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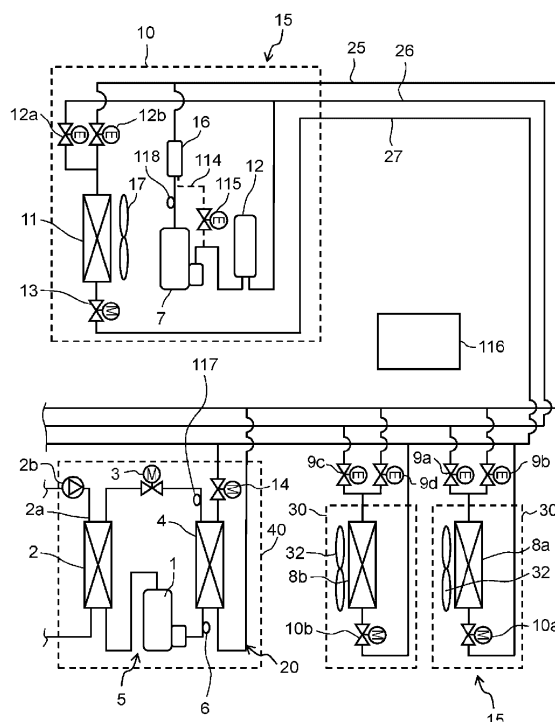
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(54) **HEAT PUMP DEVICE**

(57) A heat pump device of the present invention includes a first refrigeration circuit, a second refrigeration circuit, and a controller. The first refrigeration circuit includes a first compressor, a first condenser, a first throttle tool, and a first evaporator connected in a ring and lets a first refrigerant circulate. The second refrigeration circuit lets a second refrigerant circulate and exchanges heat with the first refrigeration circuit via the first evaporator. The controller has a first refrigeration circuit low-pressure suppression mode in which the controller reduces a flow rate of the second refrigerant circulating in the second refrigeration circuit and reduces an opening level of the first throttle such that pressure at a low pressure side of the first refrigeration circuit falls to or below a predetermined value. This configuration provides a heat pump device that prevents a rise in pressure at a low pressure side of a refrigeration cycle for hot-water supply.

FIG. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a technique for preventing a rise in pressure at a low pressure side of a heat pump device.

BACKGROUND ART

[0002] A conventionally known heat pump device of this type includes two refrigeration circuits, i.e. a refrigeration cycle for air conditioning and a refrigeration cycle for hot-water supply.

[0003] The refrigeration cycle for air conditioning includes an air-conditioning compressor, an outdoor heat exchanger, an outdoor heat-exchanger open-close unit, an outdoor heat-exchanger throttle, an indoor heat exchanger, an indoor heat-exchanger open-close unit, and an indoor heat-exchanger throttle that are connected in series. The refrigeration cycle has a refrigerant-refrigerant heat exchanger and a hot-water heat source throttle that are connected in series. The refrigerant-refrigerant heat exchanger and the hot-water heat source throttle are connected in parallel with the indoor heat exchanger, the indoor heat-exchanger open-close unit, and the indoor heat-exchanger throttle. An air conditioning refrigerant circulates through the refrigeration cycle for air conditioning.

[0004] The refrigeration cycle for hot-water supply includes a hot-water supply compressor, a heating medium-refrigerant heat exchanger, a hot-water supply throttle, and a refrigerant-refrigerant heat exchanger that are connected in series. A refrigerant for hot-water supply circulates through the refrigeration cycle for hot-water supply.

[0005] The refrigeration cycle for air conditioning is connected with the refrigeration cycle for hot-water supply such that the refrigerant-refrigerant heat exchanger exchanges heat between the air conditioning refrigerant and the hot-water supply refrigerant. This configuration enables cooling or heating on the air conditioning refrigeration cycle concurrently with heating of a heating medium for hot-water supply on the hot-water supply refrigeration cycle (e.g., see PTL 1).

[0006] Unfortunately, if the air conditioning refrigeration cycle in the conventional configuration described above is handling a high heating load or is in cooling operation under high outdoor temperature conditions, condensing temperature in the air conditioning refrigeration cycle goes up. As a result, evaporating temperature at the refrigerant-refrigerant heat exchanger in the hot-water supply refrigeration cycle rises and pressure at a low pressure side of the hot-water supply refrigeration cycle increases. If the refrigerant used in the hot-water supply refrigeration cycle is carbon dioxide, the refrigerant turns into a supercritical refrigerant when the pressure at the low pressure side reaches a critical point or

above. The supercritical refrigerant sucked into the hot-water supply compressor disadvantageously reduces oil sealing performance in the hot-water supply compressor and deteriorates the reliability of the compressor.

Citation List

Patent Literature

[0007] PTL 1: WO 2009/098751 A

SUMMARY OF THE INVENTION

[0008] In view of the problems described above, an object of the present invention is to provide a heat pump device that prevents a rise in pressure at a low pressure side of a refrigeration cycle for hot-water supply.

[0009] To accomplish the object described above, a heat pump device of the present invention includes a first refrigeration circuit, a second refrigeration circuit, and a controller. The first refrigeration circuit includes a first compressor, a first condenser, a first throttle, and a first evaporator connected in a ring and lets a first refrigerant circulate. The second refrigeration circuit lets a second refrigerant circulate and exchanges heat with the first refrigeration circuit via the first evaporator. The controller has a first refrigeration circuit low-pressure suppression mode in which the controller reduces a flow rate of the second refrigerant circulating in the second refrigeration circuit and reduces an opening level of the first throttle such that pressure at a low pressure side of the first refrigeration circuit falls to or below a predetermined value.

[0010] In this mode, in response to a decrease in the flow rate of the second refrigerant, refrigerant density at the low pressure side of the first refrigeration circuit decreases and the rate of the first refrigerant flowing in the first refrigeration circuit decreases. This in turn reduces the quantity of heat transferred at the evaporator from the second refrigerant to the first refrigerant. Consequently, the quantity of evaporation of the first refrigerant decreases and the pressure at the low pressure side of the first refrigeration circuit decreases.

[0011] The heat pump device of the present invention can reduce the pressure at the low pressure side of the first refrigeration circuit and ensure that the first refrigerant at or below its critical pressure is sucked into the first compressor. This configuration provides an improvement in the reliability of the first compressor.

[0012] A decrease in the pressure at the low pressure side of the first refrigeration circuit increases the difference in enthalpy of the first refrigerant at the evaporator. This allows the heat pump device to produce high heating performance even when the refrigeration circuit is in an initial operating state.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

FIG. 1 is a diagram of refrigeration cycles according to an exemplary embodiment of the present invention.

FIG. 2 is a diagram for illustrating an action of the refrigeration cycle.

FIG. 3 is a diagram for illustrating an action of the same.

FIG. 4 is a diagram for illustrating an action of the same.

FIG. 5 is a diagram for illustrating an action of the same.

FIG. 6 is a control flow diagram.

FIG. 7 is a control flow diagram according to a variation of the exemplary embodiment.

FIG. 8 is a control flow diagram according to another variation of the exemplary embodiment.

DESCRIPTION OF EMBODIMENT

[0014] A heat pump device according to a first aspect of the present invention includes a first refrigeration circuit, a second refrigeration circuit, and a controller. The first refrigeration circuit includes a first compressor, a first condenser, first throttle, and a first evaporator connected in a ring and lets a first refrigerant circulate. The second refrigeration circuit lets a second refrigerant circulate and exchanges heat with the first refrigeration circuit via the first evaporator. The controller has a first refrigeration circuit low-pressure suppression mode in which the controller reduces a flow rate of the second refrigerant circulating in the second refrigeration circuit and reduces an opening level of the first throttle such that pressure at a low pressure side of the first refrigeration circuit falls to or below a predetermined value.

