

(19)



(11)

EP 3 163 219 A1

(12)

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

(43) Date of publication:
03.05.2017 Bulletin 2017/18

(51) Int Cl.:
F25B 1/00 (2006.01) F24F 11/02 (2006.01)

(21) Application number: **15811419.9**

(86) International application number:
PCT/JP2015/064032

(22) Date of filing: **15.05.2015**

(87) International publication number:
WO 2015/198741 (30.12.2015 Gazette 2015/52)

(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:
MA

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(30) Priority: **24.06.2014 JP 2014129486**

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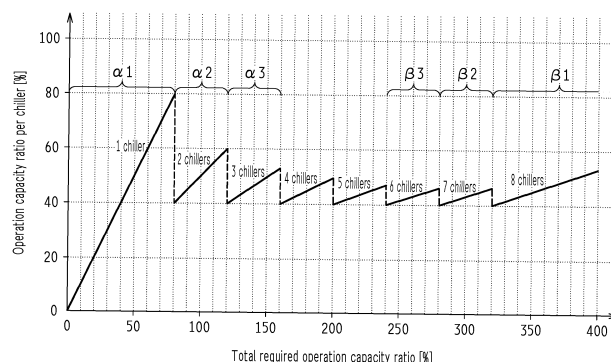
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(54) **CHILLER SYSTEM**

(57) A chiller system includes a plurality of heat pump chillers connected to each other, the plurality of heat pump chillers regulating a temperature of a circulating liquid as a heat medium for temperature regulation by condensation heat or evaporation heat of a refrigerant. When there is at least one active chiller out of the plurality of chillers, an operation command is transmitted, to one of the remaining chillers being stopped, under a condition that the following relation is satisfied: [total required op-

eration capacity] / ([number of currently active chillers] + 1) $\geq$ [partial load capacity], where the [total required operation capacity] represents a total operation capacity required of the at least one active chiller, the [number of currently active chillers] represents the number of the at least one active chiller, and the [partial load capacity] represents a load capacity of a predetermined partial load.

FIG.6



Description

Technical Field

5 **[0001]** The present invention relates to a chiller system in which a plurality of heat pump chillers is connected to each other, the chillers regulating a temperature of a circulating liquid as a heat medium for temperature regulation by condensation heat or evaporation heat of a refrigerant.

Background Art

10 **[0002]** A chiller system in which a plurality of heat pump chillers is connected to each other is conventionally known, where the chillers are to regulate the temperature of a circulating liquid as a heat medium for regulating the temperature (for example, for air conditioning) by condensation heat or evaporation heat of a refrigerant (for example, see Patent Document 1).

15 **[0003]** In such a chiller system, generally, the number of chillers to be operated is increased/decreased, out of the plurality of chillers, according to a required load capacity. In this case, it is desired to level respective cumulative operation times of the chillers by not operating particular chillers unevenly but operating each chiller evenly, from the viewpoint that it is preferable to perform maintenance on the plurality of chillers at the same time.

20 **[0004]** In this regard, Patent Document 1 discloses a configuration in which control is carried out so that a plurality of chilling units (chillers) is operated in rotation based on the number of times of thermo-ON (the number of times of thermo-ON at which a compressor is driven) for each chiller, for the purpose of levelling an actual operation time (cumulative operation time) of each of the chillers.

Prior Art Document

25 Patent Document

[0005] [Patent Document 1] JP H10-122604 A

Summary of Invention

Problem to Be Solved by Invention

35 **[0006]** However, in the chiller system described in Patent Document 1, when the load capacity is increased, a newly active chiller is added after the operation capacity of each of the current active chillers reaches 100% output (rated output) (see paragraphs [0073]-[0075] of the Patent Document 1). Thus, when a partial load at which the operation output does not reach the rated output of the chiller is continuously applied, no newly active chiller is added while such a partial load is being continuously applied. As a result, the respective cumulative operation times of the chillers are likely to vary largely.

40 **[0007]** In consideration of the above circumstances, an object of the present invention is to provide a chiller system in which a plurality of heat pump chillers is connected to each other, the chiller system capable of leveling respective cumulative operation times of the chillers even when a partial load at which an operation output does not reach a rated output of the chiller is continuously applied.

Means for Solving Problem

45 **[0008]** In order to resolve the above problem, the present invention provides a chiller system including a plurality of heat pump chillers being connected to each other, the plurality of heat pump chillers regulating a temperature of a circulating liquid as a heat medium for temperature regulation by condensation heat or evaporation heat of a refrigerant. When there is at least one active chiller out of the plurality of chillers, an operation command is transmitted, to one of the remaining chillers being stopped, under a condition that the following relation is satisfied: [total required operation capacity] / ([number of currently active chillers] + 1) $\geq$ [partial load capacity], where the [total required operation capacity] represents a total operation capacity required of the at least one active chiller, the [number of currently active chillers] represents the number of the at least one active chiller, and the [partial load capacity] represents a load capacity of a predetermined partial load.

55 **[0009]** In an exemplary aspect of the present invention, the plurality of chillers is each capable of being in a normal state, an alarming state in which an alarm is being transmitted, or a before-alarming state that is a state between the normal state and the alarming state. A target chiller for a next operation command is selected in the order of: an active

chiller in the before-alarming state; a stopped chiller in the before-alarming state; an active chiller in the normal state; and a stopped chiller in the normal state. When the chillers are in the same state, the target chiller for the next operation command is selected in ascending order of a cumulative output amount from an initial state or from a time point at which a predetermined maintenance has been performed.

[0010] In an exemplary aspect of the present invention, when there is at least one active chiller out of the plurality of chillers, a stop command is transmitted to one of the at least one active chiller under a condition that the following relation is satisfied: $[\text{total required operation capacity}] / [\text{number of currently active chillers}] \leq [\text{partial load capacity}]$.

[0011] In an exemplary aspect of the present invention, the plurality of chillers is each capable of being in the normal state, the alarming state in which an alarm is being transmitted, or the before-alarming state that is a state between the normal state and the alarming state. A target chiller for a next stop command is selected in the order of: a stopped chiller in the normal state; an active chiller in the normal state; a stopped chiller in the before-alarming state; and an active chiller in the before-alarming state. When the chillers are in the same state, the target chiller for the next stop command is selected in descending order of the cumulative output amount from the initial state or from the time point at which a predetermined maintenance has been performed.

Effects of Invention

[0012] With the present invention providing a chiller system in which a plurality of heat pump chillers is connected to each other, it is possible to level respective cumulative operation times of the chillers even when a partial load at which an operation output does not reach a rated output is continuously applied.

Brief Description of Drawings

[0013]

[FIG. 1] FIG. 1 is a system diagram showing a schematic configuration of a chiller system according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a schematic block diagram showing one chiller in the chiller system.

[FIG. 3] FIG. 3 is a schematic block diagram showing a chiller that performs a cooling operation.

[FIG. 4] FIG. 4 is a schematic block diagram showing a chiller that performs a heating operation.

[FIG. 5] FIG. 5 is a schematic block diagram showing a chiller that performs a defrost operation.

[FIG. 6] FIG. 6 is a graph indicating a control operation performed by a master chiller on each chiller in the chiller system in which the number of the chillers is set to eight.

[FIG. 7] FIG. 7 is a flowchart indicating steps of one example of the control operation by the master chiller on each chiller so as to control the number of active chillers.

[FIG. 8] FIG. 8 is a table for determining the priority of the chillers when increasing/decreasing the number of active chillers.

Modes for Carrying out Invention

[0014] Hereinafter, an embodiment according to the present invention will be described with reference to the drawings.

[0015] FIG. 1 is a system diagram showing a schematic configuration of a chiller system 1 according to an embodiment of the present invention.

[0016] In the chiller system 1 shown in FIG. 1, a plurality of heat pump chillers 100 is connected in parallel. Hereinafter, a heat pump chiller is occasionally referred to, simply, as a chiller.

[0017] Specifically, the chiller system 1 includes: the plurality of chillers 100 (1) to 100 (n) (n is an integer of ≥ 2); and a circulating liquid circuit 200. Each of the chillers 100 (1) to 100 (n) has the same configuration. Accordingly, the rated output for each of the chillers 100 (1) to 100 (n) is set to the same value. Hereinafter, each of the chillers 100 (1) to 100 (n) is occasionally indicated simply with the reference numeral 100.

[0018] The chiller system 1 further includes: the circulating liquid circuit 200 that is installed in a temperature regulation target area (for example, an air conditioning target area, not shown) for circulating a circulating liquid as a heat medium for temperature regulation (for example, for air conditioning); and circulation pumps 300 (1) to 300 (n) respectively disposed corresponding to the chillers 100 (1) to 100 (n) in the circulating liquid circuit 200 so as to circulate the circulating liquid in the circulating liquid circuit 200. The circulation pumps 300 (1) to 300 (n) regulate the temperature of the circulating liquid that flows in the circulating liquid circuit 200. Here, any circulating liquid can be used provided that it serves as the heat medium, and representative examples thereof include water. However, the circulating liquid is not limited thereto. For example, water containing antifreeze liquid can be used.

[0019] The circulating liquid circuit 200 is constituted by: an inlet main pipe 210 to flow the circulating liquid toward

the plurality of chillers 100 (1) to 100 (n); inlet branch pipes 211 (1) to 211 (n) to divide and flow the circulating liquid from the inlet main pipe 210 into the respective chillers 100 (1) to 100 (n); an outlet main pipe 220 to flow the circulating liquid out of the plurality of chillers 100 (1) to 100 (n); and outlet branch pipes 221 (1) to 221 (n) to flow and join the circulating liquid from the plurality of chillers 100 (1) to 100 (n) to the outlet main pipe 220.

[0020] Specifically, the inlet branch pipes 211 (1) to 211 (n) each connect a branch portion of the inlet main pipe 210 that corresponds to each chiller 100 (1) to 100 (n) and a circulating liquid flowing-in side of each chiller 100 (1) to 100 (n). The outlet branch pipes 221 (1) to 221 (n) each connect a circulating liquid flowing-out side of each chiller 100 (1) to 100 (n) and a confluence portion of the outlet main pipe 220 that corresponds to each chiller 100 (1) to 100 (n). On one side of each pair of the inlet branch pipes 211 (1) to 211 (n) and the outlet branch pipe 221 (1) to 221 (n) (in this example, on the side of the outlet branch pipes 221 (1) to 221 (n)), each circulation pump 300 (1) to 300 (n) is disposed to circulate the circulating liquid in the circulating liquid circuit 200.

[0021] In the chiller system 1 having the above configuration, the circulating liquid that is circulated by the circulation pumps 300 (1) to 300 (n) is divided and flows, from the inlet main pipe 210, into each chiller 100 (1) to 100 (n) via each inlet branch pipe 211 (1) to 211 (n), and the temperature of the circulating liquid is regulated by each chiller 100 (1) to 100 (n). The circulating liquid whose temperature is regulated is joined, from each chiller 100 (1) to 100 (n), to the outlet main pipe 220 via each outlet branch pipe 221 (1) to 221 (n), and is circulated in the temperature regulation target area (for example, the air conditioning target area) of the circulating liquid circuit 200. The respective load sides of the inlet main pipe 210 and the outlet main pipe 220 are connected to each other, for example, via a heat exchanger not shown, and constitute a closed circuit.

[0022] FIG. 2 is a schematic block diagram showing one chiller 100 in the chiller system 1. Note that FIG. 2 shows one inlet branch pipe 211 out of the inlet branch pipes 211 (1) to 211 (n), one outlet branch pipe 221 out of the outlet branch pipes 221 (1) to 221 (n), and one circulation pump 300 out of the circulation pumps 300 (1) to 300 (n).

[0023] The chiller 100 drives a compressor 10 that compresses a refrigerant so as to regulate the temperature of the circulating liquid by the condensation heat or the evaporation heat of the refrigerant.

[0024] That is, the chiller 100 includes: the compressor 10 that sucks and discharges the refrigerant; a refrigerant-air heat exchanger 20 that exchanges heat between the refrigerant and air (specifically, outside air); a refrigerant-air heat exchanger fan 30 for the refrigerant-air heat exchanger 20; an expansion valve 40 that expands the refrigerant compressed by the compressor 10; a refrigerant-circulating liquid heat exchanger 50 that exchanges heat between the circulating liquid and the refrigerant; an engine 60 that drives the compressor 10; and an engine exhaust heat recovery unit 70 that recovers exhaust heat of the engine 60. The chiller 100 is capable of executing a heating operation, a cooling operation and a defrost operation as described later. In this example, the expansion valve 40 is constituted by a closable first expansion valve 41 and a closable second expansion valve 42.

[0025] The compressor 10 may be constituted by a plurality of compressors connected in parallel. Also, the refrigerant-air heat exchanger 20 may be constituted by a plurality of refrigerant-air heat exchangers connected in parallel.

[0026] Specifically, the chiller 100 further includes: a refrigerant circuit 110 to circulate the refrigerant; a coolant path 120 to circulate an engine coolant for cooling the engine 60; a circulation pump 130 for the coolant path 120; and a control device 140.

[0027] In the refrigerant circuit 110, the compressor 10, the refrigerant-air heat exchanger 20, the refrigerant-circulating liquid heat exchanger 50, the expansion valve 40 and the engine exhaust heat recovery unit 70 are disposed.

