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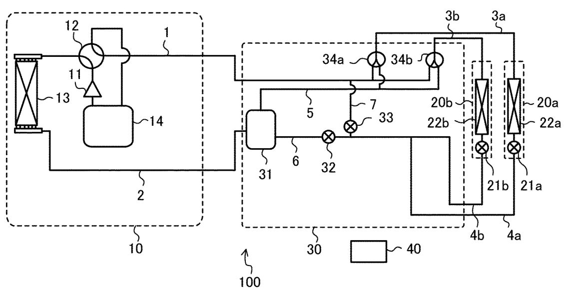
(54) REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus includes: a heat-source-side unit including a compressor and a heat-source-side heat exchanger; load-side units including respective expansion devices and respective load-side heat exchangers; and a relay unit including three-way valves that are connected between the heat-source-side unit and the load-side units, and are each provided in association with an associated one of the load-side units to switch a flow direction of refrigerant. The relay unit supplies low-temperature refrigerant to one of the load-side units that performs a cooling operation and supplies high-temperature refrigerant to one of the load-side units that performs a heating operation. Depending on an operating state, each of the three-way valves switches the flow direction of refrigerant that flows out from the heat-source-side unit such that the refrigerant flows into an associated one of the load-side units or switch the flow direction of refrigerant that flows out from the associated one of the load-side units such that the refrigerant flows into the heat-source-side unit.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a refrigeration cycle apparatus capable of simultaneously perform a cooling operation and a heating operation to cool and heat a plurality of air-conditioning target spaces.

Background Art

[0002] As a simultaneous cooling and heating type of air-conditioning apparatus, an air-conditioning apparatus has been known that can simultaneously perform a cooling operation and a heating operation to cool and heat a plurality of air-conditioning target spaces (see, for example, Patent Literature 1). An air-conditioning apparatus described in Patent Literature 1 includes a heat-source-side unit, a relay unit, and a plurality of load-side units, and the heat-source-side unit and the relay unit are connected by two connection pipes.

[0003] In the air-conditioning apparatus described in Patent Literature 1, the relay unit is provided with a plurality of solenoid vales. To be more specific, for each of the load-side units connected to the relay unit, the relay unit needs to include at least two solenoid valves for use in the cooling operation and the heating operation. Each of the solenoid valves is structurally unable to shut off a reverse flow. It is therefore necessary to ensure that the flow direction of refrigerant that flows between the heat-source-side unit and the relay unit in the cooling operation is the same as that in the heating operation. Thus, at refrigerant pipes in the heat-source-side unit, four solenoid valves are provided. By virtue of such a configuration, whichever of the cooling operation and the heating operation is performed, the flow direction of refrigerant that flows through each of two connection pipes that connect the heat-source-side unit and the relay unit is unchanged, and the flow direction of the refrigerant that flows through one of the above two connection pipes is opposite to that in the refrigerant that flows through the other connection pipe, whereby the air-conditioning apparatus can stably operate.

Citation List

Patent Literature

[0004] Patent Literature 1: PCT International Publication No. 2017/130319

Summary of Invention

Technical Problem

[0005] However, in the air-conditioning apparatus of Patent Literature 1, it is necessary to provide a plurality of valves including the four solenoid valves of the heat-source-side unit and the plurality of solenoid valves of the relay unit. Inevitably, a formed circuit is complicated, and a larger number of components are provided. Consequently, the costs are increased, the service quality is worsened, the risk that a failure will occur is increased, and the performance is deteriorated because of a pressure loss of refrigerant that is caused by an increase in the number of valves in the circuit.

[0006] The present disclosure is applied in view of the problem of the above related art, and relates to a refrigeration cycle apparatus that includes a smaller number of components and is capable of stably operating with the smaller number of components. Solution to Problem

[0007] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes: a heat-source-side unit including a compressor and a heat-source-side heat exchanger; a plurality of load-side units including respective expansion devices and respective load-side heat exchangers; and a relay unit including a plurality of three-way valves that are connected between the heat-source-side unit and the load-side units, and are each provided in association with an associated one of the load-side units to switch a flow direction of refrigerant between plural flow directions. The relay unit supplies the refrigerant having a low temperature to one of the load-side units that performs a cooling operation and supplies the refrigerant having a high temperature to one of the load-side units that performs a heating operation. Depending on an operating state, each of the three-way valves switches the flow direction of the refrigerant that flows out from the heat-source-side unit such that the refrigerant flows into an associated one of the load-side units or switch the flow direction of the refrigerant that flows out from the associated one of the load-side units such that the refrigerant flows into the heat-source-side unit.

Advantageous Effects of Invention

[0008] According to the embodiment of the present disclosure, in association with the plurality of load-side units, respective three-way valves are provided. Each of the three-way valves switches the flow direction of refrigerant depending on an operating state. Thus, it is not necessary to provide four check valves that are provided at a heat-source-side unit of an existing refrigeration cycle apparatus, and in addition, a three-way valve is used instead of solenoid valves of a relay unit. It is therefore possible to reduce the number of components as compared with the existing refrigeration cycle apparatus. Furthermore, since the number of components is reduced, it is possible to reduce a pressure loss, reduce deterioration of the performance of the apparatus, and cause the apparatus to stably operate.

Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 is a circuit diagram illustrating an example of the configuration of an air-conditioning apparatus according to Embodiment 1.

[Fig. 2] Fig. 2 is a schematic explanatory view for the flow of refrigerant in a cooling only operation mode in the air-conditioning apparatus as illustrated in Fig. 1.

[Fig. 3] Fig. 3 is a schematic explanatory view for the flow of the refrigerant in a cooling main operation mode in the air-conditioning apparatus as illustrated in Fig. 1.

[Fig. 4] Fig. 4 is a schematic explanatory view for the flow of the refrigerant in a heating only operation mode in the air-conditioning apparatus as illustrated in Fig. 1.

[Fig. 5] Fig. 5 is a schematic explanatory view for the flow of the refrigerant in a heating main operation mode in the air-conditioning apparatuses as illustrated in Fig. 1.

[Fig. 6] Fig. 6 is a schematic explanatory view for the flow of the refrigerant in a partial load stopped operation mode in the air-conditioning apparatus as illustrated in Fig. 1.

Description of Embodiments

[0010] An embodiment of the present disclosure will be described with reference to the drawings. The following description concerning the embodiment is not limiting, and various modifications can be made without departing from the gist of the present disclosure. The present disclosure encompasses all combinations of combinable ones of components described with reference to the embodiment. Furthermore, relationships in magnitude between temperatures, between pressures, etc., are not determined, especially in association with absolute values; that is, they are relatively determined based on, for example, the states and operations of a system, devices, and apparatuses, etc. In addition, in each of figures in the drawings, components that are the same as those in a previous figure or previous figures are denoted by the same reference signs. The same is true of the entire text of the specification.

Embodiment 1

[0011] A refrigeration cycle apparatus according to Embodiment 1 will be described. The following description is made by referring to by way of example the case where the refrigeration cycle apparatus is an air-conditioning apparatus. The air-conditioning apparatus corresponding to the refrigeration cycle apparatus is installed in, for example, a building or a condominium, and can perform a cooling operation or a heating operation, using a refrigeration cycle circuit in which refrigerant is circulated. In particular, it should be noted that the air-conditioning apparatus according to Embodiment 1 can perform only the cooling operation, the heating operation, or a simultaneous cooling and heating operation on a plurality of air-conditioning target spaces.

Configuration of Air-conditioning Apparatus 100

[0012] Fig. 1 is a circuit diagram illustrating an example of the configuration of the air-conditioning apparatus according to Embodiment 1. The air-conditioning apparatus 100 according to Embodiment 1 includes a heat-source-side unit 10, a plurality of load-side units 20, a relay unit 30, and a controller 40. In the example illustrated in Fig. 1, the air-conditioning apparatus 100 includes one heat-source-side unit 10, two load-side units, that is, load-side units 20a and 20b, and one relay unit 30.

