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(54) **HEAT PUMP SYSTEM, AND HEAT PUMP WATER HEATER**

WÄRMEPUMPENSYSTEM UND WÄRMEPUMPENWASSERERHITZER

SYSTÈME DE POMPE À CHALEUR, ET CHAUFFE-EAU À POMPE À CHALEUR

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Description

Technical Field

[0001] The present invention relates to a two-stage compression type heat pump system in which two independent compressors are connected in series.

Background Art

[0002] Hot water systems have been employing a heat pump in order to save energy.

[0003] A two-stage compression refrigeration cycle, which includes a refrigerant circuit in which a lower stage-side compressor and a higher stage-side compressor are connected in series and circulates a refrigerant using the refrigerant circuit, is known as a refrigerant system (for example, PTLs 1 to 3).

Citation List

Patent Literature

[0004]

[PTL 1] Japanese Unexamined Patent Application Publication No. 5-93552
[PTL 2] Japanese Unexamined Patent Application Publication No. 6-2966
[PTL 3] Japanese Unexamined Patent Application Publication No. 2009-168330
[PTL 4] JP 2001 349629 A discloses a heat pump system according to the preamble of claim 1.
[PTL 5] JP 2013 139902 A discloses a refrigeration device.

Summary of Invention

Technical Problem

[0005] It is necessary to operate two compressors of a lower stage and a higher stage with the rotational speeds, which are independent of each other, in order to always operate the two-stage compression refrigeration cycle with high efficiency. The control of the level of refrigerant oil contained in each of the two compressors is most important for this purpose. When two independent compressors are connected in series unlike in a compressor that includes two compression mechanisms of a lower stage and a higher stage provided in one housing, it is necessary to keep the amount of refrigerant oil at an appropriate uniform level between the two compressors in order to soundly operate the two compressors.

[0006] The invention has been made on the basis of this technical problem, and an object of the invention is to provide a two-stage compression type heat pump system in which the amount of refrigerant oil of the two compressors is kept uniform without operation being stopped or performing complicated operation. Further, an object of the invention is to provide a high-efficiency heat pump water heater that includes a two-stage compression type heat pump system.

Solution to Problem

[0007] The invention, which has been made to achieve the objects is defined by claim 1, and is divided into a first disclosure and a second disclosure.

[0008] First, according to the first disclosure, there is provided a heat pump system including: a compression mechanism that includes a lower stage-side compressor and a higher stage-side compressor and compresses and discharges a refrigerant; an oil separator that is provided on a discharge side of the higher stage-side compressor; a first heat exchanger that exchanges heat between the refrigerant compressed by the compression mechanism and an object to be subjected to heat exchange; an expansion valve that decompresses and expands the refrigerant flowing out of the first heat exchanger; a second heat exchanger that exchanges heat between the refrigerant decompressed and expanded by the expansion valve and an object to be subjected to heat exchange; an oil equalizing path that connects the lower stage-side compressor to the higher stage-side compressor and allows refrigerant oil to flow between the lower stage-side compressor and the higher stage-side compressor; a main return pipe that connects the oil separator to a suction side of the higher stage-side compressor; an oil return path that connects the main return pipe to the oil equalizing path; an oil-return on-off valve that is provided on the oil return path; and a refrigerant path switching mechanism that selectively switches a refrigerant path between a two-stage compression path along which the refrigerant flows through the lower stage-side compressor and the higher stage-side compressor in this order and a one-stage compression path along which the refrigerant flows through only one of the lower stage-side compressor and the higher stage-side compressor.

[0009] For example, when a heat pump water heater is assumed, high pressure of the device is determined depending on the temperature (for example, the range of 35°C to 75°C) of water entering a heat exchanger (a water-refrigerant heat exchanger) for water and a refrigerant. Accordingly, a difference in pressure between the suction side and the discharge side of the compressor can be significantly changed according to the temperature of water. When a two-stage compression operation is performed while the temperature of water at an inlet of the water-refrigerant heat exchanger is low, differential pressure between the lower stage-side compressor and the higher stage-side compressor is reduced. The amount of refrigerant oil to be returned is determined according to the differential pressure between the compressors. Accordingly, when a differential pressure between the lower stage-side compressor and the higher stage-side compressor is reduced in the middle of the two-stage compression operation in the disclosure, a compression operation is switched to the one-stage compression operation.

[0010] In the heat pump system of the first disclosure, the path of the refrigerant is switched to the one-stage compression path when the two-stage compression path is selected and any one of the following conditions (1) to (3) is satisfied.

$$\text{Condition (1): } T_W \leq T_R$$

T_W: The temperature of water entering a heat exchanger (water heat exchanger) for water and the refrigerant when the object, which is to be subjected to heat exchange, of the first heat exchanger is water

T_R: Prescribed value

$$\text{Condition (2): } (P_{HO} - P_{LI}) \leq \Delta P_{R1}$$

P_{LI}: The suction pressure of the lower stage-side compressor

P_{HO}: The discharge pressure of the higher stage-side compressor

ΔP_{R1}: Prescribed value

$$\text{Condition (3): } (P_{LO} - P_{LI}) \leq \Delta P_{R2}$$

P_{LI}: The suction pressure of the lower stage-side compressor

P_{LO}: The discharge pressure of the lower stage-side compressor

ΔP_{R2}: Prescribed value

[0011] Further, in the heat pump system of the first disclosure, when the refrigerant path switching mechanism selects the one-stage compression path, the oil-return on-off valve is opened and the refrigerant oil from the oil separator can be returned to the oil equalizing path through the oil return path without passing through the higher stage-side compressor.

[0012] Since the oil return path and the oil equalizing path formed as described above are provided, it is possible to easily recover the amount of refrigerant oil when the amount of refrigerant oil of each of the lower stage-side compressor and the higher stage-side compressor is insufficient.

[0013] In the heat pump system of the first disclosure, it is preferable that the opening/closing of the oil-return on-off valve is controlled on the basis of an estimated amount of refrigerant oil of the lower stage-side compressor and an estimated amount of refrigerant oil of the higher stage-side compressor.

[0014] It is possible to control refrigerant oil at an appropriate time on the basis of the amount of oil of each of the two compressors obtained from detection results of pressure sensors and a temperature sensor of the heat pump system.

[0015] Since the amount of refrigerant oil of each of the lower stage-side compressor and the higher stage-side compressor is ensured in a heat pump water heater including the first heat exchanger of the above-mentioned heat pump system that is a water-refrigerant heat exchanger for heating water by exchanging heat between the refrigerant and water, the heat pump water heater can stably supply hot water with high efficiency.

[0016] Next, according to a second disclosure, there is provided a heat pump system including: a compression mechanism that includes a lower stage-side compressor and a higher stage-side compressor and compresses and discharges a refrigerant; a first heat exchanger in which the refrigerant compressed by the compression mechanism exchanges heat with an object to be subjected to heat exchange; an expansion valve that decompresses and expands the refrigerant flowing out of the first heat exchanger; a second heat exchanger in which the refrigerant decompressed and expanded by the expansion valve exchanges heat with an object to be subjected to heat exchange; an oil equalizing path that connects the lower stage-side compressor to the higher stage-side compressor and allows refrigerant oil to flow between the lower stage-side compressor and the higher stage-side compressor; an oil equalizing valve that opens and closes the oil equalizing pipe; and a control device that controls an operation for opening/closing the oil equalizing valve.

[0017] When the control device determines that the refrigerant is flowing in the oil equalizing pipe, the control device instructs the oil equalizing valve to be closed.

[0018] In the heat pump system of the second disclosure, the control device can determine whether or not the refrigerant is flowing in the oil equalizing pipe on the basis of the comparison of a detected temperature T0 of the oil equalizing pipe and one or both of a detected temperature T1 of a refrigerant pipe, which allows the refrigerant to flow to the higher stage-side compressor from the lower stage-side compressor, and a detected temperature T2 of the higher stage-side compressor.

[0019] In the heat pump system of the second disclosure, it is preferable that the control device instructs the oil equalizing valve to continue to be closed during an unsteady operation even if an opening condition is satisfied.

[0020] Further, in the heat pump system of the second disclosure, it is preferable that the control device instructs the oil equalizing valve to be alternately and repeatedly opened and closed at each of predetermined times regardless of the determination of whether or not the refrigerant is flowing in the oil equalizing pipe when the rotational speed of the higher stage-side compressor is smaller than a predetermined value.

[0021] Since the amount of refrigerant oil of each of the lower stage-side compressor and the higher stage-side compressor is ensured in a heat pump water heater including the first heat exchanger of the above-mentioned heat pump system of the second disclosure that is a water-refrigerant heat exchanger for heating water by exchanging heat between the refrigerant and water, the heat pump water heater can stably supply hot water with high efficiency.

Advantageous Effects of Disclosure

[0022] According to the first disclosure, it is possible to equalize the refrigerant oil of the lower stage-side compressor and the higher stage-side compressor by only a simple operation for opening/closing the first electromagnetic valve and the second electromagnetic valve without stopping the operation of the lower stage-side compressor and the higher stage-side compressor.

[0023] Further, according to the second disclosure, it is possible to equalize the refrigerant oil in the compression mechanism by a simple operation for opening/closing the oil equalizing valve without stopping the operation of the compression mechanism. Furthermore, according to the disclosure, when the control device determines that the refrigerant is flowing in the oil equalizing pipe, the control device closes the open oil equalizing valve. Accordingly, it is possible to avoid the wasteful use of the compression mechanism that is caused when the refrigerant flows in the oil equalizing pipe.

Brief Description of Drawings

[0024]

Fig. 1 is a diagram showing the configuration of a circuit of a heat pump system according to a first embodiment.

Fig. 2 is a diagram showing the operation of the heat pump system of the first embodiment in which Fig. 2A shows a two-stage compression operation and Fig. 2B shows a one-stage compression operation.

Fig. 3 is a diagram showing the configuration of a circuit that switches a compression operation between the two-stage compression operation and the one-stage compression operation of the heat pump system of Fig. 1 by two electromagnetic valves.

Fig. 4 is a diagram showing the configuration of a circuit in which two oil separators are added to the heat pump system of Fig. 1.

Fig. 5 is a diagram showing the configuration of a circuit of a heat pump type water heating/air conditioner according to a second embodiment.

Fig. 6 shows the configuration of the circuit of the heat pump type water heating/air conditioner according to the second embodiment and shows an operation mode different from Fig. 5.

Fig. 7 is a diagram showing a modification example of an oil equalizing pipe.

Fig. 8 is a diagram showing the configuration of a circuit of a refrigeration cycle according to a third embodiment.

Fig. 9 is a diagram showing the operation of the refrigeration cycle of Fig. 8 in which an oil equalizing pipe is closed in Fig. 9A and the oil equalizing pipe is open in Fig. 9B.

Fig. 10 is a flowchart illustrating a procedure for opening/closing a valve that is provided on the oil equalizing pipe of the refrigeration cycle of Fig. 8.

Fig. 11 is a flowchart illustrating a modification example of the procedure for opening/closing the valve of Fig. 10.

Fig. 12 is a diagram showing the configuration of a circuit of a heat pump type water heating/air conditioner according to a fourth embodiment.

Fig. 13 is a diagram showing the configuration of the circuit of the heat pump type water heating/air conditioner according to the fourth embodiment and shows an operation mode different from Fig. 12.

Description of Embodiments

[0025] Embodiments of the invention will be described below with reference to the accompanying drawings.

[First embodiment]

[0026] As shown in Fig. 1, a heat pump system 1 according to a first embodiment includes a lower stage-side compressor 10a and a higher stage-side compressor 10b that compress and discharge a refrigerant, a first heat exchanger 11 that exchanges heat between the refrigerant compressed by the higher stage-side compressor 10b and fluid as an object to be subjected to heat exchange, an expansion valve 12 that decompresses and expands the refrigerant flowing out of the first heat exchanger 11 (hereinafter, simply referred to as an expansion valve), and a second heat exchanger 13 that exchanges heat between the refrigerant decompressed and expanded by the expansion valve 12 and the fluid as an object to be subjected to heat exchange. The lower stage-side compressor 10a, the higher stage-side compressor 10b, the first heat exchanger 11, the expansion valve 12, and the second heat exchanger 13 are connected in series in this order in the circulation direction of the refrigerant. In this embodiment, the first heat exchanger 11 can function as a condenser that radiates heat by exchanging heat with, for example, water and the second heat exchanger 13 can function as an evaporator that absorbs heat by exchanging heat with external air.

[0027] The heat pump system 1 includes a four-way switching valve 14 that switches a connection state of the lower stage-side compressor 10a and the higher stage-side compressor 10b as described below. That is, the four-way switching valve 14 switches the connection state between a two-stage compression operation (two-stage compression path) in which a refrigerant passes through both the lower stage-side compressor 10a and the higher stage-side compressor 10b and a one-stage compression operation (one-stage compression path) in which a refrigerant passes through only the lower stage-side compressor 10a but bypasses the higher stage-side compressor 10b.

[0028] Further, the heat pump system 1 includes an oil equalizing mechanism 20 that keeps the amount of refrigerant oil retained in the lower and higher stage-side compressors 10a and 10b uniform.

[0029] The heat pump system 1 includes a pipe L1 that connects the lower stage-side compressor 10a to the higher stage-side compressor 10b, a pipe L2 that connects the higher stage-side compressor 10b to the first heat exchanger 11, a pipe L3 that connects the first heat exchanger 11 to the second heat exchanger 13, and a pipe L4 that connects the second heat exchanger 13 to the lower stage-side compressor 10a. Accordingly, the heat pump system 1 forms a refrigerant circuit in which a refrigerant circulates. Among the pipes, the pipe L4 forms a suction-side pipe of the lower stage-side compressor 10a, the pipe L1 connecting the lower stage-side compressor 10a to the higher stage-side compressor 10b forms an intermediate-pressure pipe, and the pipe L2 forms a discharge-side pipe of the higher stage-side compressor 10b.

[0030] Further, the heat pump system 1 includes a pipe L5 that connects the discharge side (the pipe L1) of the lower stage-side compressor 10a to the discharge side (the pipe L2) of the higher stage-side compressor 10b. The above-mentioned four-way switching valve 14 is provided at a connection end of the pipe L5 that corresponds to the discharge side of the lower stage-side compressor 10a. The four-way switching valve 14 is switched so that the refrigerant discharged from the lower stage-side compressor 10a is sucked into the higher stage-side compressor 10b through the pipe L1 just as it is or is supplied to the first heat exchanger 11 through the pipes L5 and L2. Switching between the two-stage compression path and the one-stage compression path) is realized by the switching.

[0031] Meanwhile, the lower stage-side compressor 10a and the higher stage-side compressor 10b are generally referred to as a compression mechanism 10 without being distinguished from each other.

[0032] Next, the heat pump system 1 includes an oil separator 26 that is provided on the pipe L2. The oil separator 26 is directly connected to the higher stage-side compressor 10b by an oil return pipe 27. The oil return pipe 27 includes a stationary throttle 27a.

[0033] In the middle of the two-stage compression operation, the oil separator 26 separates refrigerant oil from the refrigerant, which is discharged from the higher stage-side compressor 10b, and returns the refrigerant oil to the higher stage-side compressor 10b through the return pipe 27. In the middle of the one-stage compression operation, the oil separator 26 separates refrigerant oil from the refrigerant, which is discharged from the lower stage-side compressor 10a, and returns the refrigerant oil to the higher stage-side compressor 10b through the return pipe 27.

[0034] The respective components of the heat pump system 1 will be described in turn below.

[Compression mechanism 10]

[0035] When the lower stage-side compressor 10a is rotationally driven by an electric motor that is formed integrally with the lower stage-side compressor 10a, the lower stage-side compressor 10a sucks the refrigerant, which has passed through the second heat exchanger 13 and has a low temperature and a low pressure, compresses the refrigerant to an intermediate pressure, and discharges the compressed refrigerant to the higher stage-side compressor 10b.
[0036] A publicly known compression mechanism, such as a scroll compression mechanism or a rotary compression mechanism, can be applied as the compression mechanism that is applied to the lower stage-side compressor 10a. Likewise, the same applies to the higher stage-side compressor 10b.
[0037] The higher stage-side compressor 10b sucks and compresses the refrigerant, which is discharged from the lower stage-side compressor 10a, and discharges the compressed refrigerant to the first heat exchanger 11 as a refrigerant that has a high temperature and a high pressure.

[First heat exchanger 11]

[0038] The first heat exchanger 11 heats fluid, such as water or air, as an object to be subjected to heat exchange by exchanging heat between the fluid and a refrigerant that has a high temperature and a high pressure. The refrigerant, which is discharged from the higher stage-side compressor 10b and has a high temperature and a high pressure, is cooled and condensed in the first heat exchanger 11. A publicly known heat exchanger can be used as the first heat exchanger 11. The same applies to the second heat exchanger 13 to be described below.
[0039] When an object to be subjected to heat exchange is air, the first heat exchanger 11 is provided with a blower fan 11f and heat is exchanged between air blown by the blower fan 11f and the refrigerant while the air blown by the blower fan 11f passes through the first heat exchanger 11.