[0028] The refrigerant circuit 110 includes: a four-way valve 111; a bridge circuit 112; a high pressure gas refrigerant path 113a; a first low pressure gas refrigerant path 113b; a first gas refrigerant path 113c; a first refrigerant path 113d; a high pressure liquid refrigerant path 113e; a first low pressure gas-liquid two phase refrigerant path 113f; a second refrigerant path 113g; a second gas refrigerant path 113h; a second low pressure gas-liquid two phase refrigerant path 113i; and a second low pressure gas refrigerant path 113j.

[0029] The four-way valve 111 is switched, in response to an instruction signal from the control device 140, between a first connection state (state shown in FIG. 2) in which an inlet (lower side in FIG. 2) is connected to one connection port (left side in FIG. 2) and furthermore the other connection port (right side in FIG. 2) is connected to an outlet (upper side in FIG. 2), and a second connection state in which the inlet is connected to the other connection port and furthermore the one connection port is connected to the outlet. Thus, the four-way valve 111 can switch the flowing direction of the refrigerant.

[0030] The bridge circuit 112 includes four check valves (a first check valve 112a, a second check valve 112b, a third check valve 112c and a fourth check valve 112d), and is constituted by a first check valve line 1121 including two check valves (the first check valve 112a and the second check valve 112b) and a second check valve line 1122 including the remaining two check valves (the third check valve 112c and the fourth check valve 112d).

[0031] The first check valve line 1121 is constituted by the first check valve 112a and the second check valve 112b that are connected in series so that the refrigerant flows in the same direction. The second check valve line 1122 is constituted by the third check valve 112c and the fourth check valve 112d that are connected in series so that the refrigerant flows in the same direction. Furthermore, the first check valve line 1121 and the second check valve line

1122 are connected in parallel so that the refrigerant flows in the same direction.

[0032] In the bridge circuit 112, a connection point between the first check valve 112a and the second check valve 112b is referred to as a first intermediate connection point P1, a connection point between the first check valve 112a and the third check valve 112c is referred to as an outlet connection point P2, a connection point between the third check valve 112c and the fourth check valve 112d is referred to as a second intermediate connection point P3, and a connection point between the second check valve 112b and the fourth check valve 112d is referred to as an inlet connection point P4.

[0033] The high pressure gas refrigerant path 113a connects a discharge port of the compressor 10 and the inlet of the four-way valve 111. The first low pressure gas refrigerant path 113b connects the outlet of the four-way valve 111 and a suction port of the compressor 10. The first gas refrigerant path 113c connects the one connection port of the four-way valve 111 and one connection port of the refrigerant-air heat exchanger 20. The first refrigerant path 113d connects the other connection port of the refrigerant-air heat exchanger 20 and the first intermediate connection point P1 of the bridge circuit 112. The high pressure liquid refrigerant path 113e connects the outlet connection point P2 of the bridge circuit 112 and one side of the expansion valve 40 (specifically, the first expansion valve 41 and the second expansion valve 42). The first low pressure gas-liquid two phase refrigerant path 113f connects the other side of the first expansion valve 41 constituting the expansion valve 40 and the inlet connection point P4 of the bridge circuit 112. The second refrigerant path 113g connects the second intermediate connection point P3 of the bridge circuit 112 and one refrigerant connection port of the refrigerant-circulating liquid heat exchanger 50. The second gas refrigerant path 113h connects the other refrigerant connection port of the refrigerant-circulating liquid heat exchanger 50 and the other connection port of the four-way valve 111. The second low pressure gas-liquid two phase refrigerant path 113i connects the other side of the second expansion valve 42 constituting the expansion valve 40 and a refrigerant inlet of the engine exhaust heat recovery unit 70. The second low pressure gas refrigerant path 113j connects a refrigerant outlet of the engine exhaust heat recovery unit 70 and a confluence point P5 located in the middle of the first low pressure gas refrigerant path 113b. In the first low pressure gas refrigerant path 113b, the downstream side of the confluence point P5 (the side of the compressor 10) is referred to as a confluence path 113b1.

[0034] The respective opening degrees of the first expansion valve 41 and the second expansion valve 42 can be adjusted in response to the instruction signal from the control device 140. Thus, the amount of the refrigerant circulating in the refrigerant circuit 110 can be adjusted by the first expansion valve 41 and the second expansion valve 42. Specifically, the first expansion valve 41 and the second expansion valve 42 are configured by connecting a plurality of closable expansion valves in parallel. In this way, the first expansion valve 41 and the second expansion valve 42 can adjust the amount of the refrigerant circulating in the refrigerant circuit 110 by being combined as the expansion valve(s) to be opened.

[0035] In this embodiment, the chiller 100 further includes an oil separator 81, an accumulator 82 and a receiver 83.

[0036] The oil separator 81 is disposed in the high pressure gas refrigerant path 113a, and separates a lubricant oil of the compressor 10 contained in the refrigerant so as to return the separated lubricant oil to the compressor 10 via a valve 81a (more specifically, a solenoid valve). The accumulator 82 is disposed in the confluence path 113b1 of the first low pressure gas refrigerant path 113b, and separates the liquid refrigerant that has not been completely evaporated by the refrigerant-circulating liquid heat exchanger 50 serving as an evaporator or by the refrigerant-air heat exchanger 20 serving as an evaporator. The receiver 83 is disposed in the high pressure liquid refrigerant path 113e, and temporarily stores the high pressure liquid refrigerant from the bridge circuit 112.

[0037] The coolant path 120 constitutes the path for the engine coolant that cools the engine 60, and includes a first thermostat type switching valve 121, a second thermostat type switching valve 122, a radiator 123, an outlet path 124a, an inlet path 124b, and a first path 124c to a fifth path 124g.

[0038] The outlet path 124a connects an outlet of the engine 60 and an inlet (lower side in FIG. 2) of the first thermostat type switching valve 121. The inlet path 124b connects an outlet of the radiator 123 and an inlet of the engine 60. The first path 124c connects one outlet (upper side in FIG. 2) of the first thermostat type switching valve 121 and an inlet (left side in FIG. 2) of the second thermostat type switching valve 122. The second path 124d connects the other outlet (right side in FIG. 2) of the first thermostat type switching valve 121 and an inlet of the radiator 123. The third path 124e connects one outlet (upper side in FIG. 2) of the second thermostat type switching valve 122 and a coolant inlet of the engine exhaust heat recovery unit 70. The fourth path 124f connects the other outlet (right side in FIG. 2) of the second thermostat type switching valve 122 and a confluence point P6 located in the middle of the inlet path 124b. The fifth path 124g connects a coolant outlet of the engine exhaust heat recovery unit 70 and a confluence point P7 located upstream of the confluence point P6 of the inlet path 124b. The circulation pump 130 is disposed in the inlet path 124b, between the inlet of the engine 60 and the confluence point P6. The circulation pump 130 circulates the engine coolant in the coolant path 120 in response to the instruction signal from the control device 140. The engine exhaust heat recovery unit 70 belongs to both of the refrigerant circuit 110 and the coolant path 120.

[0039] The first thermostat type switching valve 121 flows the engine coolant from the engine 60 toward the second thermostat type switching valve 122 when the temperature of the engine coolant is less than a predetermined first temperature (for example, 71°C). On the other hand, the first thermostat type switching valve 121 flows the engine

coolant from the engine 60 toward the radiator 123 when the temperature of the engine coolant is not less than the first temperature. Thus, the coolant path 120 can circulate the engine coolant toward the second thermostat type switching valve 122 when the temperature of the engine coolant is less than the first temperature, while it can circulate the engine coolant toward the radiator 123 when the temperature of the engine coolant is not less than the first temperature.

[0040] The second thermostat type switching valve 122 flows the engine coolant from the first thermostat type switching valve 121 toward both of the engine exhaust heat recovery unit 70 and the confluence point P6 of the inlet path 124b when the temperature of the engine coolant is less than a predetermined second temperature (for example, 60°C) that is lower than the first temperature. On the other hand, the second thermostat type switching valve 122 flows the engine coolant from the first thermostat type switching valve 121 toward the engine exhaust heat recovery unit 70 when the temperature of the engine coolant is not less than the second temperature. Thus, the coolant path 120 can circulate the engine coolant toward both of the engine exhaust heat recovery unit 70 and the confluence point P6 of the inlet path 124b when the temperature of the engine coolant is less than the second temperature, while it can circulate the engine coolant toward the engine exhaust heat recovery unit 70 when the temperature of the engine coolant is not less than the second temperature but less than the first temperature.

[0041] The temperature of the engine coolant can be detected by a temperature sensor (not shown) disposed in the coolant path 120.

[0042] The inlet branch pipe 211, which is a part of the circulating liquid circuit 200, connects a circulating liquid inlet of the refrigerant-circulating liquid heat exchanger 50 and a branch portion of the inlet main pipe 210 (see FIG. 1) corresponding to the chiller 100. The outlet branch pipe 221, which is a part of the circulating liquid circuit 200, connects a circulating liquid outlet of the refrigerant-circulating liquid heat exchanger 50 and a confluence portion of the outlet main pipe 220 (see FIG. 1) corresponding to the chiller 100. The refrigerant-circulating liquid heat exchanger 50 belongs to both of the refrigerant circuit 110 and the circulating liquid circuit 200.

[0043] The compressor 10 is connected to the engine 60 via a clutch 11. The clutch 11 switches, in response to the instruction signal from the control device 140, between a connection state in which the drive force is transmitted from the engine 60 to the compressor 10 and a block state in which the transmission of the drive force from the engine 60 to the compressor 10 is blocked.

[0044] The chiller 100 further includes a first pressure sensor 151, a first temperature sensor 161, a second pressure sensor 152, a second temperature sensor 162 and a rotation speed sensor 170.

[0045] The first pressure sensor 151 and the first temperature sensor 161 are disposed in the confluence path 113b1, and detect respectively the pressure and the temperature of the refrigerant in the confluence path 113b1. The second pressure sensor 152 and the second temperature sensor 162 are disposed in the second low pressure gas refrigerant path 113j, and detect respectively the pressure and the temperature of the refrigerant in the second low pressure gas refrigerant path 113j. The rotation speed sensor 170 is disposed in the engine 60, and detects the rotational speed of the engine 60.

[0046] The circulating liquid circuit 200 includes an influent circulating liquid temperature sensor 231 and an effluent circulating liquid temperature sensor 232.

[0047] Specifically, the influent circulating liquid temperature sensor 231 is disposed in the inlet branch pipe 211, and detects the temperature of the circulating liquid that flows into the refrigerant-circulating liquid heat exchanger 50 (more specifically, the circulating liquid in the inlet branch pipe 211). The effluent circulating liquid temperature sensor 232 is disposed in the outlet branch pipe 221, and detects the temperature of the circulating liquid that flows out of the refrigerant-circulating liquid heat exchanger 50 (more specifically, the circulating liquid in the outlet branch pipe 221).

[0048] The control device 140 controls, according to detection signals from various sensors, driving of the refrigerant circuit 110, the coolant path 120 and the circulating liquid circuit 200. Thus, the chiller 100 can adjust the temperature of the circulating liquid that flows in the circulating liquid circuit 200.

[0049] Specifically, the control device 140 causes the compressor 10 to compress the refrigerant that is sucked from the first low pressure gas refrigerant path 113b and to discharge the compressed refrigerant to the high pressure gas refrigerant path 113a. When the cooling operation to cool the circulating liquid in the circulating liquid circuit 200 is performed, the control device 140 makes the four-way valve 111 a first connection state in which the high pressure gas refrigerant path 113a is communicated with the first gas refrigerant path 113c and furthermore the second gas refrigerant path 113h is communicated with the first low pressure gas refrigerant path 113b. Also, when the heating operation to heat the circulating liquid in the circulating liquid circuit 200 is performed, the control device 140 makes the four-way valve 111 a second connection state in which the high pressure gas refrigerant path 113a is communicated with the second gas refrigerant path 113h and furthermore the first gas refrigerant path 113c is communicated with the first low pressure gas refrigerant path 113b.

[0050] The refrigerant-air heat exchanger 20 serves as a condenser to cause the refrigerant to release heat and liquefy during cooling operation, and serves as an evaporator to cause the refrigerant to absorb heat and vaporize during heating operation. The refrigerant-circulating liquid heat exchanger 50 serves as a cooler to cause the refrigerant to absorb heat and cool the circulating liquid during cooling operation, and serves as a heater to cause the refrigerant to release heat

and heat the circulating liquid during heating operation. The engine exhaust heat recovery unit 70 serves as an evaporator to cause the refrigerant to absorb heat and vaporize.

[0051] The first expansion valve 41 and the second expansion valve 42 are arranged, in parallel, downstream of the bridge circuit 112. In response to the instruction signal from the control device 140, the first expansion valve 41 adjusts the flow rate of the refrigerant that flows toward the refrigerant-circulating liquid heat exchanger 50 via the bridge circuit 112 during cooling operation, and adjusts the flow rate of the refrigerant that flows toward the refrigerant-air heat exchanger 20 via the bridge circuit 112 during heating operation. The second expansion valve 42 adjusts, in response to the instruction signal from the control device 140, the flow rate of the refrigerant that flows toward the engine exhaust heat recovery unit 70.

[0052] The control device 140 includes a processor 141 constituted of a microcomputer such as a CPU (central processing unit), and a memory 142 including a non-volatile memory such as a ROM (read only memory) and a volatile memory such as a RAM (random access memory).

