(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 317 844 A1

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

(43) Date of publication:
07.02.2024 Bulletin 2024/06

(21) Application number: **22781286.4**

(22) Date of filing: **31.03.2022**

(51) International Patent Classification (IPC):
F25B 7/00 (2006.01) ***F25B 1/00*** (2006.01)

(52) Cooperative Patent Classification (CPC):
F25B 1/00; F25B 7/00; F25B 13/00; F25B 29/00; F25B 43/00; F25B 49/02

(86) International application number:
PCT/JP2022/016796

(87) International publication number:
WO 2022/211076 (06.10.2022 Gazette 2022/40)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **31.03.2021 JP 2021061278**

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(54) REFRIGERATION CYCLE DEVICE

(57) Provided is a refrigeration cycle apparatus capable of efficiently performing a cooling operation and a heating operation using a low-pressure refrigerant and a high-pressure refrigerant. A refrigeration cycle apparatus using a first refrigerant having 1 MPa or less at 30°C and a second refrigerant having 1.5 MPa or more at 30°C performs a heating operation by performing a two-stage refrigeration cycle including a use-side refrigeration cycle using the first refrigerant and a heat-source-side refrigeration cycle using the second refrigerant, and performs a cooling operation by performing a single-stage refrigeration cycle using the first refrigerant.

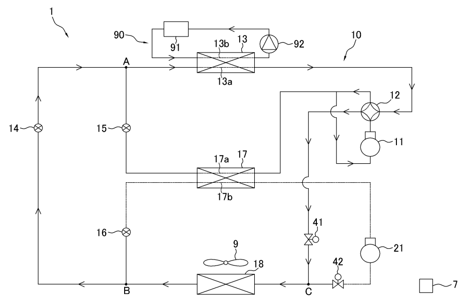

FIG. 3

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Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] To date, refrigeration cycle apparatuses have been proposed that use refrigerants with low global warming potential (GWP), taking into account the global environment.

[0003] For example, in a refrigeration cycle apparatus described in PTL 1 (Japanese Unexamined Patent Application Publication No. 2015-197254), it is proposed to fill a refrigerant circuit with a working fluid having a GWP equal to or less than a predetermined value.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] The refrigerants with low GWP described above include a low-pressure refrigerant used at a relatively low refrigerant pressure. Such a low-pressure refrigerant has low heat transfer capacity, and a sufficient amount of circulation of the refrigerant is difficult to secure during a heating operation, with the tendency that the heating operation is difficult to perform or the COP (Coefficient of Performance) is low during the heating operation.

[0005] To address this, a two-stage refrigeration cycle in which a carbon dioxide refrigerant serving as a high-pressure refrigerant with low GWP is used as a heat-source-side refrigerant and a low-pressure refrigerant is used as a use-side refrigerant may be used to secure heating operation capacity. However, even in this case, the critical pressure of the carbon dioxide refrigerant on the heat-source side is exceeded during a cooling operation, and the COP is low during the cooling operation.

[0006] Accordingly, it is desirable to provide a refrigeration cycle apparatus capable of efficiently performing a cooling operation and a heating operation when using a high-pressure refrigerant and a low-pressure refrigerant.

SOLUTION TO PROBLEM

[0007] A refrigeration cycle apparatus according to a first aspect performs a heating operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant and a heat-source-side refrigeration cycle using a second refrigerant. The first refrigerant has 1 MPa or less at 30°C. The second refrigerant has 1.5 MPa or more at 30°C. The refrigeration cycle apparatus performs a cooling operation by performing a single-stage refrigeration cycle using the first refrigerant.

[0008] In this refrigeration cycle apparatus, a two-stage refrigeration cycle is performed during the heating operation, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant that is a low-pressure refrigerant having 1 MPa or less at 30°C and a heat-source-side refrigeration cycle using a second refrigerant that is a high-pressure refrigerant having 1.5 MPa or more at 30°C. Thus, it is easy to secure heating capacity while achieving a high COP. In this refrigeration cycle apparatus, furthermore, a single-stage refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant having 1 MPa or less at 30°C, is performed during the cooling operation. Thus, it is possible to perform the two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle, without causing a reduction in COP due to the second refrigerant exceeding a critical pressure. Accordingly, the cooling operation and the heating operation can be efficiently performed when a high-pressure refrigerant and a low-pressure refrigerant are used.

[0009] A refrigeration cycle apparatus according to a second aspect is the refrigeration cycle apparatus according to the first aspect, including an outdoor heat exchanger. The outdoor heat exchanger functions as an evaporator of the second refrigerant during the heating operation, and functions as a radiator of the first refrigerant during the cooling operation.

[0010] The outdoor heat exchanger is not limited. For example, the refrigerant flowing through the outdoor heat exchanger may exchange heat with air.

[0011] In this refrigeration cycle apparatus, the heating operation and the cooling operation can be efficiently performed by using an outdoor heat source.

[0012] A refrigeration cycle apparatus according to a third aspect is the refrigeration cycle apparatus according to the second aspect, including a cascade heat exchanger. The cascade heat exchanger includes a first cascade flow path through which the first refrigerant flows during the heating operation, and a second cascade flow path that is independent of the first cascade flow path and through which the second refrigerant flows during the heating operation. The cascade heat exchanger is configured to exchange heat between the first refrigerant and the second refrigerant.

[0013] In this refrigeration cycle apparatus, the efficiency of heat exchange between the refrigerant flowing through the heat-source-side refrigeration cycle and the refrigerant flowing through the use-side refrigeration cycle can be increased.

[0014] A refrigeration cycle apparatus according to a fourth aspect is the refrigeration cycle apparatus according to the third aspect, including a use heat exchanger. In the use heat exchanger, the first refrigerant radiates heat during the heating operation. During the heating operation, the first refrigerant evaporates when passing through the first cascade flow path, and the second refrigerant radiates heat when passing through the second cascade flow path.

[0015] In this refrigeration cycle apparatus, the heating operation can be efficiently performed by using an outdoor heat source.

[0016] A refrigeration cycle apparatus according to a fifth aspect is the refrigeration cycle apparatus according to the fourth aspect, in which the first refrigerant evaporates in the use heat exchanger during the cooling operation.

[0017] In this refrigeration cycle apparatus, the cooling operation can be efficiently performed by using an outdoor heat source.

[0018] A refrigeration cycle apparatus according to a sixth aspect is the refrigeration cycle apparatus according to any one of the second to fifth aspects, in which the first refrigerant is collectable in a first region other than the outdoor heat exchanger. In this refrigeration cycle apparatus, furthermore, the second refrigerant is collectable in a second region other than the outdoor heat exchanger and other than the first region.

[0019] In this refrigeration cycle apparatus, collecting the first refrigerant in the first region or collecting the second refrigerant in the second region makes it possible to switch the refrigerant to be caused to flow through the outdoor heat exchanger between the first refrigerant and the second refrigerant.

[0020] A refrigeration cycle apparatus according to a seventh aspect performs a heating operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant and a heat-source-side refrigeration cycle using a second refrigerant. The first refrigerant has 1 MPa or less at 30°C. The second refrigerant has 1.5 MPa or more at 30°C. The refrigeration cycle apparatus performs a cooling operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using the second refrigerant and a heat-source-side refrigeration cycle using the first refrigerant.

[0021] In this refrigeration cycle apparatus, a two-stage refrigeration cycle is performed during the heating operation, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant that is a low-pressure refrigerant having 1 MPa or less at 30°C and a heat-source-side refrigeration cycle using a second refrigerant that is a high-pressure refrigerant having 1.5 MPa or more at 30°C. Thus, it is easy to secure heating capacity while achieving a high COP. In this refrigeration cycle apparatus, furthermore, a two-stage refrigeration cycle is performed during the cooling operation, the two-stage refrigeration cycle including a use-side refrigeration cycle using the second refrigerant, which is a high-pressure refrigerant having 1.5 MPa or more at 30°C, and a heat-source-side refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant having 1 MPa or less at 30°C. Thus, it is possible to perform the two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle, without causing a reduction in COP due to the second refrigerant exceeding a critical pressure. Accordingly, the cooling operation and the heating operation can be efficiently performed when a high-pressure refrigerant and a low-pressure refrigerant are used.

[0022] A refrigeration cycle apparatus according to an eighth aspect is the refrigeration cycle apparatus according to the seventh aspect, in which a refrigerant to be used in the heat-source-side refrigeration cycle and a refrigerant to be used in the use-side refrigeration cycle are interchanged between the heating operation and the cooling operation.

[0023] In this refrigeration cycle apparatus, at least part of the location where the first refrigerant flows or the location where the second refrigerant flows during the cooling operation can be shared as at least part of the location where the second refrigerant flows or the location where the first refrigerant flows during the heating operation.

[0024] A refrigeration cycle apparatus according to a ninth aspect is the refrigeration cycle apparatus according to the eighth aspect, including a refrigerant tank. The refrigerant tank temporarily stores either the first refrigerant or the second refrigerant when the refrigerants are interchanged.

[0025] In this refrigeration cycle apparatus, it is possible to interchange the refrigerants while avoiding mixing of the first refrigerant and the second refrigerant.

[0026] A refrigeration cycle apparatus according to a tenth aspect is the refrigeration cycle apparatus according to any one of the seventh to ninth aspects, including a cascade heat exchanger. The cascade heat exchanger includes a first cascade flow path in which the first refrigerant evaporates during the heating operation and a second cascade flow path that is independent of the first cascade flow path and in which the second refrigerant radiates heat during the heating operation. The cascade heat exchanger is configured to exchange heat between the first refrigerant and the second refrigerant.

[0027] In this refrigeration cycle apparatus, the efficiency of heat exchange between the refrigerant flowing through the heat-source-side refrigeration cycle and the refrigerant flowing through the use-side refrigeration cycle can be increased.

[0028] A refrigeration cycle apparatus according to an eleventh aspect is the refrigeration cycle apparatus according to any one of the seventh to tenth aspects, including a use heat exchanger. The use heat exchanger functions as a radiator of the first refrigerant during the heating operation and functions as an evaporator of the second refrigerant during the cooling operation.

[0029] The use heat exchanger is preferably a heat exchanger that processes a heat load. The refrigerant flowing through the use heat exchanger may exchange heat with air, or may exchange heat with a fluid such as brine or water.

[0030] In this refrigeration cycle apparatus, the use heat exchanger can perform heat load processing by using the first refrigerant and heat load processing by using the second refrigerant.

[0031] A refrigeration cycle apparatus according to a twelfth aspect is the refrigeration cycle apparatus according to any one of the seventh to eleventh aspects, including an outdoor heat exchanger. The outdoor heat exchanger functions as an evaporator of the second refrigerant during the heating operation and functions as a condenser of the first refrigerant during the cooling operation.

[0032] The outdoor heat exchanger is not limited. For example, the refrigerant flowing through the outdoor heat exchanger may exchange heat with air.

[0033] In this refrigeration cycle apparatus, the cooling operation and the heating operation can be efficiently performed by using an outdoor heat source.

[0034] A refrigeration cycle apparatus according to a thirteenth aspect is the refrigeration cycle apparatus according to any one of the first to twelfth aspects, in which the refrigeration cycle apparatus detects a state of mixing of the first refrigerant and the second refrigerant.

[0035] The state of mixing of the first refrigerant and the second refrigerant to be detected is not limited. For example, it may be detected that the weight percentage of the first refrigerant in the fluid becomes 90% or less or 95% or less, or it may be detected that the weight percentage of the second refrigerant in the fluid becomes 90% or less or 95% or less.

[0036] A specific method of the detection is not limited. For example, the detection may be performed based on an increase in the degree of change in the temperature of the refrigerant flowing through the heat exchanger that functions as an evaporator due to an increase in mixing ratio.

[0037] The refrigeration cycle apparatus may provide a notification of a result of the detection.

[0038] In this refrigeration cycle apparatus, it is possible to ascertain a reduction in operation efficiency due to mixing of the first refrigerant and the second refrigerant.

[0039] A refrigeration cycle apparatus according to a fourteenth aspect is the refrigeration cycle apparatus according to any one of the first to thirteenth aspects, in which the refrigeration cycle apparatus separates the first refrigerant and the second refrigerant from each other.

[0040] The method of separating the first refrigerant and the second refrigerant from each other is not limited, and a known separation method can be used. For example, adsorbents that adsorb the first refrigerant and the second refrigerant to different degrees may be used, and the refrigerant having higher adsorption efficiency may be separated. Alternatively, the separation may be performed by repeating an operation of separating the refrigerant having a higher purity phase of the gas-phase refrigerant and the liquid-phase refrigerant at a location in a gas-liquid two-phase state. The separation described above may be performed as an operation of the refrigeration cycle apparatus.

[0041] In this refrigeration cycle apparatus, separating the first refrigerant and the second refrigerant from each other makes it possible to recover the reduced operation efficiency caused by mixing of the first refrigerant and the second refrigerant.

[0042] A refrigeration cycle apparatus according to a fifteenth aspect is the refrigeration cycle apparatus according to any one of the first to fourteenth aspects, in which the first refrigerant includes at least one of R1234yf or R1234ze.

[0043] The first refrigerant may include only R1234yf or may include only R1234ze.

[0044] In this refrigeration cycle apparatus, an operation can be performed using a refrigerant having a sufficiently low global warming potential (GWP).

[0045] A refrigeration cycle apparatus according to a sixteenth aspect is the refrigeration cycle apparatus according to any one of the first to fifteenth aspects, in which the second refrigerant includes carbon dioxide.

[0046] The second refrigerant may include only carbon dioxide.

[0047] In this refrigeration cycle apparatus, an operation can be performed using a refrigerant having a sufficiently low ozone depletion potential (ODP) and a sufficiently low global warming potential (GWP).

Brief Description of Drawings

[0048]

[Fig.1] Fig. 1 is an overall configuration diagram of a refrigeration cycle apparatus according to a first embodiment.

[Fig. 2] Fig. 2 is a functional block configuration diagram of the refrigeration cycle apparatus according to the first embodiment.

[Fig. 3] Fig. 3 is a diagram illustrating how a refrigerant flows during a cooling operation according to the first embodiment.

[Fig. 4] Fig. 4 is a diagram illustrating how a refrigerant flows during a heating operation according to the first embodiment.

[Fig. 5] Fig. 5 is an overall configuration diagram of a refrigeration cycle apparatus according to a second embodiment.

[Fig. 6] Fig. 6 is a functional block configuration diagram of the refrigeration cycle apparatus according to the second embodiment.

[Fig. 7] Fig. 7 is a diagram illustrating how a refrigerant flows during a cooling operation according to the second embodiment.

[Fig. 8] Fig. 8 is a diagram illustrating how a refrigerant flows during a heating operation according to the second embodiment.

[Fig. 9] Fig. 9 is an overall configuration diagram of a refrigeration cycle apparatus according to a third embodiment.

[Fig. 10] Fig. 10 is a functional block configuration diagram of the refrigeration cycle apparatus according to the third embodiment.

[Fig. 11] Fig. 11 is a diagram illustrating how a refrigerant flows during a cooling operation according to the third embodiment.

[Fig. 12] Fig. 12 is a diagram illustrating how a refrigerant flows during a heating operation according to the third embodiment.

[Fig. 13] Fig. 13 is an overall configuration diagram of a refrigeration cycle apparatus according to a fourth embodiment.

[Fig. 14] Fig. 14 is a functional block configuration diagram of the refrigeration cycle apparatus according to the fourth embodiment.

[Fig. 15] Fig. 15 is a diagram illustrating how a refrigerant flows during a cooling operation according to the fourth embodiment.

[Fig. 16] Fig. 16 is a diagram illustrating how a refrigerant flows during a heating operation according to the fourth embodiment.

Description of Embodiments

(1) First Embodiment

[0049] Fig. 1 is a schematic configuration diagram of a refrigeration cycle apparatus 1 according to a first embodiment. Fig. 2 is a functional block configuration diagram of the refrigeration cycle apparatus 1 according to the first embodiment.

[0050] The refrigeration cycle apparatus 1 is an apparatus used to process a heat load through a vapor-compression refrigeration cycle operation. The refrigeration cycle apparatus 1 includes a heat-load circuit 90, a refrigerant circuit 10, an outdoor fan 9, and a controller 7.

[0051] The heat load to be processed by the refrigeration cycle apparatus 1 is not limited, and a fluid such as air, water, or brine may be subjected to heat exchange. In the refrigeration cycle apparatus 1 according to the present embodiment, water flowing through the heat-load circuit 90 is supplied to a heat-load heat exchanger 91, and the heat load in the heat-load heat exchanger 91 is processed. The heat-load circuit 90 is a circuit in which water serving as a heat medium circulates, and includes the heat-load heat exchanger 91, a pump 92, and a use heat exchanger 13 shared with the refrigerant circuit 10. The pump 92 is driven and controlled by the controller 7, which will be described below, to circulate the water through the heat-load circuit 90. In the heat-load circuit 90, the water flows through a heat-load flow path 13b included in the use heat exchanger 13. As described below, the use heat exchanger 13 includes a first use flow path 13a through which a first refrigerant flowing through the refrigerant circuit 10 passes. The water flowing through the heat-load flow path 13b of the use heat exchanger 13 exchanges heat with the first refrigerant flowing through the first use flow path 13a. As a result, the water is cooled during a cooling operation and is heated during a heating operation.

[0052] The refrigerant circuit 10 includes a first compressor 11, a second compressor 21, a first switching mechanism 12, the use heat exchanger 13 shared with the heat-load circuit 90, a first expansion valve 15, a second expansion valve 16, a third expansion valve 14, a cascade heat exchanger 17, an outdoor heat exchanger 18, a first on-off valve 41, and a second on-off valve 42.

[0053] The refrigerant circuit 10 is filled with the first refrigerant, which is a low-pressure refrigerant, and a second refrigerant, which is a high-pressure refrigerant, as refrigerants in a substantially separated state. The first refrigerant is a refrigerant having 1 MPa or less at 30°C, and is a refrigerant including, for example, at least one of R1234yf or R1234ze. The first refrigerant may include only R1234yf or may include only R1234ze. The second refrigerant is a refrigerant having 1.5 MPa or more at 30°C. For example, the second refrigerant may include carbon dioxide, or may include only carbon dioxide.

[0054] The first compressor 11 is a positive-displacement compressor to be driven by a compressor motor. The compressor motor is driven by electric power supplied via an inverter device. The first compressor 11 has an operating capacity that is changeable by varying a drive frequency that is the number of rotations of the compressor motor. A discharge side of the first compressor 11 is connected to a first port of the first switching mechanism 12. A suction side of the first compressor 11 is connected to a second port of the first switching mechanism 12 and a gas refrigerant side of a first cascade flow path 17a of the cascade heat exchanger 17.

[0055] The first switching mechanism 12 switches between a state in which the discharge side of the first compressor 11 is connected to a gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the first on-off valve 41 and the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17 and a state in which the discharge side of the first compressor 11 is connected to the first on-off valve 41 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. In the present embodiment, the first switching mechanism 12 is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port is connected to the discharge side of the first compressor 11. The second port is connected to the suction side of the first compressor 11 and the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. The third port is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13. The fourth port is connected to the first on-off valve 41.

[0056] The gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 through which the first refrigerant flowing through the refrigerant circuit 10 passes is connected to the first switching mechanism 12. A liquid refrigerant side of the first use flow path 13a is connected to a branch point A included in the refrigerant circuit 10.

[0057] At the branch point A, a flow path extending from the liquid refrigerant side of the first use flow path 13a, a flow path extending to the side of the first expansion valve 15 opposite to the cascade heat exchanger 17 side, and a flow path extending from the third expansion valve 14 are connected.

[0058] The first expansion valve 15 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the first expansion valve 15 is disposed between the branch point A and a liquid refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17.

[0059] The third expansion valve 14 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the third expansion valve 14 is disposed at a certain point in a flow path connecting the branch point A and a branch point B.

[0060] At the branch point B, a flow path extending from the third expansion valve 14, a flow path extending from the second expansion valve 16, and a flow path extending from a liquid refrigerant side of the outdoor heat exchanger 18 are connected.

[0061] The second expansion valve 16 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the second expansion valve 16 is disposed between the branch point B and a liquid refrigerant side of a second cascade flow path 17b of the cascade heat exchanger 17.

[0062] The cascade heat exchanger 17 is a cascade heat exchanger that includes the first cascade flow path 17a through which one of the first refrigerant and the second refrigerant passes and the second cascade flow path 17b through which the other of the first refrigerant and the second refrigerant passes, and that exchanges heat between the first refrigerant and the second refrigerant. In the cascade heat exchanger 17, the first cascade flow path 17a and the second cascade flow path 17b are independent of each other, and the first refrigerant and the second refrigerant do not mix with each other in the cascade heat exchanger 17. The gas refrigerant side of the first cascade flow path 17a is connected to the suction side of the first compressor 11. The liquid refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the first expansion valve 15. A gas refrigerant side of the second cascade flow path 17b is connected to a discharge side of the second compressor 21. The liquid refrigerant side of the second cascade flow path 17b is connected to a flow path extending from the second expansion valve 16.

[0063] The outdoor heat exchanger 18 includes a plurality of heat transfer tubes and a plurality of fins joined to the plurality of heat transfer tubes. In the present embodiment, the outdoor heat exchanger 18 is arranged outdoors. A refrigerant flowing through the outdoor heat exchanger 18 exchanges heat with air sent to the outdoor heat exchanger 18.

[0064] The outdoor fan 9 generates an air flow of outdoor air passing through the outdoor heat exchanger 18.

[0065] A branch point C is connected to a flow path extending from a gas refrigerant side of the outdoor heat exchanger 18, a flow path extending from the first on-off valve 41, and a flow path extending from the second on-off valve 42.

[0066] The first on-off valve 41 is disposed at a certain point in a flow path connecting the branch point C and the fourth port of the first switching mechanism 12.

[0067] The second on-off valve 42 is disposed at a certain point in a flow path connecting the branch point C and a suction side of the second compressor 21.

[0068] The second compressor 21 is a positive-displacement compressor to be driven by a compressor motor. The compressor motor is driven by electric power supplied via an inverter device. The second compressor 21 has an operating capacity that is changeable by varying a drive frequency that is the number of rotations of the compressor motor. The discharge side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. The suction side of the second compressor 21 is connected to a flow path extending from the second on-off valve 42.

