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(54) **REFRIGERATION CYCLE APPARATUS**

(52) **U.S. Cl.**

(71) Applicant: **Mitsubishi Electric Corporation,**
Tokyo (JP)

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2700/21 (2013.01)

(72) Inventors: **Shunya GYOTOKU,** Tokyo (JP);
Kimitaka KADOWAKI, Tokyo (JP);
Masahiro ITO, Tokyo (JP)

(57) **ABSTRACT**

(21) Appl. No.: **18/558,923**

A refrigeration cycle apparatus includes a refrigerant circuit and a non-azeotropic refrigerant that flows through a refrigerant pipe. When the non-azeotropic refrigerant passes through an outdoor heat exchanger, a temperature difference occurs between an inlet and an outlet of the outdoor heat exchanger. The outdoor heat exchanger includes: a group of fins that are stacked at intervals; and a heat transfer tube that extends through the group of fins in a stacking direction of the group of fins and allows the non-azeotropic refrigerant to flow inside the heat transfer tube. The group of fins includes: a first fin part to which frost can adhere in a humid environment; and a second fin part to which no frost adheres to ensure ventilation.

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F25B 39/02 (2006.01)

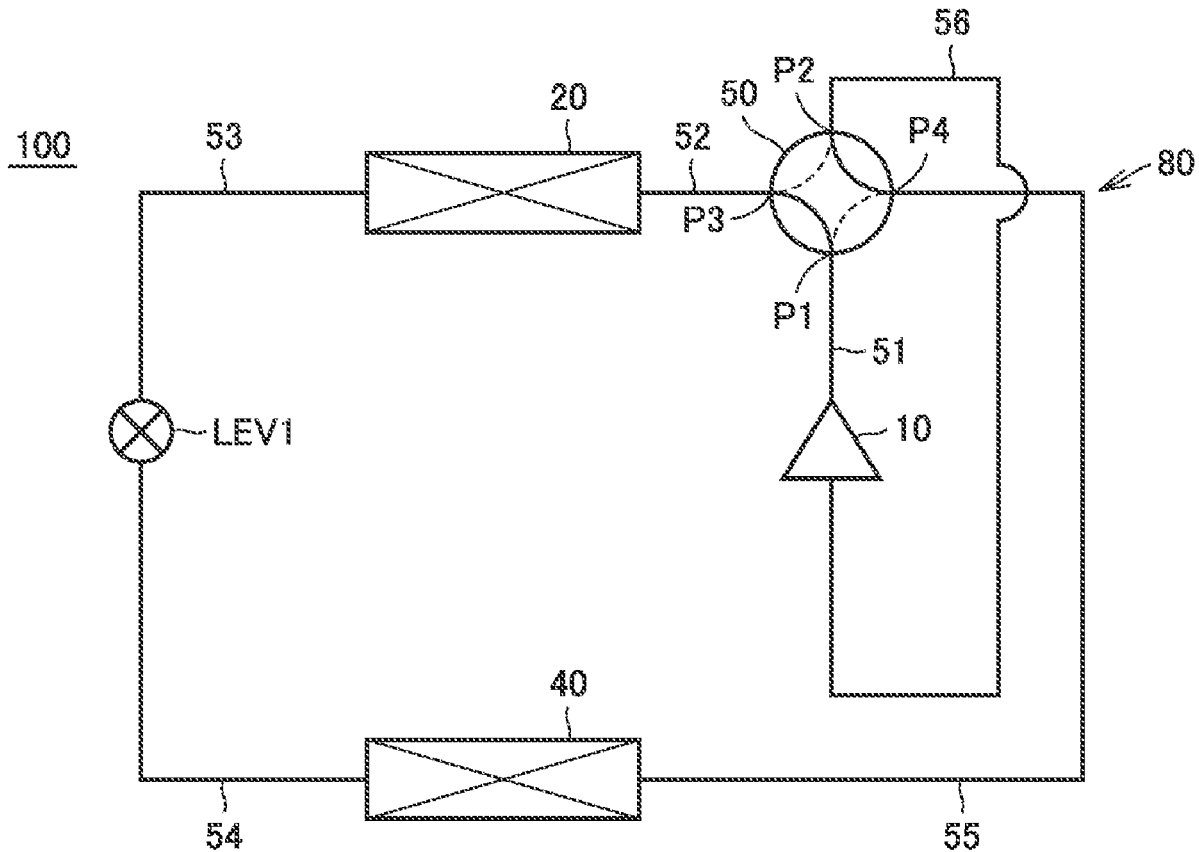


FIG.1

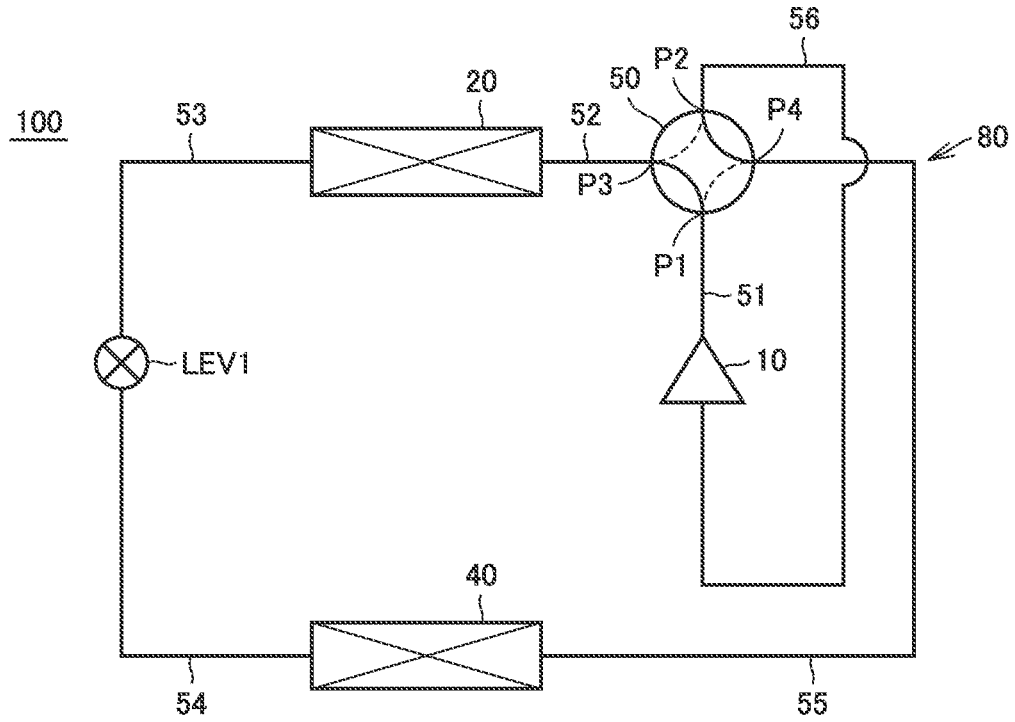


FIG.2

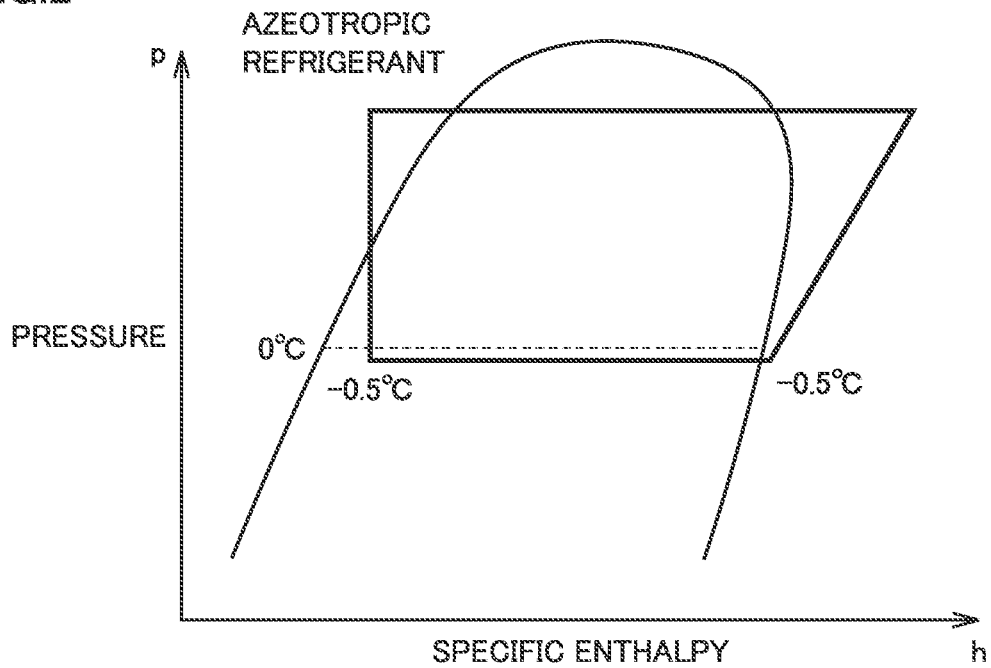


FIG.3

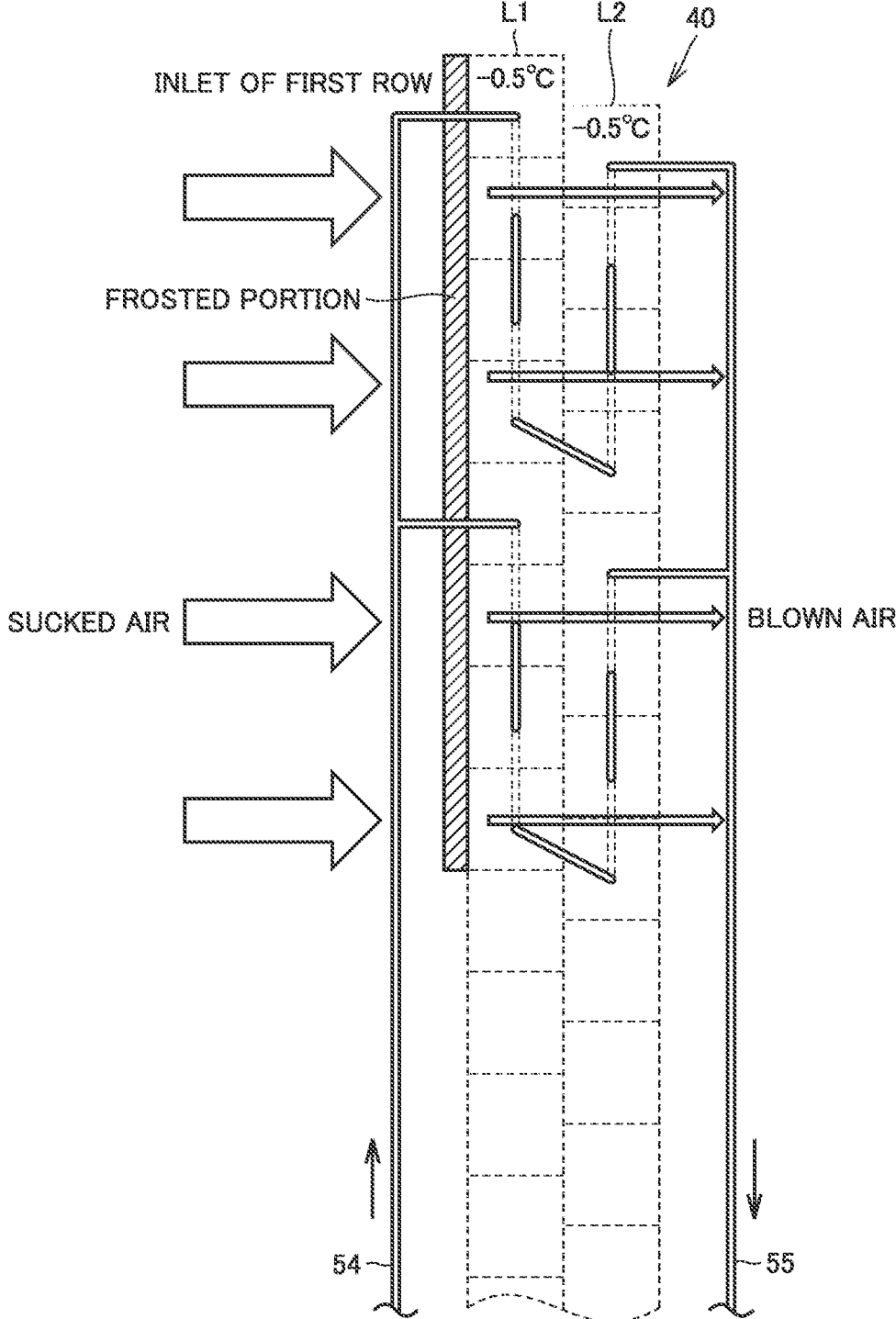


FIG.4

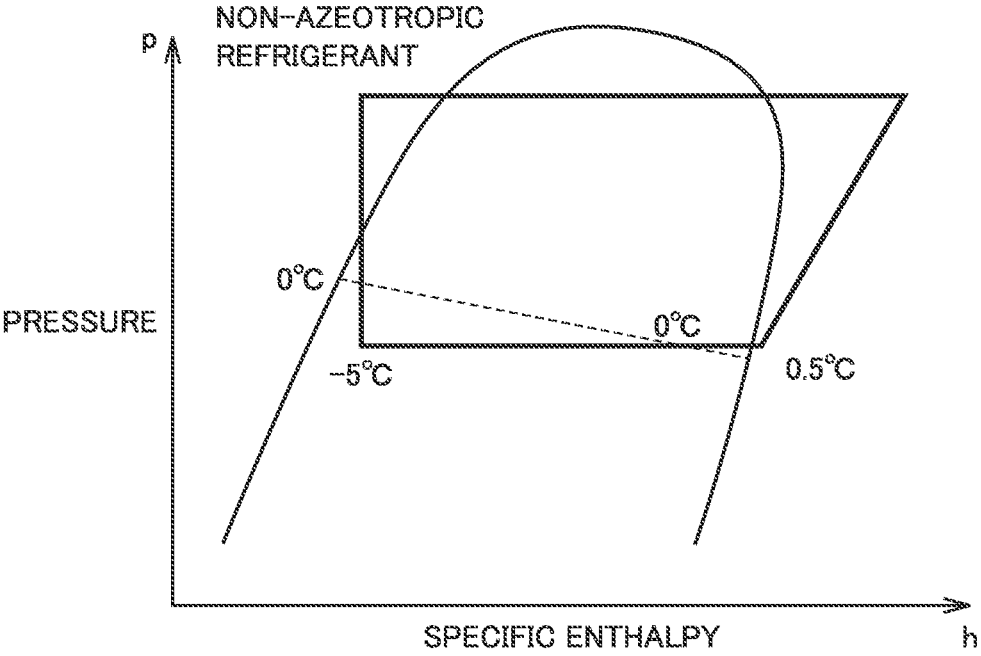


FIG.5

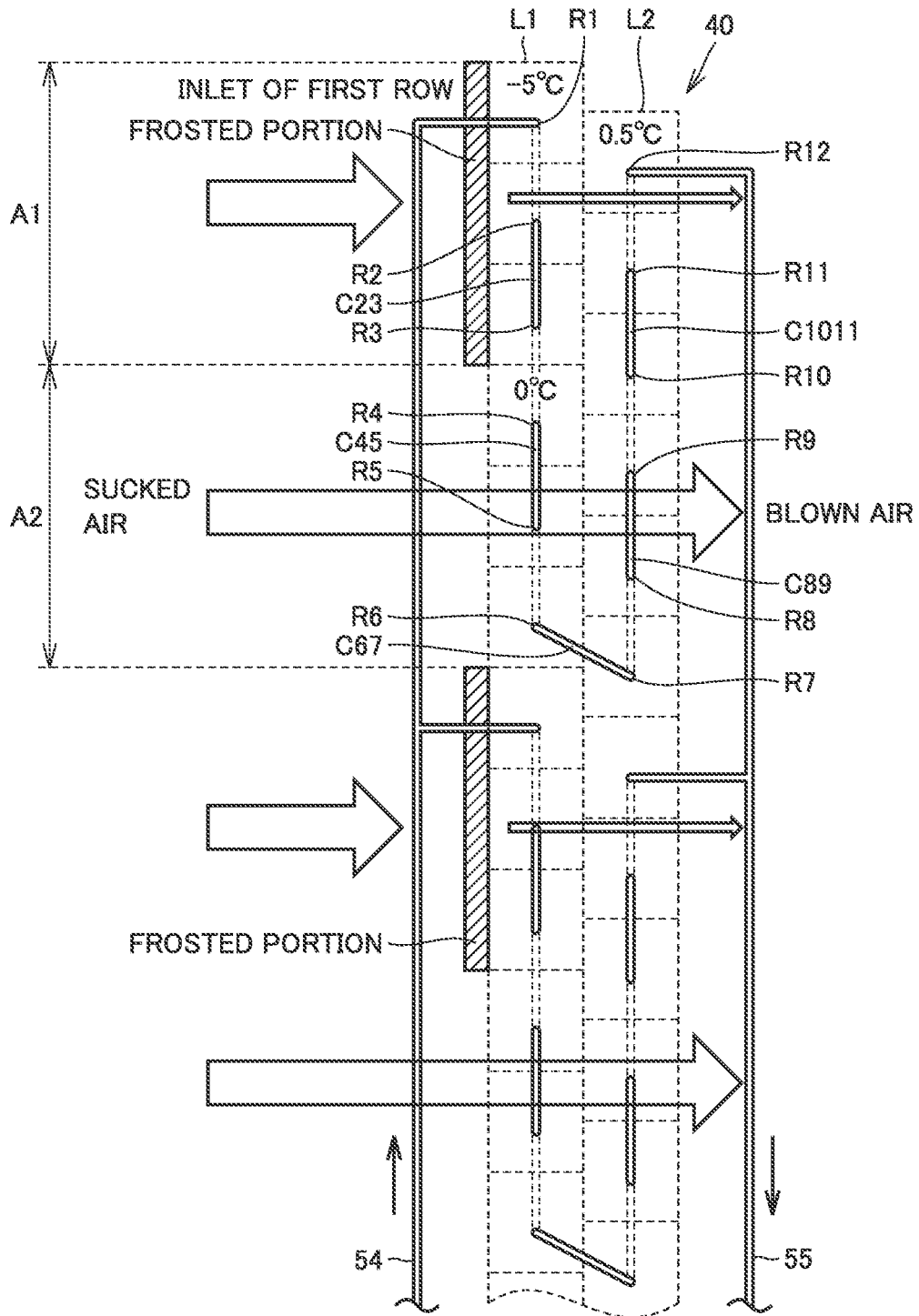


FIG. 6

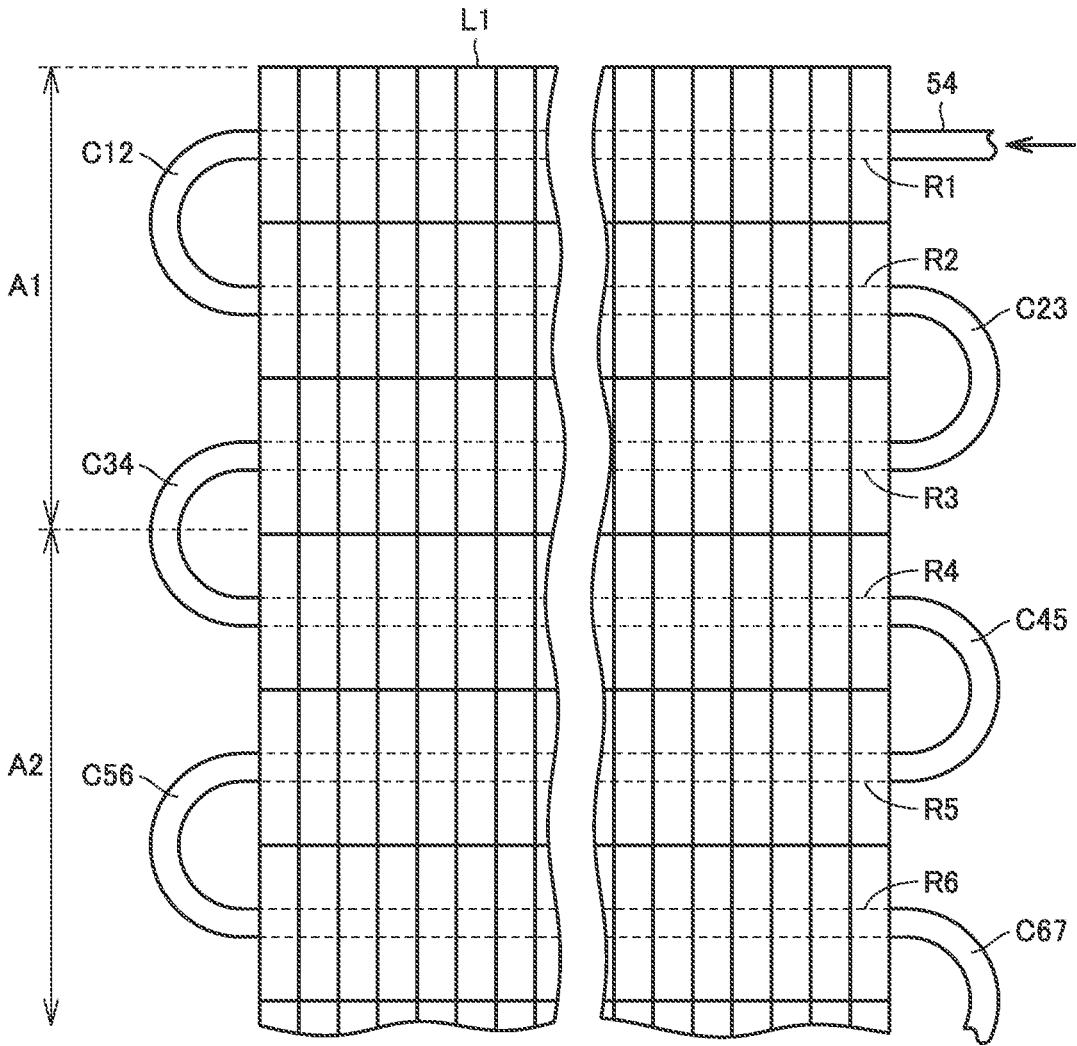


FIG. 7

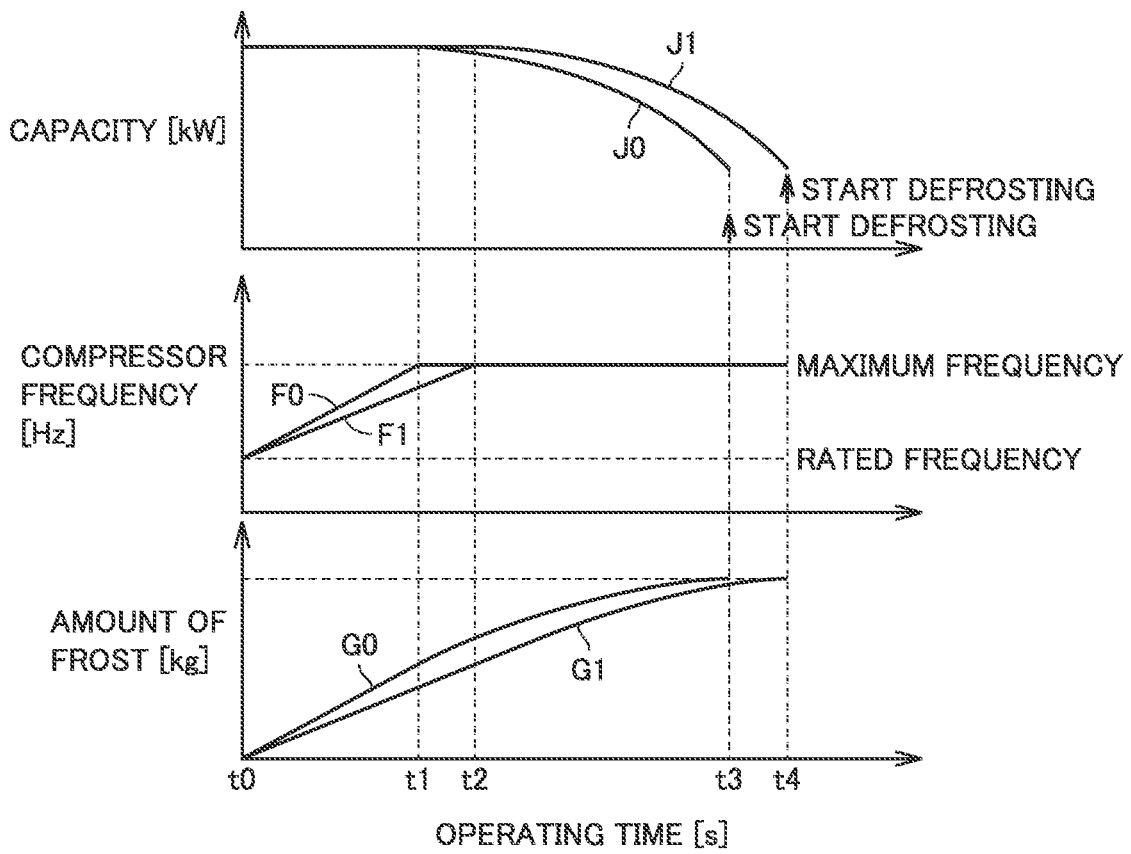


FIG.8

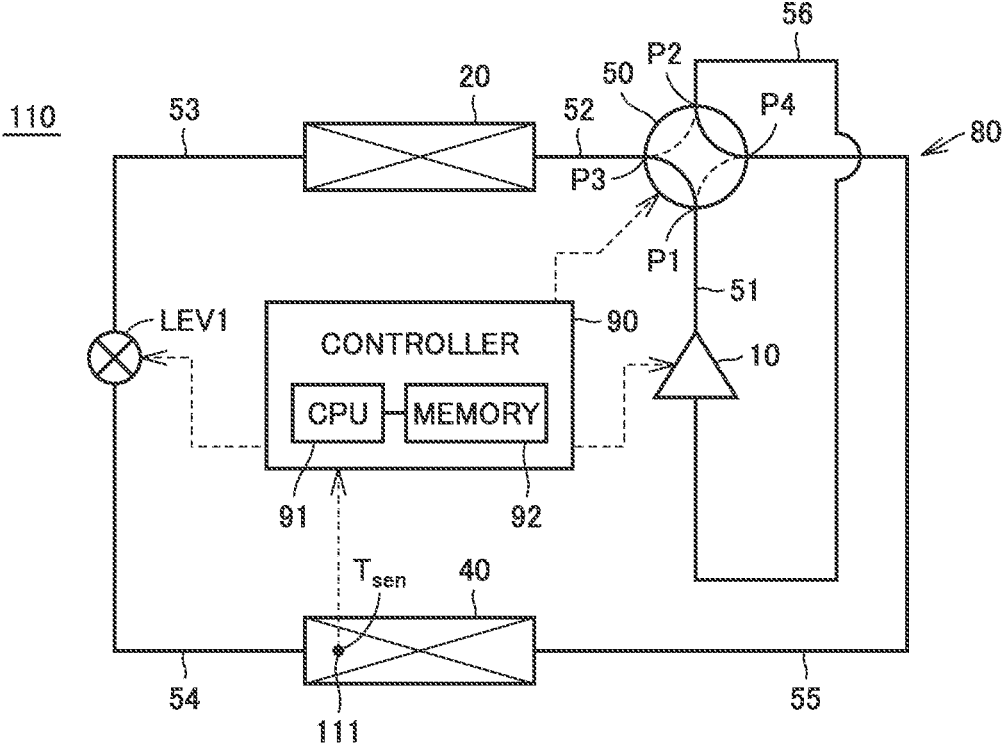


FIG. 9

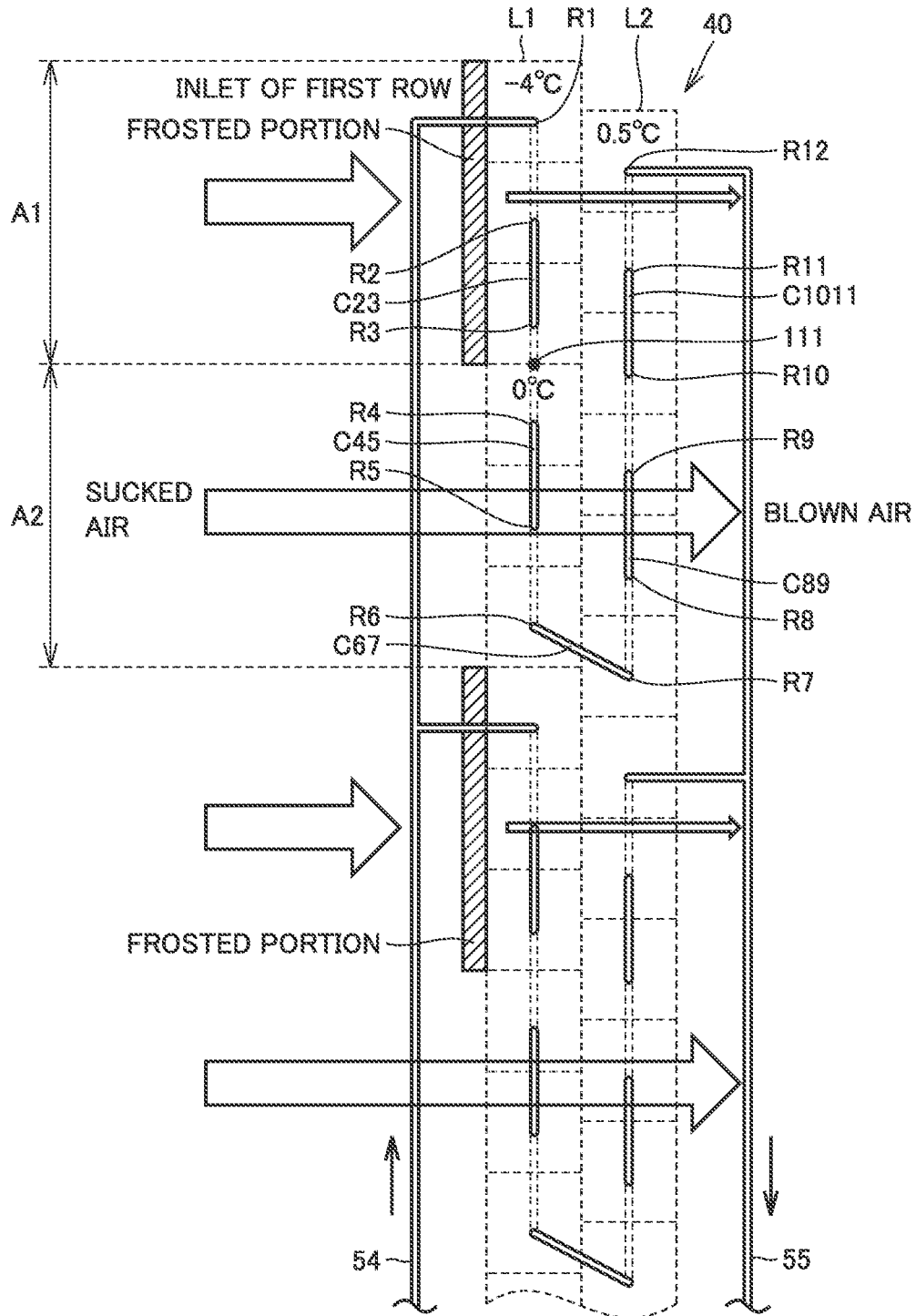


FIG.10

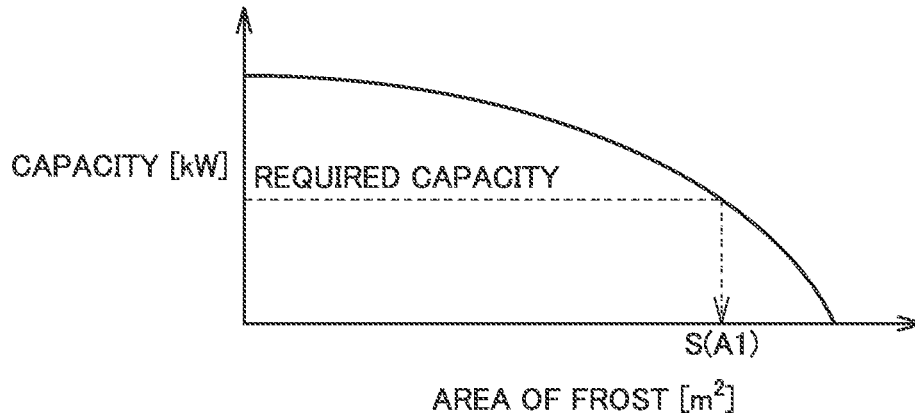


FIG.11

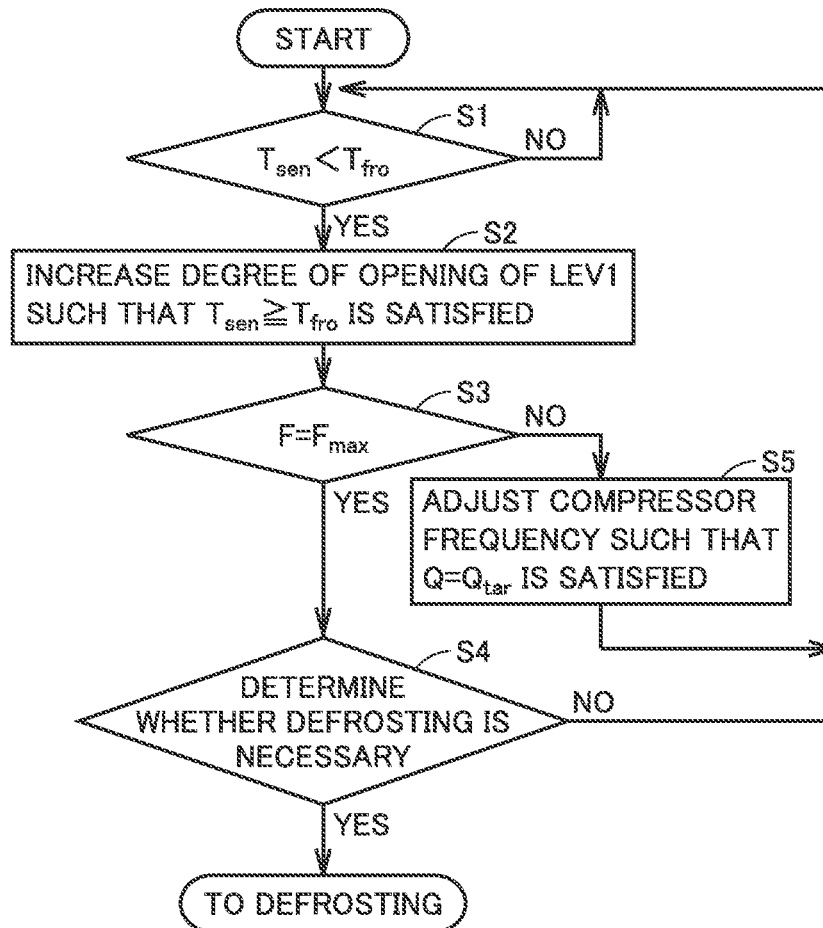


FIG.12

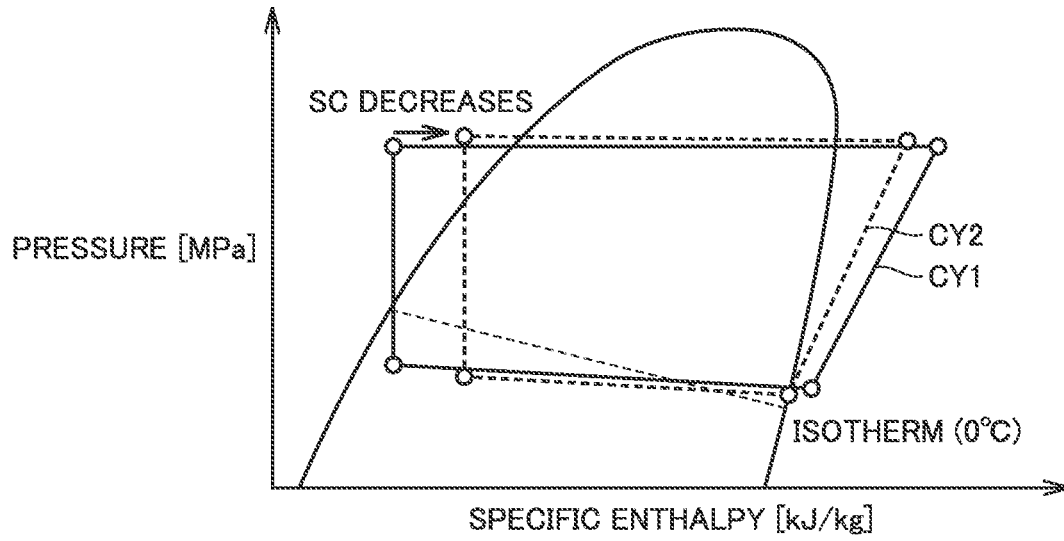


FIG.13

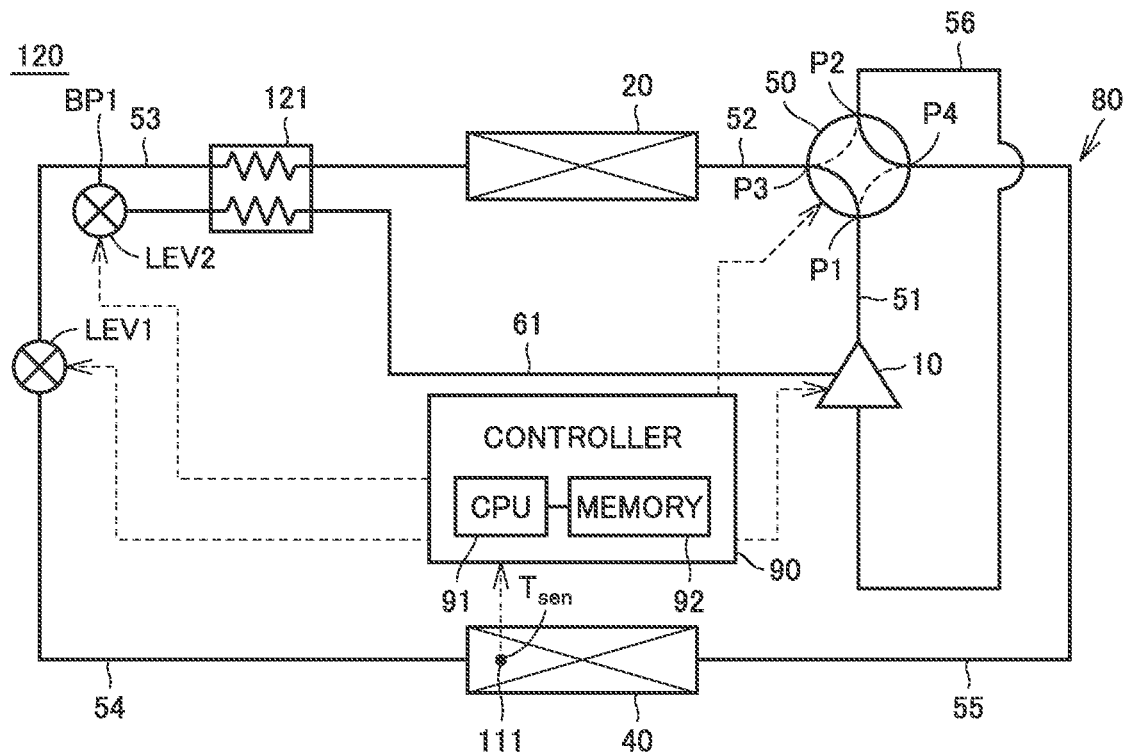


FIG.14

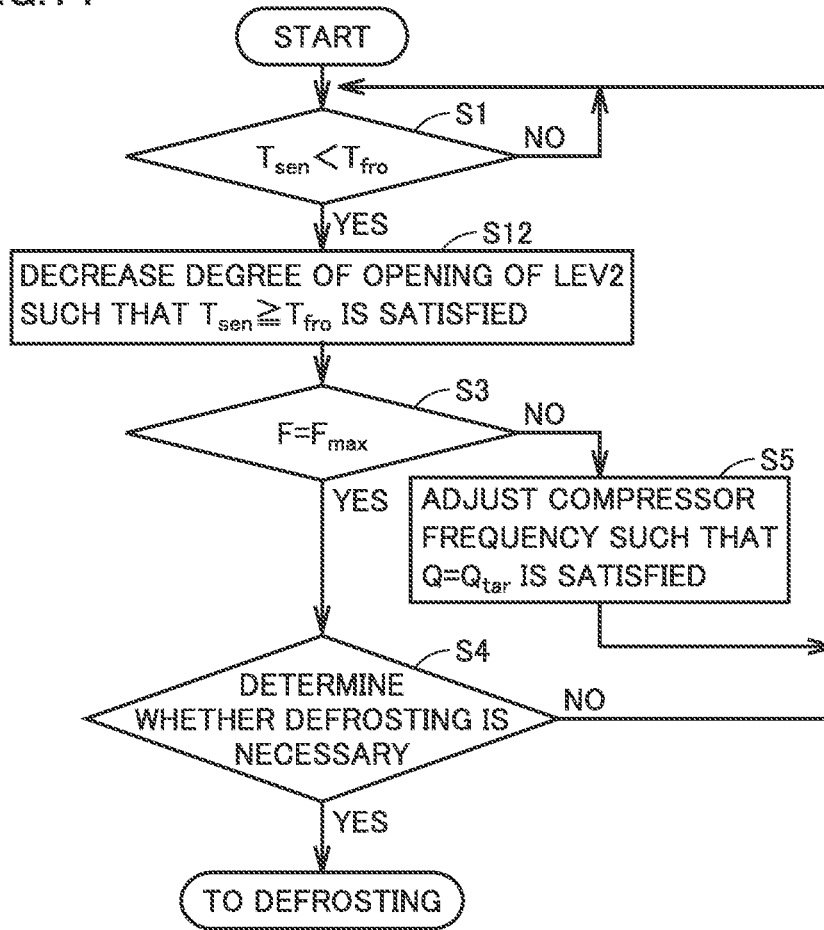


FIG.15

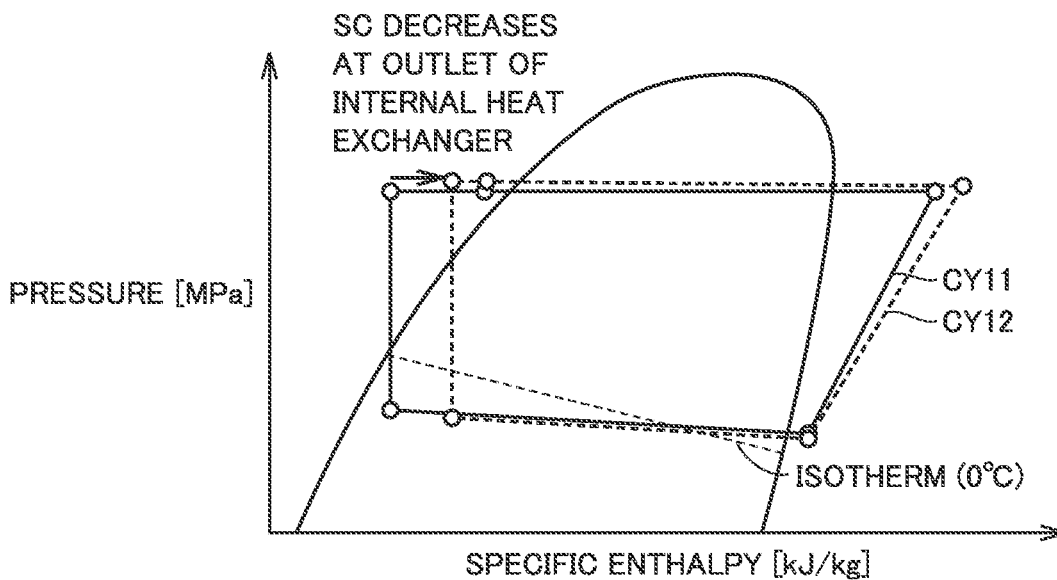


FIG.16

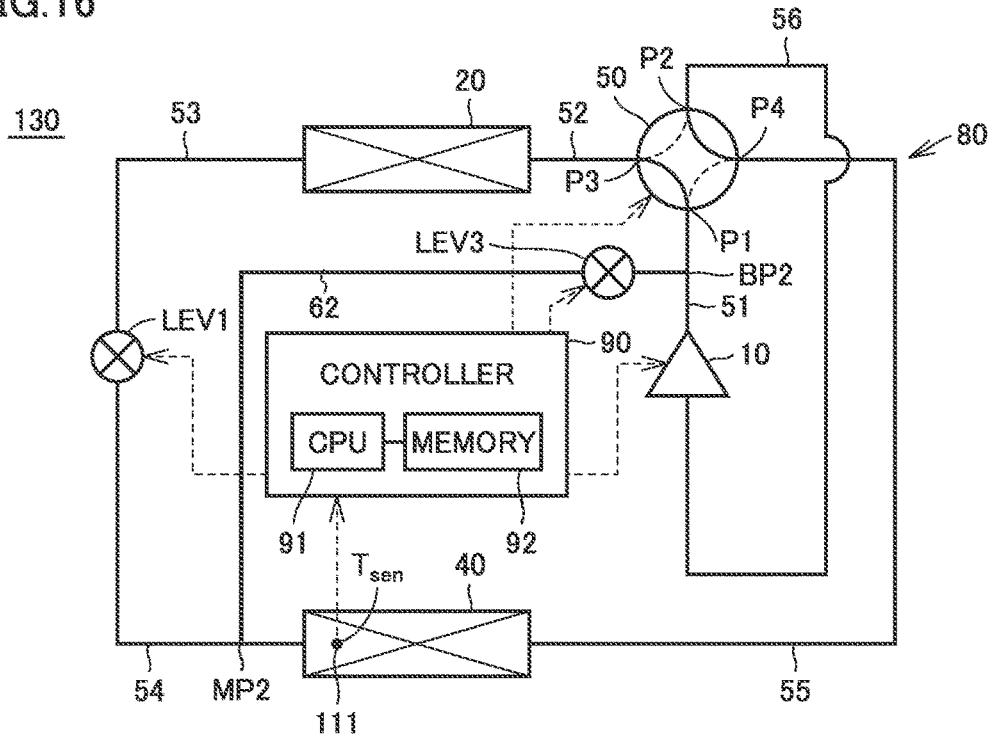


FIG.17