[0053] In the control device 140, the processor 141 executes a control program previously stored in the ROM of the memory 142 by loading the control program on the RAM of the memory 142. Thus, operations of the respective component elements are controlled.

[0054] With the chiller 100 as described above, it is possible to adjust the temperature of the circulating liquid that flows in the circulating liquid circuit 200 by performing appropriately the cooling operation or the heating operation.

[0055] First, the cooling operation performed by the chiller 100 will be described with reference to FIG. 3. Next, the heating operation performed by the chiller 100 will be described with reference to FIG. 4.

[Cooling Operation]

[0056] FIG. 3 is a schematic block diagram showing the chiller 100 that performs the cooling operation.

[0057] When the chiller 100 performs the cooling operation, the control device 140 switches the four-way valve 111 to the first connection state in which the high pressure gas refrigerant path 113a is communicated with the first gas refrigerant path 113c and furthermore the second gas refrigerant path 113h is communicated with the first low pressure gas refrigerant path 113b. In this way, the refrigerant in a state of high pressure gas (hereinafter referred to as the "high pressure gas refrigerant") that is discharged from the compressor 10 flows into the refrigerant-air heat exchanger 20 via the oil separator 81.

[0058] The temperature of the high pressure gas refrigerant that flows into the refrigerant-air heat exchanger 20 is higher than the temperature of the air that passes through the refrigerant-air heat exchanger 20. For this reason, the heat is transferred from the high pressure gas refrigerant to the air. As a result, the high pressure gas refrigerant loses the condensation heat and liquefies, thus becomes the refrigerant in a state of a high pressure liquid (hereinafter referred to as the "high pressure liquid refrigerant"). That is, in the cooling operation, the refrigerant-air heat exchanger 20 serves as a condenser of the refrigerant, in which the high pressure gas refrigerant releases heat.

[0059] The high pressure liquid refrigerant flows from the refrigerant-air heat exchanger 20 to the first intermediate connection point P1 of the bridge circuit 112 via the first refrigerant path 113d. Since the first intermediate connection point P1 is located on the outlet side of the second check valve 112b and on the inlet side of the first check valve 112a, the high pressure liquid refrigerant does not flow to the second check valve 112b and the third check valve 112c, but flows to the high pressure liquid refrigerant path 113e from the first intermediate connection point P1, via the first check valve 112a and the outlet connection point P2.

[0060] When the control device 140 performs the cooling operation, it opens the first expansion valve 41 and closes the second expansion valve 42, so that the high pressure liquid refrigerant flows through the first expansion valve 41 but does not flow through the second expansion valve 42. Thus, the high pressure liquid refrigerant passes through the first expansion valve 41 via the receiver 83 disposed in the high pressure liquid refrigerant path 113e.

[0061] When passing through the first expansion valve 41, the high pressure liquid refrigerant expands and becomes a refrigerant in a state of a low pressure gas-liquid two phase (hereinafter referred to as the "low pressure gas-liquid two phase refrigerant"). The low pressure gas-liquid two phase refrigerant flows from the first low pressure gas-liquid two phase refrigerant path 113f to the inlet connection point P4 of the bridge circuit 112. The inlet connection point P4 is located on the inlet side of the second check valve 112b and the fourth check valve 112d. However, as described above, the high pressure liquid refrigerant flows through the first intermediate connection point P1 and the outlet connection point P2. For this reason, the low pressure gas-liquid two phase refrigerant does not flow to the second check valve 112b and the third check valve 112c because of the pressure difference from the high pressure liquid refrigerant that flows through the first intermediate connection point P1 and the outlet connection point P2. The low pressure gas-liquid two phase refrigerant flows from the inlet connection point P4 to the refrigerant-circulating liquid heat exchanger 50 via the fourth check valve 112d, the second intermediate connection point P3 and the second refrigerant path 113g.

[0062] The temperature of the low pressure gas-liquid two phase refrigerant that flows on the side of the refrigerant circuit 110 relative to the refrigerant-circulating liquid heat exchanger 50 is lower than the temperature of the circulating

liquid that flows on the side of the circulating liquid circuit 200 relative to the refrigerant-circulating liquid heat exchanger 50. For this reason, the heat is transferred from the circulating liquid to the low pressure gas-liquid two phase refrigerant. As a result, the low pressure gas-liquid two phase refrigerant obtains the evaporation heat and vaporizes, thus becomes the refrigerant in a state of a low pressure gas (hereinafter referred to as the "low pressure gas refrigerant"). On the other hand, the circulating liquid is cooled by the heat absorbing action of the refrigerant. That is, in the cooling operation, the refrigerant-circulating liquid heat exchanger 50 serves as a cooler of the circulating liquid, in which the low pressure gas-liquid two phase refrigerant absorbs heat.

[0063] After that, the low pressure gas refrigerant flows from the refrigerant-circulating liquid heat exchanger 50 to the second gas refrigerant path 113h. At this time, the control device 140 communicates the second gas refrigerant path 113h with the first low pressure gas refrigerant path 113b by the four-way valve 111. Thus, the low pressure gas refrigerant is sucked into the compressor 10 via the accumulator 82 disposed in the first low pressure gas refrigerant path 113b.

[0064] In the chiller 100, the above-described series of operations as the cooling operation are repeatedly performed.

[Heating Operation]

[0065] FIG. 4 is a schematic block diagram showing the chiller 100 that performs the heating operation.

[0066] When the chiller 100 performs the heating operation, the control device 140 switches the four-way valve 111 to the second connection state in which the high pressure gas refrigerant path 113a is communicated with the second gas refrigerant path 113h and furthermore the first gas refrigerant path 113c is communicated with the first low pressure gas refrigerant path 113b. In this way, the high pressure gas refrigerant that is discharged from the compressor 10 flows into the refrigerant-circulating liquid heat exchanger 50 via the oil separator 81.

[0067] The temperature of the high pressure gas refrigerant that flows on the side of the refrigerant circuit 110 relative to the refrigerant-circulating liquid heat exchanger 50 is higher than the temperature of the circulating liquid that flows on the side of the circulating liquid circuit 200 relative to the refrigerant-circulating liquid heat exchanger 50. For this reason, the heat is transferred from the high pressure gas refrigerant to the circulating liquid. As a result, the high pressure gas refrigerant loses the condensation heat and liquefies, thus becomes the high pressure liquid refrigerant. On the other hand, the circulating liquid is heated by the heat releasing action of the refrigerant. That is, in the heating operation, the refrigerant-circulating liquid heat exchanger 50 serves as a heater of the circulating liquid, in which the high pressure gas refrigerant releases heat.

[0068] The high pressure liquid refrigerant flows from the refrigerant-circulating liquid heat exchanger 50 to the second intermediate connection point P3 of the bridge circuit 112 via the second refrigerant path 113g. Since the second intermediate connection point P3 is located on the inlet side of the third check valve 112c and on the outlet side of the fourth check valve 112d, the high pressure liquid refrigerant does not flow to the first check valve 112a and the fourth check valve 112d, but flows to the high pressure liquid refrigerant path 113e from the second intermediate connection point P3, via the third check valve 112c and the outlet connection point P2.

[0069] When the control device 140 performs the heating operation, it opens the first expansion valve 41 and closes the second expansion valve 42, so that the high pressure liquid refrigerant flows through the first expansion valve 41 but does not flow through the second expansion valve 42. Thus, the high pressure liquid refrigerant passes through the first expansion valve 41 via the receiver 83 disposed in the high pressure liquid refrigerant path 113e.

[0070] When passing through the first expansion valve 41, the high pressure liquid refrigerant expands and becomes the low pressure gas-liquid two phase refrigerant. The low pressure gas-liquid two phase refrigerant flows from the first low pressure gas-liquid two phase refrigerant path 113f to the inlet connection point P4 of the bridge circuit 112. The inlet connection point P4 is located on the inlet side of the second check valve 112b and the fourth check valve 112d. However, as described above, the high pressure liquid refrigerant flows through the second intermediate connection point P3 and the outlet connection point P2. For this reason, the low pressure gas-liquid two phase refrigerant does not flow to the fourth check valve 112d and the first check valve 112a because of the pressure difference from the high pressure liquid refrigerant that flows through the second intermediate connection point P3 and the outlet connection point P2. The low pressure gas-liquid two phase refrigerant flows from the inlet connection point P4 to the refrigerant-air heat exchanger 20 via the second check valve 112b and the first refrigerant path 113d.

[0071] The temperature of the low pressure gas-liquid two phase refrigerant that flows through the refrigerant-air heat exchanger 20 is lower than the temperature of the air that passes through the refrigerant-air heat exchanger 20. For this reason, the heat is transferred from the air to the low pressure gas-liquid two phase refrigerant. As a result, the low pressure gas-liquid two phase refrigerant obtains the evaporation heat and vaporizes, thus becomes the low pressure gas refrigerant. That is, in the heating operation, the refrigerant-air heat exchanger 20 serves as an evaporator of the refrigerant, in which the low pressure gas-liquid two phase refrigerant absorbs heat.

[0072] After that, the low pressure gas refrigerant flows from the refrigerant-air heat exchanger 20 to the first gas refrigerant path 113c. At this time, the control device 140 communicates the first gas refrigerant path 113c with the first low pressure gas refrigerant path 113b by the four-way valve 111. Thus, the low pressure gas refrigerant is sucked into

the compressor 10 via the accumulator 82 disposed in the first low pressure gas refrigerant path 113b.

[0073] In the chiller 100, the above-described series of operations as the heating operation are repeatedly performed.

[Defrost Operation]

[0074] During heating operation, the low pressure gas-liquid two phase refrigerant is supplied to the refrigerant-air heat exchanger 20, thus piping in the refrigerant-air heat exchanger 20 is cooled. In this case, frost may adhere to the piping in the refrigerant-air heat exchanger 20 depending on conditions such as an outside air temperature. Then, the chiller 100 performs the defrost operation.

[0075] Next, the defrost operation performed by the chiller 100 will be described with reference to FIG. 5.

[0076] FIG. 5 is a schematic block diagram showing the chiller 100 that performs the defrost operation.

[0077] When the chiller 100 performs the defrost operation, the control device 140 switches, as in the cooling operation, the four-way valve 111 to the first connection state in which the high pressure gas refrigerant path 113a is communicated with the first gas refrigerant path 113c and furthermore the second gas refrigerant path 113h is communicated with the first low pressure gas refrigerant path 113b. In this way, the high pressure gas refrigerant that is discharged from the compressor 10 flows into the refrigerant-air heat exchanger 20 via the oil separator 81.

[0078] The high pressure gas refrigerant that flows through the refrigerant-air heat exchanger 20 loses, as in the cooling operation, the condensation heat and liquefies, thus becomes the high pressure liquid refrigerant. That is, in the defrost operation, the refrigerant-air heat exchanger 20 serves as a condenser of the refrigerant, in which the high pressure gas refrigerant releases heat.

[0079] Similarly to the cooling operation, the high pressure liquid refrigerant flows from the refrigerant-air heat exchanger 20 to the high pressure liquid refrigerant path 113e via the first refrigerant path 113d, and the first intermediate connection point P1, the first check valve 112a and the outlet connection point P2 of the bridge circuit 112.

[0080] When the control device 140 performs the defrost operation, it opens the second expansion valve 42 and closes the first expansion valve 41, so that the high pressure liquid refrigerant flows through the second expansion valve 42 but does not flow through the first expansion valve 41. Thus, the high pressure liquid refrigerant passes through the second expansion valve 42 via the receiver 83 disposed in the high pressure liquid refrigerant path 113e.

[0081] When passing through the second expansion valve 42, the high pressure liquid refrigerant expands and becomes the low pressure gas-liquid two phase refrigerant. The low pressure gas-liquid two phase refrigerant flows from the second low pressure gas-liquid two phase refrigerant path 113i to the engine exhaust heat recovery unit 70.

[0082] The temperature of the low pressure gas-liquid two phase refrigerant that flows on the side of the refrigerant circuit 110 relative to the engine exhaust heat recovery unit 70 is lower than the temperature of the engine coolant that flows on the side of the coolant path 120 relative to the engine exhaust heat recovery unit 70. For this reason, the heat is transferred from the engine coolant to the low pressure gas-liquid two phase refrigerant. As a result, the low pressure gas-liquid two phase refrigerant obtains the evaporation heat and vaporizes, thus becomes the low pressure gas refrigerant. That is, in the defrost operation, the engine exhaust heat recovery unit 70 serves as an evaporator of the refrigerant, in which the low pressure gas-liquid two phase refrigerant absorbs heat.

[0083] After that, the low pressure gas refrigerant flows from the engine exhaust heat recovery unit 70, and is sucked into the compressor 10 via the second low pressure gas refrigerant path 113j, the confluence point P5 of the first low pressure gas refrigerant path 113b, the confluence path 113b1, and the accumulator 82.

[0084] In the chiller 100, the above-described series of operations as the defrost operation are repeatedly performed.

[0085] In the defrost operation, the high pressure gas refrigerant is supplied to the refrigerant-air heat exchanger 20, thus, the piping in the refrigerant-air heat exchanger 20 is heated. As a result, frost that adheres to the refrigerant-air heat exchanger 20 is removed by the heating operation. Furthermore, in the defrost operation, since the low pressure gas-liquid two phase refrigerant does not flow to the refrigerant-circulating liquid heat exchanger 50, the decrease in the temperature of the circulating liquid according to evaporation of the refrigerant does not occur.