[0069] The controller 7 controls the operation of the devices included in the heat-load circuit 90 and the refrigerant circuit 10. Specifically, the controller 7 includes a processor serving as a CPU provided for performing control, a memory, and the like.

[0070] In the refrigeration cycle apparatus 1 described above, the controller 7 controls the devices to execute a refrigeration cycle, thereby performing a cooling operation for processing a cooling load in the heat-load heat exchanger 91, a heating operation for processing a heating load in the heat-load heat exchanger 91, a cooling-to-heating transition operation, and a heating-to-cooling transition operation.

(1-1) Cooling Operation

[0071] During the cooling operation, as illustrated in Fig. 3, the second refrigerant is confined in a flow path (flow path indicated by a dotted line) from the second on-off valve 42 to the second expansion valve 16 via the second compressor 21 and the second cascade flow path 17b of the cascade heat exchanger 17, and the first refrigerant is circulated through the first compressor 11, the outdoor heat exchanger 18, the third expansion valve 14, and the use heat exchanger 13. As a result, a single-stage refrigeration cycle is performed. The single-stage refrigeration cycle is performed using the first refrigerant by causing the use heat exchanger 13 to function as an evaporator of the first refrigerant and the outdoor heat exchanger 18 to function as a condenser of the first refrigerant. In Fig. 3, a single-headed arrow indicates a flow path through which the first refrigerant flows.

[0072] Specifically, the second on-off valve 42 and the second expansion valve 16 are controlled to be in a fully closed state to confine the second refrigerant in the flow path from the second on-off valve 42 to the second expansion valve 16. Further, a connection state of the first switching mechanism 12 is switched to a connection state indicated by solid lines in Fig. 3, the pump 92, the first compressor 11, and the outdoor fan 9 are driven, the first on-off valve 41 is controlled to be in an open state, the first expansion valve 15 is controlled to be in a fully closed state, and the second compressor 21 is stopped. Further, the valve opening degree of the third expansion valve 14 is controlled such that the degree of superheating of the first refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition.

[0073] Accordingly, the first refrigerant discharged from the first compressor 11 is sent to the outdoor heat exchanger 18 via the first switching mechanism 12 and the first on-off valve 41. The first refrigerant sent to the outdoor heat exchanger 18 is condensed by heat exchange with the outdoor air supplied by the outdoor fan 9. The first refrigerant having passed through the outdoor heat exchanger 18 passes through the branch point B and is then decompressed in the third expansion valve 14. After that, the first refrigerant passes through the branch point A and is sent to the first use flow path 13a of the use heat exchanger 13. The first refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is evaporated by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water cooled by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the cooling load. The first refrigerant evaporated in the first use flow path 13a of the use heat exchanger 13 is sucked into the first compressor 11 via the first switching mechanism 12.

(1-2) Cooling-to-Heating Transition Operation

[0074] The refrigeration cycle apparatus 1 performs a cooling-to-heating transition operation for making a transition from a cycle state for performing the cooling operation to a cycle state for performing the heating operation.

[0075] In the cooling-to-heating transition operation, first, the third expansion valve 14 is controlled to be in a fully closed state from the state in which the cooling operation is performed, the connection state of the first switching mechanism 12 is switched to a state in which the discharge side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the first on-off valve 41 and the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17, and the first compressor 11 is operated, with the second on-off valve 42 closed and the first expansion valve 15 and the second expansion valve 16 controlled to be in the fully closed state. After this operation state is maintained for a while, the first on-off valve 41 is closed. As a result, the first refrigerant can be collected in a flow path from the first on-off valve 41 to the third expansion valve 14 via the first compressor 11 and the use heat exchanger 13.

[0076] Then, opening the first expansion valve 15 while maintaining the third expansion valve 14 in the fully closed state and also maintaining the first on-off valve 41 in the closed state allows the first refrigerant to circulate through the first compressor 11, the use heat exchanger 13, the first expansion valve 15, and the cascade heat exchanger 17. Further, opening the second expansion valve 16 and the second on-off valve 42 allows the second refrigerant to circulate through the second compressor 21, the cascade heat exchanger 17, the second expansion valve 16, and the outdoor heat exchanger 18.

[0077] Thus, the cooling-to-heating transition operation is completed.

(1-3) Heating Operation

[0078] During the heating operation, as illustrated in Fig. 4, a two-stage refrigeration cycle is performed in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. In Fig. 4, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as a condenser of the first refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, and the outdoor heat exchanger 18 is caused to function as an evaporator of the second refrigerant.

[0079] Specifically, in this two-stage refrigeration cycle, the third expansion valve 14 is controlled to be in a fully closed state, and the first on-off valve 41 is controlled to be in a closed state to prevent mixing of the first refrigerant and the second refrigerant. The connection state of the first switching mechanism 12 is switched to a connection state indicated by broken lines in Fig. 4, the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven, and the second on-off valve 42 is controlled to be in an open state. Further, the valve opening degree of the first expansion valve 15 is controlled such that the degree of superheating of the first refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the second expansion valve 16 is controlled such that the degree of superheating of the second refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0080] Accordingly, the second refrigerant discharged from the second compressor 21 is sent to the cascade heat exchanger 17. When flowing through the second cascade flow path 17b, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the first cascade flow path 17a. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, is decompressed in the second expansion valve 16. After that, the second refrigerant is evaporated by heat exchange with the outdoor air supplied by the outdoor fan 9 in the outdoor heat exchanger 18, and is sucked into the second compressor 21. The first refrigerant discharged from the first compressor 11 is sent to the first use flow path 13a of the use heat exchanger 13 via the first switching mechanism 12. The first refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is condensed by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water heated by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the heating load. The first refrigerant condensed in the first use flow path 13a of the use heat exchanger 13 passes through the branch point A and is then decompressed in the first expansion valve 15. The first refrigerant decompressed by the first expansion valve 15 is evaporated, when passing through the first cascade flow path 17a of the cascade heat exchanger 17, by heat exchange with the second refrigerant flowing through the second cascade flow path 17b. The first refrigerant evaporated in the first cascade flow path 17a of the cascade heat exchanger 17 is sucked into the first compressor 11 via the first switching mechanism 12.

(1-4) Heating-to-Cooling Transition Operation

[0081] The refrigeration cycle apparatus 1 performs a heating-to-cooling transition operation for making a transition from a cycle state for performing the heating operation to a cycle state for performing the cooling operation.

[0082] In the heating-to-cooling transition operation, first, the second expansion valve 16 is controlled to be in a fully closed state from the state in which the heating operation is performed, and the second compressor 21 is driven, with the third expansion valve 14 also maintained in the fully closed state. After this operation state is maintained for a while, the second on-off valve 42 is closed. As a result, the second refrigerant can be collected in a flow path from the second on-off valve 42 to the second expansion valve 16 via the second compressor 21 and the second cascade flow path 17b of the cascade heat exchanger 17.

[0083] Then, the first expansion valve 15 is controlled to be in a fully closed state, the third expansion valve 14 and the first on-off valve 41 is opened, and the first switching mechanism 12 is brought into a state in which the discharge side of the first compressor 11 is connected to the first on-off valve 41 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. This makes it possible to perform a cooling operation based on a single-stage refrigeration cycle using the first refrigerant.

[0084] Thus, the heating-to-cooling transition operation is completed.

(1-5) Features of First Embodiment

[0085] In the refrigeration cycle apparatus 1 according to the first embodiment, the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP) and the second refrigerant having a sufficiently low ozone depletion potential (ODP) and a sufficiently low global warming potential (GWP). Thus, global environmental deterioration can be reduced.

[0086] In addition, even when the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP), the two-stage refrigeration cycle in which the second refrigerant, which is a high-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the first refrigerant, which is a low-pressure refrigerant, is used in the use-side refrigeration cycle is performed as the heating operation. This makes it easier to secure heating operation capacity than a single-stage refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant.

[0087] Further, the refrigerant circuit 10 uses carbon dioxide as the second refrigerant. However, during the cooling operation, a single-stage refrigeration cycle using the second refrigerant is not performed, nor is performed a two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. Instead of this, a single-stage refrigeration cycle using the first refrigerant is performed. This makes it possible to perform the cooling operation without causing a reduction in COP, as in the case of performing a single-stage refrigeration cycle using a carbon dioxide refrigerant, which is a high-pressure refrigerant, or as in the case of performing a two-stage refrigeration cycle in which carbon dioxide, which is a high-pressure refrigerant, is used in the heat-source-side cycle, the reduction in COP being due to the pressure of the carbon dioxide refrigerant exceeding the critical pressure. It is also possible to reduce the compression strength standards required for the components of the refrigerant circuit 10 in which carbon dioxide, which is a high-pressure refrigerant, is used.

(2) Second Embodiment

[0088] Fig. 5 is a schematic configuration diagram of a refrigeration cycle apparatus 1a according to a second embodiment. Fig. 6 is a functional block configuration diagram of the refrigeration cycle apparatus 1a according to the second embodiment.

[0089] The refrigeration cycle apparatus 1a is an apparatus used to process a heat load through a vapor-compression refrigeration cycle operation. The refrigeration cycle apparatus 1a includes a heat-load circuit 90, a refrigerant circuit 10, an outdoor fan 9, and a controller 7.

[0090] The heat load to be processed by the refrigeration cycle apparatus 1a and the heat-load circuit 90 are similar to those according to the first embodiment.

[0091] In the present embodiment, as described below, a use heat exchanger 13 includes a first use flow path 13a through which a first refrigerant or a second refrigerant flowing through the refrigerant circuit 10 passes. Water flowing through a heat-load flow path 13b of the use heat exchanger 13 exchanges heat with the first refrigerant or second refrigerant flowing through the first use flow path 13a. As a result, the water is cooled during a cooling operation and is heated during a heating operation.

[0092] The refrigerant circuit 10 includes a first compressor 11, a second compressor 21, a first switching mechanism 12, a second switching mechanism 22, the use heat exchanger 13 shared with the heat-load circuit 90, a first expansion valve 15, a second expansion valve 16, a cascade heat exchanger 17, an outdoor heat exchanger 18, a refrigerant container 19, a third on-off valve 43, a fourth on-off valve 44, a fifth on-off valve 45, a sixth on-off valve 46, a seventh on-off valve 47, an eighth on-off valve 48, and a ninth on-off valve 49.

[0093] The refrigerant circuit 10 is filled with the first refrigerant, which is a low-pressure refrigerant, and the second refrigerant, which is a high-pressure refrigerant, as refrigerants in a substantially separated state. The first refrigerant is a refrigerant having 1 MPa or less at 30°C, and is a refrigerant including, for example, at least one of R1234yf or R1234ze. The first refrigerant may include only R1234yf or may include only R1234ze. The second refrigerant is a refrigerant having 1.5 MPa or more at 30°C. For example, the second refrigerant may include carbon dioxide, or may include only carbon dioxide.

[0094] The specific configuration of the first compressor 11 is similar to that according to the first embodiment. A discharge side of the first compressor 11 is connected to a first port of a switching valve 12a of the first switching mechanism 12. A suction side of the first compressor 11 is connected to a branch point D 1.

[0095] The branch point D1 is connected to a second port of the switching valve 12a of the first switching mechanism 12, a second port of a switching valve 12b of the first switching mechanism 12, and a flow path extending from the eighth on-off valve 48.

[0096] The first switching mechanism 12 includes the switching valve 12a and the switching valve 12b.

[0097] In the present embodiment, the switching valve 12a is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the switching valve 12a is connected to the discharge side of the first compressor 11. The second port of the switching valve 12a is connected to the suction side of the first compressor 11. The third port of the switching valve 12a is connected to a flow path extending from a branch point E2. The fourth port of the switching valve 12a is connected to a first port of the switching valve 12b.

[0098] In the present embodiment, the switching valve 12b is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the switching valve 12b is connected to the fourth port of the switching valve 12a. The second port of the switching valve 12b is connected to the suction side of the first compressor 11. The third port of the switching valve 12b is connected to a gas refrigerant side of the first use flow path 13a of the use heat exchanger 13. The fourth port of the switching valve 12b is connected to a gas refrigerant side of a first cascade flow path 17a of the cascade heat exchanger 17.

[0099] The switching valve 12a switches between a state in which the discharge side of the first compressor 11 is connected to the first port of the switching valve 12b and the suction side of the first compressor 11 is connected to the branch point E2 and a state in which the discharge side of the first compressor 11 is connected to the branch point E2 and the suction side of the first compressor 11 is connected to the first port of the switching valve 12b.

[0100] The switching valve 12b switches between a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17.

[0101] The gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 through which the refrigerant flowing through the refrigerant circuit 10 passes is connected to the switching valve 12b of the first switching mechanism 12. Aliquid refrigerant side of the first use flow path 13a is connected to a branch point A included in the refrigerant circuit 10.

[0102] At the branch point A, a flow path extending from the liquid refrigerant side of the first use flow path 13a, a flow path extending to the side of the first expansion valve 15 opposite to the cascade heat exchanger 17 side, and a flow path extending from a branch point J are connected.

[0103] The first expansion valve 15 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the first expansion valve 15 is disposed at a certain point in a flow path connecting the branch point A and a branch point F.

[0104] The branch point F connects a flow path extending from the first expansion valve 15, a flow path extending from a branch point H1, and a flow path extending from a liquid refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17.

[0105] The cascade heat exchanger 17 is a cascade heat exchanger that includes the first cascade flow path 17a through which one of the first refrigerant and the second refrigerant passes and a second cascade flow path 17b through which the other of the first refrigerant and the second refrigerant passes, and that exchanges heat between the first refrigerant and the second refrigerant. In the cascade heat exchanger 17, the first cascade flow path 17a and the second cascade flow path 17b are independent of each other, and the first refrigerant and the second refrigerant do not mix with each other in the cascade heat exchanger 17. The gas refrigerant side of the first cascade flow path 17a is connected to the switching valve 12b of the first switching mechanism 12. The liquid refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the branch point F. A gas refrigerant side of the second cascade flow path 17b is connected to a switching valve 22b of the second switching mechanism 22. A liquid refrigerant side of the second cascade flow path 17b is connected to a flow path extending from a branch point G.

[0106] The specific configuration of the second compressor 21 is similar to that according to the first embodiment. A discharge side of the second compressor 21 is connected to a first port of a switching valve 22a of the second switching mechanism 22. A suction side of the second compressor 21 is connected to a branch point E1.

[0107] The branch point E1 is connected to a second port of the switching valve 22a of the second switching mechanism 22, a second port of the switching valve 22b of the second switching mechanism 22, and a flow path extending from the seventh on-off valve 47.

[0108] The second switching mechanism 22 includes the switching valve 22a and the switching valve 22b.

[0109] In the present embodiment, the switching valve 22a is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the switching valve 22a is connected to the discharge side of the second compressor 21. The second port of the switching valve 22a is connected to the suction side of the second compressor 21. The third port of the switching valve 22a is connected to a flow path extending from a branch point D2. The fourth port of the switching valve 22a is connected to a first port of the switching valve 22b.

[0110] In the present embodiment, the switching valve 22b is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the switching valve 22b is connected to the fourth port of the switching valve 22a. The second port of the switching valve 22b is connected to the suction side of the second compressor 21. The third port of the switching valve 22b is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. The fourth port of the switching valve 22b is connected to a gas refrigerant side of the outdoor heat exchanger 18.

[0111] The switching valve 22a switches between a state in which the discharge side of the second compressor 21 is connected to the first port of the switching valve 22b and the suction side of the second compressor 21 is connected to the branch point D2 and a state in which the discharge side of the second compressor 21 is connected to the branch point D2 and the suction side of the second compressor 21 is connected to the first port of the switching valve 22b.

[0112] The switching valve 22b switches between a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the outdoor heat exchanger 18 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the outdoor heat exchanger 18.

[0113] The branch point G is connected to a flow path extending from the liquid refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17, a flow path extending from the second expansion valve 16, and a flow path extending from a branch point H2.

[0114] The second expansion valve 16 is configured as an electronic expansion valve that is adjustable in valve opening degree. The second expansion valve 16 is disposed between the branch point G and the liquid refrigerant side of the outdoor heat exchanger 18.

[0115] The outdoor heat exchanger 18 includes a plurality of heat transfer tubes and a plurality of fins joined to the plurality of heat transfer tubes. In the present embodiment, the outdoor heat exchanger 18 is arranged outdoors. A refrigerant flowing through the outdoor heat exchanger 18 exchanges heat with air sent to the outdoor heat exchanger 18.

[0116] The outdoor fan 9 generates an air flow of outdoor air passing through the outdoor heat exchanger 18.

[0117] The branch point J is connected to a flow path extending from the branch point A, a flow path extending from the sixth on-off valve 46, and a flow path extending from a branch point K 1. The branch point K1 connects a flow path extending from the branch point J, a flow path extending from an upper end portion of the refrigerant container 19, and a flow path extending from the ninth on-off valve 49. The ninth on-off valve 49 is disposed at a certain point in a flow path connecting the branch point D2 and the branch point K1. The branch point D2 connects a flow path extending from the ninth on-off valve 49, a flow path extending from the eighth on-off valve 48, and a flow path extending from the third port of the switching valve 22a of the second switching mechanism 22. The eighth on-off valve 48 is disposed at a certain point in a flow path connecting the branch point D2 and the branch point D1. The sixth on-off valve 46 is disposed at a certain point in a flow path connecting the branch point J and the branch point E2. The branch point E2 connects a flow path extending from the seventh on-off valve 47, a flow path extending from the sixth on-off valve 46, and a flow path extending from the third port of the switching valve 12a of the first switching mechanism 12. The seventh on-off valve 47 is disposed at a certain point in a flow path connecting the branch point E1 and the branch point E2.

[0118] A branch point K2 connects a flow path extending from a lower end portion of the refrigerant container 19, a flow path extending from the fourth on-off valve 44, and a flow path extending from the fifth on-off valve 45. The fourth on-off valve 44 is disposed at a certain point in a flow path connecting the branch point K2 and the branch point H1. The fifth on-off valve 45 is disposed at a certain point in a flow path connecting the branch point K2 and the branch point H2. The branch point H1 connects a flow path extending from the third on-off valve 43, a flow path extending from the fourth on-off valve 44, and a flow path extending from the branch point F. The branch point H2 connects a flow path extending from the third on-off valve 43, a flow path extending from the fifth on-off valve 45, and a flow path extending from the branch point G. The third on-off valve 43 is disposed at a certain point in a flow path connecting the branch point H1 and the branch point H2.

[0119] The third on-off valve 43, the fourth on-off valve 44, the fifth on-off valve 45, the sixth on-off valve 46, the seventh on-off valve 47, the eighth on-off valve 48, and the ninth on-off valve 49 are each an electromagnetic valve controllable to switch between an open state and a closed state.

[0120] The refrigerant container 19 is a container capable of holding therein the first refrigerant or the second refrigerant. The refrigerant container 19 can be used to move the second refrigerant within the refrigerant circuit 10 while the first refrigerant is stored in the refrigerant container 19 or to move the first refrigerant within the refrigerant circuit 10 while the second refrigerant is stored in the refrigerant container 19. The refrigerant container 19 has a capacity such that the refrigerant container 19 can store the first refrigerant and store the second refrigerant. In the present embodiment, the refrigerant container 19 used to move the first refrigerant within the refrigerant circuit 10 while the second refrigerant is stored in the refrigerant container 19 will be described as an example.

[0121] The controller 7 controls the operation of the devices included in the heat-load circuit 90 and the refrigerant circuit 10. Specifically, the controller 7 includes a processor serving as a CPU provided for performing control, a memory, and the like.

[0122] In the refrigeration cycle apparatus 1a described above, the controller 7 controls the devices to execute a refrigeration cycle, thereby performing a cooling operation for processing a cooling load in the heat-load heat exchanger 91, a heating operation for processing a heating load in the heat-load heat exchanger 91, a cooling-to-heating transition operation, and a heating-to-cooling transition operation.

(2-1) Cooling Operation

[0123] During the cooling operation, as illustrated in Fig. 7, a two-stage refrigeration cycle operation is performed in which the first refrigerant is used in a heat-source-side refrigeration cycle and the second refrigerant is used in a use-side refrigeration cycle. In Fig. 7, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as an evaporator of the second refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, and the outdoor heat exchanger 18 is caused to function as a condenser of the first refrigerant.

[0124] Specifically, in this two-stage refrigeration cycle, all of the third on-off valve 43, the fourth on-off valve 44, the fifth on-off valve 45, the sixth on-off valve 46, the seventh on-off valve 47, the eighth on-off valve 48, and the ninth on-off valve 49 are controlled to be in a closed state to prevent mixing of the first refrigerant and the second refrigerant. Then, a connection state of the first switching mechanism 12 is switched to a connection state indicated by solid lines in Fig. 7, a connection state of the second switching mechanism 22 is switched to a connection state indicated by solid lines in Fig. 7, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the first expansion valve 15 is controlled such that the degree of superheating of the second refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the second expansion valve 16 is controlled such that the degree of superheating of the first refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0125] Accordingly, the first refrigerant discharged from the second compressor 21 is sent to the outdoor heat exchanger 18 via the switching valve 22a and the switching valve 22b of the second switching mechanism 22. The first refrigerant flowing through the outdoor heat exchanger 18 is condensed by heat exchange with the outdoor air supplied by the outdoor fan 9. The first refrigerant condensed in the outdoor heat exchanger 18 is decompressed in the second expansion valve 16, passes through the branch point G, and is sent to the second cascade flow path 17b of the cascade heat exchanger 17. When flowing through the second cascade flow path 17b of the cascade heat exchanger 17, the first refrigerant is evaporated by heat exchange with the second refrigerant flowing through the first cascade flow path 17a. The first refrigerant evaporated in the cascade heat exchanger 17 is sucked into the second compressor 21 via the switching valve 22b of the second switching mechanism 22. The second refrigerant discharged from the first compressor 11 is sent to the first cascade flow path 17a of the cascade heat exchanger 17 via the switching valve 12a and the switching valve 12b of the first switching mechanism 12. When flowing through the first cascade flow path 17a of the cascade heat exchanger 17, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the second cascade flow path 17b. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, passes through the branch point F, is decompressed in the first expansion valve 15, passes through the branch point A, and is sent to the first use flow path 13a of the use heat exchanger 13. The second refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is evaporated by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water cooled by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the cooling load. The second refrigerant evaporated in the first use flow path 13a of the use heat exchanger 13 is sucked into the first compressor 11 via the switching valve 12b of the first switching mechanism 12.