[0015] According to the first aspect of the present invention, in response to a decrease in the flow rate of the second refrigerant, refrigerant density at the low pressure side of the first refrigeration circuit decreases and the rate of the first refrigerant flowing in the first refrigeration circuit decreases. This in turn reduces the quantity of heat transferred at the evaporator from the second refrigerant to the first refrigerant. This configuration can reduce the quantity of evaporation of the first refrigerant and reduce the pressure at the low pressure side of the first refrigeration circuit.

[0016] In the heat pump device according to a second aspect of the present invention, the second refrigeration circuit includes: an outdoor unit having a second compressor, an outdoor heat exchanger, and a second throttle; an indoor unit having an indoor heat exchanger; and a circulation circuit letting the second refrigerant flow through the first evaporator. The circulation circuit includes a third throttle to regulate a circulating quantity of the second refrigerant. In the first refrigeration circuit low-pressure suppression mode, the controller reduces an opening level of the third throttle and reduces the opening level of the first throttle such that the pressure at the low pressure side of the first refrigeration circuit falls to or

below a predetermined value.

[0017] According to the second aspect of the present invention, in response to a decrease in the flow rate of the second refrigerant, refrigerant density at the low pressure side of the first refrigeration circuit decreases and the rate of the first refrigerant flowing in the first refrigeration circuit decreases. This in turn reduces the quantity of heat transferred at the evaporator from the second refrigerant to the first refrigerant. This configuration can reduce the quantity of evaporation of the first refrigerant and reduce the pressure at the low pressure side of the first refrigeration circuit.

[0018] The heat pump device according to a third aspect of the present invention includes a pressure detector to detect pressure at a low pressure side of the first compressor. The controller enters the first refrigeration circuit low-pressure suppression mode when the low-pressure side pressure falls to or below a predetermined value.

[0019] According to the third aspect of the present invention, the pressure detector detects pressure at the low pressure side of the first compressor, and the controller enters the first refrigeration circuit low-pressure suppression mode when the low-pressure side pressure falls to or below the predetermined value. Thus, the controller can properly execute the first refrigeration circuit low-pressure suppression mode.

[0020] Hereinafter, an exemplary embodiment of the present invention will be described with reference to the drawings. This exemplary embodiment should not be construed to limit the scope of the present invention.

[0021] FIG. 1 is a diagram of refrigeration cycles used in a heat pump device according to the exemplary embodiment of the present invention.

[0022] The heat pump device illustrated in FIG. 1 includes two refrigeration circuits, i.e. first refrigeration circuit 5 acting as a refrigeration cycle for hot-water supply and second refrigeration circuit 15 acting as a refrigeration cycle for air conditioning.

[0023] The first refrigeration circuit configures heat generating unit 40. A refrigerant for hot-water supply (a first refrigerant) circulates through the first circuit. The second refrigeration circuit includes outdoor unit 10, indoor units 30, and circulation circuit 20 running across first refrigeration circuit 5. An air conditioning refrigerant (a second refrigerant) circulates through the second circuit. As described later, circulation circuit 20 connects gas pipe 25 with liquid pipe 27 via evaporator 4 (a first evaporator) of heat generating unit 40.

[0024] Examples of the refrigerants for hot-water supply and air conditioning include R22, R410A, R407C, R32, R134a and other chlorofluorocarbon refrigerants, as well as carbon dioxide (CO₂) and other natural refrigerants. Preferably, the refrigerant for hot-water supply, in particular, should be R407C, R134a, or carbon dioxide (CO₂), which are widely used for high temperature applications.

[0025] In this exemplary embodiment, one outdoor unit 10 is connected with two indoor units 30 and one heat

generating unit 40. The refrigeration cycle configuration is not limited to the example illustrated in FIG. 1. One or at least three indoor units 30 and two or more heat generating units 40 may be connected in parallel with two or more outdoor units 10, for example. In this exemplary embodiment, the heat pump device includes controller 116 to control first and second refrigeration circuits 5 and 15.

[0026] Heat generating unit 40 forming the first refrigeration circuit includes hot-water supply compressor 1 (a first compressor), condenser 2 (a first condenser), throttle 3 (first throttle), and evaporator 4 (the first evaporator) that are connected in series by refrigerant piping to have the hot-water supply refrigerant circulate. Condenser 2 exchanges heat between the hot-water supply refrigerant and a heating medium primarily composed of water. Evaporator 4 exchanges heat between the air conditioning refrigerant supplied from gas pipe 25 described later and the hot-water supply refrigerant. Evaporator 4 is a plate heat exchanger.

[0027] First refrigeration circuit low-pressure detector (pressure detector) 6 is disposed between hot-water supply compressor 1 and evaporator 4 to detect a pressure of the hot-water supply refrigerant sucked into hot-water supply compressor 1.

[0028] Condenser 2 (the first condenser) is connected with pipe 2a for the heating medium that exchanges heat with the hot-water supply refrigerant. Circulation pump 2b is connected to pipe 2a.

[0029] The heating medium is generally tap water. In cold climate areas, the heating medium may be an anti-freeze solution composed of water and a predetermined quantity of ethylene glycol or alcohol dissolved in the water.

[0030] The heating medium is heated at condenser 2 to a temperature of 70°C to 90°C and stored in a hot water tank (not illustrated). If the heating medium is water to drink, the hot water tank serves to directly supply hot water. If the heating medium is an antifreeze solution or something unfit for drinking, the heating medium is fed to a radiator or any other device that is installed in a room to heat the room, or the heating medium in the hot water tank may be used to transfer heat to drinking water that is supplied as hot water.

[0031] The second refrigeration circuit will now be described.

[0032] Outdoor unit 10 is connected with indoor units 30 via gas pipe 25, suction pipe 26, and liquid pipe 27. Gas pipe 25 carries the high-temperature, high-pressure gaseous air conditioning refrigerant, suction pipe 26 carries the low-pressure air conditioning refrigerant, and liquid pipe 27 carries the high-pressure liquid air conditioning refrigerant. With reference to FIG. 1, two indoor units 30 are connected in parallel to the three pipes. Meanwhile, outdoor unit 10 is connected with heat generating unit 40 via the two pipes, i.e. gas pipe 25 and liquid pipe 27, although vents of heat generating unit 40 are connected in parallel to the pipes as is the case with indoor

units 30.

[0033] Outdoor unit 10 includes air-conditioning compressor 7 (a second compressor), outdoor heat exchanger 11, outdoor gas pipe open-close unit 12b and outdoor suction pipe open-close unit 12a that are disposed at first inlet of outdoor heat exchanger 11, and outdoor heat-exchanger throttle (second throttle) 13 disposed at second inlet of outdoor heat exchanger 11.

[0034] Air-conditioning compressor 7 compresses the air conditioning refrigerant. Outdoor heat exchanger 11 exchanges heat between air sent by outdoor air-blowing fan 17 and the air conditioning refrigerant. Outdoor heat exchanger 11 is generally a finned tube heat exchanger or a micro tube heat exchanger. Outdoor gas pipe open-close unit 12b regulates a flow rate of the air conditioning refrigerant carried in gas pipe 25. Outdoor suction pipe open-close unit 12a regulates a flow rate of the air conditioning refrigerant carried in suction pipe 26. Outdoor heat-exchanger throttle 13 adjusts a flow rate of the air conditioning refrigerant fed to outdoor heat exchanger 11.

[0035] The outdoor unit includes accumulator 12 connected at a suction side of air-conditioning compressor 7 to feed the gaseous refrigerant into air-conditioning compressor 7. Oil separator 16 is connected at a discharge side of air-conditioning compressor 7 to separate refrigeration oil contained in the discharged gaseous air conditioning refrigerant. The outdoor unit returns refrigeration oil separated at oil separator 16 to air-conditioning compressor 7 through oil return pipe 114. Oil return pipe open-close valve 115 opens or closes to regulate the flow of oil passing through oil return pipe 114.