[Control on Each Chiller in Chiller System]

[0086] In the chiller system 1 in which a plurality of chillers 100 (1) to 100 (n) is connected to each other, generally, the number of chillers to be operated is increased/decreased, out of the plurality of chillers 100 (1) to 100 (n), according to a required load capacity. In this case, it is desired to level respective cumulative operation times of the chillers 100 (1) to 100 (n) by not operating particular chillers unevenly but operating each chiller 100 (1) to 100 (n) evenly, from the viewpoint that it is preferable to perform maintenance on the plurality of chillers 100 (1) to 100 (n) at the same time. Here, the "operation" means the "cooling operation" or the "heating operation", which does not include the "defrost operation".

[0087] In this regard, in the conventional chiller system as described above, when the load capacity is increased, a newly active chiller is added after the operation capacity of each of the current active chillers reaches 100% output (rated

output) (see the Patent Document 1). Thus, when a partial load at which the operation output does not reach the rated output is continuously applied, no newly active chiller is added while such a partial load is being continuously applied. As a result, the respective cumulative operation times of the chillers are likely to vary largely.

[0088] In consideration of the above circumstances, the chiller system 1 according to this embodiment includes a control mechanism to control the operation of each chiller 100 (1) to 100 (n) as described below.

[0089] That is, in this embodiment, the control mechanism is an aggregate of the respective control devices 140 of the chillers 100 (1) to 100 (n). The control devices 140 (1) to 140 (n) are connected to each other in order to communicate with each other. In the chiller system 1, one chiller is designated as a master chiller (i) (i is an integer of from 1 to n) out of the plurality of chillers 100 (1) to 100 (n). Note that the control mechanism may be a control device that integrally controls the chillers 100 (1) to 100 (n) and that is provided separated from the chillers 100 (1) to 100 (n).

[0090] When one or more chillers 100 are operated out of the plurality of chillers 100 (1) to 100 (n) (servant chillers and the master chiller 100 (i)), the master chiller 100 (i) (specifically, the control device 140 (i)) transmits an operation command to one of the stopped (inactive) chillers 100 if a relation $Q_t / (N+1) \geq Q_p$ is satisfied, where Q_t represents a [total required operation capacity] that is a total operation capacity required of the at least one active chiller 100, N represents a [number of currently active chillers] that is the number of the active chillers 100, and Q_p represents a [partial load capacity] that is the load capacity of a predetermined partial load. Here, the [partial load capacity] Q_p can be set to a value (for example, 4kW) that is obtained by multiplying the rated output (for example, 10kW) of the chiller 100 by a predetermined partial load capacity ratio (i.e., the load capacity ratio greater than 0 and smaller than 1, for example, 40%). If the chiller 100 that receives the operation command is the master chiller 100 (i) itself, the master chiller 100 (i) transmits the operation command to itself.

[0091] In other words, the master chiller 100 (i) maintains the [number of currently active chillers] N (for example, two chillers) when the [total required operation capacity] Q_t is less than a [reference load capacity for increasing active chillers] Q_i (for example, 12kW) obtained by multiplying the number of the operated chillers ($N + 1$) (for example, three chillers), which is obtained by adding one chiller to the [number of currently active chillers] N (for example, two chillers), by the [partial load capacity] Q_p (for example, 4kW). In contrast, the master chiller 100 (i) increases the number of the active chillers 100 by one (for example, increases the number of the active chillers to three) when the [total required operation capacity] Q_t is not less than the [reference load capacity for increasing active chillers] Q_i (for example, 12kW).

[0092] Here, the stopped chiller 100 means naturally the chiller that is not being operated currently but is capable of being operated. A chiller on standby can be exemplified.

[0093] When the stopped chiller 100 (specifically, the control device 140 of the stopped chiller 100) receives the operation command from the master chiller 100 (i), the operation of the stopped chiller 100 is started.

[0094] Also, when one or more chillers 100 are operated out of the plurality of chillers 100 (1) to 100 (n) including the master chiller 100 (i), the master chiller 100 (i) (specifically, the control device 140 (i)) transmits a stop command to one of the active chillers 100 if a relation $Q_t / N \leq Q_p$ is satisfied. In this way, it is possible to set a lower limit of the operation capacity per active chiller 100 when the load capacity decreases. If the chiller 100 that receives the stop command is the master chiller 100 (i) itself, the master chiller 100 (i) transmits the stop command to itself.

[0095] In other words, the master chiller 100 (i) maintains the [number of currently active chillers] N (for example, three chillers) when the [total required operation capacity] Q_t is greater than a [reference load capacity for decreasing active chillers] Q_d (for example, 12kW) obtained by multiplying the [number of currently active chillers] N (for example, three chillers) by the [partial load capacity] Q_p (for example, 4kW), i.e., when an [operation capacity per chiller] is greater than the [partial load capacity] Q_p (for example, 4kW). In contrast, the master chiller 100 (i) reduces the number of the active chillers 100 by one (for example, reduces the number of the active chillers to two) when the [total required operation capacity] Q_t is not more than the [reference load capacity for decreasing active chillers] Q_d (for example, 12kW), i.e., when the [operation capacity per chiller] is not more than the [partial load capacity] Q_p (for example, 4kW).

[0096] When the active chiller 100 (specifically, the control device 140 of the active chiller 100) receives the stop command from the master chiller 100 (i), the active chiller 100 is stopped.

[0097] FIG. 6 is a graph indicating the control operation performed by the master chiller 100 (i) on each chiller 100 (1) to 100 (8) in the chiller system 1 in which the number n of the chillers 100 is set to eight.

[0098] In FIG. 6, the [operation capacity ratio per chiller] [%] as the vertical axis represents the ratio of the operation capacity per chiller 100. That is, when the rated output is 10 [kW], 40 [%] [operation capacity ratio per chiller] means the operation capacity of 4 [kW].

[0099] Also, in FIG. 6, the [total required operation capacity ratio] [%] as the horizontal axis represents the ratio of the [total required operation capacity] Q_t that is the sum of each operation capacity (output) of the corresponding active chiller 100. In the case where two chillers 100 are operated and the rated output of each chiller 100, 100 is 10 [kW], when the [required operation capacity ratio] of the two chillers 100, 100 is each, for example, 40 [%], the [total required operation capacity ratio], which is obtained by summing up each [required operation capacity ratio] of the two chillers 100, 100 is 80 [%], and the [total required operation capacity] Q_t , which is obtained by summing up each [required operation capacity] of the two chillers 100, 100 is 8 [kW]. Similarly to the above, in the case where the rated output of

the chiller 100 is 10 [kW], when the [predetermined partial load capacity ratio], the [reference load capacity ratio for increasing active chillers] and the [reference load capacity ratio for decreasing active chillers] of the chiller 100 are respectively, for example, 40 [%], 120 [%] and 120 [%], the [partial load capacity] Q_p , the [reference load capacity for increasing active chillers] Q_i and the [reference load capacity for decreasing active chillers] Q_d of the chiller 100 are respectively 4 [kW], 12 [kW] and 12 [kW]. As the [predetermined partial load capacity ratio] increases, particular chillers 100 are likely to be operated unevenly, and as the [predetermined partial load capacity ratio] decreases, the operation efficiency is likely to degrade. Therefore, it is preferable to set the [predetermined partial load capacity ratio] to, for example, 40 [%], keeping a good balance between the above two cases.

[0100] Next, in the control operation on each chiller 100 (1) to 100 (8), the cases where the [total required operation capacity] Q_t increases so that the number of the chillers 100 is increased and where the [total required operation capacity] Q_t decreases so that the number of the chillers 100 is decreased will be described below with reference to FIG. 6. In the example indicated in FIG. 6, the [predetermined partial load capacity ratio] is 40%.

(Case in Which Number of Chillers Is Increased)

[0101] In the case where the number of the chillers 100 is increased, when the number of the active chillers 100 is one (see α_1 in FIG. 6) and when the [total required operation capacity ratio] is less than the [reference load capacity ratio for increasing active chillers] (80 [%]) that is obtained by multiplying the number of the chillers (two), which is obtained by adding one chiller to the [number of currently active chillers] (one), by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (one) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of more than 0 [%] to less than 80 [%] ($= 80 [\%] / \text{one chiller}$). On the other hand, when the [total required operation capacity ratio] is not less than the [reference load capacity ratio for increasing active chillers] (80 [%]), the number of the active chillers is increased by one, thus becomes two.

[0102] Also, when the number of the active chillers 100 are two (see α_2 in FIG. 6) and when the [total required operation capacity ratio] is less than the [reference load capacity ratio for increasing active chillers] (120 [%]) that is obtained by multiplying the number of the chillers (three), which is obtained by adding one chiller to the [number of currently active chillers] (two), by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (two) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of not less than 40 [%] ($= 80 [\%] / 2 \text{ chillers}$) to less than 60 [%] ($= 120 [\%] / \text{two chillers}$). On the other hand, when the [total required operation capacity ratio] is not less than the [reference load capacity ratio for increasing active chillers] (120 [%]), the number of the active chillers is increased by one, thus becomes three.

[0103] Also, when the number of the active chillers 100 are three (see α_3 in FIG. 6) and when the [total required operation capacity ratio] is less than the [reference load capacity ratio for increasing active chillers] (160 [%]) that is obtained by multiplying the number of the chillers (four), which is obtained by adding one chiller to the [number of currently active chiller] (three), by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (three) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of not less than 40 [%] ($= 120 [\%] / \text{three chillers}$) to less than 53.3 [%] ($= 160 [\%] / \text{three chillers}$). On the other hand, when the [total required operation capacity ratio] is not less than the [reference load capacity ratio for increasing active chillers] (160 [%]), the number of the active chillers is increased by one, thus becomes four.

[0104] Similarly to the above, the number of the active chillers 100 is increased. When the number of the active chillers 100 is eight (the maximum), the [operation capacity ratio] per chiller is in the range of not less than 40 [%] ($= 320 [\%] / \text{eight chillers}$) to not more than 100 [%] ($= 800 [\%] / \text{eight chillers}$).

(Case in Which Number of Chillers is Decreased)

[0105] In the case where the number of the chillers 100 is decreased, when the number of the active chillers 100 is eight (see β_1 in FIG. 6) and when the [total required operation capacity ratio] is more than the [reference load capacity ratio for decreasing active chillers] (320 [%]) that is obtained by multiplying the [number of currently active chillers] (eight) by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (eight) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of more than 40 [%] ($= 320 [\%] / \text{eight chillers}$) and not more than 100 [%] ($= 800 [\%] / \text{eight chillers}$). On the other hands, when the [total required operation capacity ratio] is not more than the [reference load capacity ratio for decreasing active chillers] (320 [%]), the number of the active chillers is decreased by one, thus becomes seven.

[0106] Also, when the number of the active chillers 100 is seven (see β_2 in FIG. 6) and when the [total required operation capacity ratio] is more than the [reference load capacity ratio for decreasing active chillers] (280 [%]) that is obtained by multiplying the [number of currently active chillers] (seven) by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (seven) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of more than 40 [%] ($= 280 [\%] / \text{seven chillers}$) to not more than 45.7 [%] ($= 320 [\%] / \text{seven chillers}$).

On the other hand, when the [total required operation capacity ratio] is not more than the [reference load capacity ratio for decreasing active chillers] (280 [%]), the number of the active chillers is decreased by one, thus becomes six.

[0107] Also, when the number of the active chillers 100 is six (see $\beta 3$ in FIG. 6) and when the [total required operation capacity ratio] is more than the [reference load capacity ratio for decreasing active chillers] (240 [%]) that is obtained by multiplying the [number of currently active chillers] (six) by the [predetermined partial load capacity ratio] (40 [%]), the [number of currently active chillers] (six) is maintained. In this case, the [operation capacity ratio] per chiller is in the range of more than 40 [%] (=240 [%] / six chillers) to not more than 46.6 [%] (=280 [%] / six chillers). On the other hand, when the [total required operation capacity ratio] is not more than the [reference load capacity ratio for decreasing active chillers] (240 [%]), the number of the active chillers is decreased by one, thus becomes five.

[0108] Similarly to the above, the number of the active chillers 100 is decreased. When the number of the active chillers 100 is one (the minimum), the [operation capacity ratio] per chiller is in the range of more than 0 [%] to not more than 80 [%] (= 80 [%] / one chiller).

[0109] In the example indicated in FIG. 6, the number of the chillers 100 is set to eight. However, the number of the chillers 100 is not limited thereto. The number of the chillers 100 may be in the range of two to seven or may be nine or more.

(Operation by Master Chiller to Control Each Chiller)

[0110] FIG. 7 is a flowchart indicating steps of one example of the control operation by the master chiller (i) on each chiller 100 (1) to 100 (n) so as to control the number of active chillers.

[0111] In the control operation indicated in FIG. 7, first, the control device 140 of the master chiller (i) sums up each output of the corresponding chiller 100 (1) to 100 (n) so as to calculate the total required operation capacity (current load capacity) (step S1).

[0112] Next, the control device 140 of the master chiller (i) compares the calculated total required operation capacity with the previous total required operation capacity (default: 0) stored in the memory 142 so as to determine whether the former is larger than the latter (step S2). When the control device 140 determines that the calculated total required operation capacity is larger than the previous total required operation capacity (step S2: Yes), then the control device 140 determines whether the number of the active chillers 100 is maximum or not (step S3). When the control device 140 determines that the number of the active chillers 100 is maximum (step S3: Yes), the procedure advances to step S9. When the control device 140 determines that the number of the active chillers 100 is not maximum (step S3: No), then the control device 140 determines whether the relation $Q_t / (N+1) \geq Q_p$ is satisfied or not (step S4).

