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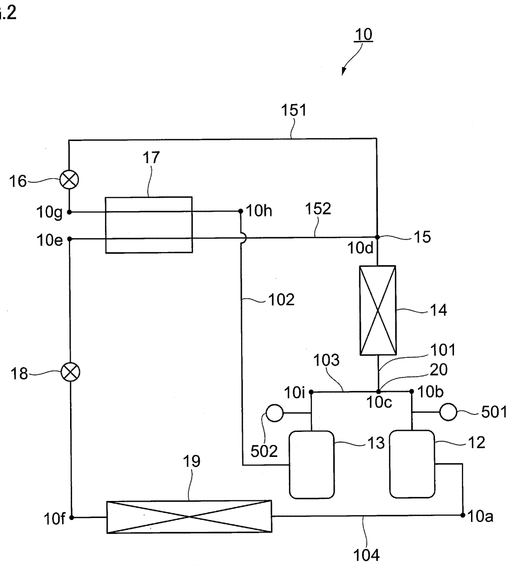
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus includes: a first compression element configured to suck in and compress refrigerant and discharge the compressed refrigerant into a first flow path; a radiator provided on the first flow path and configured to allow the refrigerant to pass therethrough and dissipate heat extracted from the refrigerant passing therethrough; a branching section configured to split the refrigerant after passing through the radiator in the first flow path into a first branch and a second branch; a first decompression element configured to decompress the refrigerant branched off into the first branch and flow the decompressed refrigerant into a second flow path; a heat exchanger configured to cause a heat exchange between the refrigerant flowing in the second flow path and the refrigerant branched off into the second branch; a second decompression element configured to decompress the refrigerant in the second branch having undergone the heat exchange in the heat exchanger; a cooler configured to cool an object through a heat exchange between the refrigerant decompressed by the second decompression element and the object and allow the refrigerant after the heat exchange to be sucked into the first compression element; a second compression element configured to suck in and compress the refrigerant in the second flow path having undergone the heat exchange in the heat exchanger and discharge the compressed refrigerant into a third flow path; and a merging section configured to allow the third flow path to merge into the first flow path.

FIG.2



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Description

Technical Field

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

Background Art

[0002] Patent Literature 1 discloses a compressor system with multiple compressors connected in parallel.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent No. 5758818

Summary of Invention

Technical Problem

[0004] For example, there is a refrigeration cycle apparatus that uses the compressor system of Patent Literature 1 to ensure refrigeration capacity by increasing the refrigerant circulation volume and thus increasing the volume of refrigerant available for cooling an object. For such a refrigeration cycle apparatus, the greater the refrigeration capacity required to cool an object, the larger the total compressor capacity needs to be. More specifically, the number of compressors needs to be increased or the capacity per compressor needs to be increased, which leads to higher equipment costs and a larger size of the refrigeration cycle apparatus as a whole.

[0005] The present disclosure proposes a refrigeration cycle apparatus with a reduced total compressor capacity, compared to ensuring the refrigeration capacity by increasing the refrigerant circulation volume.

Solution to Problem

[0006] In a first aspect, the present invention relates to a refrigeration cycle apparatus including: a first compression element configured to suck in and compress refrigerant and discharge the compressed refrigerant into a first flow path; a radiator provided on the first flow path, the radiator being configured to allow the refrigerant to pass therethrough and dissipate heat extracted from the refrigerant passing therethrough; a branching section configured to split the refrigerant after passing through the radiator in the first flow path into a first branch and a second branch; a first decompression element configured to decompress the refrigerant branched off into the first branch and flow the decompressed refrigerant into a second flow path; a heat exchanger configured to cause a heat exchange between the refrigerant flowing in the second flow path and the refrigerant branched off into the second branch; a second decompression element configured to decompress the refrigerant in the second branch having undergone the heat exchange in the heat exchanger; a cooler configured to cool an object through a heat exchange between the refrigerant decompressed by the second decompression element and the object and allow the refrigerant after the heat exchange to be sucked into the first compression element; a second compression element configured to suck in and compress the refrigerant in the second flow path having undergone the heat exchange in the heat exchanger and discharge the compressed refrigerant into a third flow path; and a merging section configured to allow the third flow path to merge into the first flow path. This configuration can reduce the total compressor capacity compared to ensuring the refrigeration capacity by increasing the refrigerant circulation volume.

[0007] In a second aspect, the present invention relates to the refrigeration cycle apparatus of the first aspect, wherein the merging section is configured to allow the third flow path to merge into the first flow path at a position in the first flow path rearward of the radiator, and the refrigeration cycle apparatus further comprises a second radiator in the third flow path, the second radiator being configured to dissipate heat extracted by allowing the refrigerant compressed by the second compression element to pass therethrough. This can increase the heat dissipation from the radiator compared to when the merging section allows the third flow path to merge into the first flow path at a position in the first flow path forward of the radiator.

[0008] In a third aspect, the present invention relates to the refrigeration cycle apparatus of the second aspect, wherein a capacity of the first compression element is larger than a capacity of the second compression element. This can increase the heat dissipation from the radiator compared to when the capacity of the first compression element is smaller than that of the second compression element.

[0009] In a fourth aspect, the present invention relates to the refrigeration cycle apparatus of the third aspect, further including a third decompression element in the third flow path, the third decompression element being configured to decompress the refrigerant after passing through the second radiator. This allows for setting a higher compression ratio for the second compression element.

[0010] In a fifth aspect, the present invention relates to the refrigeration cycle apparatus of the second aspect, further including a fourth decompression element at a position in the first flow path rearward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, the fourth decompression element being configured to decompress the refrigerant after passing through the radiator. This allows for setting a higher compression ratio for the first compression element.

[0011] In a sixth aspect, the present invention relates to the refrigeration cycle apparatus of any one of the first to fifth aspects, wherein at least a portion of a composition of the refrigerant comprises carbon dioxide. This can increase the heat dissipation from the radiator compared to using a non-azeotropic mixed refrigerant free of carbon dioxide.

[0012] In a seventh aspect, the present invention relates to the refrigeration cycle apparatus of the first aspect, further including temperature sensors configured to measure temperature of the refrigerant, one of the sensors being located at a position in the first flow path forward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, another one of the sensors being located at a position in the third flow path forward of where the third flow path is merged into the first flow path by the merging section; and a controller configured to control circulation of the refrigerant based on the temperature of the refrigerant measured by the temperature sensors, wherein the controller is configured to increase a flow resistance of the first decompression element when the temperature of the refrigerant measured in the first flow path is higher than the temperature of the refrigerant measured in the third flow path. This can reduce the enthalpy difference between the refrigerant compressed by the first compression element and the refrigerant compressed by the second compression element.

[0013] In an eighth aspect, the present invention relates to the refrigeration cycle apparatus of the first aspect, further including temperature sensors configured to measure temperature of the refrigerant, one of the sensors being located at a position in the first flow path forward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, another one of the sensors being located at a position in the third flow path forward of where the third flow path is merged into the first flow path by the merging section; and a controller configured to control circulation of the refrigerant based on the temperature of the refrigerant measured by the temperature sensors, wherein the controller is configured to control a flow rate of the second compression element when the temperature of the refrigerant measured in the first flow path is higher than the temperature of the refrigerant measured in the third flow path. This can reduce the enthalpy difference between the refrigerant compressed by the first compression element and the refrigerant compressed by the second compression element.

Brief Description of the Drawings

[0014]

FIG. 1 illustrates an example schematic configuration of an air conditioner according to exemplary embodiments.
FIG. 2 is a schematic diagram of a refrigerant circuit according to a first embodiment.
FIG. 3 is a pressure-specific enthalpy diagram illustrating a refrigeration cycle of refrigerant circulating in the refrigerant circuit according to the first embodiment.
FIG. 4 is a schematic diagram of a refrigerant circuit according to a second embodiment.
FIG. 5 is a schematic diagram of a refrigerant circuit according to a third embodiment.
FIG. 6 is a schematic diagram of a refrigerant circuit according to a fourth embodiment.
FIG. 7 illustrates a refrigerant circuit in an example application.
FIGS. 8A and 8B illustrate a conventional refrigeration cycle apparatus, where FIG. 8A is a schematic diagram of a refrigerant circuit in the conventional refrigeration cycle apparatus, and FIG. 8B is a pressure-specific enthalpy diagram illustrating a refrigeration cycle of refrigerant circulating in the refrigerant circuit.

Description of Embodiments

[0015] A conventional art apparatus without application of embodiments of the present invention is described first.

[0016] FIGS. 8A and 8B illustrate a conventional refrigeration cycle apparatus, where FIG. 8A is a schematic diagram of a refrigerant circuit 10' in the conventional refrigeration cycle apparatus, and FIG. 8B is a pressure-specific enthalpy diagram illustrating a refrigeration cycle of refrigerant circulating in the refrigerant circuit 10'. In FIG. 8B, the horizontal axis represents specific enthalpy [kJ/kg], and the vertical axis represents absolute pressure [MPa.abs] with respect to absolute vacuum.

[0017] In FIG. 8A, lines connecting respective devices represent the piping that serves as refrigerant flow paths. In

FIG. 8B, a refrigeration cycle 300' is shown with bold lines, and points 10a' to 10f' on the refrigeration cycle 300' respectively correspond to positions 10a' to 10f' on a refrigerant circuit 10'. Thus, the points 10a' to 10f' on the refrigeration cycle 300' are denoted as the positions 10a' to 10f'. In addition to the refrigeration cycle 300', FIG. 8B also shows a saturated liquid line 301, a saturated vapor line 302, a critical point 303, and a 45°C isotherm 304 of carbon dioxide refrigerant.

[0018] As shown in FIG. 8A, the refrigerant circuit 10' includes two compressors 12', 13' connected in parallel, a radiator 14', a decompression valve 18', and a cooler 19' and circulates carbon dioxide therein, which is an example of the refrigerant. More specifically, the refrigerant after passing through the cooler 19' where it exchanged heat with an object splits into two branches at a branching section 30' (position 10a'). Of the two branch streams, the refrigerant flowing into one branch is compressed by the compressor 12', while the refrigerant flowing into the other branch is compressed by the compressor 13'. The branch streams then merge at a merging section 20' (position 10b'). The merged refrigerant passes through the radiator 14' to dissipate heat (position 10e'). The refrigerant having dissipated heat is then decompressed through the decompression valve 18' (position 10f') and passes through the cooler 19' again (position 10a').