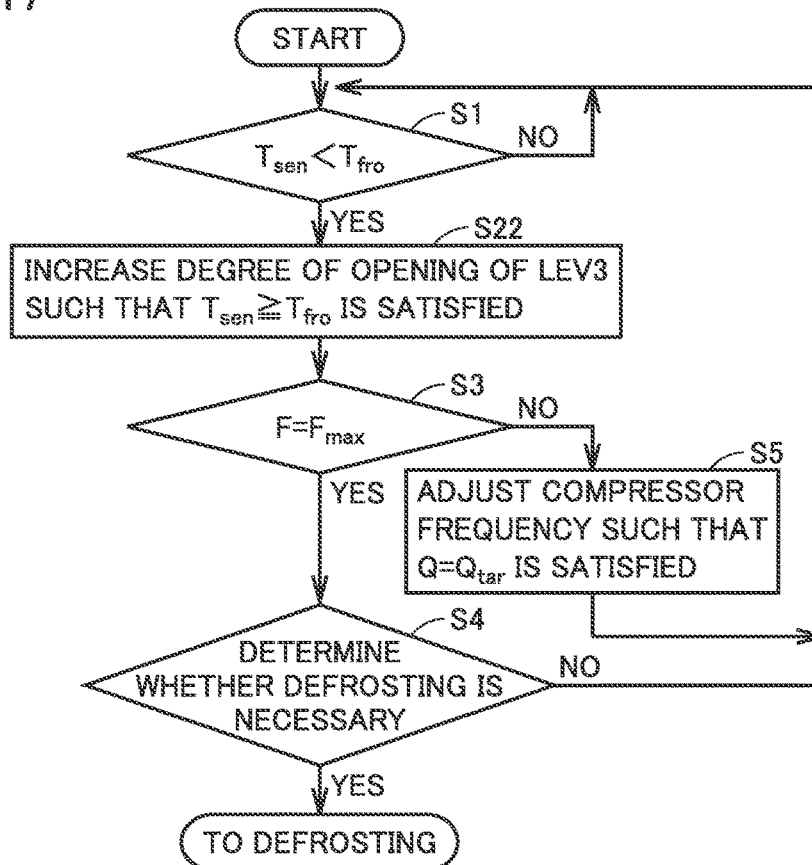


FIG.18

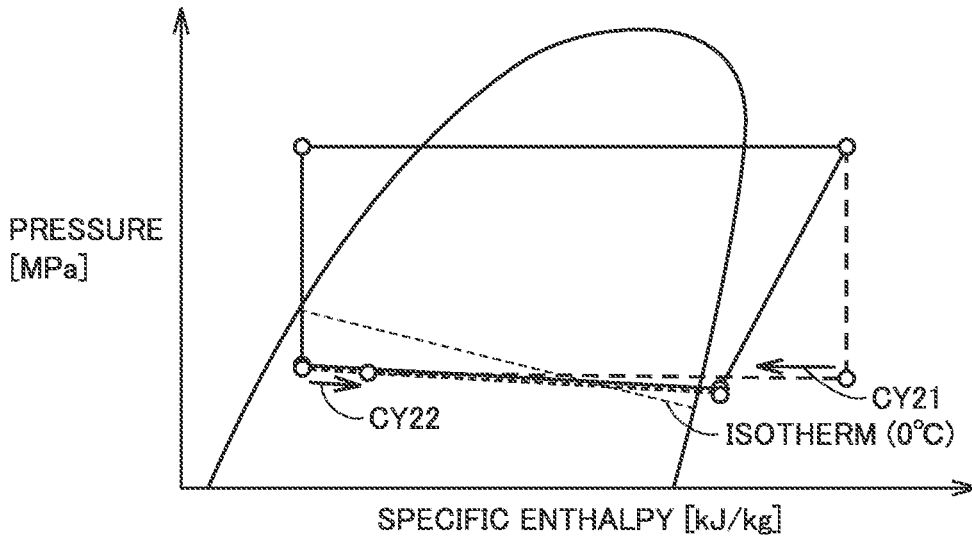


FIG.19

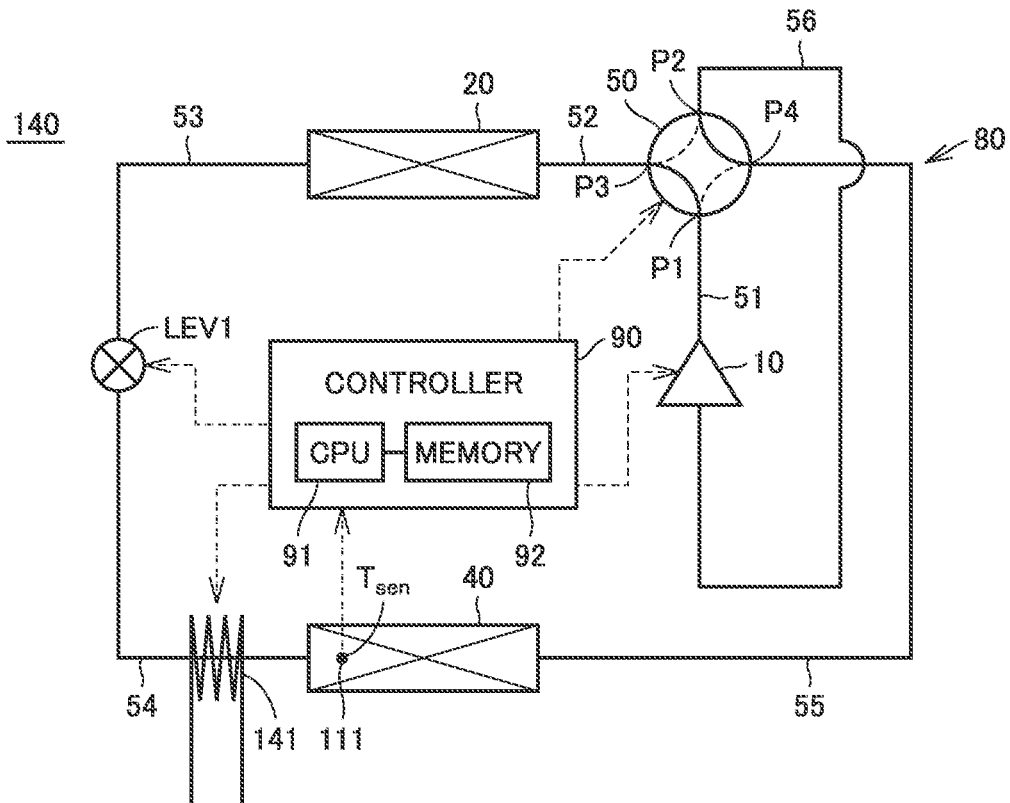


FIG.20

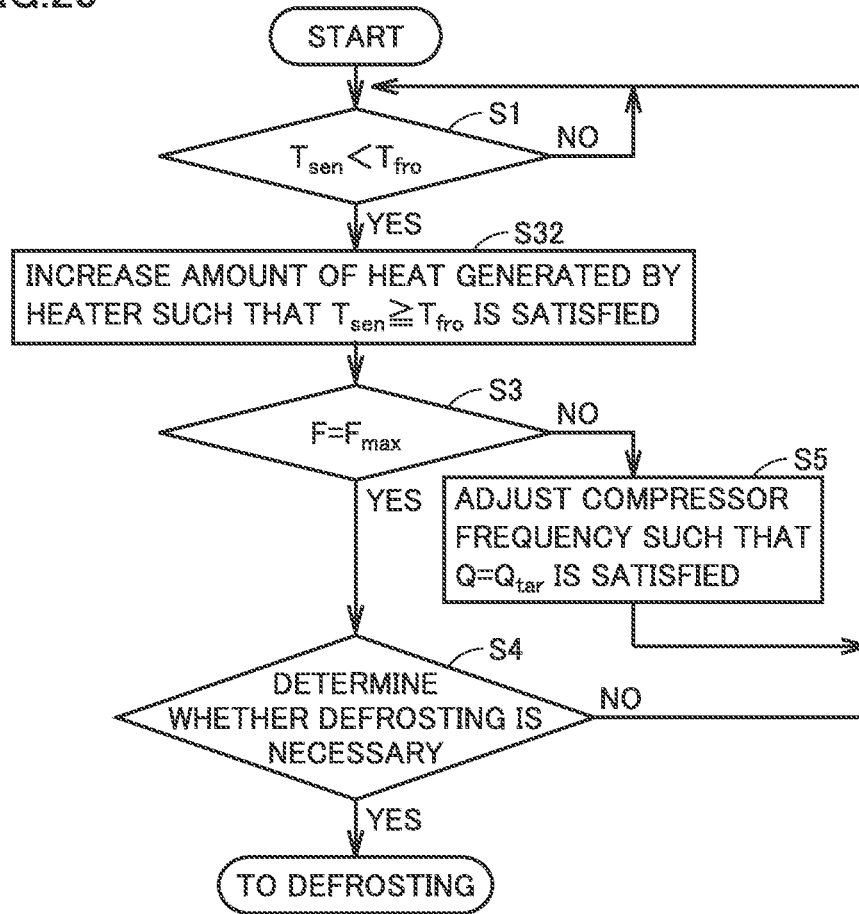


FIG.21

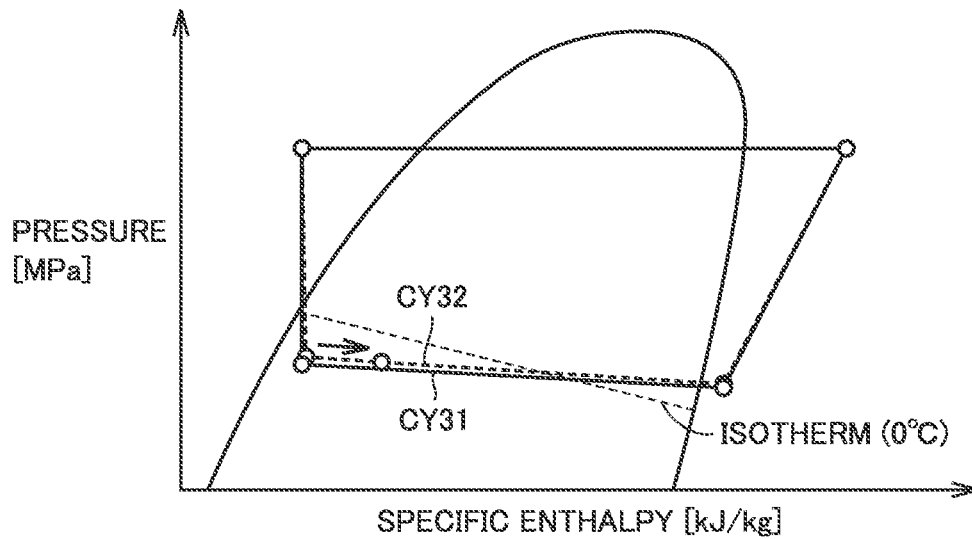


FIG.22

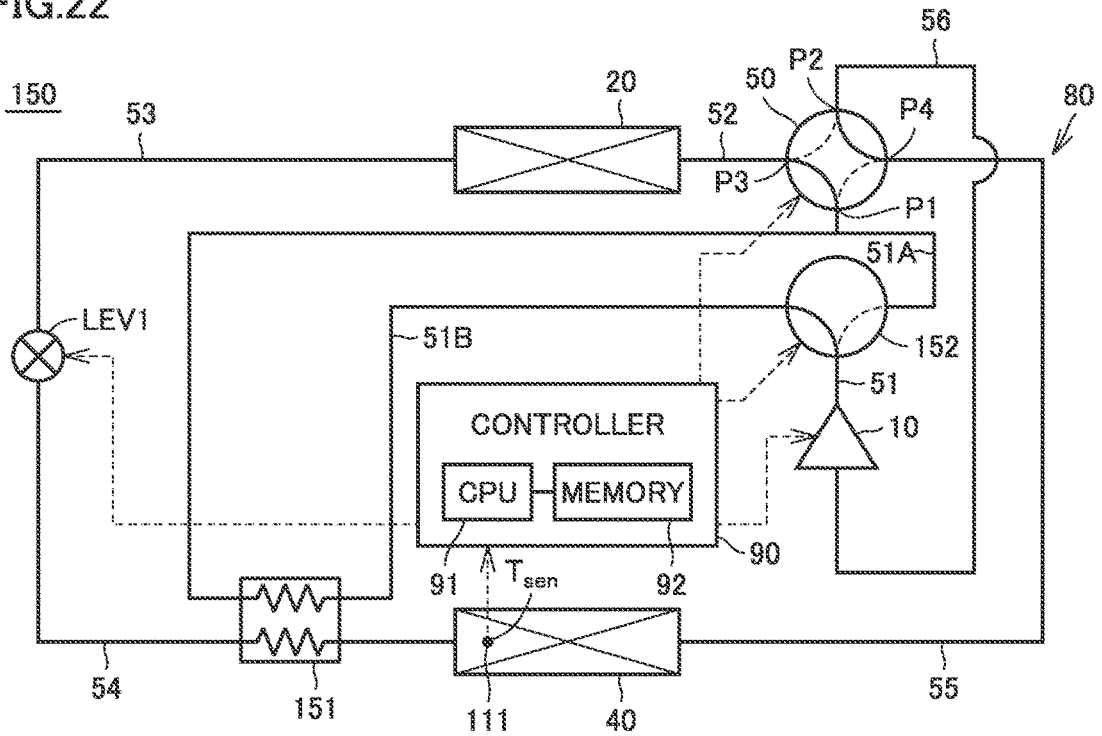


FIG.23

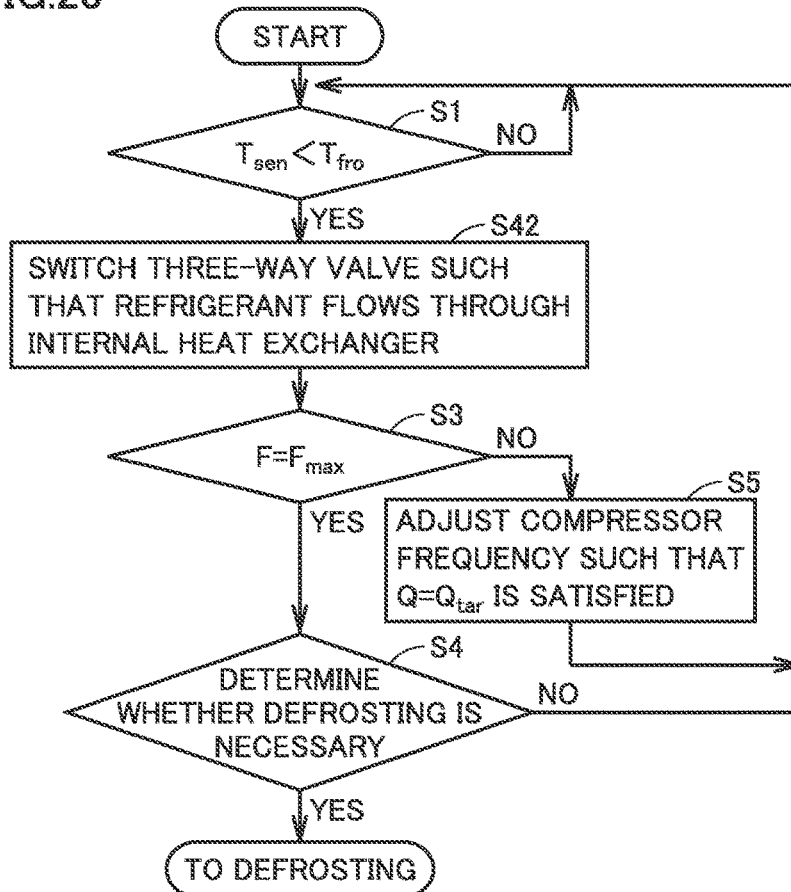
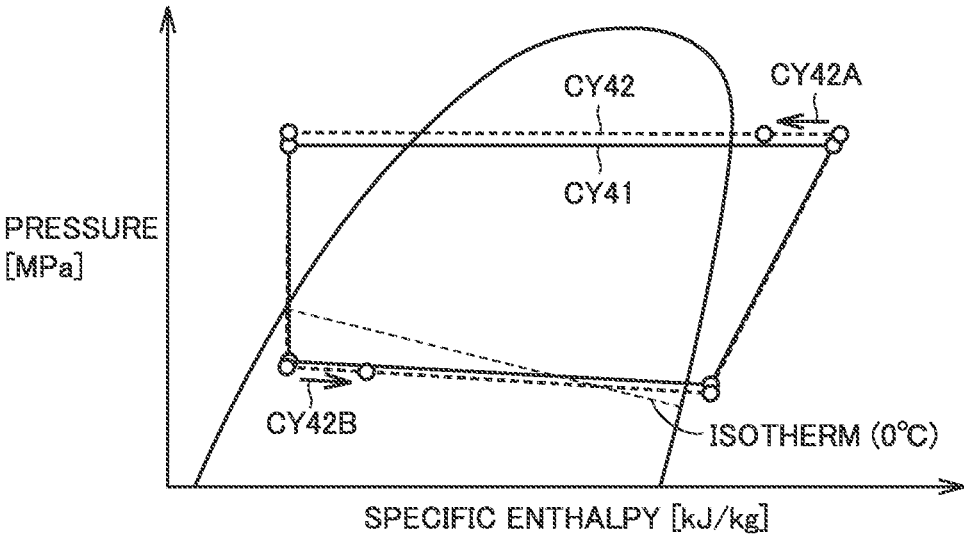


FIG.24



REFRIGERATION CYCLE APPARATUS

TECHNICAL FIELD

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

BACKGROUND ART

[0002] In recent years, it has been required to use refrigerant having a low GWP (Global Warming Potential). However, it is difficult to reduce the GWP while keeping the performance, and use of a refrigerant mixture of two or more kinds of refrigerants has been studied, in order to compensate for a disadvantage of a refrigerant with an advantage of another refrigerant. In the case of a non-azeotropic refrigerant mixture that is a mixture of refrigerants different in boiling point from each other, it is known that the isotherm is inclined in a two-phase region on a p-h chart.