[Expansion valve 12 and second heat exchanger 13]

[0040] The second heat exchanger 13 exchanges heat between the refrigerant, which passes through the expansion valve 12 and is decompressed and expanded, and the external air (blown air), and the refrigerant is evaporated and absorbs heat from the external air while heat is exchanged between the refrigerant and the external air. The second heat exchanger 13 is also provided with a blower fan 13f and heat is exchanged between air blown by the blower fan 13f and the refrigerant, so that a low-pressure refrigerant is evaporated and a heat absorbing operation is generated.
[0041] For example, an expansion valve, which includes a needle-shaped valve body and a pulse motor for driving the valve body, can be used as the expansion valve 12.

[Oil equalizing mechanism 20]

[0042] The oil equalizing mechanism 20 includes an oil equalizing pipe 21 that connects the lower stage-side compressor 10a to the higher stage-side compressor 10b, a bypass pipe 23 that connects the oil equalizing pipe 21 to the oil return pipe 27, and an electromagnetic valve 25 that is provided on the bypass pipe 23.
[0043] The oil equalizing mechanism 20 allows refrigerant oil to flow between the lower stage-side compressor 10a and the higher stage-side compressor 10b through the oil equalizing pipe 21. Further, the oil equalizing mechanism 20 returns to refrigerant oil to the oil equalizing pipe 21 from the discharge side of the higher stage-side compressor 10b through the bypass pipe 23. The function of the bypass pipe 23 is fulfilled during the one-stage compression operation, and is to apply necessary differential pressure to the oil equalizing pipe 21.
[0044] When a level representing the amount of refrigerant oil, which is necessary in each of the lower stage-side compressor 10a and the higher stage-side compressor 10b, is defined as a reference level, the oil equalizing pipe 21 is connected to the lower stage-side compressor 10a and the higher stage-side compressor 10b directly above the reference level.
[0045] Fig. 1 shows an example in which a single oil equalizing pipe 21 is provided, but a plurality of oil equalizing pipes 21 (21A, 21B, and 21C) may be provided in parallel as shown in Fig. 7. Further, the oil equalizing pipes 21B and 21C are provided with on-off valves 22B and 22C, respectively.
[0046] When the single oil equalizing pipe 21 is provided, excessive refrigerant oil may flow. However, when the plurality of oil equalizing pipes 21A, 21B, and 21C are provided as described above and the on-off valves 22B and 22C are operated so as to be opened and closed, the amount of flowing refrigerant oil can be adjusted. Further, the oil equalizing pipe 21A may also be provided with an on-off valve.
[0047] Meanwhile, the maximum amounts of refrigerant oil flowing through the oil equalizing pipes 21A, 21B, and 21C may be set to be equal to each other and may be set to be different from each other. Further, the opening and closing of the on-off valves 22B and 22C can be controlled through the detection of the temperature of the refrigerant oil that

flows into the higher stage-side compressor 10b.

[Operation of heat pump system 1]

[0048] The operation of the heat pump system 1 will be described below.

[0049] In the heat pump system 1, a refrigerant circulates and the two-stage compression operation is performed. However, the one-stage compression operation is performed under specific conditions.

[0050] The two-stage compression operation will be described first.

[0051] As shown in Fig. 2A, during the two-stage compression operation, the four-way switching valve 14 is switched so that pipes L11 and L12 (L1) communicate with each other. Accordingly, the refrigerant, which is compressed to an intermediate pressure by the lower stage-side compressor 10a, is sucked into the higher stage-side compressor 10b through the pipe L11, the four-way switching valve 14, and the pipe L12. In Fig. 2A, arrows indicate a direction in which the refrigerant flows. The same applies to Fig. 2B to be described below.

[0052] The high-pressure refrigerant, which is discharged after the refrigerant is compressed to a high temperature and a high pressure by the higher stage-side compressor 10b, flows into the first heat exchanger 11 through the pipe L2 and radiates heat to an object to be subjected to heat exchange. The high-pressure refrigerant, which has radiated heat in the first heat exchanger 11, becomes a low-pressure refrigerant by being expanded while passing through the expansion valve 12 through the pipe L3. The low-pressure refrigerant further flows into the second heat exchanger 13 through the pipe L3, absorbs heat from the outdoor air, and is evaporated. After that, the low-pressure refrigerant, which flows out of the second heat exchanger 13, is sucked into the lower stage-side compressor 10a through the pipe L4.

[0053] After the low-pressure refrigerant, which is sucked into the lower stage-side compressor 10a, is compressed and becomes an intermediate-pressure refrigerant, the intermediate-pressure refrigerant is discharged to the pipe L1. The intermediate-pressure refrigerant, which is discharged to the pipe L1 from the lower stage-side compressor 10a, is sucked into the higher stage-side compressor 10b. After the refrigerant, which is sucked into the higher stage-side compressor 10b, is compressed and becomes a high-pressure refrigerant, the high-pressure refrigerant is discharged to the pipe L2.

[0054] The heat pump system 1 ensures the level of the refrigerant oil of each of the lower stage-side compressor 10a and the higher stage-side compressor 10b in a necessary range by allowing the refrigerant oil to flow through the oil equalizing pipe 21 while a cycle of the compression, condensation, expansion, and evaporation of the refrigerant having been described above is repeated.

[0055] Here, a method in which a device, which is called an oil separator for separating oil from a refrigerant, is disposed on the discharge side of the compressor and the separated refrigerant oil returns to the suction side of the compressor through an oil return circuit including a stationary throttle such as a capillary tube is generally used as a method of returning refrigerant oil, which is contained in the refrigerant discharged from the compressor, to the compressor.

[0056] However, for example, when a heat pump water heater is assumed, high pressure of the device is determined depending on the temperature (for example, the range of 35°C to 75°C) of water entering a heat exchanger (a water-refrigerant heat exchanger) for water and a refrigerant. Accordingly, a difference in pressure between the suction side and the discharge side of the compressor can be significantly changed according to the temperature of water. When the two-stage compression operation is performed while the temperature of water at an inlet of the water-refrigerant heat exchanger is low, differential pressure between the lower stage-side compressor 10a and the higher stage-side compressor 10b is reduced. The amount of refrigerant oil to be returned is determined according to the differential pressure between the compressors. Accordingly, when differential pressure between the lower stage-side compressor 10a and the higher stage-side compressor 10b is reduced in the middle of the two-stage compression operation in this embodiment, a compression operation is switched to the one-stage compression operation and the electromagnetic valve 25 is opened. In this way, the heat pump system 1 returns refrigerant oil to the oil equalizing pipe 21 from the oil separator 26 through the bypass pipe 23 so that the refrigerant oil does not pass through the higher stage-side compressor 10b. Accordingly, the differential pressure of the oil equalizing mechanism 20 can always be kept at a value equal to or larger than a prescribed value. In addition, since the heat pump system 1 can return oil to the lower stage-side compressor 10a so that the oil does not pass through the stationary throttle 27a provided on the oil return pipe 27 and the higher stage-side compressor 10b, the reduction of the flow rate of the oil to be returned, which is caused by a pressure loss generated at the stationary throttle 27a or the higher stage-side compressor 10b, is prevented.

[0057] The heat pump system 1 switches a compression operation to the one-stage compression operation when the following conditions (1) to (3) are satisfied in the middle of the two-stage compression operation. All of the following conditions are indexes of the reduction of the differential pressure between the lower stage-side compressor 10a and the higher stage-side compressor 10b. Prescribed values T_R, ΔP_{R1}, and ΔP_{R2} of the conditions (1) to (3) are not uniquely determined and are determined corresponding to the respective components and operation conditions of the heat pump system 1 to be applied. Meanwhile, although not shown, a temperature sensor provided on the first heat exchanger 11 and pressure sensors provided on the lower stage-side compressor 10a and the higher stage-side compressor 10b detect the temperature T_W of water, a suction pressure P_{LI}, a discharge pressure P_{LO}, and a discharge pressure P_{HO}. Detected information is sent to a control device 30 shown in Fig. 1. The control device 30 determines the conditions (1) to (3) by using the information about the temperature T_W of water, the suction pressure P_{LI}, the discharge pressure P_{LO}, and the discharge pressure P_{HO} that have been acquired. The control device 30 continues to determine the conditions (1) to (3) even in the middle of the one-stage compression operation.

[0058]

(1) The temperature of water entering the heat exchanger (water heat exchanger) for water and a refrigerant: T_W, Prescribed value: T_R

$$T_W \leq T_R$$

(2) The suction pressure of the lower stage-side compressor 10a: P_{LI}
The discharge pressure of the higher stage-side compressor 10b: P_{HO}
Prescribed value: ΔP_{R1}

$$(P_{HO} - P_{LI}) \leq \Delta P_{R1}$$

(3) The suction pressure of the lower stage-side compressor 10a: P_{LI}
The discharge pressure of the lower stage-side compressor 10a: P_{LO}
Prescribed value: ΔP_{R2}

$$(P_{LO} - P_{LI}) \leq \Delta P_{R2}$$

[Two-stage compression operation→one-stage compression operation]

[0059] When the control device 30 determines that any one of the conditions (1) to (3) is satisfied in the middle of the two-stage compression operation, the control device 30 instructs the four-way switching valve 14 to be switched to a position of the one-stage compression operation shown in Fig. 2B. Further, the control device 30 instructs the electromagnetic valve 25 to be opened. In this case, the heat pump system 1 operates as follows.

[0060] The high-pressure refrigerant, which is discharged after the refrigerant is compressed to a high pressure by the lower stage-side compressor 10a, flows into the first heat exchanger 11 through the pipe L11, the four-way switching valve 14, and the pipe L5 and radiates heat to an object to be subjected to heat exchange. Meanwhile, here, since the operating ability of the lower stage-side compressor 10a is higher than that at the time of the two-stage compression operation, the lower stage-side compressor 10a compresses the refrigerant to a high pressure. Further, the higher stage-side compressor 10b stops operating.

[0061] The high-pressure refrigerant, which has radiated heat in the first heat exchanger 11, becomes a low-pressure refrigerant by being expanded while passing through the expansion valve 12 through the pipe L3. The low-pressure refrigerant further flows into the second heat exchanger 13 through the pipe L3, absorbs heat from the outdoor air, and is evaporated. After that, the low-pressure refrigerant, which flows out of the second heat exchanger 13, is sucked into the lower stage-side compressor 10a through the pipe L4.

[0062] Since the electromagnetic valve 25 is open in the one-stage compression operation while a cycle of the compression, condensation, expansion, and evaporation of the refrigerant having been described above is repeated, refrigerant oil is returned to the oil equalizing pipe 21 through the bypass pipe 23 without passing through the higher stage-side compressor 10b. Accordingly, since the differential pressure of the oil equalizing mechanism 20 can always be kept at a value equal to or larger than a prescribed value, the level of the refrigerant oil between the lower stage-side compressor 10a and the higher stage-side compressor 10b can be kept in balance.

[0063] The above-mentioned heat pump system 1 has used the four-way switching valve 14 to switch a compression operation between the two-stage compression operation and the one-stage compression operation, but the invention is not limited thereto. As shown in Fig. 3, a heat pump system 2 includes two electromagnetic valves 14a and 14b that are disposed on pipes L1 and L5, respectively, and can switch a compression operation between the two-stage compression operation and the one-stage compression operation by selectively controlling the opening and closing of the electromagnetic valves 14a and 14b. In the case of an example shown in Fig. 3, the two-stage compression operation is performed when the electromagnetic valve 14a is open and the electromagnetic valve 14b is closed, and the two-stage compression operation is performed when the electromagnetic valve 14a is closed and the electromagnetic valve 14b is open. Meanwhile, the same components as the components of Fig. 1 are denoted in Fig. 3 by the same reference numerals as the reference numerals of Fig. 1. The same applies to Fig. 4.

[0064] Fig. 1 shows an example in which the oil separator 26 is provided so as to correspond to both the lower stage-side compressor 10a and the higher stage-side compressor 10b. However, as in a heat pump system 3 shown in Fig. 4, an oil separator 28 for the lower stage-side compressor 10a can be provided in front of the four-way switching valve 14 on the discharge side of the lower stage-side compressor 10a. The oil separator 28 is connected to the oil equalizing pipe 21 through an oil return pipe 29.

[0065] Even in the middle of both the two-stage compression operation and the one-stage compression operation, the oil separator 26 separates refrigerant oil from the refrigerant, which is discharged from the lower stage-side compressor 10a, and returns the refrigerant oil to the lower stage-side compressor 10a through the oil return pipe 29 and the oil equalizing pipe 21. Accordingly, the heat pump system 3 shown in Fig. 4 can efficiently return the refrigerant oil to the lower stage-side compressor 10a.

[Second embodiment]

[0066] A heat pump type water heating/air conditioner 100 to which the heat pump system 1 described as the first embodiment is applied will be described below as a second embodiment of the invention.

[0067] As shown in Fig. 5, the water heating/air conditioner 100 includes a heat pump system 200 and a water system 300.

[Heat pump system 200]

[0068] The heat pump system 200 uses a circuit in which one oil separator 26 shown in the heat pump system 1 (Fig. 1) described in the first embodiment is provided, and exchanges heat between outdoor air (external air) and a refrigerant. When the heat pump system 200 includes components corresponding to the heat pump system 1, the components are denoted by the same reference numerals as the reference numerals of the first embodiment and the description thereof will be omitted. However, the first heat exchanger 11 is substituted with a water-refrigerant heat exchanger 11. The water-refrigerant heat exchanger 11 heats water of the water system 300 by exchanging heat between the water and a refrigerant. Further, the second heat exchanger 13 is substituted with a heat source-side heat exchanger 13. Furthermore, the heat pump system 200 includes the following components that are not included in the heat pump system 1.

[0069] The heat pump system 200 includes a four-way switching valve 15 between a pipe L2, which is provided on the discharge side of the higher stage-side compressor 10b, and a pipe L4, which is provided on the suction side of the lower stage-side compressor 10a, and can reverse the circulation direction of a refrigerant by the four-way switching valve 15, so that any one of a cooling cycle (defrosting cycle) in which a refrigerant is circulated clockwise to the water-refrigerant heat exchanger 11 through the heat source-side heat exchanger 13 and a heating cycle in which a refrigerant is circulated counterclockwise to the heat source-side heat exchanger 13 through the water-refrigerant heat exchanger 11 can be selected.

[0070] The heat pump system 200 includes a first expansion valve 12a, an intermediate pressure receiver 16a, a supercooling coil 17, a second expansion valve 12b, and an accumulator 18 on a refrigerant circuit in addition to the heat source-side heat exchanger 13, the water-refrigerant heat exchanger 11, and the four-way switching valve 15. The first expansion valve 12a serves as decompression means for controlling the temperature of a refrigerant at an outlet of the water-refrigerant heat exchanger 11, the intermediate pressure receiver 16a separates the refrigerant into a gas refrigerant and a liquid refrigerant, and the second expansion valve 12b decompresses an intermediate-pressure refrigerant. The accumulator 18 separates a liquid refrigerant that is not evaporated by the heat source-side heat exchanger 13.

[0071] Further, the heat pump system 200 includes an injection circuit 16 that includes an electromagnetic valve 16b, a check valve 16c, and an injection pipe 16d. The electromagnetic valve 16b injects the intermediate-pressure refrigerant gas, which is separated out by the intermediate pressure receiver 16a, into an intermediate-pressure refrigerant gas that is to be sucked into the higher stage-side compressor 10b.

[0072] Meanwhile, the electromagnetic valve 16b also serves as a valve for closing the injection circuit 16 so that a liquid refrigerant is not supplied to the higher stage-side compressor 10b at the time of activation in which the intermediate pressure receiver 16a is filled with a liquid refrigerant.

[0073] Furthermore, the heat pump system 200 includes a sub-pipe 121 that is provided in parallel to the oil equalizing pipe 21, and the sub-pipe 121 is provided with an electromagnetic valve 122. Likewise, the heat pump system 200 includes a sub-pipe 127 that is provided in parallel to the return pipe 27, and the sub-pipe 127 is provided with an electromagnetic valve 128. Meanwhile, each of the sub-pipes 121 and 127 is provided with a throttle.

[0074] Since the amount of refrigerant oil flowing through each of the oil equalizing pipe 21 and the return pipe 27 has a limit, the electromagnetic valves 122 and 128 of the sub-pipes 121 and 127 are opened when a larger amount of refrigerant oil needs to flow.