[0019] The specific enthalpy and pressure of the refrigerant are changed by each device at each position on the refrigerant circuit 10', establishing a refrigeration cycle of the refrigerant. More specifically, as shown in FIG. 8B, from position 10a' to position 10b', the pressure and specific enthalpy of the refrigerant increase due to the compression by the compressors 12', 13' and the gain of compression heat. From position 10b' to position 10e', the specific enthalpy of the refrigerant decreases due to the heat dissipation in the radiator 14'. Further, from position 10e' to position 10f', the pressure of the refrigerant decreases due to the decompression by the decompression valve 18'. Furthermore, from position 10f' to position 10a', the specific enthalpy of the refrigerant increases due to the heat exchange with the object in the cooler 19'.

[0020] In the refrigeration cycle apparatus, the ability of the cooler to cool an object (which may be referred to hereinafter as "refrigeration capacity") is determined by the magnitude of heat (heat absorption) taken from the object by the refrigerant passing through the cooler. Thus, in the conventional refrigeration cycle apparatus using the refrigerant circuit 10', the refrigeration capacity of the cooler 19' is determined by the product of the change in specific enthalpy when the refrigerant moves from position 10f' to position 10a' and the volume of refrigerant passing through the cooler 19'.

[0021] To increase the refrigeration capacity of the cooler 19' in the conventional refrigeration cycle apparatus using the refrigerant circuit 10', the volume of refrigerant circulating in the refrigerant circuit 10' is increased to increase the volume of refrigerant passing through the cooler 19'. More specifically, the number of compressors connected in parallel with the compressors 12', 13' is increased or the capacity of the compressors 12', 13' is increased. Thus, in the conventional refrigeration cycle apparatus using the refrigerant circuit 10', the total compressor capacity increases along with an increase in the refrigeration capacity that needs to be ensured. The "total capacity" refers to the sum of the capacities of all compressors provided in the refrigerant circuit.

[0022] A refrigeration cycle apparatus according to exemplary embodiments of the present invention includes a configuration that can reduce the total compressor capacity, compared to ensuring the refrigeration capacity by increasing the refrigerant circulation volume.

[0023] Exemplary embodiments of the present invention are now detailed below.

<First Embodiment>

(Air conditioner 1)

[0024] FIG. 1 illustrates an example schematic configuration of an air conditioner according to exemplary embodiments.

[0025] As shown in the figure, the air conditioner 1 according to the exemplary embodiments includes a refrigerant circuit 10 having refrigerant circulating therein and a controller 50 to control circulation of the refrigerant in the refrigerant circuit 10. The controller 50 is wired or wirelessly connected to devices included in the refrigerant circuit 10 (described below with reference to FIG. 2) and can transmit control signals to the devices.

[0026] The air conditioner 1 is an example of the refrigeration cycle apparatus according to the exemplary embodiments.

[0027] The air conditioner 1 cools the air taken in and supplies it to a space as cold air to cool the space. More specifically, the air conditioner 1 extracts heat from the air, which is an example of the object, through a heat exchange between the refrigerant passing through a cooler (described below with reference to FIG.2) incorporated in the refrigerant circuit 10 and the air to thereby cool the air. The air conditioner 1 then supplies the cooled air as cold air to the space through an outlet or the like (not shown) of the indoor unit to cool the space.

(Controller 50)

[0028] The controller 50 controls the circulation of the refrigerant in the refrigerant circuit 10 by sending control signals to the devices included in the refrigerant circuit 10. The controller 50 also controls the volume of cold air supplied by the air conditioner 1 to the space. The controller 50 according to the exemplary embodiments includes, for example, an operation panel or controller to accept operations from users and performs control in response to operational inputs from the users, such as those related to temperature settings and air volume settings. Also, for example, the controller 50 includes a temperature sensor to measure the temperature of the space and performs control according to the measurements of the sensor. Furthermore, for example, the controller 50 includes a temperature sensor to measure the temperature of the refrigerant in the refrigerant circuit 10 and performs control according to the measurements of the sensor.

[0029] The controller 50 may also obtain information related to the operations of the devices included in the refrigerant circuit 10, such as the effective values of the operations relative to the control values, and may control the devices according to the obtained information.

(Refrigerant circuit 10)

[0030] The refrigerant circuit 10 is a circuit that establishes a refrigeration cycle of the refrigerant through the circulation of the refrigerant and enables cooling of the object through a heat exchange with the refrigerant. More specifically, the refrigerant circuit 10 according to the exemplary embodiments establishes a refrigeration cycle of carbon dioxide refrigerant, which is an example of the refrigerant, by circulating the carbon dioxide refrigerant while adjusting its specific enthalpy and pressure, and enables cooling of the air by extracting heat from the air through a heat exchange on the low-pressure side. The carbon dioxide refrigerant circulating in the refrigerant circuit 10 may be referred to hereinafter simply as the "refrigerant".

[0031] In addition to the refrigerant, the refrigerant circuit 10 may also circulate therein a fluid(s) different from the refrigerant, such as lubricating oil to ensure lubrication in the compressors described below.

[0032] FIG. 2 is a schematic diagram of the refrigerant circuit 10 according to a first embodiment.

[0033] As shown in the figure, the refrigerant circuit 10 according to the first embodiment includes compressors 12, 13 to compress the refrigerant, a radiator 14 to extract and dissipate heat from the refrigerant, a refrigerant-refrigerant heat exchanger 17 to cause a heat exchange between refrigerants, electric valves 16, 18 with adjustable opening, and a cooler 19 to cool the air through a heat exchange with the refrigerant passing therethrough.

[0034] The refrigerant circuit 10 also includes a temperature sensor 501 to measure the temperature of the refrigerant compressed and discharged by the compressor 12 and a temperature sensor 502 to measure the temperature of the refrigerant compressed and discharged by the compressor 13. In addition to the above devices, the refrigerant circuit 10 may also include pressure and temperature sensors to measure the pressure and temperature of the refrigerant at various points, receivers that can store the refrigerant, pressure switchgears as protection mechanisms, filters, heat sinks, oil separators, etc.

[0035] In FIG. 2, the lines connecting the respective devices represent the flow paths of the refrigerant, which are implemented by, for example, meal pipes.

[0036] As shown in the figure, the flow paths of the refrigerant circuit 10 are provided with a branching section 15 for splitting the relevant flow path and a merging section 20 for merging the branched-off paths. Here, the flow path between the compressor 12 and the branching section 15 is referred to as a first flow path 101, the flow path between the electric valve 16 and the compressor 13 as a second flow path 102, the flow path between the compressor 13 and the merging section 20 as a third flow path 103, and the flow path between the electric valve 18 and the compressor 12 as a fourth flow path 104. Of the two flow paths branched off by the branching section 15, one leading to the electric valve 16 is referred to as a first branch 151 and the other leading to the cooler 19 via the electric valve 18 is referred to as a second branch 152. Each flow path may comprise a single seamless pipe or two or more pipes connected by a flange structure or the like (not shown). The flow paths may also have various devices positioned along the flow paths.

[0037] The compressor 12 is a device to compress the refrigerant sucked in from the fourth flow path 104 and discharge it into the first flow path 101. The compressor 13 is a device to compress the refrigerant sucked in from the second flow path 102 and discharge it into the third flow path 103. The mechanisms of the compressors 12, 13 are not limited, and may be of any of various types of mechanisms, such as oscillating, scroll, and rotary types.

[0038] The compressors 12, 13 compress the sucked-in refrigerant at a compression ratio (= pressure of the refrigerant to be discharged / pressure of the sucked-in refrigerant) that is set according to the control of the controller 50 (see FIG. 1) and discharge it. For the compressors 12, 13 of the present embodiments, for example, the operating frequency and the volume of refrigerant to be sucked in/discharged are controlled according to control signals from the controller 50. The "operating frequency" refers to the frequency of operation of the relevant component in the compressor performed to compress the refrigerant. Specifically, the operating frequency refers to, for example, the frequency of oscillation of the oscillating body in an oscillating compressor or the frequency of rotation of the rotating body in a scroll or rotary compressor.

[0039] The compressor 12 is an example of the first compression element, and the compressor 13 is an example of the second compression element.

[0040] The radiator 14 is a device provided on the first flow path 101 to extract and dissipate heat from the refrigerant through a heat exchange between the refrigerant passing therethrough and a fluid such as air or water. As shown in the figure, in the refrigerant circuit 10 according to the first embodiment, the radiator 14 is provided between the merging section 20 and the branching section 15 on the first flow path 101. The radiator 14 may be any of various types of heat exchangers, such as tubular and plate heat exchangers.

[0041] In the radiator 14, the fluid that exchanged heat with the refrigerant is heated by the heat extracted from the refrigerant. Thus, in one example, air may be used as the fluid, and the heated air may be supplied as hot air to the space to warm the space. In another example, water may be used as the fluid, and the heated water may be supplied to users as hot water. As such, the radiator 14 can also be used as a heater to heat fluids.

[0042] The electric valves 16, 18 are each composed of a valve, such as a ball valve, and a motor to drive the valve. The electric valves 16, 18 regulate the pressure of the flowing refrigerant as the motor adjusts the opening degree of the valve. More specifically, the electric valve 16 is provided between the first branch 151 and the second flow path 102. The electric valve 16 decompresses the refrigerant flowing in from the first branch 151 by throttle expansion according to the opening degree of the valve and flows it into the second flow path 102. The electric valve 18 is provided between the refrigerant-refrigerant heat exchanger 17 and the cooler 19 on the second branch 152. The electric valve 18 decompresses the refrigerant flowing in from the refrigerant-refrigerant heat exchanger 17 by throttle expansion according to the opening degree of the valve and flows it into the cooler 19. The opening degrees of the electric valves 16, 18 are adjusted as the respective motors are driven according to control signals from the controller 50.

[0043] The electric valves 16, 18 have a flow resistance depending on their respective opening degrees. The flow resistance is a measure of the difficulty in the refrigerant flowing through the electric valves 16, 18. The higher the opening degree, the higher the flow resistance with a more difficult flow of the refrigerant, and the lower the opening degree, the lower the flow resistance with an easier flow of the refrigerant.

[0044] The electric valve 16 is an example of the first decompression element, and the electric valve 18 is an example of the second decompression element. Other decompression elements than the electric valves that can be controlled by the controller 50 (see FIG. 1) may include solenoid valves with a valve driven by a solenoid.

