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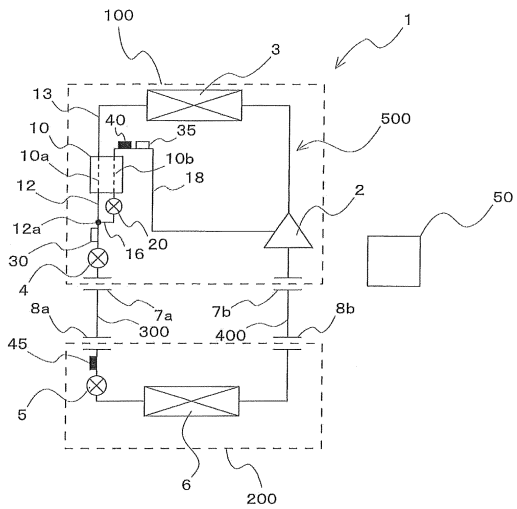
(54) REFRIGERATION CYCLE DEVICE

(57) Provided is a refrigeration cycle apparatus, including: a heat source-side unit; a load-side unit which is connected to the heat source-side unit by a first connection pipe arranged and a second connection pipe; and a controller, in which the first compressor, the first heat source-side heat exchanger, the first heat source-side pressure reducing device, the load-side pressure reducing device, and the load side heat exchanger are connected by a refrigerant pipe and form a first refrigeration cycle through which first refrigerant circulates, and in which, during cooling operation in which the load side heat exchanger functions as an evaporator, the controller regulates an opening degree of the first heat source-side pressure reducing device to cause the first refrigerant to flow into the first connection pipe as liquid refrigerant having a pressure less than a design pressure of the first connection pipe.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a refrigeration cycle apparatus in which a local pipe can be used.

Background Art

[0002] As a related-art refrigeration cycle apparatus in which a local pipe can be used, for example, there has been known a binary refrigeration apparatus in which refrigerant flowing from an outdoor unit to a liquid pipe being a local pipe is reduced in pressure by a flow control device and brought into a two-phase gas-liquid state to result in reduction in refrigerant cost (Patent Literature 1, for example).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-112622

Summary of Invention

Technical Problem

[0004] However, in the refrigeration cycle apparatus disclosed in Patent Literature 1, two-phase refrigerant flows through the liquid pipe. Accordingly, pressure loss and noise in the liquid pipe increase.

[0005] The present invention has been made to solve the above-mentioned problem, and has an object to provide a refrigeration cycle apparatus that enables reduction in pressure loss and reduction in noise in a liquid pipe.

Solution to Problem

[0006] According to one embodiment of the present invention, there is provided a refrigeration cycle apparatus, including: a heat source-side unit which houses a first compressor, a first heat source-side heat exchanger, and a first heat source-side pressure reducing device; a load-side unit which houses a load-side pressure reducing device and a load side heat exchanger, and is connected to the heat source-side unit by a first connection pipe arranged between the first heat source-side pressure reducing device and the load-side pressure reducing device and by a second connection pipe arranged between the first compressor and the load side heat exchanger; and a controller, in which the first compressor, the first heat source-side heat exchanger, the first heat source-side pressure reducing device, the load-side pressure reducing device, and the load side heat exchanger are connected by a refrigerant pipe and form a first refrigeration cycle through which first refrigerant circulates, and in which, during cooling operation in which the load side heat exchanger functions as an evaporator, the controller regulates an opening degree of the first heat source-side pressure reducing device to cause the first refrigerant to flow into the first connection pipe as liquid refrigerant having a pressure less than a design pressure of the first connection pipe.

Advantageous Effects of Invention

[0007] According to one embodiment of the present invention, the first refrigerant can be caused to flow into the first connection pipe as liquid refrigerant having a pressure less than the design pressure of the first connection pipe by regulating the opening degree of the first heat source-side pressure reducing device. Thus, according to one embodiment of the present invention, liquid refrigerant can be employed as the refrigerant flowing into the first connection pipe. Therefore, the refrigeration cycle apparatus enabling reduction in pressure loss and noise in the first connection pipe can be provided.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a schematic refrigerant circuit diagram for illustrating an example of a refrigeration cycle apparatus 1 according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a control block diagram for illustrating part of control performed in a controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a schematic refrigerant circuit diagram for illustrating an example of the refrigeration cycle apparatus 1 according to Embodiment 2 of the present invention.

[Fig. 6] Fig. 6 is a control block diagram for illustrating part of control performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2 of the present invention.

[Fig. 7] Fig. 7 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2 of the present invention.

[Fig. 8] Fig. 8 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 is a schematic refrigerant circuit diagram for illustrating an example of the refrigeration cycle apparatus 1 according to Embodiment 3 of the present invention.

[Fig. 10] Fig. 10 is a control block diagram for illustrating part of control performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 3 of the present invention.

[Fig. 11] Fig. 11 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 3 of the present invention.

[Fig. 12] Fig. 12 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 3 of the present invention.

Description of Embodiments

Embodiment 1

[0009] A refrigeration cycle apparatus 1 according to Embodiment 1 of the present invention is described. Fig. 1 is a schematic refrigerant circuit diagram for illustrating an example of the refrigeration cycle apparatus 1 according to Embodiment 1. In some cases, the dimensional relationships among components and their shapes in the following drawings including Fig. 1 differ from the actual ones.

[0010] As illustrated in Fig. 1, the refrigeration cycle apparatus 1 includes a heat source-side unit 100 (for example, an outdoor unit), and a load-side unit 200 (for example, an indoor unit) arranged in parallel with the heat source-side unit 100. The heat source-side unit 100 and the load-side unit 200 are connected to each other by a first connection pipe 300 (liquid pipe) and a second connection pipe 400 (gas pipe), which are local pipes. In the refrigeration cycle apparatus 1 in Fig. 1, one load-side unit 200 is connected. However, a plurality of load-side units 200 may be connected.

[0011] The refrigeration cycle apparatus 1 according to Embodiment 1 includes a first refrigeration cycle 500 in which a first compressor 2, a first heat source-side heat exchanger 3, a first heat source-side pressure reducing device 4, a load-side pressure reducing device 5, and a load side heat exchanger 6 are connected by a refrigerant pipe and through which first refrigerant circulates. As the first refrigerant that circulates through the first refrigeration cycle 500, any type of refrigerant can be selected in accordance with the purpose for which the refrigeration cycle apparatus 1 is used. In the refrigeration cycle apparatus 1 according to Embodiment 1, examples of first refrigerant that can be used include natural refrigerant, such as CO_2, hydrofluorocarbon, such as R32, hydrofluoroolefins, such as 2,3,3,3-tetrafluoro-1-propene (HFO-1234yf), and a mixed solvent, such as R410A.

[0012] The first compressor 2 is housed in the heat source-side unit 100, and is a variable-frequency type fluid machine that compresses sucked low-pressure first refrigerant into high-pressure first refrigerant and discharges the compressed refrigerant. As the first compressor 2, for example, a scroll compressor having a rotational frequency controlled by an inverter can be used.

[0013] In Embodiment 1, the first heat source-side heat exchanger 3 is a heat exchanger functioning as a radiator (condenser) and is housed in the heat source-side unit 100. In Embodiment 1, the first heat source-side heat exchanger 3 exchanges heat between the first refrigerant flowing through the inside of the first heat source-side heat exchanger 3 and outside air (for example, outdoor air) sent by a heat source-side heat exchanger fan (not shown). The first heat source-side heat exchanger 3 is configured as a fin-and-tube type heat exchanger of a cross-fin type including a heat transfer tube and a plurality of fins, for example.

[0014] In Embodiment 1, the first heat source-side pressure reducing device 4 expands high-pressure liquid refrigerant flowing in from the first heat source-side heat exchanger 3 and reduces pressure of the refrigerant, and causes the refrigerant to flow into the first connection pipe 300, which is a local pipe, as the first refrigerant having a pressure less than a design pressure of the first connection pipe 300. For example, a design pressure of the first connection pipe 300 is set to a withstand pressure reference value of the first connection pipe 300. The first heat source-side pressure reducing device 4 is housed in the heat source-side unit 100, and is configured as an electronic expansion valve, such as a linear electronic expansion valve (LEV), which has an opening degree capable of being regulated in a plurality of stages or continuously.

[0015] In Embodiment 1, the load-side pressure reducing device 5 further expands the first refrigerant flowing in from the first connection pipe 300 and having a pressure less than the design pressure of the first connection pipe 300 and reduces pressure of the refrigerant, and causes the refrigerant to flow into the load side heat exchanger 6. The load-side pressure reducing device 5 is housed in the load-side unit 200, and is configured as an electronic expansion valve, such as a linear electronic expansion valve, which has an opening degree capable of being regulated in a plurality of stages or continuously.

[0016] In Embodiment 1, the load side heat exchanger 6 is a heat exchanger functioning as an evaporator (cooler) and is housed in the load-side unit 200. The load side heat exchanger 6 exchanges heat between refrigerant flowing through the inside of the load side heat exchanger 6 and outside air (for example, indoor air), for example. The load side heat exchanger 6 can be configured as a fin-and-tube type heat exchanger of a cross-fin type formed of a heat transfer tube and a plurality of fins, for example. The load side heat exchanger 6 may be configured so that outside air is supplied by a load side heat exchanger fan (not shown) sending air.

[0017] Hereinafter, an operation of the refrigeration cycle apparatus 1 in which the load side heat exchanger 6 functions as an evaporator is referred to as "cooling operation".

[0018] In a refrigerant pipe housed in the heat source-side unit 100 and arranged between the first heat source-side pressure reducing device 4 and the first connection pipe 300, a first heat source-side connection valve 7a for connection with the first connection pipe 300 is provided. In a heat source-side refrigerant pipe housed in the heat source-side unit 100 and arranged between the first compressor 2 and the second connection pipe 400, a second heat source-side connection valve 7b for connection with the second connection pipe 400 is provided. In a load side refrigerant pipe housed in the load-side unit 200 and arranged between the load-side pressure reducing device 5 and the first connection pipe 300, a first load side connection valve 8a for connection with the first connection pipe 300 is provided. In a load side refrigerant pipe housed in the load-side unit 200 and arranged between the load side heat exchanger 6 and the second connection pipe 400, a second load side connection valve 8b for connection with the second connection pipe 400 is provided. The first heat source-side connection valve 7a, the second heat source-side connection valve 7b, the first load side connection valve 8a, and the second load side connection valve 8b are each formed of a two-way valve, such as a two-way solenoid valve, capable of being switched between open and closed states.