[Water system 300]

[0075] The water system 300 includes a hot-water circulation flow passage 301 in which water circulated by a pump 307 absorbs heat from a refrigerant and becomes hot water in the water-refrigerant heat exchanger 11 of the heat pump system 200 and which uses the hot water as a heat source for heating or the like by circulating the hot water between the load-side radiator (use-side heat exchanger) 303 and the water-refrigerant heat exchanger 11. A heat storage tank 305, to which hot water is introduced from the hot-water circulation flow passage 301 through a three-way switching valve 306 capable of adjusting a flow rate ratio and which can store the hot water as heat-storage hot water, is connected to the hot-water circulation flow passage 301.

[0076] The heat storage tank 305 takes heat-storage hot water from an upper portion thereof through the three-way switching valve 306, which is provided on the hot-water circulation flow passage 301 through which hot water heated by the water-refrigerant heat exchanger 11 is circulated to the radiator 303, and discharges the heat-storage hot water to the hot-water circulation flow passage 301 at a necessary time.

[0077] Further, the heat storage tank 305 is provided with a sanitary water supply circuit (not shown) for supplying hot water to be supplied, which is heated by the heat of the stored heat-storage hot water, and an electric heater (not shown) to which current is applied as necessary.

[0078] The water system 300 having the above-mentioned configuration is adapted to selectively perform one of a heating operation in which hot water is supplied to the radiator 303 and a heat storage operation in which hot water is supplied to the heat storage tank 305 by controlling the opening and closing of the three-way switching valve 306 to selectively switch the three-way switching valve 306, and to simultaneously perform both the heating operation and the heat storage operation using hot water by distributing and supplying hot water to both the radiator 303 and the heat storage tank 305.

[0079] Furthermore, in the water system 300, water, which is supplied from the heat storage tank 305 by the water circulation pump 307, as an object to be heated is heated by exchanging heat with the refrigerant of the heat pump system 200 in the water-refrigerant heat exchanger 11.

[0080] Meanwhile, when the heating cycle is selected in the heat pump system 200, a gas refrigerant, which has a low temperature and a low pressure, is compressed by the compression mechanism 10 (the lower stage-side compressor 10a and the higher stage-side compressor 10b) and is discharged to the heat pump system 200 as a gas refrigerant having a high temperature and a high pressure. As shown in Fig. 5 by solid-line arrows, this gas refrigerant is guided to the water-refrigerant heat exchanger 11 by the four-way switching valve 14 and is circulated clockwise. In this case, the water-refrigerant heat exchanger 11 is a heat exchanger for exchanging heat between the water, which is circulated by the water circulation pump 307, of the water system 300 and a gas refrigerant that has a high temperature and a high pressure; and functions as a condenser in which water is heated by the heat of condensation radiated due to the condensation of the refrigerant. As a result, the gas refrigerant, which has a high temperature and a high pressure and flows in the heat pump system 200, becomes a liquid refrigerant, which has a high temperature and a high pressure, by being condensed; and water, which flows in the water system 300, absorbs heat from the refrigerant and becomes hot water.

[0081] The refrigerant, which is condensed in the water-refrigerant heat exchanger 11, flows into the intermediate pressure receiver 16a through the first expansion valve 12a that is fully opened. The refrigerant is separated into a gas refrigerant and a liquid refrigerant in the intermediate pressure receiver 16a, and the separated gas refrigerant having an intermediate pressure is injected through the electromagnetic valve 16b and the check valve 16c with an intermediate pressure between the lower stage-side compressor 10a and the higher stage-side compressor 10b.

[0082] Meanwhile, the liquid refrigerant, which is separated out by the intermediate pressure receiver 16a, passes through the supercooling coil 17 and becomes a gas-liquid two-phase refrigerant having a low temperature and a low pressure by being decompressed by the second expansion valve 12b, and is guided to the heat source-side heat exchanger 13. The gas-liquid two-phase refrigerant, which is introduced to the heat source-side heat exchanger 13 functioning as an evaporator, absorbs heat from the external air and is vaporized by exchanging heat with the external air.

[0083] A gas refrigerant, which has a low temperature and a low pressure and is obtained when the gas-liquid two-phase refrigerant absorbs heat from the external air and is vaporized while passing through the heat source-side heat exchanger 13 as described above, is sucked into the lower stage-side compressor 10a through the four-way switching valve 15 again. The gas refrigerant, which has a low temperature and a low pressure and is sucked into the lower stage-side compressor 10a as described above, becomes a gas refrigerant, which has a high temperature and a high pressure, by being compressed in turn by the lower stage-side compressor 10a and the higher stage-side compressor 10b; and is repeatedly subjected to a gas-liquid phase change while being circulated along the same path as described below. In this case, moisture or the like in the air freezes on the outer peripheral surface, which has a low temperature, of the heat source-side heat exchanger 13, so that a frost formation phenomenon occurs.

[0084] Since frost formation inhibits heat exchange between the refrigerant and the external air in the heat source-side heat exchanger 13 and reduces heat exchange efficiency, it is necessary to detect whether or not frost has been accumulated and to remove frost by performing a defrosting operation at each of appropriate operation times. In the above-mentioned heat pump system 200, the four-way switching valve 15 is switched to reverse the circulation direction of a refrigerant and to switch a cycle to the cooling cycle (defrosting cycle) that circulates the refrigerant in a direction indicated by broken-line arrows of Fig. 6, a gas refrigerant, which has a high temperature and a high pressure and is discharged from the higher stage-side compressor 10b, is introduced to the heat source-side heat exchanger 13, and frost adhering to the heat source-side heat exchanger 13 is melted by the heat (heat of condensation) of the gas refrigerant. In this way, the defrosting operation is performed.

[0085] During the defrosting operation using this reverse cycle method, the water-refrigerant heat exchanger 11 functions as an evaporator, absorbs heat from the water flowing through the hot-water circulation flow passage 301, vaporizes the refrigerant, and melts frost, which is formed on the heat source-side heat exchanger 13, by using the heat. In this case, when the temperature of the water is excessively lowered, the water freezes in the water-refrigerant heat exchanger 11 and a risk of damage to the heat exchanger is generated. For this reason, it is necessary to prevent the temperature of the water, which is circulated in the water-refrigerant heat exchanger 11, and the evaporation temperature of the refrigerant from being excessively lowered.

[0086] Also in the above-mentioned water heating/air conditioner 100, a compression operation is switched to the one-stage compression operation as in the first embodiment when the following conditions (1) to (3) are satisfied in the middle of the two-stage compression operation. The switching is the same as described with reference to Figs. 2A and 2B.

(1) The temperature of water entering the heat exchanger (water heat exchanger) for water and a refrigerant: T_W, Prescribed value: T_R

$$T_W \leq T_R$$

(2) The suction pressure of the lower stage-side compressor 10a: P_{LI}
The discharge pressure of the higher stage-side compressor 10b: P_{HO}
Prescribed value: ΔP_{R1}

$$(P_{HO} - P_{LI}) \leq \Delta P_{R1}$$

(3) The suction pressure of the lower stage-side compressor 10a: P_{LI}
The discharge pressure of the lower stage-side compressor 10a: P_{LO}
Prescribed value: ΔP_{R2}

$$(P_{LO} - P_{LI}) \leq \Delta P_{R2}$$

[Two-stage compression operation→one-stage compression operation]

[0087] When a compression operation is switched to the one-stage compression operation, the high-pressure refrigerant, which is discharged after the refrigerant is compressed to a high temperature by the lower stage-side compressor 10a, flows into the water-refrigerant heat exchanger 11 through the pipe L11, the four-way switching valve 14, and the pipe L5 and radiates heat to an object to be subjected to heat exchange. Meanwhile, here, since the operating ability of the lower stage-side compressor 10a is higher than that at the time of the two-stage compression operation, the lower stage-side compressor 10a compresses the refrigerant to a high pressure. Further, the higher stage-side compressor 10b stops operating.

[Third embodiment]

[0088] As shown in Fig. 8, a heat pump system 4 according to a third embodiment includes a lower stage-side compressor 10a and a higher stage-side compressor 10b that compress and discharge a refrigerant, a first heat exchanger 11 that exchanges heat between the refrigerant compressed by the higher stage-side compressor 10b and fluid as an object to be subjected to heat exchange, an expansion valve 12 that decompresses and expands the refrigerant flowing out of the first heat exchanger 11, and a second heat exchanger 13 that exchanges heat between the refrigerant decompressed and expanded by the expansion valve 12 and the fluid as an object to be subjected to heat exchange. The lower stage-side compressor 10a, the higher stage-side compressor 10b, the first heat exchanger 11, the expansion valve 12, and the second heat exchanger 13 are connected in series in this order in the circulation direction of the refrigerant. In this embodiment, the first heat exchanger 11 can function as a condenser that radiates heat by exchanging heat with, for example, water and the second heat exchanger 13 can function as an evaporator that absorbs heat by exchanging heat with external air.

[0089] Further, the heat pump system 4 includes an oil equalizing mechanism 20 that keeps the amount of refrigerant oil retained in the lower and higher stage-side compressors 10a and 10b uniform. The details of the oil equalizing mechanism 20, which are the characteristics of this embodiment, will be described below.

[0090] The heat pump system 4 includes a pipe L1 that connects the lower stage-side compressor 10a to the higher stage-side compressor 10b, a pipe L2 that connects the higher stage-side compressor 10b to the first heat exchanger 11, a pipe L3 that connects the first heat exchanger 11 to the second heat exchanger 13, and a pipe L4 that connects the second heat exchanger 13 to the lower stage-side compressor 10a. Accordingly, the heat pump system 1 forms a refrigerant circuit in which a refrigerant circulates. Among the pipes, the pipe L4 forms a suction-side pipe of the lower stage-side compressor 10a, the pipe L1 connecting the lower stage-side compressor 10a to the higher stage-side compressor 10b forms an intermediate-pressure pipe, and the pipe L2 forms a discharge-side pipe of the higher stage-side compressor 10b.

[0091] Meanwhile, the lower stage-side compressor 10a and the higher stage-side compressor 10b are generally referred to as a compression mechanism 10 without being distinguished from each other.

[0092] The respective components of the heat pump system 4 will be described in turn below.

[Compression mechanism 10]

[0093] When the lower stage-side compressor 10a is rotationally driven by an electric motor that is formed integrally with the lower stage-side compressor 10a, the lower stage-side compressor 10a sucks the refrigerant, which has passed through the second heat exchanger 13 and has a low temperature and a low pressure, compresses the refrigerant to an intermediate pressure, and discharges the compressed refrigerant to the higher stage-side compressor 10b.

[0094] A publicly known compression mechanism, such as a scroll compression mechanism or a rotary compression mechanism, can be applied as the compression mechanism that is applied to the lower stage-side compressor 10a. Likewise, the same applies to the higher stage-side compressor 10b.

[0095] The higher stage-side compressor 10b sucks and compresses the refrigerant, which is discharged from the lower stage-side compressor 10a, and discharges the compressed refrigerant to the first heat exchanger 11 as a refrigerant that has a high temperature and a high pressure.

[First heat exchanger 11]

[0096] The first heat exchanger 11 heats fluid, such as water or air, as an object to be subjected to heat exchange by exchanging heat between the fluid and a refrigerant that has a high temperature and a high pressure. The refrigerant, which is discharged from the higher stage-side compressor 10b and has a high temperature and a high pressure, is cooled and condensed in the first heat exchanger 11. A publicly known heat exchanger can be used as the first heat exchanger 11. The same applies to the second heat exchanger 13 to be described below.

[0097] When an object to be subjected to heat exchange is air, the first heat exchanger 11 is provided with a blower fan 11f and heat is exchanged between air blown by the blower fan 11f and the refrigerant while the air blown by the blower fan 11f passes through the first heat exchanger 11.

[Expansion valve 12 and second heat exchanger 13]

[0098] The second heat exchanger 13 exchanges heat between the refrigerant, which passes through the expansion valve 12 and is decompressed and expanded, and the external air, and the refrigerant is evaporated and absorbs heat from the external air while heat is exchanged between the refrigerant and the external air. The second heat exchanger 13 is also provided with a blower fan 13f and heat is exchanged between air blown by the blower fan 13f and the refrigerant, so that a low-pressure refrigerant is evaporated and a heat absorbing operation is generated.

[0099] The expansion valve 12 is formed of, for example, an electronic expansion valve that includes a needle-shaped valve body and a pulse motor for driving the valve body.

[Oil equalizing mechanism 20]

[0100] The oil equalizing mechanism 20 includes an oil equalizing pipe 21 that connects the lower stage-side compressor 10a to the higher stage-side compressor 10b, an oil equalizing valve (on-off valve) 23 that is provided on the oil equalizing pipe 21 and controls the flow of the refrigerant oil between the lower stage-side compressor 10a and the higher stage-side compressor 10b, a first temperature sensor 34 that is provided near the oil equalizing pipe 21 and detects the temperature of the inside of the oil equalizing pipe 21, and a second temperature sensor 35 that is provided near the pipe L2 and detects the temperature of the inside of the pipe L2.

[0101] Temperature information (detected temperature) T_0 and temperature information (detected temperature) T_1, which are detected by the first temperature sensor 34 and the second temperature sensor 35, are transmitted to the control device 30. The control device 30 controls the opening/closing of the oil equalizing valve 23 on the basis of the temperature information T_0 and the temperature information T_1 that are transmitted.

[0102] The oil equalizing mechanism 20 supplies surplus refrigerant oil of the higher stage-side compressor 10b to the lower stage-side compressor 10a or stops supplying the surplus refrigerant oil through the control of the opening/closing of the oil equalizing valve 23.

[0103] A reference level representing the amount of refrigerant oil, which is necessary for a normal operation of each of the lower stage-side compressor 10a and the higher stage-side compressor 10b, is set and the oil equalizing pipe 21 is connected to the lower stage-side compressor 10a and the higher stage-side compressor 10b at a position corresponding to the reference level. Further, it is preferable that each of the connection ends of the oil equalizing pipe 21 is always immersed in the refrigerant oil.

[0104] When the oil equalizing valve 23 of the oil equalizing pipe 21 is open as shown in Fig. 9B, refrigerant oil flows to the lower stage-side compressor 10a from the higher stage-side compressor 10b. The reason for this is that the pressure of the inside of the higher stage-side compressor 10b is higher than the pressure of the inside of the lower stage-side compressor 10a. Meanwhile, in Fig. 9, the closed oil equalizing valve 23 is represented as a black valve (Fig. 9A) and the open oil equalizing valve 23 is represented as an empty valve (Fig. 9B). Further, in Fig. 9, the oil equalizing pipe 21 is shown by a solid line when refrigerant oil flows in the oil equalizing pipe, and the oil equalizing pipe 21 is shown by a broken line when refrigerant oil does not flow in the oil equalizing pipe.

[0105] However, the flow of the refrigerant oil to the lower stage-side compressor 10a from the higher stage-side compressor 10b is premised on the fact that the connection end of the oil equalizing pipe 21 corresponding to the higher stage-side compressor 10b is immersed in the refrigerant oil. When this premise is not satisfied, the oil equalizing pipe 21 serves as a passage for a refrigerant. Accordingly, a part of the refrigerant, which is compressed by the higher stage-side compressor 10b, goes back to the lower stage-side compressor 10a. This means that power used to compress the refrigerant is wasted in both the lower stage-side compressor 10a and the higher stage-side compressor 10b. Therefore, when the refrigerant oil does not flow in the oil equalizing pipe 21, it is preferable that the oil equalizing valve 23 is closed to close the oil equalizing pipe 21 as shown in Fig. 9A so that a refrigerant does not flow to the lower stage-side compressor 10a.

[Control device 30]

[0106] The control device 30 takes charge of the operation of the heat pump system 4, but particularly controls the opening/closing of the oil equalizing valve 23 of the oil equalizing pipe 21 in this embodiment. The control device 30 acquires the temperature information T_0 and the temperature information T_1 from the first and second temperature sensors 34 and 35, respectively, in order to control the opening/closing of the oil equalizing valve 23. The control device 30 determines the opening/closing of the oil equalizing valve 23 through the comparison of the temperature information T_0 and the temperature information T_1 that are acquired. That is, when the temperature of the refrigerant oil flowing in the oil equalizing pipe 21 is compared with the temperature of the refrigerant flowing in the pipe L2, the temperature of the refrigerant is significantly low. However, when the refrigerant rather than the refrigerant oil flows in the oil equalizing pipe 21, a difference between the temperature information T_0, which is detected in the oil equalizing pipe 21, and the temperature information T_1, which is detected in the pipe L2, is reduced. Accordingly, the control device 30 can determine whether the refrigerant oil is flowing in the oil equalizing pipe 21 or whether the refrigerant is flowing in the oil equalizing pipe 21 through the comparison of the temperature information T_0 and the temperature information T_1.

[Operation of heat pump system 4]

[0107] The operation of the heat pump system 4 will be described below.