[0113] When the control device 140 of the master chiller (i) determines that the relation $Q_t / (N+1) \geq Q_p$ is not satisfied in step S4 (step S4: No), the procedure advances to step S9. When the control device 140 determines that the relation $Q_t / (N+1) \geq Q_p$ is satisfied (step S4: Yes), the control device 140 increases the number of the active chillers 100 by one (step S5), thus the procedure advances to step S9.

[0114] Meanwhile, when the control device 140 of the master chiller (i) determines that the total required operation capacity is equal to or smaller than the previous total required operation capacity in step S2 (step S2: No), then the control device 140 determines whether the number of the active chillers 100 is minimum or not (step S6). When the control device 140 determines that the number of the active chillers 100 is minimum (step S6: Yes), the procedure advances to step S9. When the control device 140 determines that the number of the active chillers 100 is not minimum (step S6: No), then the control device 140 determines whether the relation $Q_t / N \leq Q_p$ is satisfied or not (step S7).

[0115] When the control device 140 of the master chiller (i) determines that the relation $Q_t / N \leq Q_p$ is not satisfied in step S7 (step S7: No), the procedure advances to step S9. When the control device 140 determines that the relation $Q_t / N \leq Q_p$ is satisfied (step S7: Yes), then the control device 140 reduces the number of the active chillers 100 by one (step S8), thus the procedure advances to step S9.

[0116] The control device 140 of the master chiller (i) subsequently stores the total required operation capacity in the memory 142, and continues the procedure of step S1 to step S10 until it receives the termination instruction (step S10: No). When it receives the termination instruction (step S10: Yes), the procedure is terminated.

(Selection of Chiller When Increasing/Decreasing Number of Active Chillers)

[0117] In this embodiment, the plurality of chillers 100 (1) to 100 (n) including the master chiller 100 (i) can be in any of the following states: a "normal state"; an "alarming state" in which an alarm is being transmitted; and a "before-alarming state" that is before transmission of the alarm (specifically, a state in which a forecast is transmitted before the transmission of the alarm) between the "normal state" and the "alarming state".

[0118] Specifically, each of the chillers 100 (1) to 100 (n) transmits an alarm when it becomes in an inoperable state in which the operation cannot be continued, while it transmits a forecast to get attention of a user when it becomes in quasi-operation state in which the operation is being continued although it cannot be deemed as a normal state. Here, examples of the "inoperable state" can include: a physically inoperable state due to a significant abnormality such as

an engine failure; a state that requires inhibition of the operation although the operation is physically possible; and a state in which the operation is switched to the defrost operation. Also, examples of the "quasi-operation state" can include a state in which the inhibition of the operation is not needed although a minor abnormality such as a temporary abnormality (for example, a temporarily abnormal output from the sensors and the like) occurs.

[0119] When the master chiller 100 (i) (specifically, the control device 140 (i)) transmits the operation command to one chiller 100 of the stopped chillers 100 out of the plurality of chillers 100 (1) to 100 (n) including the master chiller 100 (i), the master chiller 100 (i) selects the chiller 100 as a target for a next operation command in the order of: the active chiller 100 in the "before-alarming state"; the stopped chiller 100 in the "before-alarming state"; the active chiller 100 in the "normal state"; and the stopped chiller 100 in the "normal state". Since the master chiller 100 (i) actually transmits the operation command to the stopped chiller 100, it selects the target chiller 100 for the next operation command substantially in the order of the stopped chiller in the "before-alarming state" and the stopped chiller 100 in the "normal state".

[0120] Furthermore, when the master chiller 100 (i) transmits the operation command to one chiller 100 of the stopped chillers 100 out of the plurality of chillers 100 (1) to 100 (n) including the master chiller 100 (i), the master chiller 100 (i) selects, if the chillers 100 are in the same state (i.e., have the same priority), the target chiller 100 for the next operation command in ascending order of a cumulative output amount (kWh) obtained by summing the outputs (kWh) from an initial state (a state in which no predetermined maintenance has been performed yet) or from the time point at which the predetermined maintenance has been performed (i.e., the time point at which the latest maintenance has been performed).

[0121] When the master chiller 100 (i) (specifically, the control device 140 (i)) transmits the stop command to one chiller 100 of the active chillers 100, the master chiller 100 (i) selects the chiller 100 as a target for a next stop command in the order of: the stopped chiller 100 in the "normal state"; the active chiller 100 in the "normal state"; the stopped chiller 100 in the "before-alarming state"; and the active chiller 100 in the "before-alarming state". Since the master chiller 100 (i) actually transmits the stop command to the active chiller 100, it selects the target chiller 100 for the next stop command substantially in the order of the active chiller 100 in the "normal state" and the active chiller 100 in the "before-alarming state".

[0122] Furthermore, when the master chiller 100 (i) transmits the stop command to one chiller 100 of the active chillers 100 out of the plurality of chillers 100 (1) to 100 (n) including the master chiller 100 (i), the master chiller 100 (i) selects, if the chillers 100 are in the same state (i.e., have the same priority), the target chiller 100 for the next stop command in descending order of the cumulative output amount (kWh) obtained by summing the outputs (kWh) from an initial state (a state in which no predetermined maintenance has been performed yet) or from the time point at which the predetermined maintenance has been performed (i.e., the time point at which the latest maintenance has been performed).

[0123] FIG. 8 is a table for determining the priority of the chillers 100 when increasing/decreasing the number of the active chillers 100. In FIG. 8, "Ba" represents the active chiller 100 in the "before-alarming state", "Bs" represents the stopped chiller 100 in the "before-alarming state", "Na" represents the active chiller 100 in the "normal state", "Ns" represents the stopped chiller 100 in the "normal state", and "X" represents the chiller 100 in the "inoperable state".

[0124] When increasing/decreasing the number of the active chillers 100, the chiller can be selected by step [1] to step [11] as shown in FIG. 8. Note that in the example in FIG. 8, the case in which $n = 8$ is presented.

[0125] Step [1]: The chillers 100 (1) to 100 (8) are rearranged in ascending order of the cumulative output amount of the engine 60 (i.e., in ascending order from the left side of the table in FIG. 8).

[0126] Step [2]: The number of the active chillers 100 in the "before-alarming state" (active chiller number before-alarming) is counted. In the example shown in FIG. 8, the number of "Ba" (two) out of the chillers 100 (1) to 100 (8) is counted and thus counted number (two) of "Ba" is recorded for each chiller 100 (1) to 100 (8).

[0127] Step [3]: The number of the stopped chillers 100 in the "before-alarming state" (stopped chiller number before-alarming) is counted. In the example shown in FIG. 8, the number of "Bs" (zero) out of the chillers 100 (1) to 100 (8) is counted and thus counted number (zero) of "Bs" is recorded for each chiller 100 (1) to 100 (8).

[0128] Step [4]: The number of the active chillers 100 in the "normal state" (normal active chiller number) is counted. In the example shown in FIG. 8, the number of "Na" (three) out of the chillers 100 (1) to 100 (8) is counted and thus counted number (three) of "Na" is recorded for each chiller 100 (1) to 100 (8).

[0129] Step [5]: The number of the stopped chillers 100 in the "normal state" (normal stopped chiller number) is counted. In the example shown in FIG. 8, the number of "Ns" (two) out of the chillers 100 (1) to 100 (8) is counted and thus counted number (two) of "Ns" is recorded for each chiller 100 (1) to 100 (8).

[0130] Step [6]: From the smallest side in ascending order of the cumulative output amount (see step [1]) of the engine 60 (i.e., from the left side of the table in FIG. 8), if any active chiller 100 "Ba" in the "before-alarming state" exists, a before-alarming operation counter C1 (see FIG. 2) that is stored in the memory 142 is caused to count up. In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the before-alarming operation counter C1 for "Ba" is caused to count up by one at the second chiller "2" and at the eighth chiller "8", which are "Ba" in the table.

[0131] Step [7]: From the smallest side in ascending order of the cumulative output amount (see step [1]) of the engine 60 (i.e., from the left side of the table in FIG. 8), if any stopped chiller 100 "Bs" in the "before-alarming state" exists, a before-alarming operation stop counter C2 (see FIG. 2) that is stored in the memory 142 is caused to count up. In the example shown in FIG. 8, there is no "Bs" in the alignment order from "1" to "8" of the cumulative output amount of the engine 60, thus the before-alarming stop counter C2 for "Bs" is not caused to count up at any of the alignment order from "1" to "8".

[0132] Step [8]: From the smallest side in ascending order of the cumulative output amount (see step [1]) of the engine 60 (i.e., from the left side of the table in FIG. 8), if any active chiller 100 "Na" in the "normal state" exists, a normal operation counter C3 (see FIG. 2) that is stored in the memory 142 is caused to count up. In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the normal operation counter C3 for "Na" is caused to count up by one at the first chiller "1", at the third chiller "3" and at the sixth chiller "6", which are "Na" in the table.

[0133] Step [9]: From the smallest side in ascending order of the cumulative output amount (see step [1]) of the engine 60 (i.e., from the left side of the table in FIG. 8), if any stopped chiller 100 "Ns" in the "normal state" exists, a normal operation stop counter C4 (see FIG. 2) that is stored in the memory 142 is caused to count up. In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the normal operation stop counter C4 for "Ns" is caused to count up by one at the fourth chiller "4" and at the fifth chiller "5", which are "Ns" in the table.

[0134] Step [10]: From the smallest side of ascending order of the cumulative output amount (see step [1]) of the engine 60 (i.e., from the left side of the table in FIG. 8), if any chiller 100 "X" in the "inoperable state" exists, an inoperable state counter C5 (see FIG. 2) that is stored in the memory 142 is caused to count up. In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the inoperable state counter C5 for "X" is caused to count up by one at the seventh chiller "7", which is "X" in the table.

[0135] Step [11]: In order to determine priority of the chiller to be operated out of the stopped chillers 100 and the priority of the chiller to be stopped out of the active chillers 100, (Expression 1) to (Expression 5) described below are used based on the values obtained by steps [1] to [10]. Here, as each value obtained from (Expression 1) to (Expression 5) becomes smaller, it represents a higher priority to determine which chiller of the stopped chillers 100 should be operated, while as it becomes greater, it represents a higher priority to determine which chiller of the active chillers 100 should be stopped.

• Active Chiller 100 "Ba" in "Before-Alarming State"

[0136]

Priority Value of "Ba" = Value Counted up by Before-Alarming
Operation Counter C1 for "Ba" (Expression 1)

[0137] In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the priority value of "Ba" at the second alignment order "2" equals "1" (see the table, the shaded value at the second column "Ba" from the left side and at the row of step [6]). The priority value of "Ba" at the eighth alignment order "8" equals "2" (see the table, the shaded value at the right most column "Ba" and at the row of step [6]).

• Stopped Chiller 100 "Bs" in "Before-Alarming State"

[0138]

Priority Value of "Bs" = Value of [Active Chiller "Ba" Number Before-
Alarming] + Value Counted Up by Before-Alarming Operation Stop
Counter C2 for "Bs" (Expression 2)

[0139] In the example shown in FIG. 8, no priority is determined since there is no chiller "Bs" in the alignment order from "1" to "8" of the cumulative output amount of the engine 60.

- Active Chiller 100 "Na" in "Normal State"

[0140]

Priority Value of "Na" = Value of [Active Chiller "Ba" Number Before-
Alarming] + Value of [Stopped Chiller "Bs" Number Before Alarming]
+ Value Counted Up by Normal Operation Counter C3 for "Na"
(Expression 3)

[0141] In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the priority value of "Na" at the first alignment order "1" is expressed by the expression "2" + "0" + "1" = "3" (see the table, the total value of the respective shaded values at the left most column "Na" and at the rows of steps [2], [3] and [8]). The priority value of "Na" at the third alignment order "3" is expressed by the expression "2" + "0" + "2" = "4" (see the table, the total value of the respective shaded values at the third column "Na" from the left and at the rows of steps [2], [3] and [8]). The priority value of "Na" at the sixth alignment order "6" is expressed by the expression "2" + "0" + "3" = "5" (see the table, the total value of the respective shaded values at the third column "Na" from the right and at the rows of steps [2], [3] and [8]).

- Stopped Chiller 100 "Ns" in "Normal State"

[0142]

Priority Value of "Ns" = Value of [Active Chiller "Ba" Number Before-
Alarming] + Value of [Stopped Chiller "Bs" Number Before Alarming]
+ Value of [Normal Active Chiller "Na" Number] + Value Counted Up
by Normal Operation Stop Counter C4 for "Ns" (Expression 4)

[0143] In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of the engine 60, the priority value of "Ns" at the fourth alignment order "4" is expressed by the expression "2" + "0" + "3" + "1" = "6" (see the table, the total value of the respective shaded values at the fourth column "Ns" from the left and at the rows of steps [2], [3], [4] and [9]). The priority value of "Ns" at the fifth alignment order "5" is expressed by the expression "2" + "0" + "3" + "2" = "7" (see the table, the total value of the respective shaded values at the fourth column "Ns" from the right and at the rows of steps [2], [3], [4] and [9]).