[0019] Next, a subcooling heat exchanger 10 and a second heat source-side pressure reducing device 20 in the refrigeration cycle apparatus 1 according to Embodiment 1 are described.

[0020] The subcooling heat exchanger 10 is arranged between the first heat source-side heat exchanger 3 and the first heat source-side pressure reducing device 4. The subcooling heat exchanger 10 includes a first heat transfer tube 10a and a second heat transfer tube 10b, and is housed in the heat source-side unit 100. In Embodiment 1, the subcooling heat exchanger 10 is a heat exchanger that exchanges heat between the high-pressure first refrigerant flowing through the first heat transfer tube 10a and first refrigerant having been reduced in pressure and flowing through the second heat transfer tube 10b during cooling operation. The subcooling heat exchanger 10 can be configured as a fin-and-tube type heat exchanger of a cross-fin type formed of the first heat transfer tube 10a, the second heat transfer tube 10b, and a plurality of fins, for example.

[0021] One end of the first heat transfer tube 10a and the first heat source-side pressure reducing device 4 are connected to each other by a first heat source-side refrigerant pipe 12. The other end of the first heat transfer tube 10a and the first heat source-side heat exchanger 3 are connected to each other by a second heat source-side refrigerant pipe 13. A branch joint portion 12a arranged in the first heat source-side refrigerant pipe 12 and one end of the second heat transfer tube 10b are connected to each other by a first heat source-side branched refrigerant pipe 16. The other end of the second heat transfer tube 10b and an intermediate-pressure portion of the first compressor 2 are connected to each other by a second heat source-side branched refrigerant pipe 18. The first heat source-side refrigerant pipe 12 and the second heat source-side refrigerant pipe 13 are some of refrigerant pipes forming the first refrigeration cycle 500. The first heat source-side refrigerant pipe 12, the second heat source-side refrigerant pipe 13, the first heat source-side branched refrigerant pipe 16, and the second heat source-side branched refrigerant pipe 18 are housed in the heat source-side unit 100.

[0022] The second heat source-side pressure reducing device 20 is arranged in the first heat source-side branched refrigerant pipe 16. The second heat source-side pressure reducing device 20 expands high-pressure liquid refrigerant that has been branched from the first heat source-side refrigerant pipe 12 to flow into the first heat source-side branched refrigerant pipe 16 and reduces pressure of the ,refrigerant and causes the refrigerant to flow into the second heat transfer tube 10b. The second heat source-side pressure reducing device 20 is housed in the heat source-side unit 100, and is configured as an electronic expansion valve, such as a linear electronic expansion valve (LEV), which has an opening degree capable of being regulated in a plurality of stages or continuously.

[0023] Next, sensors arranged in the refrigeration cycle apparatus 1 according to Embodiment 1 are described.

[0024] The refrigeration cycle apparatus 1 according to Embodiment 1 includes a first temperature sensor 30, a second temperature sensor 35, a first pressure sensor 40, and a second pressure sensor 45.

[0025] The first temperature sensor 30 is arranged on the first heat source-side refrigerant pipe 12 and between the branch joint portion 12a and the first heat source-side pressure reducing device 4. The first temperature sensor 30 is a temperature sensor that detects, during cooling operation, a temperature of the first refrigerant having flowed out from the first heat transfer tube 10a of the subcooling heat exchanger 10 and flowing into the first heat source-side pressure reducing device 4 with the refrigerant pipe interposed between the first temperature sensor 30 and the first refrigerant.

[0026] The second temperature sensor 35 is arranged on the second heat source-side branched refrigerant pipe 18. The second temperature sensor 35 is a temperature sensor that detects, during cooling operation, a temperature of the first refrigerant having flowed out from the second heat transfer tube 10b of the subcooling heat exchanger 10 and being injected into the intermediate-pressure portion of the first compressor 2 with the refrigerant pipe interposed between the second temperature sensor 35 and the first refrigerant.

[0027] As a material of the first temperature sensor 30 and the second temperature sensor 35, for example, a semiconductor (for example, a thermistor), or metal (for example, a resistance temperature detector) is used. The first temperature sensor 30 and the second temperature sensor 35 may be formed of the same material or may be formed of different materials.

[0028] The first pressure sensor 40 is arranged on the second heat source-side branched refrigerant pipe 18. The first pressure sensor 40 is a pressure sensor that detects, during cooling operation, a pressure of the first refrigerant having flowed out from the second heat transfer tube 10b of the subcooling heat exchanger 10 and being injected into the intermediate-pressure portion of the first compressor 2.

[0029] The second pressure sensor 45 is housed in the load-side unit 200 and arranged on the load side refrigerant pipe arranged between the first load side connection valve 8a and the load-side pressure reducing device 5. The second pressure sensor 45 is a pressure sensor that detects, during cooling operation, a pressure of the first refrigerant having passed through the first connection pipe 300 and flowing into the second pressure sensor 45.

[0030] As the first pressure sensor 40 and the second pressure sensor 45, for example, a quartz crystal piezoelectric pressure sensor, a semiconductor sensor, or a pressure transducer is used. The first pressure sensor 40 and the second pressure sensor 45 may be formed of the same type of sensor or may be formed of different types of sensors.

[0031] Next, a controller 50 of Embodiment 1 is described with reference to Fig. 2. Fig. 2 is a control block diagram for illustrating part of control performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1.

[0032] The controller 50 of Embodiment 1 controls the first refrigeration cycle 500 and includes a microcomputer including a CPU, memory (for example, ROM, RAM, and other memory), and an I/O port. As illustrated in Fig. 2, the controller 50 of Embodiment 1 is configured so that the controller 50 receives electrical signals of temperature information detected by the first temperature sensor 30 and the second temperature sensor 35, and electrical signals of pressure information detected by the first pressure sensor 40 and the second pressure sensor 45. The controller 50 transmits control signals based on the electrical signals of temperature information and the electrical signals of pressure information to the first heat source-side pressure reducing device 4, the load-side pressure reducing device 5, and the second heat source-side pressure reducing device 20. In the first heat source-side pressure reducing device 4, the opening degree of the first heat source-side pressure reducing device 4 is regulated in accordance with a transmitted control signal. In the load-side pressure reducing device 5, the opening degree of the load-side pressure reducing device 5 is regulated in accordance with a transmitted control signal. In the second heat source-side pressure reducing device 20, the opening degree of the second heat source-side pressure reducing device 20 is regulated in accordance with a transmitted control signal. Further, the controller 50 can be configured to control other components of the first refrigeration cycle 500. For example, the controller 50 can be configured to control operation states, such as the starting and stopping of the operation of the heat source-side unit 100 and the load-side unit 200, and the regulation of an operating frequency of the first compressor 2.

[0033] The controller 50 includes a storage unit (not shown) that can store various pieces of data, such as the design pressure of the first connection pipe 300. Further, the controller 50 can be configured to include an interface unit (not shown) through which various pieces of data, such as the design pressure of the first connection pipe 300, can be input.

[0034] Next, an operation of the refrigeration cycle apparatus 1 according to Embodiment 1 during cooling operation is described.

[0035] The first refrigerant is discharged from the first compressor 2 as high-temperature high-pressure gas refrigerant and flows into the first heat source-side heat exchanger 3. The high-temperature high-pressure gas refrigerant having flowed into the first heat source-side heat exchanger 3 is subjected to heat exchange by transferring heat to a low-temperature medium, such as outdoor air, and the first refrigerant turns into high-pressure liquid refrigerant.

[0036] The high-pressure liquid refrigerant flows into the first heat transfer tube 10a of the subcooling heat exchanger 10, and is subjected to heat exchange with the first refrigerant flowing through the second heat transfer tube 10b, thereby being subcooled. Then, the first refrigerant turns into subcooled high-pressure liquid refrigerant. In the refrigeration cycle apparatus 1 according to Embodiment 1, the first refrigerant flowing through the second heat transfer tube 10b is (intermediate-pressure, for example) liquid refrigerant or two-phase refrigerant into which the high-pressure liquid refrigerant has been branched at the branch joint portion 12a of the first heat source-side refrigerant pipe 12 to flow into the first heat source-side branched refrigerant pipe 16 and has been expanded and reduced in pressure by the second heat source-side pressure reducing device 20 to turn. The first refrigerant having flowed out from the second heat transfer tube 10b is injected into the intermediate-pressure portion of the first compressor 2 through the second heat source-side branched refrigerant pipe 18.

[0037] The high-pressure liquid refrigerant subcooled in the subcooling heat exchanger 10 flows into the first heat source-side pressure reducing device 4, and is expanded and reduced in pressure by the first heat source-side pressure reducing device 4, and the first refrigerant turns into (intermediate-pressure, for example) liquid refrigerant or two-phase refrigerant reduced in pressure. The liquid refrigerant or two-phase refrigerant reduced in pressure flows out from the heat source-side unit 100, and flows into the load-side unit 200 through the first connection pipe 300.

[0038] The liquid refrigerant or two-phase refrigerant reduced in pressure having flowed into the load-side unit 200 flows into the load-side pressure reducing device 5. The liquid refrigerant or two-phase refrigerant reduced in pressure having flowed into the load-side pressure reducing device 5 is further expanded and reduced in pressure, and the first refrigerant turns into low-temperature low-pressure two-phase refrigerant. The low-temperature low-pressure two-phase refrigerant flows into the load side heat exchanger 6, and receives heat from a high-temperature medium, such as indoor air, and the first refrigerant evaporates to turn into high-quality two-phase refrigerant or low-temperature low-pressure gas refrigerant. The high-quality two-phase refrigerant or low-temperature low-pressure gas refrigerant having flowed out from the load side heat exchanger 6 flows out from the load-side unit 200, and flows into the heat source-side unit 100 through the second connection pipe 400. The high-quality two-phase refrigerant or low-temperature low-pressure gas refrigerant having flowed into the load-side unit 200 is sucked into the first compressor 2. The refrigerant sucked into the first compressor 2 is compressed, and the first refrigerant turns into high-temperature high-pressure gas refrigerant, and is discharged from the first compressor 2. In the cooling operation performed by the refrigeration cycle apparatus 1, the above-described cycle is repeated.

