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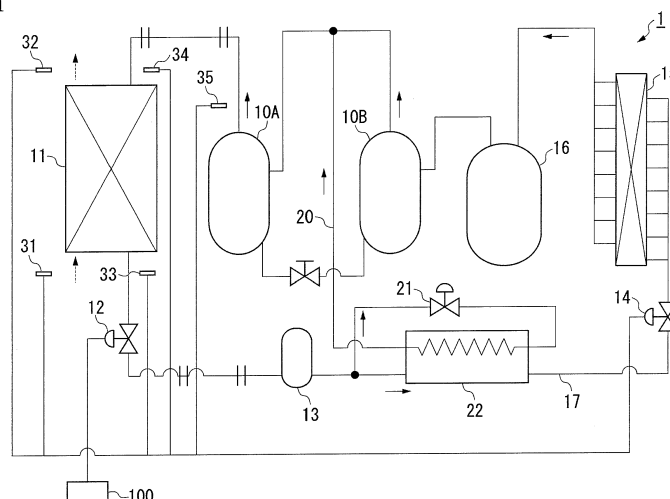
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(54) **REFRIGERANT CIRCUIT SYSTEM AND CONTROL METHOD**

(57) A refrigerant circuit system (1) includes a main-stream circuit which connects a plurality of compressors (10A, 10B), a use-side heat exchanger (11), a first expansion valve (12), a receiver (13), a second expansion valve (14) which depressurizes the refrigerant flowing out from the receiver (13), and a heat-source-side heat exchanger (15), an injection circuit which branches some of the refrigerant flowing out from the receiver (13) and supplies the branched refrigerant to a suction side of a

predetermined compressor among the plurality of compressors (10A, 10B), and a control device which switches between operation and non-operation of the injection circuit on the basis of a difference between an inlet temperature on an inlet side of the use-side heat exchanger (11) of a use-side medium that receives a supply of heat by the use-side heat exchanger (11) and an outlet temperature on an outlet side of the use-side heat exchanger.

FIG. 1



Description

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001] The present invention relates to a refrigerant circuit system and a control method.

[0002] Priority is claimed on Japanese Patent Application No. 2017-10248, filed January 24, 2017, the content of which is incorporated herein by reference.

10 Description of Related Art

[0003] Conventionally, as a refrigerant circuit including a multi-stage compressor, a refrigerant circuit with an injection circuit for branching some of a high-pressure refrigerant condensed by a condenser and injecting the branched refrigerant into a compressor to improve a cooling capacity and a coefficient of performance (COP) is known. For example, in Patent Document 1, a technology for switching between operation and non-operation of an injection circuit and improving a COP in accordance with a load level and a ratio of a condensed pressure to an evaporation pressure in a refrigerant circuit with the injection circuit is described.

[0004] In addition, as a water heater using a heat pump, a transient system which raises a temperature of supply water at a low temperature to a set temperature and supplies the hot water, and a circulation-type system which circulates supply water at a constant temperature, raises a temperature of the supply water to a set temperature, and supplies the hot water are known. A water heater of the transient system raises a temperature of supply water at a low temperature (for example, 5°C) to a set temperature (for example, 80°C). A water heater of the circulation-type system raises a temperature of supply water at a predetermined temperature (for example, 75°C) to the set temperature (for example, 80°C).

[Patent Documents]

[0005] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2003-185286

SUMMARY OF THE INVENTION

[0006] When a water heater corresponding to both a transient system and a circulation-type system is considered, it is necessary to raise a temperature of supply water so that a use-side outlet temperature thereof becomes a predetermined set temperature under a situation in which a use-side inlet temperature changes in a refrigerant circuit included in such a water heater. A control method for efficiently operating the refrigerant circuit has not been provided so far.

[0007] An object of the invention herein is to provide a refrigerant circuit system and a control method which can solve the above problems.

[0008] According to a first aspect of the present invention, a refrigerant circuit system includes a mainstream circuit which connects a plurality of compressors which compress a refrigerant, a use-side heat exchanger which condenses the refrigerant compressed by the compressor, a first expansion valve which depressurizes the refrigerant flowing out from the use-side heat exchanger, a receiver which stores some of the refrigerant depressurized by the first expansion valve, a second expansion valve which depressurizes the refrigerant flowing out from the receiver, and a heat-source-side heat exchanger which evaporates the refrigerant depressurized by the second expansion valve, an injection circuit which branches some of the refrigerant flowing out from the receiver and supplies the branched refrigerant to a suction side of a predetermined compressor among the plurality of compressors, and includes a third expansion valve which depressurizes the branched refrigerant and an intermediate heat exchanger which performs heat exchange between a refrigerant passing through the third expansion valve and a refrigerant passing through the mainstream circuit, and a control device which switches between operation and non-operation of the injection circuit on the basis of a difference between an inlet temperature on an inlet side of the use-side heat exchanger of a use-side medium that receives a supply of heat by the use-side heat exchanger and an outlet temperature on an outlet side of the use-side heat exchanger of the use-side medium.

[0009] The control device according to a second aspect of the present invention performs control so that the third expansion valve is completely closed when a difference between the inlet temperature and the outlet temperature is equal to or greater than a predetermined first threshold value.

[0010] The control device according to a third aspect of the present invention performs control so that the third expansion valve is opened at a predetermined level larger than zero when a difference between the inlet temperature and the outlet temperature is equal to or less than a predetermined second threshold value.

[0011] The control device according to a fourth aspect of the present invention controls the number of rotations of a compressor provided on the highest stage side among the plurality of compressors on the basis of a target value of an outlet temperature of the use-side medium, and controls an opening of the first expansion valve by setting an outlet side temperature of the use-side heat exchanger based on an inlet temperature of the use-side medium as a target value.

[0012] The control device according to a fifth aspect of the present invention switches between operation and non-operation of the injection circuit on the basis of a difference between an outlet side temperature of the use-side heat exchanger instead of the inlet temperature and the outlet temperature.

[0013] The control device according to a sixth aspect of the present invention switches between operation and non-operation of the injection circuit on the basis of a difference between the inlet temperature and a condensed pressure saturation temperature or a discharge pressure saturation temperature instead of the outlet temperature.

[0014] According to a seventh aspect of the present invention, in a refrigerant circuit system that includes a mainstream circuit which connects a plurality of compressors which compress a refrigerant, a use-side heat exchanger which condenses the refrigerant compressed by the compressor, a first expansion valve which depressurizes the refrigerant flowing out from the use-side heat exchanger, a receiver which stores some of the refrigerant depressurized by the first expansion valve, a second expansion valve which depressurizes the refrigerant flowing out from the receiver, and a heat-source-side heat exchanger which evaporates the refrigerant depressurized by the second expansion valve, an injection circuit which branches some of the refrigerant flowing out from the receiver, supplies the branched refrigerant to a suction side of a predetermined compressor among the plurality of compressors, and includes a third expansion valve which depressurizes the branched refrigerant, and an intermediate heat exchanger which performs heat exchange between a refrigerant passing through the third expansion valve and a refrigerant passing through the mainstream circuit, a control method includes switching between operation and non-operation of the injection circuit on the basis of a difference between an inlet temperature on an inlet side of the use-side heat exchanger of a use-side medium that receives a supply of heat by the use-side heat exchanger and an outlet temperature on an outlet side of the use-side heat exchanger of the use-side medium.

[0015] According to the present invention, it is possible to operate a refrigerant circuit efficiently in a situation in which operation conditions change.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a diagram showing an example of a refrigerant circuit system in an embodiment of the present invention. FIG. 2 is a diagram showing a relationship between a use-side inlet temperature and a condenser outlet temperature in the embodiment of the present invention.