[0013] In the air-conditioning apparatus 100, the heat-source-side unit 10 and the relay unit 30 are connected by a gas pipe 1 and a liquid pipe 2. The relay unit 30 and the load-side unit 20a are connected by a gas branch pipe 3a and a liquid branch pipe 4a, and the relay unit 30 and the load-side unit 20b are connected by a gas branch pipe 3b and a liquid branch pipe 4b. As described above, the heat-source-side unit 10, the relay unit 30, and the load-side units 20a and 20b are connected by respective pipes in the above manner, whereby a refrigeration cycle circuit is provided. It should be noted that the number of load-side units 20 is not limited to two and may be three or more. Also, the number of heat-source-side units 10 and that of relay units 30 may be, for example, two or more.

Heat-source-side Unit 10

[0014] The heat-source-side unit 10 is provided to supply heat to the load-side units 20. The heat-source-side unit 10 includes a compressor 11, a refrigerant flow switching device 12, a heat-source-side heat exchanger 13, and an accumulator 14.

[0015] The compressor 11 sucks low-temperature and low-pressure gas refrigerant, then compresses the low-temperature and low-pressure gas refrigerant to change it into high-temperature and high-pressure refrigerant, and discharges the high-temperature and high-pressure refrigerant. The compressor 11 is, for example, an inverter compressor whose driving frequency can be arbitrarily changed, thereby controlling its capacity that is a refrigerant delivery amount per unit time. The driving frequency of the compressor 11 is controlled by the controller 40.

[0016] It should be noted that the compressor 11 is not limited to the inverter compressor, and may be, for example, a fixed-speed compressor or a compressor that is obtained by combining the inverter compressor and the fixed-speed compressor. Furthermore, the compressor 11 may be any type of compressor as long as it can compress sucked refrigerant to change it into high-pressure refrigerant, such as a reciprocating compressor, a rotary compressor, a scroll compressor, or a screw compressor.

[0017] The refrigerant flow switching device 12 is, for example, a four-way valve, and switches the flow direction of the refrigerant between plural flow directions to switch the operation between the cooling operation and the heating operation. This switching operation of the refrigerant flow switching device 12 is controlled by the controller 40. It should be noted that the above description concerning the refrigerant flow switching device 12 is not limiting, and the refrigerant flow switching device 12 may be a combination of, for example, two-way valves or three-way valves.

[0018] The heat-source-side heat exchanger 13 causes heat exchange to be performed between the refrigerant and a fluid such as water or outdoor air. To be more specific, in the cooling operation, the heat-source-side heat exchanger 13 operates as a condenser that transfers heat of the refrigerant to outdoor air to condense and liquefy the refrigerant; and in the heating operation, the heat-source-side heat exchanger 13 operates as an evaporator that evaporates and gasifies the refrigerant and absorbs heat from the outdoor air as heat of evaporation.

[0019] In the case where the heat-source-side heat exchanger 13 is an air-cooled heat exchanger, an air-sending device (not illustrated) such as a heat-source-side fan is provided in the heat-source-side unit 10 to send outdoor air to the heat-source-side heat exchanger 13. The rotation speed of the heat-source-side fan is controlled by the controller 40, whereby a condensing performance or evaporating performance of the heat-source-side heat exchanger 13 is controlled.

[0020] In the case where the heat-source-side heat exchanger 13 is a water-cooled heat exchanger, a water circulating pump (not illustrated) is provided in the heat-source-side unit 10 to circulate and transfer a fluid such as water to the heat-source-side heat exchanger 13. The rotation speed of the water circulating pump is controlled by the controller 40, whereby the condensing performance or evaporating performance of the heat-source-side heat exchanger 13 is controlled.

[0021] The accumulator 14 is provided on a low pressure side of the compressor 11 that is a suction side thereof. The accumulator 14 stores surplus refrigerant the amount of which corresponds to the difference between the amount of the refrigerant that flows in the heating operation and the amount of the refrigerant that flows in the cooling operation, or the amount of which corresponds to the difference between the amount of the refrigerant that flows after a transient change of the operation and the amount of the refrigerant that flows before the transient change of the operation. It is not indispensable that the accumulator 14 is provided.

Load-side Units 20a and 20b

[0022] The load-side units 20a and 20b each supply heat from the heat-source-side unit 10 to a cooling load or a heating load, thereby performing cooling or heating. The load-side unit 20a includes a load-side expansion device 21a and a load-side heat exchanger 22a. The load-side unit 20b includes a load-side expansion device 21b and a load-side heat exchanger 22b.

[0023] In the following description, in the case where the load-side units 20a and 20b does not particularly need to be distinguished from each other, they are each referred to as "load-side unit 20" as appropriate. In addition, the load-side expansion devices 21a and 21b have the same configuration, and the load-side heat exchangers 22a and 22b have the same configuration. Therefore, the following description is made by referring to the load-side expansion device 21a and the load-side heat exchanger 22a only.

[0024] The load-side expansion device 21a has functions of a pressure-reducing valve and an expansion valve, and adjusts the flow rate of the refrigerant to reduce the pressure of the refrigerant and expand the refrigerant. The load-side expansion device 21a is a valve whose opening degree can be controlled, such as an electronic expansion valve. In this case, the opening degree of the load-side expansion device 21a is controlled by the controller 40. It should be noted that the above description concerning the load-side expansion device 21a is not limiting, and another expansion valve such as a capillary tube may be used as the load-side expansion device 21a.

[0025] The load-side heat exchanger 22a causes heat exchange to be performed between the refrigerant and a fluid such as indoor air or water. To be more specific, in the cooling operation, the load-side heat exchanger 22a operates an evaporator to evaporate and gasify the refrigerant and receive heat as the heat of evaporation from outdoor air. In the heating operation, the load-side heat exchanger 22a operates as a condenser to transfer heat of the refrigerant to the indoor air, thereby condensing and liquefying the refrigerant.

[0026] In the case where the refrigeration cycle apparatus is the air-conditioning apparatus 100 as in Embodiment 1, in general, an air-sending device (not illustrated) such as a load-side fan is provided in the load-side unit 20a to send indoor air to the load-side heat exchanger 22a. The rotation speed of the load-side fan is controlled by the controller 40, thereby controlling the evaporating performance or condensing performance of the load-side heat exchanger 22a.

Relay Unit 30

[0027] The relay unit 30 switches the flow of the refrigerant depending on the operating states of the load-side units to distribute refrigerant to the load-side units 20 such that low-temperature refrigerant is supplied to one of the load-side units 20 that performs the cooling operation and high-temperature refrigerant is supplied to another one or the other of the load-side units 20 that performs the heating operation.

[0028] The relay unit 30 includes a gas-liquid separator 31, a first expansion valve 32, a second expansion valve 33, and three-way valves 34a and 34b. In the case where the three-way valves 34a and 34b do not particularly need to be distinguished from each other, they will be each referred to as "three-way valve 34".

[0029] Furthermore, in the relay unit 30, connection pipes 5 and 6 and a relay pipe 7 are provided. The connection pipe 5 is a pipe that connects a gas side of the gas-liquid separator 31 and the three-way valves 34a and 34b and through which gas refrigerant flows. The connection pipe 6 is a pipe that connects a liquid side of the gas-liquid separator 31 and the load-side units 20 and through which liquid refrigerant flows. The relay pipe 7 is a relay between the connection pipe 5 and the connection pipe 6.