[0039] Next, a control process performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1 is described.

[0040] The controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1 regulates the opening degree of the first heat source-side pressure reducing device 4 to cause the first refrigerant to flow into the first connection pipe 300 as liquid refrigerant having a pressure less than the design pressure of the first connection pipe 300.

[0041] Further, during cooling operation, the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1 can be configured to regulate the opening degree of the second heat source-side pressure reducing device 20 to increase a degree of subcooling so that the temperature of the first refrigerant flowing into the first heat source-side pressure reducing device 4 falls below a saturated liquid temperature of the first refrigerant at the design pressure.

[0042] In the following descriptions of the control process in Embodiment 1, an opening degree DH1 of the first heat source-side pressure reducing device 4 can be regulated in a range of $0 \leq DH \leq 1$. A state of the opening degree satisfying DH1=0 represents that the first heat source-side pressure reducing device 4 is in a closed state. A state of the opening degree DH1=1 represents that the first heat source-side pressure reducing device 4 is in a fully open state.

[0043] An opening degree DH2 of the second heat source-side pressure reducing device 20 can be regulated in a range of $0 \leq DH2 \leq 1$. A state of the opening degree satisfying DH2=0 represents that the second heat source-side pressure reducing device 20 is in a closed state. A state of the opening degree satisfying DH2=1 represents that the second heat source-side pressure reducing device 20 is in a fully open state.

[0044] Fig. 3 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 1. The control process illustrated in Fig. 3 may be performed at all times during cooling operation, or may be performed whenever variations in parameter of the refrigeration cycle apparatus 1, such as variations in frequency of the first compressor 2, are detected.

[0045] In Embodiment 1, in the storage unit (not shown) of the controller 50, data of a design pressure Pm (for example, a withstand pressure reference value) of the first connection pipe 300 is stored. Further, in the storage unit of the controller 50, data about a Mollier diagram (P-h diagram) representing the state of the first refrigerant in the refrigeration cycle apparatus 1 is stored as a table, for example.

[0046] In Step S11, the controller 50 determines whether a temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 detected by the first temperature sensor 30 is not less than a saturated liquid temperature Ta of the first refrigerant at the design pressure Pm. The saturated liquid temperature Ta is a temperature value calculated by the controller 50 based on a value of the design pressure Pm.

[0047] When the temperature Tc of the first refrigerant is not less than the saturated liquid temperature Ta, the controller 50 controls, in Step S12, the opening degree DH2 of the second heat source-side pressure reducing device 20 to open the second heat source-side pressure reducing device 20 by a regulation value $\Delta DH2$. Here, the regulation value $\Delta DH2$ is a certain constant determined in view of specifications of, for example, the structure of the second heat source-side pressure reducing device 20. For example, the regulation value $\Delta DH2$ can be set to 0.02. Subsequently, until the temperature Tc of the first refrigerant falls below the saturated liquid temperature Ta, the control process of Step S12 is repeated in the controller 50.

[0048] When the temperature Tc of the first refrigerant is less than the saturated liquid temperature Ta, the controller 50 determines in Step S13 whether a pressure P of the first refrigerant flowing into the load-side pressure reducing device 5 is not greater than a saturated liquid pressure Ps. The pressure P of the first refrigerant flowing into the load-side pressure reducing device 5 is detected by the second pressure sensor 45. The saturated liquid pressure Ps is a pressure value calculated by the controller 50 based on a value of the temperature Tc of the first refrigerant. On the Mollier diagram, the saturated liquid pressure Ps is represented as a point on a saturated liquid line obtained through an isenthalpic change from the temperature Tc of the first refrigerant. When the pressure P of the first refrigerant is greater than the saturated liquid pressure Ps, the control process ends.

[0049] When the pressure P of the first refrigerant is not greater than the saturated liquid pressure Ps, the controller 50 controls, in Step S14, the opening degree DH1 of the first heat source-side pressure reducing device 4 to open the first heat source-side pressure reducing device 4 by a regulation value ΔDH1. Here, the regulation value ΔDH1 is a certain constant determined in view of specifications of, for example, the structure of the first heat source-side pressure reducing device 4. For example, the regulation value ΔDH1 can be set to 0.01. Subsequently, until the pressure P of the first refrigerant exceeds the saturated liquid pressure Ps, the control process of Step S14 is repeated in the controller 50.

[0050] Next, effects of the present invention according to Embodiment 1 are described.

[0051] As described above, the refrigeration cycle apparatus 1 according to Embodiment 1 includes: the heat source-side unit 100 which receives the first compressor 2, the first heat source-side heat exchanger 3, and the first heat source-side pressure reducing device 4; the load-side unit 200, which receives the load-side pressure reducing device 5 and the load side heat exchanger 6, and is connected to the heat source-side unit 100 by the first connection pipe 300 arranged between the first heat source-side pressure reducing device 4 and the load-side pressure reducing device 5 and by the second connection pipe 400 arranged between the first compressor 2 and the load side heat exchanger 6; and the controller 50. The first compressor 2, the first heat source-side heat exchanger 3, the first heat source-side pressure reducing device 4, the load-side pressure reducing device 5, and the load side heat exchanger 6 are connected by a refrigerant pipe and form the first refrigeration cycle 500 through which first refrigerant circulates. During cooling operation in which the load side heat exchanger 6 functions as an evaporator, the controller 50 regulates the opening degree of the first heat source-side pressure reducing device 4 to cause the first refrigerant to flow into the first connection pipe 300 as liquid refrigerant having a pressure less than a design pressure of the first connection pipe 300.

[0052] As a related-art refrigeration apparatus, for example, as a binary refrigeration apparatus, there is a typical refrigeration apparatus that causes two-phase refrigerant to pass through a local liquid pipe, to thereby reduce the amount of refrigerant in the overall refrigeration apparatus and reduce refrigerant cost and product cost. In the related-art refrigeration apparatus, in order to cause two-phase refrigerant to pass through the local liquid pipe, a first expansion valve is provided in an outdoor unit to reduce the pressure and expand refrigerant, and to cause two-phase refrigerant to flow into the local liquid pipe. Further, in the related-art refrigeration apparatus, a second expansion valve is provided in an indoor unit to reduce the pressure of and expand the two-phase refrigerant flowing in from the local liquid pipe further and to cause the refrigerant to flow into an indoor side heat exchanger functioning as an evaporator. As described above, the related-art refrigeration apparatus has a so-called two-stage expansion structure in which the first expansion valve and the second expansion valve are provided in front of and behind the local liquid pipe.

[0053] In the related-art refrigeration apparatus, however, the two-phase refrigerant is caused to flow into the local liquid pipe, and hence pressure loss and noise in the local pipe increase. Further, when a plurality of indoor side heat exchangers are installed (for example, when a plurality of indoor units are installed), the two-phase refrigerant having flowed in from the local liquid pipe is not evenly distributed into the indoor side heat exchangers, and an increase in the number of the indoor side heat exchangers causes uneven distribution of the refrigerant.

[0054] Meanwhile, the configuration according to Embodiment 1 enables, during cooling operation, the first refrigerant to flow into the first connection pipe 300 as liquid refrigerant having a pressure less than the design pressure of the first connection pipe 300 by regulating the opening degree of the first heat source-side pressure reducing device 4.

[0055] In Embodiment 1, refrigerant flowing into the first connection pipe 300 can serve as liquid refrigerant, and reductions in pressure loss and noise in the first connection pipe 300 can be achieved. Thus, reduction in the amount of energy consumption in the refrigeration cycle apparatus 1 can be achieved. Further, the refrigerant flowing from the first connection pipe 300 into the load-side unit 200 serves as liquid refrigerant. Thus, even when a plurality of load side heat exchangers 6 are installed in the refrigeration cycle apparatus 1, the refrigerant can be distributed evenly.

[0056] Further, in Embodiment 1, the pressure of the liquid refrigerant flowing into the first connection pipe 300 can be set to less than the design pressure of the first connection pipe 300. Thus, the refrigeration cycle apparatus 1 in which an existing local pipe can be used can be provided. For example, as the first connection pipe 300, any connection pipe that causes pressure loss of the first refrigerant to occur in a range where a saturation temperature of the refrigerant in the load side heat exchanger 6 does not fall below an evaporating temperature in the load side heat exchanger 6 can be used.

[0057] Further, in the refrigeration cycle apparatus 1 according to Embodiment 1, the heat source-side unit 100 further includes: the subcooling heat exchanger 10, which is arranged between the first heat source-side heat exchanger 3 and the first heat source-side pressure reducing device 4, and includes the first heat transfer tube 10a and the second heat transfer tube 10b; the first heat source-side refrigerant pipe 12 connecting the one end of the first heat transfer tube 10a to the first heat source-side pressure reducing device 4; the second heat source-side refrigerant pipe 13 connecting the other end of the first heat transfer tube 10a to the first heat source-side heat exchanger 3; the first heat source-side branched refrigerant pipe 16 connecting the branch joint portion

12a arranged in the first heat source-side refrigerant pipe 12 to the one end of the second heat transfer tube 10b; the second heat source-side branched refrigerant pipe 18 connecting the other end of the second heat transfer tube 10b to the intermediate-pressure portion of the first compressor 2; and the second heat source-side pressure reducing device 20 arranged in the first heat source-side branched refrigerant pipe 16. During cooling operation, the subcooling heat exchanger 10 exchanges heat between the first refrigerant flowing through the first heat transfer tube 10a and the first refrigerant flowing through the second heat transfer tube 10b. During cooling operation, the controller 50 regulates the opening degree of the second heat source-side pressure reducing device 20 to increase a degree of subcooling so that the temperature of the first refrigerant flowing into the first heat source-side pressure reducing device 4 can fall below a saturated liquid temperature of the first refrigerant at the design pressure.