(2-2) Cooling-to-Heating Transition Operation

[0126] The refrigeration cycle apparatus 1a performs a cooling-to-heating transition operation including (a1) to (f1) below in this order to make a transition from a cycle state for performing the cooling operation to a cycle state for performing the heating operation.

(a1) First, the first expansion valve 15 is controlled to be in a fully closed state from the state in which the cooling operation is performed, and the first compressor 11 is operated, with the fourth on-off valve 44 opened. Here, the second compressor 21 and the like are operated such that the refrigeration cycle for the cooling operation using the first refrigerant is performed. As a result, an operation of recovering the second refrigerant into the refrigerant container 19 from below the refrigerant container 19 is performed. At this time, the sixth on-off valve 46 is controlled to switch between the open state and the closed state at predetermined time intervals, thereby allowing the gaseous second refrigerant in a flow path from an upper end of the refrigerant container 19 to the sixth on-off valve 46 to be sucked into the first compressor 11. This provides efficient recovery of the second refrigerant into the refrigerant container 19. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the refrigerant container 19.

(b 1) Then, the fourth on-off valve 44 is closed after the second refrigerant has been recovered into the refrigerant container 19 by a predetermined amount or more. After that, the switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the branch point E2 and the suction side of the first compressor 11 is connected to the first port of the switching valve 12b, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. Further, the switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the first port of the switching valve 22b and the suction side of the second compressor 21 is connected to the branch point D2, and the switching valve 22b is switched to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the outdoor heat exchanger 18. In this state, the sixth on-off valve 46 is controlled to be in an open state, and the first compressor 11 and the second compressor 21 are operated to heat and expel the second refrigerant remaining in the first cascade flow path 17a of the cascade heat exchanger 17 by using the heat of the first refrigerant. Then, the second refrigerant is collected in the refrigerant container 19 via the first compressor 11, the branch point E2, the sixth on-off valve 46, the branch point J, and the branch point K1. After this operation is continued for a predetermined period of time, the sixth on-off valve 46 is controlled to be in a closed state, and the recovery of the second refrigerant into the refrigerant container 19 is completed.

(c1) Then, the switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the first port of the switching valve 12b and the suction side of the first compressor 11 is connected to the branch point E2, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. In this state, the second expansion valve 16 is controlled to be in a fully closed state, the third on-off valve 43 is opened while the fourth on-off valve 44 and the fifth on-off valve 45 are maintained in the closed state, and the first compressor 11 and the second compressor 21 are operated. As a result, the first refrigerant existing in a portion from the second expansion valve 16 to the suction side of the second compressor 21 is sent to the first cascade flow path 17a of the cascade heat exchanger 17 via the second switching mechanism 22, the second cascade flow path 17b of the cascade heat exchanger 17, the branch point G, the branch point H2, the third on-off valve 43, the branch point H1, and the branch point F. Further, the first refrigerant is sucked into the first compressor 11 via the switching valve 12b of the first switching mechanism 12. Then, the first refrigerant discharged from the first compressor 11 is sent to the use heat exchanger 13 via the switching valve 12a of the first switching mechanism 12.

(d1) Then, the third on-off valve 43 is closed, and the eighth on-off valve 48 is opened. The switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the branch point D2 and the suction side of the second compressor 21 is connected to the first port of the switching valve 22b, and the switching valve 22b is switched to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the outdoor heat exchanger 18 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. In this state, the first compressor 11 and the second compressor 21 are operated to discharge, from the second compressor 21, the first refrigerant existing in a portion from the third on-off valve 43 to the suction side of the second compressor 21. Then, the first refrigerant is sucked into the first compressor 11 via the branch point D2, the eighth on-off valve 48, and the branch point D 1.

(e1) Then, the eighth on-off valve 48 is closed, the first expansion valve 15 is opened, with the opening degree thereof controlled. The switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the first port of the switching valve 12b and the suction side of the first compressor 11 is connected to the branch point E2, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13. Further, the fifth on-off valve 45 is opened, with the second expansion valve 16 maintained in the fully closed state. The switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the first port of the switching valve 22b and the suction side of the second compressor 21 is connected to the branch point D2, and the switching valve 22b is switched to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the outdoor heat exchanger 18 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. In this state, the first compressor 11 and the second compressor 21 are operated. As a result, the second refrigerant stored in the refrigerant container 19 is drawn into the second cascade flow path 17b of the cascade heat exchanger 17 via the branch point K2, the fifth on-off valve 45, the branch point H2, and the branch point G. At this time, the second refrigerant flowing through the second cascade flow path 17b of the cascade heat exchanger 17 is heated by heat exchange with the first refrigerant flowing through the first cascade flow path 17a of the cascade heat exchanger 17. After that, the heated second refrigerant is sent to the second compressor 21 via the switching valve 22b. The second refrigerant is further discharged from the second compressor 21, passes through the switching valve 22a and the switching valve 22b, and is then stored in the outdoor heat exchanger 18.

(f1) Finally, the fifth on-off valve 45 is closed and the ninth on-off valve 49 is opened, with the second expansion valve 16 maintained in the fully closed state while the connection state of the second switching mechanism 22 is maintained. The switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. In this state, the second compressor 21 is operated, and the first compressor 11 is operated or stopped. As a result, the gaseous second refrigerant remaining in an upper portion of the refrigerant container 19 can be sucked into the second compressor 21 via the branch point K1, the ninth on-off valve 49, the branch point D2, and the switching valve 22a. After the refrigerant container 19 is emptied through this operation, the ninth on-off valve 49 is closed.

[0127] Thus, the cooling-to-heating transition operation is completed.

(2-3) Heating Operation

[0128] During the heating operation, as illustrated in Fig. 8, a two-stage refrigeration cycle is performed in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. In Fig. 8, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as a condenser of the first refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, and the outdoor heat exchanger 18 is caused to function as an evaporator of the second refrigerant.

[0129] Specifically, in this two-stage refrigeration cycle, all of the third on-off valve 43, the fourth on-off valve 44, the fifth on-off valve 45, the sixth on-off valve 46, the seventh on-off valve 47, the eighth on-off valve 48, and the ninth on-off valve 49 are controlled to be in a closed state to prevent mixing of the first refrigerant and the second refrigerant. Then, a connection state of the switching valve 12a of the first switching mechanism 12 is changed to a state indicated by solid lines in Fig. 8, a connection state of the switching valve 12b of the first switching mechanism 12 is changed to a state indicated by broken lines in Fig. 8, a connection state of the switching valve 22a of the second switching mechanism 22 is changed to a state indicated by solid lines in Fig. 8, a connection state of the switching valve 22b of the second switching mechanism 22 is switched to a connection state indicated by broken lines in Fig. 8, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the first expansion valve 15 is controlled such that the degree of superheating of the first refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the second expansion valve 16 is controlled such that the degree of superheating of the second refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0130] Accordingly, the second refrigerant discharged from the second compressor 21 is sent to the cascade heat exchanger 17. When flowing through the second cascade flow path 17b, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the first cascade flow path 17a. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, is decompressed in the second expansion valve 16. After that, the second refrigerant is evaporated by heat exchange with the outdoor air supplied by the outdoor fan 9 in the outdoor heat exchanger 18, and is sucked into the second compressor 21. The first refrigerant discharged from the first compressor 11 is sent to the first use flow path 13a of the use heat exchanger 13 via the first switching mechanism 12. The first refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is condensed by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water heated by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the heating load. The first refrigerant condensed in the first use flow path 13a of the use heat exchanger 13 passes through the branch point A and is then decompressed in the first expansion valve 15. The first refrigerant decompressed by the first expansion valve 15 is evaporated, when passing through the first cascade flow path 17a of the cascade heat exchanger 17, by heat exchange with the second refrigerant flowing through the second cascade flow path 17b. The first refrigerant evaporated in the first cascade flow path 17a of the cascade heat exchanger 17 is sucked into the first compressor 11 via the first switching mechanism 12.

(2-4) Heating-to-Cooling Transition Operation

[0131] The refrigeration cycle apparatus 1a performs a heating-to-cooling transition operation including (a2) to (f2) below in this order to make a transition from a cycle state for performing the heating operation to a cycle state for performing the cooling operation.

(a2) First, the second expansion valve 16 is controlled to be in a fully closed state from the state in which the heating operation is performed, the fifth on-off valve 45 is controlled to be in an open state, and the second compressor 21 is operated. Here, the first compressor 11 and the like are operated such that the use-side refrigeration cycle for the heating operation using the first refrigerant is maintained. As a result, an operation of recovering the second refrigerant into the refrigerant container 19 from below the refrigerant container 19 is performed. At this time, the ninth on-off valve 49 is controlled to switch between the open state and the closed state at predetermined time intervals, thereby allowing the gaseous second refrigerant in a flow path from the upper end of the refrigerant container 19 to the ninth on-off valve 49 to be sucked into the second compressor 21. This provides efficient recovery of the second refrigerant into the refrigerant container 19. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the refrigerant container 19.

(b2) Then, the fifth on-off valve 45 is closed after the second refrigerant has been recovered into the refrigerant container 19 by a predetermined amount or more. After that, the switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the first port of the switching valve 12b and the suction side of the first compressor 11 is connected to the branch point E2, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13. Further, the switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the branch point D2 and the suction side of the second compressor 21 is connected to the first port of the switching valve 22b, and the switching valve 22b is switched to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the outdoor heat exchanger 18 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. In this state, the ninth on-off valve 49 is opened, and the first compressor 11 and the second compressor 21 are operated to heat and expel the second refrigerant remaining in the second cascade flow path 17b of the cascade heat exchanger 17 by using the heat of the first refrigerant. Then, the second refrigerant is collected in the refrigerant container 19 via the second compressor 21, the branch point D2, the ninth on-off valve 49, and the branch point K1. After this operation is continued for a predetermined period of time, the ninth on-off valve 49 is controlled to be in a closed state, and the recovery of the second refrigerant into the refrigerant container 19 is completed.

(c2) Then, the switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the first port of the switching valve 22b and the suction side of the second compressor 21 is connected to the branch point D2, and the switching valve 22b is changed to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the outdoor heat exchanger 18 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. In this state, the first expansion valve 15 is controlled to be in a fully closed state, the third on-off valve 43 is opened while the fourth on-off valve 44 and the fifth on-off valve 45 are maintained in the closed state, and the first compressor 11 and the second compressor 21 are operated. As a result, the first refrigerant existing in a portion from the first expansion valve 15 to the suction side of the first compressor 11 is sent to the second cascade flow path 17b of the cascade heat exchanger 17 via the first switching mechanism 12, the first cascade flow path 17a of the cascade heat exchanger 17, the branch point F, the branch point H1, the third on-off valve 43, the branch point H2, and the branch point G. Further, the first refrigerant is sucked into the second compressor 21 via the switching valve 22b of the second switching mechanism 22. The first refrigerant discharged from the second compressor 21 is sent to the outdoor heat exchanger 18 via the switching valve 22a of the second switching mechanism 22.

(d2) Then, the third on-off valve 43 is closed, the seventh on-off valve 47 is opened, the switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the branch point E2 and the suction side of the first compressor 11 is connected to the first port of the switching valve 12b, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. In this state, the first compressor 11 and the second compressor 21 are operated to discharge, from the first compressor 11, the first refrigerant existing in a portion from the third on-off valve 43 to the suction side of the first compressor 11. Then, the first refrigerant is sucked into the second compressor 21 through the branch point E2, the seventh on-off valve 47, and the branch point E1.

(e2) Then, the seventh on-off valve 47 is closed, the second expansion valve 16 is opened, with the opening degree thereof controlled. The switching valve 22a is switched to a state in which the discharge side of the second compressor 21 is connected to the first port of the switching valve 22b and the suction side of the second compressor 21 is connected to the branch point D2, and the switching valve 22b is switched to a state in which the fourth port of the switching valve 22a is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and the suction side of the second compressor 21 is connected to the gas refrigerant side of the outdoor heat exchanger 18. Further, the fourth on-off valve 44 is opened, with the first expansion valve 15 maintained in the fully closed state. The switching valve 12a is switched to a state in which the discharge side of the first compressor 11 is connected to the first port of the switching valve 12b and the suction side of the first compressor 11 is connected to the branch point E2, and the switching valve 12b is switched to a state in which the fourth port of the switching valve 12a is connected to the gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 and the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. In this state, the first compressor 11 and the second compressor 21 are operated. As a result, the second refrigerant stored in the refrigerant container 19 is drawn into the first cascade flow path 17a of the cascade heat exchanger 17 via the branch point K2, the fourth on-off valve 44, the branch point H1, and the branch point F. At this time, the second refrigerant flowing through the first cascade flow path 17a of the cascade heat exchanger 17 is heated by heat exchange with the first refrigerant flowing through the second cascade flow path 17b of the cascade heat exchanger 17. After that, the heated second refrigerant is sent to the first compressor 11 via the switching valve 12b. The second refrigerant is further discharged from the first compressor 11, passes through the switching valve 12a and the switching valve 12b, and is then stored in the use heat exchanger 13.

(f2) Finally, the fourth on-off valve 44 is closed and the sixth on-off valve 46 is opened, with the first expansion valve 15 maintained in the fully closed state while the connection state of the first switching mechanism 12 is maintained. In this state, the first compressor 11 is operated, and the second compressor 21 is operated or stopped. As a result, the gaseous second refrigerant remaining in the upper portion of the refrigerant container 19 can be sucked into the first compressor 11 via the branch point K 1, the branch point J, the sixth on-off valve 46, the branch point E2, and the switching valve 12a. After the refrigerant container 19 is emptied through this operation, the sixth on-off valve 46 is closed.

[0132] Thus, the heating-to-cooling transition operation is completed.

(2-5) Features of Second Embodiment

[0133] In the refrigeration cycle apparatus 1a according to the second embodiment, the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP) and the second refrigerant having a sufficiently low ozone depletion potential (ODP) and a sufficiently low global warming potential (GWP). Thus, global environmental deterioration can be reduced.

[0134] In addition, even when the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP), the two-stage refrigeration cycle in which the second refrigerant, which is a high-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the first refrigerant, which is a low-pressure refrigerant, is used in the use-side refrigeration cycle is performed as the heating operation. This makes it easier to secure heating operation capacity than a single-stage refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant.

[0135] Further, the refrigerant circuit 10 uses carbon dioxide as the second refrigerant. However, during the cooling operation, a single-stage refrigeration cycle using the second refrigerant is not performed, nor is performed a two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. Instead of this, a two-stage refrigeration cycle in which the first refrigerant, which is a low-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the second refrigerant, which is a high-pressure refrigerant, is used in the use-side refrigeration cycle is performed. This makes it possible to perform the cooling operation without causing a reduction in COP, as in the case of performing a single-stage refrigeration cycle using a carbon dioxide refrigerant, which is a high-pressure refrigerant, or as in the case of performing a two-stage refrigeration cycle in which carbon dioxide, which is a high-pressure refrigerant, is used in the heat-source-side cycle, the reduction being due to the pressure of the carbon dioxide refrigerant exceeding the critical pressure. It is also possible to reduce the compression strength standards required for the components of the refrigerant circuit 10 in which carbon dioxide, which is a high-pressure refrigerant, is used.

(3) Third Embodiment

[0136] Fig. 9 is a schematic configuration diagram of a refrigeration cycle apparatus 1b according to a third embodiment. Fig. 10 is a functional block configuration diagram of the refrigeration cycle apparatus 1b according to the third embodiment.

[0137] The refrigeration cycle apparatus 1b is an apparatus used to process a heat load through a vapor-compression refrigeration cycle operation. The refrigeration cycle apparatus 1b includes a heat-load circuit 90, a refrigerant circuit 10, an outdoor fan 9, and a controller 7.

[0138] The heat load to be processed by the refrigeration cycle apparatus 1b and the heat-load circuit 90 are similar to those according to the first embodiment.

[0139] In the present embodiment, as described below, a use heat exchanger 13 includes a first use flow path 13a through which a first refrigerant or a second refrigerant flowing through the refrigerant circuit 10 passes. Water flowing through a heat-load flow path 13b of the use heat exchanger 13 exchanges heat with the first refrigerant or second refrigerant flowing through the first use flow path 13a. As a result, the water is cooled during a cooling operation and is heated during a heating operation.

[0140] The refrigerant circuit 10 includes a first compressor 11, a second compressor 21, a first switching mechanism 12, a second switching mechanism 22, the use heat exchanger 13 shared with the heat-load circuit 90, a first expansion valve 15, a second expansion valve 16, a third expansion valve 33, a fourth expansion valve 34, a fifth expansion valve 35, a sixth expansion valve 36, a cascade heat exchanger 17, an outdoor heat exchanger 18, a first receiver 19a, a second receiver 19b, a tenth on-off valve 50, an eleventh on-off valve 51, a twelfth on-off valve 52, and a thirteenth on-off valve 53.

[0141] The refrigerant circuit 10 is filled with the first refrigerant, which is a low-pressure refrigerant, and the second refrigerant, which is a high-pressure refrigerant, as refrigerants in a substantially separated state. The first refrigerant is a refrigerant having 1 MPa or less at 30°C, and is a refrigerant including, for example, at least one of R1234yf or R1234ze. The first refrigerant may include only R1234yf or may include only R1234ze. The second refrigerant is a refrigerant having 1.5 MPa or more at 30°C. For example, the second refrigerant may include carbon dioxide, or may include only carbon dioxide.

[0142] The specific configuration of the first compressor 11 is similar to that according to the first embodiment. A discharge side of the first compressor 11 is connected to a first port of the first switching mechanism 12. A suction side of the first compressor 11 is connected to a second port of the first switching mechanism 12.

[0143] In the present embodiment, the first switching mechanism 12 is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the first switching mechanism 12 is connected to a branch point P. The branch point P is connected to a flow path extending from the discharge side of the first compressor 11, a flow path extending from a gas refrigerant side of a first cascade flow path 17a of the cascade heat exchanger 17, and a flow path extending from the first port of the first switching mechanism 12. The second port of the first switching mechanism 12 is connected to the suction side of the first compressor 11. The third port of the first switching mechanism 12 is connected to a flow path extending from the eleventh on-off valve 51. The fourth port of the first switching mechanism 12 is connected to a flow path extending from the tenth on-off valve 50.

[0144] The first switching mechanism 12 switches between a state in which the branch point P is connected to the eleventh on-off valve 51 and the suction side of the first compressor 11 is connected to the tenth on-off valve 50 and a state in which the branch point P is connected to the tenth on-off valve 50 and the suction side of the first compressor 11 is connected to the eleventh on-off valve 51.

[0145] The tenth on-off valve 50 is an electromagnetic valve controllable to switch between an open state and a closed state. The tenth on-off valve 50 is disposed at a certain point in a flow path connecting the fourth port of the first switching mechanism 12 and a branch point M.

[0146] The branch point M is connected to a flow path extending from the tenth on-off valve 50, a flow path extending from the thirteenth on-off valve 53, and a flow path extending from a gas refrigerant side of the first use flow path 13a of the use heat exchanger 13.

[0147] The gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 through which the refrigerant flowing through the refrigerant circuit 10 passes is connected to a flow path extending from the branch point M. A liquid refrigerant side of the first use flow path 13a is connected to a flow path extending from a branch point A.

[0148] At the branch point A, a flow path extending from the liquid refrigerant side of the first use flow path 13a, a flow path extending to the side of the first expansion valve 15 opposite to a branch point F side, and a flow path extending from the sixth expansion valve 36 are connected.

[0149] The first expansion valve 15 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the first expansion valve 15 is disposed at a certain point in a flow path connecting the branch point A and the branch point F.

[0150] The branch point F connects a flow path extending from the first expansion valve 15, a flow path extending from the fifth expansion valve 35, and a flow path extending from an upper end of the first receiver 19a.

[0151] The first receiver 19a is a refrigerant container that stores a refrigerant therein. The first receiver 19a is disposed at a certain point in a flow path connecting the branch point F and the third expansion valve 33. In the present embodiment, the first receiver 19a stores the second refrigerant.

[0152] The third expansion valve 33 is configured as an electronic expansion valve that is adjustable in valve opening degree. The third expansion valve 33 is disposed at a certain point in a flow path connecting a lower end of the first receiver 19a and a liquid refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17.

[0153] The cascade heat exchanger 17 is a cascade heat exchanger that includes the first cascade flow path 17a through which one of the first refrigerant and the second refrigerant passes and a second cascade flow path 17b through which the other of the first refrigerant and the second refrigerant passes, and that exchanges heat between the first refrigerant and the second refrigerant. In the cascade heat exchanger 17, the first cascade flow path 17a and the second cascade flow path 17b are independent of each other, and the first refrigerant and the second refrigerant do not mix with each other in the cascade heat exchanger 17. The gas refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the branch point P. The liquid refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the third expansion valve 33. A gas refrigerant side of the second cascade flow path 17b is connected to a flow path extending from a second port of the second switching mechanism 22 and a flow path extending from a suction side of the second compressor 21. A liquid refrigerant side of the second cascade flow path 17b is connected to a flow path extending from the fourth expansion valve 34.

[0154] The specific configuration of the second compressor 21 is similar to that according to the first embodiment. A discharge side of the second compressor 21 is connected to a first port of the second switching mechanism 22. The suction side of the second compressor 21 is connected to the second port of the second switching mechanism 22 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17.

[0155] In the present embodiment, the second switching mechanism 22 is constituted by a four-way switching valve having four ports including the first port, the second port, a third port, and a fourth port. The first port of the second switching mechanism 22 is connected to the discharge side of the second compressor 21. The second port of the second switching mechanism 22 is connected to the suction side of the second compressor 21 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. The third port of the second switching mechanism 22 is connected to a flow path extending from the thirteenth on-off valve 53. The fourth port of the second switching mechanism 22 is connected to a flow path extending from the twelfth on-off valve 52.

[0156] The second switching mechanism 22 switches between a state in which the discharge side of the second compressor 21 is connected to the twelfth on-off valve 52 and the suction side of the second compressor 21 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 are connected to the thirteenth on-off valve 53 and a state in which the discharge side of the second compressor 21 is connected to the thirteenth on-off valve 53 and the suction side of the second compressor 21 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 are connected to the twelfth on-off valve 52.

[0157] The liquid refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 is connected to a flow path extending from the fourth expansion valve 34.