[0045] The refrigerant-refrigerant heat exchanger 17 is a device to cause a heat exchange between the refrigerant flowing in the second flow path 102 and the refrigerant flowing in the second branch 152. More specifically, the refrigerant-refrigerant heat exchanger 17 causes a heat exchange between the refrigerant branched off at the branching section 15 into the first branch 151 and flowing in the second flow path 102 after decompression by the electric valve 16 and the refrigerant branched off at the branching section 15 into the second branch 152. In the heat exchange in the refrigerant-refrigerant heat exchanger 17, the refrigerant flowing in the second flow path 102 extracts heat from the refrigerant flowing in the second branch 152, resulting in cooling the refrigerant flowing in the second branch 152.

[0046] The cooler 19 is a device provided on the fourth flow path 104 to cool the air by extracting heat from the air through a heat exchange between the refrigerant passing therethrough and the air. The cooler 19 may be a heat exchanger such as a tubular heat exchanger.

[0047] The air that has been cooled through the heat exchange with the refrigerant in the cooler 19 is supplied to the space via an air passage (not shown) to cool the space. This implements the cooling function of the air conditioner 1 (see FIG. 1).

[0048] The circulation of the refrigerant in the refrigerant circuit 10 is now described. In the refrigerant circuit 10 according to the first embodiment, the refrigerant after cooling the air as it passed through the cooler 19 (position 10a) is compressed by the compressor 12 and discharged into the first flow path 101 (position 10b). The refrigerant discharged into the first flow path 101 merges with the refrigerant flowing in from the third flow path 103 at the merging section 20 (position 10c). The merged refrigerant then passes through the radiator 14 to dissipate heat and is then branched off at the branching section 15 into the first branch 151 and the second branch 152 (position 10d). The refrigerant branched off into the first branch 151 is decompressed by the electric valve 16 and flows into the second flow path 102 (position 10g), where it exchanges heat in the refrigerant-refrigerant heat exchanger 17 with the refrigerant branched off into the second branch 152 (position 10h). The refrigerant is then compressed by the compressor 13 and discharged into the third flow path 103 (position 10i), which merges with the first flow path 101 at the merging section 20 (position 10c). Meanwhile, the refrigerant branched off into the second branch 152 and having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17 (position 10e) is decompressed by the electric valve 18 (position 10f) and then passes through the cooler 19 to cool the air (position 10a).

[0049] With this refrigerant circulation, the refrigerant circuit 10 establishes a refrigeration cycle of the refrigerant.

(Refrigeration cycle)

[0050] The refrigeration cycle in the refrigerant circuit 10 is detailed with reference to FIGS. 2 and 3.

[0051] FIG. 3 is a pressure-specific enthalpy diagram illustrating the refrigeration cycle 300 of the refrigerant circulating in the refrigerant circuit 10 according to the first embodiment. In FIG. 3, the horizontal axis represents specific enthalpy [kJ/kg], and the vertical axis represents absolute pressure [MPa.abs] with respect to absolute vacuum.

[0052] In FIG. 3, the refrigeration cycle 300 is shown with bold lines. Points 10a to 10i on the refrigeration cycle 300 respectively correspond to the positions 10a to 10i on the refrigerant circuit 10 shown in FIG. 2. Thus, the points 10a to 10i on the refrigeration cycle 300 are denoted as the positions 10a to 10i. In addition to the refrigeration cycle 300, FIG. 3 also shows a saturated liquid line 301, a saturated vapor line 302, a critical point 303, and a 45°C isotherm 304 of the carbon dioxide refrigerant.

[0053] In the refrigerant circuit 10 according to the first embodiment, the pressure and specific enthalpy of the refrigerant increase from position 10a to position 10b on the refrigeration cycle 300 as the refrigerant compressed by the compressor 12 and having gained compression heat is discharged into the first flow path 101. The specific enthalpy of the refrigerant varies from position 10b to position 10c as the third flow path 103 merges at the merging section 20. Further, the specific enthalpy of the refrigerant decreases from position 10c to position 10d as the merged refrigerant dissipates heat through the heat exchange with the fluid in the radiator 14. The refrigerant at position 10c is pressurized to an elevated temperature by the compressors 12, 13, having a high temperature of more than 45°C, for example. Thus, the fluid with which the refrigerant exchanges heat in the radiator 14 can take heat from the refrigerant even if the fluid is, for example, at room temperature (15°C to 25°C).

[0054] At position 10d, the refrigerant in the first branch 151 branched off at the branching section 15 is decompressed by the electric valve 16 before flowing into the second flow path 102, so that the pressure of the refrigerant decreases from position 10d to position 10g. Along with this decrease in pressure, the temperature of the refrigerant flowing in the second flow path 102 decreases below the temperature of the refrigerant flowing in the second branch 152. Thus, the refrigerant flowing in the second flow path 102 takes heat from the refrigerant in the first branch 151 through the heat exchange with the refrigerant in the first branch 151 in the refrigerant-refrigerant heat exchanger 17, resulting in the specific enthalpy increasing from position 10g to position 10h. Conversely, the specific enthalpy of the refrigerant in the second branch 152 decreases from position 10d to position 10e due to the heat loss through the heat exchange.

[0055] The refrigerant in the second branch 152 after passing through the refrigerant-refrigerant heat exchanger 17 is decompressed by the electric valve 18, so that the pressure of the refrigerant decreases from position 10e to position 10f. The specific enthalpy of the decompressed refrigerant increases from position 10f to position 10a as it exchanges heat with the air in the cooler 19 to take heat from the air. The refrigerant at position 10f has been decompressed to a reduced temperature by the electric valve 18, having a sufficiently low temperature relative to the air to be cooled. Thus, the refrigerant can take heat from the air, with which it exchanges heat in the cooler 19.

[0056] The refrigerant in the second flow path 102 after passing through the refrigerant-refrigerant heat exchanger 17 is compressed by the compressor 13 to gain compression heat, resulting in the pressure and specific enthalpy of the refrigerant increasing from position 10h to position 10i.

[0057] The above establishes the refrigeration cycle 300 of the refrigerant circuit 10.

[0058] Here, the refrigerant to cool the air in the cooler 19 has lost its heat through the heat exchange with the counterpart refrigerant in the refrigerant-refrigerant heat exchanger 17, prior to being decompressed by the electric valve 18. Thus, the refrigerant to cool the air in the cooler 19 of the refrigerant circuit 10 (position 10f in FIGS. 2 and 3) has a lower specific enthalpy than the refrigerant to cool the air in the cooler 19' of the conventional refrigerant circuit 10' (position 10f' in FIG. 8). This increases the volume of heat taken by the refrigerant per unit volume in the cooler 19 of the refrigerant circuit 10 compared to the conventional refrigerant circuit 10' where the heat exchange between refrigerants does not take place. This allows for ensuring the refrigeration capacity without increasing the refrigerant circulation volume.

[0059] In the refrigerant circuit 10, the carbon dioxide refrigerant enters a supercritical state in part of the refrigeration cycle 300, where the refrigerant has larger density changes along with its pressure changes than when it is in a non-supercritical state. Thus, a greater refrigeration capacity can be ensured for the compression work of the compressors 12, 13 than when the refrigerant does not go through a supercritical state. This is also the case in the refrigerant circuits according to the second to fourth embodiments described below.

[0060] Referring now to FIGS. 2, 8, and Table 1, the performance of the refrigerant circuit 10 according to the first embodiment is compared with that of the conventional refrigerant circuit 10'.

Table 1 lists the capacities and coefficients of performance (COP) of the compressors 12, 13/12', 13' in the air conditioner 1 using the refrigerant circuit 10 according to the first embodiment and an air conditioner using the conventional refrigerant circuit 10'. The COP is a value obtained by dividing the cooling effect of the coolers 17/17' of the refrigerant circuits 10/10' by the power consumption for the operations of the refrigerant circuits 10/10', and corresponds to the efficiency of the cooling effect relative to the power consumption.

[Table 1]

		Refrigerant circuit 10	Refrigerant circuit 10'
Compressor 12/12' capacity	cc	106	81.5
Compressor 13/13' capacity	cc	33	81.5
Total capacity	cc	139	163
COP		1.90	1.60
Total capacity comparison	%	85	100 (basis)
COP comparison	%	119	100 (basis)

[0061] As shown in Table 1, based on the capacities of the compressors 12, 13 in the refrigerant circuit 10 being 106 cc and 33 cc, respectively, for a total capacity of 139 cc, the COP of the air conditioner 1 is 1.90. On the other hand, based on the capacities of the compressors 12', 13' in the conventional refrigerant circuit 10' each being 81.5 cc for a total capacity of 163 cc, the COP of the air conditioner is 1.60. That is, based on the total capacity and COP of the air conditioner using the conventional refrigerant circuit 10' taken as 100% (basis), the air conditioner 1 using the refrigerant circuit 10 can improve the COP to 119% while reducing the total capacity to 85%.

[0062] As described above, in the air conditioner 1 using the refrigerant circuit 10, the refrigeration capacity is ensured through the heat exchange between the refrigerants in the refrigerant-refrigerant heat exchanger 17, which can increase the cooling effect of the air conditioner 1 even with a reduced total compressor capacity, compared to using the conventional refrigerant circuit 10 which ensures the refrigeration capacity by increasing the refrigerant circulation volume.

(Control by the controller 50)

[0063] By the way, the controller 50 of the air conditioner 1 (see FIG. 1) may control the circulation of the refrigerant based on the temperature of the refrigerant measured by the temperature sensors 501, 502 (see FIG. 2).

[0064] For example, when the temperature of the refrigerant measured by the temperature sensor 501 is higher than the temperature of the refrigerant measured by the temperature sensor 502, the controller 50 may reduce the opening degree of the electric valve 16 to increase the flow resistance. Also, for example, when the temperature of the refrigerant measured by the temperature sensor 501 is higher than the temperature of the refrigerant measured by the temperature sensor 502, the controller 50 may increase the volume of refrigerant sucked in by the compressor 13 to increase the flow rate of the refrigerant in the compressor 13. These controls reduce the enthalpy difference between the refrigerant compressed by the compressor 12 (position 10b in FIG. 2) and the refrigerant compressed by the compressor 13 (position 10i in FIG. 2). This, in turn, allows for setting a higher compression ratio for the compressor 13.