[0030] The gas-liquid separator 31 is provided at the liquid pipe 2, and the connection pipes 5 and 6 are connected to the gas-liquid separator 31. The gas-liquid separator 31 separates two-phase refrigerant that flows through the liquid pipe 2 into gas refrigerant and liquid refrigerant. The gas refrigerant obtained through the above separation by the gas-liquid separator 31 is supplied to the three-way valves 34a and 34b through the connection pipe 5. The liquid refrigerant obtained through the separation by the gas-liquid separator 31 is supplied to the first expansion valve 32 through the connection pipe 6.

[0031] The first expansion valve 32 is provided at the connection pipe 6. The first expansion valve 32 has functions of a pressure reducing valve and an expansion valve, and adjusts the flow rate of the refrigerant to reduce the pressure of the refrigerant and expand the refrigerant. The first expansion valve 32 is a valve whose opening degree can be controlled, such as an electronic expansion valve. In this case, the opening degree of the first expansion valve 32 is controlled by the controller 40. It should be noted that the above description concerning the first expansion valve 32 is not limiting, and another expansion valve such as a capillary tube may be used as the first expansion valve 32.

[0032] The second expansion valve 33 is provided at the relay pipe 7. The second expansion valve 33 has functions of a pressure reducing valve and an expansion valve, and adjusts the flow rate of the refrigerant to reduce the pressure of the refrigerant and expand the refrigerant. The second expansion valve 33 is a valve whose opening degree can be controlled, such as an electronic expansion valve. In this case, the opening degree of the second expansion valve 33 is controlled by the controller 40. It should be noted that the above description concerning the second expansion valve 33 is not limiting, and another expansion valve such as a capillary tube may be used as the second expansion valve 33.

[0033] The three-way valves 34 each switch the flow direction of the refrigerant between plural flow directions, depending on the operating state of an associated one of the load-side units 20. The number of three-way valves 34 is determined depending on the number of the load-side units 20. In the example illustrated in Fig. 1, the three-way valves 34a and 34b are provided in association with the load-side units 20a and 20b, respectively. The three-way valve 34a is connected to the connection pipe 5, the gas branch pipe 3a, and the gas pipe 1; and the three-way valve 34b is connected to the connection pipe 5, the gas branch pipe 3b, and the gas pipe 1.

[0034] To be more specific, the three-way valve 34a switches a flow passage therein to cause the gas branch pipe 3a to communicate with the gas pipe 1 or the connection pipe 5 depending on the operating state of the load-side unit 20a; and the three-way valve 34a switches a flow passage therein to cause the gas branch pipe 3b to communicate with the gas pipe 1 or the connection pipe 5 depending on the operating state of the load-side unit 20b.

[0035] It should be noted that the three-way valves 34a and 34b can be set such that the gas branch pipes 3a and 3b are connected with neither the gas pipe 1 nor the connection pipe 5. To be more specific, in the case where the operation of the load-side unit 20a is stopped, the three-way valve 34a switches the flow passage such that the gas branch pipe 3a is connected to neither the gas pipe 1 nor the connection pipe 5; and in the case where the operation of the load-side unit 20b is stopped, the three-way valve 34b switches the flow passage such that the gas branch pipe 3b is connected with neither the gas pipe 1 nor the connection pipe 5.

Controller 40

[0036] The controller 40 controls the entire air-conditioning apparatus 100. For example, depending on the operation mode of the air-conditioning apparatus 100, the controller 40 controls the refrigerant flow switching device 12, the load-side expansion devices 21a and 21b, the first expansion valve 32, the second expansion valve 33, the three-way valves 34a and 34b, etc. The functions of the controller 40 are fulfilled by running software on an arithmetic device such as a microcomputer, or the controller 40 is, for example, hardware such as a circuit device that fulfills the functions.

Flow of Refrigerant in Air-conditioning Apparatus 100

[0037] It will be how the refrigerant flows in each of operation modes in the air-conditioning apparatus 100 having the above configuration. The air-conditioning apparatus 100 according to Embodiment 1 performs any of a cooling only operation, a cooling main operation, a heating only operation, and a heating main operation.

[0038] The cooling only operation is an operation in which all or both the load-side units 20 each perform the cooling operation. The cooling main operation is an operation that is performed when a cooling load of one of the load-side units 20 that performs the cooling operation exceeds a heating load of one or the other of the load-side units 20 that performs the heating operation. The heating only operation is an operation in which all or both the load-side units 20 perform the heating operation. The heating main operation is an operation that is performed when the heating load of one of the load-side units 20 that performs the heating operation exceeds the cooling operation of one of the load-side units 20 that performs the cooling operation.

Cooling Only Operation Mode

[0039] Fig. 2 is a schematic explanatory view for the flow of the refrigerant in a cooling only operation mode in the air-conditioning apparatus as illustrated in Fig. 1. In the cooling only operation mode, both the load-side units 20a and 20b each perform the cooling operation. Referring to Fig. 2, flow passages indicated by bold lines are flow passages for the refrigerant in the cooling only operation mode, and arrows indicate the flow directions of the refrigerant in the flow passages for the refrigerant.

[0040] In the cooling only operation mode, first, the flow passage in the refrigerant flow switching device 12 in the heat-source-side unit 10 is switched such that the discharge side of the compressor 11 and the heat-source-side heat exchanger 13 are connected and the suction side of the compressor 11 and the gas pipe 1 are connected. Furthermore, the flow passages in the three-way valves 34a and 34b are switched such that the gas pipe 1 is connected to the gas branch pipes 3a and 3b, respectively.

[0041] Low-temperature and low-pressure refrigerant is compressed by the compressor 11 to change into high-temperature and high-pressure gas refrigerant, and the high-temperature and high-pressure gas refrigerant is then discharged from the compressor 11. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 passes through the refrigerant flow switching device 12 and flows into the heat-source-side heat exchanger 13. The high-temperature and high-pressure gas refrigerant that has flowed into the heat-source-side heat exchanger 13 exchanges heat with outdoor air to condense while transferring heat to the outdoor air, and changes into high-pressure liquid refrigerant, and the high-pressure liquid refrigerant then flows out from the heat-source-side heat exchanger 13. The high-pressure liquid refrigerant that has flowed out from the heat-source-side heat exchanger 13 passes through the liquid pipe 2, flows out from the heat-source-side unit 10, and flows into the relay unit 30.

[0042] The high-pressure liquid refrigerant that has flowed into the relay unit 30 passes through the gas-liquid separator 31, flows into the first expansion valve 32, and is decompressed and expanded to change into intermediate-pressure liquid refrigerant. Then, the intermediate-pressure liquid refrigerant passes through the connection pipe 6, branches to flow into the liquid branch pipes 4a and 4b, and flows out from the relay unit 30. The liquid refrigerant that has flowed out from the relay unit 30 flows into the load-side units 20a and 20b through the liquid branch pipes 4a and 4b.

[0043] The intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20a is decompressed and expanded by the load-side expansion device 21a to change into low-temperature and low-pressure liquid-gas refrigerant, and the low-temperature and low-pressure liquid-gas refrigerant flows into the load-side heat exchanger 22a. The low-temperature and low-pressure liquid-gas refrigerant that has flowed into the load-side heat exchanger 22a exchanges heat with indoor air to receive heat therefrom and evaporate. As a result, the low-temperature and low-pressure liquid-gas refrigerant cools the indoor air and changes into low-pressure gas refrigerant. The low-pressure gas refrigerant then flows out from the load-side heat exchanger 22a. The low-pressure gas refrigerant that has flowed out from the load-side heat exchanger 22a flows out from the load-side unit 20a through the gas branch pipe 3a, and flows into the relay unit 30.