FIG. 3 is a first P-h diagram of the refrigerant circuit system in the embodiment of the present invention.

FIG. 4 is a second P-h diagram of the refrigerant circuit system in an embodiment of the present invention.

FIG. 5 is a diagram showing an effect of an injection circuit of the refrigerant circuit system in the embodiment of the present invention.

FIG. 6 is a diagram showing an example of a method of determining switching of an injection circuit in the embodiment of the present invention.

FIG. 7 is a flowchart of a control device in the embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

<Embodiment>

[0017] Hereinafter, a refrigerant circuit system according to an embodiment of the present invention will be described with reference to FIGS. 1 to 7. FIG. 1 is a diagram showing an example of the refrigerant circuit system in the embodiment of the present invention.

[0018] The refrigerant circuit system 1 is a refrigerant circuit used in a water heater. The refrigerant circuit system 1 raises a temperature of supply water (a use-side medium receiving a supply of heat) supplied from the outside to a predetermined set target temperature (for example, 80°C), and supplies this hot water to a user. In the present embodiment, the set target temperature (hot water supply temperature) of supply water supplied to a user is constant, and the temperature of supply water supplied from the outside changes. The temperature of supplied supply water is a return temperature (for example, 75°C) with a small difference from the hot water supply temperature in a circulation-type system, and the temperature of supply water is a temperature (for example, 5°C) near a normal temperature (outside air temperature) in a transient system in which hot water is not returned. The set target temperature of supply water is referred to as a use-side outlet temperature. In addition, the temperature of supply water supplied from the outside is

referred to as a use-side inlet temperature.

[0019] The refrigerant circuit system 1 shown in FIG. 1 is configured to include a mainstream circuit configured to include a high-stage-side compressor 10A, a low-stage-side compressor 10B, a use-side heat exchanger (condenser) 11, a first expansion valve 12, a receiver 13, a second expansion valve 14, a heat-source-side heat exchanger (evaporator) 15, an accumulator 16, and main flow piping 17 connected to these, an injection circuit configured to include injection piping 20, a third expansion valve 21, and an intermediate heat exchanger 22, and a control device 100.

[0020] A specific configuration of the refrigerant circuit system 1 shown in FIG. 1 schematically shows a basic configuration of the refrigerant circuit system 1, and other constituent elements may further be included.

[0021] The high-stage-side compressor 10A and the low-stage-side compressor 10B compress a refrigerant and discharge a high-pressure refrigerant. The low-stage-side compressor 10B and the high-stage-side compressor 10A are connected in series. A suction side of the low-stage-side compressor 10B is connected to the accumulator 16. In addition, a discharge side of the low-stage-side compressor 10B is connected to a suction side of the high-stage-side compressor 10A. The low-stage-side compressor 10B sucks a low-pressure refrigerant supplied from the accumulator 16 and compresses it to discharge an intermediate pressure refrigerant to the high-stage-side compressor 10A side. In addition, the injection piping 20 is connected to the suction side of the high-stage-side compressor 10A, and an intermediate pressure refrigerant is supplied from the injection piping 20 as will be described below. The number of rotations of the high-stage-side compressor 10A and the low-stage-side compressor 10B are controlled by an inverter circuit of the control device 100. In the present embodiment, the number of rotations of the high-stage-side compressor 10A is controlled by the control device 100 so that a discharge pressure saturation temperature of the high-stage-side compressor 10A is a predetermined temperature (for example, 82°C) according to a use-side outlet temperature (for example, 80°C) set in advance. As described above, in the present embodiment, a target high pressure is determined in accordance with the use-side outlet temperature, and the value of the target high pressure is controlled to be constant regardless of a change (for example, 5°C and 75°C) in a use-side inlet temperature. A refrigerant with a high temperature and high pressure discharged by the high-stage-side compressor 10A is supplied to a use-side heat exchanger 11.

[0022] The use-side heat exchanger 11 functions as a condenser. A high-pressure refrigerant supplied to the use-side heat exchanger 11 radiates heat by exchanging heat with supply water used by a user and is condensed into a liquid. Water supplied to the use-side heat exchanger 11 absorbs heat from the high-pressure refrigerant and a temperature is raised to a predetermined set target temperature (the use-side outlet temperature) to be supplied to a user. In the drawing, a dotted arrow indicates a flow direction of the supply water and a solid arrow indicates a flow direction of the refrigerant.

[0023] The first expansion valve 12 is a flow control valve which depressurizes a refrigerant. The high-pressure refrigerant after the heat exchange of the use-side heat exchanger 11 is depressurized and expanded by the first expansion valve 12 and is supplied to the receiver 13. An opening of the first expansion valve 12 is controlled by the control device 100. In the present embodiment, the control device 100 controls the opening of the first expansion valve 12 so that an outlet side temperature of the use-side heat exchanger 11 is a predetermined temperature based on a use-side inlet temperature. The predetermined temperature based on the use-side inlet temperature is a temperature higher than the use-side inlet temperature by a predetermined value (for example, 2°C). For example, a set target temperature of the outlet side temperature of the use-side heat exchanger 11 is 7°C in the case of the transient system, and a set target temperature of the outlet side temperature of the use-side heat exchanger 11 is 77°C in the case of operation in the circulation-type system. FIG. 2 shows a relationship between a use-side inlet temperature and a condenser outlet temperature (the outlet side temperature of the use-side heat exchanger 11) in the present embodiment. A solid line in FIG. 2 indicates the outlet side temperature of the use-side heat exchanger 11. As shown in FIG. 2, the outlet side temperature of the use-side heat exchanger 11 is controlled to always be a target value higher than a use-side inlet temperature indicated by a dotted line by a predetermined temperature (for example, 2°C). The control device 100 realizes the target value by adjusting the opening of the first expansion valve 12.

[0024] The receiver 13 is a pressure vessel for temporarily storing some of a supplied refrigerant. Two phases of refrigerant such as gas and liquid are mixed and stored in the receiver 13. The first expansion valve 12 is provided on an upstream side of the receiver 13, and a branching to the injection piping 20, the intermediate heat exchanger 22, and the second expansion valve 14 are provided on a downstream side thereof. Some of a refrigerant flowing out from the receiver 13 is branched to the injection piping 20 and the remaining refrigerant flows through the mainstream circuit.

[0025] The second expansion valve 14 is a flow control valve which depressurizes a refrigerant. In the intermediate heat exchanger 22, the liquid refrigerant flowing through the mainstream circuit is cooled by heat exchange with some of the refrigerant flowing (branched) through the injection piping 20, and is depressurized and expanded by the second expansion valve 14 to become a low-pressure refrigerant.

[0026] The heat-source-side heat exchanger 15 functions as an evaporator. The heat-source-side heat exchanger 15 evaporates a low-pressure refrigerant flowing in from the second expansion valve 14 by heat absorption from a heat source such as outside air. In the present embodiment, opening of the second expansion valve 14 is controlled by the control device 100 so that an evaporation temperature is constant. The refrigerant passing through the heat-source-side

heat exchanger 15 is supplied to the accumulator 16. The refrigerant is separated into a gas and a liquid in the accumulator 16 and only the gas refrigerant is sucked into the low-stage-side compressor 10B. The low-stage-side compressor 10B compresses the refrigerant and discharges it to the high-stage-side compressor 10A side.

[0027] The refrigerant branched on the downstream side of the receiver 13 is supplied to the suction side of the high-stage-side compressor 10A via the injection piping 20. The third expansion valve 21 and the intermediate heat exchanger 22 are provided in the injection piping 20.

[0028] The third expansion valve 21 is a flow control valve which depressurizes some branched refrigerant.