[0058] The above-described configuration enables the temperature of the first refrigerant flowing into the first heat source-side pressure reducing device 4 to fall below a saturated liquid temperature of the first refrigerant at the design pressure, thereby facilitating the first refrigerant to be kept in a liquid state even after the first refrigerant is reduced in pressure and expanded by the first heat source-side pressure reducing device 4.

[0059] Fig. 4 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 1. In the Mollier diagram of Fig. 4, the vertical axis represents absolute pressure (MPa), and the horizontal axis represents specific enthalpy (kJ/kg). In Fig. 4, a saturated liquid line, a saturated vapor line, and steps in the first refrigeration cycle 500 are illustrated. For convenience of explanation, the first heat source-side pressure reducing device 4 and the load-side pressure reducing device 5 are schematically represented at corresponding positions in an expansion step. In the Mollier diagram of Fig. 4, a bent dashed-dotted line represents the state of the refrigerant that is reduced in pressure and expanded by the second heat source-side pressure reducing device 20, and is subjected to heat exchange in the second heat transfer tube 10b of the subcooling heat exchanger 10.

[0060] Further, a point A on the Mollier diagram of Fig. 4 represents a position of the saturated liquid temperature Ta of the first refrigerant calculated from the design pressure Pm. A point B on the Mollier diagram of Fig. 4 represents a position in a condensation step in the first refrigeration cycle 500 that is equal in specific enthalpy to the point A. A point C on the Mollier diagram of Fig. 4 represents a position of the temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 in the condensation step in the first refrigeration cycle 500. A point D on the Mollier diagram of Fig. 4 represents a position in the expansion step in the first refrigeration cycle 500 that is equal in specific enthalpy to the point C and at which a pressure reaches the design pressure Pm. A point E on the Mollier diagram of Fig. 4 represents a point of intersection of a straight line representing the expansion step in the first refrigeration cycle 500 and the saturated liquid line and is a position at which the pressure of the first refrigerant reaches the saturated liquid pressure Ps.

[0061] The above-described configuration enables an increase in degree of subcooling by regulating the opening degree of the second heat source-side pressure reducing device 20 and exchanging heat between the first refrigerant flowing through the first heat transfer tube 10a and the first refrigerant flowing through the second heat transfer tube 10b in the subcooling heat exchanger 10. That is, the above-described configuration enables adjustment to be performed so that the point C is located on the left side of the point B in the Mollier diagram of Fig. 4. The temperature of the first refrigerant at the point B is equal to or slightly higher than the saturated liquid temperature Ta at the point A. Thus, when the point C is located on the left side of the point B, the temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 is lower than the saturated liquid temperature Ta at all times.

[0062] Thus, the above-described configuration enables control to be performed so that a state is obtained in which the pressure P of the first refrigerant flowing into the first connection pipe 300 is greater than the saturated liquid pressure Ps and less than the design pressure Pm by regulating the opening degree of the first heat source-side pressure reducing device 4. In the Mollier diagram of Fig. 4, the state in which the pressure P of the first refrigerant is greater than the saturated liquid pressure Ps and less than the design pressure Pm corresponds to a position of the expansion step between the point D and the point E in Fig. 4.

[0063] Specifically, when a design pressure of the first connection pipe 300 (the local pipe) is 1.64 MPa, the point A is 38 degrees Celsius. Assuming that a condensing temperature is 50 degrees Celsius, a degree of subcooling is about 30 degrees Celsius, and thus the point C is 20 degrees Celsius. Thus, in order that, in the first connection pipe 300, the pressure of the refrigerant may not be greater than the design pressure and the refrigerant may be in a liquid state, the pressure is controlled to be in a range of from 1.00 MPa to 1.64 MPa by the first heat source-side pressure reducing device 4.

[0064] As described above, the configuration according to Embodiment 1 causes the temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 to be less than the saturated liquid temperature Ta, thereby enabling the first refrigerant to be kept in a liquid state even after the first refrigerant is reduced in pressure and expanded by the first heat source-side pressure reducing device 4.

Embodiment 2

[0065] Embodiment 2 of the present invention is a modification of the refrigeration cycle apparatus 1 according to Embodiment 1 described above. Fig. 5 is a schematic refrigerant circuit diagram for illustrating an example of the refrigeration cycle apparatus 1 according to Embodiment 2.

[0066] The heat source-side unit 100 of the refrigeration cycle apparatus 1 according to Embodiment 2 includes a third heat source-side refrigerant pipe 14 connected between the second connection pipe 400 and the one end of the second heat transfer tube 10b of the subcooling heat exchanger 10 in place of the first heat source-side branched refrigerant pipe 16 of the refrigeration cycle apparatus 1 according to Embodiment 1 described above. The heat source-side unit 100 of the refrigeration cycle apparatus 1 according to Embodiment 2 further includes a fourth heat source-side refrigerant pipe 15 connected between the other end of the second heat transfer tube 10b of the subcooling heat exchanger 10 and the first compressor 2 in place of the second heat source-side branched refrigerant pipe 18 of the refrigeration cycle apparatus 1 according to Embodiment 1 described above. The heat source-side unit 100 of the refrigeration cycle apparatus 1 according to Embodiment 2 does not include the second heat source-side pressure reducing device 20. In the refrigeration cycle apparatus 1 according to Embodiment 2, the second temperature sensor 35 and the first pressure sensor 40 are provided on the fourth heat source-side refrigerant pipe 15. The other components of the heat source-side unit 100 of the refrigeration cycle apparatus 1 according to Embodiment 2 are the same as those in the refrigeration cycle apparatus 1 according to Embodiment 1 described above.

[0067] Fig. 6 is a control block diagram for illustrating part of control performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2. Fig. 6 is the same control block diagram as that of Fig. 2 except that it does not include the second heat source-side pressure reducing device 20.

[0068] Next, a control process performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2 is described.

[0069] During cooling operation, the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2 is configured to regulate the opening degree of the load-side pressure reducing device to increase a degree of subcooling so that the temperature of the first refrigerant flowing into the first heat source-side pressure reducing device falls below a saturated liquid temperature of the first refrigerant at the design pressure.

[0070] In the following descriptions of the control process in Embodiment 2, an opening degree DH1 of the first heat source-side pressure reducing device 4 can be regulated in a range of $0 \leq DH \leq 1$. A state of the opening degree DH1=0 represents that the first heat source-side pressure reducing device 4 is in a closed state. A state of the opening degree DH1=1 represents that the first heat source-side pressure reducing device 4 is in a fully open state.

[0071] An opening degree DL of the load-side pressure reducing device 5 can be regulated in a range of $0 \leq DL \leq 1$. A state of the opening degree satisfying DL=0 represents that the load-side pressure reducing device 5 is in a closed state. A state of the opening degree satisfying DL=1 represents that the load-side pressure reducing device 5 is in a fully open state.

[0072] Fig. 7 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 2. Similarly to the control process illustrated in Fig. 3, the control process illustrated in Fig. 7 may be performed at all times during cooling operation, or may be performed whenever variations in parameter of the refrigeration cycle apparatus 1, such as variations in frequency of the first compressor 2, are detected.

[0073] In Embodiment 2 as well as in Embodiment 1 described above, in the storage unit (not shown) of the controller 50, data of a design pressure Pm (for example, a withstand pressure reference value) of the first connection pipe 300 is stored. Further, in the storage unit of the controller 50, data about a Mollier diagram (P-h diagram) representing the state of the first refrigerant in the refrigeration cycle apparatus 1 is stored as a table, for example.

[0074] In Step S21, as in Step S11 in Embodiment 1 described above, the controller 50 determines whether a temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 detected by the first temperature sensor 30 is not less than a saturated liquid temperature Ta of the first refrigerant at the design pressure Pm.

[0075] When the temperature Tc of the first refrigerant is not less than the saturated liquid temperature Ta, the controller 50 controls, in Step S22, the opening degree DL of the load-side pressure reducing device 5 to open the load-side pressure reducing device 5 by a regulation value ΔDL. Here, the regulation value ΔDL is a certain constant determined in view of specifications of, for example, the structure of the load-side pressure reducing device 5. For example, the regulation value $\Delta DH2$ can be set to 0.02. Subsequently, until the temperature Tc of the first refrigerant falls below the saturated liquid temperature Ta, the control process of Step S22 is repeated in the controller 50.

[0076] In Step S23, as in Step S13 in Embodiment 1 described above, when the temperature Tc of the first refrigerant is less than the saturated liquid temperature Ta, the controller 50 determines whether a pressure P of the first refrigerant flowing into the load-side pressure reducing device 5 is not greater than a saturated liquid pressure Ps. When the pressure P of the first refrigerant is greater than the saturated liquid pressure Ps, the control process ends.

[0077] In Step S24, as in Step S14 in Embodiment 1 described above, when the pressure P of the first refrigerant is not greater than the saturated liquid pressure Ps, the controller 50 controls the opening degree DH1 of the first heat source-side pressure reducing device 4 to open the first heat source-side pressure reducing device 4 by a regulation value ΔDH1.

[0078] The heat source-side unit 100 of the refrigeration cycle apparatus 1 according to Embodiment 2 further includes: the subcooling heat exchanger 10, which is arranged between the first heat source-side heat exchanger 3 and the first heat source-side pressure reducing device 4, and includes the first heat transfer tube 10a and the second heat transfer tube 10b; the first heat source-side refrigerant pipe 12 connecting the one end of the first heat transfer tube 10a to the first heat source-side pressure reducing device 4; the second heat source-side refrigerant pipe 13 connecting the other end of the first heat transfer tube 10a to the first heat source-side heat exchanger 3; the third heat source-side refrigerant pipe 14 connected between the second connection pipe 400 and the one end of the second heat transfer tube 10b; and the fourth heat source-side refrigerant pipe 15 connected between the other end of the second heat transfer tube 10b and the first compressor 2. During cooling operation, the subcooling heat exchanger 10 exchanges heat between the first refrigerant flowing through the first heat transfer tube 10a and the first refrigerant flowing through the second heat transfer tube 10b. During cooling operation, the controller 50 regulates the opening degree of the load-side pressure reducing device 5 to increase a degree of subcooling so that the temperature of the first refrigerant flowing into the first heat source-side pressure reducing device 4 falls below a saturated liquid temperature of the first refrigerant at the design pressure.