[0044] The intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20b is changed in the same manner as the refrigerant that has flowed into the load-side unit 20a; that is, the intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20b is changed into low-pressure gas refrigerant through the load-side expansion device 21b and the load-side heat exchanger 22b. The low-pressure gas refrigerant flows out from the load-side unit 20b through the gas branch pipe 3b, and flows into the relay unit 30.

[0045] The low-pressure gas refrigerant that has flowed into the relay unit 30 passes through the three-way valves 34a and 34b and reaches the gas pipe 1 through the three-way valves 34a and 34b, and then after flowing out from the relay unit 30, the low-pressure gas refrigerant flows into the heat-source-side unit 10. The low-pressure gas refrigerant that has flowed into the heat-source-side unit 10 passes through the refrigerant flow switching device 12 and the accumulator 14, and is sucked into the compressor 11. Thereafter, the above cycle will be repeated.

Cooling Main Operation Mode

[0046] Fig. 3 is a schematic explanatory view for the flow of the refrigerant in the cooling main operation mode in the air-conditioning apparatus as illustrated in Fig. 1. The following description is made by referring to by way of example the case where the load-side unit 20a performs the cooling operation, and the load-side unit 20b performs the heating operation. In Fig. 3, flow passages indicated by bold lines are flow passages for the refrigerant in the cooling main operation mode, and the flow directions of the refrigerant in the flow passages for the refrigerant are indicated by arrows.

[0047] In the cooling main operation mode, first, the flow passage in the refrigerant flow switching device 12 in the heat-source-side unit 10 is switched such that the discharge side of the compressor 11 and the heat-source-side heat exchanger 13 are connected and the suction side of the compressor 11 and the gas pipe 1 are connected. Furthermore, the flow passage in the three-way valve 34a is switched such that the gas pipe 1 and the gas branch pipe 3a are connected. The flow passage in the three-way valve 34b is switched such that the connection pipe 5 and the gas branch pipe 3b are connected.

[0048] The low-temperature and low-pressure refrigerant is compressed by the compressor 11 to change into high-temperature and high-pressure gas refrigerant, and the high-temperature and high-pressure gas refrigerant is then discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 passes through the refrigerant flow switching device 12 and flows into the heat-source-side heat exchanger 13. The high-temperature and high-pressure gas refrigerant that has flowed into the heat-source-side heat exchanger 13 exchanges heat with outdoor air to condense while transferring heat to the outdoor air. As a result, the high-temperature and high-pressure gas refrigerant changes into high-pressure two-phase gas-liquid refrigerant. The high-pressure two-phase gas-liquid refrigerant then flows out from the heat-source-side heat exchanger 13. The high-pressure two-phase gas-liquid refrigerant that has flowed out from the heat-source-side heat exchanger 13 flows out from the heat-source-side unit 10 through the liquid pipe 2, and flows into the relay unit 30.

[0049] The high-pressure two-phase gas-liquid refrigerant that has flowed into the relay unit 30 flows into the gas-liquid separator 31 and is separated into high-pressure gas refrigerant and high-pressure liquid refrigerant. The high-pressure gas refrigerant obtained through the above separation by the gas-liquid separator 31 passes through the connection pipe 5, then passes through the gas branch pipe 3b via the three-way valve 34b, and flows out from the relay unit 30. The high-pressure gas refrigerant that has flowed out from the relay unit 30 flows into the load-side unit 20b.

[0050] The high-pressure gas refrigerant that has flowed into the load-side unit 20b flows into the load-side heat exchanger 22b and exchanges heat with indoor air to condense while transferring to heat the indoor air. As a result, the high-pressure gas refrigerant heats the indoor air and changes into high-pressure liquid refrigerant. The high-pressure liquid refrigerant then flows out from the load-side heat exchanger 22b. The high-pressure liquid refrigerant that has flowed out from the load-side heat exchanger 22b is decompressed and expanded by the load-side expansion device 21b to change into intermediate-pressure liquid refrigerant, and the intermediate-pressure liquid refrigerant then flows out from the load-side unit 20b and flows into the relay unit 30.

[0051] The intermediate-pressure liquid refrigerant that has flowed into the relay unit 30 passes through the liquid branch pipe 4b and then branches into plural refrigerants, and one of the refrigerants passes through the liquid branch pipe 4a and flows out from the relay unit 30. The intermediate-pressure liquid refrigerant that has flowed out from the relay unit 30 flows into the load-side unit 20a.

[0052] The intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20a is decompressed and expanded by the load-side expansion device 21a to change into low-temperature and low-pressure liquid-gas refrigerant, and low-temperature and low-pressure liquid-gas refrigerant then flows into the load-side heat exchanger 22a. The low-temperature and low-pressure liquid-gas refrigerant that has flowed into the load-side heat exchanger 22a exchanges heat with indoor air to receive heat from the indoor air and evaporate. As a result, the low-temperature and low-pressure liquid-gas refrigerant cools the indoor air and changes into low-pressure gas refrigerant. The low-pressure gas refrigerant then flows out from the load-side heat exchanger 22a. The low-pressure gas refrigerant that has flowed out from the load-side heat exchanger 22a flows out from the load-side unit 20a through the gas branch pipe 3a, and flows into the relay unit 30. The low-pressure gas refrigerant that has flowed into the relay unit 30 passes through the three-way valve 34a and reaches the gas pipe 1.

[0053] On the other hand, the high-pressure liquid refrigerant obtained through separation by the gas-liquid separator 31 flows into the first expansion valve 32 through the connection pipe 6, and is decompressed and expanded to change into intermediate-pressure liquid refrigerant. The intermediate-pressure liquid refrigerant that has flowed out from the first expansion valve 32 joins the intermediate-pressure liquid refrigerant that branches after flowing from the load-side unit 20b into the relay unit 30, and then passes through the relay pipe 7. The intermediate-pressure liquid refrigerant that has passed through the replay pipe 7 is decompressed and expanded by the second expansion valve 33 to change into low-pressure liquid refrigerant. The low-pressure liquid refrigerant then reaches the gas pipe 1, joins the low-pressure gas refrigerant that passes through the three-way valve 34a and then through the gas pipe 1, and flows out from the relay unit 30.

[0054] The low-pressure refrigerant that has flowed out from the relay unit 30 flows into the heat-source-side unit 10 through the gas pipe 1. The low-pressure refrigerant that has flowed into the heat-source-side unit 10 passes through the refrigerant flow switching device 12 and the accumulator 14 and is sucked into the compressor 11. Thereafter, the above cycle will be repeated.

Heating Only Operation Mode

[0055] Fig. 4 is a schematic explanatory view for the flow of the refrigerant in the heating only operation mode in the air-conditioning apparatus as illustrated in Fig. 1. In the heating only operation mode, both the load-side units 20a and 20b perform the heating operation. Referring to Fig. 4, flow passages indicated by bold lines are flow passages for the refrigerant in the heating only operation mode, and arrows indicate the flow directions of the refrigerant in the flow passages.

[0056] In the heating only operation mode, first, the flow passage in the refrigerant flow switching device 12 in the heat-source-side unit 10 is switched such that the discharge side of the compressor 11 and the gas pipe 1 are connected and the suction side of the compressor 11 and the heat-source-side heat exchanger 13 are connected. Furthermore, the flow passages in the three-way valves 34a and 34b are switched such that the gas pipe 1 is connected to the gas branch pipes 3a and 3b, respectively. Furthermore, the second expansion valve 33 is in the fully closed state or in the slightly opened state.

[0057] The low-temperature and low-pressure refrigerant is compressed by the compressor 11 to change into high-temperature and high-pressure gas refrigerant, and the high-temperature and high-pressure gas refrigerant is then discharged therefrom. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant flow switching device 12 and the gas pipe 1, and flows out from heat-source-side unit 10 and flows into the relay unit 30. The high-temperature and high-pressure gas refrigerant that has flowed into the relay unit 30 flows through the three-way valves 34a and 34b and the gas branch pipes 3a and 3b, and then flows out from the relay unit 30 and flows into the load-side units 20a and 20b.