[0029] The intermediate heat exchanger 22 performs heat exchange between the refrigerant passing through the third expansion valve 21 and the refrigerant passing through the main flow piping 17. The refrigerant depressurized by the third expansion valve 21 is heated by the heat exchange of the intermediate heat exchanger 22, and is returned to the high-stage-side compressor 10A to be compressed. Due to this injection circuit, it is possible to improve a COP of a refrigeration cycle.

[0030] The control device 100 is a computer device such as a microcomputer. The control device 100 controls an apparatus constituting a refrigerant circuit such as the high-stage-side compressor 10A and the first expansion valve 12 as described above, for example. Particularly, in the present embodiment, the control device 100 performs control to switch between operation and non-operation of the injection circuit. A refrigerant flows through the injection circuit when the injection circuit is operated, and a refrigerant does not flow through the injection circuit when the injection circuit is not operated.

[0031] In addition, a detection unit such as a temperature sensor or a pressure sensor is installed in the refrigerant circuit system 1. For example, a temperature sensor 31 and a temperature sensor 32 are provided in an inlet and an outlet of the use-side heat exchanger 11 through which supply water (use-side medium) passes, respectively. The temperature sensor 31 measures a use-side inlet temperature and the temperature sensor 32 measures a use-side outlet temperature. In addition, a temperature sensor 33 is provided on an outlet side of the use-side heat exchanger 11. The temperature sensor 33 measures a temperature of a refrigerant on the outlet side of the use-side heat exchanger 11. The temperature sensor 31, the temperature sensor 32, and the temperature sensor 33 output information on the measured temperatures to the control device 100. In addition, a pressure sensor 34 is provided on an inlet side of the use-side heat exchanger 11. The pressure sensor 34 measures a pressure of the refrigerant on the inlet side of the use-side heat exchanger 11. Moreover, a pressure sensor 35 is provided on a discharge side of the high-stage-side compressor 10A. The pressure sensor 35 measures a pressure of the refrigerant on the discharge side of the high-stage-side compressor 10A. The pressure sensor 34 and the pressure sensor 35 output information on the measured pressures to the control device 100. For example, a temperature sensor (not shown) and a pressure sensor (not shown) are provided on an outlet side of the heat-source-side heat exchanger, and the control device 100 performs control on the basis of the values measured by these sensors so that the evaporation temperature is constant.

[0032] Next, efficiency of the refrigerant circuit when the use-side inlet temperature has changed in the refrigerant circuit system 1 exemplified in FIG. 1 will be described.

[0033] First, a case in which a use-side inlet temperature is high will be described.

[0034] FIG. 3 is a first P-h diagram of the refrigerant circuit system in the embodiment of the present invention. FIG. 3 is a diagram of a relationship between pressure and enthalpy that represents a refrigeration cycle when the refrigerant circuit system 1 is operated. A diagram indicated by a solid line in FIG. 3 is a first P-h diagram when the injection circuit is operated in the case in which a use-side inlet temperature is high (75°C) (circulation-type system). The signs in the P-h diagram indicated by a solid line in FIG. 3 represent the following states. A1 indicates a state of the refrigerant discharged by the high-stage-side compressor 10A, A2 indicates a state of the refrigerant on the outlet side of the use-side heat exchanger 11, A3 indicates a state of the refrigerant on the outlet side of the first expansion valve 12, A4 indicates a state of the refrigerant on the inlet side of the second expansion valve 14, A5 indicates a state of the refrigerant on the outlet side of the second expansion valve 14, A6 indicates a state of the refrigerant on the outlet side of the heat-source-side heat exchanger 15, A7 indicates a state of the refrigerant discharged by the low-stage-side compressor 10B, A8 indicates a state of the refrigerant on the outlet side of the third expansion valve 21, and A9 indicates a state of the refrigerant on the suction side of the high-stage-side compressor 10A.

[0035] When the use-side inlet temperature is high (75°C), the refrigerant (state A1) with a high temperature and a high pressure discharged from the high-stage-side compressor 10A radiates heat to the use-side heat exchanger 11 and is condensed to be a liquid which is a high-pressure liquid refrigerant (state A2). Then, a refrigerant flowing through a mainstream circuit among refrigerants (state A3) passing through the first expansion valve 12 to be depressurized is cooled by the intermediate heat exchanger 22 (state A4), and reaches the second expansion valve 14. Then, the refrigerant is further depressurized by the second expansion valve 14 (state A5), flows into the heat-source-side heat exchanger 15 to evaporate, and becomes a low-pressure gas refrigerant (state A6). The low-pressure gas refrigerant has a pressure raised to an intermediate pressure by the low-stage-side compressor 10B (state A7), and is supplied to the suction side of the high-stage-side compressor 10A. The refrigerant branched to the injection circuit has a pressure depressurized to the intermediate pressure by the third expansion valve 21 (state A8), absorbs heat via the intermediate

heat exchanger 22, and is supplied to the suction side of the high-stage-side compressor 10A via the injection piping 20. Then, the refrigerant supplied via the injection piping 20 and the refrigerant compressed by the low-stage-side compressor 10B are mixed, and the refrigerant with the intermediate pressure whose temperature is lowered (state A9) is supplied to the high-stage-side compressor 10A. The high-stage-side compressor 10A compresses the refrigerant with the intermediate pressure and discharges the refrigerant with a high temperature and a high pressure (state A1). Thereafter, the same cycle is repeated.

[0036] A dotted line diagram in FIG. 3 is a P-h diagram when the use-side inlet temperature is high and the injection circuit is not operated. When the injection circuit is not operated, there is no process from the state A3 to the state A4 and no process from the state A8 to the state A9 by the intermediate heat exchanger 22, and thus the P-h diagram is shaped as indicated by a dotted line.

[0037] If a case in which the injection circuit is operated and a case in which the injection circuit is not operated are compared, in the case in which the injection circuit is operated, a pressure difference before and after the third expansion valve 21 is large (a pressure difference between the state A3 and the state A8) and it is possible to ensure a flow rate of the refrigerant flowing into the injection piping 20. Therefore, a circulation amount of the refrigerant flowing into an evaporator (the heat-source-side heat exchanger 15) can be reduced and the COP is increased. In addition, a refrigerant pressure loss can also be reduced as the circulation amount of a refrigerant is reduced.

[0038] Next, a case in which the use-side inlet temperature is low will be described.

[0039] FIG. 4 is a second P-h diagram of the refrigerant circuit system in the embodiment of the present invention. FIG. 4 is a diagram of a relationship between pressure and enthalpy representing a refrigeration cycle when the refrigerant circuit system 1 is operated. A diagram indicated by a solid line in FIG. 4 is a P-h diagram when the injection circuit is operated in the case (transient system) in which the use-side inlet temperature is low (5°C). The signs in the P-h diagram indicated by a solid line in FIG. 4 indicate the following states. B1 indicates a state of the refrigerant discharged by the high-stage-side compressor 10A, B2 indicates a state of the refrigerant on the outlet side of the use-side heat exchanger 11, B3 indicates a state of the refrigerant on the outlet side of the first expansion valve 12, B4 indicates a state of the refrigerant on the inlet side of the second expansion valve 14, B5 indicates a state of the refrigerant on the outlet side of the second expansion valve 14, B6 indicates a state of the refrigerant on the outlet side of the heat-source-side heat exchanger 15, B7 indicates a state of the refrigerant discharged by the low-stage-side compressor 10B, B8 indicates a state of the refrigerant on the outlet side of the third expansion valve 21, and B9 indicates a state of the refrigerant on the suction side of the high-stage-side compressor 10A.