[0079] Fig. 8 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 2. Fig. 8 is the same Mollier diagram as that of Fig. 4 except that there is not illustrated a bent dashed-dotted line representing the state of the refrigerant that is subjected to heat exchange in the second heat transfer tube 10b of the subcooling heat exchanger 10.

[0080] The configuration according to Embodiment 2 enables an increase in degree of subcooling by regulating the opening degree of the load-side pressure reducing device 5 and exchanging heat between the first refrigerant flowing through the first heat transfer tube 10a and the first refrigerant flowing through the second heat transfer tube 10b in the subcooling heat exchanger 10. Further, the configuration causes the temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 to be less than the saturated liquid temperature Ta, thereby enabling the first refrigerant to be kept in a liquid state even after the first refrigerant is reduced in pressure and expanded by the first heat source-side pressure reducing device 4.

[0081] Further, in the configuration according to Embodiment 2, the high-quality two-phase refrigerant or low-temperature low-pressure gas refrigerant having flowed out from the load side heat exchanger 6 is further heated in the subcooling heat exchanger 10 so that liquid is prevented from returning to the first compressor 2. Thus, the configuration according to Embodiment 2 enables an improvement in the reliability of the refrigeration cycle apparatus 1. Further, in the configuration according to Embodiment 2, all the first refrigerant flowing through the refrigeration cycle apparatus 1 can be used in heat exchange in the load side heat exchanger 6, thereby enabling an improvement in cooling capacity of the refrigeration cycle apparatus 1.

Embodiment 3

[0082] In Embodiment 3 of the present invention, the refrigeration cycle apparatus 1 according to Embodiment 1 described above further includes a second refrigeration cycle 600. Fig. 9 is a schematic refrigerant circuit diagram for illustrating an example of the refrigeration cycle apparatus 1 according to Embodiment 3.

[0083] In the refrigeration cycle apparatus 1 according to Embodiment 3, in addition to the configuration according to Embodiment 1 described above, the heat source-side unit 100 further includes the second refrigeration cycle 600 in which a second compressor 62, a second heat source-side heat exchanger 63, a third heat source-side pressure reducing device 64, and the first heat source-side heat exchanger 3 are connected by a refrigerant pipe and through which second refrigerant circulates. During cooling operation, the first heat source-side heat exchanger 3 exchanges heat between the first refrigerant flowing in from the first compressor 2 and the second refrigerant flowing in from the third heat source-side pressure reducing device 64. The second heat source-side heat exchanger functions as a radiator.

[0084] In the second refrigeration cycle 600, structures and operations of the second compressor 62, the second heat source-side heat exchanger 63, and the third heat source-side pressure reducing device 64 are the same as those of the first compressor 2, the first heat source-side heat exchanger 3, and the first heat source-side pressure reducing device 4. In Embodiment 3, as described above, the first heat source-side heat exchanger 3 functions as a cascade heat exchanger that exchanges heat between the first refrigerant flowing in from the first compressor 2 and the second refrigerant flowing in from the third heat source-side pressure reducing device 64 during cooling operation.

[0085] In the second refrigeration cycle 600 of Embodiment 3, examples of second refrigerant that can be used include hydrofluorocarbon, such as R32, hydrofluoroolefins, such as 2,3,3,3-tetrafluoro-1-propene (HFO-1234yf), and a mixed solvent, such as R410A.

[0086] Fig. 10 is a control block diagram for illustrating part of control performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 3. Fig. 10 is the same control block diagram as that of Fig. 2 except that the controller 50 controls the opening degree of the third heat source-side pressure reducing device 64.

[0087] Fig. 11 is a flowchart for illustrating an example of a control process during cooling operation performed in the controller 50 of the refrigeration cycle apparatus 1 according to Embodiment 3. The control process illustrated in Fig. 11 is the same as the control process illustrated in Fig. 3, and Step S31 to Step S34 in Fig. 11 correspond to Step S11 to Step S14 in Fig. 3. The other descriptions of the control process are also the same as those of the control process in Embodiment 1 described above.

[0088] Fig. 12 is a Mollier diagram for illustrating an operation of the refrigeration cycle apparatus 1 according to Embodiment 3. Fig. 12 is the same Mollier diagram as that of Fig. 4.

[0089] The configuration according to Embodiment 3 also enables, as in Embodiment 1 described above, an increase in degree of subcooling by regulating the opening degree of the second heat source-side pressure reducing device 20 and exchanging heat between the first refrigerant flowing through the first heat transfer tube 10a and the first refrigerant flowing through the second heat transfer tube 10b in the subcooling heat exchanger 10. Further, the configuration causes the temperature Tc of the first refrigerant flowing into the first heat source-side pressure reducing device 4 to be less than the saturated liquid temperature Ta, thereby enabling the first refrigerant to be kept in a liquid state even after the first refrigerant is reduced in pressure and expanded by the first heat source-side pressure reducing device 4.

[0090] Further, in the configuration according to Embodiment 3, CO_2 is used as the first refrigerant, and CO_2 can be used in a state equal to or below a supercritical state. Thus, the refrigeration cycle apparatus 1 exhibiting excellent safety can be provided.

Other Embodiments

[0091] The present invention is not limited to Embodiments described above, and various modifications can be made. For example, the refrigeration cycle apparatus 1 according to Embodiments described above can be used in an air-conditioning apparatus, a refrigerating machine, and other apparatus.

[0092] In the case where the refrigeration cycle apparatus 1 is used as an air-conditioning apparatus, the refrigeration cycle apparatus 1 can be configured so that heating operation can be performed. For example, a refrigerant flow switching device (for example, a four-way valve) is provided in the refrigeration cycle apparatus 1, thereby enabling switching between cooling operation and heating operation.

[0093] Further, with use of the second temperature sensor 35 and the first pressure sensor 40 in Embodiments described above, the opening degree of the second heat source-side pressure reducing device 20 or the load-side pressure reducing device 5 is regulated, thereby enabling control to be performed so that the amount of liquid return to the first compressor 2 is reduced.

[0094] Further, Embodiments described above can be used in combination with one another.

Reference Signs List

[0095] 1 refrigeration cycle apparatus 2 first compressor 3 first heat source-side heat exchanger 4 first heat source-side pressure reducing device 5 load-side pressure reducing device 6 load side heat exchanger 7a first heat source-side connection valve 7b second heat source-side connection valve 8a first load side connection valve 8b second load side connection valve 10 subcooling heat exchanger 10a first heat transfer tube 10b second heat transfer tube 12 first heat source-side refrigerant pipe 12a branch joint portion 13 second heat source-side refrigerant pipe 14 third heat source-side refrigerant pipe 15 fourth heat source-side refrigerant pipe 16 first heat source-side branched refrigerant pipe 18 second heat source-side branched refrigerant pipe 20 second heat source-side pressure reducing device 30 first temperature sensor 35 second temperature sensor 40 first pressure sensor45 second pressure sensor 50 controller 62 second compressor 63 third heat source-side heat exchanger 64 third heat source-side pressure reducing device 100 heat source-side unit 200 load-side unit 300 first connection pipe
400 second connection pipe 500 first refrigeration cycle 600 second refrigeration cycle

Claims

1. A refrigeration cycle apparatus comprising:

a heat source-side unit which houses a first compressor, a first heat source-side heat exchanger, and a first heat source-side pressure reducing device;
a load-side unit which houses a load-side pressure reducing device and a load side heat exchanger, and is connected to the heat source-side unit by a first connection pipe arranged between the first heat source-side pressure reducing device and the load-side pressure reducing device and by a second connection pipe arranged between the first compressor and the load side heat exchanger; and
a controller,
wherein the first compressor, the first heat source-side heat exchanger, the first heat source-side pressure reducing device, the load-side pressure reducing device, and the load side heat exchanger are connected by a refrigerant pipe and form a first refrigeration cycle through which first refrigerant circulates, and
wherein, during a cooling operation in which the load side heat exchanger functions as an evap-

orator, the controller is configured to regulate an opening degree of the first heat source-side pressure reducing device to cause first refrigerant to flow into the first connection pipe as liquid refrigerant having a pressure less than a design pressure of the first connection pipe.

2. The refrigeration cycle apparatus of claim 1, wherein the heat source-side unit further includes

a subcooling heat exchanger which is arranged between the first heat source-side heat exchanger and the first heat source-side pressure reducing device, and includes a first heat transfer tube and a second heat transfer tube,
a first heat source-side refrigerant pipe connecting one end of the first heat transfer tube to the first heat source-side pressure reducing device,
a second heat source-side refrigerant pipe connecting an other end of the first heat transfer tube to the first heat source-side heat exchanger,
a first heat source-side branched refrigerant pipe connecting a branch joint portion arranged in the first heat source-side refrigerant pipe to one end of the second heat transfer tube,
a second heat source-side branched refrigerant pipe connecting an other end of the second heat transfer tube to an intermediate-pressure portion of the first compressor, and
a second heat source-side pressure reducing device arranged in the first heat source-side branched refrigerant pipe,

wherein, during the cooling operation, the subcooling heat exchanger is configured to exchange heat between the first refrigerant flowing through the first heat transfer tube and the first refrigerant flowing through the second heat transfer tube, and
wherein, during the cooling operation, the controller is configured to regulate an opening degree of the second heat source-side pressure reducing device to increase a degree of subcooling so that a temperature of the first refrigerant flowing into the first heat source-side pressure reducing device falls below a saturated liquid temperature of the first refrigerant at the design pressure.