[0158] The fourth expansion valve 34 is configured as an electronic expansion valve that is adjustable in valve opening degree. The fourth expansion valve 34 is disposed between the liquid refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and an upper end of the second receiver 19b.

[0159] The second receiver 19b is a refrigerant container that stores a refrigerant therein. The second receiver 19b is disposed at a certain point in a flow path connecting a branch point G and the fourth expansion valve 34. In the present embodiment, the second receiver 19b stores the first refrigerant.

[0160] The branch point G is connected to a flow path extending from a lower end of the second receiver 19b, a flow path extending from the sixth expansion valve 36, and a flow path extending from the second expansion valve 16.

[0161] The second expansion valve 16 is configured as an electronic expansion valve that is adjustable in valve opening degree. The second expansion valve 16 is disposed between the branch point G and a branch point B.

[0162] The branch point B is connected to a flow path extending from the second expansion valve 16, a flow path extending from a liquid refrigerant side of the outdoor heat exchanger 18, and a flow path extending from the fifth expansion valve 35.

[0163] The outdoor heat exchanger 18 includes a plurality of heat transfer tubes and a plurality of fins joined to the plurality of heat transfer tubes. In the present embodiment, the outdoor heat exchanger 18 is arranged outdoors. A refrigerant flowing through the outdoor heat exchanger 18 exchanges heat with air sent to the outdoor heat exchanger 18. The outdoor heat exchanger 18 is disposed at a certain point in a flow path connecting the branch point B and a branch point N.

[0164] The outdoor fan 9 generates an air flow of outdoor air passing through the outdoor heat exchanger 18.

[0165] The branch point N is connected to a flow path extending from a gas refrigerant side of the outdoor heat exchanger 18, a flow path extending from the twelfth on-off valve 52, and a flow path extending from the eleventh on-off valve 51.

[0166] The eleventh on-off valve 51 is an electromagnetic valve controllable to switch between an open state and a closed state. The eleventh on-off valve 51 is disposed at a certain point in a flow path connecting the third port of the first switching mechanism 12 and the branch point N.

[0167] The twelfth on-off valve 52 is an electromagnetic valve controllable to switch between an open state and a closed state. The twelfth on-off valve 52 is disposed at a certain point in a flow path connecting the fourth port of the second switching mechanism 22 and the branch point N.

[0168] The thirteenth on-off valve 53 is an electromagnetic valve controllable to switch between an open state and a closed state. The thirteenth on-off valve 53 is disposed at a certain point in a flow path connecting the third port of the second switching mechanism 22 and the branch point M.

[0169] The fifth expansion valve 35 is configured as an electronic expansion valve that is adjustable in valve opening degree. The fifth expansion valve 35 is disposed at a certain point in a flow path connecting the branch point F and the branch point B.

[0170] The sixth expansion valve 36 is configured as an electronic expansion valve that is adjustable in valve opening degree. The sixth expansion valve 36 is disposed at a certain point in a flow path connecting the branch point A and the branch point G.

[0171] The controller 7 controls the operation of the devices included in the heat-load circuit 90 and the refrigerant circuit 10. Specifically, the controller 7 includes a processor serving as a CPU provided for performing control, a memory, and the like.

[0172] In the refrigeration cycle apparatus 1b described above, the controller 7 controls the devices to execute a refrigeration cycle, thereby performing a cooling operation for processing a cooling load in the heat-load heat exchanger 91, a heating operation for processing a heating load in the heat-load heat exchanger 91, a cooling-to-heating transition operation, and a heating-to-cooling transition operation.

(3-1) Cooling Operation

[0173] During the cooling operation, as illustrated in Fig. 11, a two-stage refrigeration cycle operation is performed in which the first refrigerant is used in a heat-source-side refrigeration cycle and the second refrigerant is used in a use-side refrigeration cycle. In Fig. 11, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as an evaporator of the second refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, and the outdoor heat exchanger 18 is caused to function as a condenser of the first refrigerant.

[0174] Specifically, in this two-stage refrigeration cycle, all of the eleventh on-off valve 51 and the thirteenth on-off valve 53 are controlled to be in a closed state, and the fifth expansion valve 35 and the sixth expansion valve 36 are controlled to be in a fully closed state to prevent mixing of the first refrigerant and the second refrigerant. The tenth on-off valve 50 and the twelfth on-off valve 52 are controlled to be in an open state. Then, a connection state of the first switching mechanism 12 is switched to a connection state indicated by solid lines in Fig. 11, a connection state of the second switching mechanism 22 is switched to a connection state indicated by solid lines in Fig. 11, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the first expansion valve 15 is controlled such that the degree of superheating of the second refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the fourth expansion valve 34 is controlled such that the degree of superheating of the first refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0175] Accordingly, the first refrigerant discharged from the second compressor 21 is sent to the outdoor heat exchanger 18 via the second switching mechanism 22 and the twelfth on-off valve 52. The first refrigerant flowing through the outdoor heat exchanger 18 is condensed by heat exchange with the outdoor air supplied by the outdoor fan 9. The first refrigerant condensed in the outdoor heat exchanger 18 passes through the second expansion valve 16, which is controlled to be in a fully open state. After that, the first refrigerant passes through the branch point G and flows into the second receiver 19b. The refrigerant having flowed out of the second receiver 19b is decompressed in the fourth expansion valve 34 and is sent to the second cascade flow path 17b of the cascade heat exchanger 17. When flowing through the second cascade flow path 17b of the cascade heat exchanger 17, the first refrigerant is evaporated by heat exchange with the second refrigerant flowing through the first cascade flow path 17a. The first refrigerant evaporated in the cascade heat exchanger 17 is sucked into the second compressor 21. The second refrigerant discharged from the first compressor 11 passes through the branch point P and is sent to the first cascade flow path 17a of the cascade heat exchanger 17. When flowing through the first cascade flow path 17a of the cascade heat exchanger 17, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the second cascade flow path 17b. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, passes through the third expansion valve 33, which is controlled to be in a fully open state, and flows into the first receiver 19a. The second refrigerant having flowed out of the first receiver 19a is decompressed in the first expansion valve 15, passes through the branch point A, and is sent to the first use flow path 13a of the use heat exchanger 13. The second refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is evaporated by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water cooled by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the cooling load. The second refrigerant evaporated in the first use flow path 13a of the use heat exchanger 13 is sucked into the first compressor 11 via the tenth on-off valve 50 and the first switching mechanism 12.

(3-2) Cooling-to-Heating Transition Operation

[0176] The refrigeration cycle apparatus 1b performs a cooling-to-heating transition operation including (a3) to (b3) below in this order to make a transition from a cycle state for performing the cooling operation to a cycle state for performing the heating operation.

(a3) First, the first compressor 11 is operated after the first expansion valve 15 is controlled to be in a fully closed state from the state in which the cooling operation is performed. Here, the second compressor 21 and the like are operated such that the refrigeration cycle for the cooling operation using the first refrigerant is performed. As a result, an operation of recovering the second refrigerant into the first receiver 19a from below the first receiver 19a is performed. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the first receiver 19a.

(b3) Then, the tenth on-off valve 50 is closed and the first compressor 11 is stopped after the second refrigerant has been recovered into the first receiver 19a by a predetermined amount or more. After that, the second switching mechanism 22 is switched to a state in which the discharge side of the second compressor 21 is connected to the thirteenth on-off valve 53 and the suction side of the second compressor 21 is connected to the twelfth on-off valve 52 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger

17. Further, the twelfth on-off valve 52 and the thirteenth on-off valve 53 are controlled to be in an open state, the second expansion valve 16 and the fourth expansion valve 34 are controlled to be in a fully closed state, and the sixth expansion valve 36 is controlled to be in an open state. In this state, the second compressor 21 is operated to heat and expel the first refrigerant remaining in the outdoor heat exchanger 18 by using the heat of the air obtained from the outdoor fan 9. Then, the first refrigerant is sucked into the second compressor 21 via the twelfth on-off valve 52 and the second switching mechanism 22. The first refrigerant remaining in the second cascade flow path 17b of the cascade heat exchanger 17 is also sucked into the second compressor 21. The first refrigerant discharged from the second compressor 21 is sent to the first use flow path 13a of the use heat exchanger 13 via the second switching mechanism 22, the thirteenth on-off valve 53, and the branch point M. Further, the first refrigerant condenses when flowing through the first use flow path 13a of the use heat exchanger 13, and flows into the second receiver 19b via the branch point A and the sixth expansion valve 36. After this operation is continued for a predetermined period of time, the twelfth on-off valve 52 is controlled to be in a closed state, and the fourth expansion valve 34 is controlled to be in an open state.

[0177] Thus, the cooling-to-heating transition operation is completed.

(3-3) Heating Operation

[0178] During the heating operation, as illustrated in Fig. 12, a two-stage refrigeration cycle is performed in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. In Fig. 12, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as a condenser of the first refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, and the outdoor heat exchanger 18 is caused to function as an evaporator of the second refrigerant.

[0179] Specifically, in this two-stage refrigeration cycle, the tenth on-off valve 50 and the twelfth on-off valve 52 are controlled to be in a closed state, and the first expansion valve 15 and the second expansion valve 16 are controlled to be in a fully closed state to prevent mixing of the first refrigerant and the second refrigerant. Then, a connection state of the first switching mechanism 12 is changed to a state indicated by broken lines in Fig. 12, a connection state of the second switching mechanism 22 is switched to a connection state indicated by broken lines in Fig. 12, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the fifth expansion valve 35 is controlled such that the degree of superheating of the second refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the fourth expansion valve 34 is controlled such that the degree of superheating of the first refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0180] Accordingly, the second refrigerant discharged from the first compressor 11 is sent to the cascade heat exchanger 17. When flowing through the first cascade flow path 17a, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the second cascade flow path 17b. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, is decompressed in the fifth expansion valve 35 via the third expansion valve 33, the first receiver 19a, and the branch point F. The second refrigerant decompressed in the fifth expansion valve 35 is sent to the outdoor heat exchanger 18 via the branch point B. The second refrigerant is evaporated by heat exchange with the outdoor air supplied by the outdoor fan 9 in the outdoor heat exchanger 18, and is sucked into the first compressor 11 via the branch point N, the eleventh on-off valve 51, and the first switching mechanism 12. The first refrigerant discharged from the second compressor 21 is sent to the first use flow path 13a of the use heat exchanger 13 via the second switching mechanism 22, the thirteenth on-off valve 53, and the branch point M. The first refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is condensed by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water heated by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the heating load. The first refrigerant condensed in the first use flow path 13a of the use heat exchanger 13 passes through the branch point A. After that, the first refrigerant passes through the sixth expansion valve 36 and flows into the second receiver 19b. The first refrigerant having flowed out of the second receiver 19b is decompressed in the fourth expansion valve 34. The first refrigerant decompressed by the fourth expansion valve 34 is evaporated, when passing through the second cascade flow path 17b of the cascade heat exchanger 17, by heat exchange with the second refrigerant flowing through the first cascade flow path 17a. The first refrigerant evaporated in the second cascade flow path 17b of the cascade heat exchanger 17 is sucked into the second compressor 21.

(3-4) Heating-to-Cooling Transition Operation

[0181] The refrigeration cycle apparatus 1b performs a heating-to-cooling transition operation including (a4) to (c4) below in this order to make a transition from a cycle state for performing the heating operation to a cycle state for performing the cooling operation.

(a4) First, the fifth expansion valve 35 is controlled to be in a fully closed state from the state in which the heating operation is performed, and the first compressor 11 is operated. Here, the second compressor 21 and the like are operated such that the use-side refrigeration cycle for the heating operation using the first refrigerant is maintained. Accordingly, an operation of, while sucking the second refrigerant in the outdoor heat exchanger 18 into the first compressor 11, causing the second refrigerant discharged from the first compressor 11 to radiate heat in the first cascade flow path 17a of the cascade heat exchanger 17, causing the second refrigerant to flow into the first receiver 19a, and recovering the second refrigerant into the first receiver 19a is performed. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the first receiver 19a.

(b4) Then, the eleventh on-off valve 51 is closed and the first compressor 11 is stopped after the second refrigerant has been recovered into the first receiver 19a by a predetermined amount or more. After that, the second switching mechanism 22 is switched to a state in which the discharge side of the second compressor 21 is connected to the twelfth on-off valve 52 and the suction side of the second compressor 21 is connected to the thirteenth on-off valve 53 and the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. Then, the sixth expansion valve 36 and the fourth expansion valve 34 are controlled to be in a fully closed state, and the second expansion valve 16 is controlled to be in a fully open state. In this state, the second compressor 21 is operated to suck the first refrigerant remaining in and around the first use flow path 13a of the use heat exchanger 13 into the second compressor 21 and discharge the first refrigerant from the second compressor 21. As a result, the first refrigerant is condensed in the outdoor heat exchanger 18. The first refrigerant condensed in the outdoor heat exchanger 18 begins to accumulate in the second receiver 19b. Then, this operation is continued for a predetermined period of time.

(c4) Then, after a predetermined amount or more of the first refrigerant has accumulated in the second receiver 19b, the thirteenth on-off valve 53 is controlled to be in a closed state. Then, the first switching mechanism 12 is switched to a state in which the discharge side of the first compressor 11 is connected to the eleventh on-off valve 51 and the suction side of the first compressor 11 is connected to the tenth on-off valve 50, the tenth on-off valve 50 is controlled to be in an open state, and the first expansion valve 15 is controlled to have a predetermined valve opening degree.

[0182] Thus, the heating-to-cooling transition operation is completed.

(3-5) Features of Third Embodiment

[0183] In the refrigeration cycle apparatus 1b according to the third embodiment, the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP) and the second refrigerant having a sufficiently low ozone depletion potential (ODP) and a sufficiently low global warming potential (GWP). Thus, global environmental deterioration can be reduced.

[0184] In addition, even when the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP), the two-stage refrigeration cycle in which the second refrigerant, which is a high-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the first refrigerant, which is a low-pressure refrigerant, is used in the use-side refrigeration cycle is performed as the heating operation. This makes it easier to secure heating operation capacity than a single-stage refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant.

[0185] Further, the refrigerant circuit 10 uses carbon dioxide as the second refrigerant. However, during the cooling operation, a single-stage refrigeration cycle using the second refrigerant is not performed, nor is performed a two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. Instead of this, a two-stage refrigeration cycle in which the first refrigerant, which is a low-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the second refrigerant, which is a high-pressure refrigerant, is used in the use-side refrigeration cycle is performed. This makes it possible to perform the cooling operation without causing a reduction in COP, as in the case of performing a single-stage refrigeration cycle using a carbon dioxide refrigerant, which is a high-pressure refrigerant, or as in the case of performing a two-stage refrigeration cycle in which carbon dioxide, which is a high-pressure refrigerant, is used in the heat-source-side cycle, the reduction being due to the pressure of the carbon dioxide refrigerant exceeding the critical pressure. It is also possible to reduce the compression strength standards required for the components of the refrigerant circuit 10 in which carbon dioxide, which is a high-pressure refrigerant, is used.

[0186] In the refrigeration cycle apparatus 1b according to the third embodiment, furthermore, the first refrigerant and the second refrigerant can be collected by using the first receiver 19a and the second receiver 19b used in the heat-source-side refrigeration cycle and the use-side refrigeration cycle. This eliminates the need to separately secure the refrigerant container 19 as described in the second embodiment, which is not used in the heat-source-side refrigeration cycle or the use-side refrigeration cycle.

(4) Fourth Embodiment

[0187] Fig. 13 is a schematic configuration diagram of a refrigeration cycle apparatus 1c according to a fourth embodiment. Fig. 14 is a functional block configuration diagram of the refrigeration cycle apparatus 1c according to the fourth embodiment.

[0188] The refrigeration cycle apparatus 1c is an apparatus used to process a heat load through a vapor-compression refrigeration cycle operation. The refrigeration cycle apparatus 1c includes a heat-load circuit 90, a refrigerant circuit 10, an outdoor fan 9, and a controller 7.

[0189] The heat load to be processed by the refrigeration cycle apparatus 1c and the heat-load circuit 90 are similar to those according to the first embodiment.

[0190] In the present embodiment, as described below, a use heat exchanger 13 includes a first use flow path 13a through which a first refrigerant or a second refrigerant flowing through the refrigerant circuit 10 passes. Water flowing through a heat-load flow path 13b of the use heat exchanger 13 exchanges heat with the first refrigerant or second refrigerant flowing through the first use flow path 13a. As a result, the water is cooled during a cooling operation and is heated during a heating operation.

[0191] The refrigerant circuit 10 includes a first compressor 11, a second compressor 21, a first switching mechanism 12, a second switching mechanism 22, the use heat exchanger 13 shared with the heat-load circuit 90, a first expansion valve 15, a second expansion valve 16, a third expansion valve 33, a fourth expansion valve 34, a fifth expansion valve 35, a sixth expansion valve 36, a cascade heat exchanger 17, an outdoor heat exchanger 18, a first receiver 19a, a second receiver 19b, a fourteenth on-off valve 54, a fifteenth on-off valve 55, a sixteenth on-off valve 56, and a seventeenth on-off valve 57.

[0192] The refrigerant circuit 10 is filled with the first refrigerant, which is a low-pressure refrigerant, and the second refrigerant, which is a high-pressure refrigerant, as refrigerants in a substantially separated state. The first refrigerant is a refrigerant having 1 MPa or less at 30°C, and is a refrigerant including, for example, at least one of R1234yf or R1234ze. The first refrigerant may include only R1234yf or may include only R1234ze. The second refrigerant is a refrigerant having 1.5 MPa or more at 30°C. For example, the second refrigerant may include carbon dioxide, or may include only carbon dioxide.

[0193] The specific configuration of the first compressor 11 is similar to that according to the first embodiment. A discharge side of the first compressor 11 is connected to a switching valve 12c, a switching valve 12d, and a switching valve 12e of the first switching mechanism 12. A suction side of the first compressor 11 is connected to different ports of the switching valve 12c, the switching valve 12d, and the switching valve 12e of the first switching mechanism 12.

[0194] The first switching mechanism 12 includes the switching valve 12c, the switching valve 12d, and the switching valve 12e, which are disposed in parallel to each other on the discharge side of the first compressor 11. In the present embodiment, the switching valve 12c, the switching valve 12d, and the switching valve 12e are each constituted by a three-way valve. The switching valve 12c switches between a state in which the discharge side of the first compressor 11 is connected to the fourteenth on-off valve 54 and a state in which the suction side of the first compressor 11 is connected to the fourteenth on-off valve 54. The switching valve 12d switches between a state in which the discharge side of the first compressor 11 is connected to a gas refrigerant side of a first cascade flow path 17a of the cascade heat exchanger 17 and a state in which the suction side of the first compressor 11 is connected to the gas refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17. The switching valve 12e switches between a state in which the discharge side of the first compressor 11 is connected to the sixteenth on-off valve 56 and a state in which the suction side of the first compressor 11 is connected to the sixteenth on-off valve 56.

[0195] The fourteenth on-off valve 54 is an electromagnetic valve controllable to switch between an open state and a closed state. The fourteenth on-off valve 54 is disposed at a certain point in a flow path connecting the switching valve 12c of the first switching mechanism 12 and a branch point M.

[0196] The branch point M is connected to a flow path extending from the fourteenth on-off valve 54, a flow path extending from the fifteenth on-off valve 55, and a flow path extending from a gas refrigerant side of the first use flow path 13a of the use heat exchanger 13.

[0197] The gas refrigerant side of the first use flow path 13a of the use heat exchanger 13 through which the refrigerant flowing through the refrigerant circuit 10 passes is connected to a flow path extending from the branch point M. A liquid refrigerant side of the first use flow path 13a is connected to a flow path extending from a branch point A.

[0198] At the branch point A, a flow path extending from the liquid refrigerant side of the first use flow path 13a, a flow path extending to the side of the first expansion valve 15 opposite to a branch point F side, and a flow path extending from the sixth expansion valve 36 are connected.

[0199] The first expansion valve 15 is configured as an electronic expansion valve that is adjustable in valve opening degree. In the refrigerant circuit 10, the first expansion valve 15 is disposed at a certain point in a flow path connecting the branch point A and the branch point F.

[0200] The branch point F connects a flow path extending from the first expansion valve 15, a flow path extending from the fifth expansion valve 35, and a flow path extending from an upper end of the first receiver 19a.

[0201] The first receiver 19a is a refrigerant container that stores a refrigerant therein. The first receiver 19a is disposed at a certain point in a flow path connecting the branch point F and the third expansion valve 33. In the present embodiment, the first receiver 19a stores the second refrigerant.

[0202] The third expansion valve 33 is configured as an electronic expansion valve that is adjustable in valve opening degree. The third expansion valve 33 is disposed at a certain point in a flow path connecting a lower end of the first receiver 19a and a liquid refrigerant side of the first cascade flow path 17a of the cascade heat exchanger 17.

[0203] The cascade heat exchanger 17 is a cascade heat exchanger that includes the first cascade flow path 17a through which one of the first refrigerant and the second refrigerant passes and a second cascade flow path 17b through which the other of the first refrigerant and the second refrigerant passes, and that exchanges heat between the first refrigerant and the second refrigerant. In the cascade heat exchanger 17, the first cascade flow path 17a and the second cascade flow path 17b are independent of each other, and the first refrigerant and the second refrigerant do not mix with each other in the cascade heat exchanger 17. The gas refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the switching valve 12d of the first switching mechanism 12. The liquid refrigerant side of the first cascade flow path 17a is connected to a flow path extending from the third expansion valve 33. A gas refrigerant side of the second cascade flow path 17b is connected to a flow path extending from a switching valve 22d of the second switching mechanism 22. A liquid refrigerant side of the second cascade flow path 17b is connected to a flow path extending from the fourth expansion valve 34.

[0204] The specific configuration of the second compressor 21 is similar to that according to the first embodiment. A discharge side of the second compressor 21 is connected to a switching valve 22c, the switching valve 22d, and a switching valve 22e of the second switching mechanism 22. A suction side of the second compressor 21 is connected to different ports of the switching valve 22c, the switching valve 22d, and the switching valve 22e of the second switching mechanism 22.