[0040] When the use-side inlet temperature is low (5°C), the refrigerant (state B1) with a high temperature and a high pressure discharged from the high-stage-side compressor 10A radiates heat to the use-side heat exchanger 11 and is condensed into a liquid which is a high-pressure liquid refrigerant (state B2). Then, a refrigerant flowing through a mainstream circuit among refrigerants (state B3) passing through the first expansion valve 12 to be depressurized is cooled by the intermediate heat exchanger 22 (state B4), and reaches the second expansion valve 14. Then, the refrigerant is further depressurized by the second expansion valve 14 (state B5), flows into the heat-source-side heat exchanger 15 to evaporate, and becomes a low-pressure gas refrigerant (state B6). The low-pressure gas refrigerant has a pressure raised to an intermediate pressure by the low-stage-side compressor 10B (state B7), and is supplied to the suction side of the high-stage-side compressor 10A. The refrigerant branched to the injection circuit has a pressure depressurized to the intermediate pressure by the third expansion valve 21 (state B8), absorbs heat via the intermediate heat exchanger 22, and is supplied to the suction side of the high-stage-side compressor 10A via the injection piping 20. The refrigerant supplied via the injection piping 20 and the refrigerant compressed by the low-stage-side compressor 10B are mixed, and the refrigerant with the intermediate pressure whose temperature is lowered (state B9) is supplied to the high-stage-side compressor 10A. The high-stage-side compressor 10A compresses the refrigerant with the intermediate pressure and discharges the refrigerant with a high temperature and a high pressure (state B1). Thereafter, the same cycle is repeated.

[0041] A diagram indicated by a dotted line in FIG. 4 is a P-h diagram when the use-side inlet temperature is low and the injection circuit is not operated. When the injection circuit is not operated, there is no process from the state B3 to the state B4 and no process from the state B8 to the state B9 by the intermediate heat exchanger 22, and thus the P-h diagram is shaped as indicated by a dotted line.

[0042] If the case in which the injection circuit is operated and the case in which the injection circuit is not operated are compared, in the case in which the injection circuit is operated, a pressure difference before and after the third expansion valve 21 is small (a pressure difference between the state B3 and the state B8) and it is not possible to ensure a flow rate of the refrigerant flowing into the injection piping 20. Therefore, as seen by comparing a diagram shape indicated by a solid line and a diagram shape indicated by a dotted line, there is not much difference between the case in which the injection circuit is operated and the case in which the injection circuit is not operated, and the injection circuit has little effect. As shown in FIG. 4, a circulation amount of the refrigerant flowing in the evaporator can be reduced and the COP is expected to be improved by lowering the condenser outlet temperature as much as possible (operating at a point of the state B2 at the leftmost point) and increasing an enthalpy difference between an inlet side and an outlet

side of the condenser (the use-side heat exchanger 11). However, in the present embodiment, since a target temperature on the condenser outlet side is set in accordance with the use-side inlet temperature as described in FIG. 2, the condenser outlet temperature can be lowered if a temperature of the user-side medium (supply water) is low, and an efficient operation is possible even without operating the injection circuit by increasing an enthalpy difference.

[0043] In addition, when the use-side inlet temperature is low, a refrigerant flowing through the injection circuit is reduced due to a low differential pressure, an effect on the COP decreases, and it is necessary to perform flow rate control in a low flow rate region to perform stable operation, but control may be difficult according to characteristics of a flow control valve. Such a problem can be avoided by stopping operation of the injection circuit.

[0044] FIG. 5 is a diagram showing an effect of the injection circuit in the refrigerant circuit system in the embodiment of the present invention.

[0045] FIG. 5 is a graph obtained by plotting a COP of a case in which the injection circuit is operated and a COP of a case in which the injection circuit is not operated. The COP of a case in which the injection circuit is operated is indicated by a circle, and the COP of a case in which the injection circuit is not operated is indicated by a triangle. A vertical axis of FIG. 5 represents a COP, and a horizontal axis thereof represents an outlet side temperature of the condenser (the use-side heat exchanger 11). The outlet side temperature of the condenser is set to be higher than the use-side inlet temperature by 2°C, and is controlled by the control device 100 so that the outlet side temperature can reach this set target temperature. In addition, as prerequisites for the graph of FIG. 5, the use-side outlet temperature is set to 80°C, a condensation temperature (a temperature of the refrigerant at an inlet of the use-side heat exchanger 11) is set to 82°C, the evaporation temperature (a temperature of the refrigerant at an outlet of the heat-source-side heat exchanger 15) is set to 15°C, an outside air temperature is set to 25°C, and an intermediate pressure saturation temperature is set to 45.2°C.

[0046] For example, when the condenser outlet temperature is 45°C, COPs of the case in which the injection circuit is operated and the case in which the injection is not operated are the same, and the COP of the case in which the injection circuit is operated exceeds the COP of the case in which the injection circuit is not operated in the vicinity of 60°C. In addition, a difference in the COP becomes larger in the vicinity of 60°C. In addition, when the condenser outlet temperature is in a range equal to or lower than 45°C, there is no significant difference seen between the case in which the injection circuit is operated and the case in which the injection circuit is not operated (the circles are not shown at 45°C or lower). That is, as described in FIGS. 3 and 4, the operation of the injection circuit increases an effect on COP improvement as the condenser outlet temperature increases, and the operation of the injection circuit has less effect on COP as the condenser outlet temperature decreases. Then, if the condenser outlet temperature is equal to or lower than 45°C, it is known that there is almost no difference between the case in which the injection circuit is operated and the case in which the injection circuit is not operated. Therefore, in the present embodiment, the control device 10 switches between operation and non-operation of the injection circuit in accordance with a level of the condenser outlet temperature.

[0047] FIG. 6 is a diagram showing an example of a method of determining switching of the injection circuit in the embodiment of the present invention.

[0048] FIG. 6 shows a determination condition for switching, by the control device 100, between operation and non-operation of the injection circuit on the basis of a temperature difference ΔT obtained by subtracting a use-side inlet temperature measured by the temperature sensor 31 from a use-side outlet temperature measured by the temperature sensor 32. For example, if the temperature difference ΔT is equal to or less than 40°C (the second threshold value), the control device 100 determines that the injection circuit is made to operate. If the temperature difference ΔT is equal to or greater than 50°C (the first threshold value), the control device 100 determines that the injection circuit is made not to operate. For example, when the use-side outlet temperature is 80°C, if the use-side inlet temperature is equal to or greater than 40°C, the control device 100 determines that the injection circuit is controlled to operate. Moreover, if the use-side inlet temperature is equal to or lower than 30°C, the control device 100 determines that the injection circuit is controlled not to operate. With such control, as described in FIG. 5, operation of the injection circuit becomes valid in the circulation-type system, and operation of the injection circuit becomes invalid in the transient system. Accordingly, it is possible to improve a COP of the refrigerant circuit system 1.

[0049] In addition, as shown in FIG. 6, a hysteresis width is provided in determination of "operation of the injection circuit" and "non-operation of the injection circuit." By providing the hysteresis width, it is possible to prevent unstable control caused by frequent switching between operation and non-operation of the injection circuit according to fluctuations in the temperature difference ΔT caused by, for example, a detection error of the temperature sensors 31 and 32, a change in supply water temperature at a use-side inlet of a condenser, and the like.

[0050] In FIG. 6, a case in which switching determination of the injection circuit is performed on the basis of a value obtained by the following Equation (1) is described as an example.

switching determination evaluation value = use-side outlet temperature
 measured by temperature sensor 32—use-side inlet temperature measured by temperature
 sensor 31 ... (1)

[0051] The switching determination evaluation value may also be calculated by the following equations.