[0036] Indoor units 30 include indoor heat exchangers 8a, 8b, indoor gas pipe open-close units 9b, 9d and indoor suction pipe open-close units 9a, 9c that are disposed at first inlets of indoor heat exchangers 8a, 8b, and indoor heat-exchanger throttles 10a, 10b that are disposed at second inlets of indoor heat exchangers 8a, 8b. Indoor heat exchangers 8a, 8b each exchange heat between air sent by indoor air-blowing fan 32 and the air conditioning refrigerant. Indoor heat exchangers 8a, 8b are generally finned or micro tube heat exchangers. Indoor gas pipe open-close units 9b, 9d regulate enabling or disabling of flow of the air conditioning refrigerant from gas pipe 25. Indoor suction pipe open-close units 9a, 9c regulate enabling or disabling of flow of the air conditioning refrigerant from suction pipe 26. Indoor heat-exchanger throttles 10a, 10b adjust flow rates of the air conditioning refrigerant fed to indoor heat exchangers 8a, 8b.

[0037] The discharge side of air-conditioning compressor 7 is connected with one end of outdoor heat exchanger 11 via outdoor gas pipe open-close unit 19 by refrigerant piping. Liquid pipe 27 connected to the other end of outdoor heat exchanger 11 passes through outdoor heat-exchanger throttle 13 and branches at a place outside outdoor unit 10. First sections of liquid pipe 27 that branch off the place are connected by refrigerant piping

with first ends of indoor heat exchangers 8a, 8b via indoor heat-exchanger throttles 10a, 10b in parallel-connected indoor units 30, respectively.

[0038] Second ends of indoor heat exchangers 8a, 8b are connected to two way-split refrigerant pipes. One of the split pipes are connected through indoor gas pipe open-close units 9b, 9d to gas pipe 25, whereas the other of the split pipes are connected through indoor suction pipe open-close units 9a, 9c to suction pipe 26.

[0039] A second section of liquid pipe 27 that branches off the place is connected with one end of evaporator 4 via evaporator throttle 14 (third throttle). The other end of evaporator 4 is connected with gas pipe 25.

[0040] Operation and action of the heat pump device will now be described.

[0041] A description is given about the action of the heat pump device when second refrigeration circuit 15 is in heating operation by the use of indoor heat exchangers 8a, 8b as condensers and when first refrigeration circuit 5 is in operation. With reference to FIG. 2, the second refrigerant discharged from air-conditioning compressor 7 passes through indoor gas pipe open-close units 9b, 9d that are each in an open state and flows into indoor heat exchangers 8a, 8b before dissipating heat into air in a room. In first refrigeration circuit 5, the first refrigerant discharged from hot-water supply compressor 1 dissipates heat at condenser 2 and gets throttled by throttle 3. Then, the first refrigerant flows into evaporator 4 and absorbs heat from the second refrigerant before being sucked into hot-water supply compressor 1.

[0042] The second refrigerant from which the first refrigerant has absorbed heat at evaporator 4 and the second refrigerant that has flowed out of indoor heat exchangers 8a, 8b merge with each other after passing through evaporator throttle 14 and indoor heat-exchanger throttles 10a, 10b, respectively without being virtually throttled. The merging second refrigerant gets throttled at outdoor heat-exchanger throttle 13 and flows into outdoor heat exchanger 11. The second refrigerant that has flowed into outdoor heat exchanger 11 absorbs heat from air outside the room. Then, the second refrigerant passes through outdoor suction pipe open-close unit 12a that is in an open state and gets sucked into air-conditioning compressor 7.

[0043] Indoor suction pipe open-close units 9a, 9c and outdoor gas pipe open-close unit 12b are closed to prevent the second refrigerant from flowing.

[0044] The following description refers to the action of the heat pump device when second refrigeration circuit 15 is in cooling operation by the use of indoor heat exchangers 8a, 8b as evaporators and when first refrigeration circuit 5 is in operation. With reference to FIG. 3, the second refrigerant discharged from air-conditioning compressor 7 passes through outdoor gas pipe open-close unit 12b that is in an open state and flows into outdoor heat exchanger 11 before dissipating heat into air outside the room. In first refrigeration circuit 5, similarly to the action when second refrigeration circuit 15 is in

heating operation, the first refrigerant discharged from hot-water supply compressor 1 dissipates heat at condenser 2 and gets throttled by throttle 3. Then, the first refrigerant flows into evaporator 4 and absorbs heat from the second refrigerant before being sucked into hot-water supply compressor 1.

[0045] The second refrigerant from which the first refrigerant has absorbed heat at evaporator 4 and the second refrigerant that has flowed out of outdoor heat exchanger 11 pass through evaporator throttle 14 and outdoor heat-exchanger throttle 13, respectively without being virtually throttled, and get throttled by indoor heat-exchanger throttles 10a, 10b. The throttled refrigerant flows into indoor heat exchangers 8a, 8b and absorbs heat from air in the room. The second refrigerant that has exchanged heat at indoor heat exchangers 8a, 8b passes through indoor suction pipe open-close units 9a, 9c that are each in an open state and gets sucked into air-conditioning compressor 7. Indoor gas pipe open-close units 9b, 9d and outdoor suction pipe open-close unit 12a are closed to prevent the second refrigerant from flowing.

[0046] Further, a description refers to the action of the heat pump device when second refrigeration circuit 15 is in simultaneous heating and cooling operation by the use of indoor heat exchanger 8a as a condenser and indoor heat exchanger 8b as an evaporator and when first refrigeration circuit 5 is in operation. With reference to FIG. 4, the second refrigerant discharged from air-conditioning compressor 7 passes through indoor gas pipe open-close unit 9b that is in an open state and flows into indoor heat exchanger 8a before dissipating heat into air in the room. In first refrigeration circuit 5, the first refrigerant discharged from hot-water supply compressor 1 dissipates heat at condenser 2 and gets throttled by throttle 3. Then, the first refrigerant flows into evaporator 4 and absorbs heat from the second refrigerant before being sucked into hot-water supply compressor 1.

[0047] The second refrigerant from which the first refrigerant has absorbed heat at evaporator 4 and the second refrigerant that has flowed out of indoor heat exchanger 8a pass through evaporator throttle 14 and indoor heat-exchanger throttle 10a without being virtually throttled and get throttled by indoor heat-exchanger throttle 10b and outdoor heat-exchanger throttle 13, respectively before flowing into indoor heat exchanger 8b and outdoor heat exchanger 11. The second refrigerant that has flowed into indoor heat exchanger 8b and outdoor heat exchanger 11 absorbs heat from air in and outside the room and gets sucked into air-conditioning compressor 7 after passing through indoor suction pipe open-close unit 9c and outdoor suction pipe open-close unit 12a that are each in an open state. In the meantime, indoor suction pipe open-close unit 9a, indoor gas pipe open-close unit 9d, and outdoor gas pipe open-close unit 12b are closed to prevent the second refrigerant from flowing.

[0048] A description refers to the action of the heat pump device when the second refrigeration circuit is in

simultaneous heating and cooling operation by the use of indoor heat exchanger 8a as an evaporator and indoor heat exchanger 8b as a condenser and when first refrigeration circuit 5 is in operation. With reference to FIG. 5, the heat pump device operates without changing the open or close states of the outdoor heat-exchanger open-close unit while indoor suction pipe open-close unit 9a and indoor gas pipe open-close unit 9d are opened, and indoor gas pipe open-close unit 9b and indoor suction pipe open-close unit 9c are closed.