3. The refrigeration cycle apparatus of claim 1, wherein the heat source-side unit further includes

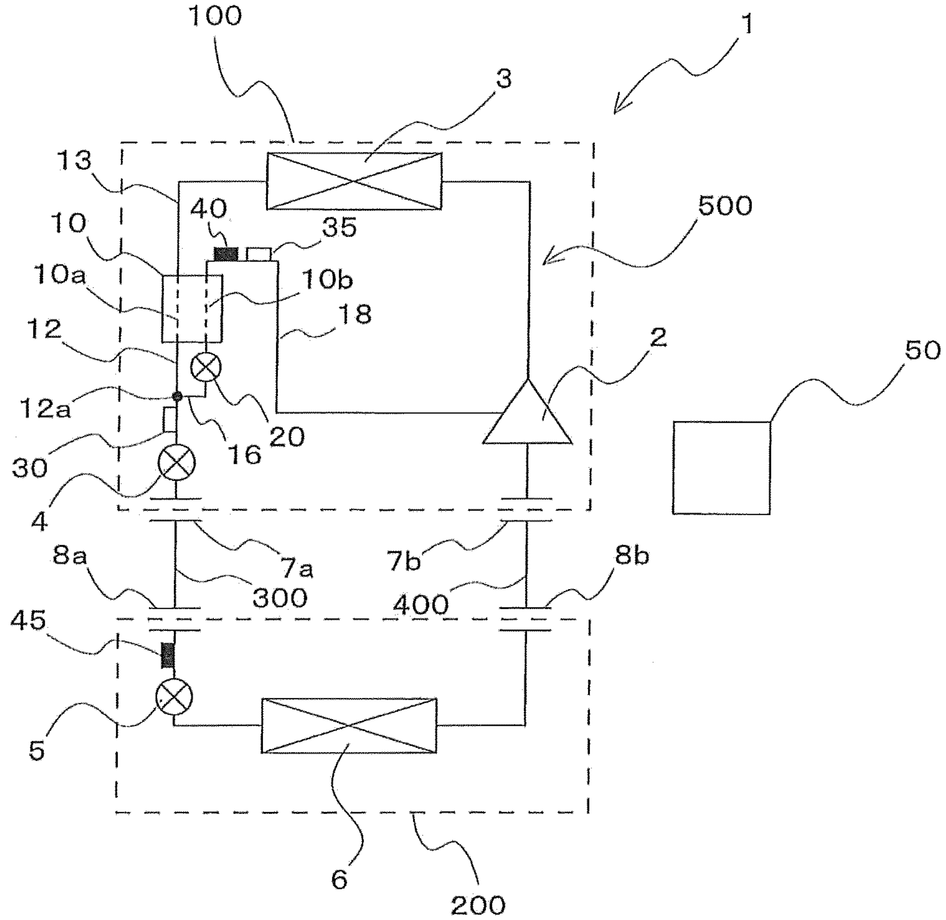
a subcooling heat exchanger which is being arranged between the first heat source-side heat exchanger and the first heat source-side pressure reducing device, and includes a first heat transfer tube and a second heat transfer tube,
a first heat source-side refrigerant pipe connecting one end of the first heat transfer tube to the first heat source-side pressure reducing device,
a second heat source-side refrigerant pipe connecting an other end of the first heat transfer tube to the first heat source-side heat exchanger,
a third heat source-side refrigerant pipe connected between the second connection pipe and one end of the second heat transfer tube, and
a fourth heat source-side refrigerant pipe connected between an other end of the second heat transfer tube and the first compressor,

wherein, during the cooling operation, the subcooling heat exchanger is configured to exchange heat between the first refrigerant flowing through the first heat transfer tube and the first refrigerant flowing through the second heat transfer tube, and
wherein, during the cooling operation, the controller is configured to regulate an opening degree of the load-side pressure reducing device to increase a degree of subcooling so that a temperature of the first refrigerant flowing into the first heat source-side pressure reducing device falls below a saturated liquid temperature of the first refrigerant at the design pressure.

4. The refrigeration cycle apparatus of any one of claims 1 to 3, wherein the first refrigerant comprises CO_2.

5. The refrigeration cycle apparatus of any one of claims 1 to 4,
wherein the heat source-side unit further includes a second refrigeration cycle in which a second compressor, a second heat source-side heat exchanger, a third heat source-side pressure reducing device, and the first heat source-side heat exchanger are connected by a refrigerant pipe and through which second refrigerant circulates,
wherein, during the cooling operation, the first heat source-side heat exchanger is configured to exchange heat between the first refrigerant flowing in from the first compressor and the second refrigerant flowing in from the third heat source-side pressure reducing device, and
wherein, during the cooling operation, the second heat source-side heat exchanger functions as a radiator.

FIG. 1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1
3
13
500
40
35
10
10a
10b
18
12
2
50
12a
20
16
30
4
8a
7a
7b
8b
300
400
45
5
6
200

FIG. 2

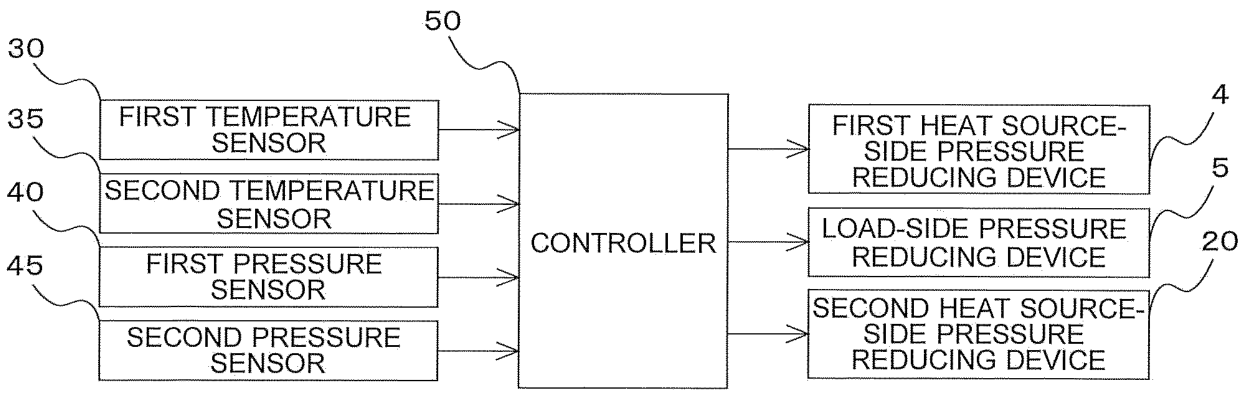

50
30
FIRST TEMPERATURE SENSOR
35
SECOND TEMPERATURE SENSOR
40
FIRST PRESSURE SENSOR
45
SECOND PRESSURE SENSOR
CONTROLLER
4
FIRST HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE
5
LOAD-SIDE PRESSURE REDUCING DEVICE
20
SECOND HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE

FIG. 3

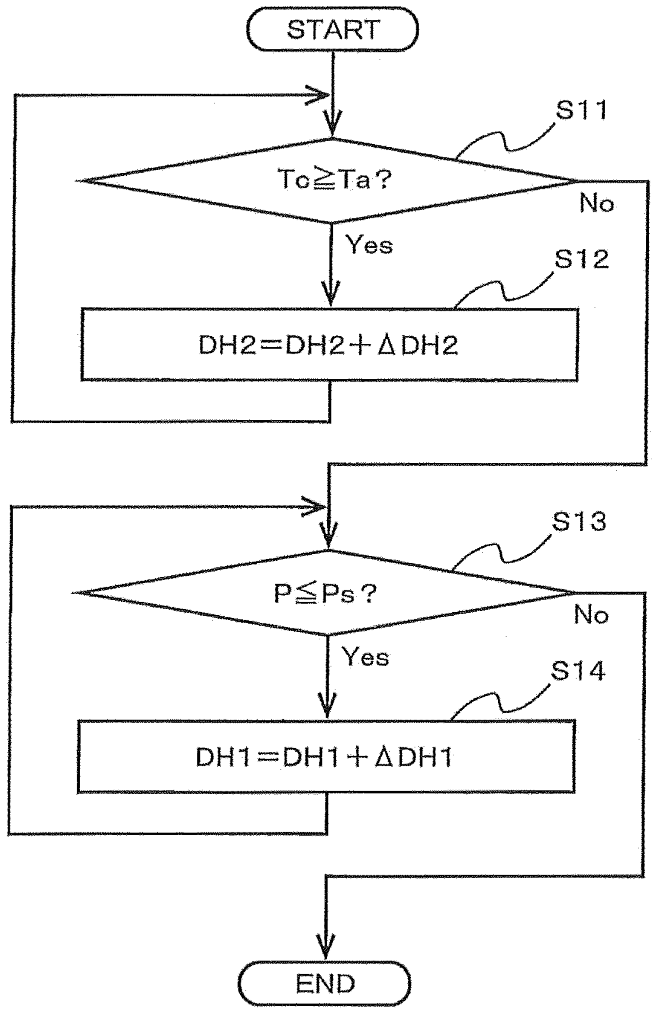

START
S11
Tc≧Ta?
No
Yes
S12
DH2=DH2+ΔDH2
S13
P≦Ps?
No
Yes
S14
DH1=DH1+ΔDH1
END

FIG. 4

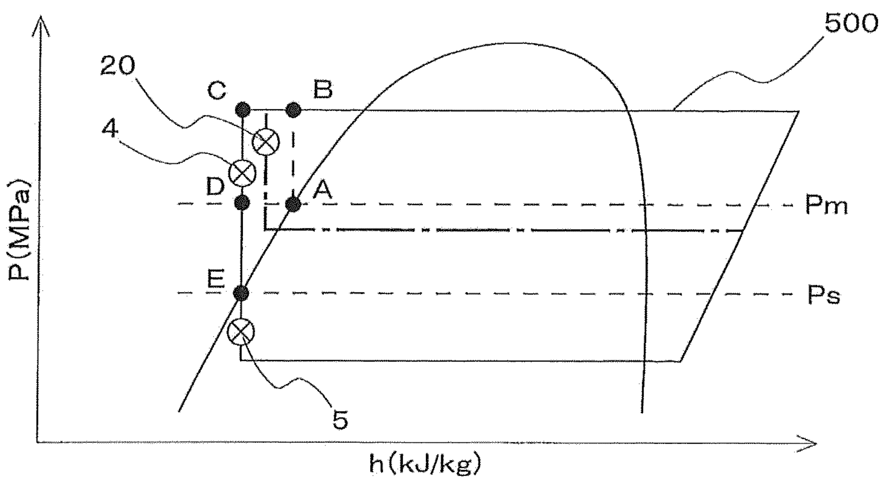
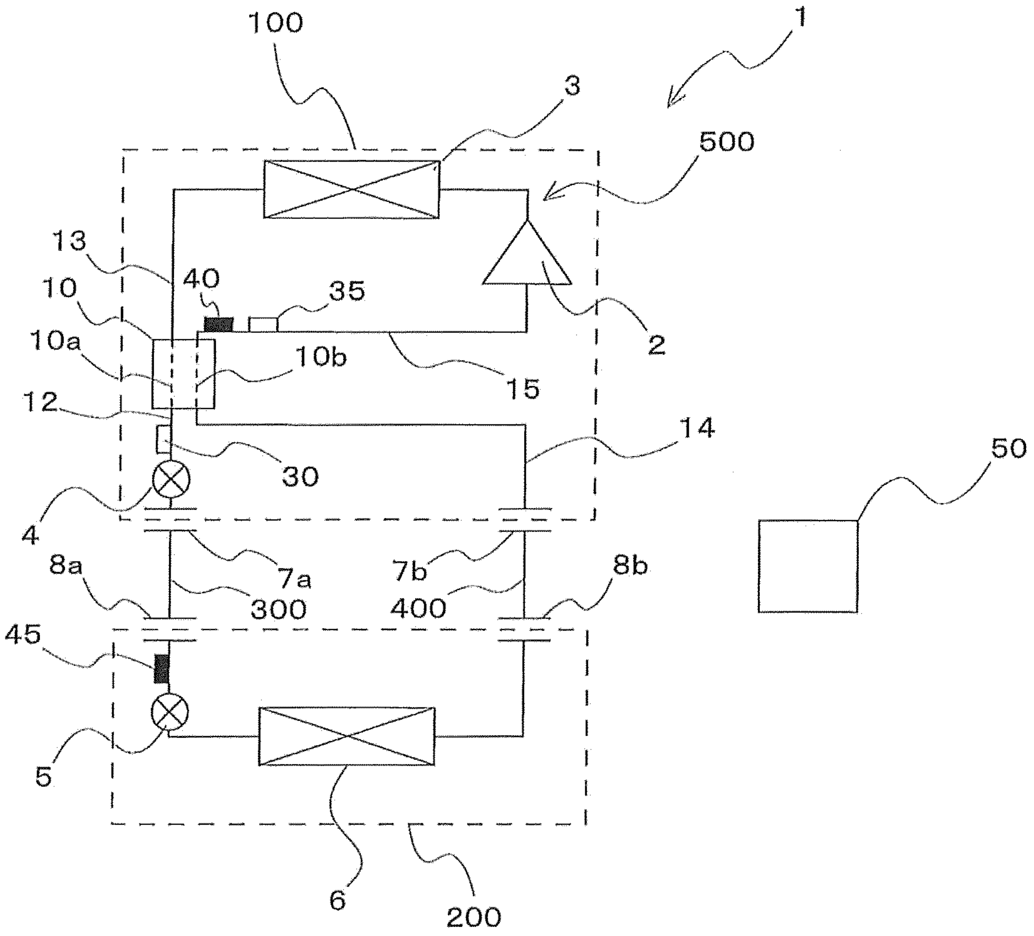

500
20
C
B
4
D
A
Pm
E
Ps
5
P(MPa)
h(kJ/kg)

FIG. 5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100
3
500
13
40
35
10
2
10a
10b
15
12
14
30
50
4
8a
7a
7b
8b
300
400
45
5
6
200

FIG. 6

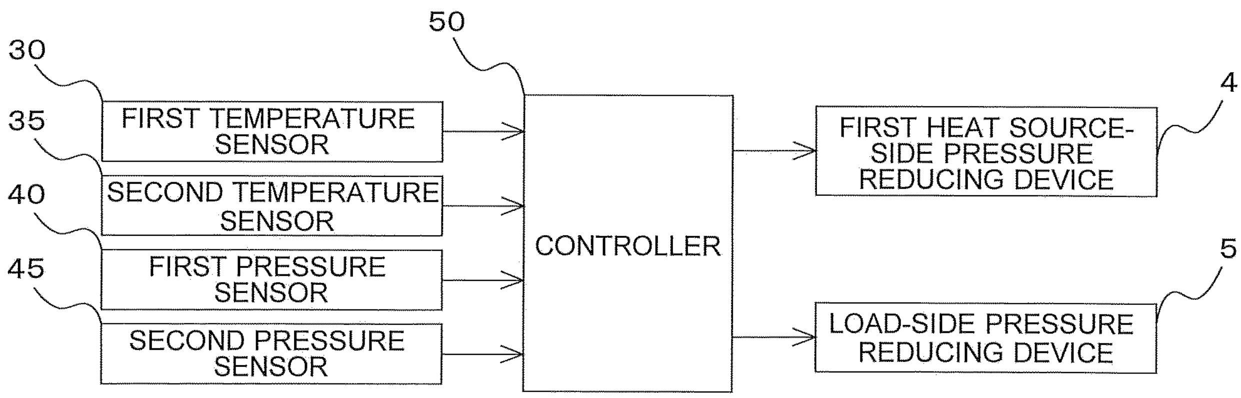

50
30
FIRST TEMPERATURE SENSOR
35
SECOND TEMPERATURE SENSOR
40
FIRST PRESSURE SENSOR
45
SECOND PRESSURE SENSOR
CONTROLLER
4
FIRST HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE
5
LOAD-SIDE PRESSURE REDUCING DEVICE