[0108] In the heat pump system 4, a refrigerant circulates and a two-stage compression refrigeration cycle is performed.

[0109] In the heat pump system 4, the refrigerant, which is discharged from the higher stage-side compressor 10b and has a high temperature and a high pressure, flows into the first heat exchanger 11 through the pipe L2 and radiates heat to an object to be subjected to heat exchange. The refrigerant, which has radiated heat in the first heat exchanger 11, becomes a low-pressure refrigerant by being expanded while passing through the expansion valve 12 through the pipe L3. The low-pressure refrigerant further flows into the second heat exchanger 13 through the pipe L3, absorbs heat from the outdoor air, and is evaporated. After that, the low-pressure refrigerant, which flows out of the second heat exchanger 13, is sucked into the lower stage-side compressor 10a through the pipe L4.

[0110] After the low-pressure refrigerant, which is sucked into the lower stage-side compressor 10a, is compressed and becomes an intermediate-pressure refrigerant, the intermediate-pressure refrigerant is discharged to the pipe L1. The intermediate-pressure refrigerant, which is discharged to the pipe L1 from the lower stage-side compressor 10a, is sucked into the higher stage-side compressor 10b. After the refrigerant, which is sucked into the higher stage-side compressor 10b, is compressed and becomes a high-pressure refrigerant, the high-pressure refrigerant is discharged to the pipe L2.

[0111] The heat pump system 4 alternately repeats an operation in which the oil equalizing valve 23 is closed for a closing period t_w and an operation in which the oil equalizing valve 23 is open for an oil equalizing period t_m while a cycle of the compression, condensation, expansion, and evaporation of the refrigerant having been described above is repeated. This embodiment is characterized in that the oil equalizing valve 23 is forcibly closed even for the oil equalizing period t_m. A procedure of an operation for opening/closing the oil equalizing valve 23 will be described below with reference to Fig. 10.

[0112] As shown in Fig. 10, the control device 30 instructs the oil equalizing valve 23 to be closed (OFF) as initial setting in which the heat pump system 4 is instructed to start to operate (S101 of Fig. 10). When the oil equalizing valve 23 is closed from the first, the procedure continues as it is.

[0113] The control device 30 measures an elapsed time t after the heat pump system 4 is instructed to start to operate, and the control device 30 instructs the oil equalizing valve 23 to be opened (ON) when the elapsed time t reaches a predetermined closing period t_w (S103 of Fig. 10). When the elapsed time reaches a predetermined closing period t_m after the control device 30 instructs the oil equalizing valve 23 to be opened, the control device 30 instructs the oil equalizing valve 23 to be closed (S111 of Fig. 10). The operation in which the oil equalizing valve 23 of the first embodiment is closed for a closing period t_w and the operation in which the oil equalizing valve 23 of the first embodiment is open for an oil equalizing period t_m are alternately repeated as described above.

[0114] However, the control device 30 has two exceptions to be described below in regard to the opening/closing of the oil equalizing valve 23.

[0115] First, the control device 30 determines whether or not the heat pump system 4 is performing a steady operation. If the heat pump system 4 is performing a steady operation, the procedure proceeds to the determination of the second exception (Yes in Step 105, S107). However, if the heat pump system 4 is not performing a steady operation, the oil equalizing valve 23 is kept closed (No in S105 of Fig. 10). Here, the case of an unsteady operation, which does not correspond to a steady operation, corresponds to a case in which, for example, a defrosting operation is performed. The reason for this is that there is a concern that the premise of this embodiment that the temperature of the refrigerant oil flowing through the oil equalizing valve 23 is higher than the temperature of the refrigerant sucked into the higher stage-side compressor 10b may not be satisfied during the unsteady operation. Further, the early stage of the activation of the heat pump system 4 also corresponds to an unsteady operation, but the early stage of the activation is regarded as the above-mentioned closing period t_w in this embodiment.

[0116] Next, as the second exception, the control device 30 compares the rotational speed R of the higher stage-side compressor 10b with a predetermined rotational speed R_0 (S107 of Fig. 10); and the control device 30 instructs the oil equalizing valve 23 to be alternately and repeatedly opened (ON) and closed (OFF) at each of predetermined times (Yes in S107 of Fig. 10, S108) if the rotational speed R is smaller than the rotational speed R_0.

[0117] In a case that does not correspond to the above-mentioned two exceptions, the control device 30 instructs the oil equalizing valve 23 to be opened (S109 of Fig. 10). After receiving this instruction, the oil equalizing valve 23 is kept open for the oil equalizing period t_m (S111 of Fig. 3).

[0118] During this period, the control device 30 determines whether a difference (T_0-T_1) between the temperature information T_0, which is acquired from the first temperature sensor 34, and the temperature information T_1, which is acquired from the second temperature sensor 35, is equal to or smaller than a predetermined value ΔT (S113 of Fig. 10). Here, the temperature information T_0 is regarded as the temperature of fluid (refrigerant oil or a refrigerant) flowing in the oil equalizing pipe 21, and the temperature information T_1 is regarded as the temperature of the refrigerant sucked into the higher stage-side compressor 10b.

[0119] If the difference (T_0-T_1) is equal to or smaller than ΔT, the control device 30 determines that the refrigerant rather than the refrigerant oil is flowing in the oil equalizing pipe 21 and closes the oil equalizing valve 23 (Yes in S113 of Fig. 10). Meanwhile, if the difference (T_0-T_1) exceeds ΔT, the oil equalizing valve 23 continues to be open until the oil equalizing period t_m terminates. If the oil equalizing period t_m terminates, the oil equalizing valve 23 is closed (No in S113 and Yes in S111 Yes of Fig. 10).

[0120] As described above, according to this embodiment, it is possible to supply refrigerant oil to the lower stage from the higher stage and to equalize the refrigerant oil of both the lower stage-side compressor 10a and the higher stage-side compressor 10b by a simple operation for opening/closing the oil equalizing valve 23 without stopping the operation of the lower stage-side compressor 10a and the higher stage-side compressor 10b. In addition, according to this embodiment, when the control device 30 determines that a refrigerant rather than refrigerant oil is flowing in the oil equalizing pipe 21, the control device 30 closes the oil equalizing valve 23. Accordingly, it is possible to avoid the wasteful use of the compression mechanism 10 that is caused when the refrigerant flows in the oil equalizing pipe 21.

[0121] The invention has been described above on the basis of the embodiments, but components described in the above-mentioned embodiments may be appropriately selected or may be appropriately substituted with other components without departing from the gist of the invention.

[0122] In the above description, the general opening/closing of the oil equalizing valve 23 has been controlled by the closing period t_w and the oil equalizing period t_m. However, the invention is not limited thereto. The temperature information T_0 and the temperature information T_1 can be used as conditions that are necessary to open the oil equalizing valve 23. That is, as shown in Fig. 11, the oil equalizing valve 23 may be opened (Step 203 and Step 109 of Fig. 11) when T_0-T_1 exceeds ΔT, and the oil equalizing valve 23 may be closed (Step 113 and Step S101 of Fig. 11) when T_0-T_1 is equal to or smaller than ΔT.

[0123] Further, temperature information, which is to be compared with the temperature information T_0, is not limited to the temperature information T_1, and the temperature information T_0, may be compared with a detected temperature (temperature information) T_2 of the higher stage-side compressor 10b. A difference, which is obtained in this case, is T_2-T_0, and the control device 30 determines that a refrigerant is flowing in the oil equalizing pipe 21 when the difference is equal to or smaller than a predetermined value ΔTT. Meanwhile, the temperature of the higher stage-side compressor 10b is detected at a lower portion of the higher stage-side compressor in which the refrigerant oil is stored.

[Fourth embodiment]

[0124] A heat pump type water heating/air conditioner 100 to which the heat pump system 4 described as the first embodiment is applied will be described below as a fourth embodiment of the invention.

[0125] As shown in Figs. 12 and 13, the water heating/air conditioner 100 includes a heat pump system 200 and a water system 300.

[Heat pump system 200]

[0126] The heat pump system 200 uses the heat pump system 4 described in the first embodiment, and exchanges heat between the outdoor air (external air) and a refrigerant. When the heat pump system 200 includes components corresponding to the heat pump system 4, the components are denoted by the same reference numerals as the reference numerals of the third embodiment and the description thereof will be omitted. However, the first heat exchanger 11 is substituted with a water-refrigerant heat exchanger 11. The water-refrigerant heat exchanger 11 heats water of the water system 300 by exchanging heat between the water and a refrigerant. Further, the second heat exchanger 13 is substituted with a heat source-side heat exchanger 13. Furthermore, the heat pump system 200 includes the following components that are not included in the heat pump system 4.

[0127] The heat pump system 200 includes a four-way switching valve 15 between a pipe L2, which is provided on the discharge side of the higher stage-side compressor 10b, and a pipe L4, which is provided on the suction side of the lower stage-side compressor 10a, and can reverse the circulation direction of a refrigerant by the four-way switching valve 15, so that any one of a cooling cycle (defrosting cycle) in which a refrigerant is circulated clockwise to the water-refrigerant heat exchanger 11 through the heat source-side heat exchanger 13 and a heating cycle in which a refrigerant is circulated counterclockwise to the heat source-side heat exchanger 13 through the water-refrigerant heat exchanger 11 can be selected.

[0128] The heat pump system 200 includes an expansion valve 12a for cooling, an expansion valve 12b for heating, and a receiver 39 as a throttle mechanism, in addition to the heat source-side heat exchanger 13, the water-refrigerant heat exchanger 11, and the four-way switching valve 15. The expansion valve 12a for cooling and the expansion valve 12b for heating are disposed in series with the receiver 18 interposed therebetween.

[0129] Further, the heat pump system 200 includes an economizer circuit 36 that is provided on the pipe L3. The economizer circuit 36 includes a heat exchanger 36a for an economizer, an expansion valve 36b for an economizer, and an injection pipe 36c. After a part of the liquid refrigerant having passed through the water-refrigerant heat exchanger 11 is introduced to the heat exchanger 36a for an economizer through the expansion valve 36b for an economizer and is evaporated by exchanging heat with a liquid refrigerant flowing in the pipe L3, a gas refrigerant is injected to the intermediate-pressure pipe L1, which is provided between the lower stage-side compressor 10a and the higher stage-side compressor 10b, through the injection pipe 36c.

[0130] Furthermore, the heat pump system 200 includes an oil separator 37 that is provided on the discharge side of the lower stage-side compressor 10a and an oil separator 38 that is provided on the discharge side of the higher stage-side compressor 10b. Refrigerant oil, which is contained in the refrigerant discharged from the lower stage-side compressor 10a, is separated from the refrigerant by the oil separator 37 and is returned to the lower stage-side compressor

10a through a return pipe 37L. Likewise, refrigerant oil, which is contained in the refrigerant discharged from the higher stage-side compressor 10b, is separated from the refrigerant by the oil separator 38 and is returned to the higher stage-side compressor 10b through a return pipe 38L.

[Water system 300]

[0131] The water system 300 includes a hot-water circulation flow passage 301 in which water circulated by a water circulation pump 307 absorbs heat from a refrigerant in the water-refrigerant heat exchanger 11 of the heat pump system 200 and becomes hot water and which uses the hot water as a heat source for heating or the like by circulating the hot water between the load-side radiator 303 and the water-refrigerant heat exchanger 11. A heat storage tank 305, to which hot water is introduced from the hot-water circulation flow passage 301 through a three-way switching valve 306 capable of adjusting a flow rate ratio and which can store the hot water as heat-storage hot water, is connected to the hot-water circulation flow passage 301.

[0132] The heat storage tank 305 takes heat-storage hot water from an upper portion thereof through the three-way switching valve 306, which is provided on the hot-water circulation flow passage 301 through which hot water heated by the water-refrigerant heat exchanger 11 is circulated to the radiator 303, and discharges the heat-storage hot water to the hot-water circulation flow passage 301 at a necessary time.

[0133] Further, the heat storage tank 305 is provided with a sanitary water supply circuit (not shown) for supplying hot water to be supplied, which is heated by the heat of the stored heat-storage hot water, and an electric heater (not shown) to which current is applied as necessary.

[0134] The water system 300 having the above-mentioned configuration is adapted to selectively perform one of a heating operation in which hot water is supplied to the radiator 303 and a heat storage operation in which hot water is supplied to the heat storage tank 305 by selectively switching the three-way switching valve 306, and to simultaneously perform both the heating operation and the heat storage operation using hot water by distributing and supplying hot water to both the radiator 303 and the heat storage tank 305.

[0135] Furthermore, in the water system 300, water, which is supplied from the heat storage tank 305 by the water circulation pump 307, as an object to be heated is heated by exchanging heat with the refrigerant of the heat pump system 200 in the water-refrigerant heat exchanger 11.

[0136] Meanwhile, when the heating cycle is selected in the heat pump system 200, a gas refrigerant, which has a low temperature and a low pressure, is compressed by the compression mechanism 10 (the lower stage-side compressor 10a and the higher stage-side compressor 10b) and is discharged to the heat pump system 200 as a gas refrigerant having a high temperature and a high pressure. As shown in Fig. 12 by solid-line arrows, this gas refrigerant is guided to the water-refrigerant heat exchanger 11 by the four-way switching valve 15 and is circulated counterclockwise. In this case, the water-refrigerant heat exchanger 11 is a heat exchanger for exchanging heat between the water, which is circulated by the water circulation pump 307, of the water system 300 and a gas refrigerant that has a high temperature and a high pressure; and functions as a condenser in which water is heated by the heat of condensation radiated due to the condensation of the refrigerant. As a result, the gas refrigerant, which has a high temperature and a high pressure and flows in the heat pump system 200, becomes a liquid refrigerant, which has a high temperature and a high pressure, by being condensed; and water, which flows in the water system 300, absorbs heat from the refrigerant and becomes hot water.

[0137] The refrigerant, which is condensed by the water-refrigerant heat exchanger 11, flows into the receiver 39 through the expansion valve 12a for cooling that is fully opened. In the receiver 39, the refrigerant is separated into a gas refrigerant and a liquid refrigerant and the amount of the circulating refrigerant is adjusted. The expansion valve 12b for heating, which decompresses a liquid refrigerant having a high temperature and a high pressure, is disposed on the downstream side of the receiver 39. The liquid refrigerant having a high temperature and a high pressure becomes a gas-liquid two-phase refrigerant having a low temperature and a low pressure by being decompressed while the refrigerant passes through the expansion valve 12b for heating. Then, the gas-liquid two-phase refrigerant is guided to the heat source-side heat exchanger 13. The gas-liquid two-phase refrigerant, which is introduced to the heat source-side heat exchanger 13 functioning as an evaporator, absorbs heat from the external air and is vaporized by exchanging heat with the external air.

[0138] A gas refrigerant, which has a low temperature and a low pressure and is obtained when the gas-liquid two-phase refrigerant absorbs heat from the external air and is vaporized while passing through the heat source-side heat exchanger 13 as described above, is sucked into the lower stage-side compressor 10a through the four-way switching valve 15 again. The gas refrigerant, which has a low temperature and a low pressure and is sucked into the lower stage-side compressor 10a as described above, becomes a gas refrigerant, which has a high temperature and a high pressure, by being compressed in turn by the lower stage-side compressor 10a and the higher stage-side compressor 10b; and is repeatedly subjected to a gas-liquid phase change while being circulated along the same path as described below. In this case, moisture or the like in the air freezes on the outer peripheral surface, which has a low temperature, of the heat source-side heat exchanger 13, so that a frost formation phenomenon occurs.

[0139] Since frost formation inhibits heat exchange between the refrigerant and the external air in the heat source-side heat exchanger 13 and reduces heat exchange efficiency, it is necessary to detect whether or not frost has been accumulated and to remove frost by performing a defrosting operation at each of appropriate operation times. In the above-mentioned heat pump system 200, the four-way switching valve 15 is switched to reverse the circulation direction of a refrigerant and to switch a cycle to the cooling cycle (defrosting cycle) that circulates the refrigerant in a direction indicated by one-dot-dashed line arrows in Fig. 13, a gas refrigerant, which has a high temperature and a high pressure and is discharged from the higher stage-side compressor 10b, is introduced to the heat source-side heat exchanger 13, and frost adhering to the heat source-side heat exchanger 13 is melted by the heat (heat of condensation) of the gas refrigerant. In this way, the defrosting operation is performed.

[0140] During the defrosting operation using this reverse cycle method, the water-refrigerant heat exchanger 11 functions as an evaporator, absorbs heat from the water flowing through the hot-water circulation flow passage 301, vaporizes the refrigerant, and melts frost, which is formed on the heat source-side heat exchanger 13, by using the heat. In this case, when the temperature of the water is excessively lowered, the water freezes in the water-refrigerant heat exchanger 11 and a risk of damage to the heat exchanger is generated. For this reason, it is necessary to prevent the temperature of the water, which is circulated in the water-refrigerant heat exchanger 11, and the evaporation temperature of the refrigerant from being excessively lowered.