[0065] The locations of the temperature sensors 501, 502 used for control are not limited to those illustrated in FIG. 2; the temperature sensor 501 may be located at any position in the first flow path 101 forward of the radiator 14 and forward of where the third flow path 103 is merged into the first flow path 101 by the merging section 20, and the temperature sensor 502 may be located at any position in the third flow path 103 forward of where it is merged into the first flow path 101 by the merging section 20.

<Second Embodiment>

(Refrigerant circuit 10-2)

[0066] In a distinction from the first embodiment, the air conditioner 1 according to the second embodiment includes a refrigerant circuit 10-2 instead of the refrigerant circuit 10 (see FIG. 2).

[0067] FIG. 4 is a schematic diagram of the refrigerant circuit 10-2 according to the second embodiment.

[0068] As shown in the figure, the refrigerant circuit 10-2 according to the second embodiment differs from the refrigerant circuit 10 according to the first embodiment only in that a radiator 21 is provided on the third flow path 103 and that the merging section 20 allows the third flow path 103 to merge into the first flow path 101 at a position rearward of the radiator 14 in the first flow path 101. Accordingly, common elements between the refrigerant circuit 10 and the refrigerant circuit 10-2 are identified by the same names and reference numerals, and detailed descriptions thereof are omitted.

[0069] The radiator 21 is a device provided on the third flow path 103 to extract and dissipate heat from the refrigerant through a heat exchange between the refrigerant passing therethrough and a fluid such as air or water. In other words, the radiator 21 takes heat from the refrigerant compressed by the compressor 13 through a heat exchange between the refrigerant compressed by the compressor 13 and the fluid.

[0070] The radiator 21 may be a heat exchanger similar to the radiator 14. As with the radiator 14, the radiator 21 can also be used as a heater to heat fluids.

[0071] The radiator 21 is an example of the second radiator.

[0072] In the refrigerant circuit 10-2, the refrigerant after cooling the air as it passed through the cooler 19 is compressed by the compressor 12 and discharged into the first flow path 101. The refrigerant discharged into the first flow path 101 passes through the radiator 14 to dissipate heat. After the refrigerant in the third flow path 103 merges at the merging section 20, the merged refrigerant is blanched off at the branching section 15 into the first branch 151 and the second branch 152. The refrigerant branched off into the first branch 151 is decompressed by the electric valve 16 and flows into the second flow path 102, where it exchanges heat in the refrigerant-refrigerant heat exchanger 17 with the refrigerant branched off into the first branch 151. The refrigerant is then compressed by the compressor 13 and discharged into the third flow path 103. The refrigerant then passes through the radiator 21 to dissipate heat and merges into the first flow path 101 at the merging section 20. Meanwhile, the refrigerant branched off into the second branch 152 and having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17 is decompressed by the electric valve 18 and then passes through the cooler 19 to cool the air.

[0073] With this refrigerant circulation, the refrigerant circuit 10-2 establishes a refrigeration cycle of the refrigerant.

[0074] As with the first embodiment, the second embodiment using the refrigerant circuit 10-2 described above can reduce the total compressor capacity compared to using the conventional refrigerant circuit 10 that ensures the refrigeration capacity by increasing the refrigerant circulation volume.

[0075] Additionally, in the refrigerant circuit 10-2, the merging section 20 allows the third flow path 103 to merge into the first flow path 101 at a position in the first flow path 101 rearward of the radiator 14, which can increase the heat dissipation from the radiator 14 compared to when the third flow path 103 is allowed to merge into the first flow path 101 at a position forward of the radiator 14.

[0076] In the refrigerant circuit 10-2 according to the second embodiment, the capacity of the compressor 12 may be larger than that of the compressor 13. Such a configuration can increase the heat dissipation from the radiator 14 compared to when the capacity of the compressor 12 is smaller than that of the compressor 13.

<Third Embodiment>

(Refrigerant circuit 10-3)

[0077] In a distinction from the first embodiment, the air conditioner 1 according to the third embodiment includes a refrigerant circuit 10-3 instead of the refrigerant circuit 10 (see FIG. 2).

[0078] FIG. 5 is a schematic diagram of the refrigerant circuit 10-3 according to the third embodiment.

[0079] As shown in the figure, the refrigerant circuit 10-3 according to the third embodiment differs from the refrigerant circuit 10-2 according to the second embodiment only in that the refrigerant circuit 10-3 includes an electric valve 22 to decompress the refrigerant after passing through the radiator 21. Accordingly, common elements between the refrigerant circuit 10-2 and the refrigerant circuit 10-3 are identified by the same names and reference numerals, and detailed descriptions thereof are omitted.

[0080] The electric valve 22 is provided at a position in the third flow path 103 rearward of the radiator 21 to decompress the refrigerant passing through the electric valve 22.

[0081] The electric valve 22 may have the same configuration as the electric valves 16, 18, with its opening degree adjustable by the controller 50.

[0082] The electric valve 22 is an example of the third decompression element.

[0083] In the refrigerant circuit 10-3, the refrigerant after cooling the air as it passed through the cooler 19 is compressed by the compressor 12 and discharged into the first flow path 101. The refrigerant discharged into the first flow path 101 passes through the radiator 14 to dissipate heat. After the refrigerant in the third flow path 103 merges at the merging section 20, the merged refrigerant is branched off at the branching section 15 into the first branch 151 and the second branch 152. The refrigerant branched off into the first branch 151 is decompressed by the electric valve 16 and flows into the second flow path 102, where it exchanges heat in the refrigerant-refrigerant heat exchanger 17 with the refrigerant branched off into the first branch 151. The refrigerant is then compressed by the compressor 13 and discharged into the third flow path 103. The refrigerant then passes through the radiator 21 to dissipate heat and is further decompressed by the electric valve 22 before merging into the first flow path 101 at the merging section 20. Meanwhile, the refrigerant branched off into the second branch 152 and having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17 is decompressed by the electric valve 18 and then passes through the cooler 19 to cool the air.

[0084] With this refrigerant circulation, the refrigerant circuit 10-3 establishes a refrigeration cycle of the refrigerant.

[0085] As with the first and second embodiments, the third embodiment using the refrigerant circuit 10-3 described above can reduce the total compressor capacity compared to using the conventional refrigerant circuit 10 that ensures the refrigeration capacity by increasing the refrigerant circulation volume.

[0086] Additionally, in the refrigerant circuit 10-3, the refrigerant compressed by the compressor 13 is decompressed by the electric valve 22, which can increase the compression ratio for the compressor 13 compared to the absence of the electric valve 22.

<Fourth Embodiment>

(Refrigerant circuit 10-4)

[0087] In a distinction from the first embodiment, the air conditioner 1 according to the fourth embodiment includes a refrigerant circuit 10-4 instead of the refrigerant circuit 10 (see FIG. 2).
[0088] FIG. 6 is a schematic diagram of the refrigerant circuit 10-4 according to the fourth embodiment.
[0089] As shown in the figure, the refrigerant circuit 10-4 according to the fourth embodiment differs from the refrigerant circuit 10-2 according to the second embodiment only in that the refrigerant circuit 10-4 includes an electric valve 23 to decompress the refrigerant after passing through the radiator 14. Accordingly, common elements between the refrigerant circuit 10-2 and the refrigerant circuit 10-4 are identified by the same names and reference numerals, and detailed descriptions thereof are omitted.
[0090] The electric valve 23 is provided at a position in the first flow path 101 rearward of the radiator 14 and forward of where the third flow path 103 is merged into the first flow path 101 by the merging section 20 and decompresses the refrigerant passing through the electric valve 23.
[0091] The electric valve 23 may have the same configuration as the electric valves 16, 18, 22, with its opening degree adjustable by the controller 50.
[0092] The electric valve 23 is an example of the fourth decompression element.
[0093] In the refrigerant circuit 10-4, the refrigerant after cooling the air as it passed through the cooler 19 is compressed by the compressor 12 and discharged into the first flow path 101. The refrigerant discharged into the first flow path 101 passes through the radiator 14 to dissipate heat and is then decompressed by the electric valve 23. After the refrigerant in the third flow path 103 merges at the merging section 20, the merged refrigerant is branched off at the branching section 15 into the first branch 151 and the second branch 152. The refrigerant branched off into the first branch 151 is decompressed by the electric valve 16 and flows into the second flow path 102, where it exchanges heat in the refrigerant-refrigerant heat exchanger 17 with the refrigerant branched off into the second branch 152. The refrigerant is then compressed by the compressor 13 and discharged into the third flow path 103. The refrigerant then passes through the radiator 21 to dissipate heat and merges into the first flow path 101 at the merging section 20. Meanwhile, the refrigerant branched off into the second branch 152 and having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17 is decompressed by the electric valve 18 and then passes through the cooler 19 to cool the air.
[0094] With this refrigerant circulation, the refrigerant circuit 10-4 establishes a refrigeration cycle of the refrigerant.
[0095] As with the first to third embodiments, the fourth embodiment using the refrigerant circuit 10-4 described above can reduce the total compressor capacity compared to using the conventional refrigerant circuit 10 that ensures the refrigeration capacity by increasing the refrigerant circulation volume.
[0096] Additionally, in the refrigerant circuit 10-4, the refrigerant compressed by the compressor 12 is decompressed by the electric valve 23, which can increase the compression ratio for the compressor 12 compared to the absence of the electric valve 23.

<Example Application>

(Switching between cooling/heating)

[0097] The air conditioner 1 may switch between a cooling function of supplying cold air to a space to cool the space and a heating function of supplying hot air to a space to warm the space. In this case, sharing the same heat exchanger for both the cooling function to cool the air and the heating function to heat the air enables the shared use of air supply paths used for heat exchange and air passages used for supplying the cold air/hot air after heat exchange to the space.
[0098] The refrigerant circuit in one example application includes a switcher for switching the cooler 19 (see FIGS. 2, 4 to 6) in the above embodiments between serving as a heat exchanger to cool the air in the cooling function and serving as a heat exchanger to heat the air in the heating function.
[0099] FIG. 7 illustrates a refrigerant circuit 10-5 in one application example.
[0100] As shown in the figure, the refrigerant circuit 10-5 in the example application differs from the refrigerant circuit 10 according to the first embodiment only in that the refrigerant circuit 10-5 includes a four-way switching valve 60 to switch the connections of four flow paths. Accordingly, common elements between the refrigerant circuit 10 and the refrigerant circuit 10-5 are identified by the same names and reference numerals, and detailed descriptions thereof are omitted.