(A condenser outlet temperature is used as a substitute for the use-side inlet temperature)

[0052]

switching determination evaluation value = use-side outlet temperature
 measured by temperature sensor 32—outlet side temperature of use-side heat exchanger
 measured by temperature sensor 33 ... (2)

[0053] The outlet side temperature of the use-side heat exchanger is set to a temperature 2°C higher than the use-side inlet temperature. Accordingly, when switching is determined by Expression (2), the control device 100 determines that there is an injection if, for example, a temperature difference ΔT is equal to or less than 38°C, and determines that there is no injection if the temperature difference ΔT is equal to or greater than 48°C.

(A condensed pressure saturation temperature is used as a substitute for the use-side outlet temperature)

[0054]

switching determination evaluation value = saturation temperature of pressure
 measured by pressure sensor 34—use-side inlet temperature measured by temperature
 sensor 31 ... (3)

(A discharge pressure saturation temperature is used as a substitute for the use-side outlet temperature)

[0055]

switching determination evaluation value = saturation temperature of pressure
 measured by pressure sensor 35—use-side inlet temperature measured by temperature
 sensor 31 ... (4)

[0056] A value of the determination condition is adjusted on the basis of a condensed pressure saturation temperature and a difference between a discharge pressure saturation temperature and a use-side outlet temperature even when determination is performed according to Equations (3) and (4). The control device 100 stores a conversion table of a pressure and a saturation temperature in a storage unit (not shown) embedded therein, and calculates a saturation temperature at each pressure on the basis of this conversion table.

[0057] Furthermore, for example, a value obtained by subtracting the outlet side temperature of the use-side heat exchanger measured by the temperature sensor 33 from the saturation temperature of a pressure measured by the

pressure sensor 34 by combining Equation (2) and Equation (3) or Equation (2) and Equation (4) may be used as a switching determination evaluation value.

[0058] Next, a process flow of switching control between presence and absence of injection will be described using FIG. 7.

[0059] FIG. 7 is a flowchart of a control device in the embodiment of the present invention.

[0060] As a premise, as described in FIG. 5, the use-side outlet temperature, the condensation temperature, the evaporation temperature, and the intermediate pressure saturation temperature are controlled to be constant. In addition, the control device 100 acquires information on temperatures measured by the temperature sensor 31, the temperature sensor 32, and the temperature sensor 33 and information on pressures measured by the pressure sensor 34 and the pressure sensor 35 at predetermined time intervals, and records the acquired information on temperatures and pressures in an embedded storage unit (not shown). In addition, the control device 100 controls the number of rotations of the high-stage-side compressor 10A on the basis of the use-side outlet temperature (the set target temperature), controls an opening of the first expansion valve 12 on the basis of the use-side inlet temperature, and controls an opening of the second expansion valve 14 on the basis of the evaporation temperature. Moreover, the control device 100 controls presence or absence of operation of the injection circuit, completely closes the third expansion valve 21 when there is no injection circuit, and performs control so that a valve opening of the third expansion valve 21 has a predetermined opening larger than zero when there is an injection circuit. In addition, when there is operation of the injection circuit, the control device 100 controls the valve opening of the third expansion valve 21 to have a predetermined intermediate pressure as a target.

[0061] First, the control device 100 calculates a switching determination evaluation value by the Expression (1) described above (step S11). Next, the control device 100 determines whether there is operation of the injection circuit (step S12). For example, the control device 100 determines that there is operation of the injection circuit if a valve opening of the third expansion valve 21 is larger than zero, and determines that there is no operation of the injection circuit if the third expansion valve is completely closed.

[0062] When it is determined that there is operation of the injection circuit (Yes in step S12), the control device 100 determines whether a switching determination evaluation value (the temperature difference ΔT of FIG. 6) calculated in step S11 is equal to or greater than a first threshold value (50°C in the example of FIG. 6) (step S13). When the switching determination evaluation value is equal to or greater than the first threshold value (Yes in step S13), the control device 100 performs control so that there is no operation of the injection circuit (step S14). Specifically, the control device 100 completely closes the third expansion valve 21. When the switching determination evaluation value is less than the first threshold value (No in step S13), the control device 100 does not switch the operation of the injection circuit (step S17). That is, the control device 100 continues to control the valve opening of the third expansion valve 21 targeting the intermediate pressure.

[0063] When it is determined that there is no operation of the injection circuit (No in step S12), the control device 100 determines whether the switching determination evaluation value (the temperature difference ΔT of FIG. 6) is equal to or less than a second threshold value (40°C in the example of FIG. 6) (step S15). When the switching determination evaluation value is equal to or less than the second threshold value (Yes in step S15), the control device 100 performs control so that the injection circuit is operated (step S16). Specifically, the control device 100 switches the third expansion valve 21 to open and performs control so that the third expansion valve 21 has a valve opening targeting a predetermined intermediate pressure. When the switching determination evaluation value exceeds the second threshold value (No in step S15), the control device 100 does not switch the operation of the injection circuit (step S17). That is, the control device 100 maintains a state in which the third expansion valve 21 is completely closed.

[0064] According to the present invention, in a multi-stage heat pump in which the use-side outlet temperature is set to be constant, whether to operate the injection circuit is determined according to a difference between the use-side outlet temperature and the use-side inlet temperature. Specifically, when the temperature difference is small, the injection circuit is operated. This enables increases in the condenser outlet temperature, a heat exchange amount between the injection circuit and the mainstream circuit by the intermediate heat exchanger 22, and a flow rate of the refrigerant flowing through the injection circuit, and a reduction in a flow rate of the refrigerant of the mainstream circuit, and thereby it is possible to improve a COP. When the temperature difference is large, the flow rate of the refrigerant flowing through the injection circuit decreases and a difference from a refrigerant circuit without an injection circuit becomes small. Therefore, in this case, operation of the injection circuit is stopped. As a result, it is possible to eliminate pressure loss caused by the refrigerant flowing through the injection circuit. In addition, when the temperature difference is large, since the condenser outlet temperature can be lowered, it is possible to improve a COP by ensuring an enthalpy difference and to reduce a refrigerant circulation amount. As a result, it is possible to suppress a rise in the number of rotations of the compressor and to operate the refrigerant circuit at an efficient operation point. By switching between operation and non-operation of the injection circuit in this manner, the refrigerant circuit system 1 can operate efficiently in response to a change in the use-side inlet temperature (also in both the transient system and the circulation-type system).

[0065] In addition, it is possible to appropriately replace a constituent element in the embodiment described above

with a well-known constituent element in a range not departing from the scope of the present invention, which is defined by the claims. In addition, a technical scope of the invention is not limited to the embodiment described above, and various modifications can be made in the range not departing from the scope of the present invention as defined by the claims. For example, the number of compressors need not be two, but may be a plurality (for example, three).

EXPLANATION OF REFERENCES

[0066]

1 Refrigerant circuit system
 10A High-stage-side compressor
 10B Low-stage-side compressor
 11 Use-side heat exchanger
 12 First expansion valve
 13 Receiver
 14 Second expansion valve
 15 Heat-source-side heat exchanger
 16 Accumulator
 17 Main flow piping
 20 Injection piping
 21 Third expansion valve
 22 Intermediate heat exchanger
 31, 32, 33 Temperature sensor
 34, 35 Pressure sensor
 100 Control device

Claims

1. A refrigerant circuit system (1), comprising:

a mainstream circuit which connects a plurality of compressors (10A, 10B) which compress a refrigerant, a use-side heat exchanger (11) which condenses the refrigerant compressed by the compressor (10A, 10B), a first expansion valve (12) which depressurizes the refrigerant flowing out from the use-side heat exchanger (11), a receiver (13) which stores some of the refrigerant depressurized by the first expansion valve (12), a second expansion valve (14) which depressurizes the refrigerant flowing out from the receiver (13), and a heat-source-side heat exchanger (15) which evaporates the refrigerant depressurized by the second expansion valve (14); an injection circuit which branches some of the refrigerant flowing out from the receiver (13), supplies the branched refrigerant to a suction side of a predetermined compressor among the plurality of compressors (10A, 10B), and includes a third expansion valve (21) which depressurizes the branched refrigerant and an intermediate heat exchanger (22) which performs heat exchange between a refrigerant passing through the third expansion valve (21) and a refrigerant passing through the mainstream circuit; and a control device (100) which switches between operation and non-operation of the injection circuit on the basis of a difference between an inlet temperature on an inlet side of the use-side heat exchanger (11) of a use-side medium that receives a supply of heat by the use-side heat exchanger (11) and an outlet temperature on an outlet side of the use-side heat exchanger (11) of the use-side medium.