- "Inoperable State" Chiller 100 "X"

[0144]

Priority Value of "X" = Value of [Active Chiller "Ba" Number Before-
Alarming] + Value of [Stopped Chiller "Bs" Number Before Alarming]
+ Value of [Normal Active Chiller "Na" Number] + Value of [Normal
Stopped Chiller "Ns" Number] + Value Counted Up by Inoperable
State Counter C5 for "X" (Expression 5)

[0145] In the example shown in FIG. 8, out of the alignment order from "1" to "8" of the cumulative output amount of

the engine 60, the priority value of "X" at the seventh alignment order "7" is expressed by the expression "2" + "0" + "3" + "2" + "1" = "8" (see the table, the total value of the respective shaded values at the second column "X" from the right and at the rows of steps [2], [3], [4], [5] and [10]).

[0146] In the example shown in FIG. 8, the case in which $n = 8$ is shown. However, the value n is not limited thereto. Any value n may be applied provided that it satisfies: $n = 2$ to 7 or $n \geq 9$.

[Embodiment of Present Invention]

[0147] As described above, in the chiller system 1 according to this embodiment, the operation command is transmitted to one chiller 100 out of the stopped chillers 100 when the following relation is satisfied: $[\text{total required operation capacity}] Q_t / ([\text{number of currently active chillers}] N + 1) \geq [\text{partial load capacity}] Q_p$. In other words, the $[\text{number of currently active chillers}] N$ is maintained when the $[\text{total required operation capacity}] Q_t$ is less than the $[\text{reference load capacity for increasing active chillers}] Q_i$ obtained by multiplying the number of the active chillers $(N + 1)$, which is obtained by adding one chiller to the $[\text{number of currently active chillers}] N$, by the $[\text{partial load capacity}] Q_p$. On the other hand, the number of the active chillers 100 is increased by one when the $[\text{total required operation capacity}] Q_t$ is not less than the $[\text{reference load capacity for increasing active chillers}] Q_i$. Thus, it is possible to increase the number of the active chillers 100 before the operation output of the active chillers reaches 100% output (rated output). Therefore, even when a partial load at which the operation output does not reach the rated output is continuously applied, it is possible to suppress the variation in the cumulative operation time among the respective chillers 100 (1) to 100 (n), which leads to the chiller system being capable of leveling the respective cumulative operation times of the chillers 100 (1) to 100 (n).

[0148] Also, in the chiller system 1, when the operation command is transmitted to one chiller 100 of the stopped chillers 100 out of the plurality of chillers 100 (1) to 100 (n), the chiller 100 is selected as the target for the next operation command in the order of: the active chiller 100 in the [before-alarming state]; the stopped chiller 100 in the [before-alarming state]; the active chiller 100 in the [normal state]; and the stopped chiller 100 in the [normal state]. In this way, it is possible to select the chiller 100 in the [before-alarming state] preferentially as the target for the next operation command out of the plurality of chillers 100 (1) to 100 (n), and thus, it is possible to make the chiller 100 having a minor abnormality such as a temporary abnormality a maintenance target state in an early stage. Furthermore, if the chillers 100 are in the same state (i.e., have the same priority), the chiller 100 is selected as the target for the next operation command in ascending order of the cumulative output amount from the initial state or from the time point at which the predetermined maintenance has been performed. Thus, when the chillers 100 are in the same state, it is possible to preferentially operate the chiller 100 having a smaller cumulative output amount. Thus, it is possible to level the respective cumulative operation times of the chillers 100 (1) to 100 (n), which reliably allows the chillers 100 (1) to 100 (n) to have the same maintenance time.

[0149] Also, in the chiller system 1, the stop command is transmitted to one chiller 100 out of the active chillers 100 when the following relation is satisfied: $[\text{total required operation capacity}] Q_t / [\text{number of currently active chillers}] N \leq [\text{partial load capacity}] Q_p$. In other words, the $[\text{number of currently active chillers}] N$ is maintained when the $[\text{total required operation capacity}] Q_t$ is greater than the $[\text{reference load capacity for decreasing active chillers}] Q_d$ obtained by multiplying the $[\text{number of currently active chillers}] N$ by the $[\text{partial load capacity}] Q_p$ (i.e., when the $[\text{operation capacity per chiller}]$ is greater than the $[\text{partial load capacity}] Q_p$). In contrast, the number of the active chillers 100 is reduced by one when the $[\text{total required operation capacity}] Q_t$ is not more than the $[\text{reference load capacity for decreasing active chillers}] Q_d$ (i.e., when the $[\text{operation capacity per chiller}]$ is not more than the $[\text{partial load capacity}] Q_p$). Thus, it is possible to set the lower limit of the operation capacity per chiller (i.e., the $[\text{partial load capacity}] Q_p$), which prevents the operation in the range of the low operation efficiency.

[0150] Also, in the chiller system 1, when the stop command is transmitted to one chiller 100 of the active chillers 100 out of the plurality of chillers 100 (1) to 100 (n), the chiller 100 is selected as the target for the next stop command in the order of: the stopped chiller 100 in the [normal state]; the active chiller 100 in the [normal state]; the stopped chiller 100 in the [before-alarming state]; and the active chiller 100 in the [before-alarming state]. In this way, it is possible to select the chiller 100 in the [before-alarming state] preferentially as the target for continuous operation out of the plurality of chillers 100 (1) to 100 (n), and thus, it is possible to make the chiller 100 having a minor abnormality such as a temporary abnormality a maintenance target state in an early stage. Furthermore, if the chillers 100 are in the same state (i.e., have the same priority), the chiller 100 is selected as the target for the next stop command in descending order of the cumulative output amount from the initial state or from the time point at which the predetermined maintenance has been performed. Thus, when the chillers 100 are in the same state, it is possible to preferentially stop the chiller 100 having a greater cumulative output amount. Thus, it is possible to level the respective cumulative operation times of the chillers 100 (1) to 100 (n), which reliably allows the chillers 100 (1) to 100 (n) to have the same maintenance time.

[0151] The present invention is not limited to the above-described embodiments, and may be embodied in other forms without departing from the gist or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects as illustrative and not limiting. The scope of the invention is indicated by the appended claims

rather than by the foregoing description, and all modifications and changes that come within the meaning and range of equivalency of the claims are intended to be embraced therein.

[0152] This application claims priority based on Patent Application No. 2014-129486 filed in Japan on June 24, 2014. The entire contents thereof are hereby incorporated in this application by reference.

Industrial Applicability

[0153] The present invention relates to a chiller system in which a plurality of heat pump chillers is connected to each other. The present invention is particularly suitable for leveling respective cumulative operation times of the chillers even when a partial load at which an operation output does not reach a rated output is continuously applied.

Description of Reference Numerals

[0154]

- 1 Chiller system
- 10 Compressor
- 11 Clutch
- 20 Refrigerant-air heat exchanger
- 30 Refrigerant-air heat exchanger fan
- 40 Expansion valve
- 41 First expansion valve
- 42 Second expansion valve
- 50 Refrigerant-circulating liquid heat exchanger
- 60 Engine
- 70 Engine exhaust heat recovery unit
- 81 Oil separator
- 81a Valve
- 82 Accumulator
- 83 Receiver
- 100 Chiller
- 110 Refrigerant circuit
- 111 Four-way valve
- 112 Bridge circuit
- 1121 First check valve line
- 1122 Second check valve line
- 112a First check valve
- 112b Second check valve
- 112c Third check valve
- 112d Fourth check valve
- 113a High pressure gas refrigerant path
- 113b First low pressure gas refrigerant path
- 113b1 Confluence path
- 113c First gas refrigerant path
- 113d First refrigerant path
- 113e High pressure liquid refrigerant path
- 113f First low pressure gas-liquid two phase refrigerant path
- 113g Second refrigerant path
- 113h Second gas refrigerant path
- 113i Second low pressure gas-liquid two phase refrigerant path
- 113j Second low pressure gas refrigerant path
- 120 Coolant path
- 121 First thermostat type switching valve
- 122 Second thermostat type switching valve
- 123 Radiator
- 124a Outlet path
- 124b Inlet path
- 124c First path

124d	Second path
124e	Third path
124f	Fourth path
124g	Fifth path
5 130	Circulation pump
140	Control device
141	Processor
142	Memory
151	First pressure sensor
10 152	Second pressure sensor
161	First temperature sensor
162	Second temperature sensor
170	Rotation speed sensor
200	Circulating liquid circuit
15 210	Inlet main pipe
211	Inlet branch pipe
220	Outlet main pipe
221	Outlet branch pipe
231	Influent circulating liquid temperature sensor
20 232	Effluent circulating liquid temperature sensor
300	Circulation pump
C1	Before-alarming operation counter
C2	Before-alarming operation stop counter
C3	Normal operation counter
25 C4	Normal operation stop counter
C5	Inoperable state counter
N	Number of currently active chillers
P1	First intermediate connection point
P2	Outlet connection point
30 P3	Second intermediate connection point
P4	Inlet connection point
P5	Confluence point
P6	Confluence point
P7	Confluence point
35 Qd	Reference load capacity for decreasing active chillers
Qi	Reference load capacity for increasing active chillers
Qp	Partial load capacity
Qt	Total required operation capacity

40

Claims

1. A chiller system comprising a plurality of heat pump chillers being connected to each other, the plurality of heat pump chillers regulating a temperature of a circulating liquid as a heat medium for temperature regulation by condensation heat or evaporation heat of a refrigerant,
 45 wherein, when there is at least one active chiller out of the plurality of chillers, an operation command is transmitted, to one of the remaining chillers being stopped, under a condition that the following relation is satisfied:

$$50 \quad \frac{[\text{total required operation capacity}]}{([\text{number of currently active chillers}] + 1)} \geq [\text{partial load capacity}],$$

where the [total required operation capacity] represents a total operation capacity required of the at least one active chiller, the [number of currently active chillers] represents a number of the at least one active chiller, and the [partial load capacity] represents a load capacity of a predetermined partial load.

2. The chiller system according to claim 1,

wherein the plurality of chillers is each capable of being in a normal state, an alarming state in which an alarm is being transmitted, or a before-alarming state that is a state between the normal state and the alarming state, wherein a target chiller for a next operation command is selected in an order of: an active chiller in the before-alarming state; a stopped chiller in the before-alarming state; an active chiller in the normal state ; and a stopped chiller in the normal state, and

wherein, when the chillers are in a same state, the target chiller for the next operation command is selected in ascending order of a cumulative output amount from an initial state or from a time point at which a predetermined maintenance has been performed.

3. The chiller system according to claim 1 or 2,
wherein, when there is at least one active chiller out of the plurality of chillers, a stop command is transmitted to one of the at least one active chiller under a condition that the following relation is satisfied:

$$[\text{total required operation capacity}] / [\text{number of currently active chillers}] \leq [\text{partial load capacity}].$$

4. The chiller system according to claim 3,
wherein the plurality of chillers is each capable of being in a normal state, an alarming state in which an alarm is being transmitted, or a before-alarming state that is a state between the normal state and the alarming state, wherein a target chiller for a next stop command is selected in an order of: a stopped chiller in the normal state; an active chiller in the normal state; a stopped chiller in the before-alarming state ; and an active chiller in the before-alarming state, and
wherein, when the chillers are in a same state, the target chiller for the next stop command is selected in descending order of a cumulative output amount from an initial state or from a time point at which a predetermined maintenance has been performed.