[0205] The second switching mechanism 22 includes the switching valve 22c, the switching valve 22d, and the switching valve 22e, which are disposed in parallel to each other on the discharge side of the second compressor 21. In the present embodiment, the switching valve 22c, the switching valve 22d, and the switching valve 22e are each constituted by a three-way valve. The switching valve 22c switches between a state in which the discharge side of the second compressor 21 is connected to the fifteenth on-off valve 55 and a state in which the suction side of the second compressor 21 is connected to the fifteenth on-off valve 55. The switching valve 22d switches between a state in which the discharge side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and a state in which the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. The switching valve 22e switches between a state in which the discharge side of the second compressor 21 is connected to the seventeenth on-off valve 57 and a state in which the suction side of the second compressor 21 is connected to the seventeenth on-off valve 57.

[0206] The liquid refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 is connected to a flow path extending from the fourth expansion valve 34.

[0207] The fourth expansion valve 34 is configured as an electronic expansion valve that is adjustable in valve opening degree. The fourth expansion valve 34 is disposed between the liquid refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17 and an upper end of the second receiver 19b.

[0208] The second receiver 19b is a refrigerant container that stores a refrigerant therein. The second receiver 19b is disposed at a certain point in a flow path connecting a branch point G and the fourth expansion valve 34. In the present embodiment, the second receiver 19b stores the first refrigerant.

[0209] The branch point G is connected to a flow path extending from a lower end of the second receiver 19b, a flow path extending from the sixth expansion valve 36, and a flow path extending from the second expansion valve 16.

[0210] The second expansion valve 16 is configured as an electronic expansion valve that is adjustable in valve opening degree. The second expansion valve 16 is disposed between the branch point G and a branch point B.

[0211] The branch point B is connected to a flow path extending from the second expansion valve 16, a flow path extending from a liquid refrigerant side of the outdoor heat exchanger 18, and a flow path extending from the fifth expansion valve 35.

[0212] The outdoor heat exchanger 18 includes a plurality of heat transfer tubes and a plurality of fins j oined to the plurality of heat transfer tubes. In the present embodiment, the outdoor heat exchanger 18 is arranged outdoors. A refrigerant flowing through the outdoor heat exchanger 18 exchanges heat with air sent to the outdoor heat exchanger 18. The outdoor heat exchanger 18 is disposed at a certain point in a flow path connecting the branch point B and a branch point N.

[0213] The outdoor fan 9 generates an air flow of outdoor air passing through the outdoor heat exchanger 18.

[0214] The branch point N is connected to a flow path extending from a gas refrigerant side of the outdoor heat exchanger 18, a flow path extending from the sixteenth on-off valve 56, and a flow path extending from the seventeenth on-off valve 57.

[0215] The fifteenth on-off valve 55 is an electromagnetic valve controllable to switch between an open state and a closed state. The fifteenth on-off valve 55 is disposed at a certain point in a flow path connecting the switching valve 22c of the second switching mechanism 22 and a branch point M.

[0216] The sixteenth on-off valve 56 is an electromagnetic valve controllable to switch between an open state and a closed state. The sixteenth on-off valve 56 is disposed at a certain point in a flow path connecting the switching valve 12e of the first switching mechanism 12 and the branch point N.

[0217] The seventeenth on-off valve 57 is an electromagnetic valve controllable to switch between an open state and a closed state. The seventeenth on-off valve 57 is disposed at a certain point in a flow path connecting the switching valve 22e of the second switching mechanism 22 and the branch point N.

[0218] The fifth expansion valve 35 is configured as an electronic expansion valve that is adjustable in valve opening degree. The fifth expansion valve 35 is disposed at a certain point in a flow path connecting the branch point F and the branch point B.

[0219] The sixth expansion valve 36 is configured as an electronic expansion valve that is adjustable in valve opening degree. The sixth expansion valve 36 is disposed at a certain point in a flow path connecting the branch point A and the branch point G.

[0220] The controller 7 controls the operation of the devices included in the heat-load circuit 90 and the refrigerant circuit 10. Specifically, the controller 7 includes a processor serving as a CPU provided for performing control, a memory, and the like.

[0221] In the refrigeration cycle apparatus 1c described above, the controller 7 controls the devices to execute a refrigeration cycle, thereby performing a cooling operation for processing a cooling load in the heat-load heat exchanger 91, a heating operation for processing a heating load in the heat-load heat exchanger 91, a cooling-to-heating transition operation, and a heating-to-cooling transition operation.

(4-1) Cooling Operation

[0222] During the cooling operation, as illustrated in Fig. 15, a two-stage refrigeration cycle operation is performed in which the first refrigerant is used in a heat-source-side refrigeration cycle and the second refrigerant is used in a use-side refrigeration cycle. In Fig. 15, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as an evaporator of the second refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, and the outdoor heat exchanger 18 is caused to function as a condenser of the first refrigerant.

[0223] Specifically, in this two-stage refrigeration cycle, all of the fifteenth on-off valve 55 and the sixteenth on-off valve 56 are controlled to be in a closed state, and the fifth expansion valve 35 and the sixth expansion valve 36 are controlled to be in a fully closed state to prevent mixing of the first refrigerant and the second refrigerant. The fourteenth on-off valve 54 and the seventeenth on-off valve 57 are controlled to be in an open state. Then, a connection state of the first switching mechanism 12 is switched to a connection state indicated by solid lines in Fig. 15, a connection state of the second switching mechanism 22 is switched to a connection state indicated by solid lines in Fig. 15, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the first expansion valve 15 is controlled such that the degree of superheating of the second refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the fourth expansion valve 34 is controlled such that the degree of superheating of the first refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0224] Accordingly, the first refrigerant discharged from the second compressor 21 is sent to the outdoor heat exchanger 18 via the switching valve 22e of the second switching mechanism 22, the seventeenth on-off valve 57, and the branch point N. The first refrigerant flowing through the outdoor heat exchanger 18 is condensed by heat exchange with the outdoor air supplied by the outdoor fan 9. The first refrigerant condensed in the outdoor heat exchanger 18 passes through the second expansion valve 16, which is controlled to be in a fully open state. After that, the first refrigerant passes through the branch point G and flows into the second receiver 19b. The refrigerant having flowed out of the second receiver 19b is decompressed in the fourth expansion valve 34 and is sent to the second cascade flow path 17b of the cascade heat exchanger 17. When flowing through the second cascade flow path 17b of the cascade heat exchanger 17, the first refrigerant is evaporated by heat exchange with the second refrigerant flowing through the first cascade flow path 17a. The first refrigerant evaporated in the cascade heat exchanger 17 is sucked into the second compressor 21 via the switching valve 22d of the second switching mechanism 22. The second refrigerant discharged from the first compressor 11 is sent to the first cascade flow path 17a of the cascade heat exchanger 17 via the switching valve 12d of the first switching mechanism 12. When flowing through the first cascade flow path 17a of the cascade heat exchanger 17, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the second cascade flow path 17b. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, passes through the third expansion valve 33, which is controlled to be in a fully open state, and flows into the first receiver 19a. The second refrigerant having flowed out of the first receiver 19a is decompressed in the first expansion valve 15, passes through the branch point A, and is sent to the first use flow path 13a of the use heat exchanger 13. The second refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is evaporated by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water cooled by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the cooling load. The second refrigerant evaporated in the first use flow path 13a of the use heat exchanger 13 is sucked into the first compressor 11 via the fourteenth on-off valve 54 and the switching valve 12c of the first switching mechanism 12.

(4-2) Cooling-to-Heating Transition Operation

[0225] The refrigeration cycle apparatus 1c performs a cooling-to-heating transition operation including (a5) to (b5) below in this order to make a transition from a cycle state for performing the cooling operation to a cycle state for performing the heating operation.

(a5) First, the first compressor 11 is operated after the first expansion valve 15 is controlled to be in a fully closed state from the state in which the cooling operation is performed. Here, the second compressor 21 and the like are operated such that the refrigeration cycle for the cooling operation using the first refrigerant is performed. As a result, an operation of recovering the second refrigerant into the first receiver 19a from below the first receiver 19a is performed. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the first receiver 19a.

(b5) Then, the fourteenth on-off valve 54 is closed and the first compressor 11 is stopped after the second refrigerant has been recovered into the first receiver 19a by a predetermined amount or more. After that, the switching valve 22c of the second switching mechanism 22 is switched to a state in which the discharge side of the second compressor 21 is connected to the fifteenth on-off valve 55, the switching valve 22e of the second switching mechanism 22 is switched to a state in which the suction side of the second compressor 21 is connected to the seventeenth on-off valve 57, and the switching valve 22d of the second switching mechanism 22 is maintained in a state in which the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. Further, the fifteenth on-off valve 55 is controlled to be in an open state, the second expansion valve 16 and the fourth expansion valve 34 are controlled to be in a fully closed state, and the sixth expansion valve 36 is controlled to be in an open state. In this state, the second compressor 21 is operated to heat and expel the first refrigerant remaining in the outdoor heat exchanger 18 by using the heat of the air obtained from the outdoor fan 9. Then, the first refrigerant is sucked into the second compressor 21 via the seventeenth on-off valve 57 and the switching valve 22e of the second switching mechanism 22. The first refrigerant remaining in the second cascade flow path 17b of the cascade heat exchanger 17 is also sucked into the second compressor 21 via the switching valve 22d of the second switching mechanism 22. The first refrigerant discharged from the second compressor 21 is sent to the first use flow path 13a of the use heat exchanger 13 via the switching valve 22c of the second switching mechanism 22, the fifteenth on-off valve 55, and the branch point M. Further, the first refrigerant condenses when flowing through the first use flow path 13a of the use heat exchanger 13, and flows into the second receiver 19b via the branch point A and the sixth expansion valve 36. After this operation is continued for a predetermined period of time, the seventeenth on-off valve 57 is controlled to be in a closed state, and the fourth expansion valve 34 is controlled to be in an open state.

[0226] Thus, the cooling-to-heating transition operation is completed.

(4-3) Heating Operation

[0227] During the heating operation, as illustrated in Fig. 16, a two-stage refrigeration cycle is performed in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. In Fig. 16, a single-headed arrow indicates a flow path through which the first refrigerant flows, and a double-headed arrow indicates a flow path through which the second refrigerant flows. In this two-stage refrigeration cycle, the use heat exchanger 13 is caused to function as a condenser of the first refrigerant, the cascade heat exchanger 17 is caused to function as an evaporator of the first refrigerant, the cascade heat exchanger 17 is caused to function as a radiator of the second refrigerant, and the outdoor heat exchanger 18 is caused to function as an evaporator of the second refrigerant.

[0228] Specifically, in this two-stage refrigeration cycle, the fourteenth on-off valve 54 and the seventeenth on-off valve 57 are controlled to be in a closed state, and the first expansion valve 15 and the second expansion valve 16 are controlled to be in a fully closed state to prevent mixing of the first refrigerant and the second refrigerant. Then, a connection state of the switching valve 12d and the switching valve 12c of the first switching mechanism 12 is changed to a state indicated by solid lines in Fig. 16, a connection state of the switching valve 12e of the first switching mechanism 12 is changed to a state indicated by a broken line in Fig. 16, a connection state of the switching valve 22d and the switching valve 22e of the second switching mechanism 22 is changed to a connection state indicated by solid lines in Fig. 16, a connection state of the switching valve 22c of the second switching mechanism 22 is switched to a connection state indicated by a broken line in Fig. 16, and the pump 92, the first compressor 11, the second compressor 21, and the outdoor fan 9 are driven. Further, the valve opening degree of the fifth expansion valve 35 is controlled such that the degree of superheating of the second refrigerant to be sucked into the first compressor 11 satisfies a predetermined condition, and the valve opening degree of the fourth expansion valve 34 is controlled such that the degree of superheating of the first refrigerant to be sucked into the second compressor 21 satisfies a predetermined condition.

[0229] Accordingly, the second refrigerant discharged from the first compressor 11 is sent to the cascade heat exchanger 17 via the switching valve 12d of the first switching mechanism 12. When flowing through the first cascade flow path 17a, the second refrigerant radiates heat by heat exchange with the first refrigerant flowing through the second cascade flow path 17b. The second refrigerant, which has radiated heat in the cascade heat exchanger 17, is decompressed in the fifth expansion valve 35 via the third expansion valve 33, the first receiver 19a, and the branch point F. The second refrigerant decompressed in the fifth expansion valve 35 is sent to the outdoor heat exchanger 18 via the branch point B. The second refrigerant is evaporated by heat exchange with the outdoor air supplied by the outdoor fan 9 in the outdoor heat exchanger 18, and is sucked into the first compressor 11 via the branch point N, the sixteenth on-off valve 56, and the switching valve 12e of the first switching mechanism 12. The first refrigerant discharged from the second compressor 21 is sent to the first use flow path 13a of the use heat exchanger 13 via the switching valve 22c of the second switching mechanism 22, the fifteenth on-off valve 55, and the branch point M. The first refrigerant flowing through the first use flow path 13a of the use heat exchanger 13 is condensed by heat exchange with the water flowing through the heat-load flow path 13b of the use heat exchanger 13 included in the heat-load circuit 90. The water heated by this heat exchange is sent to the heat-load heat exchanger 91 in the heat-load circuit 90 to process the heating load. The first refrigerant condensed in the first use flow path 13a of the use heat exchanger 13 passes through the branch point A. After that, the first refrigerant passes through the sixth expansion valve 36 and flows into the second receiver 19b. The first refrigerant having flowed out of the second receiver 19b is decompressed in the fourth expansion valve 34. The first refrigerant decompressed by the fourth expansion valve 34 is evaporated, when passing through the second cascade flow path 17b of the cascade heat exchanger 17, by heat exchange with the second refrigerant flowing through the first cascade flow path 17a. The first refrigerant evaporated in the second cascade flow path 17b of the cascade heat exchanger 17 is sucked into the second compressor 21 via the switching valve 22d of the second switching mechanism 22.

(4-4) Heating-to-Cooling Transition Operation

[0230] The refrigeration cycle apparatus 1c performs a heating-to-cooling transition operation including (a6) to (c6) below in this order to make a transition from a cycle state for performing the heating operation to a cycle state for performing the cooling operation.

(a6) First, the fifth expansion valve 35 is controlled to be in a fully closed state from the state in which the heating operation is performed, and the first compressor 11 is operated. Here, the second compressor 21 and the like are operated such that the use-side refrigeration cycle for the heating operation using the first refrigerant is maintained. Accordingly, an operation of, while sucking the second refrigerant in the outdoor heat exchanger 18 into the first compressor 11, causing the second refrigerant discharged from the first compressor 11 to radiate heat in the first cascade flow path 17a of the cascade heat exchanger 17, causing the second refrigerant to flow into the first receiver 19a, and recovering the second refrigerant into the first receiver 19a is performed. This operation is continued for a predetermined period of time, for example, until a predetermined sufficient amount of the second refrigerant is recovered in the first receiver 19a.

(b6) Then, the sixteenth on-off valve 56 is closed and the first compressor 11 is stopped after the second refrigerant has been recovered into the first receiver 19a by a predetermined amount or more. After that, the switching valve 22c of the second switching mechanism 22 is switched to a state in which the suction side of the second compressor 21 is connected to the fifteenth on-off valve 55, the switching valve 22e of the second switching mechanism 22 is switched to a state in which the discharge side of the second compressor 21 is connected to the seventeenth on-off valve 57, and the switching valve 22d of the second switching mechanism 22 is maintained in a state in which the suction side of the second compressor 21 is connected to the gas refrigerant side of the second cascade flow path 17b of the cascade heat exchanger 17. Then, the fourth expansion valve 34 and the sixth expansion valve 36 are controlled to be in a fully closed state, the second expansion valve 16 is controlled to be in a fully open state, and the seventeenth on-off valve 57 is controlled to be in an open state. In this state, the second compressor 21 is operated to suck the first refrigerant remaining in and around the first use flow path 13a of the use heat exchanger 13 into the second compressor 21 via the branch point M, the fifteenth on-off valve 55, and the switching valve 22c of the second switching mechanism 22. Then, the first refrigerant discharged from the second compressor 21 is sent to the outdoor heat exchanger 18 via the switching valve 22e of the second switching mechanism 22, the seventeenth on-off valve 57, and the branch point N. The first refrigerant, which has exchanged heat with the air sent by the outdoor fan 9 in the outdoor heat exchanger 18, is condensed, passes through the branch point B, the second expansion valve 16, and the branch point G, and begins to accumulate in the second receiver 19b. Then, this operation is continued for a predetermined period of time.

(c6) Then, after a predetermined amount or more of the first refrigerant has accumulated in the second receiver 19b, the fifteenth on-off valve 55 is controlled to be in a closed state. Further, the fourteenth on-off valve 54 is controlled to be in an open state, and the first expansion valve 15 is controlled to have a predetermined valve opening degree. Then, the switching valve 12c of the first switching mechanism 12 is switched to a state in which the suction side of the first compressor 11 is connected to the fourteenth on-off valve 54, the switching valve 12e of the first switching mechanism 12 is switched to a state in which the discharge side of the first compressor 11 is connected to the sixteenth on-off valve 56, and the switching valve 12d of the first switching mechanism 12 is switched to a state in which the discharge side of the first compressor 11 and the gas refrigerant side of the first cascade flow path 17a is connected to the cascade heat exchanger 17 is maintained.

[0231] Thus, the heating-to-cooling transition operation is completed.

(4-5) Features of Fourth Embodiment

[0232] In the refrigeration cycle apparatus 1c according to the fourth embodiment, the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP) and the second refrigerant having a sufficiently low ozone depletion potential (ODP) and a sufficiently low global warming potential (GWP). Thus, global environmental deterioration can be reduced.

[0233] In addition, even when the refrigerant circuit 10 uses the first refrigerant having a sufficiently low global warming potential (GWP), the two-stage refrigeration cycle in which the second refrigerant, which is a high-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the first refrigerant, which is a low-pressure refrigerant, is used in the use-side refrigeration cycle is performed as the heating operation. This makes it easier to secure heating operation capacity than a single-stage refrigeration cycle using the first refrigerant, which is a low-pressure refrigerant.

[0234] Further, the refrigerant circuit 10 uses carbon dioxide as the second refrigerant. However, during the cooling operation, a single-stage refrigeration cycle using the second refrigerant is not performed, nor is performed a two-stage refrigeration cycle in which the second refrigerant is used in the heat-source-side refrigeration cycle and the first refrigerant is used in the use-side refrigeration cycle. Instead of this, a two-stage refrigeration cycle in which the first refrigerant, which is a low-pressure refrigerant, is used in the heat-source-side refrigeration cycle and the second refrigerant, which is a high-pressure refrigerant, is used in the use-side refrigeration cycle is performed. This makes it possible to perform the cooling operation without causing a reduction in COP, as in the case of performing a single-stage refrigeration cycle using a carbon dioxide refrigerant, which is a high-pressure refrigerant, or as in the case of performing a two-stage refrigeration cycle in which carbon dioxide, which is a high-pressure refrigerant, is used in the heat-source-side cycle, the reduction being due to the pressure of the carbon dioxide refrigerant exceeding the critical pressure. It is also possible to reduce the compression strength standards required for the components of the refrigerant circuit 10 in which carbon dioxide, which is a high-pressure refrigerant, is used.

[0235] In the refrigeration cycle apparatus 1c according to the fourth embodiment, furthermore, the first refrigerant and the second refrigerant can be collected by using the first receiver 19a and the second receiver 19b used in the heat-source-side refrigeration cycle and the use-side refrigeration cycle. This eliminates the need to separately secure the refrigerant container 19 as described in the second embodiment, which is not used in the heat-source-side refrigeration cycle or the use-side refrigeration cycle.

(5) Other Embodiments

(5-1) Other Embodiment A

[0236] In the embodiments described above, basically, the first refrigerant and the second refrigerant are circulated without mixing each other. However, various operations performed in the refrigerant circuit 10 may cause a flow of the second refrigerant to a location where the first refrigerant has flowed, and cause a flow of the first refrigerant to a location where the second refrigerant has flowed. In consequence, the first refrigerant and the second refrigerant may sometimes be slightly mixed with each other.

[0237] The first refrigerant and the second refrigerant are of different refrigerant types. As a result of mixing of these refrigerants, a non-azeotropic refrigerant mixture flows. In a heat exchanger that functions as an evaporator, the non-azeotropic refrigerant mixture has a temperature gradient such that the refrigerant temperature on the upstream side at the start of evaporation is different from the refrigerant temperature on the downstream side at the end of evaporation. In a heat exchanger that functions as a condenser, the non-azeotropic refrigerant mixture has a temperature gradient such that the refrigerant temperature on the upstream side at the start of condensation is different from the refrigerant temperature on the downstream side at the end of condensation.

[0238] Accordingly, the controller 7 may evaluate that the first refrigerant and the second refrigerant are mixed with each other if the difference between the evaporation temperature of the refrigerant at a predetermined upstream position and the evaporation temperature of the refrigerant at a predetermined downstream position in the heat exchanger that functions as an evaporator is equal to or greater than a predetermined value. The controller 7 may evaluate that the first refrigerant and the second refrigerant are mixed with each other if the difference between the condensation temperature of the refrigerant at a predetermined upstream position and the condensation temperature of the refrigerant at a predetermined downstream position in the heat exchanger that functions as a condenser is equal to or greater than a predetermined value. The detection of each temperature is not limited. These temperatures can be detected with temperature sensors disposed at predetermined upstream and downstream locations in the heat exchanger. The controller 7 may evaluate that the first refrigerant and the second refrigerant are mixed with each other when the concentration of one of the refrigerants is 90 wt% or less, 95 wt% or less, or 98 wt% or less.

[0239] In addition, when the controller 7 evaluates that the first refrigerant and the second refrigerant are mixed with each other, the controller 7 may display and output the evaluation result on a display (not illustrated) to provide a notification.

(5-2) Other Embodiment B

[0240] As described in the other embodiment A described above, in some cases, the first refrigerant and the second refrigerant are mixed with each other.

[0241] Accordingly, the refrigeration cycle apparatus may be configured to perform a separation process for separating the first refrigerant and the second refrigerant from each other when, as described in the other embodiment A described above, it is evaluated that the first refrigerant and the second refrigerant are mixed with each other, when the cooling operation and the heating operation are switched, or when the cooling operation and the heating operation are switched a predetermined number of times.

[0242] The separation process is not limited. For example, the refrigerant container 19, the first receiver 19a, and the second receiver 19b may be provided with an adsorbent that selectively adsorbs the first refrigerant or the second refrigerant. Examples of the adsorbent may include, but not limited to, a metal-organic framework (MOF).

[0243] Further, the refrigeration cycle apparatus may be capable of performing an operation of distilling the first refrigerant or an operation of distilling the second refrigerant.