2. The refrigerant circuit system (1) according to Claim 1,

wherein, when a difference between the inlet temperature and the outlet temperature is equal to or greater than a predetermined first threshold value, the control device (100) performs control so that the third expansion valve (21) is completely closed.

3. The refrigerant circuit system (1) according to Claim 1 or 2,

wherein, when a difference between the inlet temperature and the outlet temperature is equal to or less than a predetermined second threshold value, the control device (100) performs control so that the third expansion (21) valve is opened at a predetermined level larger than zero.

4. The refrigerant circuit system (1) according to any one of Claims 1 to 3,

wherein the control device (100) controls the number of rotations of a compressor (10A) provided on the highest stage side among the plurality of compressors (10A, 10B) on the basis of a target value of an outlet temperature of the use-side medium, and controls an opening of the first expansion valve (12) by setting an outlet side temperature of the use-side heat exchanger (11) based on an inlet temperature of the use-side medium as a target value.

5. The refrigerant circuit system (1) according to any one of Claims 1 to 3,

wherein the control device (100) switches between operation and non-operation of the injection circuit on the basis of a difference between an outlet side temperature of the use-side heat exchanger (11) instead of the inlet temperature and the outlet temperature.

6. The refrigerant circuit system (1) according to any one of Claims 1 to 4,

wherein the control device (100) switches between operation and non-operation of the injection circuit on the basis of a difference between the inlet temperature and a condensed pressure saturation temperature or a discharge pressure saturation temperature instead of the outlet temperature.

7. A control method for a refrigerant circuit system (1) that includes a mainstream circuit which connects a plurality of compressors (10A, 10B) which compress a refrigerant, a use-side heat exchanger (11) which condenses the refrigerant compressed by the compressor, a first expansion valve (12) which depressurizes the refrigerant flowing out from the use-side heat exchanger (11), a receiver (13) which stores some of the refrigerant depressurized by the first expansion valve (12), a second expansion valve (14) which depressurizes the refrigerant flowing out from the receiver (13), and a heat-source-side heat exchanger (15) which evaporates the refrigerant depressurized by the second expansion valve (14), an injection circuit which branches some of the refrigerant flowing out from the receiver (13), supplies the branched refrigerant to a suction side of a predetermined compressor among the plurality of compressors (10A, 10B), and includes a third expansion valve (21) which depressurizes the branched refrigerant, and an intermediate heat exchanger (22) which performs heat exchange between a refrigerant passing through the third expansion valve (21) and a refrigerant passing through the mainstream circuit, the control method comprising:

switching between operation and non-operation of the injection circuit on the basis of a difference between an inlet temperature on an inlet side of the use-side heat exchanger (15) of a use-side medium that receives a supply of heat by the use-side heat exchanger and an outlet temperature on an outlet side of the use-side heat exchanger (15) of the use-side medium.