FIG.1

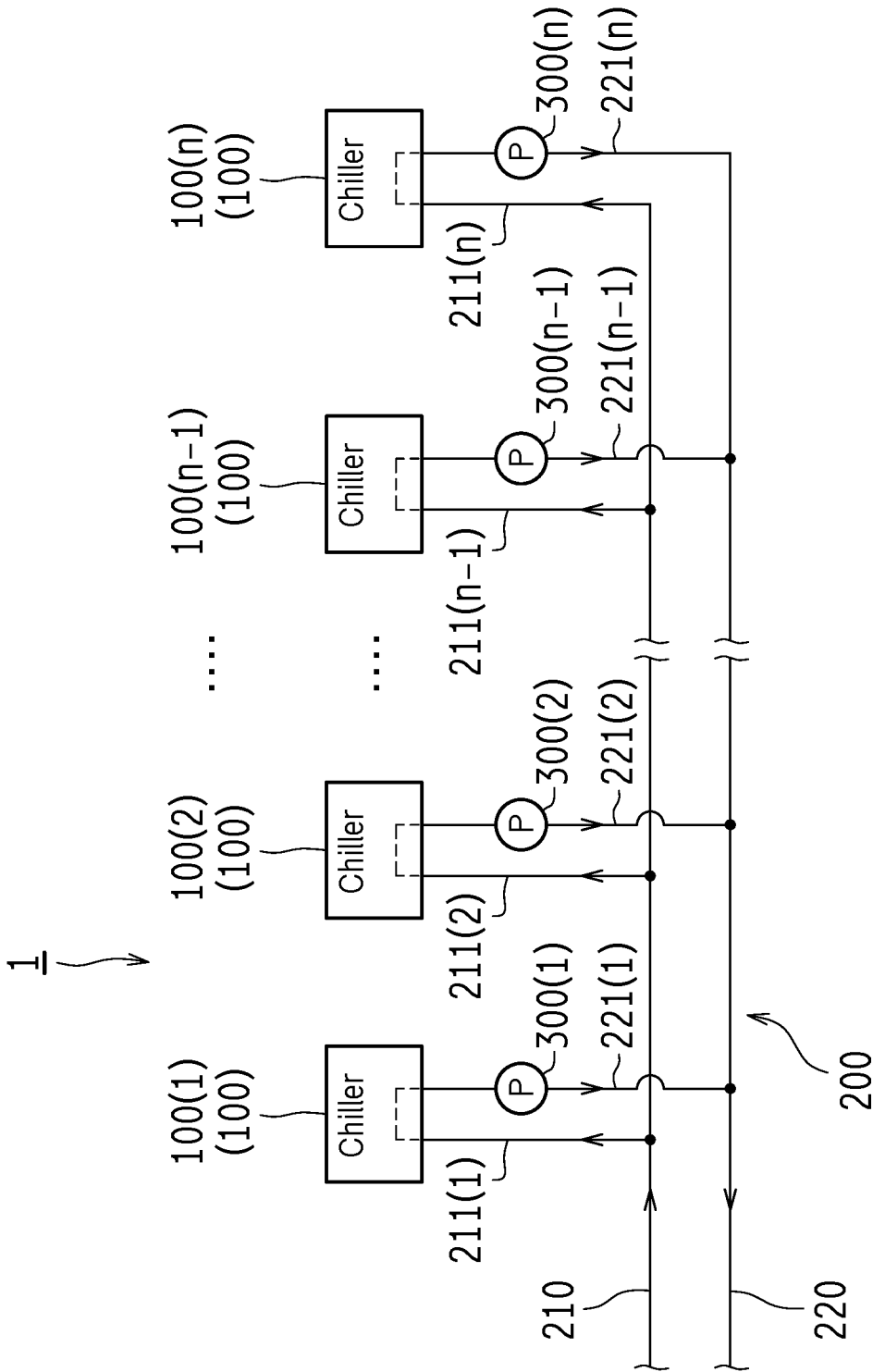


FIG.2

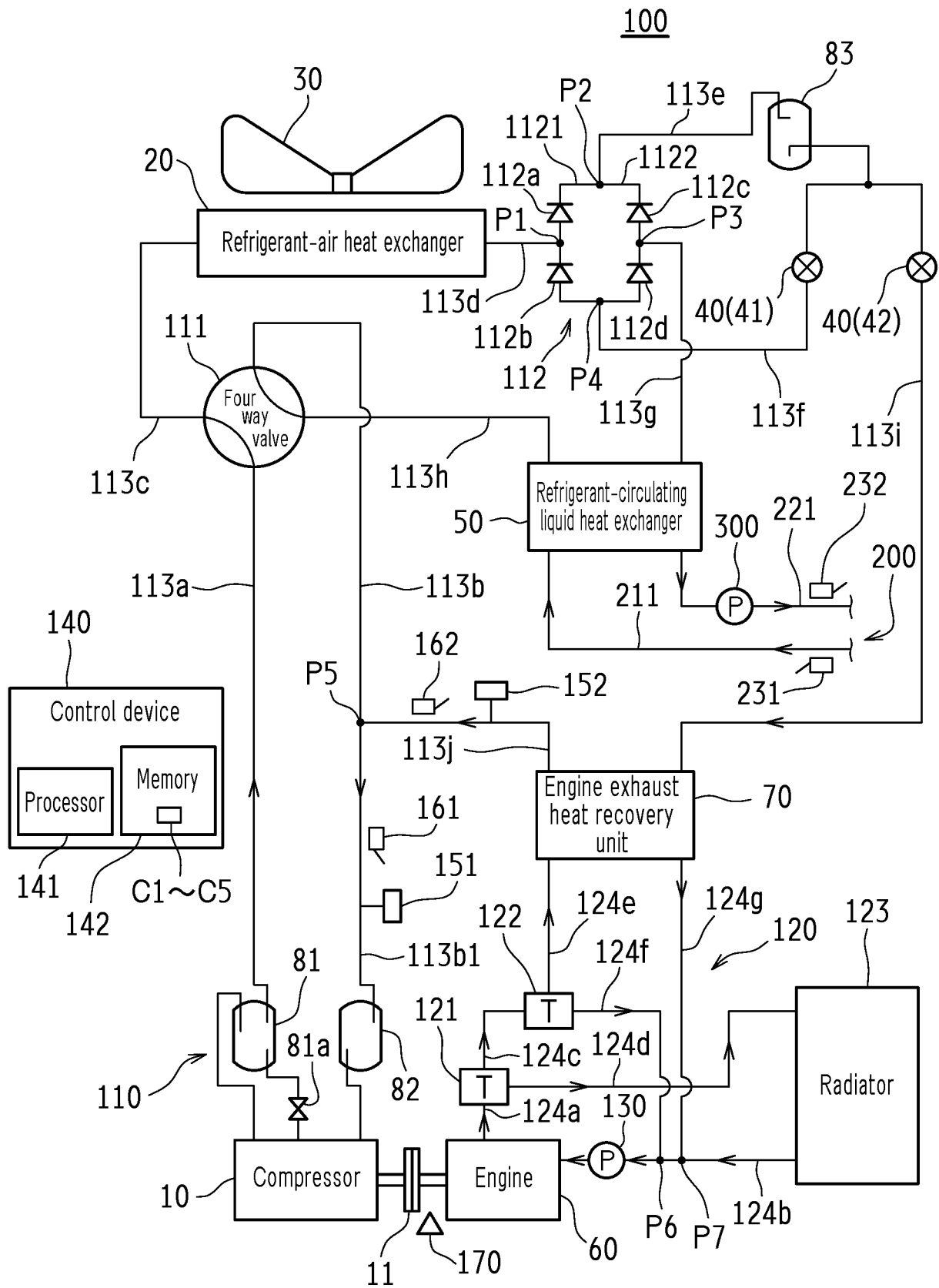


FIG.3

(Cooling operation)

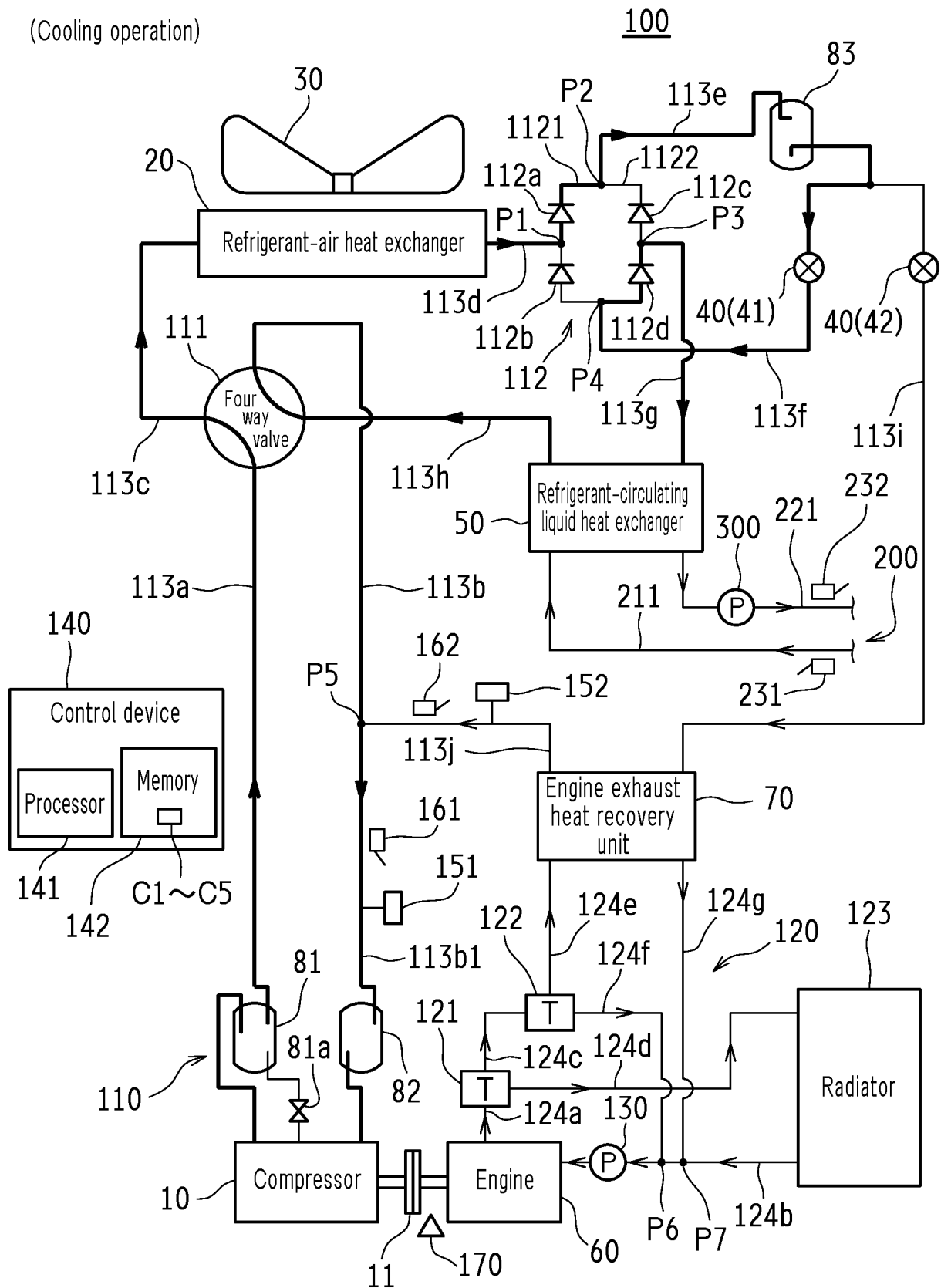


FIG. 4

(Heating operation)

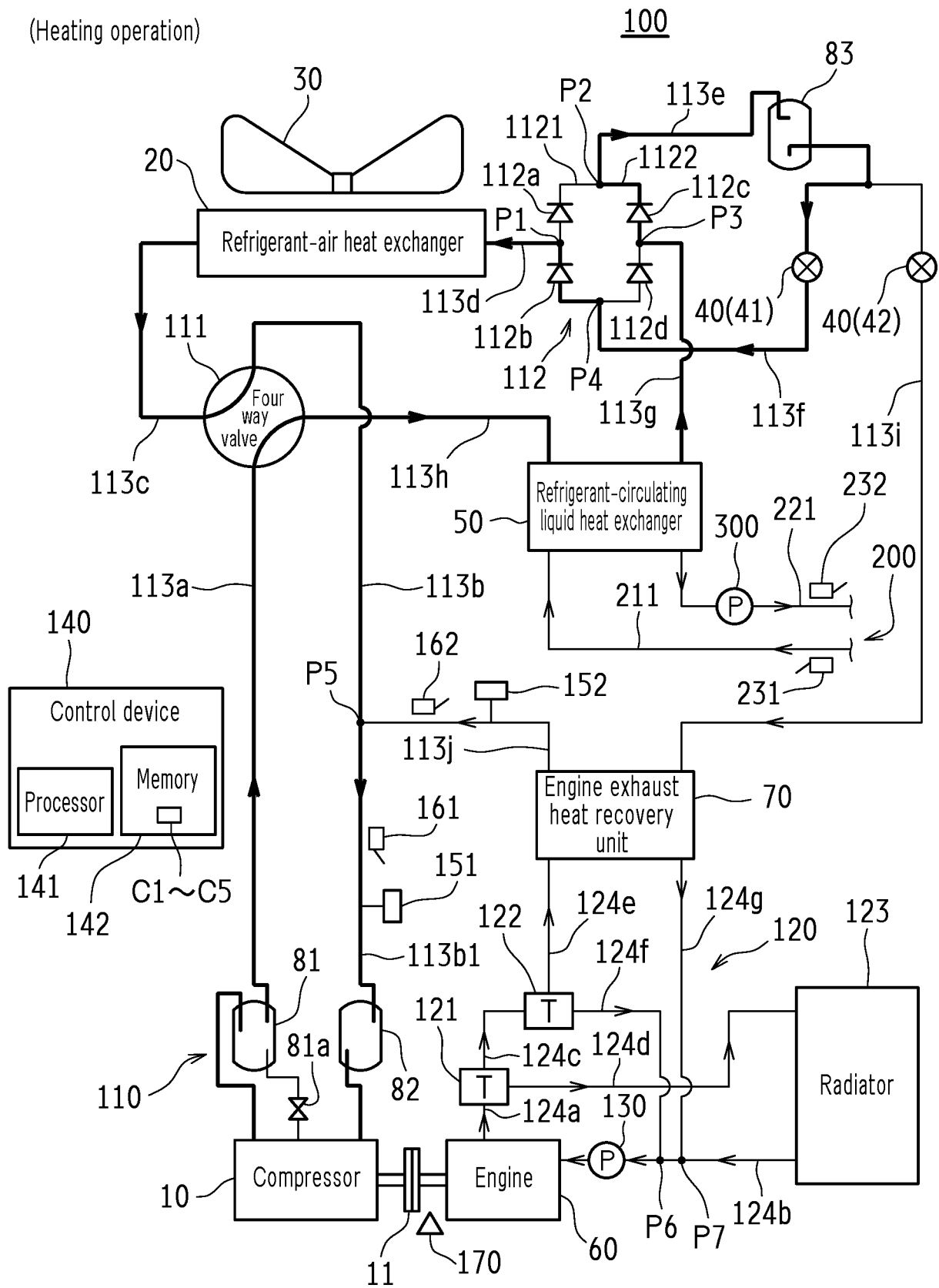


FIG.5

(Defrost operation)