<Supplementary Note>

[0244] While embodiments of the present disclosure have been described, it will be understood that various changes may be made in form and details without departing from the spirit and scope of the present disclosure as defined in the claims.

REFERENCE SIGNS LIST

[0245]

1, 1a, 1b, 1c refrigeration cycle apparatus
12 first switching mechanism
13 use heat exchanger
13a first use flow path
13b heat-load flow path
14 third use expansion valve
15 first expansion valve
16 second expansion valve
17 cascade heat exchanger
17a first cascade flow path
17b second cascade flow path
18 outdoor heat exchanger
19 refrigerant container (second region)
19a first receiver (second region)
19b second receiver (first region)
21 second compressor
33-36 third to sixth expansion valves
41-49 first to ninth on-off valves
50-57 tenth to seventeenth on-off valves
90 heat-load circuit
91 heat-load heat exchanger
92 pump

CITATION LIST

PATENT LITERATURE

[0246] PTL 1: Japanese Unexamined Patent Application Publication No. 2015-197254

Claims

1. A refrigeration cycle apparatus (1), wherein the re-

frigeration cycle apparatus

performs a heating operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant having 1 MPa or less at 30°C and a heat-source-side refrigeration cycle using a second refrigerant having 1.5 MPa or more at 30°C, and
performs a cooling operation by performing a single-stage refrigeration cycle using the first refrigerant.

2. The refrigeration cycle apparatus according to claim 1, comprising
an outdoor heat exchanger (18) that functions as an evaporator of the second refrigerant during the heating operation and functions as a radiator of the first refrigerant during the cooling operation.

3. The refrigeration cycle apparatus according to claim 2, comprising
a cascade heat exchanger (17) including a first cascade flow path (17a) through which the first refrigerant flows during the heating operation and a second cascade flow path (17b) that is independent of the first cascade flow path and through which the second refrigerant flows during the heating operation, the cascade heat exchanger (17) being configured to exchange heat between the first refrigerant and the second refrigerant.

4. The refrigeration cycle apparatus according to claim 3, comprising

a use heat exchanger (13) in which the first refrigerant radiates heat during the heating operation, wherein
during the heating operation, the first refrigerant evaporates when passing through the first cascade flow path (17a), and the second refrigerant radiates heat when passing through the second cascade flow path (17b).

5. The refrigeration cycle apparatus according to claim 4, wherein
the first refrigerant evaporates in the use heat exchanger (13) during the cooling operation.

6. The refrigeration cycle apparatus according to any one of claims 2 to 5, wherein
the first refrigerant is collectable in a first region (19b) other than the outdoor heat exchanger, and the second refrigerant is collectable in a second region (19, 19a) other than the outdoor heat exchanger and other than the first region.

7. A refrigeration cycle apparatus (1a, 1b, 1c), wherein the refrigeration cycle apparatus

performs a heating operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using a first refrigerant having 1 MPa or less at 30°C and a heat-source-side refrigeration cycle using a second refrigerant having 1.5 MPa or more at 30°C, and
performs a cooling operation by performing a two-stage refrigeration cycle, the two-stage refrigeration cycle including a use-side refrigeration cycle using the second refrigerant and a heat-source-side refrigeration cycle using the first refrigerant.

8. The refrigeration cycle apparatus according to claim 7, wherein
a refrigerant to be used in the heat-source-side refrigeration cycle and a refrigerant to be used in the use-side refrigeration cycle are interchanged between the heating operation and the cooling operation.

9. The refrigeration cycle apparatus according to claim 8, comprising
a refrigerant tank (19, 19a, 19b) that temporarily stores either the first refrigerant or the second refrigerant when the refrigerants are interchanged.

10. The refrigeration cycle apparatus according to any one of claims 7 to 9, comprising
a cascade heat exchanger (17) including a first cascade flow path (17a) in which the first refrigerant evaporates during the heating operation and a second cascade flow path (17b) that is independent of the first cascade flow path and in which the second refrigerant radiates heat during the heating operation, the cascade heat exchanger (17) being configured to exchange heat between the first refrigerant and the second refrigerant.

11. The refrigeration cycle apparatus according to any one of claims 7 to 10, comprising
a use heat exchanger (13) that functions as a radiator of the first refrigerant during the heating operation and functions as an evaporator of the second refrigerant during the cooling operation.

12. The refrigeration cycle apparatus according to any one of claims 7 to 11, comprising
an outdoor heat exchanger (18) that functions as an evaporator of the second refrigerant during the heating operation and functions as a condenser of the first refrigerant during the cooling operation.

13. The refrigeration cycle apparatus according to any one of claims 1 to 12, wherein the refrigeration cycle apparatus detects a state of mixing of the first refrigerant and the second refrigerant.

14. The refrigeration cycle apparatus according to any one of claims 1 to 13, wherein
the refrigeration cycle apparatus separates the first refrigerant and the second refrigerant from each other.

15. The refrigeration cycle apparatus according to any one of claims 1 to 14, wherein
the first refrigerant includes at least one of R1234yf or R1234ze.

16. The refrigeration cycle apparatus according to any one of claims 1 to 15, wherein
the second refrigerant includes carbon dioxide.

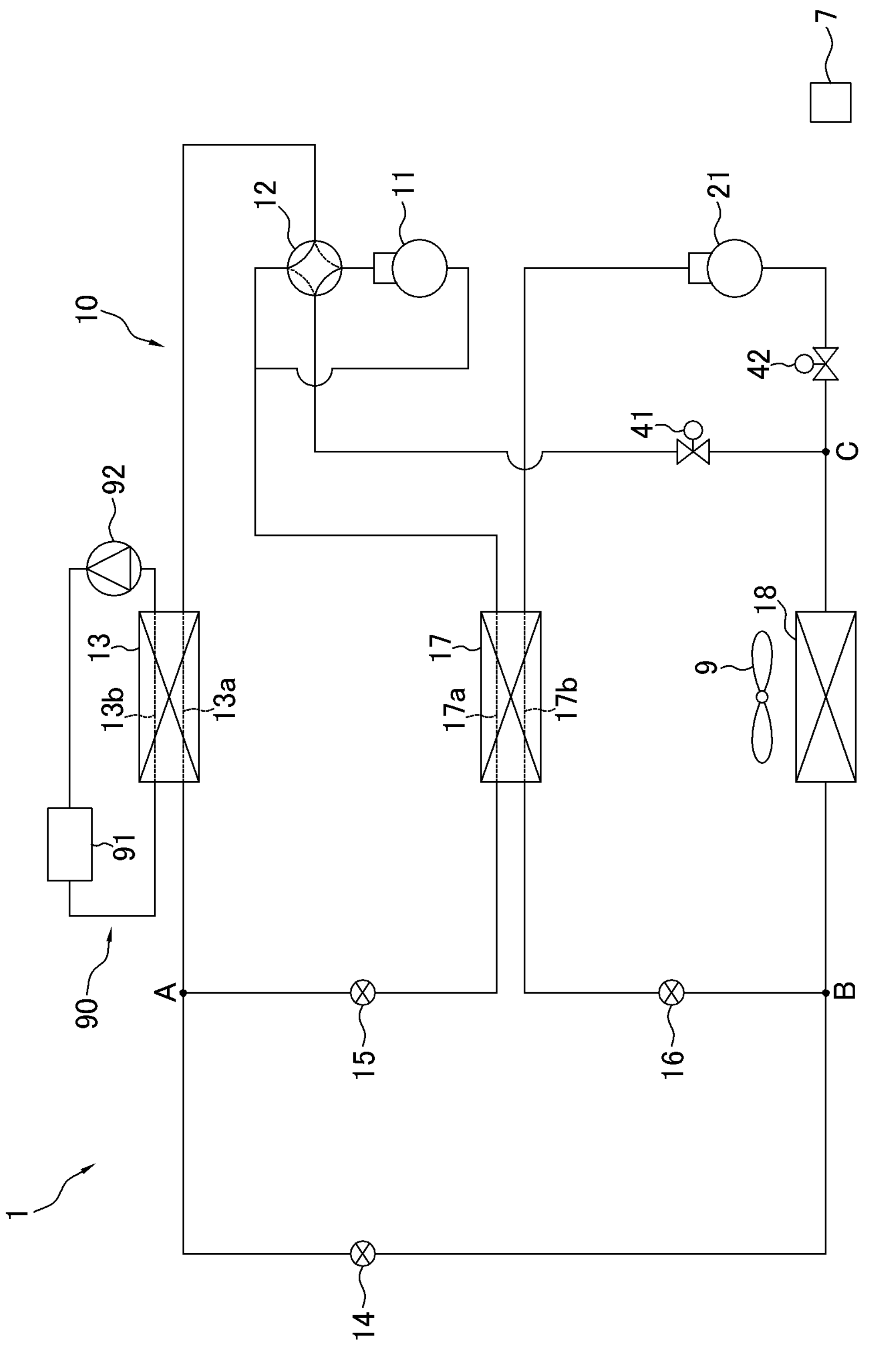

FIG. 1

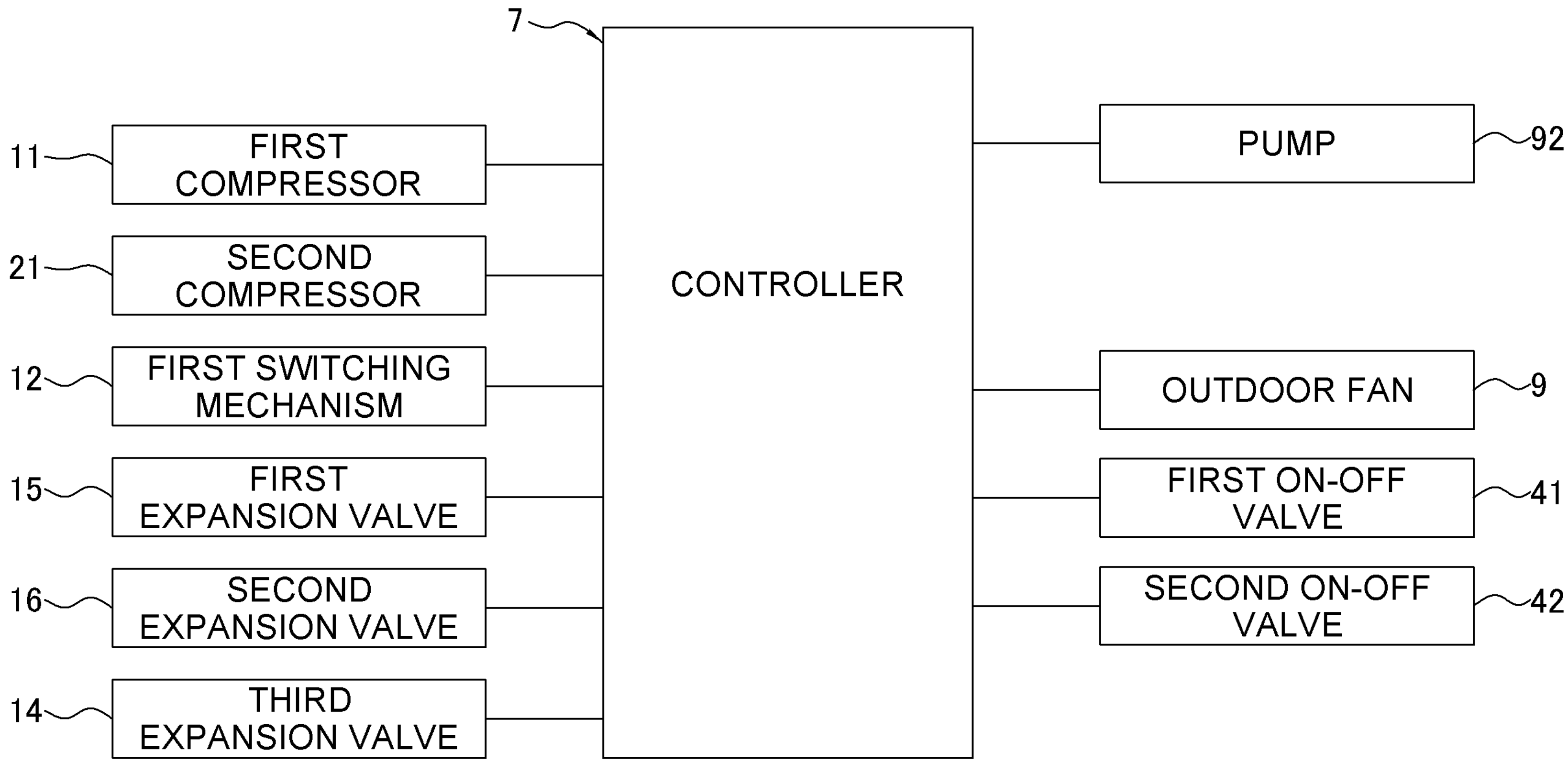
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FIG. 2

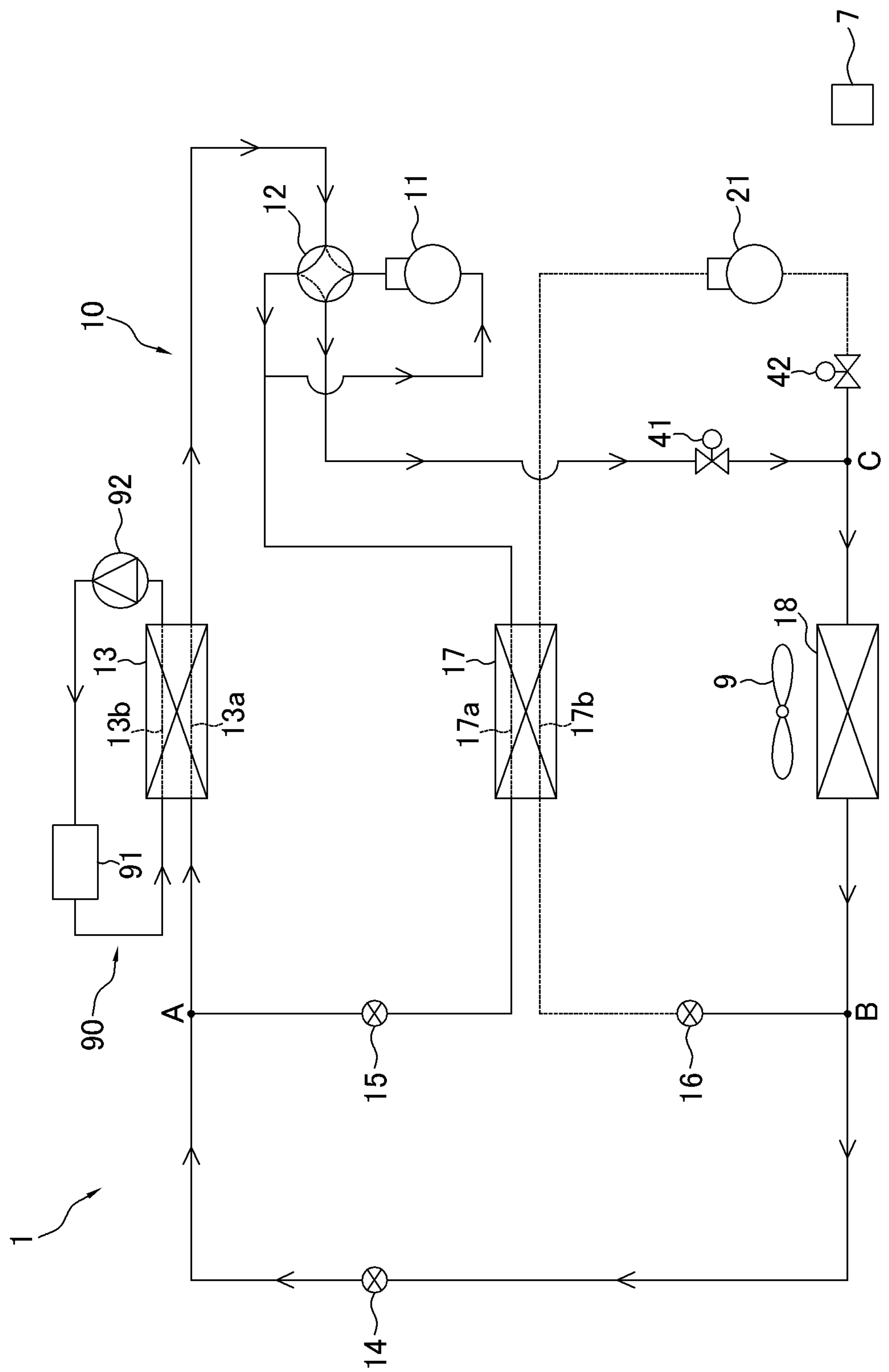

FIG. 3

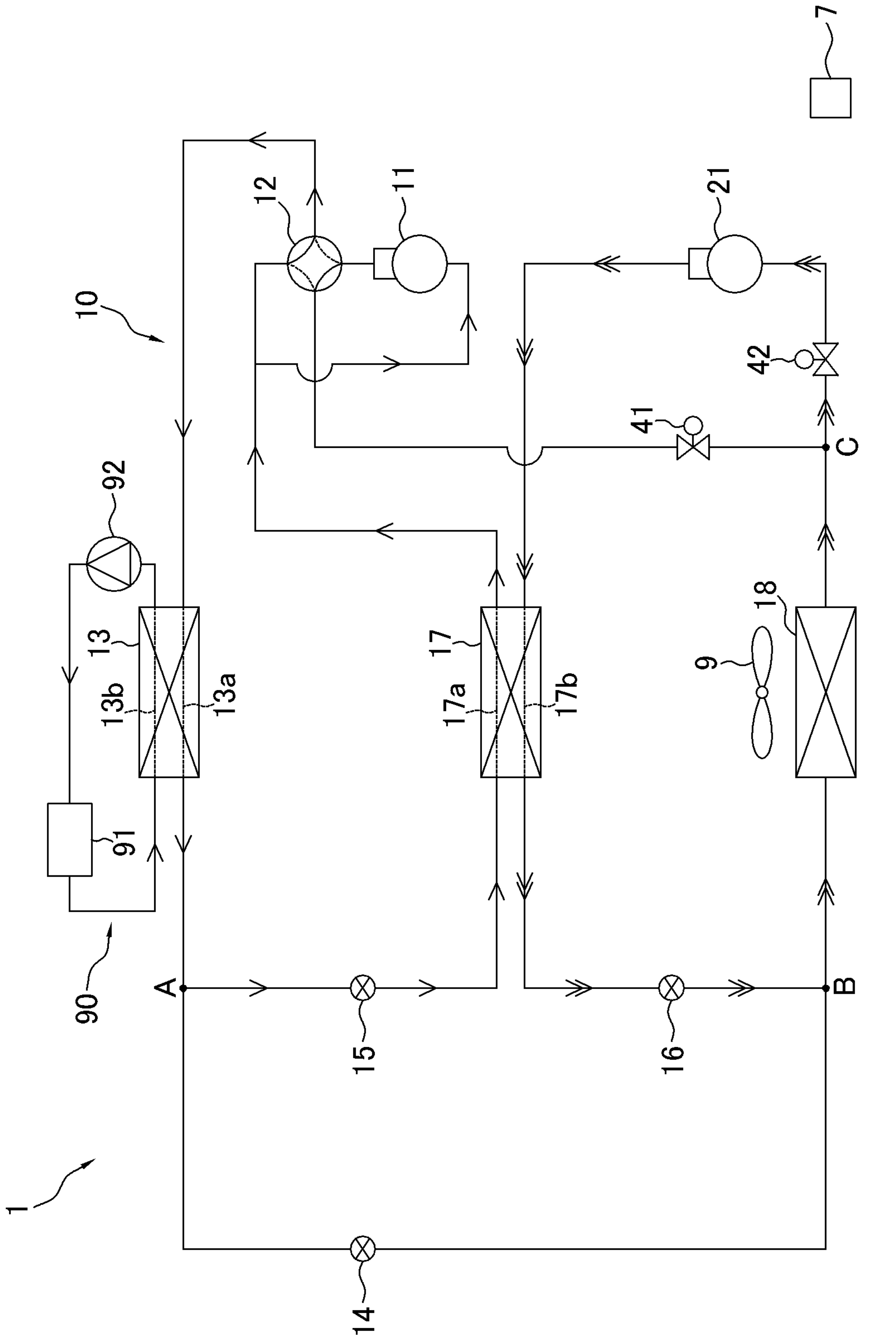

FIG. 4

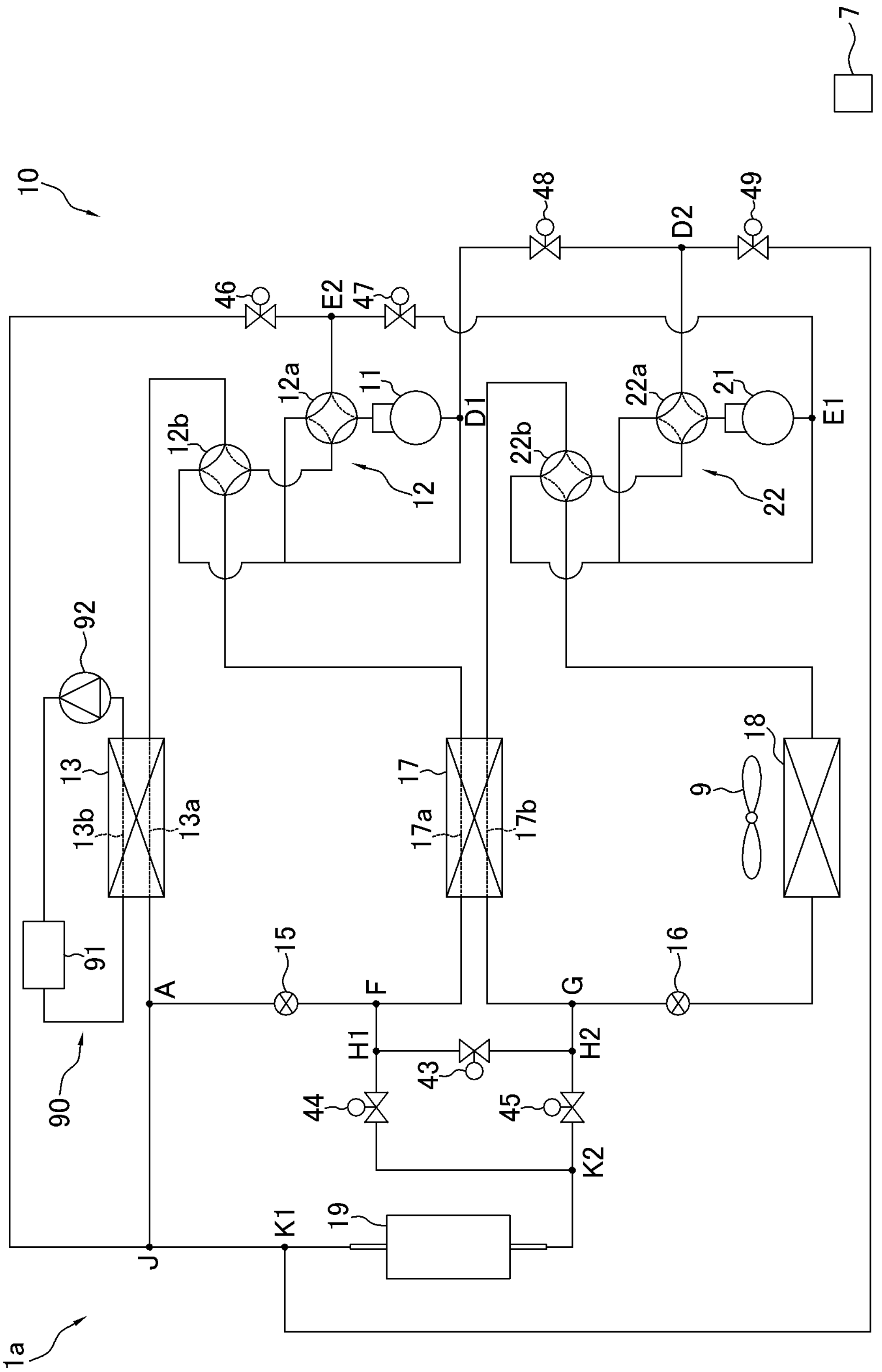
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FIG. 5