[0003] Japanese Patent Laying-Open No. 2018-21721 (PTL 1) discloses a refrigeration cycle apparatus for which a non-azeotropic refrigerant mixture is used, with a reduced deviation of the temperature distribution for the entire evaporator.

CITATION LIST

Patent Literature

[0004] PTL 1: Japanese Patent Laying-Open No. 2018-21721

SUMMARY OF INVENTION

Technical Problem

[0005] For example, for a low-temperature high-humidity heating operation performed at an outside air temperature of around 2° C., there is a concern that the heating capacity may be lowered due to frosting. Therefore, for introducing an air conditioning system, generally the system is designed such that the maximum capacity that can be exhibited in a non-frosted state under a low-temperature high-humidity condition is sufficient. When a frost is formed, the operating frequency of the compressor is increased so as to increase the amount of circulating refrigerant, thereby avoiding deterioration of the heating capacity due to frosting.

[0006] Defrosting operation is performed when the compressor frequency reaches the maximum frequency and the capacity is deteriorated due to frosting. During this operation, there is a problem that low-temperature refrigerant flows into the load side to lower the temperature, which impairs comfort of the load side. There is also a problem that shortening of the total period, i.e., defrosting period, which is the sum of the time of a single heating operation and a subsequent defrosting time, results in deterioration of the integrated heating capacity and reduction of the average coefficient of performance (COP). During heating operation under low-temperature high-humidity condition, the evaporation temperature of refrigerant is lower than the outside air and frosting is unavoidable, and therefore, a technique for extending the defrosting period while suppressing frosting is required.

[0007] An object of the present disclosure is to provide a refrigeration cycle apparatus that enables extension of the defrosting period while suppressing frosting.