FIG. 1

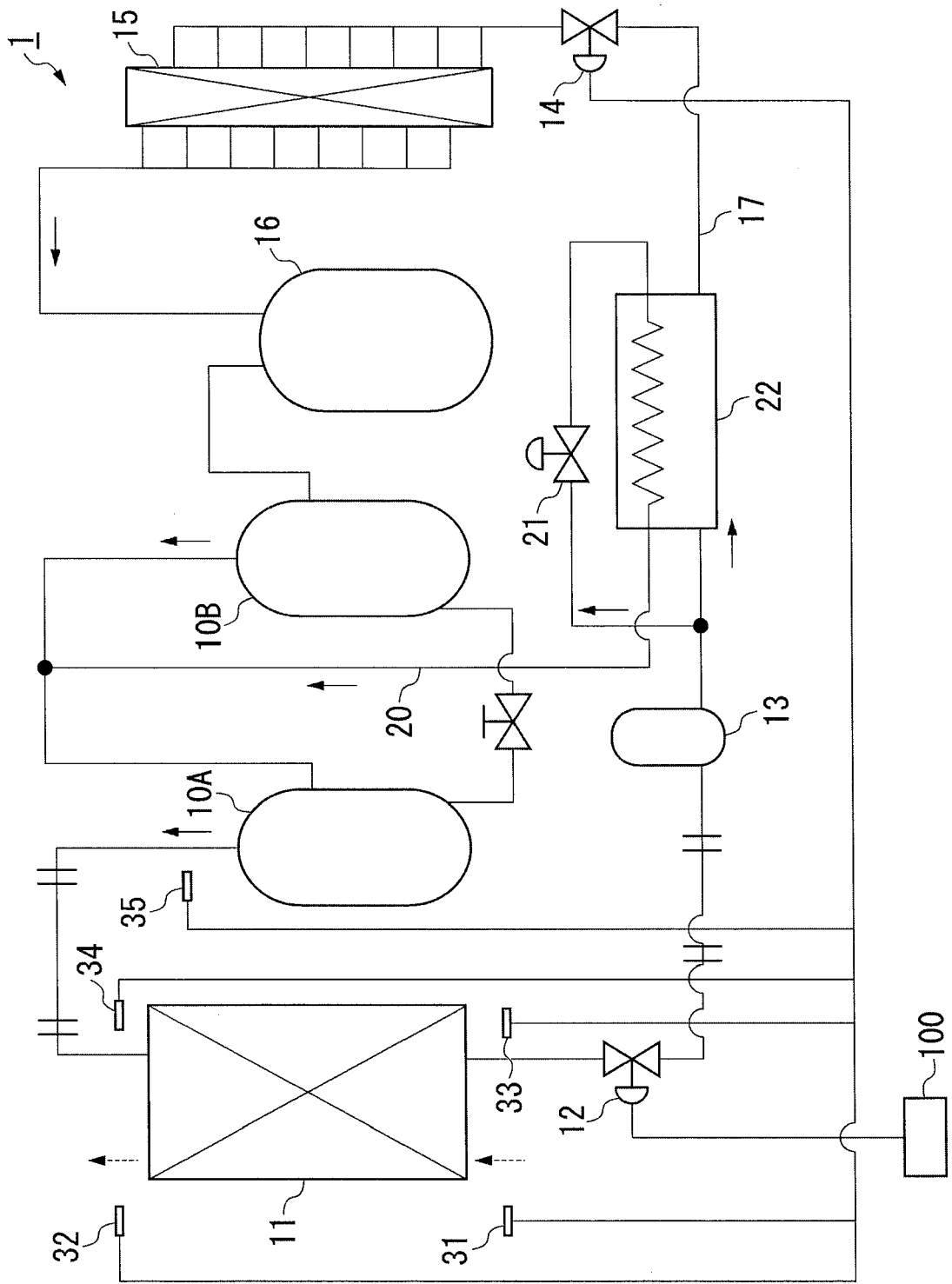


FIG. 2

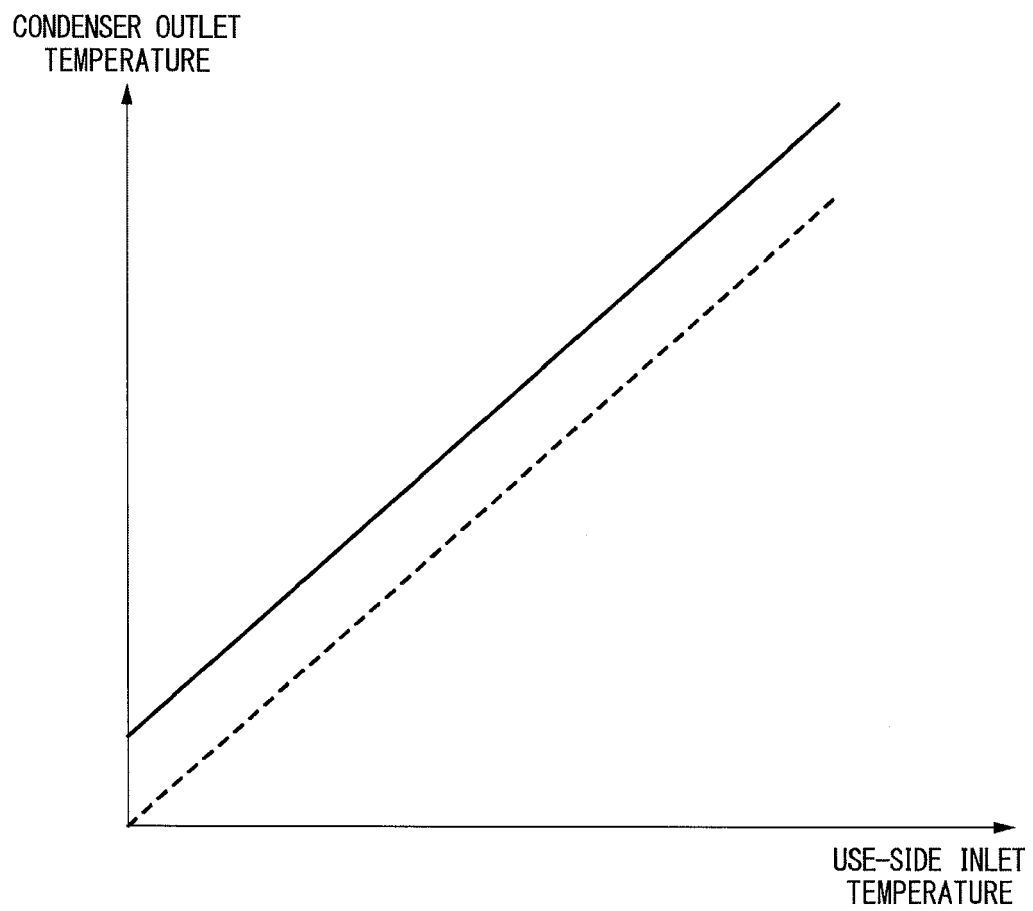


FIG. 3

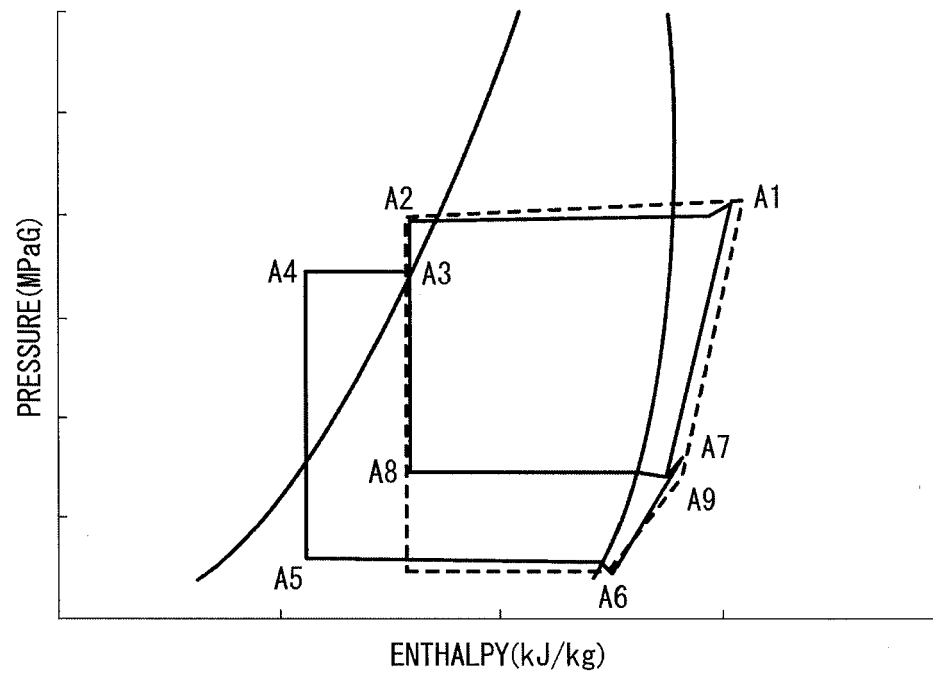


FIG. 4

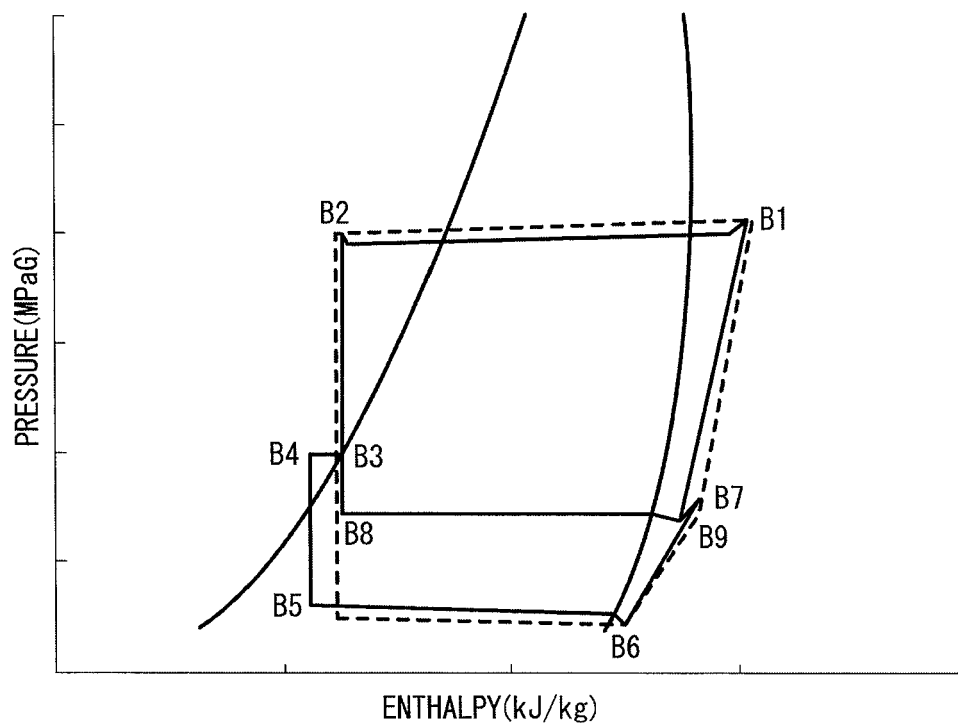