[0049] Under the operating states described above, pressure at a high pressure side of second refrigeration circuit 15 increases if second refrigeration circuit 15 in heating operation needs to dissipate much heat into air in the room (e.g. a room temperature of 5°C and a set temperature of 30°C), or if due to a high outdoor air temperature (e.g. 40°C) circuit 15 in cooling operation has to increase the temperature of the second refrigerant flowing into outdoor heat exchanger 11 to at or above the outdoor air temperature. This increases the pressure of the second refrigerant flowing into evaporator 4, and thus results in a high condensing temperature and an increased quantity of heat transferred from the second refrigerant to the first refrigerant. As a result, pressure at a low pressure side of first refrigeration circuit 5 rises.

[0050] When the first refrigerant is carbon dioxide (CO₂) having a low critical point (31.1°C, 7.4 MPa) in particular, a high condensing temperature in second refrigeration circuit 15 as described above can bring the first refrigerant into a supercritical state at the low pressure side of first refrigeration circuit 5, and the first refrigerant is sucked into hot-water supply compressor 1. A supercritical refrigerant sucked into hot-water supply compressor 1 reduces oil sealing performance in hot-water supply compressor 1 and decreases the reliability of hot-water supply compressor 1.

[0051] With reference to FIG. 6, controller 116 in this exemplary embodiment determines whether pressure Ps1 detected by first refrigeration circuit low-pressure detector 6 is greater than or equal to predetermined value α (e.g. 5.5 Mps) in step S1. If pressure Ps1 is predetermined value α or greater, the controller enables a first refrigeration circuit low-pressure suppression mode. When the first refrigeration circuit low-pressure suppression mode is enabled, the controller decreases a valve opening level of evaporator throttle 14 to reduce the flow rate of the second refrigerant circulating in second refrigeration circuit 15 and decreases a valve opening level of first throttle 3 in step S2 such that low-pressure side pressure Ps1 falls to or below predetermined value α .

[0052] In response to a decrease in the valve opening level of first throttle 3, refrigerant density at the low pressure side of first refrigeration circuit 5 decreases and the rate of the first refrigerant flowing in first refrigeration circuit 5 decreases. This reduces the quantity of heat transferred at evaporator 4 from the second refrigerant to the first refrigerant. Consequently, the quantity of evaporation of the first refrigerant decreases and the pressure at

the low pressure side of first refrigeration circuit 5 decreases.

[0053] Since the heating medium used in condenser 2 has large thermal capacity and low temperature (e.g. water with a temperature of 10°C), the condensing temperature at condenser 2 does not rise in an initial operating state of first refrigeration circuit 5. This causes evaporator 4 to have high pressure at the low pressure side of first refrigeration circuit 5 and the heat pump device to produce low heating performance.

[0054] A decrease in the pressure at the low pressure side of first refrigeration circuit 5 in the initial operating state of first refrigeration circuit 5 increases the difference in enthalpy of the first refrigerant at evaporator 4. This allows the heat pump device to produce high heating performance even in the initial operating state.

[0055] When a degree of superheat of the first refrigerant sucked into hot-water supply compressor 1 is high, a decrease in the pressure at the low pressure side of first refrigeration circuit 5 brings down the degree of superheat of the first refrigerant at an outlet of evaporator 4. This prevents a decline in efficiency owing to an increased degree of superheat of the first refrigerant sucked into hot-water supply compressor 1 and inhibits an excessive rise in the temperature of the first refrigerant discharged from hot-water supply compressor 1.

[0056] In this exemplary embodiment, the opening level of evaporator throttle 14 is reduced as a way to reduce the flow rate of the second refrigerant in second refrigeration circuit 15. However, the way to reduce the refrigerant flow rate is not limited to this example. The controller may reduce the load carried by air-conditioning compressor 7, such as reducing the frequency of air-conditioning compressor 7 (in step S2), to reduce the flow rate of the second refrigerant in second refrigeration circuit 15. The controller may both decrease the opening level of evaporator throttle 14 and reduce the load carried by air-conditioning compressor 7 to reduce the flow rate of the second refrigerant in second refrigeration circuit 15.

[0057] In this exemplary embodiment, first refrigeration circuit low-pressure detector 6 disposed between hot-water supply compressor 1 and evaporator 4 is used to detect the pressure at the low pressure side of first refrigeration circuit 5. Detector 6 may be disposed between throttle 3 and evaporator 4.

[0058] In this exemplary embodiment, evaporator 4 is a plate heat exchanger. The plate heat exchanger serving as evaporator 4 allows a reduction in the quantity of the first refrigerant held at the low-pressure side and thus prevents a rapid rise in the pressure at the high-pressure side in response to an increase in the load carried to the high-pressure side.

[0059] In this exemplary embodiment, when a degree of superheat of the first refrigerant sucked into hot-water supply compressor 1 is high, decrease in the pressure at the low pressure side of first refrigeration circuit 5 can bring down the degree of superheat of the first refrigerant at the outlet of evaporator 4. This configuration prevents

a decline in efficiency owing to an increased degree of superheat of the first refrigerant sucked into hot-water supply compressor 1 and inhibits an excessive rise in the temperature of the first refrigerant discharged from hot-water supply compressor 1.

[0060] In this exemplary embodiment, first refrigeration circuit low-pressure detector 6 is used as a way to detect the pressure at the low pressure side of first refrigeration circuit 5. With reference to FIG. 1, the heat pump device may have evaporator inlet temperature detector 117 to detect temperature at an inlet of evaporator 4 according to a variation of the exemplary embodiment.

[0061] In this case, the controller follows control flow in FIG. 7. The control flow in FIG. 7 has a different criterion in step S11 as compared with control flow in FIG. 6. Since the other step is identical to that in the control flow of FIG. 6, a description thereof is omitted.

[0062] Specifically, the controller determines whether temperature T_{in} detected by evaporator inlet temperature detector 117 is greater than or equal to 20°C in step S11, for example.

[0063] When the detected temperature is 20°C or greater, for example, the controller makes a transition to step S2 in like manner with the control flow in FIG. 6.

[0064] The controller thus reduces the quantity of heat transferred at evaporator 4 from the second refrigerant to the first refrigerant. As a result, the quantity of evaporation of the first refrigerant decreases and the pressure at the low pressure side of first refrigeration circuit 5 decreases.

[0065] This configuration ensures that the first refrigerant at or below its critical pressure is sucked into the compressor and provides improved compressor reliability more economically.

[0066] In this exemplary embodiment, as illustrated in FIG. 1, the heat pump device may have air-conditioning compressor discharge pressure detector 118 to detect pressure discharged from air-conditioning compressor 7 according to another variation of the exemplary embodiment.

[0067] In this case, the controller follows control flow in FIG. 8. The control flow in FIG. 8 has a different criterion in step S12 as compared with the control flow in FIG. 6. Since the other step is identical to that in the control flow of FIG. 6, a description thereof is omitted.

[0068] Specifically, the controller determines whether pressure detected by air-conditioning compressor discharge pressure detector 118 is greater than or equal to 3.7 Mps in step S11, for example.

[0069] When the detected pressure is 3.7 Mps, for example, the controller makes a transition to step S2 in like manner with the control flow in FIG. 6.

[0070] According to this control flow, the pressure at the low pressure side of first refrigeration circuit 5 decreases irrespective of temperature at a heat-absorbing side of evaporator 4. This configuration ensures that hot-water supply compressor 1 absorbs the refrigerant at or below the critical pressure at the low pressure side of

first refrigeration circuit 5 irrespective of the temperature at the heat-absorbing side of evaporator 4 and provides improved compressor reliability in a simpler structure.

[0071] The scope of the present invention should not be limited to the exemplary embodiment described above which is intended for purposes of illustration only, and should include various modifications and alterations without deviating from the gist of the present invention.