Solution to Problem

[0008] The present disclosure relates to a refrigeration cycle apparatus. The refrigeration cycle apparatus comprises: a refrigerant circuit in which a compressor, a condenser, a first expansion valve, and an evaporator are connected by a refrigerant pipe; and a non-azeotropic refrigerant that flows through the refrigerant pipe. When the non-azeotropic refrigerant passes through the evaporator, a temperature difference occurs between an inlet and an outlet of the evaporator. The evaporator comprises: a group of fins that are stacked at intervals; and a heat transfer tube that extends through the group of fins in a stacking direction of the group of fins and allows the non-azeotropic refrigerant to flow inside the heat transfer tube. The group of fins comprises: a first fin part to which frost can adhere in a humid environment; and a second fin part to which no frost adheres to ensure ventilation.

Advantageous Effects of Invention

[0009] The refrigeration cycle apparatus of the present disclosure enables suppression of frosting and extension of the defrosting period during low-temperature high-humidity heating operation, to thereby enable improvement in the comfort of the load side.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is shows a configuration of a refrigeration cycle apparatus according to Embodiment 1.

[0011] FIG. 2 is a p-h diagram of a refrigeration cycle apparatus in a reference example using an azeotropic refrigerant.

[0012] FIG. 3 shows a frost region of an outdoor heat exchanger in a reference example using an azeotropic refrigerant.

[0013] FIG. 4 is a p-h diagram of the refrigeration cycle apparatus of the present embodiment using a non-azeotropic refrigerant.

[0014] FIG. 5 shows a configuration of an outdoor heat exchanger and a frost region of the present embodiment using a non-azeotropic refrigerant.

[0015] FIG. 6 is a front view of the outdoor heat exchanger shown in FIG. 5.

[0016] FIG. 7 illustrates a difference in defrosting period between a refrigeration cycle apparatus in a reference example and the refrigeration cycle apparatus of the present embodiment.

[0017] FIG. 8 shows a configuration of a refrigeration cycle apparatus according to Embodiment 2.

[0018] FIG. 9 illustrates arrangement of a temperature sensor 111.

[0019] FIG. 10 illustrates how the position where temperature sensor 111 is to be attached is determined.

[0020] FIG. 11 is a flowchart for illustrating a process performed by a controller according to Embodiment 2.

[0021] FIG. 12 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 2.

[0022] FIG. 13 shows a configuration of a refrigeration cycle apparatus according to Embodiment 3.

[0023] FIG. 14 is a flowchart for illustrating a process performed by a controller according to Embodiment 3.

[0024] FIG. 15 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 3.

[0025] FIG. 16 shows a configuration of a refrigeration cycle apparatus according to Embodiment 4.

[0026] FIG. 17 is a flowchart for illustrating a process performed by a controller according to Embodiment 4.

[0027] FIG. 18 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 4.

[0028] FIG. 19 shows a configuration of a refrigeration cycle apparatus according to Embodiment 5.

[0029] FIG. 20 is a flowchart for illustrating a process performed by a controller according to Embodiment 5.

[0030] FIG. 21 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 5.

[0031] FIG. 22 shows a configuration of a refrigeration cycle apparatus according to Embodiment 6.

[0032] FIG. 23 is a flowchart for illustrating a process performed by a controller according to Embodiment 6.

[0033] FIG. 24 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 6.

DESCRIPTION OF EMBODIMENTS

[0034] Embodiments of the present invention are herein-after described in detail with reference to the drawings. In the following, a plurality of embodiments are described, and it is originally intended that characteristics described in connection with respective embodiments are combined as appropriate. In the drawings, the same or corresponding parts are denoted by the same reference characters, and a description thereof is not herein repeated. In the following drawings, the relation in size between components may be different from the actual relation in size therebetween.

Embodiment 1

[0035] FIG. 1 shows a configuration of a refrigeration cycle apparatus according to Embodiment 1. Refrigeration cycle apparatus 100 includes a refrigerant circuit 80 including a compressor 10, an indoor heat exchanger 20, an expansion valve LEV1, an outdoor heat exchanger 40, pipes 51 to 56, and a four-way valve 50. Four-way valve 50 has ports P1 to P4.

[0036] Pipe 51 is connected between a discharge outlet of compressor 10 and port P1 of four-way valve 50. Pipe 52 is connected between port P3 of four-way valve 50 and port P1 of indoor heat exchanger 20. Pipe 53 is connected between indoor heat exchanger 20 and expansion valve LEV1. Pipe 54 is connected between LEV1 and outdoor heat exchanger 40.

[0037] Pipe 55 is connected between port P2 of outdoor heat exchanger 40 and port P4 of four-way valve 50. Pipe 56 is connected between a suction inlet of compressor 10 and port P2 of four-way valve 50.

[0038] Compressor 10 is configured to change the operating frequency based on a control signal received from a controller (not shown). Specifically, compressor 10 has a drive motor incorporated therein, the rotational speed of the drive motor is a variable under inverter control, and changing of the operating frequency causes the rotational speed of the drive motor to change. The output of compressor 10 is adjusted by changing the operating frequency of compressor 10. Any of various types of compressors, such as rotary type, reciprocating type, scroll type, screw type and like may be employed as compressor 10.

[0039] Four-way valve 50 is controlled to be set in either a cooling operation state or a heating operation state by a

control signal received from a controller (not shown). In the heating operation state, port P1 communicates with port P3 and port P2 communicates with port P4, as shown by a solid line. In the cooling operation state, ports P1 and P4 communicate with each other and ports P2 and P3 communicate with each other, as shown by a broken line.

[0040] In the heating operation state, compressor 10 is operated to cause refrigerant to circulate in the refrigerant circuit in the order of compressor 10, indoor heat exchanger 20, LEV1, outdoor heat exchanger 40, and compressor 10. In the cooling operation state, compressor 10 is operated to cause refrigerant to circulate in the refrigerant circuit in the order of compressor 10, outdoor heat exchanger 40, LEV1, indoor heat exchanger 20, and compressor 10.

[0041] FIG. 2 is a p-h line diagram of a refrigeration cycle apparatus in a reference example using an azeotropic refrigerant. FIG. 3 shows a frost region of an outdoor heat exchanger in a reference example using an azeotropic refrigerant.

[0042] As shown in FIG. 2, when azeotropic refrigerant is used, there is no temperature rise in the two-phase region, and therefore, the front surface of outdoor heat exchanger 40 exposed to air sucked into the heat exchanger during low-temperature high-humidity heating operation is uniformly frosted. In such a case, the frost causes an air passage to be narrowed, and thus the amount of air blown out of outdoor heat exchanger 40 decreases. It is therefore necessary to frequently perform defrosting before the air passage is blocked, and thus the defrosting period is short.

[0043] FIG. 4 is a p-h diagram of the refrigeration cycle apparatus of the present embodiment using a non-azeotropic refrigerant. FIG. 5 shows a configuration of an outdoor heat exchanger and a frost region of the present embodiment using a non-azeotropic refrigerant. FIG. 6 is a front view of the outdoor heat exchanger shown in FIG. 5.

[0044] As shown in the p-h diagram of FIG. 4, when the non-azeotropic refrigerant is used, the isotherm is inclined in the two-phase region, and therefore, the temperature of a refrigerant outlet of outdoor heat exchanger 40 can be set to 0.5° C. during heating operation even when the temperature of a refrigerant inlet of outdoor heat exchanger 40 is -5° C. This means that the temperature of a part of outdoor heat exchanger 40 can be set to 0° C. or more. In the present embodiment, the refrigeration cycle apparatus is operated so as to have a temperature distribution as shown in FIG. 4 during low-temperature high-humidity heating operation performed at an outside air temperature of around 2° C.

[0045] As shown in FIG. 5, the refrigerant flows from pipe 54 into outdoor heat exchanger 40, and the refrigerant flows from outdoor heat exchanger 40 into pipe 55. Supposing that the side from which air is sucked is the front side of outdoor heat exchanger 40, a group of fins L1 in the first row is disposed on the front side and a group of fins L2 in the second row is disposed on the rear side. A pipe serving as a refrigerant flow path and made up of six pipes is arranged for each of respective groups of fins L1 and L2, and these pipes are arranged in parallel and connected together on each lateral side. The six pipes for fin group L1 are herein referred to as heat transfer tubes R1 to R6 in order from the top, and the six pipes for fin group L2 are herein referred to as heat transfer tubes R7 to R12 in order from the bottom.

[0046] As shown in FIGS. 5 and 6, refrigerant flows from the right side of heat transfer tube R1 which is the top one in fin group L1 in the first row, flows from right to left

through heat transfer tube R1, then flows through a connection pipe C12, and the refrigerant flows from left to right through heat transfer tube R2, thus completing a single go-and-return passage.

[0047] The refrigerant flowing out from heat transfer tube R2 flows through a connection pipe C23, and flows from right to left through heat transfer tube R3. Then, the refrigerant flows through a connection pipe C34, and flows from left to right through heat transfer tube R4, thus completing a further single go-and-return passage.

[0048] The refrigerant flowing out from heat transfer tube R4 flows through a connection pipe C45, and flows from right to left through heat transfer tube R5. Then, the refrigerant flows through a connection pipe C56, and flows from left to right through heat transfer tube R6, thus completing a further single go-and-return passage. Through heat transfer tubes R7 to R12 shown in FIG. 5 as well, refrigerant

[0049] similarly flows through three go-and-return passages in the left-right direction in FIG. 6. Heat transfer tubes R7 to R12, however, differ from heat transfer tubes R1 to R6 in that the refrigerant flows in order from the lower stage toward the upper stage.

[0050] Specifically, refrigerant flowing out from heat transfer tube R6 flows through a connection pipe C67, and flows through heat transfer tube R7 from right to left in FIG. 6. Then, the refrigerant flows through a connection pipe, and flows from left to right through heat transfer tube R8, thus completing a further single go-and-return passage.

[0051] The refrigerant flowing out from heat transfer tube R8 flows through a connection pipe C89, and flows through heat transfer tube R9 from right to left in FIG. 6. Then, the refrigerant flows through a connection pipe, and flows from left to right through heat transfer tube R10, thus completing a further single go-and-return passage.

[0052] The refrigerant flowing out from heat transfer tube R10 flows through a connection pipe C1011, and flows through heat transfer tube R11 from right to left in

[0053] FIG. 6. Then, the refrigerant flows through a connection pipe, flows from left to right through heat transfer tube R12, thus completing a further single go-and-return passage, and flows to pipe 55.

[0054] When non-azeotropic refrigerant is applied to outdoor heat exchanger 40 having such a configuration as described above, a frost region A1 where frost can adhere and a non-frost region A2 where frost does not adhere can be distinguished from each other, in low-temperature high-humidity heating operation performed at an outside air temperature of around 2° C. Therefore, even if the volume of blown air decreases in frost region A1, an adequate volume of blown air can be ensured in non-frost region A2. Thus, the defrosting period can be extended by causing unbalanced frosting on outdoor heat exchanger 40.

[0055] FIG. 7 illustrates a difference in defrosting period between a reference example and the refrigeration cycle apparatus of the present embodiment. FIG. 7 shows capacity J0, compressor frequency F0, and amount of frost G0 of the refrigeration cycle apparatus in the comparative example shown in FIGS. 2 and 3, and capacity J1, compressor frequency F1, and amount of frost G1 of the refrigeration cycle apparatus in the present embodiment shown in FIGS. 4 to 6.

[0056] As in the comparative example, the amount of frost, if formed on the entire surface, satisfies $G0 > G1$ for time t0 to t1. Moreover, in order to ensure a required

capacity, compressor frequency F0 reaches the maximum frequency (upper limit frequency) at time t1. Therefore, for time t1 to t3, with the increase of amount of frost G0, capacity J0 decreases earlier and defrosting becomes necessary and started at time t3.

[0057] In contrast, in the present embodiment, amount of frost G1 is smaller than amount of frost G0, and compressor frequency F1 reaches the upper limit at time t2 later than time t1. Therefore, capacity J1 has decreased to reach a value at which start of defrosting is required at time t4 later than time t3. The subsequent defrosting time is substantially constant in both the comparative example and the present embodiment, and therefore, the defrosting period of the present embodiment, in which the heating operation time is longer, is longer than that of the comparative example. Therefore, the refrigeration cycle apparatus of the present embodiment has the extended defrosting period, which provides improvement in the comfort for the load, as well as improvement in the average COP.

Embodiment 2

[0058] FIG. 8 shows a configuration of a refrigeration cycle apparatus according to Embodiment 2. Refrigeration cycle apparatus 110 shown in FIG. 8 further includes a controller 90 and a temperature sensor 111, in addition to the components of refrigeration cycle apparatus 100 in FIG. 1. The description of the other components is given above in connection with FIG. 1, and therefore, the description thereof is not herein repeated.

[0059] Controller 90 includes a CPU (Central Processing Unit) 91, a memory 92 (ROM (Read Only Memory) and RAM (Random Access Memory)), and an input/output buffer (not shown), for example. CPU 91 deploys and executes, on the RAM for example, a program stored in the ROM. The program stored in the ROM is a program in which a processing procedure for controller 90 is specified. Controller 90 controls each device in refrigeration cycle apparatus 110 in accordance with these programs. This control is not limited to processing by software, but may also be performed by dedicated hardware (electronic circuit). In particular, controller 90 is configured to control LEV1 based on an output of temperature sensor 111.

[0060] FIG. 9 illustrates arrangement of temperature sensor 111. FIG. 9 shows temperature sensor 111 disposed in outdoor heat exchanger 40 shown in FIG. 5. The description of outdoor heat exchanger 40 is given above in connection with FIGS. 4 to 6, and therefore, the description thereof is not herein repeated.