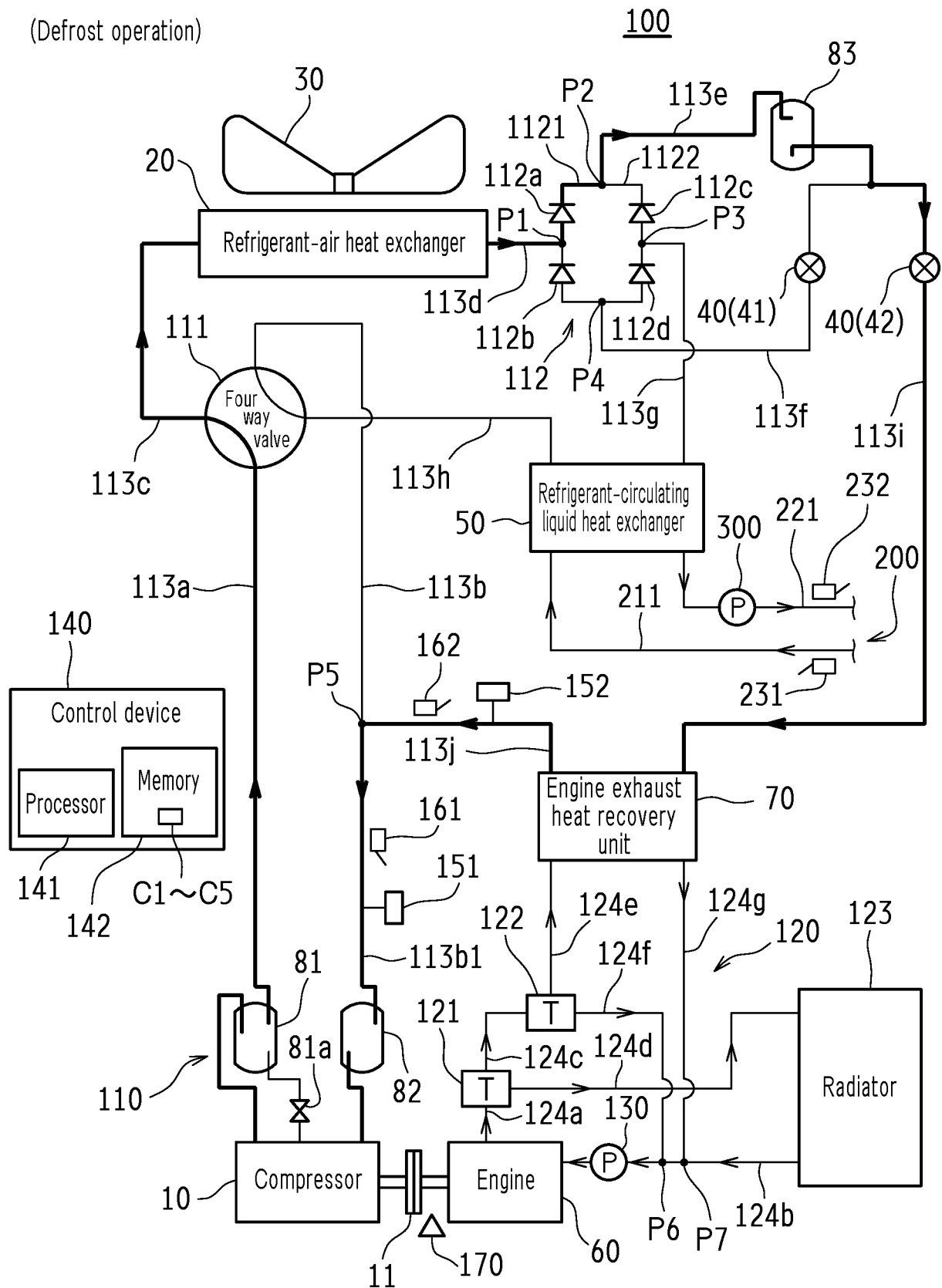


FIG.6

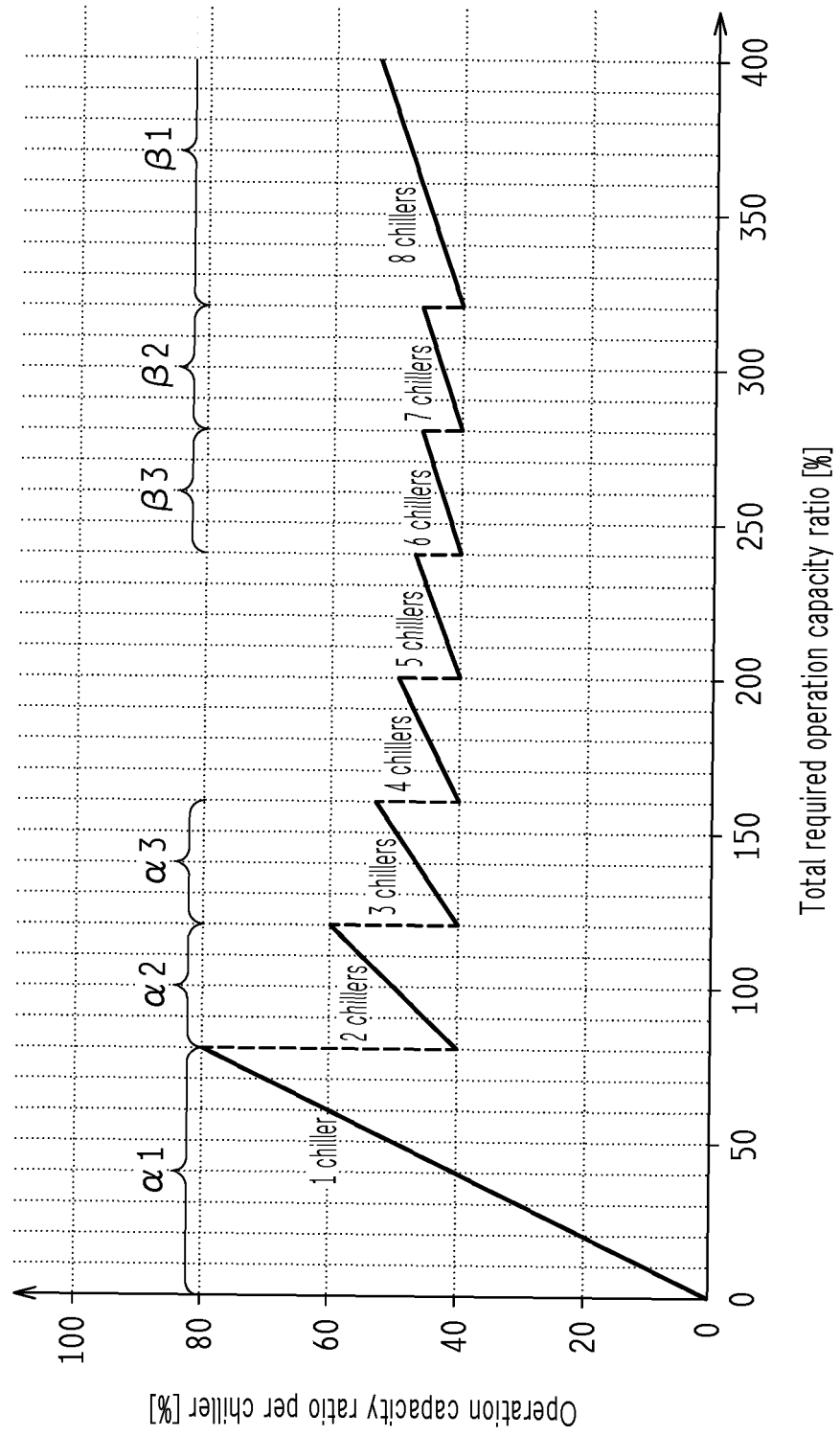


FIG. 7

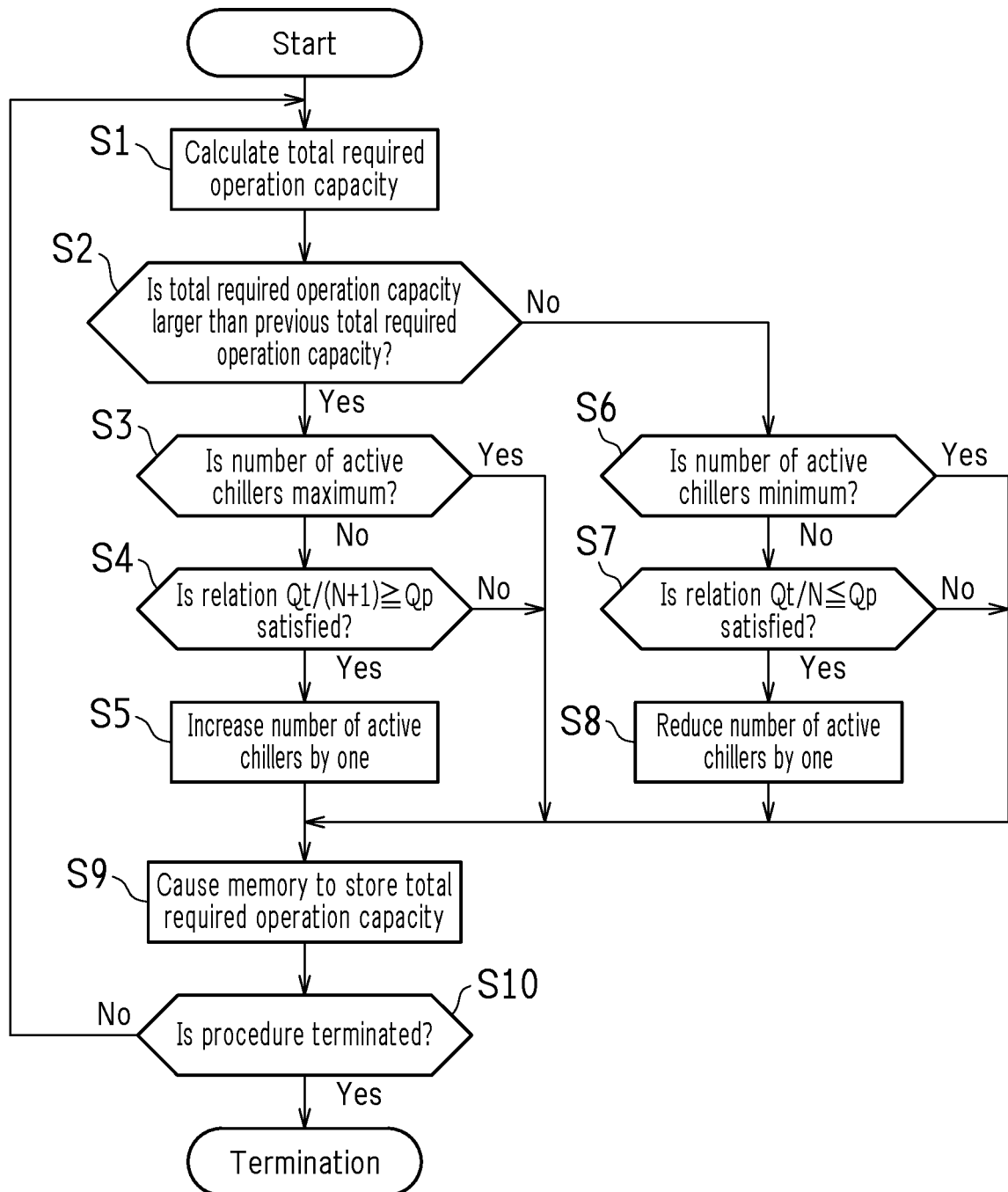


FIG.8

Step of determining priority		Operation state							
		Na	Ba	Na	Ns	Ns	Na	X	Ba
1	Cumulative output amount of engine (ascending order)	1	2	3	4	5	6	7	8
2	Active chiller 「Ba」 number before-alarming	2	2	2	2	2	2	2	2
3	Stopped chiller 「Bs」 number before-alarming	0	0	0	0	0	0	0	0
4	Normal active chiller 「Na」 number	3	3	3	3	3	3	3	3
5	Normal stopped chiller 「Ns」 number	2	2	2	2	2	2	2	2
6	Before-alarming operation counter for 「Ba」	0	1	1	1	1	1	1	2
7	Before-alarming stop counter for 「Bs」	0	0	0	0	0	0	0	0
8	Normal operation counter for 「Na」	1	1	2	2	2	3	3	3
9	Normal operation stop counter for 「Ns」	0	0	0	1	2	2	2	2
10	Inoperable state counter for 「X」	0	0	0	0	0	0	1	1
11	Priority order	3	1	4	6	7	5	8	2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/064032

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/00(2006.01)i, F24F11/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00, F24F11/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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 2010-032155 A (Daikin Industries, Ltd.),	1
Y	12 February 2010 (12.02.2010),	3
A	paragraphs [0005] to [0010], [0018] to [0030]; fig. 1 to 3 (Family: none)	2, 4
Y	JP 08-261544 A (Yamatate-Honeywell Co., Ltd.),	3
A	11 October 1996 (11.10.1996), paragraphs [0015] to [0017]; fig. 1, 3 (Family: none)	2, 4

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

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search
23 July 2015 (23.07.15)Date of mailing of the international search report
04 August 2015 (04.08.15)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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