[0058] The high-temperature and high-pressure gas refrigerant that has flowed into the load-side unit 20a flows into the load-side heat exchanger 22a, and exchanges heat with indoor air to condense while transferring heat to the indoor air. As a result, the high-temperature and high-pressure gas refrigerant heats the indoor air and changes into high-pressure liquid refrigerant. The high-pressure liquid refrigerant then flows out from the load-side heat exchanger 22a. The high-pressure liquid refrigerant that has flowed out from the load-side heat exchanger 22a is decompressed and expanded by the load-side expansion device 21a to change into low-pressure liquid refrigerant. The low-pressure liquid refrigerant flows out from the load-side unit 20a, and then flows into the relay unit 30 through the liquid branch pipe 4a.

[0059] The high-temperature and high-pressure gas refrigerant that has flowed into the load-side unit 20b flows in the same manner as the refrigerant that has flowed into the load-side unit 20a. To be more specific, the high-temperature and high-pressure gas refrigerant that has flowed into the load-side unit 20b flows through the load-side heat exchanger 22b and the load-side expansion device 21b to change into low-pressure liquid refrigerant. The low-pressure liquid refrigerant flows into the relay unit 30 flows out from the load-side unit 20b through the liquid branch pipe 4b and flows into the relay unit 30. The low-pressure liquid refrigerant that has flowed into the relay unit 30 flows through the gas-liquid separator 31 and flows out from the relay unit 30.

[0060] The low-pressure liquid refrigerant that has flowed out from the relay unit 30 flows into the heat-source-side unit 10 through the liquid pipe 2. The low-pressure liquid refrigerant that has flowed into the heat-source-side unit 10 flows into the heat-source-side heat exchanger 13. The low-pressure liquid refrigerant that has flowed into the heat-source-side heat exchanger 13 exchanges heat with outdoor air to receive heat therefrom and evaporate. As a result, the low-pressure liquid refrigerant changes into low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant then flows out from the heat-source-side heat exchanger 13. The low-pressure gas refrigerant that has flowed out from the heat-source-side heat exchanger 13 flows through the refrigerant flow switching device 12 and the accumulator 14 and is sucked into the compressor 11. Thereafter, the above cycle will be repeated.

Heating Main Operation Mode

[0061] Fig. 5 is a schematic explanatory view for the flow of the refrigerant in the heating main operation mode in the air-conditioning apparatuses as illustrated in Fig. 1. The following description is made by referring to the case where the load-side unit 20a performs the heating operation and the load-side unit 20b performs the cooling operation. In Fig. 5, flow passages indicated by bold lines are flow passages for the refrigerant in the heating main operation mode, and arrows indicate the flow directions of the refrigerant in the flow passages for the refrigerant.

[0062] In the heating main operation mode, first, the flow passage in the refrigerant flow switching device 12 in the heat-source-side unit 10 is switched such that the discharge side of the compressor 11 and the gas pipe 1 are connected and the suction side of the compressor 11 and the heat-source-side heat exchanger 13 are connected. The flow passage in the three-way valve 34a is switched such that the gas pipe 1 and the gas branch pipe 3a are connected. The flow passage in the three-way valve 34 is switched such that the connection pipe 5 and the gas branch pipe 3b are connected.

[0063] The low-temperature and low-pressure refrigerant is compressed by the compressor 11 to change into high-temperature and high-pressure gas refrigerant, and the high-temperature and high-pressure gas refrigerant is then discharged therefrom. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant flow switching device 12 and the gas pipe 1, flows out from the heat-source-side unit 10, and flows into the relay unit 30. The high-temperature and high-pressure gas refrigerant that has flowed into the relay unit 30 flows through the three-way valve 34a and the gas branch pipe 3a, then flows out from the relay unit 30, and flows into the load-side unit 20a.

[0064] The high-temperature and high-pressure gas refrigerant that has flowed into the load-side unit 20a flows into the load-side heat exchanger 22a, and exchanges heat with indoor air to condense while transferring heat to the indoor air. As a result, the high-temperature and high-pressure gas refrigerant heats the indoor air and changes into high-pressure liquid refrigerant. The high-pressure liquid refrigerant then flows out from the load-side heat exchanger 22a. The high-pressure liquid refrigerant that has flowed out from the load-side heat exchanger 22a is decompressed and expanded by the load-side expansion device 21a to change into intermediate-pressure liquid refrigerant. The intermediate-pressure liquid refrigerant flows out from the load-side unit 20a, and then flows into the relay unit 30 through the liquid branch pipe 4a.

[0065] The intermediate-pressure liquid refrigerant that has flowed into the relay unit 30 flows through the liquid branch pipe 4a and then through the liquid branch pipe 4b, and flows out from the relay unit 30. The intermediate-pressure liquid refrigerant that has flowed out from the relay unit 30 flows into the load-side unit 20b.

[0066] The intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20b is decompressed and expanded by the load-side expansion device 21b to change into low-temperature and low-pressure liquid-gas refrigerant, and the low-temperature and low-pressure liquid-gas refrigerant then flows into the load-side heat exchanger 22b. The low-temperature and low-pressure liquid-gas refrigerant that has flowed into the load-side heat exchanger 22b exchanges heat with indoor air to receive heat from the indoor air and evaporate. As a result, the low-temperature and low-pressure liquid-gas refrigerant cools the indoor air and changes into low-pressure gas refrigerant. The low-pressure gas refrigerant then flows out from the load-side heat exchanger 22b. The low-pressure gas refrigerant that has flowed out from the load-side heat exchanger 22b flows out from the load-side unit 20b through the gas branch pipe 3b, and flows into the relay unit 30. The low-pressure gas refrigerant that has flowed into the relay unit 30 flows through the three-way valve 34b and reaches the connection pipe 5. The low-pressure gas refrigerant then flows through the gas-liquid separator 31 and flows out from the relay unit 30.

[0067] Low-pressure liquid refrigerant that has flowed out from the relay unit 30 flows into the heat-source-side unit 10 through the liquid pipe 2. The low-pressure liquid refrigerant that has flowed into the heat-source-side unit 10 flows into the heat-source-side heat exchanger 13. The low-pressure liquid refrigerant that has flowed into the heat-source-side heat exchanger 13 exchanges heat with outdoor air to receive heat from the outdoor air and evaporate. As a result, the low-pressure liquid refrigerant changes into low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant then flows out from the heat-source-side heat exchanger 13. The low-pressure gas refrigerant that has flowed out from the heat-source-side heat exchanger 13 flows through the refrigerant flow switching device 12 and the accumulator 14, and is sucked into the compressor 11. Thereafter, the above cycle will be repeated.

Partial Load Stopped Operation Mode (Cooling Operation)

[0068] Next, a partial load stopped operation mode will be described. The air-conditioning apparatus 100 according to Embodiment 1 can also perform a partial load stopped operation in which the cooling operation or the heating operation is performed, with any of the plurality of load-side units 20 stopped.

[0069] Fig. 6 is a schematic explanatory view for the flow of the refrigerant in the partial load stopped operation mode in the air-conditioning apparatus as illustrated in Fig. 1. The following description is made with respect to the case where the cooling operation is performed by the load-side unit 20a, with the load-side unit 20b stopped. In Fig. 6, a flow passage indicated by a bold line is a flow passage for the refrigerant in the partial load stopped operation mode, and the flow directions of the refrigerant in the flow passage for the refrigerant are indicated by arrows.