[0061] Temperature sensor 111 is disposed at the boundary between a portion intended to serve as frost region A1 of outdoor heat exchanger 40 and a portion intended to serve as non-frost region A2 thereof. The refrigeration cycle apparatus is controlled in such a manner that the temperature detected by temperature sensor 111 is 0° C., so that frost is formed in frost region A1 and no frost is formed in non-frost region A2 during low-temperature high-humidity heating operation, so that ventilation in non-frost region A2 can be ensured and the defrosting period can be extended appropriately. The boundary between frost region A1 and non-frost region A2 can be determined experimentally in advance so as to be appropriate for performing low-load heating under a low-temperature low-humidity condition.

[0062] FIG. 10 illustrates how the position where temperature sensor 111 is to be attached is determined. As

shown by the solid line in FIG. 10, the relation between the area of frost and the capacity at the maximum frequency under a low-temperature high-humidity operating condition is determined in advance. The position where temperature sensor 111 is to be attached is determined, such that the area of frost region A1 is equal to an area of frost S (A1) with which the capacity required during low-temperature high-humidity operation is exhibited.

[0063] FIG. 11 is a flowchart for illustrating a process performed by the controller according to Embodiment 2. Controller 90 determines whether or not temperature Tsen detected by temperature sensor 111 attached to outdoor heat exchanger 40 is lower than frosting temperature Tfro (step S1). Frosting temperature Tfro may for example be set to 0° C.

[0064] While Tsen<Tfro is not satisfied (NO in S1), controller 90 repeats the process in step S1. When Tsen<Tfro is satisfied (YES in S1), controller 90 increases the degree of opening of LEV1 such that Tsen≥ Tfro is satisfied (S2).

[0065] FIG. 12 is a p-h diagram for illustrating a change in a refrigeration cycle according to Embodiment 2. When the degree of opening of LEV1 is increased in step S2, the degree of subcooling at the outlet of the load-side heat exchanger decreases, so that the refrigeration cycle changes from the state indicated by solid line CY1 to the state indicated by broken line CY2 on the p-h diagram.

[0066] At this time, until compressor frequency F reaches maximum value Fmax (NO in S3), controller 90 adjusts compressor frequency F such that heating capacity Q reaches target heating capacity Qtar (S5), and then performs the process from step S1 again.

[0067] In contrast, when compressor frequency F reaches maximum value Fmax (YES in S3), the target capacity has not been reached, and controller 90 determines whether or not defrosting is necessary. Whether or not defrosting is necessary can be determined based on the time for which heating operation is continued, and/or an allowable ratio of decrease in capacity during heating (decrease of refrigerant pressure in low-pressure portion), for example.

[0068] When defrosting is unnecessary (NO in S4), controller 90 performs the process again from step S1. When defrosting is necessary (YES in S4), controller 90 starts defrosting operation.

[0069] As described above, the refrigeration cycle apparatus according to Embodiment 2 increases, during low-temperature high-humidity heating operation, the enthalpy at the refrigerant inlet of outdoor heat exchanger 40 and increases the temperature using the temperature gradient of non-azeotropic refrigerant. In this way, only a partial region of outdoor heat exchanger 40 is frosted, and the defrosting period is extended. In particular, temperature sensor 111 is disposed at the boundary between the frost region and the non-frost region of outdoor heat exchanger 40, and therefore, the frost region can be controlled accurately.

Embodiment 3

[0070] FIG. 13 shows a configuration of a refrigeration cycle apparatus according to Embodiment 3. In refrigeration cycle apparatus 120 shown in FIG. 13, refrigerant circuit 80 further includes an internal heat exchanger 121 and an expansion valve LEV2, in addition to the components of refrigeration cycle apparatus 110 in FIG. 8. A part of refrigerant flowing through pipe 53 is branched into a bypass flow path 61, reduced in pressure by expansion valve LEV2,

and returned to compressor 10. While the refrigerant is returned to an intermediate pressure port of compressor 10 in FIG. 13, the bypass flow path may be formed to cause the refrigerant to be returned to a suction inlet of compressor 10. Internal heat exchanger 121 is configured to exchange heat between the refrigerant flowing out from indoor heat exchanger 20 and the refrigerant after being reduced in pressure by expansion valve LEV2 in bypass flow path 61. The description of the other components is given above in connection with FIG. 8, and therefore, the description thereof is not herein repeated.

[0071] FIG. 14 is a flowchart for illustrating a process performed by a controller according to Embodiment 3. The process in the flowchart of FIG. 14 includes step S12 instead of step S2 of the process in the flowchart shown in FIG. 11. The description of the other features of the process is given above in connection with FIG. 11, and therefore, step S12 is described here.

[0072] While the process in FIG. 11 increases the degree of opening of LEV1 such that Tsen>Tfro detected by temperature sensor 111 is satisfied (S2), the process in FIG. 14 decreases the degree of opening of LEV2 such that Tsen>Tfro is satisfied (S12), when Tsen<Tfro is satisfied (YES in S1).

[0073] FIG. 15 is a p-h diagram for illustrating a change in refrigeration cycle according to Embodiment 3. When the degree of opening of LEV2 is decreased in step S12, the degree of subcooling at the outlet of internal heat exchanger 121 decreases, so that the refrigeration cycle changes from the state indicated by solid line CY11 to the state indicated by broken line CY12 on the p-h diagram.

[0074] In this way, Embodiment 3 changes the degree of opening of LEV2 so as to keep, at around 0° ° C., the portion where temperature sensor 111 is disposed, and keep the boundary as intended between frost region A1 and non-frost region A2.

[0075] When compressor frequency F reaches maximum value Fmax during operation and the target capacity is not reached, the defrosting operation is started after the determination of whether or not defrosting is necessary (S4).

[0076] By employing the configuration and control like those in Embodiment 3 as well, only a partial region of outdoor heat exchanger 40 can be frosted and the defrosting period can be extended.

Embodiment 4

[0077] FIG. 16 shows a configuration of a refrigeration cycle apparatus according to Embodiment 4. In refrigeration cycle apparatus 130 shown in FIG. 16, refrigerant circuit 80 further includes a bypass flow path 62 and an expansion valve LEV3, in addition to the components of refrigeration cycle apparatus 110 in FIG. 8. A part of discharged gas refrigerant flowing through pipe 51 is branched into bypass flow path 62 at a branch point BP2, adjusted in flow rate by expansion valve LEV3, and merged into refrigerant in pipe 54 at a merging point MP2. The description of the other components is given above in connection with FIG. 8, and therefore, the description thereof is not be herein repeated.

[0078] FIG. 17 is a flowchart for illustrating a process performed by a controller according to Embodiment 4. The process in the flowchart of FIG. 17 includes step S22 instead of step S2 of the process in the flowchart shown in FIG. 11.

The description of the other features of the process is given above in connection with FIG. 11, and therefore, step S22 is described here.

[0079] While the process in FIG. 11 increases the degree of opening of LEV1 such that $T_{sen} > T_{fro}$ detected by temperature sensor 111 is satisfied (S2), the process in FIG. 17 increases the degree of opening of LEV3 such that $T_{sen} > T_{fro}$ is satisfied (S22), when $T_{sen} < T_{fro}$ is satisfied (YES in S1).

[0080] FIG. 18 is a p-h diagram for illustrating a change in the refrigeration cycle according to Embodiment 4. In step S22, the degree of opening of LEV3 is increased, which increases refrigerant in bypass flow path 62 that merges into two-phase refrigerant flowing into outdoor heat exchanger 40, so that the temperature at the inlet of outdoor heat exchanger 40 increases. In the refrigeration cycle, as shown by arrows CY21 and CY22 on the p-h diagram shown in FIG. 18, a part of the discharged gas merges into the refrigerant, and accordingly, the specific enthalpy of the refrigerant at the inlet of outdoor heat exchanger 40 also increases.

[0081] In this way, Embodiment 4 changes the degree of opening of LEV3 so as to keep, at around 0° C., the portion where temperature sensor 111 is disposed, and keep the boundary as intended between frost region A1 and non-frost region A2.

[0082] When compressor frequency F reaches maximum value F_{max} during operation and the target capacity is not reached, the defrosting operation is started after the determination of whether or not defrosting is necessary (S4).

[0083] By employing the configuration and control like those in Embodiment 4 as well, only a partial region of outdoor heat exchanger 40 can be frosted and the defrosting period can be extended.

Embodiment 5

[0084] FIG. 19 shows a configuration of a refrigeration cycle apparatus according to Embodiment 5. In refrigeration cycle apparatus 140 shown in FIG. 19, refrigerant circuit 80 further includes a heater 141, in addition to the components of refrigeration cycle apparatus 110 in FIG. 8. Heater 141 is capable of heating refrigerant flowing in pipe 54. The description of the other components is given above in connection with FIG. 8, and therefore, the description thereof is not be herein repeated.

[0085] FIG. 20 is a flowchart for illustrating a process performed by a controller according to Embodiment 5. The process in the flowchart of FIG. 20 includes step S32 instead of step S2 of the process in the flowchart shown in FIG. 11. The description of the other features of the process is given above in connection with FIG. 11, and therefore, step S32 is described here.

[0086] While the process in FIG. 11 increases the degree of opening of LEV1 such that $T_{sen} > T_{fro}$ detected by temperature sensor 111 is satisfied (S2), the process in FIG. 20 increases the amount of heat generated by heater 141 such that $T_{sen} \geq T_{fro}$ is satisfied (S32), when $T_{sen} < T_{fro}$ is satisfied (YES in S1).

[0087] FIG. 21 is a p-h diagram for illustrating a change in the refrigeration cycle according to Embodiment 5. In step S32, the amount of heat generated by heater 141 is increased, which raises the temperature of refrigerant flowing into outdoor heat exchanger 40, so that the temperature at the inlet of outdoor heat exchanger 40 increases. The

refrigeration cycle changes from CY31 to CY32 on the p-h diagram shown in FIG. 21, and the specific enthalpy of refrigerant at the inlet of outdoor heat exchanger 40 also increases as shown by an arrow in the drawing.

[0088] In this way, Embodiment 5 changes the amount of heat generated by heater 141, so as to keep, at around 0° C., the portion where temperature sensor 111 is disposed, and keep the boundary as intended between frost region A1 and non-frost region A2.

[0089] When compressor frequency F reaches maximum value F_{max} during operation and the target capacity is not reached, the defrosting operation is started after the determination of whether or not defrosting is necessary (S4).

[0090] By employing the configuration and control like those in Embodiment 5 as well, only a partial region of outdoor heat exchanger 40 can be frosted and the defrosting period can be extended.

Embodiment 6

[0091] FIG. 22 shows a configuration of a refrigeration cycle apparatus according to Embodiment 6. In refrigeration cycle apparatus 150 shown in FIG. 22, refrigerant circuit 80 further includes, in addition to the components of refrigeration cycle apparatus 110 in FIG. 8, a three-way valve 152 and an internal heat exchanger 151. Three-way valve 152 is a flow-path switching device that is provided on pipe 51 and switches, in accordance with a control signal from controller 90, the flow path to convey refrigerant discharged from compressor 10 directly to port P1 of the four-way valve, or to convey the refrigerant through internal heat exchanger 151 to port P1. Internal heat exchanger 151 is configured to exchange heat between refrigerant flowing through pipe 54 and refrigerant conveyed from compressor 10 through three-way valve 152. The description of the other components is given above in connection with FIG. 8, and therefore, the description thereof is not be herein repeated.

[0092] FIG. 23 is a flowchart for illustrating a process performed by a controller according to Embodiment 6. The process in the flowchart of FIG. 23 includes step S42 instead of step S2 of the process in the flowchart shown in FIG. 11. The description of the other features of the process is given above in connection with FIG. 11, and therefore, step S42 is described here.

[0093] While the process in FIG. 11 increases the degree of opening of LEV1 such that $T_{sen} > T_{fro}$ detected by temperature sensor 111 is satisfied (S2), the process in FIG. 20 switches three-way valve 152 such that refrigerant discharged from compressor 10 flows through internal heat exchanger 151 (S42), when $T_{sen} < T_{fro}$ is satisfied (YES in S1). Accordingly, the state of refrigerant circuit 80 becomes a state where $T_{sen} \geq T_{fro}$ is satisfied, or becomes closer to such a state.

[0094] FIG. 24 is a p-h diagram for illustrating a change in the refrigeration cycle according to Embodiment 6. In step S42, three-way valve 152 is switched so as to introduce the discharged refrigerant into internal heat exchanger 151, and then, the refrigeration cycle changes from CY41 to CY42 on the p-h diagram shown in FIG. 24. Specifically, as shown by CY42, refrigerant discharged from compressor 10 releases heat as shown by arrow CY42A until the refrigerant flows into indoor heat exchanger 20. The refrigerant having passed through LEV1 receives heat as indicated by arrow CY42B, and therefore, the temperature of the refrigerant flowing into outdoor heat exchanger 40 increases.

[0095] In this way, Embodiment 6 changes the destination of the discharged refrigerant so as to cause the refrigerant to flow through internal heat exchanger 151 so as to keep, at around 0° C., the portion where temperature sensor 111 is disposed, and keep the boundary as intended between frost region A1 and non-frost region A2.

[0096] When compressor frequency F reaches maximum value Fmax during operation and the target capacity is not reached, the defrosting operation is started after the determination of whether or not defrosting is necessary (S4).

[0097] By employing the configuration and control like those in Embodiment 6 as well, only a partial region of outdoor heat exchanger 40 can be frosted and the defrosting period can be extended.