[0101] The four-way switching valve 60 is provided to connect the flow paths between the cooler 19 and the compressor 12 to the flow paths between the merging section 20 and the radiator 14. The connections of the flow paths are switched between a first state and a second state under the control of the controller 50, the first state being where the cooler 19 and the compressor 12 are connected and the merging section 20 and the radiator 14 are connected, the second state being where the cooler 19 and the merging section 20 are connected and the compressor 12 and the radiator 14 are connected.

[0102] The four-way switching valve 60 is an example of the switcher, and other components may be used for switching.

[0103] In the refrigerant circuit 10-5 in the first state, the refrigerant circulates in the same manner as in the refrigerant circuit 10 described with reference to FIG. 2, cooling the air with which the refrigerant exchanges heat in the cooler 19. This implements the cooling function of the air conditioner 1.

[0104] On the other hand, in the refrigerant circuit 10-5 in the second state, the refrigerant circulates in a different manner than in the first state, and the pressure and specific enthalpy of the refrigerant change along the reverse path of the refrigeration cycle 300 described with reference to FIG. 3. More specifically, the refrigerant compressed by the compressors 12, 13 merges at the merging section 20 and then passes through the cooler 19. Here, the refrigerant passing through the cooler 19 has been pressurized to an elevated temperature by the compressors 12, 13 and has a sufficiently high temperature relative to the air with which it exchanges heat. Thus, the air with which the refrigerant exchanges heat in the cooler 19 is heated by taking heat from the refrigerant. This implements the heating function of the air conditioner 1.

[0105] In the illustrated example of FIG. 7, the switcher is used in the refrigerant circuit 10 according to the first embodiment to implement the refrigerant circuit 10-5 of the example application. However, a similar switcher may be used in the refrigerant circuits 10-2, 10-3, 10-4 according to the second, third, and fourth embodiments.

[0106] In the second, third, and fourth embodiments described above as well as in the example application using the switcher, the controller 50 of the air conditioner 1 may control the circulation of the refrigerant based on the refrigerant temperature measured by the temperature sensors 501, 502 (see FIGS. 2, 4 to 7).

<Other variants>

[0107] The above embodiments have illustrated the refrigeration cycle apparatus as being used in the air conditioner 1. However, the scope of use of the refrigeration cycle apparatus is not limited to this, and it may be used in various types of equipment for cooling objects, such as refrigerated warehouses, refrigerators, and ice machines. As described above with reference to FIG. 2, taking advantage of the heat dissipation at the radiator 14, the refrigeration cycle apparatus may also be used in various devices for heating objects, such as heaters, water boilers, and water heaters.

[0108] Carbon dioxide refrigerant has been provided as an example of the refrigerant circulating in each refrigerant circuit. However, the type of refrigerant is not limited to this. A mixed refrigerant made of carbon dioxide and one or more other components may be used, or a single component refrigerant or mixed refrigerant free of carbon dioxide may be used. However, using a refrigerant that contains carbon dioxide in at least a portion of its composition, such as the carbon dioxide refrigerant in the above embodiments, leads to increased heat dissipation at the radiators 14, 21 compared to using a non-azeotropic mixed refrigerant free of carbon dioxide.

[0109] Furthermore, the first and second compression elements may be integrated into a single component such that the compression operation in each compression element is implemented by a common motor or the like. However, providing the compression elements as distinct components, like the compressors 12, 13 in the above embodiments, allows for controlling each compression element individually according to the condition of the sucked-in refrigerant and other factors.

[0110] Also, multiple compressors connected in parallel may be used instead of the compressor 12, and/or multiple compressors connected in parallel may be used instead of the compressor 13. Such configurations can also reduce the total capacity compared to ensuring the refrigeration capacity by increasing the refrigerant circulation volume as in the conventional refrigerant circuit 10'.

[0111] In the above embodiments, electric valves or solenoid valves are used as the decompression elements to enable control of the opening degrees by the controller 50. However, if control by the controller 50 is not necessary, capillary tubes or orifice plates may be used as the decompression elements.

[0112] In the above embodiments, the flow of refrigerant is illustrated as being split into two branches of the first and second branches 151, 152. However, the flow may be split into three or more branches including the first and second branches 151, 152. Correspondingly, multiple flow paths including the third flow path 103 may merge into the first flow path 101. When the flow is split into three or more branches, such split may take place at multiple branching sections including the branching section 15, and the merging may take place at multiple merging sections including the merging section 20.

<Additional remarks>

[0113] The above embodiments can be described as having the following aspects.

[0114] The air conditioner 1 of the above embodiments includes any one of the refrigerant circuits 10-1, 10-2, 10-3, 10-4, 10-5, each of which includes: the compressor 12 configured to suck in and compress refrigerant and discharge the compressed refrigerant into the first flow path 101; the radiator 14 provided on the first flow path 101, the radiator 14 being configured to allow refrigerant to pass therethrough and dissipate heat extracted from the refrigerant passing therethrough; a branching section 15 configured to split the refrigerant after passing through the radiator 14 in the first flow path 101 into the first branch 151 and the second branch 152; the electric valve 16 configured to decompress the refrigerant branched off into the first branch 151 and flow the decompressed refrigerant into the second flow path 102; the refrigerant-refrigerant heat exchanger 17 configured to cause a heat exchange between the refrigerant flowing in the second flow path 102 and the refrigerant branched off into the second branch 152; the electric valve 18 configured to decompress the refrigerant in the second branch 152 having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17; the cooler 19 configured to cool air through a heat exchange between the refrigerant decompressed by the electric valve 18 and the air and allow the refrigerant after the heat exchange to be sucked into the compressor 12; the compressor 13 configured to suck in and compress the refrigerant in the second flow path 102 having undergone the heat exchange in the refrigerant-refrigerant heat exchanger 17 and discharge the compressed refrigerant into the third flow path 103; and the merging section 20 configured to allow the third flow path 103 to merge into the first flow path 101. This configuration can reduce the total capacity of the compressors 12, 13 compared to air conditioners including the conventional refrigerant circuit 10' that ensures the refrigeration capacity by increasing the refrigerant circulation volume.

[0115] In the refrigerant circuit 10-2 according to the second embodiment, the merging section 15 allows the third flow path 103 to merge into the first flow path 101 at the position in the first flow path 101 rearward of the radiator 14. The third flow path 103 is provided with the radiator 21 to dissipate heat extracted by allowing the refrigerant compressed by the compressor 13 to pass therethrough. This can increase the heat dissipation from the radiator 14 compared to when the merging section 15 allows the third flow path 103 to merge into the first flow path 101 at a position in the first flow path 101 forward of the radiator 14.

[0116] In the refrigerant circuit 10-2, the capacity of the compressor 12 is larger than that of the compressor 13. This can increase the heat dissipation from the radiator 14 compared to when the capacity of the compressor 12 is smaller than that of the compressor 13.

[0117] In addition to the configuration of the refrigerant circuit 10-2, the refrigerant circuit 10-3 according to the third embodiment includes the electric valve 22 in the third flow path 103 to decompress the refrigerant after passing through the radiator 21. This allows for setting a higher compression ratio for the compressor 13.

[0118] In addition to the configuration of the refrigerant circuit 10-2, the refrigerant circuit 10-4 according to the fourth embodiment includes, at a position in the first flow path 101 rearward of the radiator 14 and forward of where the third flow path 103 is merged into the first flow path 101 by the merging section 20, the electric value 23 to decompress the refrigerant after passing through the radiator 14. This allows for setting a higher compression ratio for the compressor 12.

[0119] Carbon dioxide refrigerant is used in the air conditioner 1 of the above embodiments. This can increase the heat dissipation from the radiator 14 compared to using a non-azeotropic mixed refrigerant free of carbon dioxide.

[0120] The air conditioner 1 of the above embodiments includes the temperature sensors 501, 502 for measuring the temperature of the refrigerant, the temperature sensor 501 being located at the position in the first flow path 101 forward of the radiator 14 and forward of where the third flow path 103 is merged into the first flow path 101 by the merging section 15, the temperature sensor 502 being located at the position in the third flow path 103 forward of where the third flow path 103 is merged into the first flow path 101 by the merging section 15. The controller 50 of the air conditioner 1 may increase the flow resistance of the electric valve 16 when the temperature of the refrigerant measured by the temperature sensor 501 is higher than the temperature of the refrigerant measured in the third flow path 103. This can reduce the enthalpy difference between the refrigerant compressed by the compressor 12 and the refrigerant compressed by the compressor 13.

[0121] In the air conditioner 1 of the above embodiments, the controller 50 may increase the flow rate of the compressor 13 when the temperature of the refrigerant measured in the first flow path 101 is higher than the temperature of the refrigerant measured in the third flow path 103. This can also reduce the enthalpy difference between the refrigerant compressed by the compressor 12 and the refrigerant compressed by the compressor 13.

[0122] While exemplary embodiments have been described above, it will be understood that various modifications can be made to the forms and details without departing from the sprit and scope of the appended claims.

[0123] For example, part of the configurations described above may be omitted, or other features may be added to the configurations described above. Also, for example, a configuration included in one embodiment may be replaced with a configuration included in another embodiment, or a configuration included in one embodiment may be added to another embodiment.

Reference Signs List

[0124]

1 Air conditioner
10, 10-2, 10-3, 10-4, 10-5 Refrigerant circuit
12, 13 Compressor
14, 21 Radiator
15 Branching section
16, 18, 22, 23 Electric valve
17 Refrigerant-refrigerant heat exchanger
19 Cooler
20 Merging section
50 Controller
60 Switching circuit
101 First flow path
102 Second flow path
103 Third flow path
151 First branch
152 Second branch
501, 502 Temperature sensor

Claims

1. A refrigeration cycle apparatus comprising:

    a first compression element configured to suck in and compress refrigerant and discharge the compressed refrigerant into a first flow path;
    a radiator provided on the first flow path, the radiator being configured to allow the refrigerant to pass therethrough and dissipate heat extracted from the refrigerant passing therethrough;
    a branching section configured to split the refrigerant after passing through the radiator in the first flow path into a first branch and a second branch;
    a first decompression element configured to decompress the refrigerant branched off into the first branch and flow the decompressed refrigerant into a second flow path;
    a heat exchanger configured to cause a heat exchange between the refrigerant flowing in the second flow path and the refrigerant branched off into the second branch;
    a second decompression element configured to decompress the refrigerant in the second branch having undergone the heat exchange in the heat exchanger;
    a cooler configured to cool an object through a heat exchange between the refrigerant decompressed by the second decompression element and the object and allow the refrigerant after the heat exchange to be sucked into the first compression element;
    a second compression element configured to suck in and compress the refrigerant in the second flow path having undergone the heat exchange in the heat exchanger and discharge the compressed refrigerant into a third flow path; and
    a merging section configured to allow the third flow path to merge into the first flow path.