[0141] Even in the above-mentioned water heating/air conditioner 100, the opening/closing of the oil equalizing valve 23 provided between the lower stage-side compressor 10a and the higher stage-side compressor 10b is controlled as in the first embodiment. Accordingly, according to the water heating/air conditioner 100 of this embodiment, it is possible to equalize the refrigerant oil of the lower stage-side compressor 10a and the higher stage-side compressor 10b by a simple operation for opening/closing the oil equalizing valve 23 without stopping the operation of the lower stage-side compressor 10a and the higher stage-side compressor 10b.

[0142] The invention has been described above on the basis of the embodiments, but components described in the above-mentioned embodiments may be appropriately selected or may be appropriately substituted with other components without departing from the gist of the invention.

Reference Signs List

[0143]

1, 2, 3, 4: heat pump system
10a: lower stage-side compressor
10b: higher stage-side compressor
11: first heat exchanger, water-refrigerant heat exchanger
11f: blower fan
12: expansion valve
12a: first expansion valve, expansion valve for cooling
12b: second expansion valve, expansion valve for heating
13: second heat exchanger, heat source-side heat exchanger
13f: blower fan
14, 15: four-way switching valve
14a, 14b: electromagnetic valve
16: injection circuit
16a: intermediate pressure receiver
16b: electromagnetic valve
16c: check valve
16d: injection pipe
17: supercooling coil
18: accumulator
20: oil equalizing mechanism
21: oil equalizing pipe
23: oil equalizing valve
25: electromagnetic valve
26, 28: oil separator
27, 29: oil return pipe
30: control device
34: first temperature sensor

35: second temperature sensor
36: economizer circuit
36a: heat exchanger for an economizer
36b: expansion valve for an economizer
36c: injection pipe
37, 38: oil separator
37L, 38L: return pipe
39: receiver
100: water heating/air conditioner
121, 127: sub-pipe
122, 128: electromagnetic valve
200: heat pump system
300: water system
301: hot-water circulation flow passage
303: radiator
305: heat storage tank
306: three-way switching valve
307: water circulation pump
L1, L11, L12, L2, L3, L4, L5: pipe

Claims

1. A heat pump system (1; 2; 3) comprising:

a compression mechanism that includes a lower stage-side compressor (10a) and a higher stage-side compressor (10b) configured to compress and discharge a refrigerant;
an oil separator (26) that is provided on a discharge side of the higher stage-side compressor (10b);
a first heat exchanger (11) configured to exchange heat between the refrigerant compressed by the compression mechanism and an object to be subjected to heat exchange;
an expansion valve (12) configured to decompress and expand the refrigerant flowing out of the first heat exchanger (11);
a second heat exchanger (13) configured to exchange heat between the refrigerant decompressed and expanded by the expansion valve (12) and an object to be subjected to heat exchange; and
a main return pipe (27) that connects the oil separator (26) to a suction side of the higher stage-side compressor (10b); **characterized by** comprising
an oil equalizing path (21) that connects the lower stage-side compressor (10a) to the higher stage-side compressor (10b) configured to allow refrigerant oil to flow between the lower stage-side compressor (10a) and the higher stage-side compressor (10b);
an oil return path (23) that connects the main return pipe (27) to the oil equalizing path (21);
an oil-return on-off valve (25) that is provided on the oil return path (23); and
a refrigerant path switching mechanism (14) configured to selectively switch a refrigerant path between a two-stage compression path along which the refrigerant flows through the lower stage-side compressor (10a) and the higher stage-side compressor (10b) in this order and a one-stage compression path along which the refrigerant flows through only one of the lower stage-side compressor and the higher stage-side compressor,
a control device (30) configured to instruct the refrigerant path switching mechanism (14) and the oil-return on-off valve (25) such that when the control device (30) instructs refrigerant path switching mechanism (14) to select the one-stage compression path, the control device (30) instructs the oil-return on-off valve (25) to be opened and the refrigerant oil from the oil separator (26) is returned to the oil equalizing path (21) through the oil return path (23) without passing through the higher stage-side compressor (10b).

2. The heat pump system (1; 2; 3) according to claim 1,
wherein when the two-stage compression path is selected and any one of the following conditions (1) to (3) is satisfied, the control device (30) is configured to switch the path of the refrigerant to the one-stage compression path.

$$\text{Condition (1): } T_W \leq T_R$$

T_W: The temperature of water entering a heat exchanger (water heat exchanger) for water and the refrigerant when the object, which is to be subjected to heat exchange, of the first heat exchanger is water
T_R: Prescribed value

$$\text{Condition (2): } (P_{HO}-P_{LI}) \leq \Delta P_{R1}$$

P_{LI}: The suction pressure of the lower stage-side compressor
P_{HO}: The discharge pressure of the higher stage-side compressor
ΔP_{R1}: Prescribed value

$$\text{Condition (3): } (P_{LO}-P_{LI}) \leq \Delta P_{R2}$$

P_{LI}: The suction pressure of the lower stage-side compressor
P_{LO}: The discharge pressure of the lower stage-side compressor
ΔP_{R2}: Prescribed value

3. The heat pump system (1; 2; 3) according to claim 1 or 2,
wherein the control device (30) is configured to control the opening/closing of the oil-return on-off valve (25) on the basis of an estimated amount of refrigerant oil of the lower stage-side compressor (10a) and an estimated amount of refrigerant oil of the higher stage-side compressor (10b).

4. A heat pump water heater comprising:
the first heat exchanger (11) of the heat pump system (1; 2; 3) according to any one of claims 1 to 3 that is a water-refrigerant heat exchanger for heating water by exchanging heat between the refrigerant and water.

Patentansprüche

1. Wärmepumpensystem (1; 2; 3), aufweisend:

einen Verdichtungsmechanismus, aufweisend einen Unterstufenseiten-Verdichter (10a) und einen Oberstufenseiten-Verdichter (10b), konfiguriert für Verdichten und Auslassen eines Kältemittels;
einen Ölabscheider (26), bereitgestellt auf einer Auslassseite des Oberstufenseiten-Verdichters (10b);
einen ersten Wärmetauscher (11), konfiguriert für Wärmeaustausch zwischen dem durch den Verdichtungsmechanismus verdichteten Kältemittel und einem dem Wärmeaustausch zu unterwerfenden Objekt;
ein Expansionsventil (12), konfiguriert für Dekomprimieren und Expandieren des vom ersten Wärmetauscher (11) ausströmenden Kältemittels;
einen zweiten Wärmetauscher (13), konfiguriert für Wärmeaustausch zwischen dem durch das Expansionsventil (12) dekomprimierten und expandierten Kältemittel und einem dem Wärmeaustausch zu unterwerfenden Objekt; und
eine Hauptrückführleitung (27), die den Ölabscheider (26) mit einer Saugseite des Oberstufenseiten-Verdichters (10b) verbindet; **dadurch gekennzeichnet, dass** das System Folgendes aufweist:

einen Ölausgleichsweg (21), der den Unterstufenseiten-Verdichter (10a) mit dem Oberstufenseiten-Verdichter (10b) verbindet, konfiguriert für Ermöglichen eines Kältemittelölstromes zwischen dem Unterstufenseiten-Verdichter (10a) und dem Oberstufenseiten-Verdichter (10b)
einen Ölrückführweg (23), der die Hauptrückführleitung (27) mit dem Ölausgleichsweg (21) verbindet;
ein Ölrücklauf-Ein-Aus-Ventil (25), das im Ölrückführweg (23) bereitgestellt ist; und
einen Kältemittelweg-Umschaltmechanismus (14), konfiguriert für selektives Umschalten eines Kältemittelweges zwischen einem zweistufigen Verdichtungsweg, entlang dem das Kältemittel durch den Unterstufenseiten-Verdichter (10a) und den Oberstufenseiten-Verdichter (10b) in dieser Reihenfolge strömt, und einem einstufigen Verdichtungsweg, entlang dem das Kältemittel nur durch einen vom Unterstufenseiten-Verdichter und Oberstufenseiten-Verdichter strömt;
eine Steuervorrichtung (30), konfiguriert für Anweisen des Kältemittelweg-Umschaltmechanismus (14) und des Ölrücklauf-Ein-Aus-Ventils (25), so dass, wenn die Steuervorrichtung (30) den Kältemittelweg-Um-

schaltmechanismus (14) zum Wählen des einstufigen Verdichtungswegs anweist, die Steuervorrichtung (30) das Ölrücklauf-Ein-Aus-Ventil (25) zum Öffnen anweist, und das Kältemittelöl vom Ölabscheider (26) durch den Ölrückführweg (23) ohne Durchströmen des Oberstufenseiten-Verdichters (10b) zurück zum Ölausgleichsweg (21) geleitet wird.

2. Wärmepumpensystem (1; 2; 3) nach Anspruch 1,
wobei, wenn der zweistufige Verdichtungsweg gewählt ist und eine der folgenden Bedingungen (1) bis (3) erfüllt ist, die Steuervorrichtung (30), konfiguriert ist für Umschalten des Wegs des Kältemittels auf den einstufigen Verdichtungsweg.

$$\text{Bedingung (1): } T_W \leq T_R$$

T_W Die Temperatur von Wasser, das in einen Wärmetauscher (Wasserwärmetauscher) für Wasser eintritt, und des Kältemittels, wenn das dem Wärmeaustausch zu unterwerfende Objekt des ersten Wasserwärmetauschers Wasser ist.
T_R: Vorgeschriebener Wert

$$\text{Bedingung (2): } (P_{HO} - P_{LI}) \leq \Delta P_{R1}$$

P_{LI}: Ansaugdruck des Unterstufenseiten-Verdichters
P_{HO}: Auslassdruck des Oberstufenseiten-Verdichters
ΔP_{R1}: Vorgeschriebener Wert

$$\text{Bedingung (3): } (P_{LO} - P_{LI}) \leq \Delta P_{R2}$$

P_{LI}: Ansaugdruck des Unterstufenseiten-Verdichters
P_{LO}: Auslassdruck des Unterstufenseiten-Verdichters
ΔP_{R2}: Vorgeschriebener Wert

3. Wärmepumpensystem (1; 2; 3) nach Anspruch 1 oder 2,
wobei die Steuervorrichtung (30) konfiguriert ist für Steuern des Öffnens/Schließens des Ölrücklauf-Ein-Aus-Ventil (25) auf Basis einer geschätzten Menge von Kältemittelöl des Unterstufenseiten-Verdichters (10a) und einer geschätzten Menge von Kältemittelöl des Oberstufenseiten-Verdichters (10b) .

4. Wärmepumpen-Wassererhitzer, aufweisend:
den ersten Wärmeaustauscher (11) des Wärmepumpensystems (1; 2; 3) nach einem der Ansprüche 1 bis 3, der ein Wasser-Kältemittel-Wärmeaustauscher zum Erwärmen von Wasser durch Austauschen von Wärme zwischen dem Kältemittel und Wasser ist.

Revendications

1. Système de pompe à chaleur (1 ; 2 ; 3) comprenant :

un mécanisme de compression qui comprend un compresseur du côté de l'étage inférieur (10a) et un compresseur du côté de l'étage supérieur (10b) configurés pour comprimer et décharger un réfrigérant ;
un séparateur d'huile (26) qui est prévu sur un côté de décharge du compresseur du côté de l'étage supérieur (10b) ;
un premier échangeur de chaleur (11) configuré pour échanger la chaleur entre le réfrigérant comprimé par le mécanisme de compression et un objet à soumettre à l'échange de chaleur ;
un détendeur (12) configuré pour décompresser et dilater le réfrigérant s'écoulant du premier échangeur de chaleur (11) ;
un second échangeur de chaleur (13) configuré pour échanger la chaleur entre le réfrigérant décompressé et dilaté par le détendeur (12) et un objet à soumettre à l'échange de chaleur ; et

un tuyau de retour principal (27) qui raccorde le séparateur d'huile (26) à un côté d'aspiration du compresseur du côté de l'étage supérieur (10b) ; **caractérisé en ce qu'**il comprend :

un circuit de compensation d'huile (21) qui raccorde le compresseur du côté de l'étage inférieur (10a) au compresseur du côté de l'étage supérieur (10b) configuré pour permettre à l'huile de réfrigérant de s'écouler entre le compresseur du côté de l'étage inférieur (10a) et le compresseur du côté de l'étage supérieur (10b) ;
un circuit de retour d'huile (23) qui raccorde le tuyau de retour principal (27) au circuit de compensation d'huile (21) ;
une valve de marche - arrêt de retour d'huile (25) qui est prévue sur le circuit de retour d'huile (23) ; et
un mécanisme de commutation de circuit de réfrigérant (14) configuré pour commuter sélectivement un circuit de réfrigérant entre un circuit de compression à deux étages le long duquel le réfrigérant s'écoule à travers le compresseur du côté de l'étage inférieur (10a) et le compresseur du côté de l'étage supérieur (10b) dans cet ordre et un circuit de compression d'un étage le long duquel le réfrigérant s'écoule à travers uniquement le compresseur du côté de l'étage inférieur ou le compresseur du côté de l'étage supérieur,
un dispositif de commande (30) configuré pour donner une instruction au mécanisme de commutation de circuit de réfrigérant (14) et à la valve de marche - arrêt de retour d'huile (25) de sorte que lorsque le dispositif de commande (30) donne l'instruction au mécanisme de commutation de circuit de réfrigérant (14) de sélectionner le circuit de compression d'un étage, le dispositif de commande (30) donne l'instruction à la valve de marche - arrêt de retour d'huile (25) de s'ouvrir et l'huile de réfrigérant provenant du séparateur d'huile (26) revient dans le circuit de compensation d'huile (21) en passant par le circuit de retour d'huile (23) sans passer par le compresseur du côté de l'étage supérieur (10b).

2. Système de pompe à chaleur (1 ; 2 ; 3) selon la revendication 1,
dans lequel lorsque le circuit de compression à deux étages est sélectionné et que l'une quelconque des conditions suivantes (1) à (3) est satisfaite, le dispositif de commande (30) est configuré pour faire passer le circuit du réfrigérant dans le circuit de compression d'un étage ;

$$\text{condition (1)} : T_W \leq T_R$$

T_W : la température de l'eau entrant dans l'échangeur de chaleur (échangeur de chaleur à eau) pour l'eau et le réfrigérant lorsque l'objet, qui doit être soumis à l'échange de chaleur, du premier échangeur de chaleur est l'eau
T_R : valeur prescrite

$$\text{condition (2)} : (P_{HO} - P_{LI}) \leq \Delta P_{R1}$$

P_{LI} : la pression d'aspiration du compresseur du côté de l'étage inférieur
P_{HO} : la pression de décharge du compresseur du côté de l'étage supérieur
ΔP_{R1} : valeur prescrite

$$\text{condition (3)} : (P_{LO} - P_{LI}) \leq \Delta P_{R2}$$

P_{LI} : la pression d'aspiration du compresseur du côté de l'étage inférieur
P_{LO} : la pression de décharge du compresseur du côté de l'étage inférieur
ΔP_{R2} : valeur prescrite.

3. Système de pompe à chaleur (1 ; 2 ; 3) selon la revendication 1 ou 2,
dans lequel le dispositif de commande (30) est configuré pour commander l'ouverture / fermeture de la valve de marche - arrêt de retour d'huile (25) sur la base d'une quantité estimée d'huile de réfrigérant du compresseur du côté de l'étage inférieur (10a) et d'une quantité estimée d'huile de réfrigérant du compresseur du côté de l'étage supérieur (10b).

4. Chauffe-eau à pompe à chaleur comprenant :
le premier échangeur de chaleur (11) du système de pompe à chaleur (1 ; 2 ; 3) selon l'une quelconque des reven-

dications 1 à 3 qui est un échangeur de chaleur à réfrigérant par eau pour chauffer l'eau en échangeant la chaleur entre le réfrigérant et l'eau.