SUMMARY

[0098] The above embodiments are now summarized again with reference to the drawings.

[0099] The present disclosure relates to refrigeration cycle apparatus 100. Refrigeration cycle apparatus 100 shown in FIG. 1 includes: refrigerant circuit 80 in which compressor 10, indoor heat exchanger 20 (condenser), first expansion valve LEV1, and outdoor heat exchanger 40 (evaporator) are connected by refrigerant pipes 51 to 56; and a non-azeotropic refrigerant that flows through refrigerant pipes 51 to 56. When the non-azeotropic refrigerant passes through outdoor heat exchanger 40 (evaporator), a temperature difference occurs between the inlet and the outlet of outdoor heat exchanger 40 (evaporator). As shown in FIGS. 5 and 6, outdoor heat exchanger 40 (evaporator) includes: groups of fins L1, L2 that are stacked at intervals; and heat transfer tubes R1 to R12 that extend through groups of fins L1, L2 in a stacking direction of groups of fins L1, L2 and allow the non-azeotropic refrigerant to flow inside the heat transfer tubes. Groups of fins L1, L2 each include: a first fin part (frost region A1) to which frost can adhere in a humid environment; and a second fin part (non-frost region A2) to which no frost adhere to ensure ventilation.

[0100] Preferably, refrigeration cycle apparatus 100 further includes controller 90 configured to control refrigerant circuit 80. As described above in connection with FIGS. 4 and 5, controller 90 is configured to control refrigerant circuit 80 such that the non-azeotropic refrigerant flowing in the heat transfer tubes (heat transfer tubes R1 to R3) extending through the first fin part has a temperature of 0° C. or lower and the non-azeotropic refrigerant flowing in the heat transfer tubes (heat transfer tubes R4 to R12) extending through the second fin part has a temperature of 0° C. or higher.

[0101] Preferably, as shown in FIGS. 8 and 9, the first fin part is disposed in predetermined frost region A1 in outdoor heat exchanger 40 (evaporator). The second fin part is disposed in predetermined non-frost region A2 in outdoor heat exchanger 40 (evaporator). Refrigeration cycle apparatus 110 further includes temperature sensor 111 disposed at a boundary between frost region A1 and non-frost region A2 in outdoor heat exchanger 40 (evaporator). Controller 90 is configured to control the degree of opening of first expansion valve LEV1 based on an output of temperature sensor 111 such that the temperature of the boundary between frost region A1 and non-frost region A2 is 0° C.

[0102] Preferably, in refrigeration cycle apparatus 120 shown in FIG. 13, refrigerant circuit 80 further includes: bypass flow path 61 that branches at branching point BP1

from refrigerant pipe 53 connecting indoor heat exchanger 20 (condenser) to first expansion valve LEV1, to return refrigerant to compressor 10; second expansion valve LEV2 disposed in bypass flow path 61; and internal heat exchanger 121 configured to exchange heat between refrigerant flowing from indoor heat exchanger 20 (condenser) toward branching point BP1 and refrigerant having passed through second expansion valve LEV2.

[0103] Preferably, as shown in FIGS. 8 and 9, the first fin part is disposed in predetermined frost region A1 in outdoor heat exchanger 40 (evaporator). The second fin part is disposed in predetermined non-frost region A2 in outdoor heat exchanger 40 (evaporator). Refrigeration cycle apparatus 120 shown in FIG. 13 further includes temperature sensor 111 disposed at a boundary between frost region A1 and non-frost region A2 in outdoor heat exchanger 40 (evaporator). Controller 90 is configured to control the degree of opening of second expansion valve LEV2 based on an output of temperature sensor 111, as shown in FIG. 14, such that the temperature of the boundary between frost region A1 and non-frost region A2 is 0° C.

[0104] Preferably, in refrigeration cycle apparatus 130 shown in FIG. 16, refrigerant circuit 80 further includes: bypass flow path 62 that branches from the refrigerant pipe between a discharge outlet of compressor 10 and indoor heat exchanger 20 (condenser) and merges into the refrigerant pipe connecting first expansion valve LEV1 to outdoor heat exchanger 40 (evaporator); and expansion valve LEV3 serving as a flow rate adjustment valve disposed in bypass flow path 62.

[0105] More preferably, as shown in FIGS. 8 and 9, the first fin part is disposed in predetermined frost region A1 in outdoor heat exchanger 40 (evaporator). The second fin part is disposed in predetermined non-frost region A2 in outdoor heat exchanger 40 (evaporator). Refrigeration cycle apparatus 130 shown in FIG. 16 further includes temperature sensor 111 disposed at a boundary between frost region A1 and non-frost region A2 in outdoor heat exchanger 40 (evaporator). Controller 90 is configured to control the degree of opening of LEV3 based on an output of temperature sensor 111, as shown in FIG. 17, such that the temperature of the boundary between frost region A1 and non-frost region A2 is 0° C.

[0106] Preferably, in refrigeration cycle apparatus 140 shown in FIG. 19, refrigerant circuit 80 further includes heater 141 configured to heat refrigerant flowing in refrigerant pipe 54 connecting first expansion valve LEV1 to outdoor heat exchanger 40 (evaporator).

[0107] More preferably, as shown in FIGS. 8 and 9, the first fin part is disposed in predetermined frost region A1 in outdoor heat exchanger 40 (evaporator). The second fin part is disposed in predetermined non-frost region A2 in outdoor heat exchanger 40 (evaporator). Refrigeration cycle apparatus 140 shown in FIG. 19 further includes temperature sensor 111 disposed at a boundary between frost region A1 and non-frost region A2 in outdoor heat exchanger 40 (evaporator). Controller 90 is configured to control the amount of heat generated by heater 141 based on an output of temperature sensor 111, as shown in FIG. 20, such that the temperature of the boundary between frost region A1 and non-frost region A2 is 0° C.

[0108] Preferably, in refrigeration cycle apparatus 150 shown in FIG. 22, refrigerant pipe 51, which is a part of the refrigerant pipe connecting the discharge outlet of compres-

sor **10** to indoor heat exchanger **20** (condenser), includes a first flow path **51A** and a second flow path **51B** disposed in parallel with first flow path **51A**. Refrigerant circuit **80** further includes: internal heat exchanger **151** configured to exchange heat between refrigerant flowing from first expansion valve **LEV1** toward outdoor heat exchanger **40** (evaporator), and refrigerant flowing in second flow path **51B**; and three-way valve **152** configured to switch to allow refrigerant discharged from compressor **10** to flow in first flow path **51A** or flow in second flow path **51B**.

[0109] More preferably, as shown in FIGS. **8** and **9**, the first fin part is disposed in predetermined frost region **A1** in outdoor heat exchanger **40** (evaporator). The second fin part is disposed in predetermined non-frost region **A2** in outdoor heat exchanger **40** (evaporator). Refrigeration cycle apparatus **150** shown in FIG. **22** further includes temperature sensor **111** disposed at a boundary between frost region **A1** and non-frost region **A2** in outdoor heat exchanger **40** (evaporator). Controller **90** is configured to control three-way valve **152** based on an output of temperature sensor **111** as shown in FIG. **23**, such that the temperature of the boundary between frost region **A1** and non-frost region **A2** is 0° C.

[0110] Preferably, refrigeration cycle apparatus **100** further includes a four-way valve **50** capable of interchanging the discharge outlet and the suction inlet of compressor **10** to connect the discharge outlet and the suction inlet to refrigerant circuit **80**. Four-way valve **50** is capable of switching to allow refrigerant to flow through refrigerant circuit **80** in a first direction in which refrigerant flows in the order of compressor **10**, indoor heat exchanger **20** (condenser), first expansion valve **LEV1**, and outdoor heat exchanger **40** (evaporator), or a second direction in which refrigerant flows in the order of compressor **10**, outdoor heat exchanger **40** (evaporator), first expansion valve **LEV1**, and indoor heat exchanger **20** (condenser).

[0111] The above configuration provide unbalanced frosting to enable extension of the defrosting period, which also provides improvement in comfort for the load. Further, the integrated heating capacity increases, which improves the average COP.

[0112] It should be construed that the embodiments disclosed herein are given by way of illustration in all respects, not by way of limitation. It is intended that the scope of the present disclosure is defined by claims, not by the above description of the embodiments, and encompasses all modifications equivalent in meaning and scope to the claims.

REFERENCE SIGNS LIST

[0113] **10** compressor; **20, 40, 121, 151** heat exchanger; **50** four-way valve; **51-56** pipe; **51A** first flow path; **51B** second flow path; **61, 62** bypass flow path; **80** refrigerant circuit; **90** controller; **91** CPU; **92** memory; **100, 110, 120, 130, 140, 150** refrigeration cycle apparatus; **111** temperature sensor; **141** heater; **152** three-way valve; **A1** frost region; **A2** non-frost region; **BP1, BP2** branching point; **C12, C23, C34, C45, C56, C67, C89, C1011** connection pipe; **L1, L2** group of fins; **LEV1, LEV2, LEV3** expansion valve; **P1, P2, P3, P4** port; **R1-R12** heat transfer tube

1. A refrigeration cycle apparatus comprising:

a refrigerant circuit in which a compressor, a condenser, a first expansion valve, and an evaporator are connected by a refrigerant pipe; and

a non-azeotropic refrigerant that flows through the refrigerant pipe, wherein

when the non-azeotropic refrigerant passes through the evaporator, a temperature difference occurs between an inlet and an outlet of the evaporator,

the evaporator comprises:

a group of fins that are stacked at intervals; and

a heat transfer tube that extends through the group of fins in a stacking direction of the group of fins and allows the non-azeotropic refrigerant to flow inside the heat transfer tube, and

the group of fins comprises:

a first fin part to which frost can adhere in a humid environment; and

a second fin part to which no frost adheres to ensure ventilation;

the first fin part is disposed in a predetermined frost region in the evaporator, and

the second fin part is disposed in a predetermined non-frost region in the evaporator,

the refrigeration cycle apparatus further comprises a temperature sensor disposed at a boundary between the frost region and the non-frost region in the evaporator.

2. The refrigeration cycle apparatus according to claim 1, further comprising a controller configured to control the refrigerant circuit, wherein

the controller is configured to control the refrigerant circuit such that, when air exchanging heat with the evaporator has a temperature of 0° C. or higher, the non-azeotropic refrigerant flowing in the heat transfer tube extending through the first fin part has a temperature of 0° C. or lower and the non-azeotropic refrigerant flowing in the heat transfer tube in the second fin part has a temperature of 0° C. or higher and lower than or equal to the temperature of the air.

3. The refrigeration cycle apparatus according to claim 2, wherein

the controller is configured to control a degree of opening of the first expansion valve based on an output of the temperature sensor such that a temperature of the boundary is 0° C.

4. The refrigeration cycle apparatus according to claim 2, wherein

the refrigerant circuit further comprises:

a bypass flow path that branches at a branching point from the refrigerant pipe connecting the condenser to the first expansion valve, to return refrigerant to the compressor,

a second expansion valve disposed in the bypass flow path, and

an internal heat exchanger configured to exchange heat between refrigerant flowing from the condenser toward the branching point and refrigerant having passed through the second expansion valve.

5. The refrigeration cycle apparatus according to claim 4, wherein

the controller is configured to control a degree of opening of the second expansion valve based on an output of the temperature sensor such that a temperature of the boundary is 0° C.

6. The refrigeration cycle apparatus according to claim 2, wherein

the refrigerant circuit further comprises

- a bypass flow path that branches from the refrigerant pipe between a discharge outlet of the compressor and the condenser and merges into the refrigerant pipe between the first expansion valve and the evaporator, and
- a flow rate adjustment valve disposed in the bypass flow path.

7. The refrigeration cycle apparatus according to claim 6, wherein

the controller is configured to control a degree of opening of the flow rate adjustment valve based on an output of the temperature sensor such that a temperature of the boundary is 0° C.

8. The refrigeration cycle apparatus according to claim 2, wherein the refrigerant circuit further comprises a heater configured to heat refrigerant flowing in the refrigerant pipe connecting the first expansion valve to the evaporator.

9. The refrigeration cycle apparatus according to claim 8, wherein

the controller is configured to control an amount of heat generated by the heater based on an output of the temperature sensor such that a temperature of the boundary is 0° C.

10. The refrigeration cycle apparatus according to claim 2, wherein

- a part of the refrigerant pipe connecting a discharge outlet of the compressor to the condenser comprises:
 - a first flow path; and
 - a second flow path disposed in parallel with the first flow path, and

the refrigerant circuit further comprises:

- an internal heat exchanger configured to exchange heat between refrigerant flowing from the first expansion valve toward the evaporator, and refrigerant flowing in the second flow path, and

- a flow path switching device configured to switch to allow refrigerant discharged from the compressor to flow in the first flow path or flow in the second flow path.

11. The refrigeration cycle apparatus according to claim 10, wherein

the controller is configured to control the flow path switching device based on an output of the temperature sensor such that a temperature of the boundary is 0° C.

12. The refrigeration cycle apparatus according to claim 1, further comprising a four-way valve configured to interchange a discharge outlet and a suction inlet of the compressor to connect the discharge outlet and the suction inlet to the refrigerant circuit, wherein

the four-way valve is configured to switch to allow refrigerant to flow through the refrigerant circuit in a first direction or a second direction, the refrigerant flowing in order of the compressor, the condenser, the first expansion valve, and the evaporator in the first direction, the refrigerant flowing in order of the compressor, the evaporator, the first expansion valve, and the condenser in the second direction.

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