2. The refrigeration cycle apparatus according to claim 1, wherein

    the merging section is configured to allow the third flow path to merge into the first flow path at a position in the first flow path rearward of the radiator, and
    the refrigeration cycle apparatus further comprises a second radiator in the third flow path, the second radiator being configured to dissipate heat extracted by allowing the refrigerant compressed by the second compression element to pass therethrough.

3. The refrigeration cycle apparatus according to claim 2, wherein a capacity of the first compression element is larger than a capacity of the second compression element.

4. The refrigeration cycle apparatus according to claim 3, further comprising a third decompression element in the third flow path, the third decompression element being configured to decompress the refrigerant after passing through the second radiator.

5. The refrigeration cycle apparatus according to claim 2, further comprising a fourth decompression element at a position in the first flow path rearward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, the fourth decompression element being configured to decompress the refrigerant after passing through the radiator.

6. The refrigeration cycle apparatus according to any one of claims 1 to 5, wherein at least a portion of a composition of the refrigerant comprises carbon dioxide.

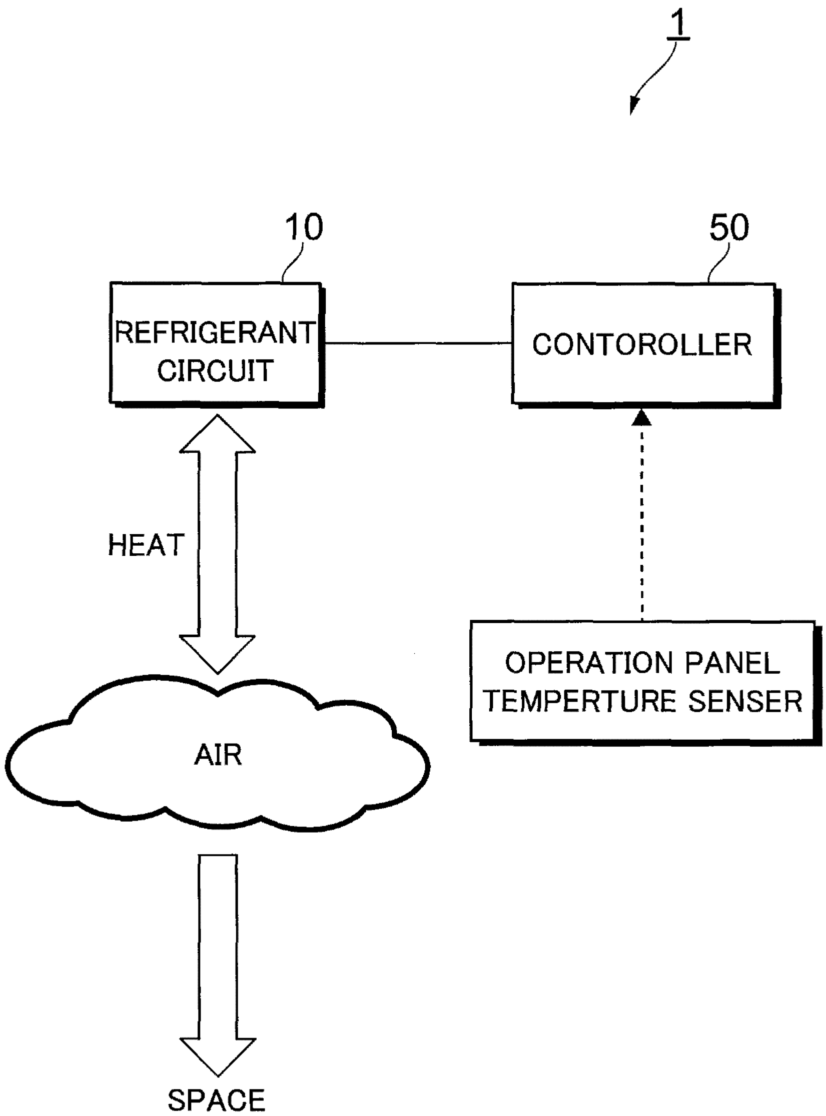
7. The refrigeration cycle apparatus according to claim 1, further comprising:

temperature sensors configured to measure temperature of the refrigerant, one of the sensors being located at a position in the first flow path forward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, another one of the sensors being located at a position in the third flow path forward of where the third flow path is merged into the first flow path by the merging section; and
a controller configured to control circulation of the refrigerant based on the temperature of the refrigerant measured by the temperature sensors, wherein
the controller is configured to increase a flow resistance of the first decompression element when the temperature of the refrigerant measured in the first flow path is higher than the temperature of the refrigerant measured in the third flow path.

8. The refrigeration cycle apparatus according to claim 1, further comprising:

temperature sensors configured to measure temperature of the refrigerant, one of the sensors being located at a position in the first flow path forward of the radiator and forward of where the third flow path is merged into the first flow path by the merging section, another one of the sensors being located at a position in the third flow path forward of where the third flow path is merged into the first flow path by the merging section; and
a controller configured to control circulation of the refrigerant based on the temperature of the refrigerant measured by the temperature sensors, wherein
the controller is configured to control a flow rate of the second compression element when the temperature of the refrigerant measured in the first flow path is higher than the temperature of the refrigerant measured in the third flow path.

FIG.1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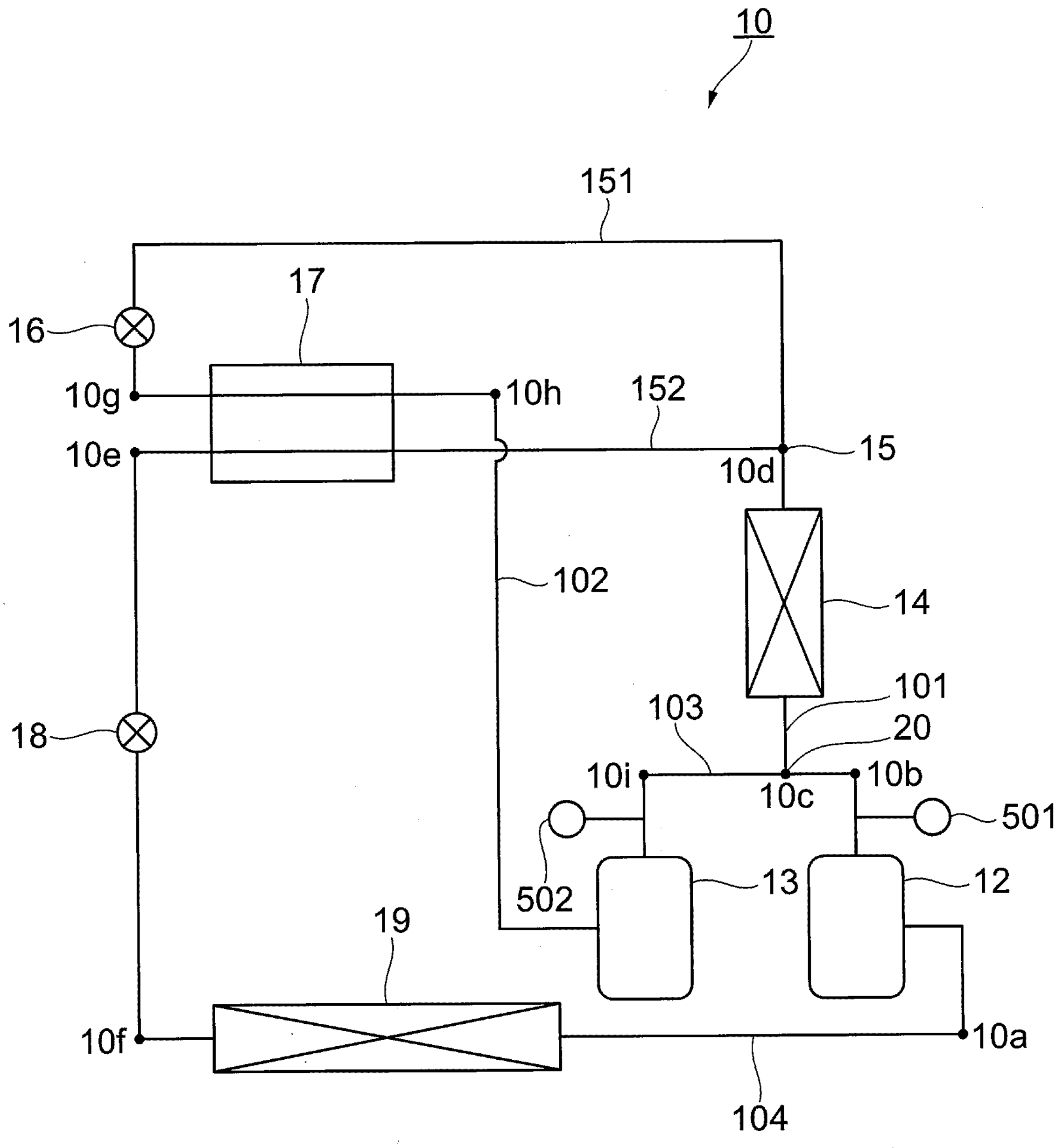
10
50
REFRIGERANT CIRCUIT
CONTOROLLER
HEAT
OPERATION PANEL TEMPERTURE SENSER
AIR
SPACE