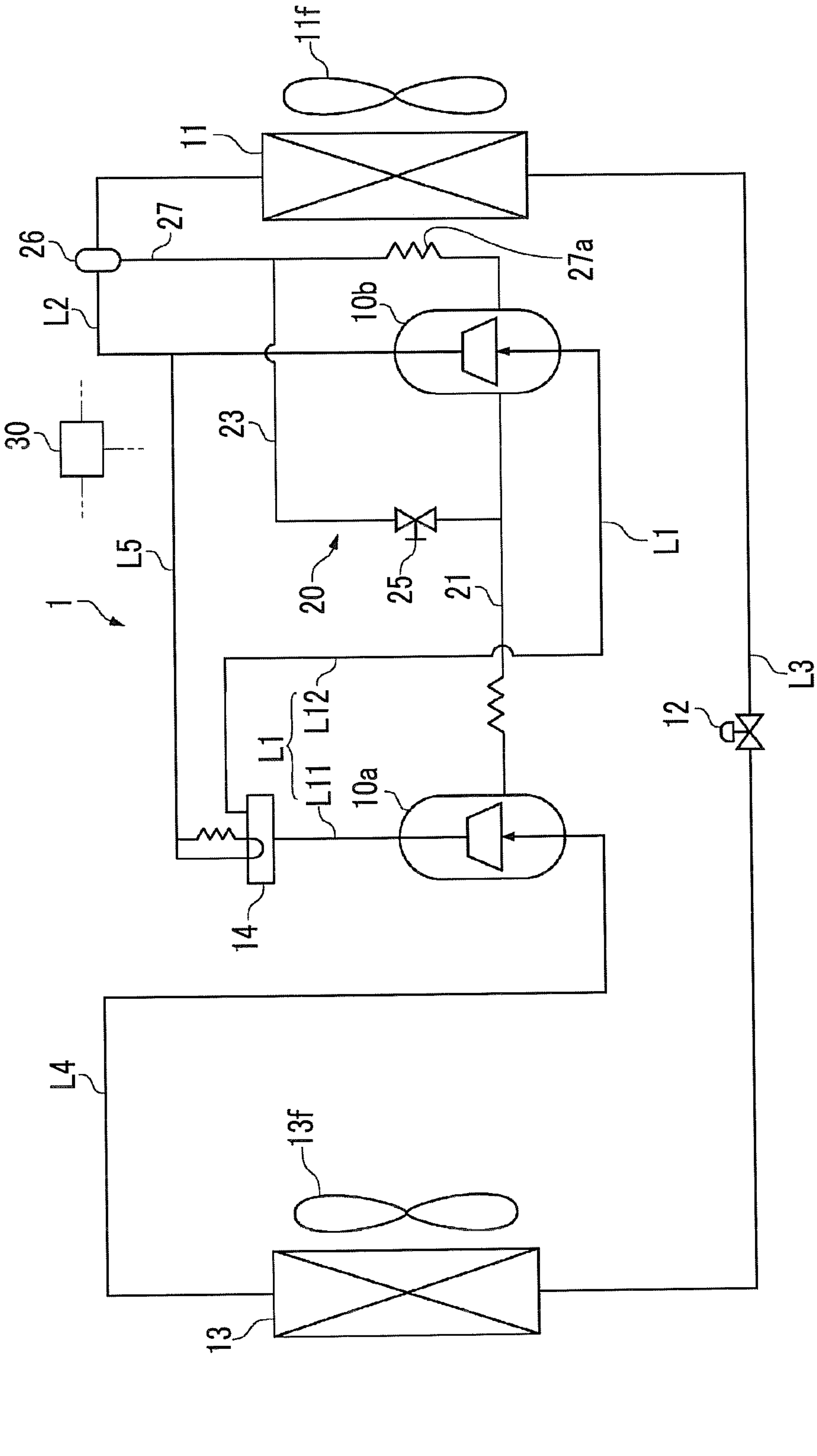

1
11f
11
26
27
27a
L2
10b
30
23
L5
L1
20
25
21
L12
L11
10a
14
12
L3
L4
13f
13

FIG. 1

FIG. 2

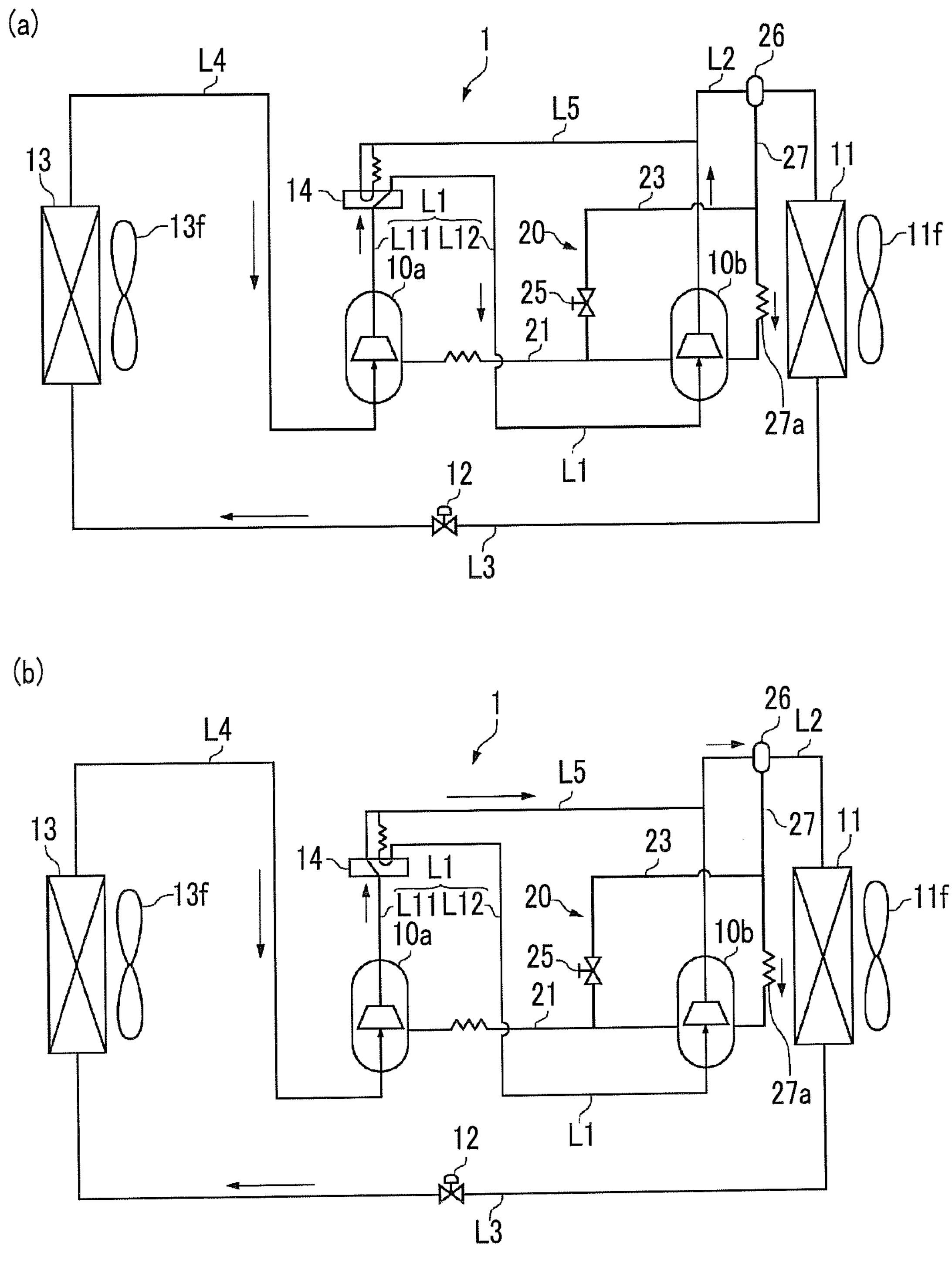

(a)
1
L4
L2
26
L5
13
14
L1
L11 L12
23
27
11
13f
20
10a
25
10b
11f
21
27a
12
L1
L3
(b)
1
26
L2
L4
L5
13
14
L1
L11 L12
23
27
11
13f
20
10a
25
10b
11f
21
27a
12
L1
L3

FIG. 3

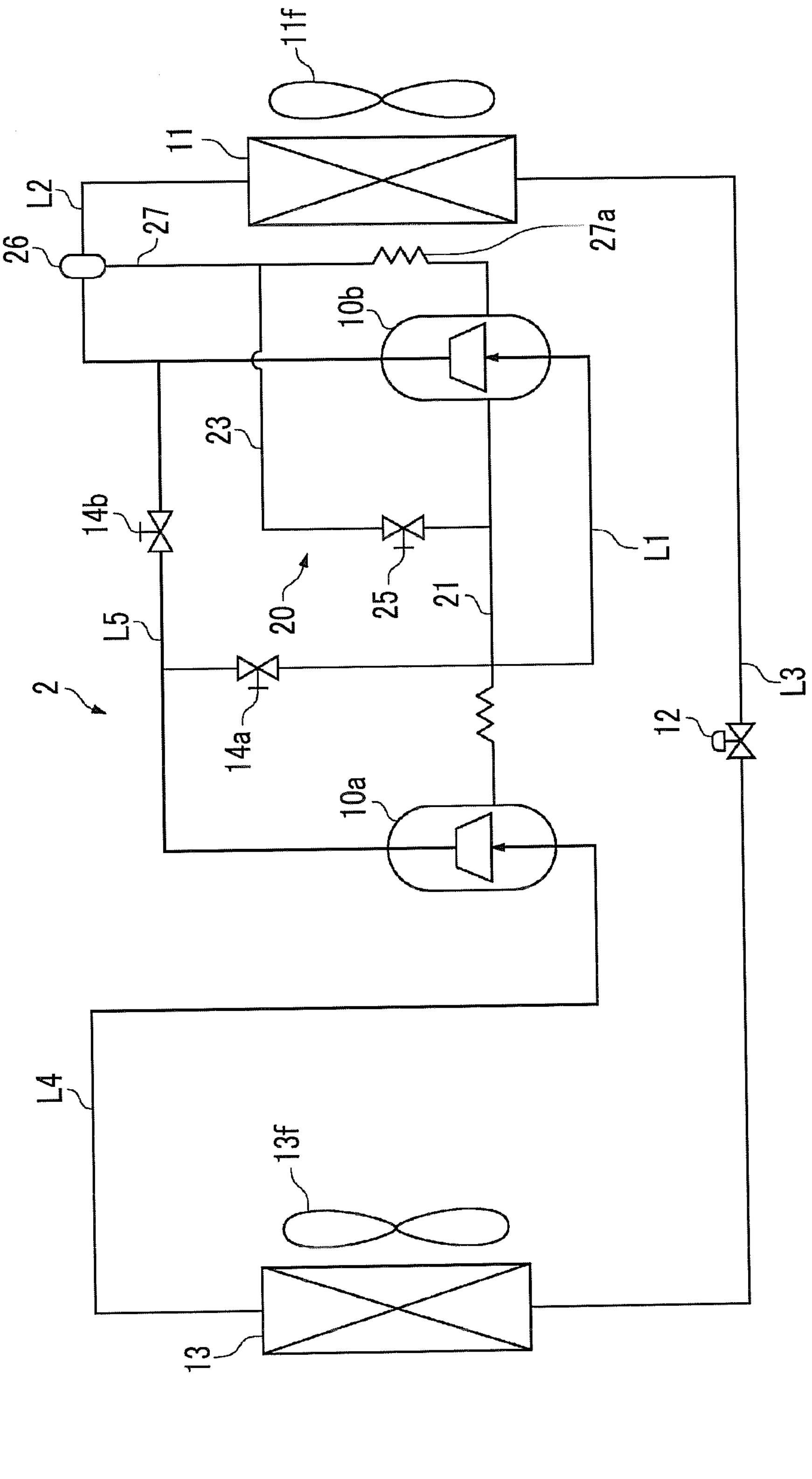

11f
11
L2
26
27
27a
10b
23
14b
L1
20
25
21
L5
2
14a
10a
12
L3
L4
13f
13

FIG. 4

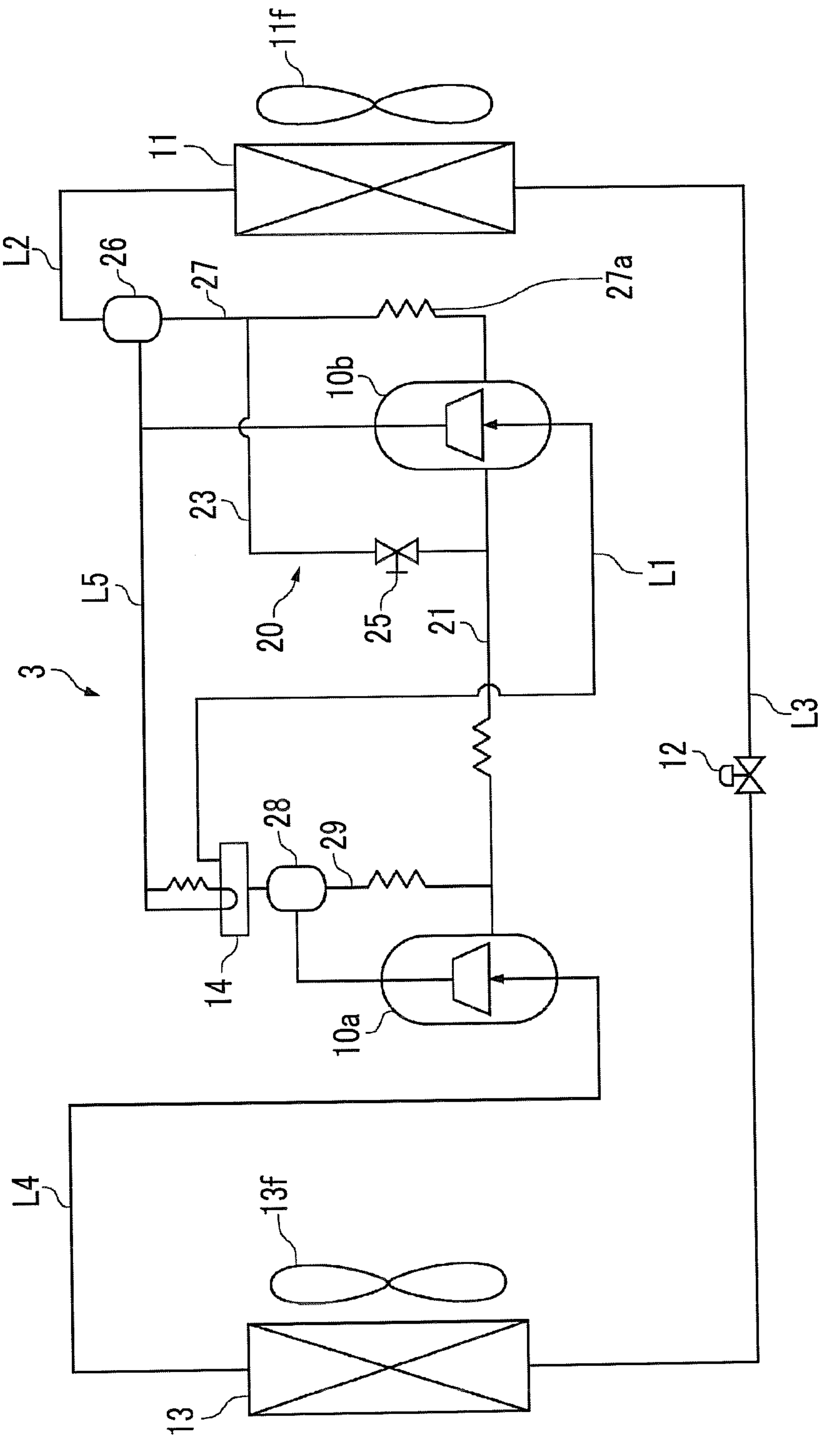

3
11f
11
L2
26
27
27a
10b
23
L5
20
25
21
L1
L3
12
28
29
14
10a
L4
13f
13

FIG. 5

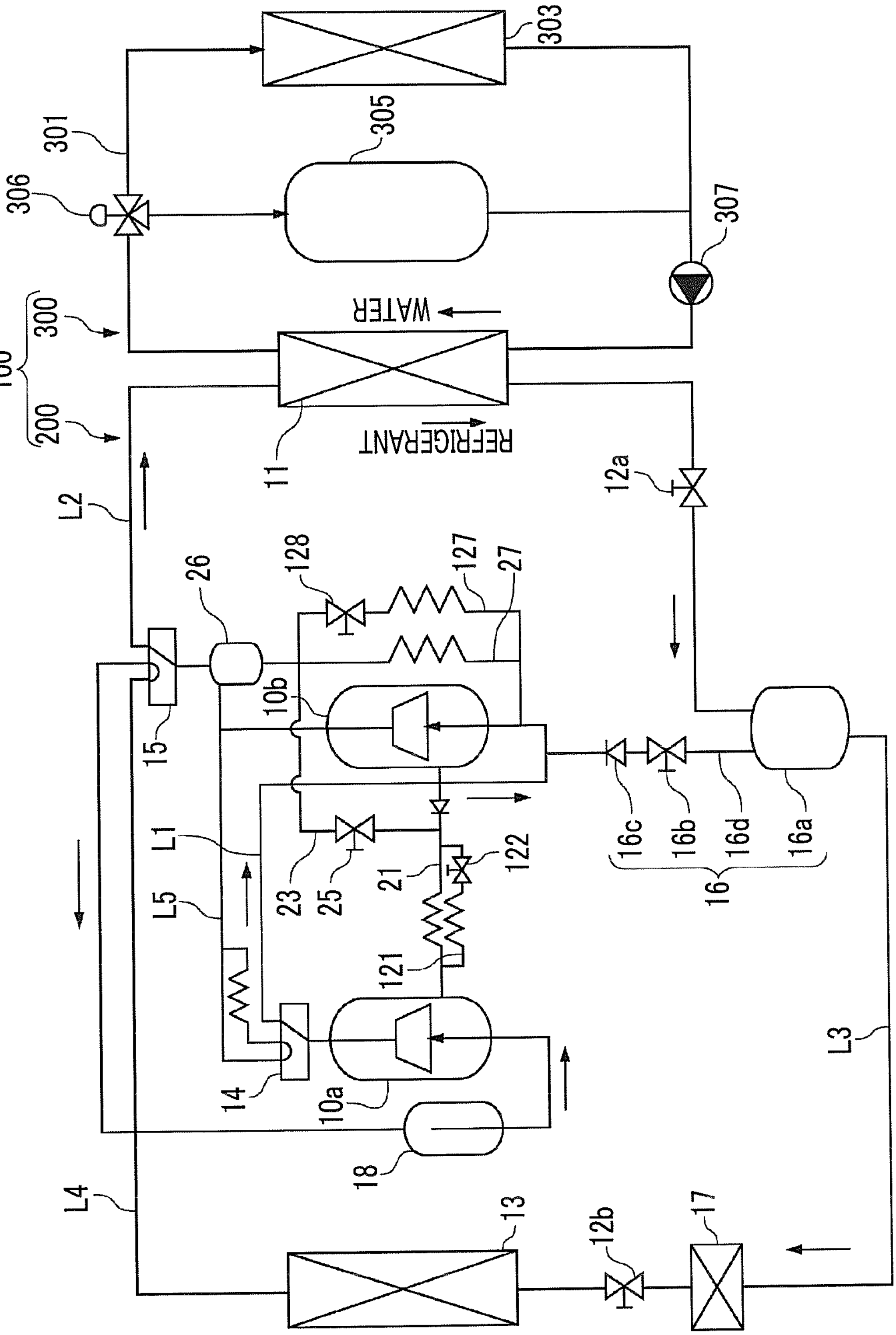

100
200
300
301
303
305
306
307
WATER
REFRIGERANT
11
12a
12b
13
14
15
16
16a
16b
16c
16d
17
18
21
23
25
26
27
10a
10b
121
122
127
128
L1
L2
L3
L4
L5

