8
Y	JP 7-35430 A (KUBOTA CORP) 07 February 1995 (1995-02-07) paragraphs [0049], [0069]-[0070]	5-8

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 March 2022	**05 April 2022**

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

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/009494

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 7-218008 A	18 August 1995	(Family: none)	
JP 2011-247504 A	08 December 2011	(Family: none)	
JP 7-35430 A	07 February 1995	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2004053191 A **[0006] [0007]**