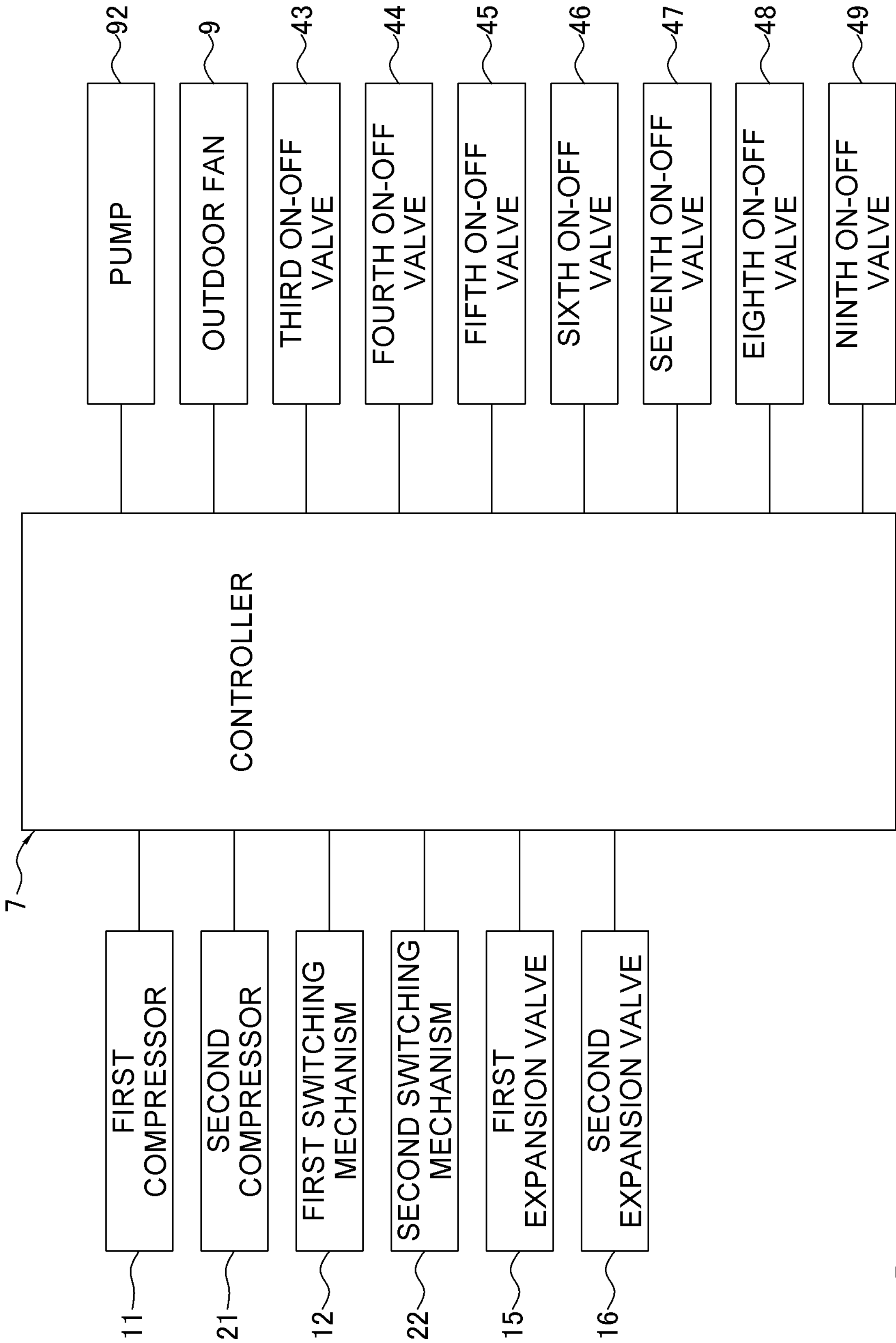
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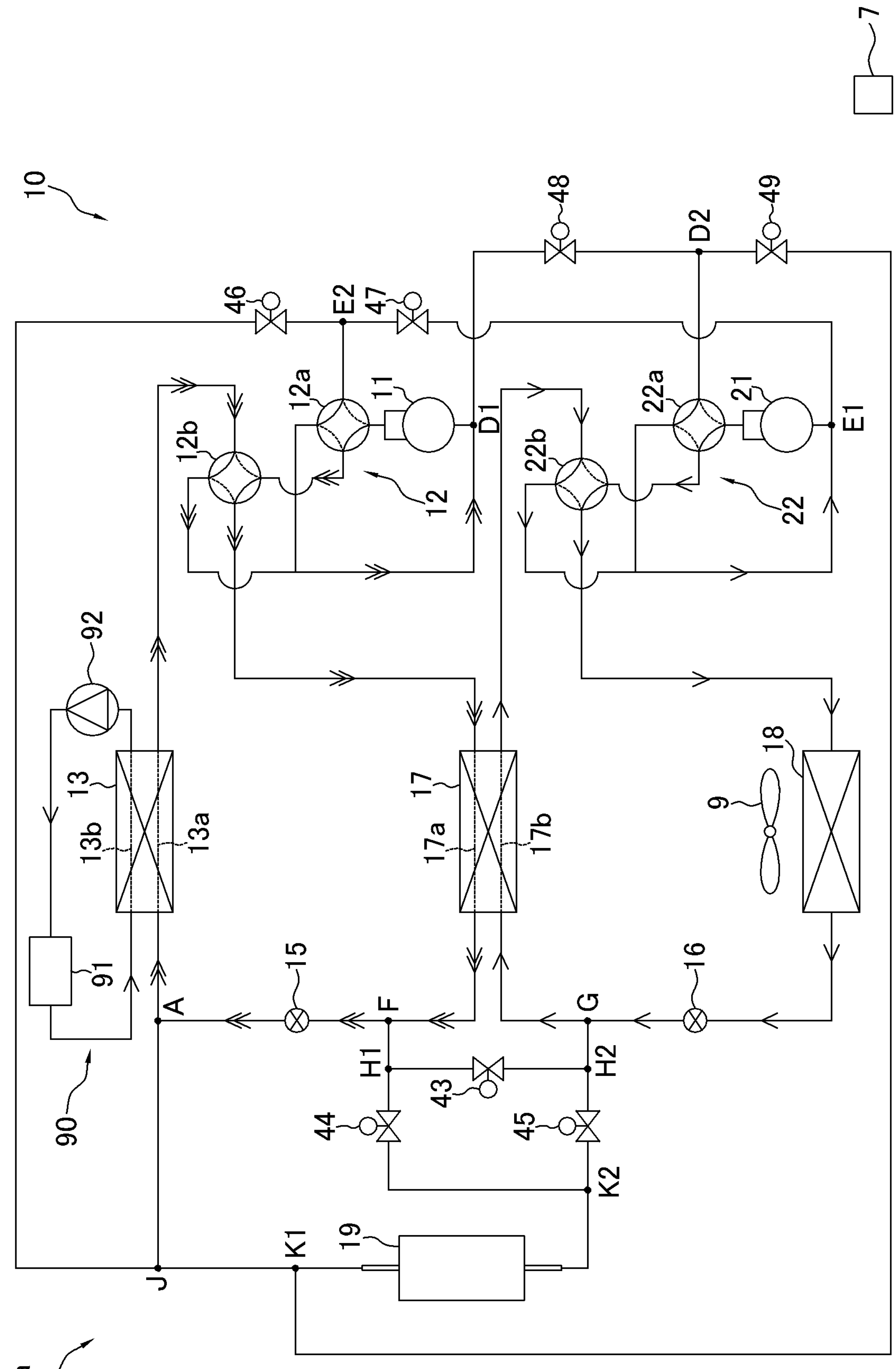
FIG. 6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H2
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K1
K2

FIG. 7

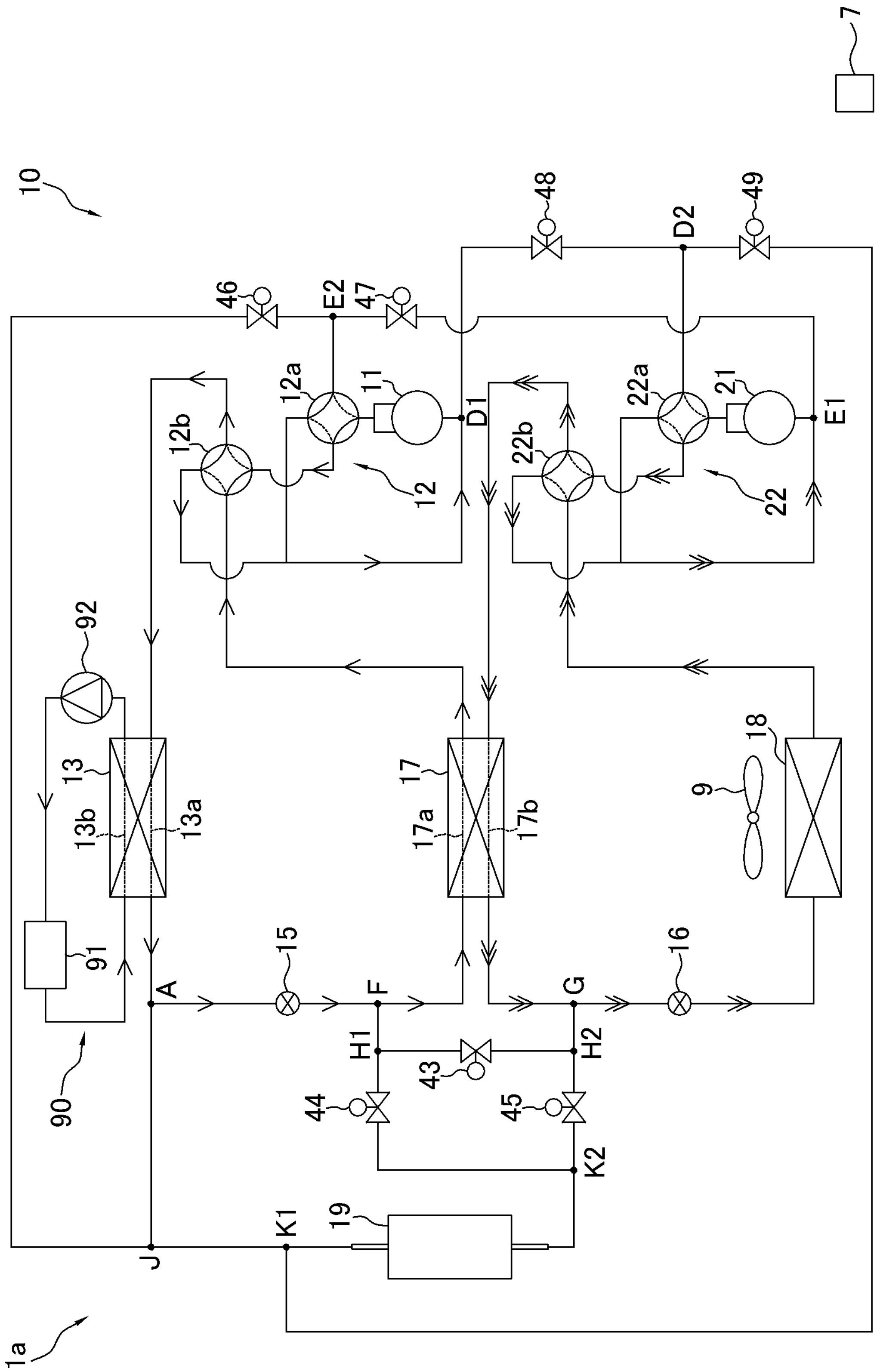

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FIG. 8

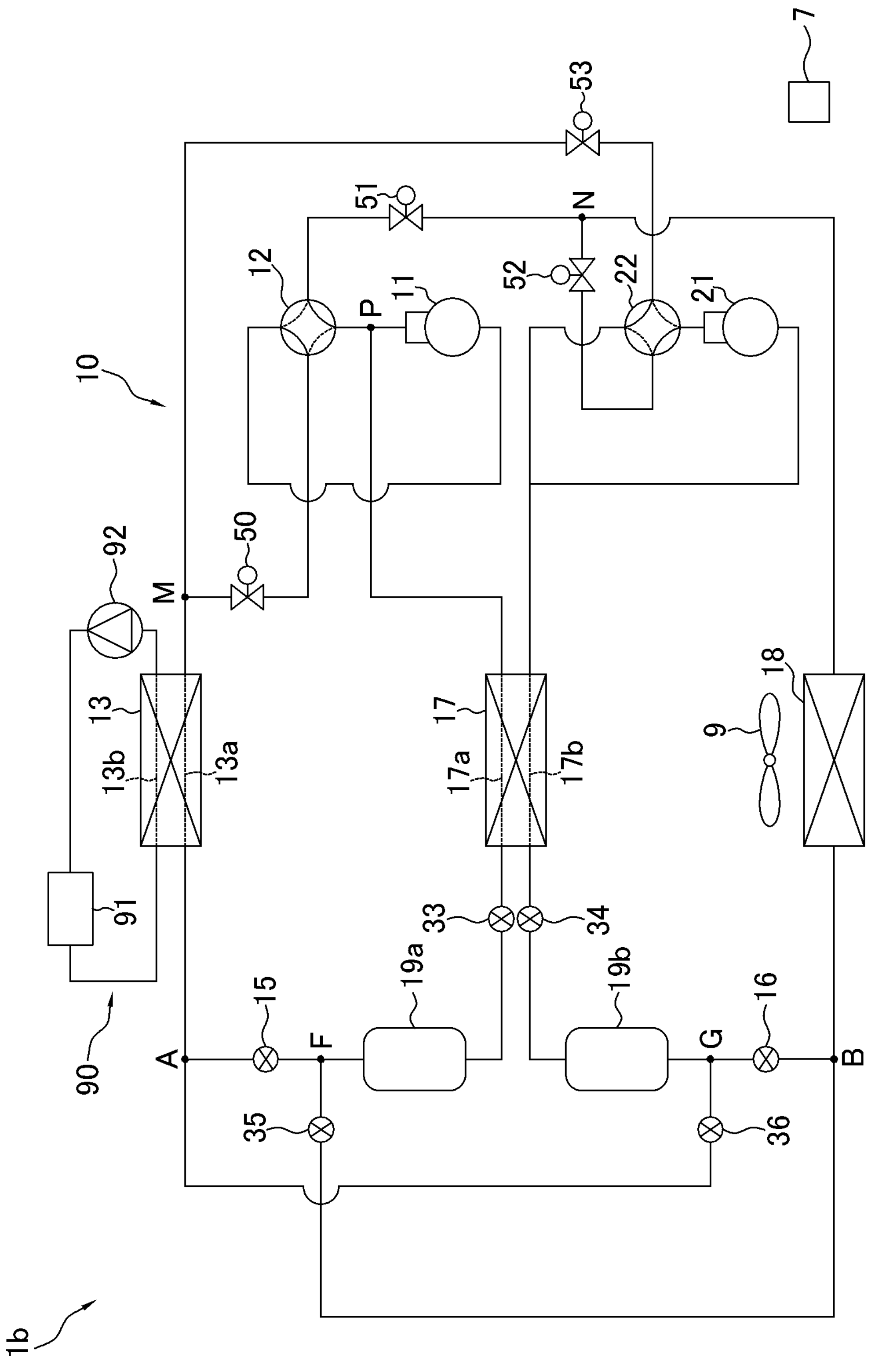
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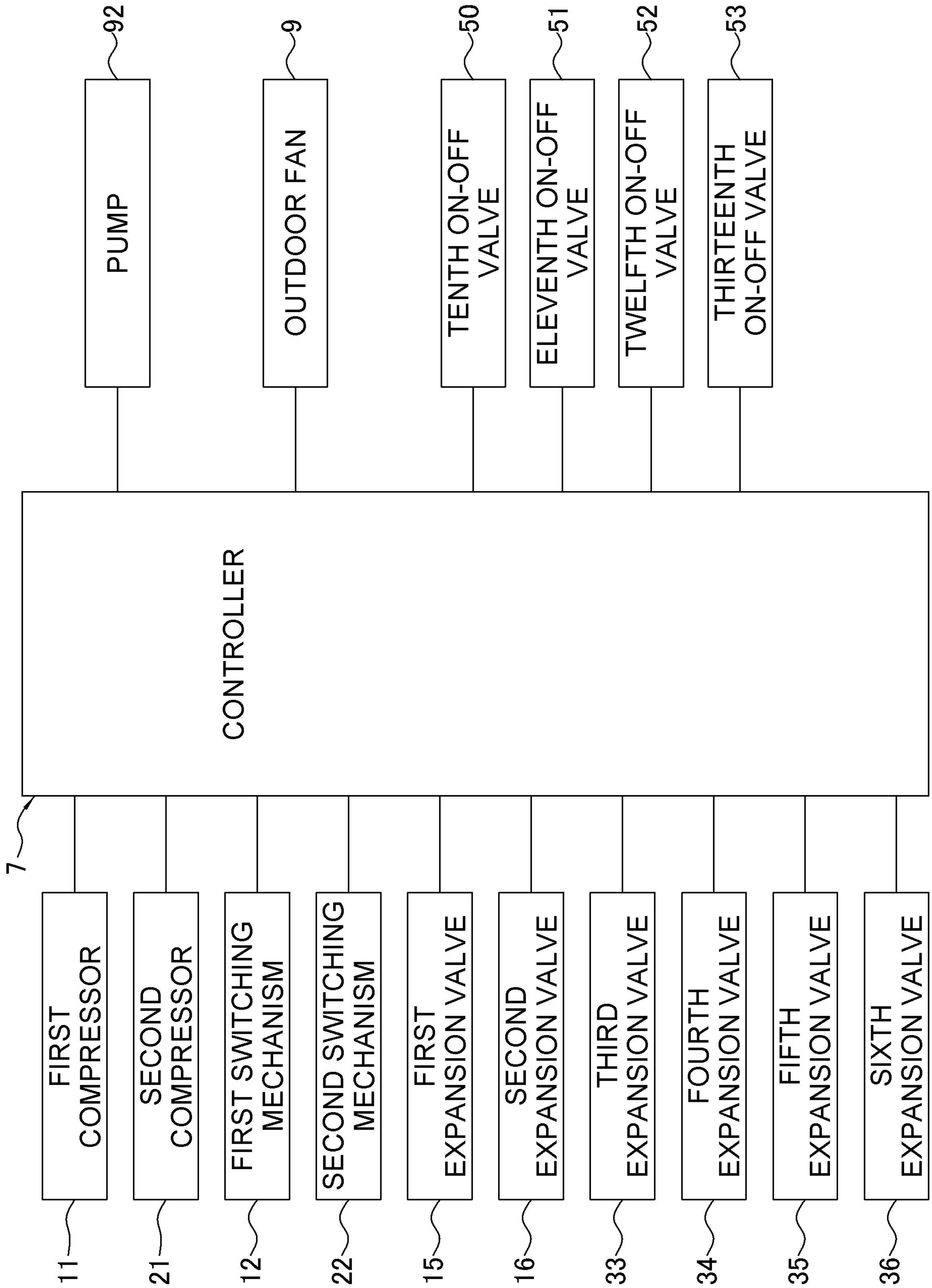
FIG. 9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SIXTH EXPANSION VALVE
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FIG. 10