[0070] In the partial load stopped operation mode, first, the flow passage in the refrigerant flow switching device 12 in the heat-source-side unit 10 is switched such that the discharge side of the compressor 11 and the heat-source-side heat exchanger 13 are connected and the suction side of the compressor 11 and the gas pipe 1 are connected. The flow passage in the three-way valve 34a is switched such that the gas pipe 1 and the gas branch pipe 3a are connected. The flow passage in the three-way valve 34b is set such that the gas branch pipe 3b is not connected with the gas pipe 1 or the connection pipe 5. It should be noted that the load-side expansion device 21b at the load-side unit 20b that is stopped is set in the closed state.

[0071] The low-temperature and low-pressure refrigerant is compressed by the compressor 11 to change into high-temperature and high-pressure gas refrigerant, and the high-temperature and high-pressure gas refrigerant is then discharged therefrom. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant flow switching device 12 and flows into the heat-source-side heat exchanger 13. The high-temperature and high-pressure gas refrigerant that has flowed into the heat-source-side heat exchanger 13 exchanges heat with outdoor air to condense while transferring heat to the outdoor air. As a result, the high-temperature and high-pressure gas refrigerant changes into high-pressure liquid refrigerant, and the high-pressure liquid refrigerant then flows out from the heat-source-side heat exchanger 13. The high-pressure liquid refrigerant that has flowed from the heat-source-side heat exchanger 13 flows out from the heat-source-side unit 10 through the liquid pipe 2, and flows into the relay unit 30.

[0072] The high-pressure liquid refrigerant that has flowed into the relay unit 30 flows through the gas-liquid separator 31 and flows into the first expansion valve 32, and is then decompressed and expanded to change into intermediate-pressure liquid refrigerant. The intermediate-pressure liquid refrigerant flows through the connection pipe 6 and then through the liquid branch pipe 4a, and flows out from the relay unit 30. The liquid refrigerant that has flowed out from the relay unit 30 flows into the load-side units 20a and 20b through the liquid branch pipe 4a.

[0073] The intermediate-pressure liquid refrigerant that has flowed into the load-side unit 20a is decompressed and expanded by the load-side expansion device 21a to change into low-temperature and low-pressure liquid-gas refrigerant, and the low-temperature and low-pressure liquid-gas refrigerant then flows into the load-side heat exchanger 22a. The low-temperature and low-pressure liquid-gas refrigerant that has flowed into the load-side heat exchanger 22a exchanges heat with indoor air to receive heat from the indoor air and evaporate. As a result, the low-temperature and low-pressure liquid-gas refrigerant cools the indoor air and changes into low-pressure gas refrigerant. The low-pressure gas refrigerant then flows out from the load-side heat exchanger 22a. The low-pressure gas refrigerant that has flowed out from the load-side heat exchanger 22a flows out from the load-side unit 20a through the gas branch pipe 3a and flows into the relay unit 30.

[0074] The low-pressure gas refrigerant that has flowed into the relay unit 30 flows through the three-way valve 34a and reaches the gas pipe 1. The low-pressure gas refrigerant flows out from the relay unit 30 and then flows into the heat-source-side unit 10. The low-pressure gas refrigerant that has flowed into the heat-source-side unit 10 flows through the refrigerant flow switching device 12 and the accumulator 14, and is sucked into the compressor 11. Thereafter, the above cycle will be repeated.

[0075] As described above, in the partial load stopped operation mode, the load-side expansion device 21b in the load-side unit 20b that is stopped is caused to be in the closed state, whereby it is possible to prevent refrigerant from staying in the load-side unit 20b. It is therefore possible to prevent shortage of the refrigerant in the refrigeration cycle circuit.

[0076] It should be noted that the above description is made with respect to the case where in the partial load stopped operation mode, any of the load-side units 20 that should be in operation performs the cooling operation. The description, however, is not limiting. For example, in the partial load stopped operation mode, the load-side unit 20 that is operated may perform the cooling main operation, the heating only operation, or the heating main operation.

[0077] As described above, in the air-conditioning apparatus 100 according to Embodiment 1, for the plurality of load-side units 20, respective three-way valves 34 are provided, and can each switch the flow of the refrigerant depending on the operating state. Thus, in Embodiment 1, it is not necessary to provide four check valves that are necessary for an existing heat-source-side unit that performs a simultaneous cooling and heating operation. In addition, in an existing relay unit, two solenoid valves are used for each of load-side units. In contrast, in Embodiment 1, a single three-way valve 34 is used instead of two solenoid valves, and it is therefore possible to reduce the number of components as compared with the existing air-conditioning apparatus that performs the simultaneous cooling and heating operation.

[0078] Furthermore, since it is possible to reduce the number of components, it is also possible to reduce costs, improve the service quality, and reduce a failure probability. In addition, since it is not necessary to provide four check valves, it is possible to reduce a pressure loss, reduce deterioration of the performance of the air-conditioning apparatus 100, and cause the air-conditioning apparatus 100 to stably operate.

[0079] Moreover, the existing heat-source-side unit in which the four check valves are provided is made specifically for the simultaneous cooling and heating operation. By contrast, in the heat-source-side unit 10, since the three-way valve 34 is provided in the relay unit 30, the heat-source-side unit 10 does not need to incorporate four check valves. The heat-source-side unit 10 can thus incorporate a circuit that is used in common in a cooling-heating switching apparatus and a simultaneous cooling and heating type of air-conditioning apparatus.

[0080] The above description of the present disclosure concerning Embodiment 1 is not limiting, and various modifications can be made without departing the gist of the present disclosure.

[0081] For example, the above description concerning Embodiment 1 is made with respect to the case where the refrigeration cycle apparatus is the air-conditioning apparatus 100, but it is not limiting. The refrigeration cycle apparatus may be a refrigeration apparatus or a cooling apparatus that cools, for example, a refrigeration warehouse or a cold storage warehouse.

[0082] The kind of the refrigerant for use in the air-conditioning apparatus 100 is not limited to a specific one. For example, as the refrigerant, any of natural refrigerant such as carbon dioxide, hydro-carbon, or helium, or alternative refrigerant not containing chlorine, such as HFC410A, HFC407C, or HFC404A, or fluorocarbon refrigerant such as R22 or R134a may be used.

Reference Signs List

[0083] 1: gas pipe, 2: liquid pipe, 3a, 3b: gas branch pipe, 4a, 4b: liquid branch pipe, 5, 6: connection pipe, 7: relay pipe, 10: heat-source-side unit, 11: compressor, 12: refrigerant flow switching device, 13: heat-source-side heat exchanger, 14: accumulator, 20, 20a, 20b: load-side unit, 21a, 21b: load-side expansion device, 22a, 22b: load-side heat exchanger, 30: relay unit, 31: gas-liquid separator, 32: first expansion valve, 33: second expansion valve, 34, 34a, 34b: three-way valve, 40: controller, 100: the air-conditioning apparatus

Claims

1. A refrigeration cycle apparatus comprising:

   a heat-source-side unit including a compressor and a heat-source-side heat exchanger;
   a plurality of load-side units including respective expansion devices and respective load-side heat exchangers; and
   a relay unit including a plurality of three-way valves connected between the heat-source-side unit and the load-side units, the three-way valves being each provided in association with an associated one of the load-side units and configured to switch a flow direction of refrigerant between plural flow directions, the relay unit being configured to supply the refrigerant having a low temperature to one of the load-side units that performs a cooling operation and supply the refrigerant having a high temperature to one of the load-side units that performs a heating operation,
   wherein each of the three-way valves is configured to switch the flow direction of the refrigerant that flows out from the heat-source-side unit such that the refrigerant flows into an associated one of the load-side units or switch the flow direction of the refrigerant that flows out from the associated one of the load-side units such that the refrigerant flows into the heat-source-side unit, depending on an operating state.