FIG. 7

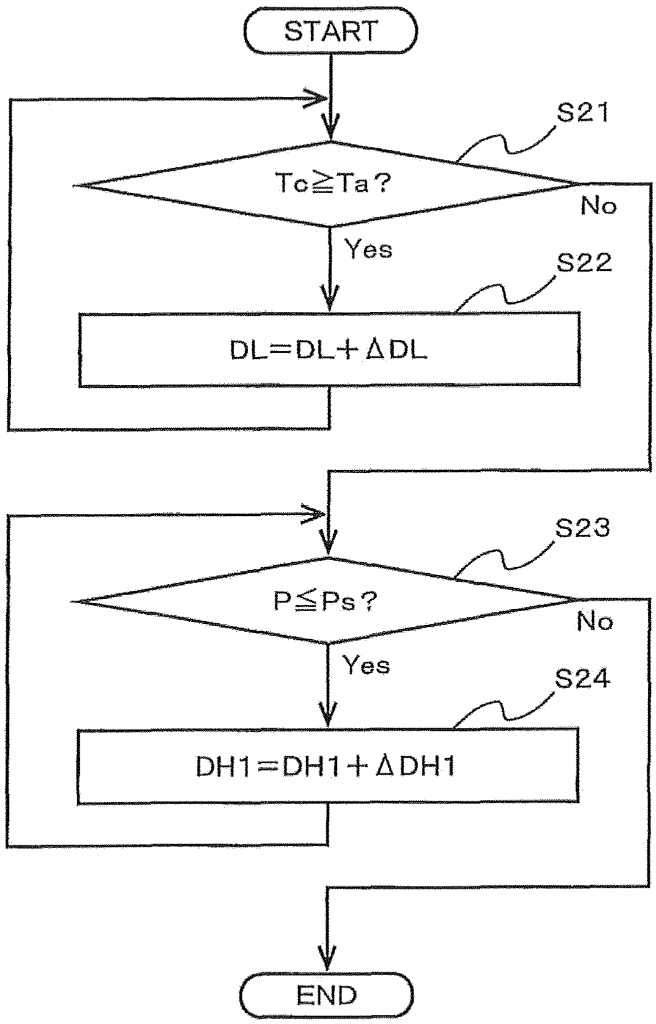

START
S21
Tc≧Ta?
No
Yes
S22
DL=DL+ΔDL
S23
P≦Ps?
No
Yes
S24
DH1=DH1+ΔDH1
END

FIG. 8

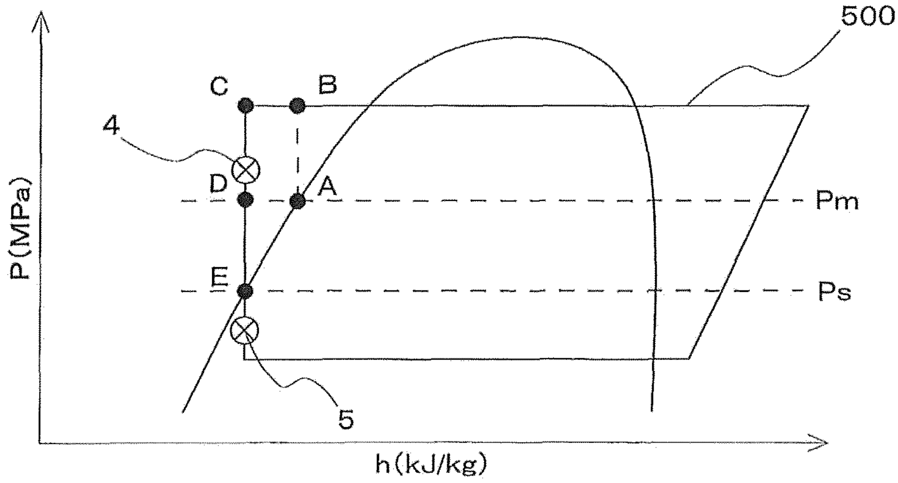
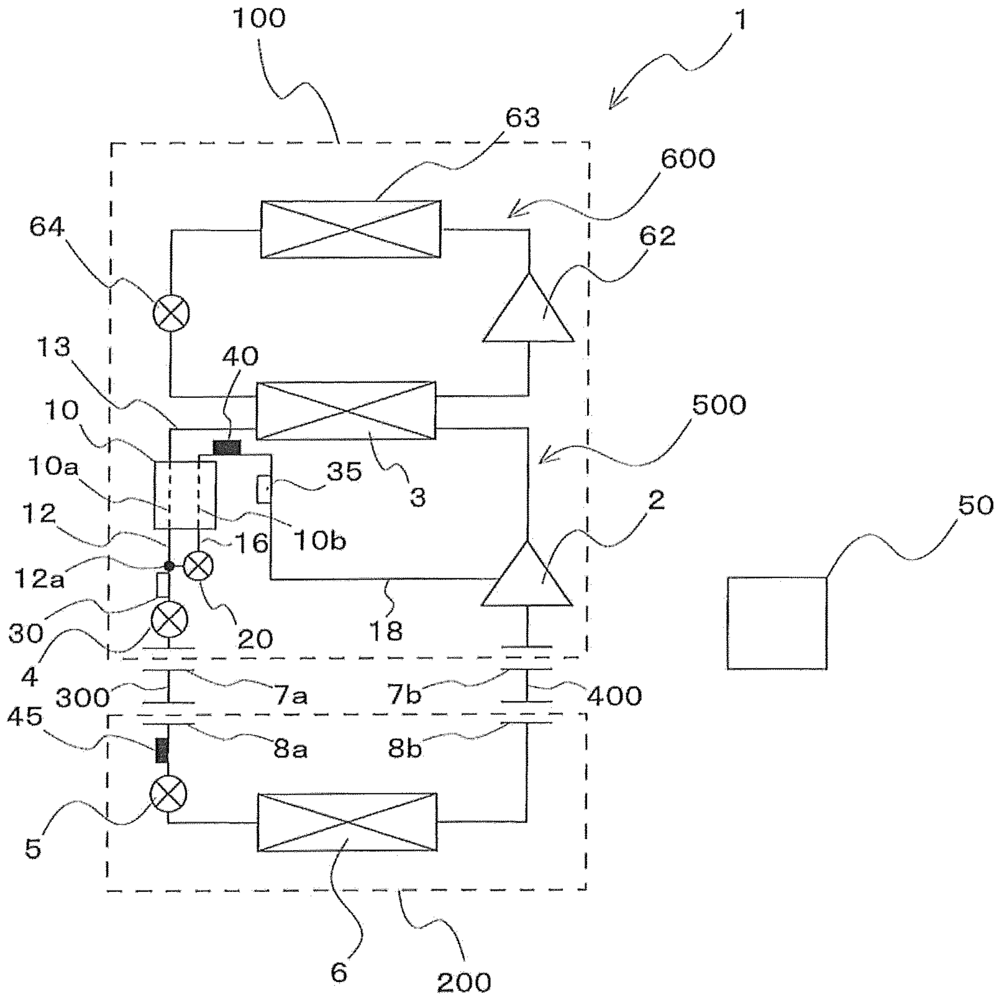

500
C
B
4
D
A
Pm
E
Ps
5
P(MPa)
h(kJ/kg)

FIG. 9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1
63
600
64
62
13
40
500
10
10a
35
3
12
16
10b
2
50
12a
20
18
30
4
300
7a
7b
400
45
8a
8b
5
6
200

FIG. 10

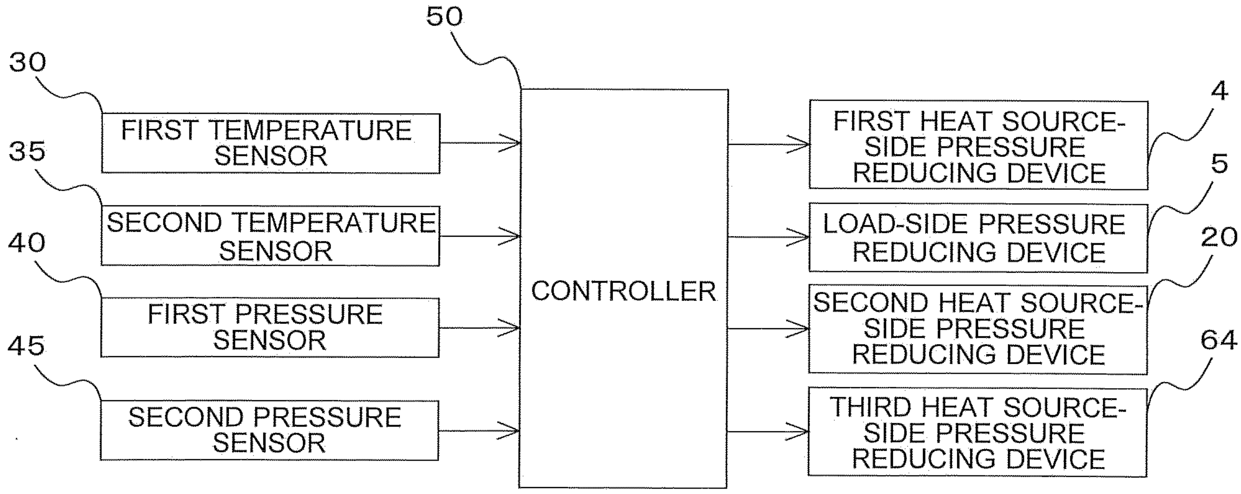

50
30
FIRST TEMPERATURE SENSOR
35
SECOND TEMPERATURE SENSOR
40
FIRST PRESSURE SENSOR
45
SECOND PRESSURE SENSOR
CONTROLLER
4
FIRST HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE
5
LOAD-SIDE PRESSURE REDUCING DEVICE
20
SECOND HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE
64
THIRD HEAT SOURCE-SIDE PRESSURE REDUCING DEVICE

FIG. 11

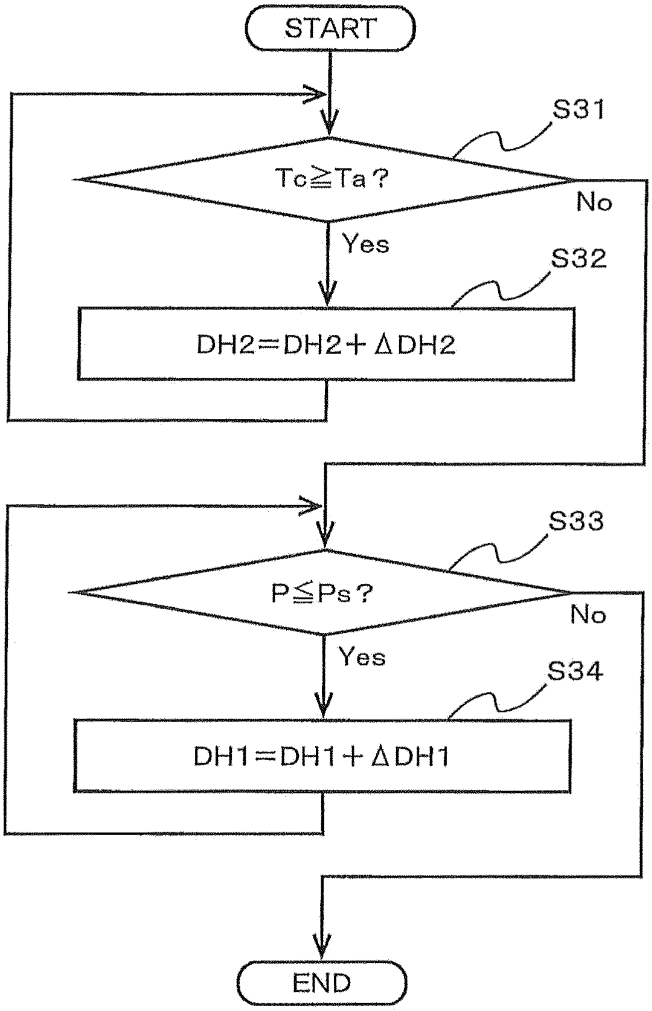
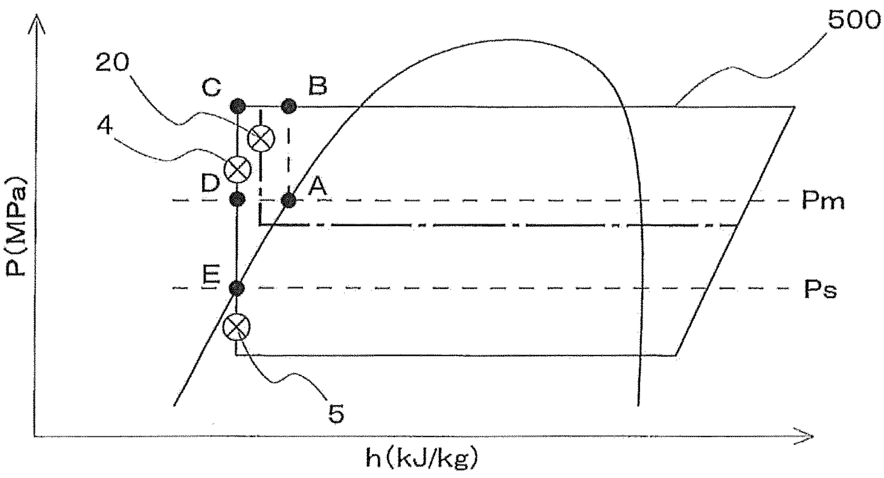

START
S31
Tc≧Ta ?
No
Yes
S32
DH2=DH2+ΔDH2
S33
P≦Ps ?
No
Yes
S34
DH1=DH1+ΔDH1
END

FIG. 12


500
20
C
B
4
D
A
Pm
E
Ps
5
P(MPa)
h(kJ/kg)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2015/067652

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, *F24F11/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B1/00, F24F11/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2012-112622 A (Mitsubishi Electric Corp.), 14 June 2012 (14.06.2012), paragraphs [0005] to [0048]; fig. 1 (Family: none)	1,4
Y	JP 2011-106695 A (Mitsubishi Electric Corp.), 02 June 2011 (02.06.2011), paragraph [0029] (Family: none)	1,4
A	JP 2011-12825 A (Sanyo Electric Co., Ltd.), 20 January 2011 (20.01.2011), paragraph [0028] (Family: none)	1-5

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 September 2015 (09.09.15)	29 September 2015 (29.09.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012112622 A **[0003]**