FIG. 6

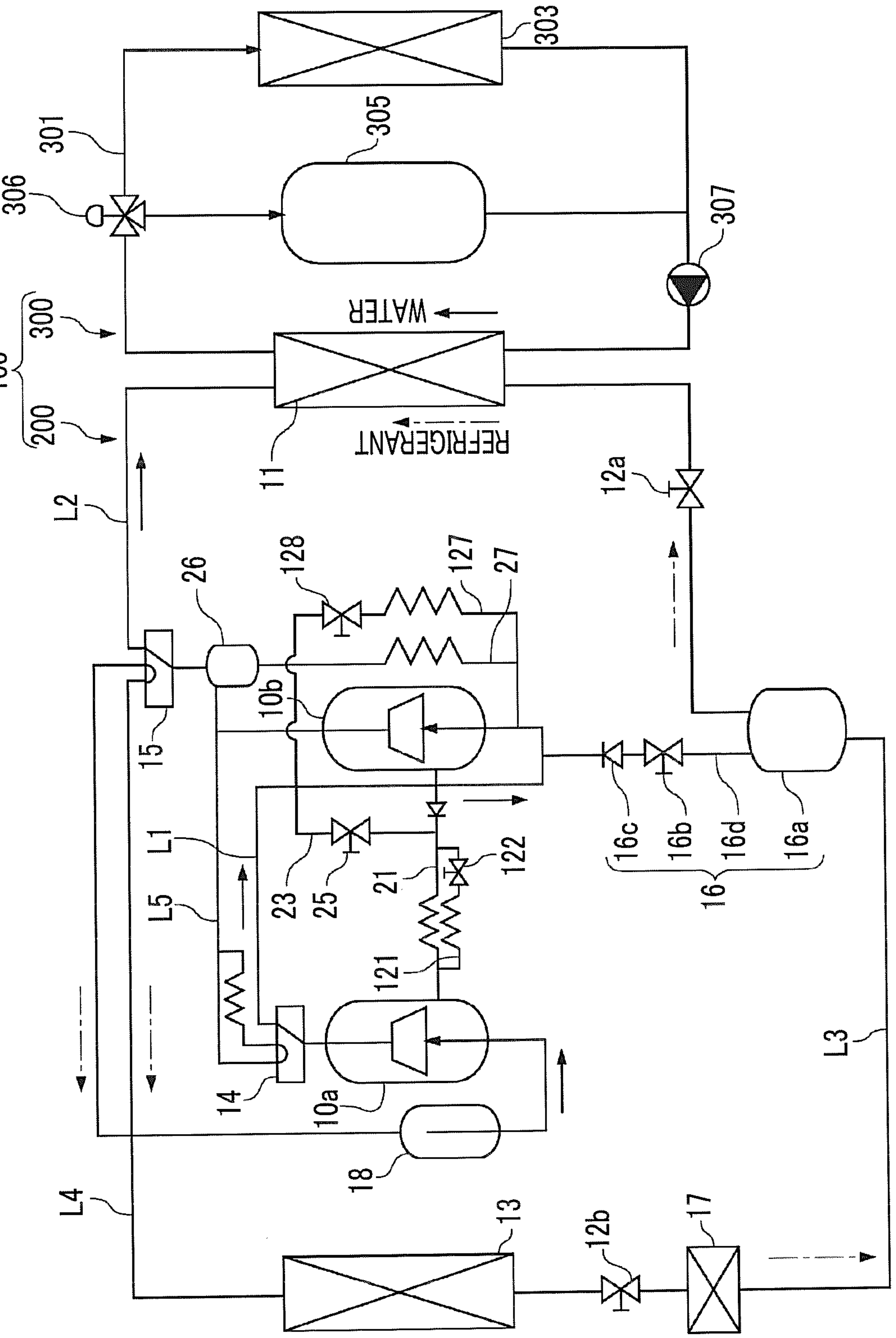

100
200
300
301
303
305
306
307
WATER
REFRIGERANT
11
12a
L2
26
128
127
27
10b
15
L1
L5
23
25
21
122
121
16c
16b
16d
16a
16
14
10a
18
L4
13
12b
17
L3

FIG. 7

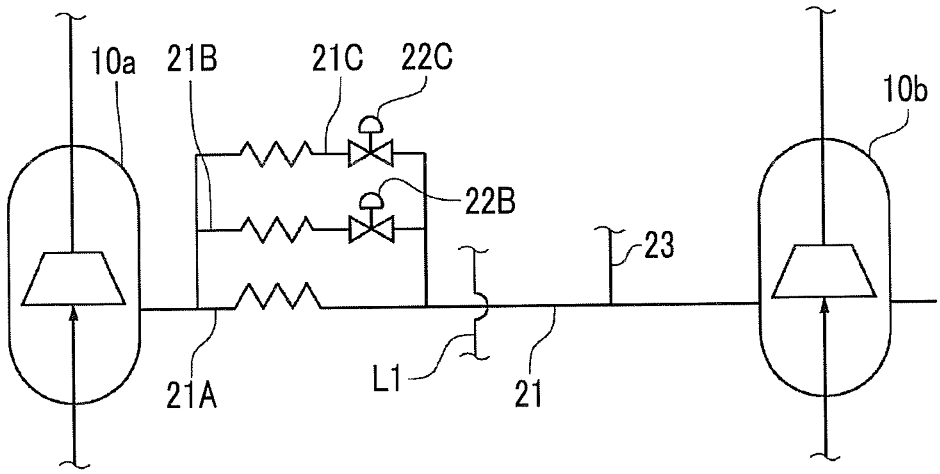


FIG. 8

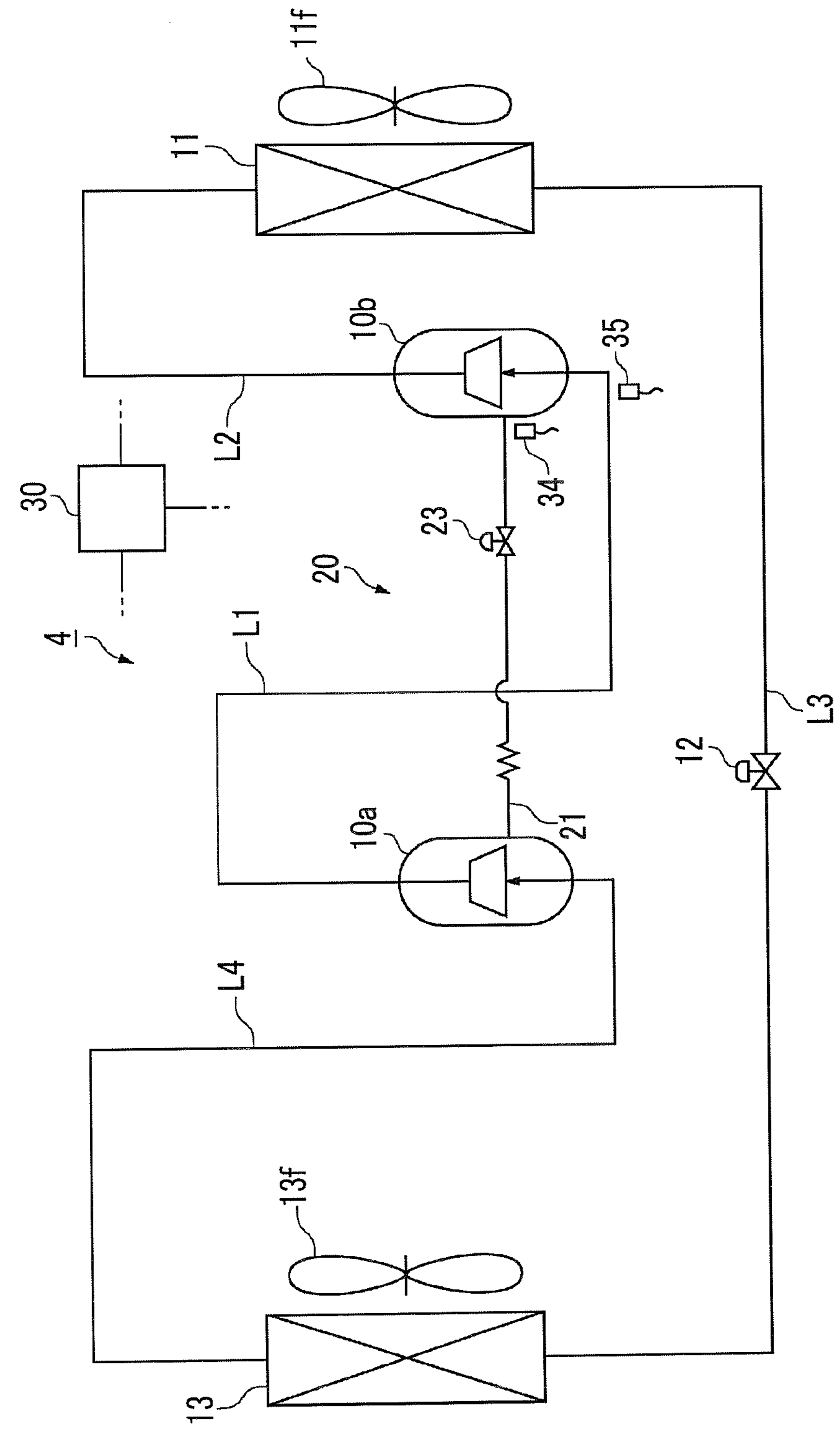
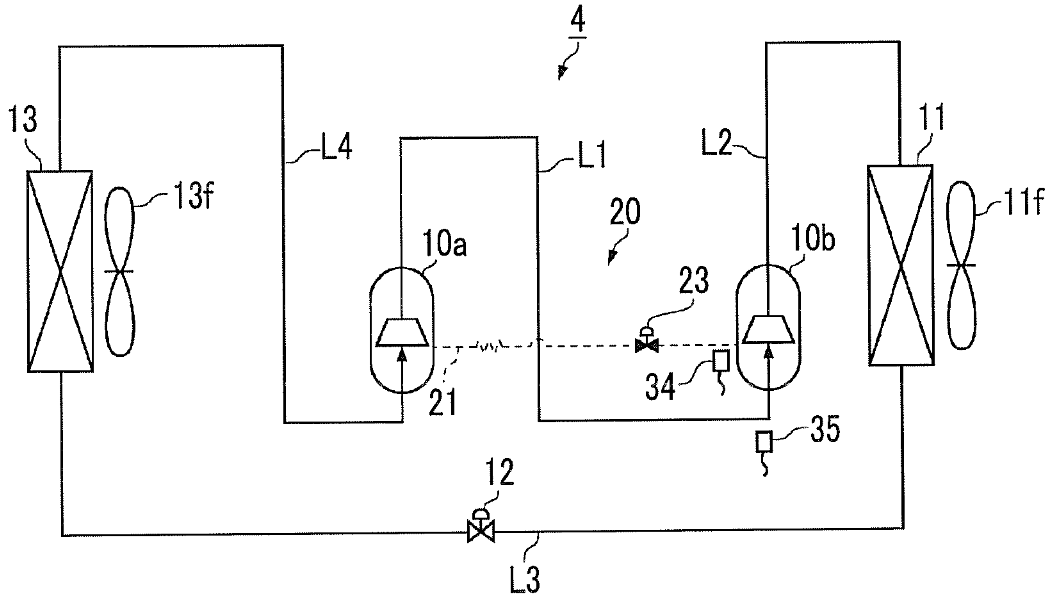


FIG. 9

(a)


4
13
L4
L1
L2
11
13f
11f
20
10a
10b
23
21
34
35
12
L3

(b)