2. The refrigeration cycle apparatus of claim 1, wherein when at least one of the load-side units performs the cooling operation, at least one of the three-way valves that is associated with the at least one load-side unit switches the flow direction of the refrigerant that flows out from the at least one load-side unit such that the refrigerant flows into the heat-source-side unit.

3. The refrigeration cycle apparatus of claim 1 or 2, wherein when at least one of the load-side units performs the heating operation, at least one of the three-way valves that is associated with the at least one load-side unit switches the flow direction of the refrigerant that flows out from the heat-source-side unit such that the refrigerant flows into the at least one load-side unit.

4. The refrigeration cycle apparatus of any one of claims 1 to 3, wherein in a partial load stopped operation in which at least one of the load-side units is stopped, a state of at least one of the three-way valves that is associated with the at least one load-side unit is switched such that the at least one three-way valve shuts off the flow of the refrigerant.

5. The refrigeration cycle apparatus of claim 4, wherein the expansion device of the at least one load-side unit is caused to be in a closed state.

FIG. 1

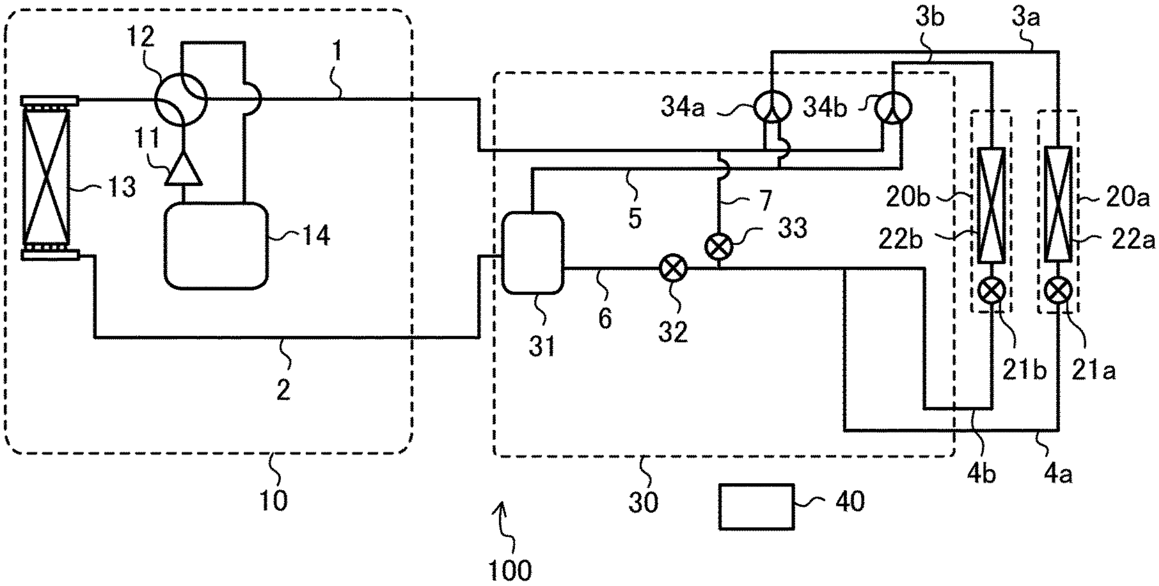
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FIG. 2

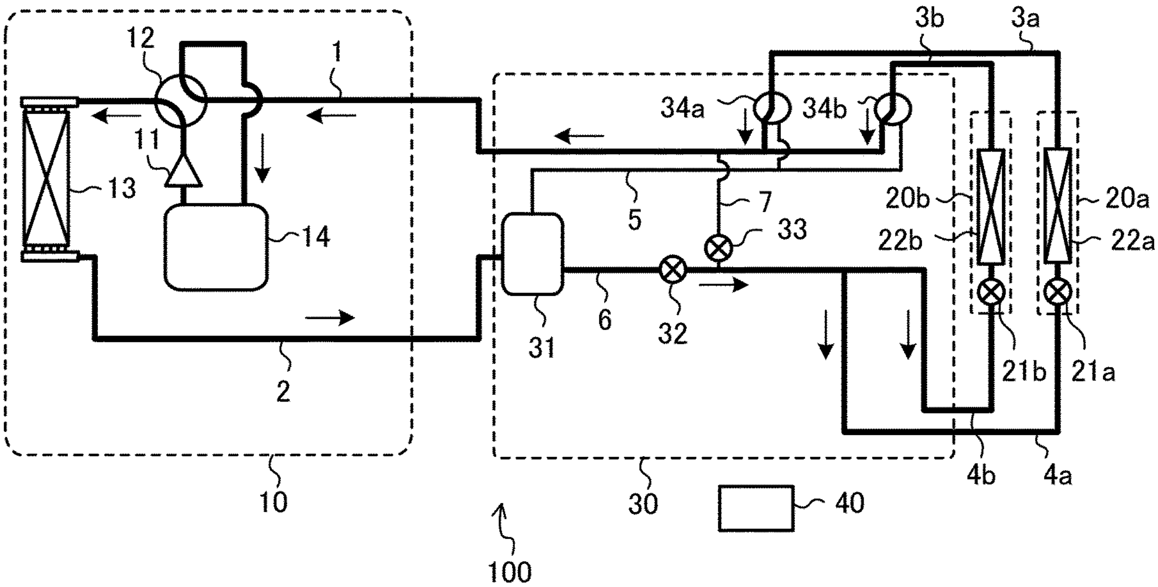
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FIG. 3

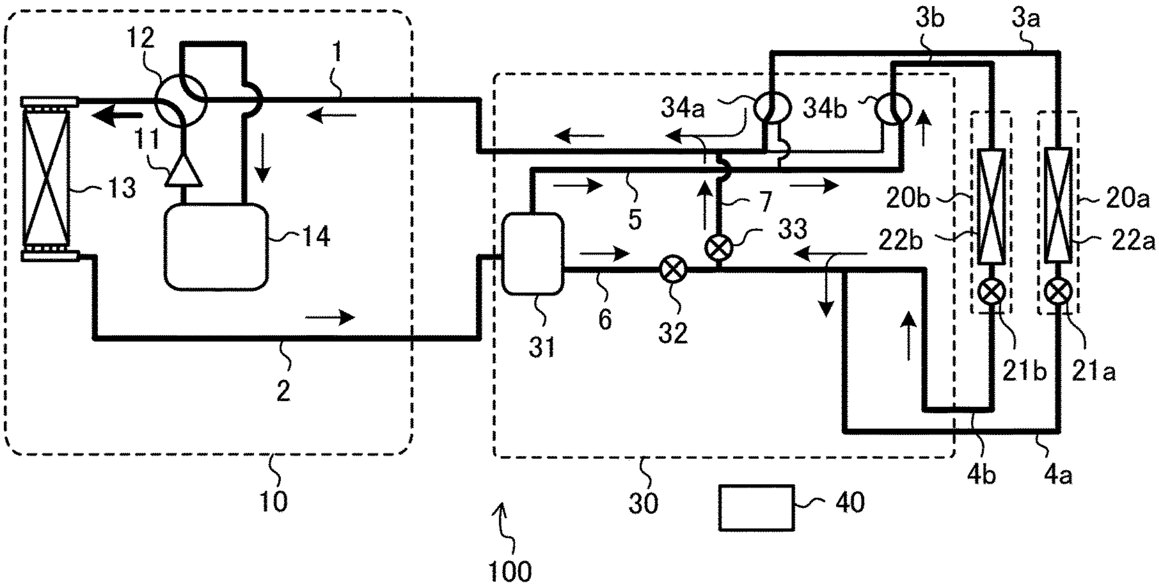
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FIG. 4