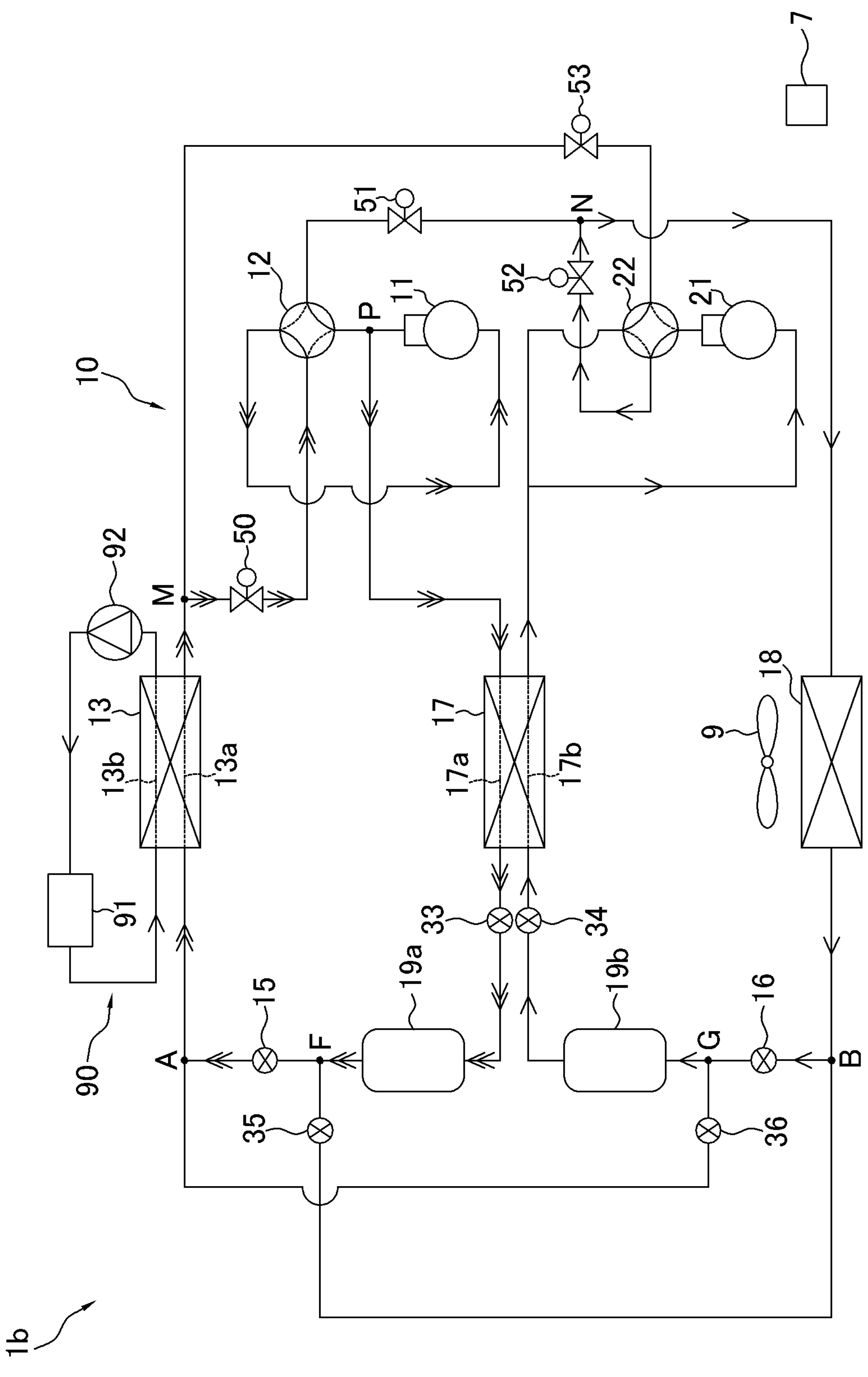
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FIG. 11

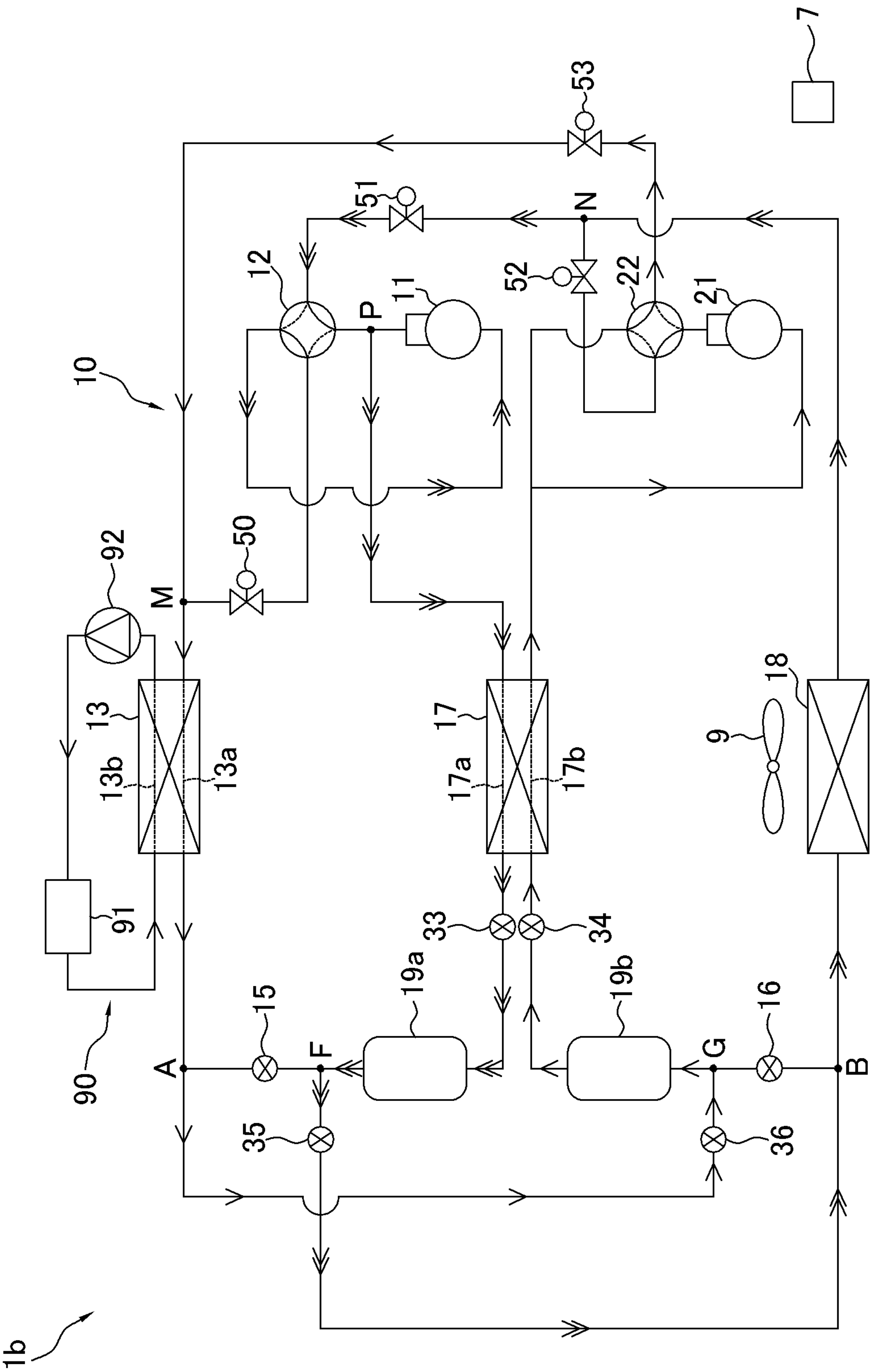
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FIG. 12

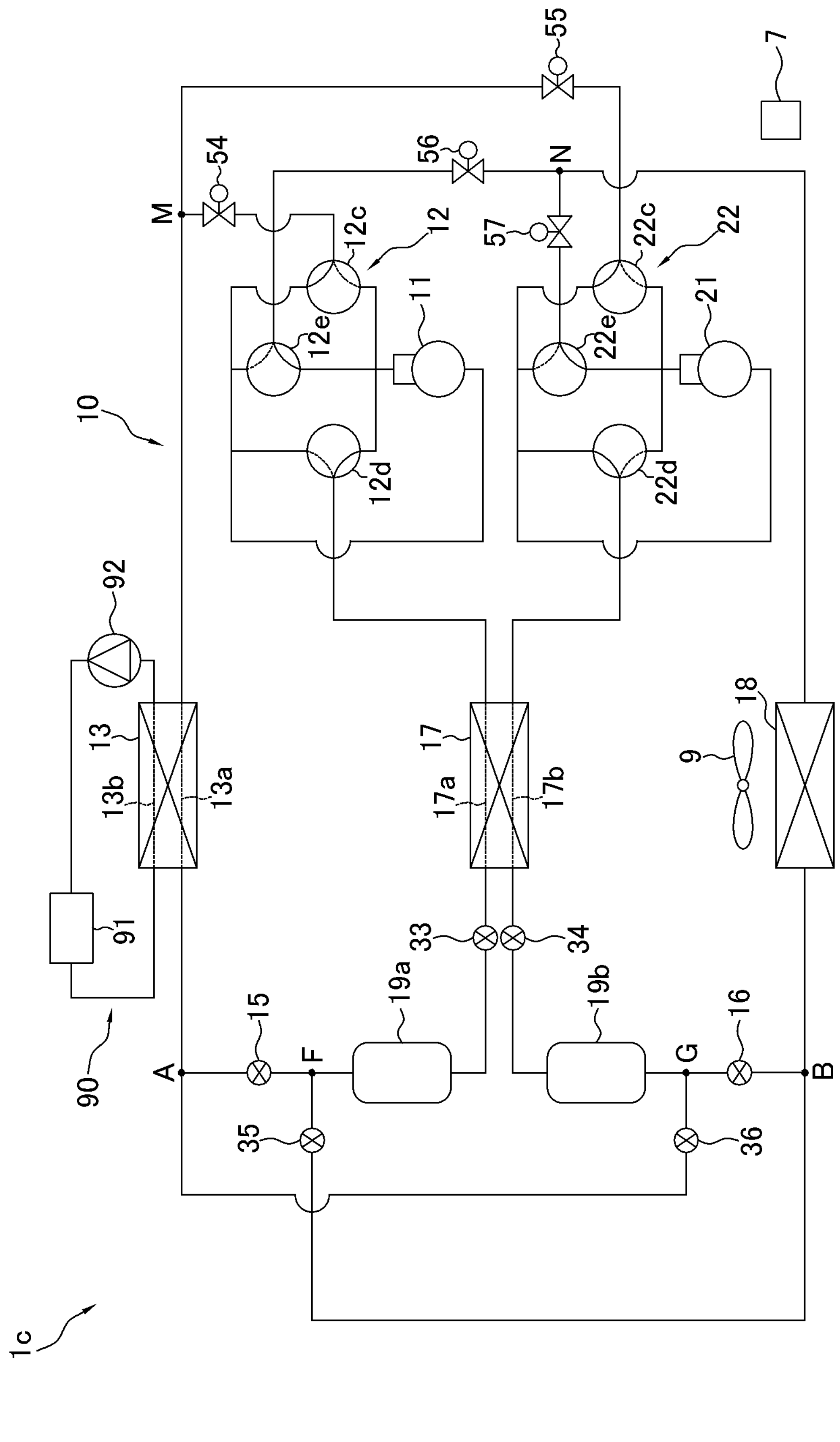
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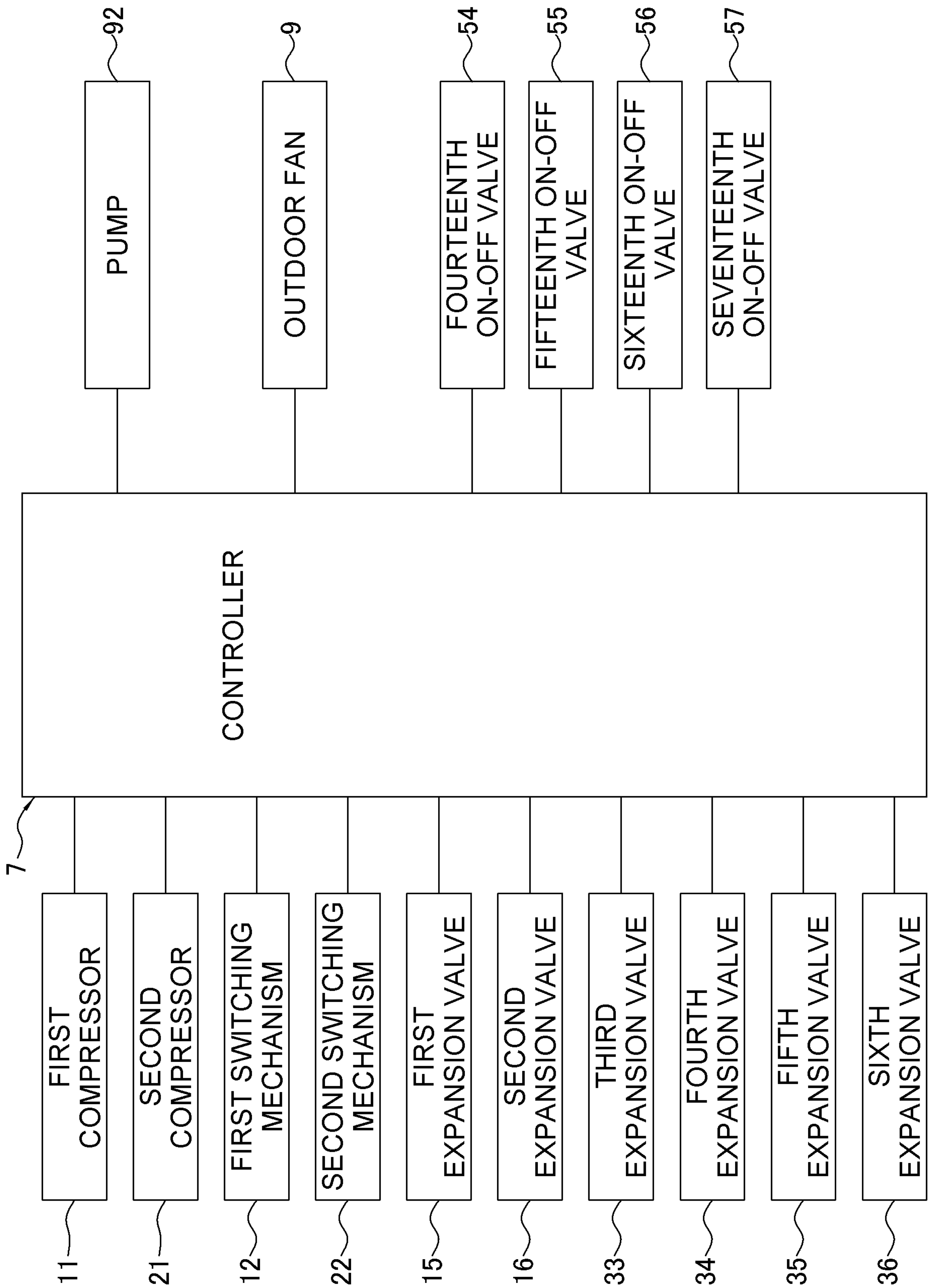
FIG. 13



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FOURTH EXPANSION VALVE
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SIXTH EXPANSION VALVE
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PUMP
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OUTDOOR FAN
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FIG. 14

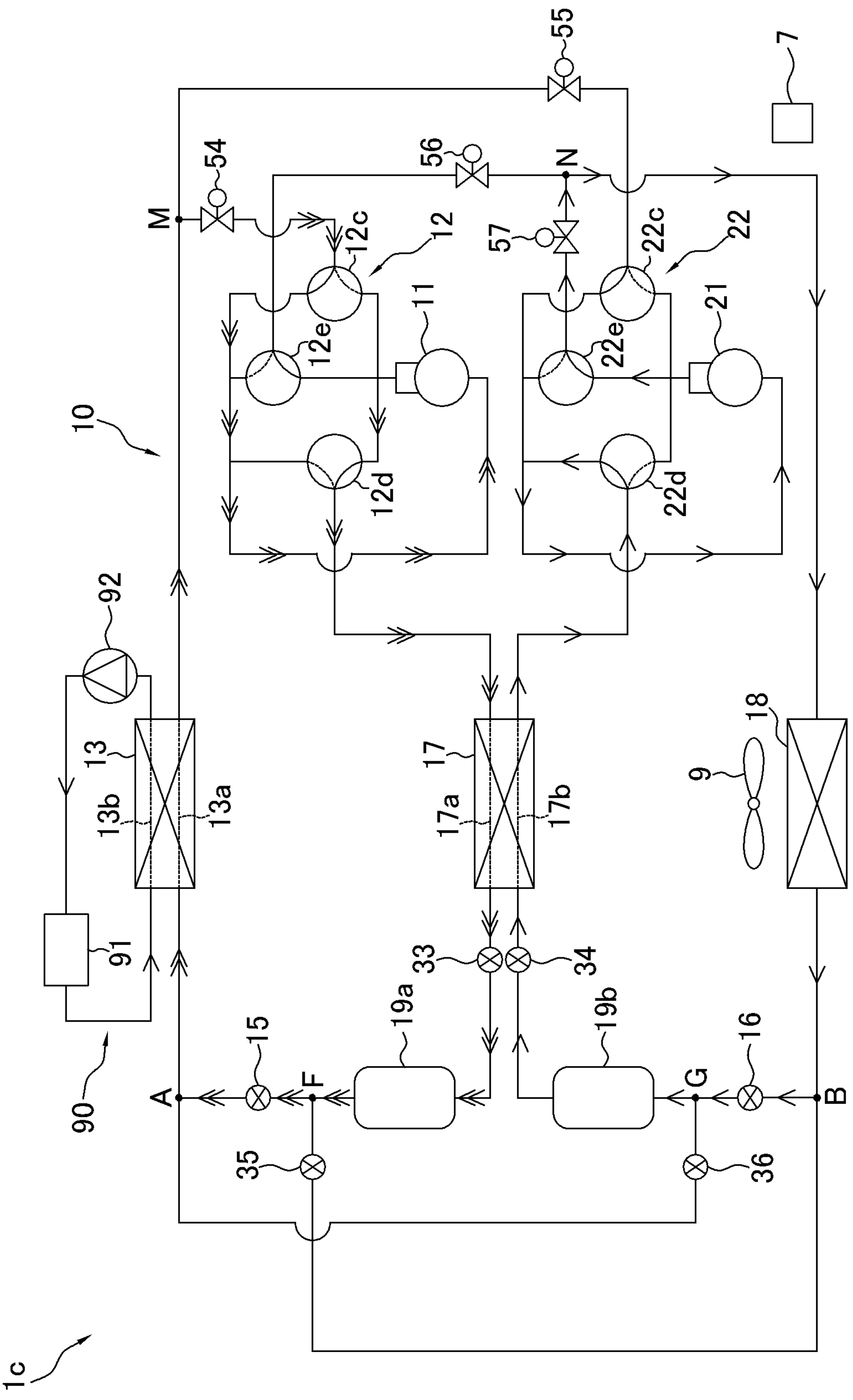
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FIG. 15

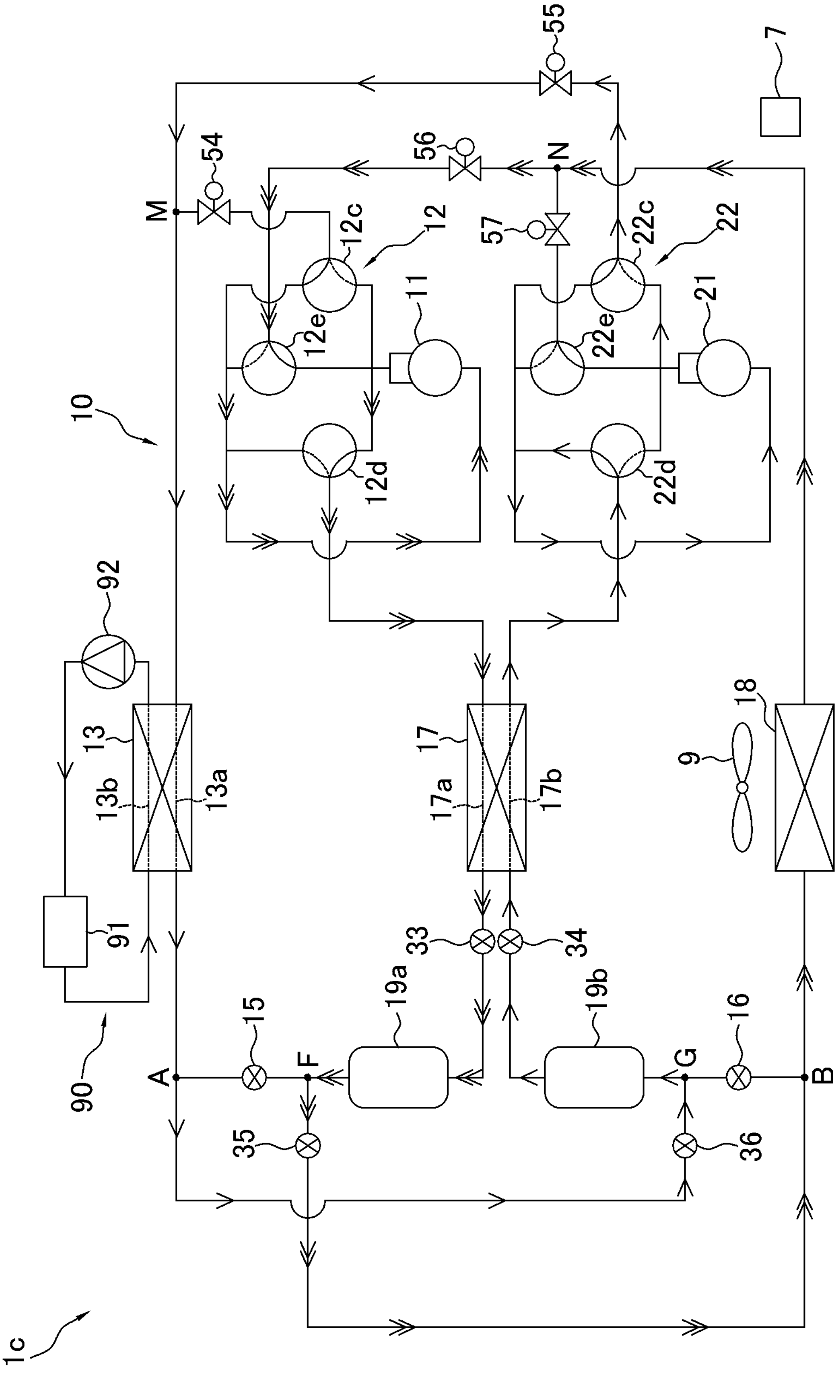

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FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/016796

A. CLASSIFICATION OF SUBJECT MATTER

F25B 7/00(2006.01)i; ***F25B 1/00***(2006.01)i
FI: F25B7/00 D; F25B7/00 A; F25B1/00 396D; F25B1/00 396Z; F25B1/00 396U

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)

F25B7/00; F25B1/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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 A	JP 2000-320914 A (DAIKIN IND LTD) 24 November 2000 (2000-11-24) paragraphs [0028]-[0054], fig. 1-6	1, 15-16 2-14
Y A	JP 2021-11985 A (FUJI ELECTRIC CO LTD) 04 February 2021 (2021-02-04) paragraph [0022]	1, 15-16 2-14
Y A	WO 2017/221382 A1 (MITSUBISHI ELECTRIC CORP) 28 December 2017 (2017-12-28) paragraphs [0036]-[0037]	1, 15-16 2-14

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 May 2022	**07 June 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/016796

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