FIG.2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10d
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12
19
10f
10a
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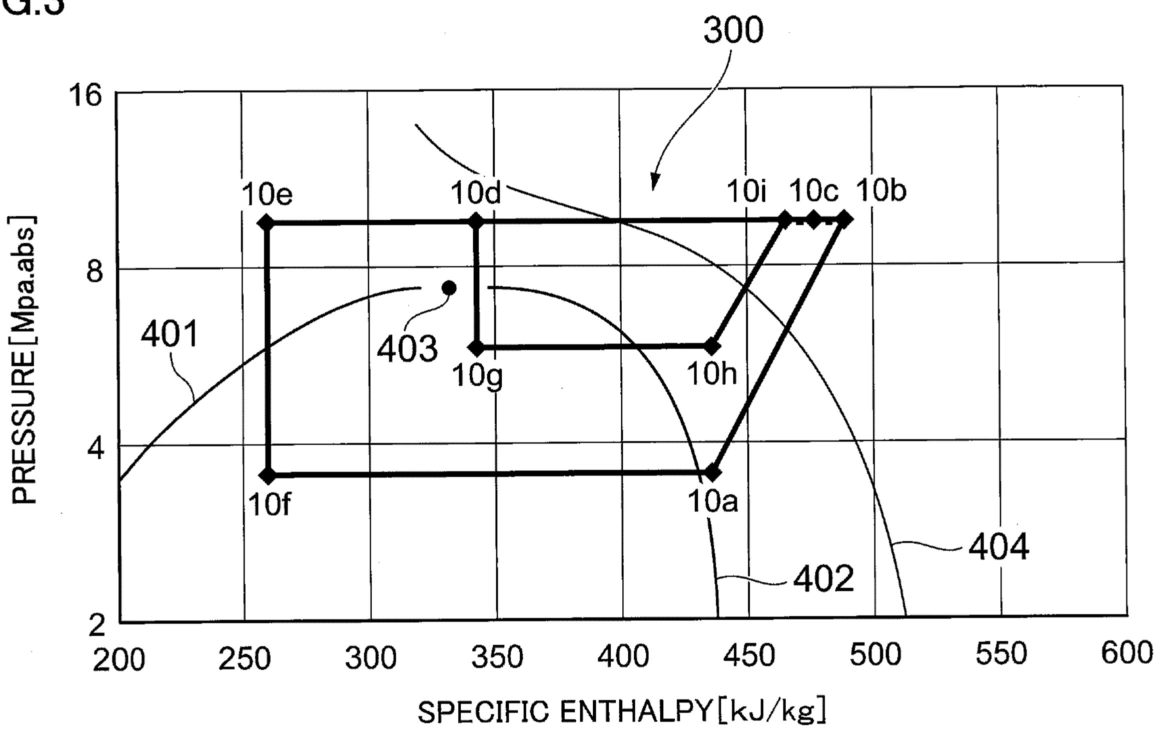
FIG.3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350
400
450
500
550
600
SPECIFIC ENTHALPY[kJ/kg]