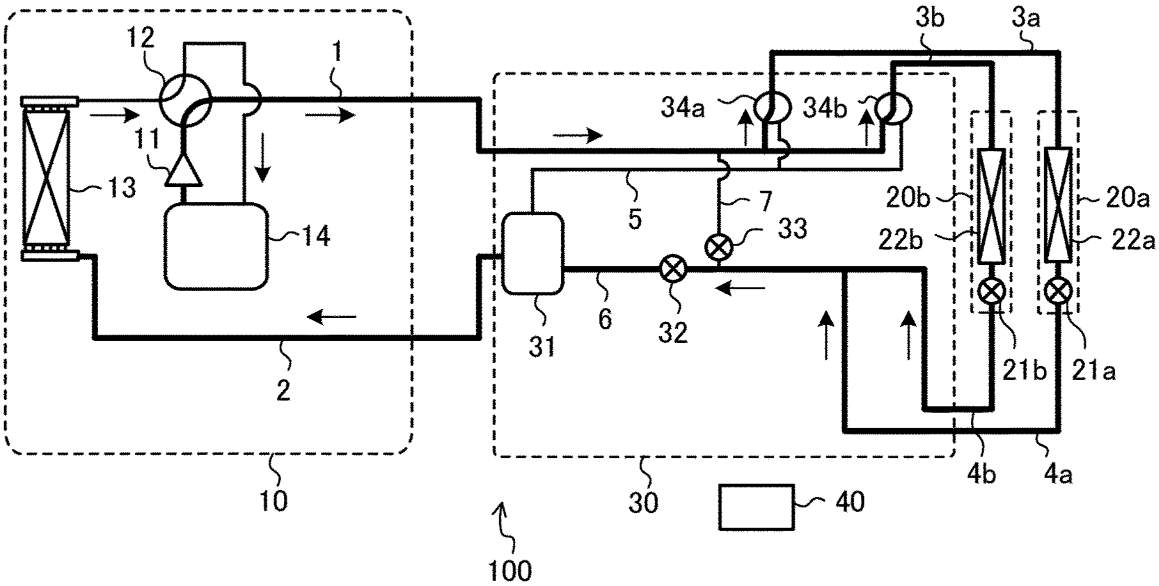
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FIG. 5

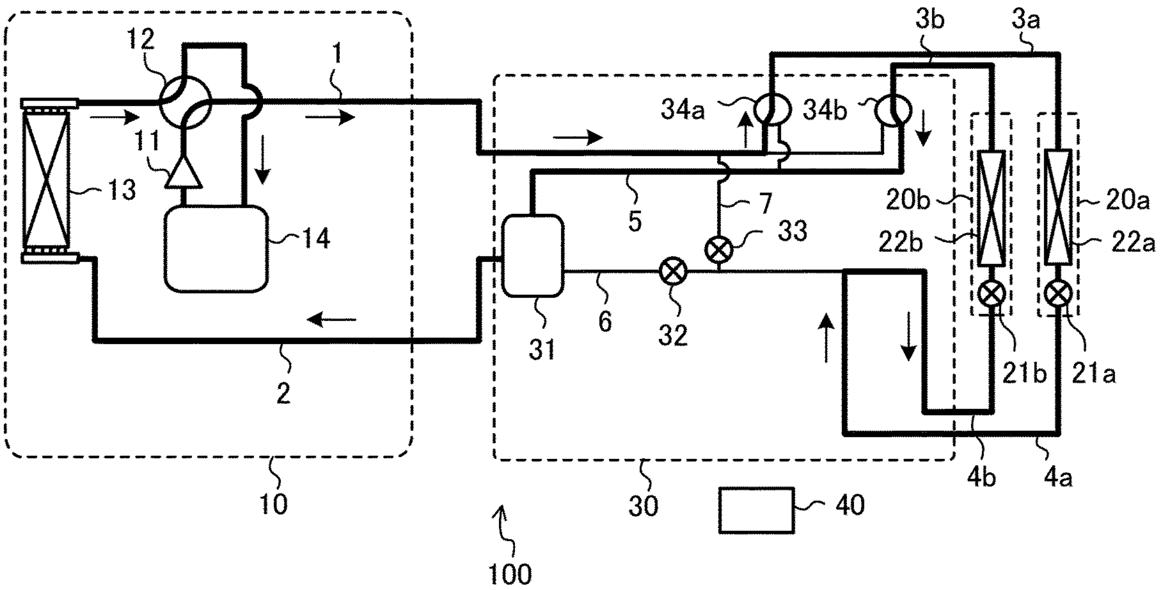
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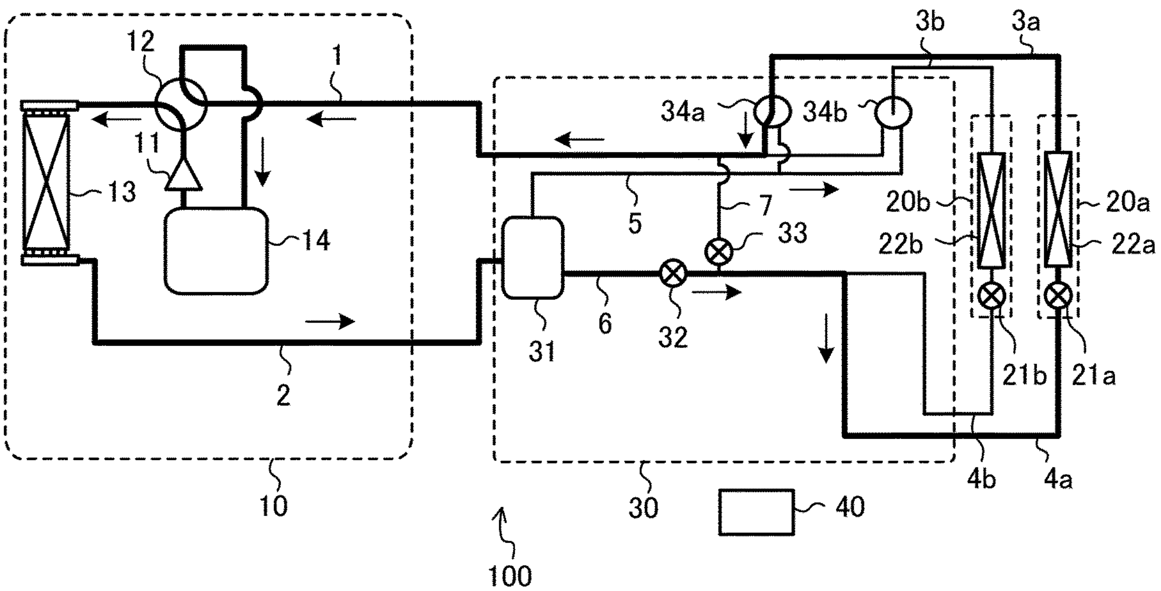
FIG. 6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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/001825

A. CLASSIFICATION OF SUBJECT MATTER

F25B 13/00(2006.01)i
FI: F25B13/00 104

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)

F25B13/00

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.
X	JP 2003-343936 A (MITSUBISHI ELECTRIC CORP) 03 December 2003 (2003-12-03) paragraphs [0027]-[0030]	1-3
Y		4-5
Y	JP 3-177756 A (HITACHI LTD) 01 August 1991 (1991-08-01) p. 2, upper left column, line 15 to lower right column, line 14	4-5
Y	JP 2012-97922 A (MITSUBISHI ELECTRIC CORP) 24 May 2012 (2012-05-24) paragraph [0003]	5

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

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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
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"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
04 February 2022	**15 March 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/JP2022/001825

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2003-343936 A	03 December 2003	(Family: none)	
JP 3-177756 A	01 August 1991	(Family: none)	
JP 2012-97922 A	24 May 2012	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

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