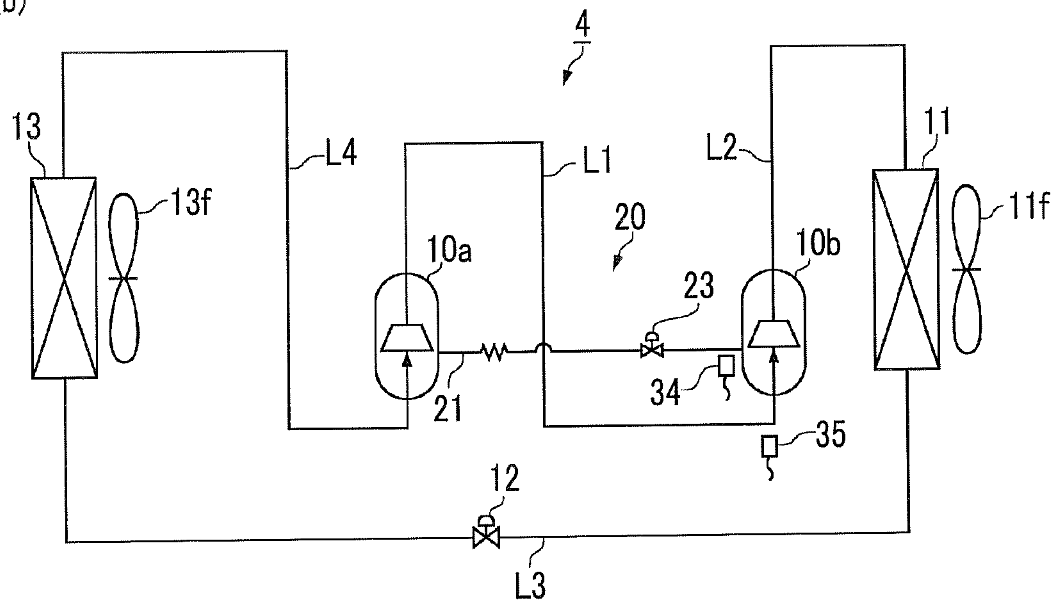

4
13
L4
L1
L2
11
13f
11f
20
10a
10b
23
21
34
35
12
L3

FIG. 10

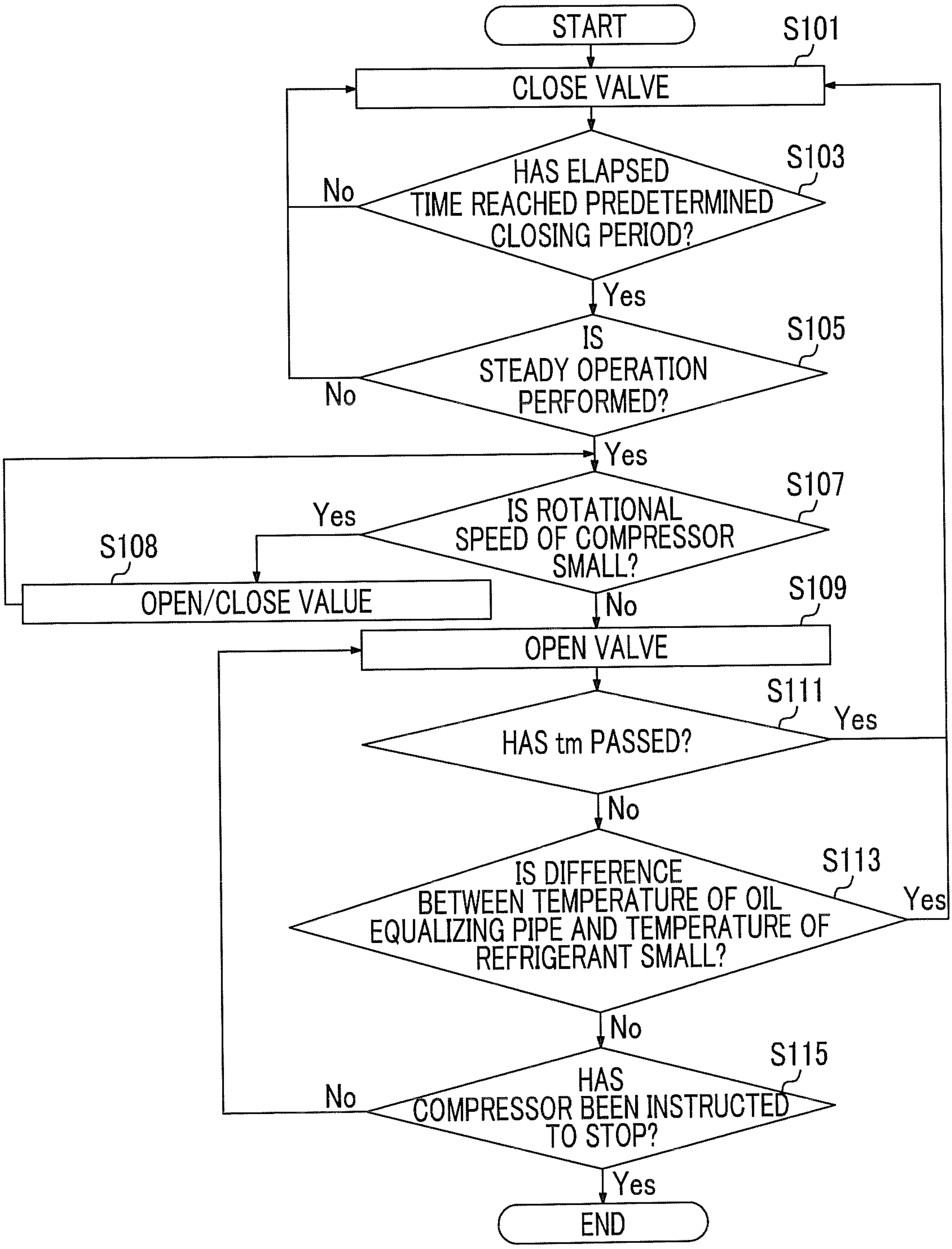

START
S101
CLOSE VALVE
S103
HAS ELAPSED TIME REACHED PREDETERMINED CLOSING PERIOD?
No
Yes
S105
IS STEADY OPERATION PERFORMED?
No
Yes
S107
IS ROTATIONAL SPEED OF COMPRESSOR SMALL?
Yes
S108
OPEN/CLOSE VALUE
No
S109
OPEN VALVE
S111
HAS tm PASSED?
Yes
No
S113
IS DIFFERENCE BETWEEN TEMPERATURE OF OIL EQUALIZING PIPE AND TEMPERATURE OF REFRIGERANT SMALL?
Yes
No
S115
HAS COMPRESSOR BEEN INSTRUCTED TO STOP?
No
Yes
END

FIG. 11

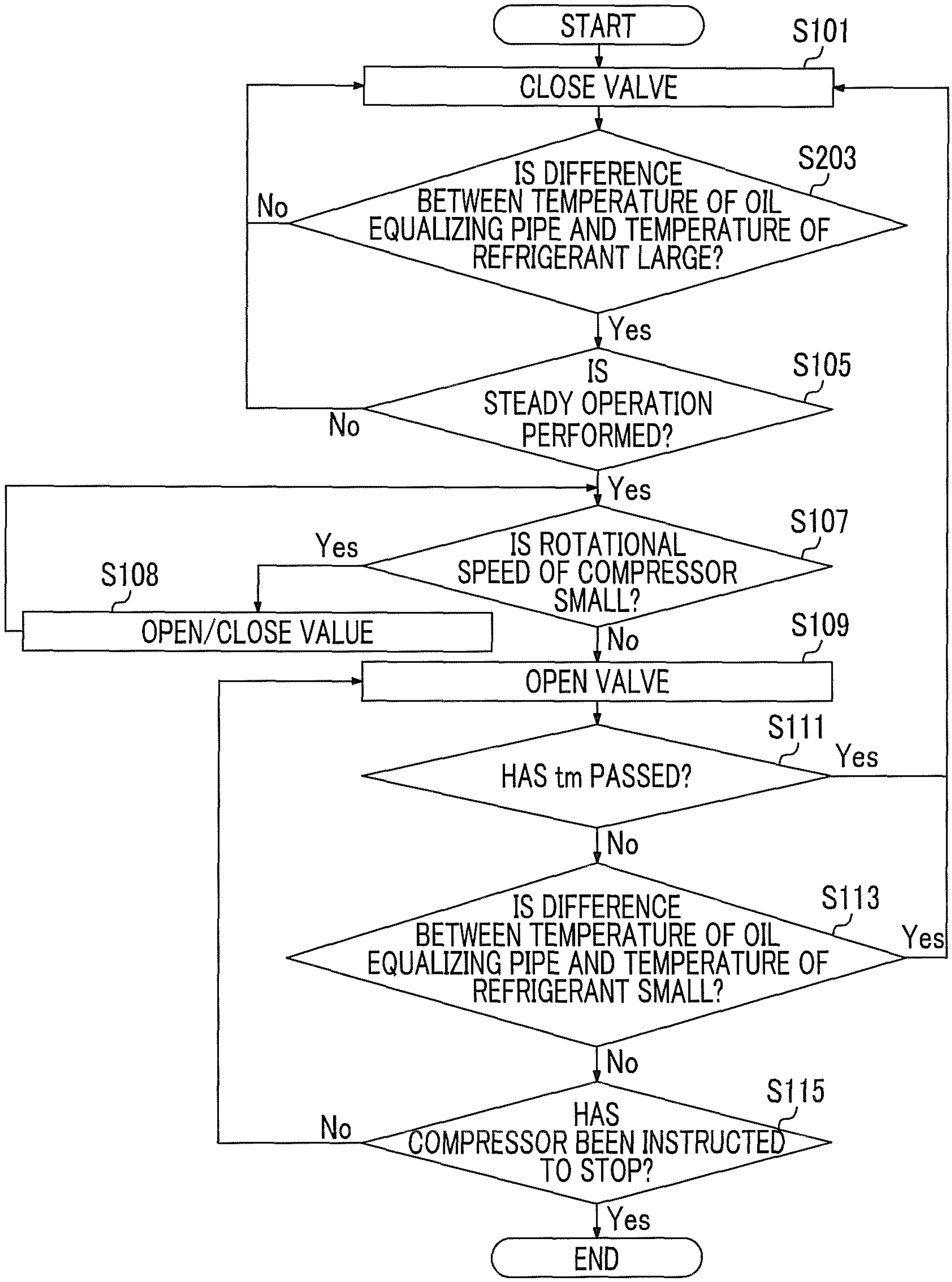

START
S101
CLOSE VALVE
S203
IS DIFFERENCE BETWEEN TEMPERATURE OF OIL EQUALIZING PIPE AND TEMPERATURE OF REFRIGERANT LARGE?
No
Yes
S105
IS STEADY OPERATION PERFORMED?
No
Yes
S107
IS ROTATIONAL SPEED OF COMPRESSOR SMALL?
Yes
S108
OPEN/CLOSE VALUE
No
S109
OPEN VALVE
S111
HAS tm PASSED?
Yes
No
S113
IS DIFFERENCE BETWEEN TEMPERATURE OF OIL EQUALIZING PIPE AND TEMPERATURE OF REFRIGERANT SMALL?
Yes
No
S115
HAS COMPRESSOR BEEN INSTRUCTED TO STOP?
No
Yes
END

FIG. 12

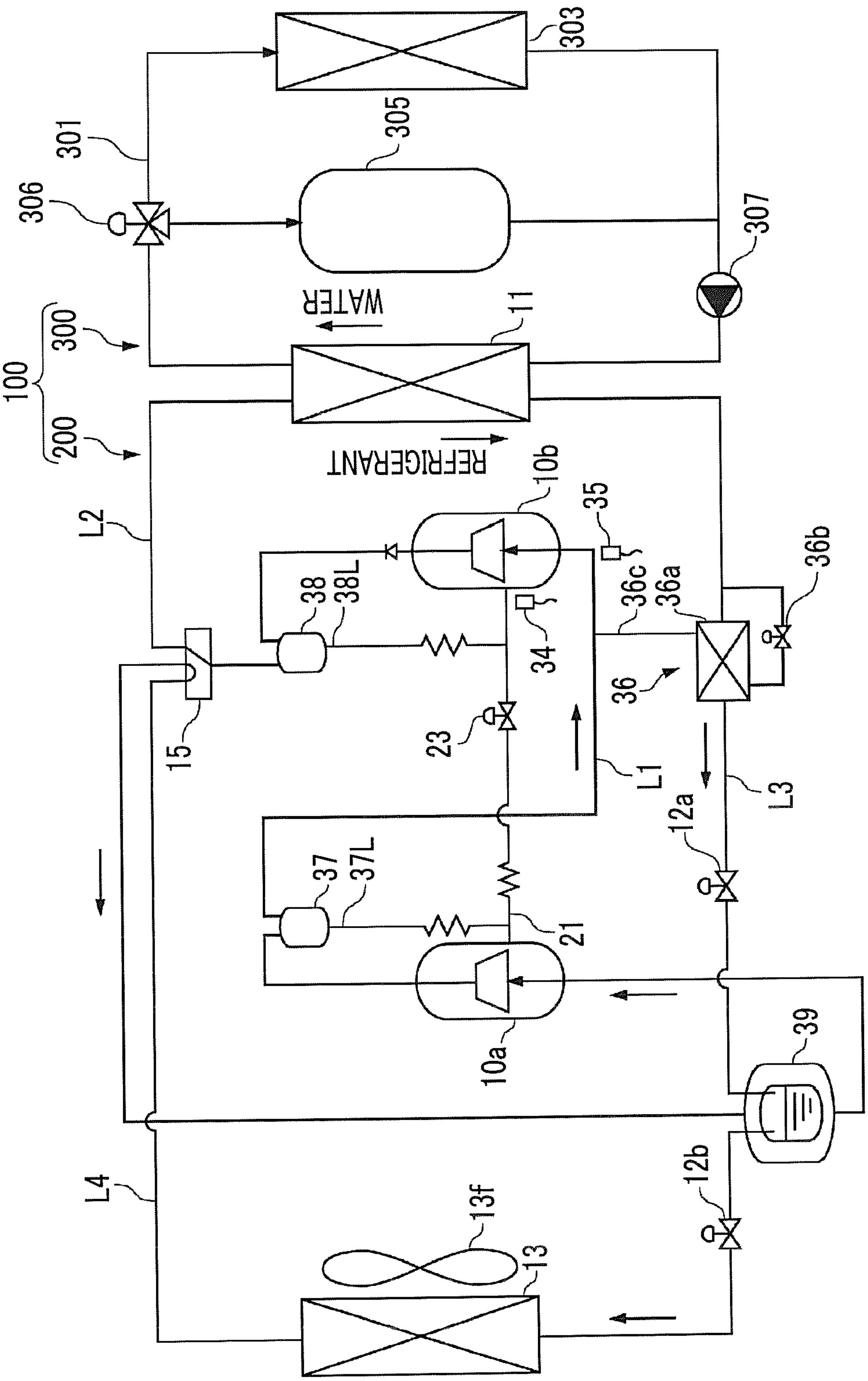
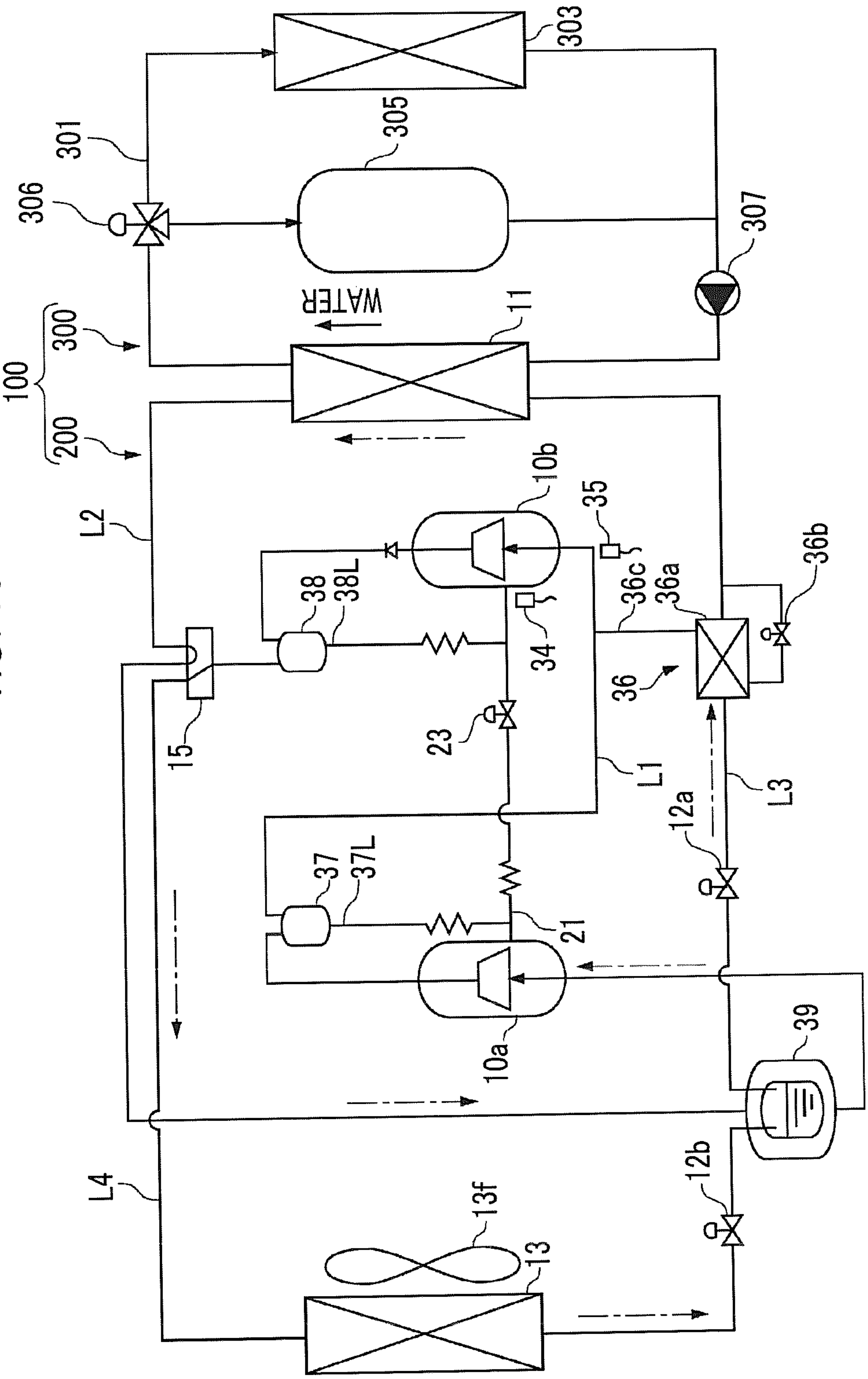

100
200
300
301
303
305
306
307
11
WATER
REFRIGERANT
10a
10b
12a
12b
13
13f
15
21
23
34
35
36
36a
36b
36c
37
37L
38
38L
39
L1
L2
L3
L4

FIG. 13


100
200
300
301
303
305
306
307
11
WATER
L1
L2
L3
L4
10a
10b
12a
12b
13
13f
15
21
23
34
35
36
36a
36b
36c
37
37L
38
38L
39

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 5093552 A **[0004]**
- JP 6002966 A **[0004]**
- JP 2009168330 A **[0004]**
- JP 2001349629 A **[0004]**
- JP 2013139902 A **[0004]**