FIG. 5

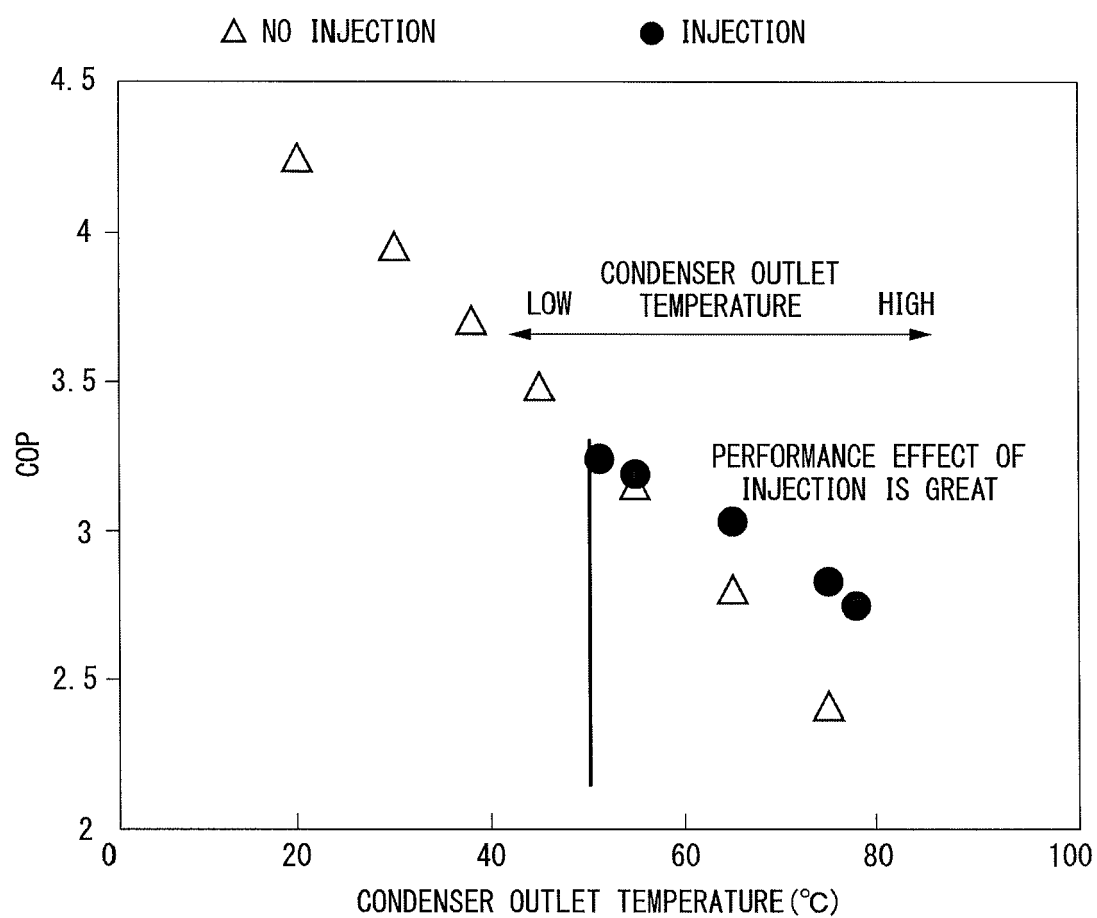


FIG. 6

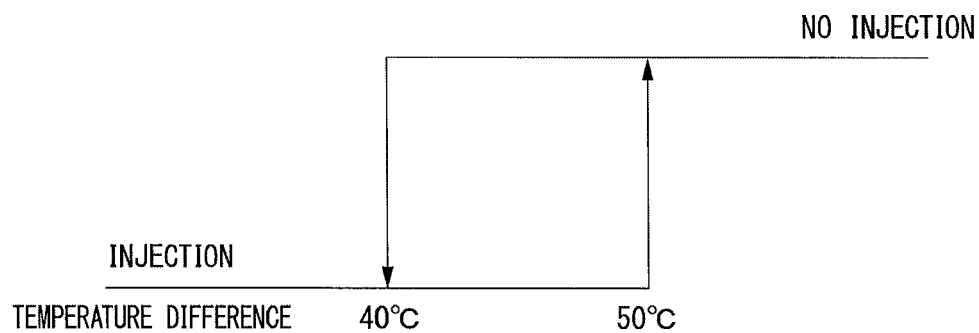
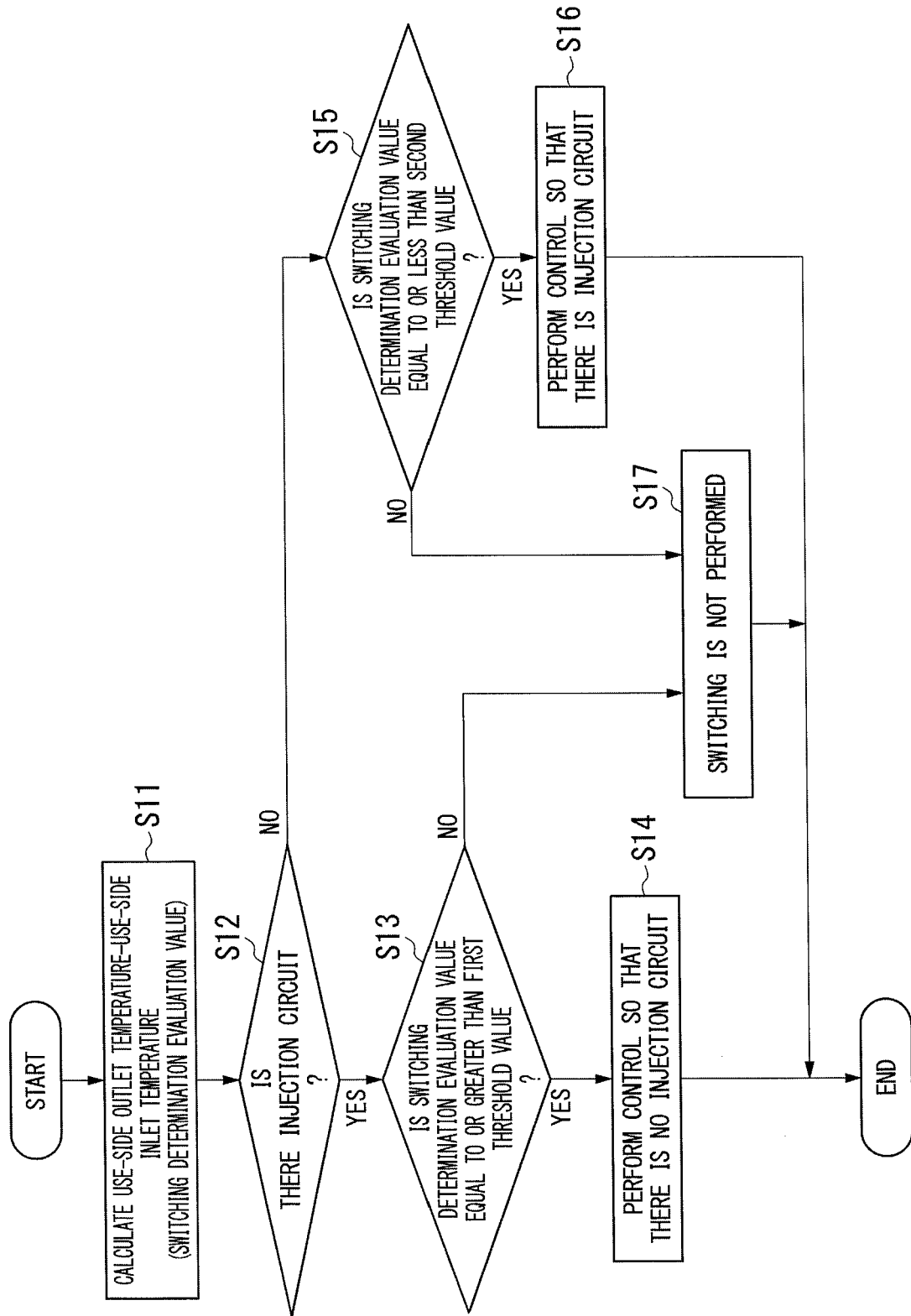


FIG. 7





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