10 INDUSTRIAL APPLICABILITY

[0072] As described above, a heat pump device of the present invention prevents a rise in pressure at a low pressure side of a refrigeration cycle for hot-water supply, and thus the present invention can be applied to heat pump devices provided with hot-water supply or heating functions.

REFERENCE MARKS IN THE DRAWINGS

[0073]

- 1 hot-water supply compressor (first compressor)
- 2 condenser (first condenser)
- 3 throttle (first throttle)
- 4 evaporator (first evaporator)
- 5 refrigeration cycle for hot-water (first refrigeration circuit)
- 6 first refrigeration circuit low-pressure detector (pressure detector)
- 7 air-conditioning compressor (second compressor)
- 10 outdoor unit
- 11 outdoor heat exchanger
- 13 outdoor heat-exchanger throttle (second throttle)
- 14 evaporator throttle (third throttle)
- 15 refrigeration cycle for air conditioning (second refrigeration circuit)
- 116 controller
- 20 circulation circuit
- 30 indoor unit

Claims

45 1. A heat pump device comprising:

- a first refrigeration circuit including a first compressor, a first condenser, a first throttle, and a first evaporator connected in a ring, the first refrigeration circuit letting a first refrigerant circulate;
 - a second refrigeration circuit letting a second refrigerant circulate and exchanging heat with the first refrigeration circuit via the first evaporator; and
 - a controller,
- wherein the controller has a first refrigeration circuit low-pressure suppression mode in which

the controller reduces a flow rate of the second refrigerant circulating in the second refrigeration circuit and reduces an opening level of the first throttle such that pressure at a low pressure side of the first refrigeration circuit falls to or below a predetermined value. 5

2. The heat pump device according to claim 1, wherein the second refrigeration circuit includes

an outdoor unit having a second compressor, an outdoor heat exchanger, and a second throttle, 10
an indoor unit having an indoor heat exchanger, and 15
a circulation circuit letting the second refrigerant flow through the first evaporator,

the circulation circuit includes a third throttle to regulate a circulating quantity of the second refrigerant, 20
and
in the first refrigeration circuit low-pressure suppression mode, the controller reduces an opening level of the third throttle and reduces the opening level of the first throttle such that the pressure at the low 25
pressure side of the first refrigeration circuit falls to or below a predetermined value.

3. The heat pump device according to any one of claims 1 and 2, further comprising a pressure detector to detect pressure at a low pressure side of the first compressor, 30
wherein the controller enters the first refrigeration circuit low-pressure suppression mode when the low-pressure side pressure falls to or below a predetermined value. 35

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FIG. 1

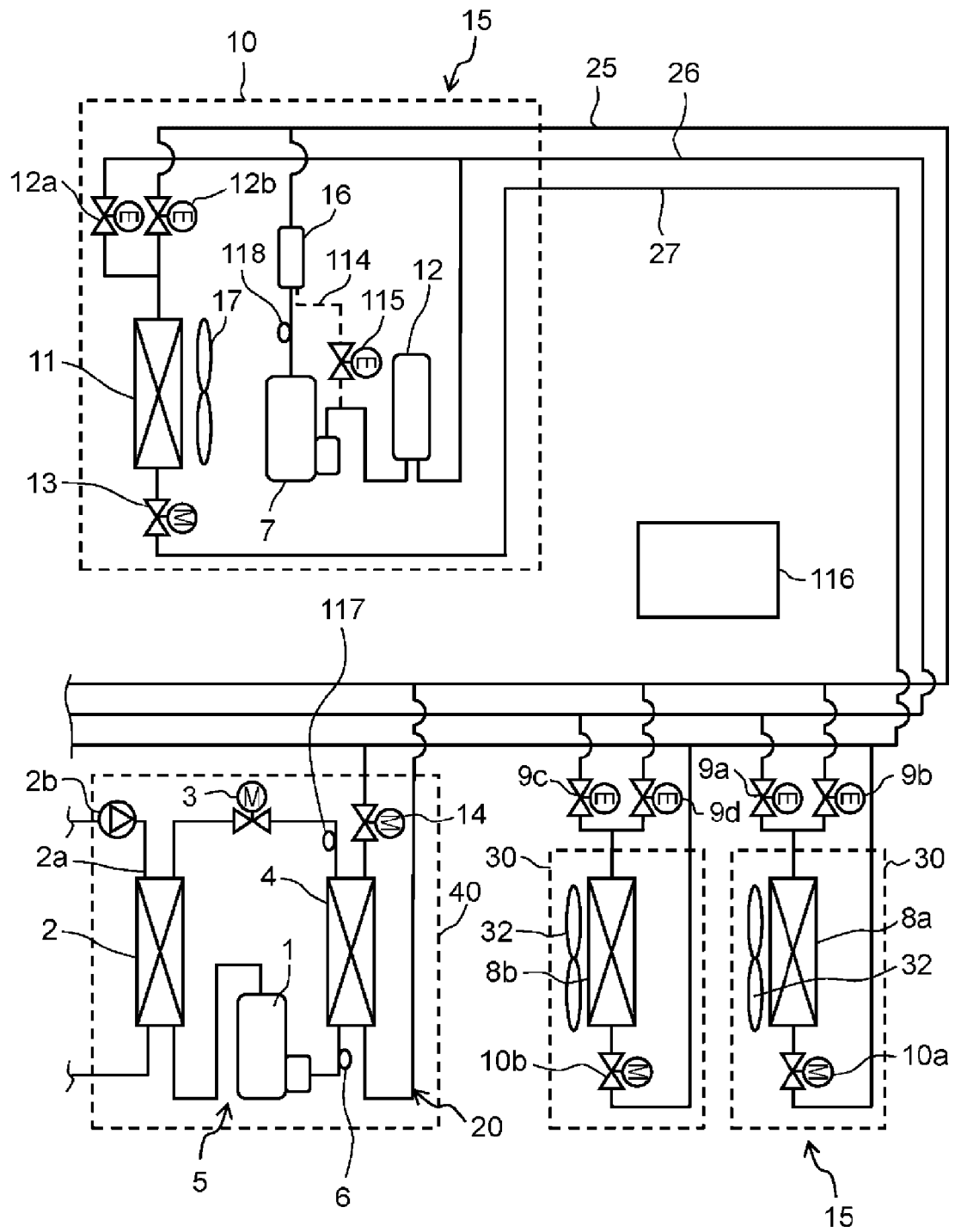


FIG. 2

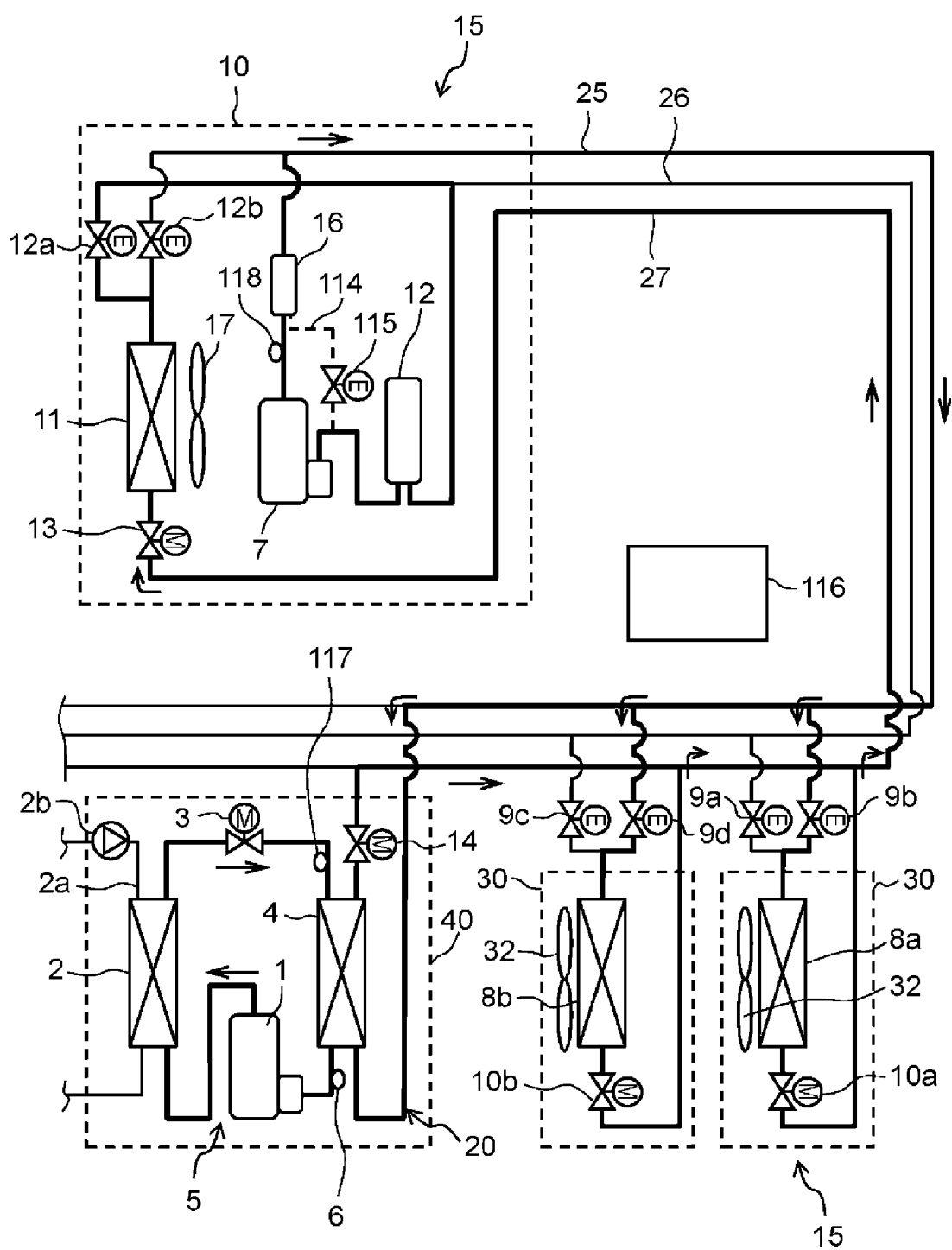


FIG. 3

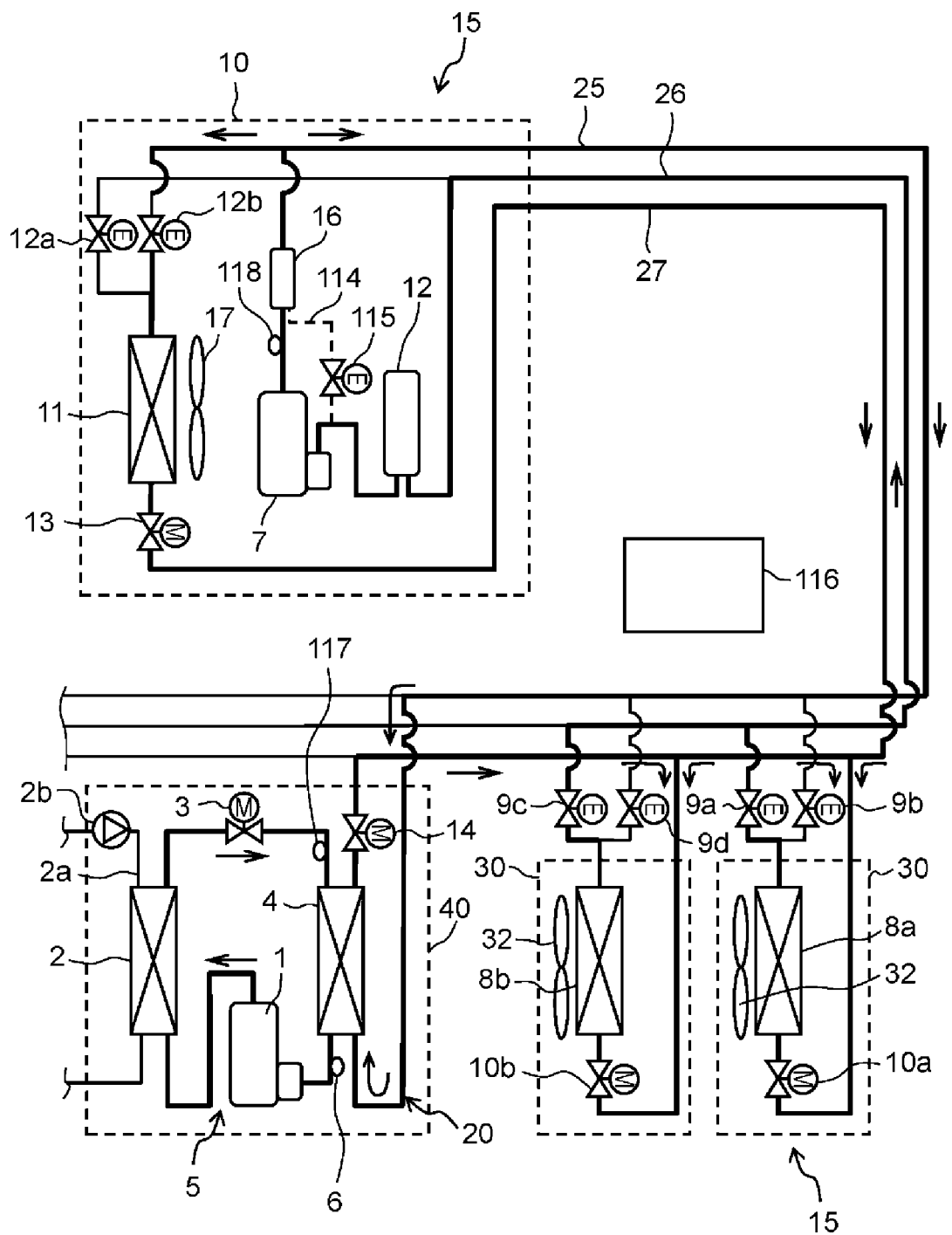


FIG. 4

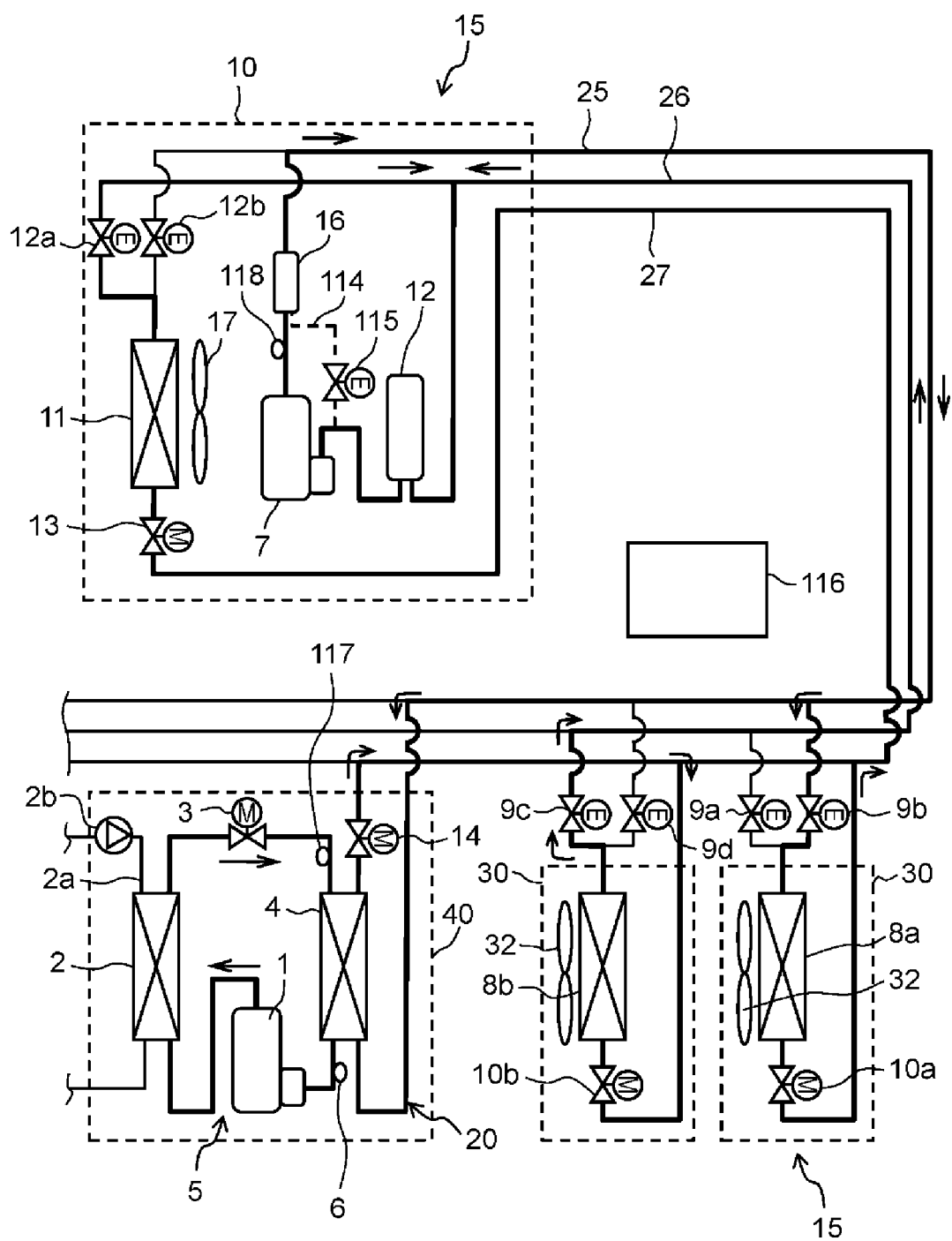


FIG. 5

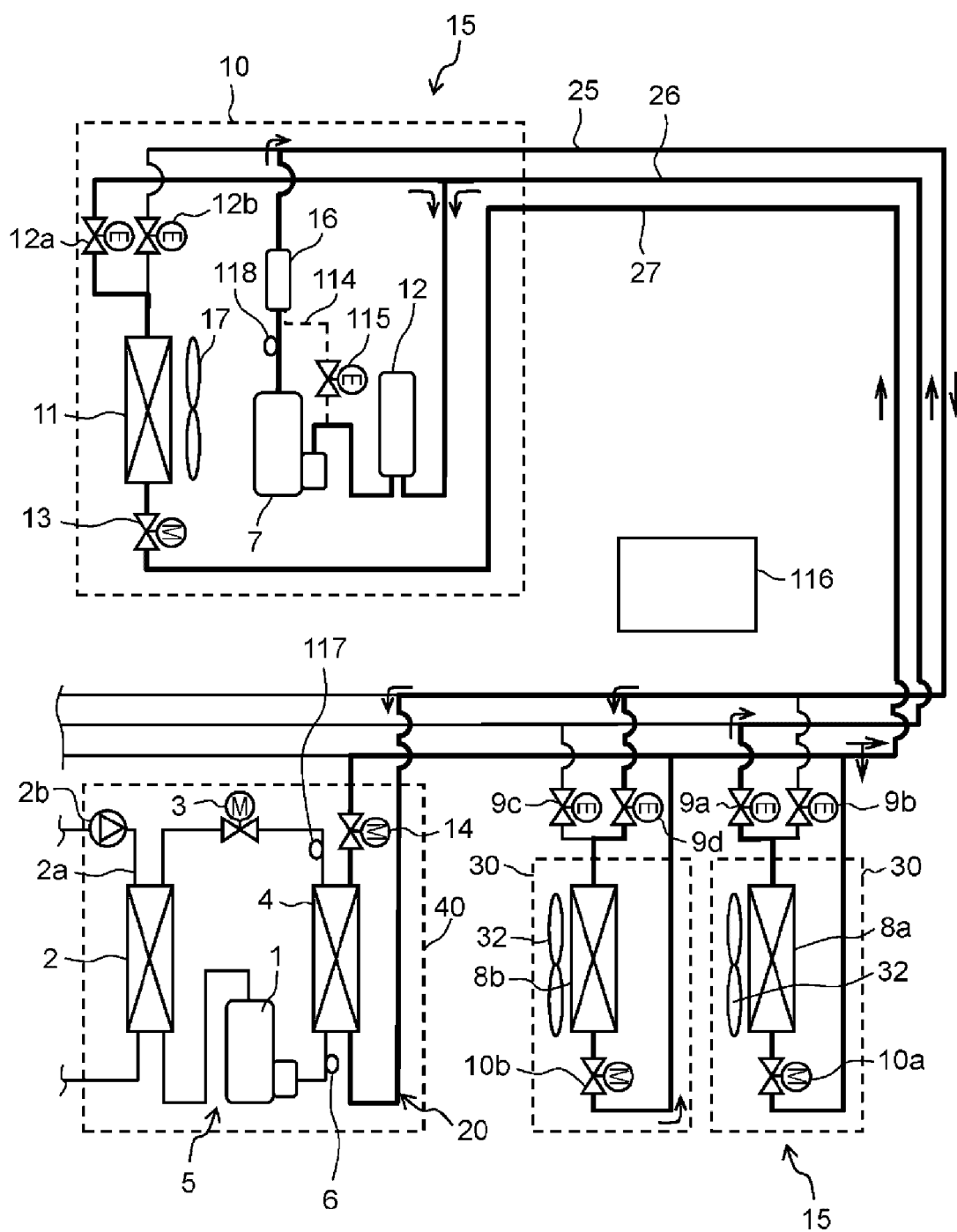


FIG. 6

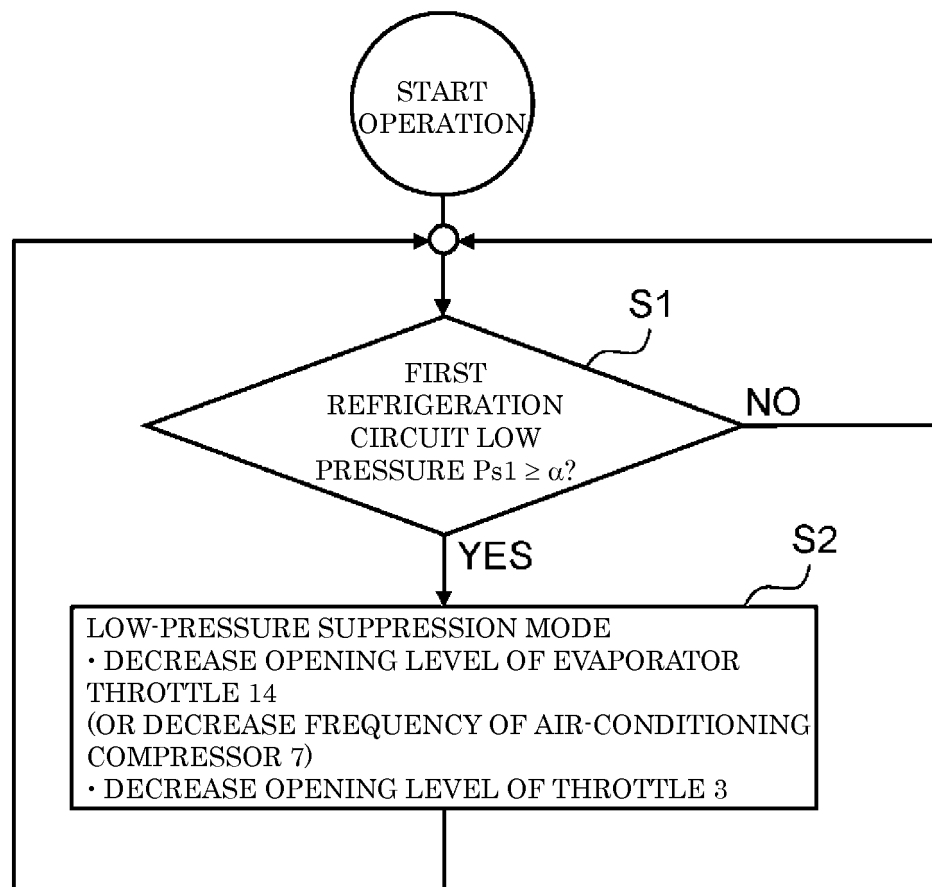


FIG. 7

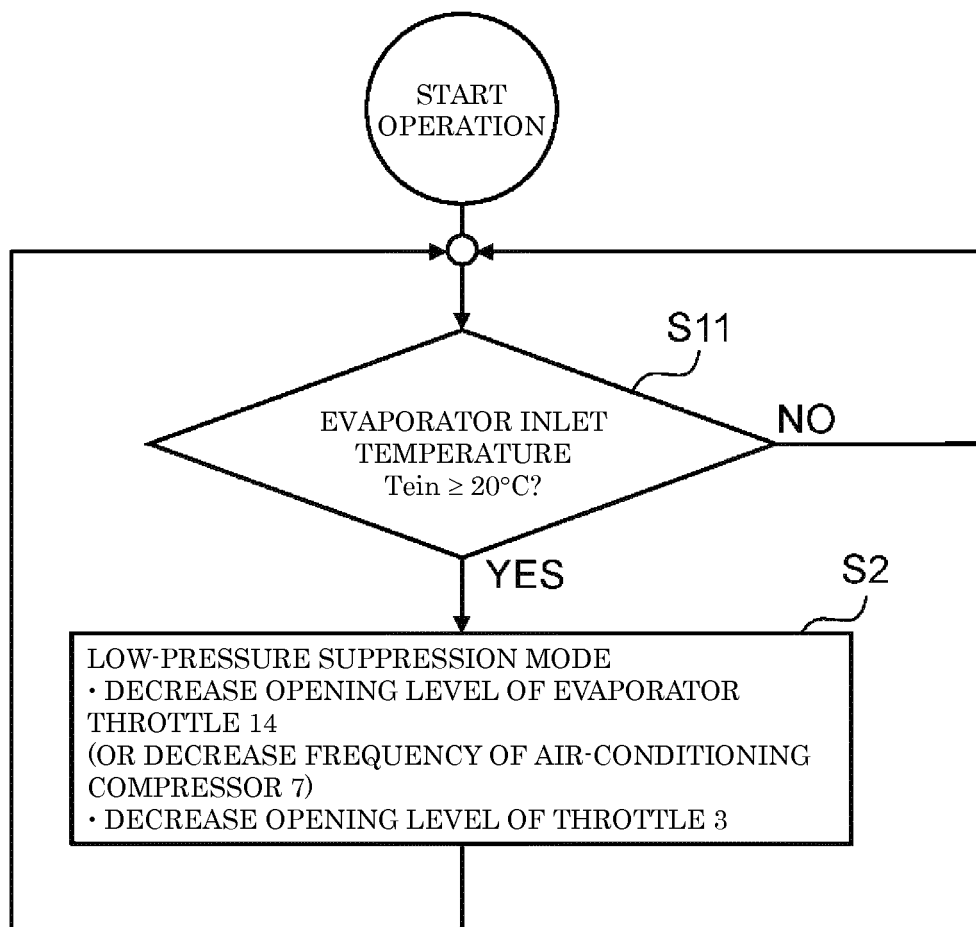
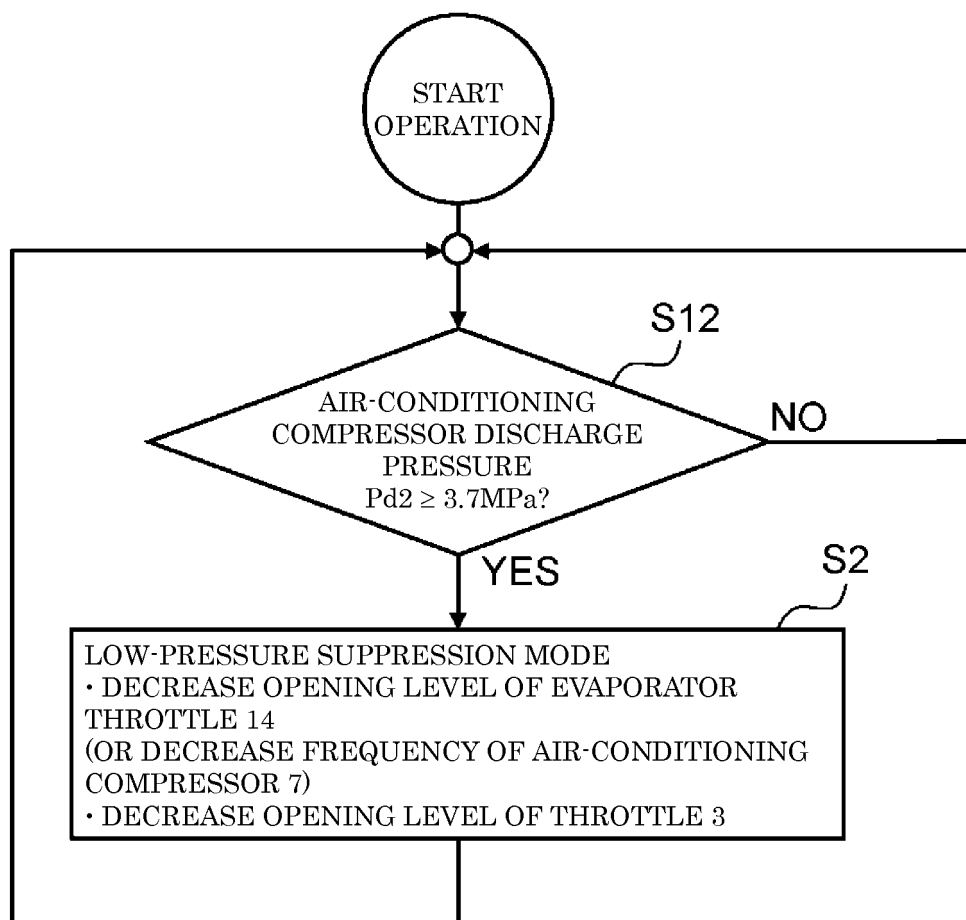


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/002319

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/00(2006.01) i, F25B7/00(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00, F25B7/00

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2012-145254 A (Mitsubishi Electric Corp.), 02 August 2012 (02.08.2012), paragraphs [0023] to [0029]; fig. 4 (Family: none)	1-3
Y	JP 2009-97779 A (Denso Corp.), 07 May 2009 (07.05.2009), paragraphs [0002] to [0007], [0047]; fig. 1 (Family: none)	1-3

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

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Date of the actual completion of the international search

25 July 2016 (25.07.16)

Date of mailing of the international search report

02 August 2016 (02.08.16)

Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2009098751 A [0007]