FIG.4

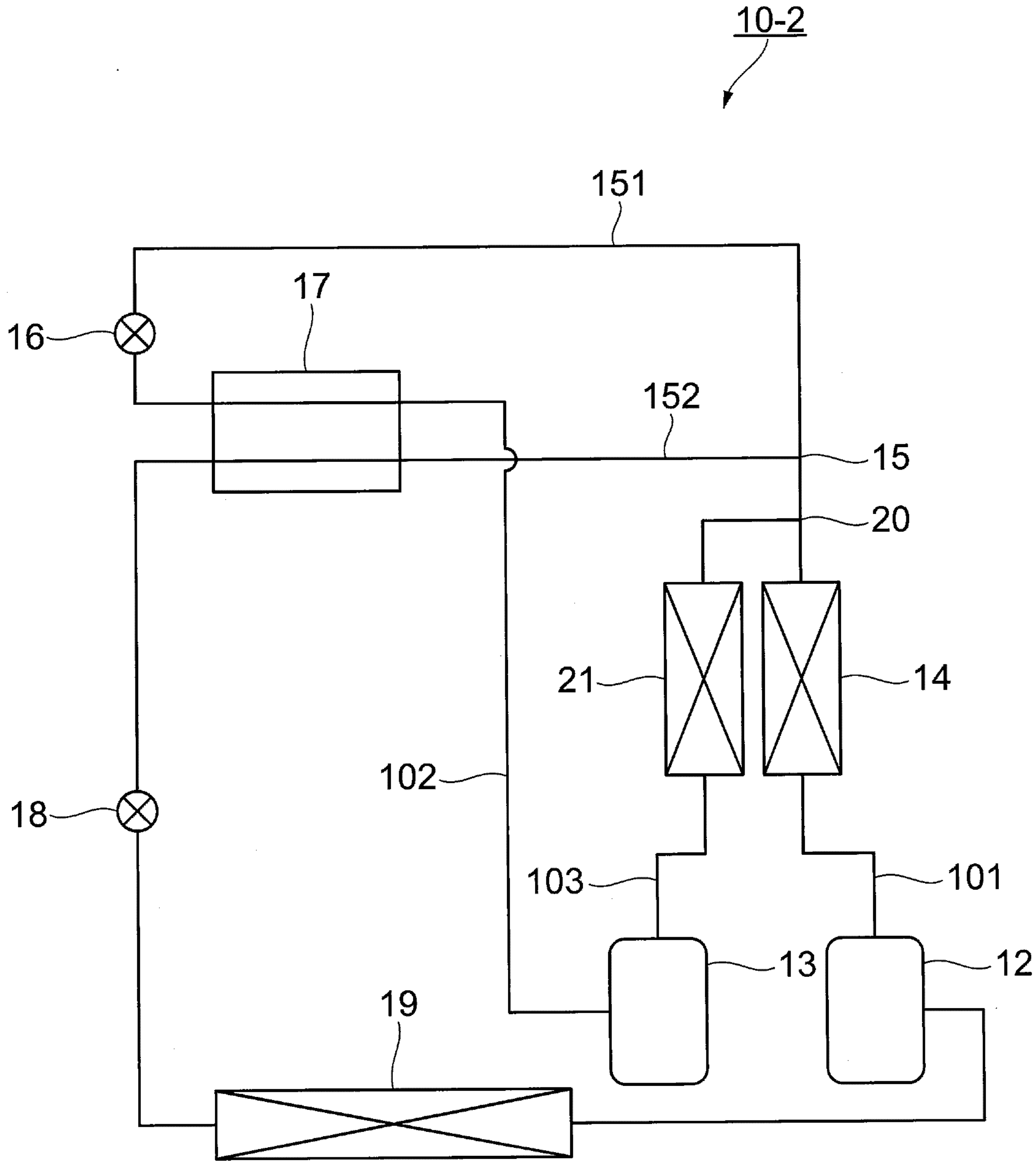


FIG.5

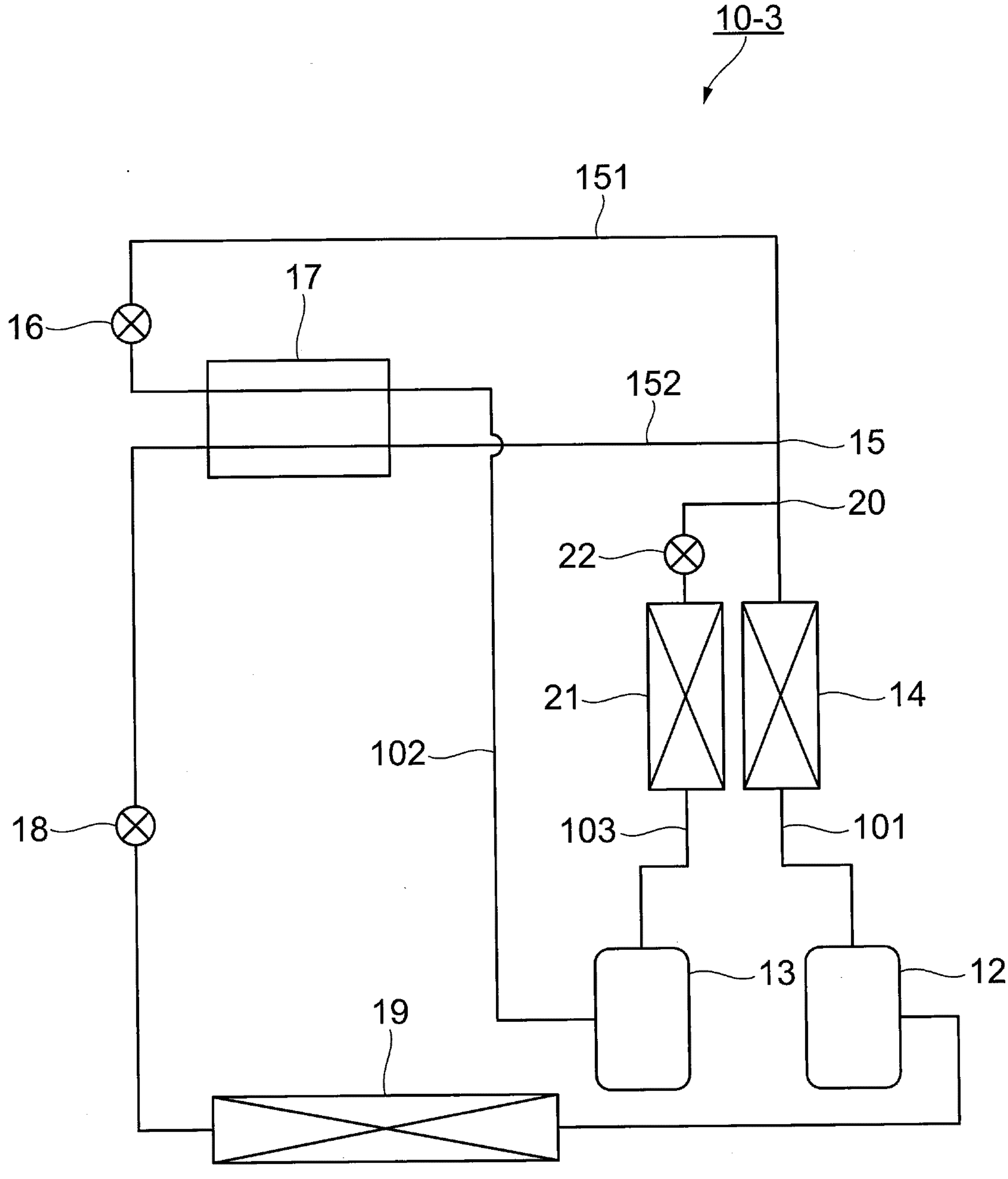


FIG.6

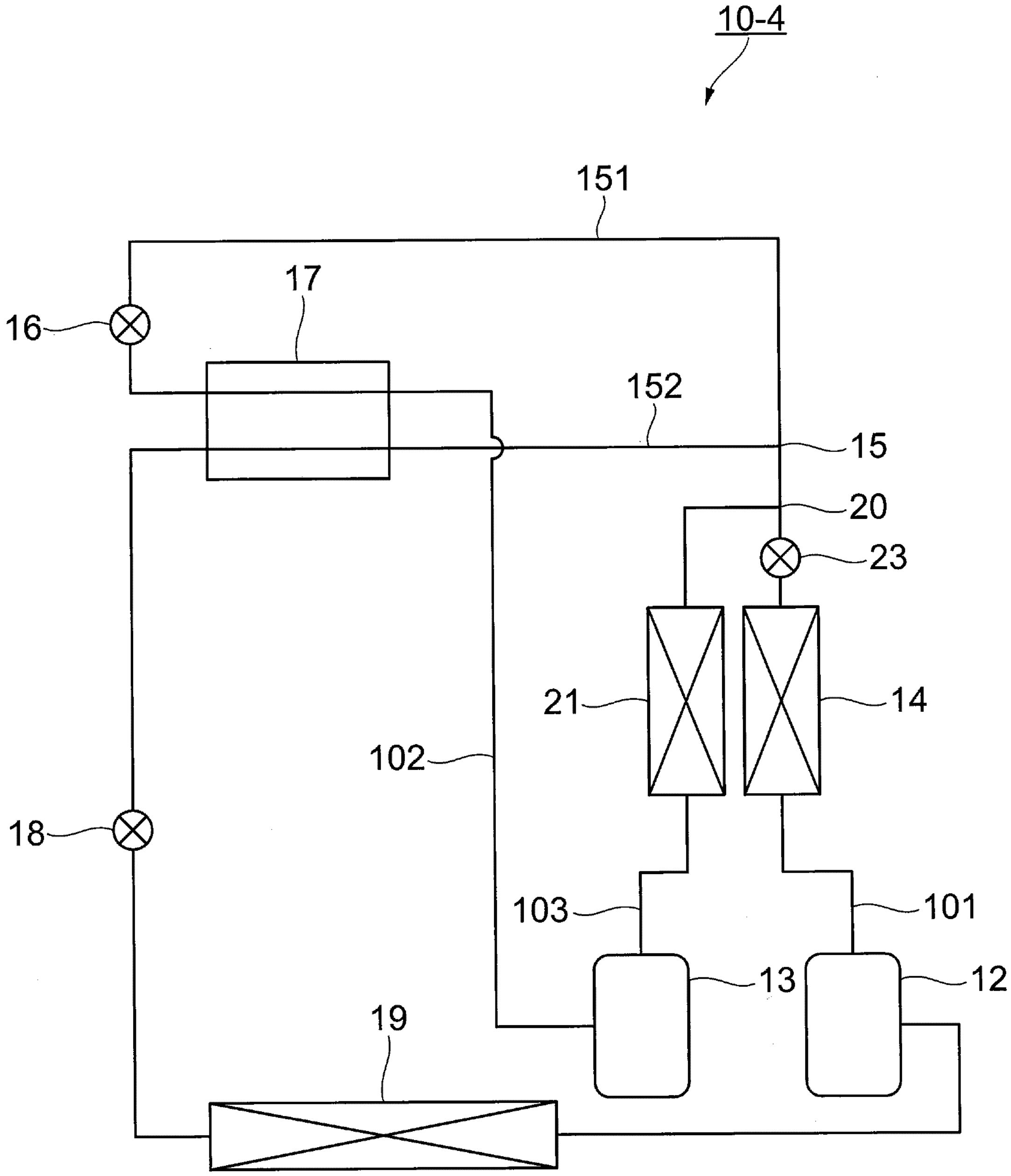


FIG.7

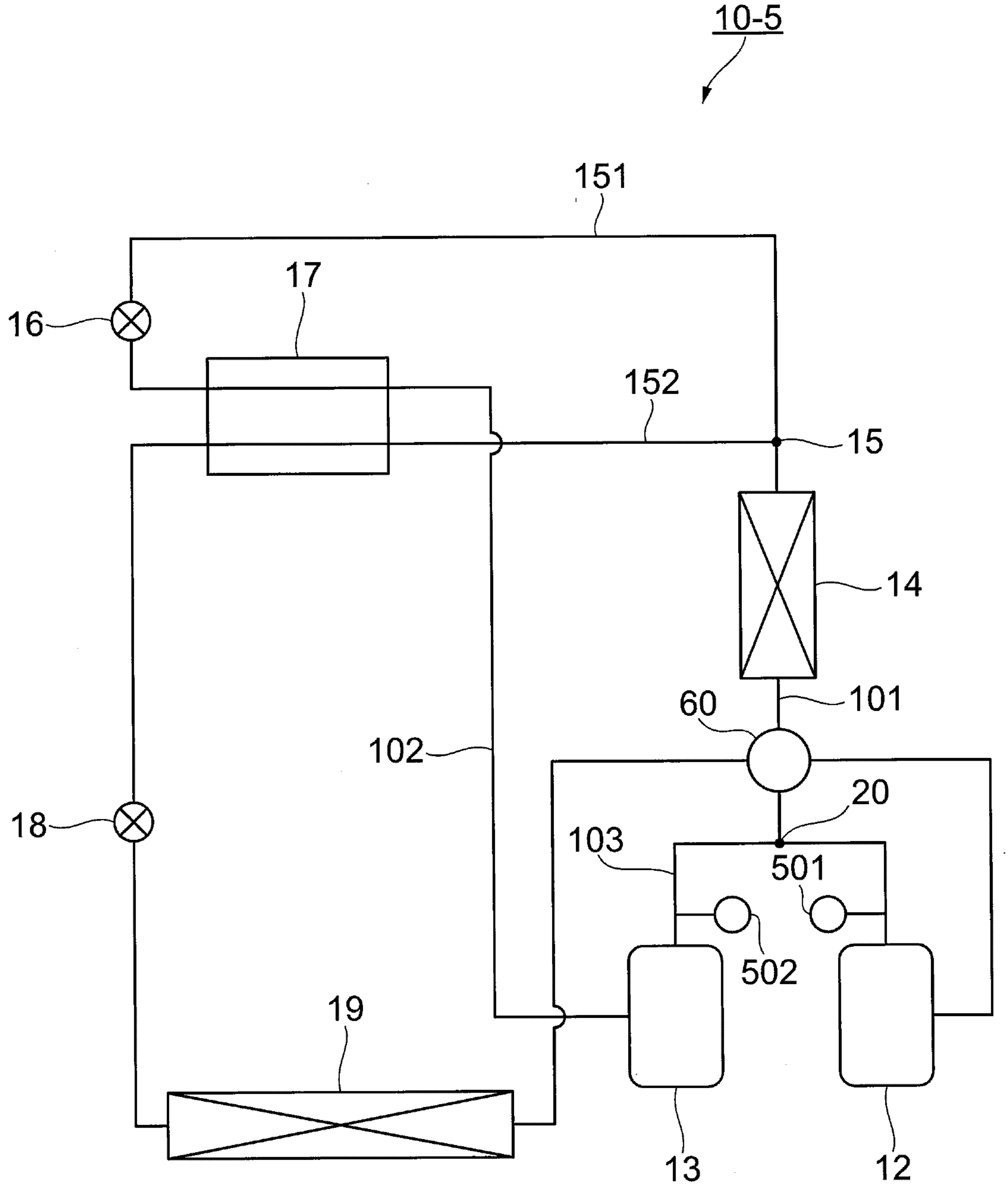
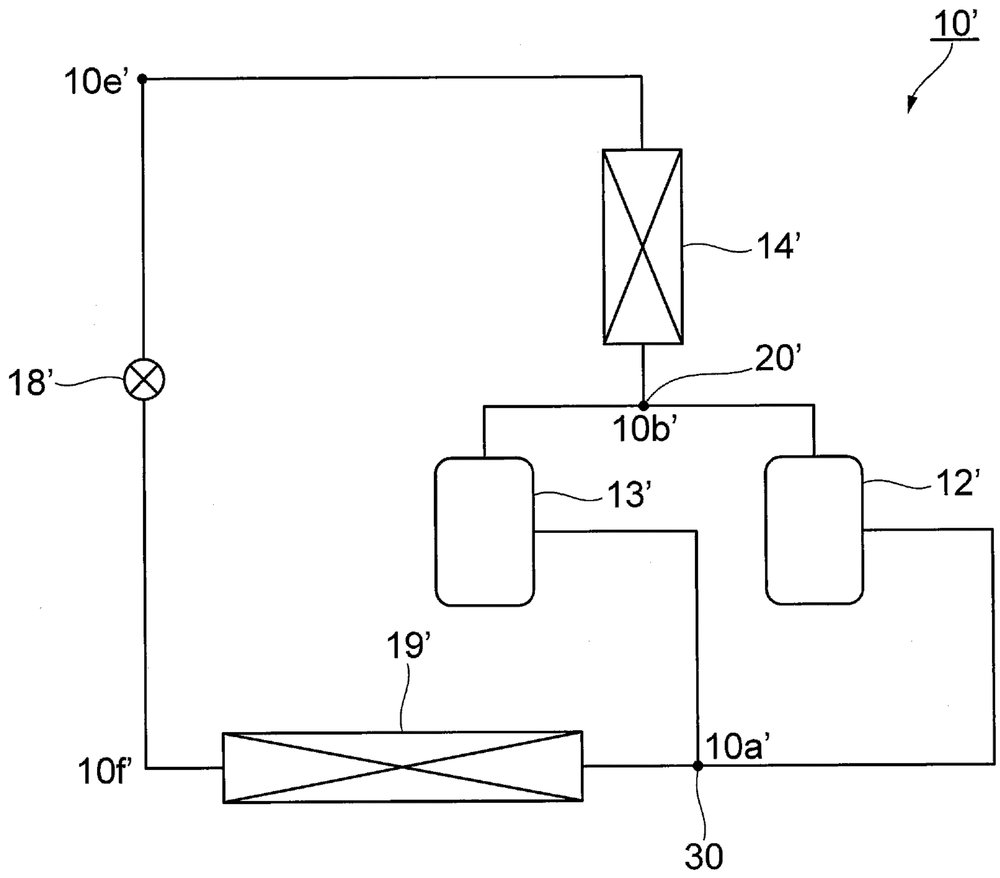


FIG.8A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18'
20'
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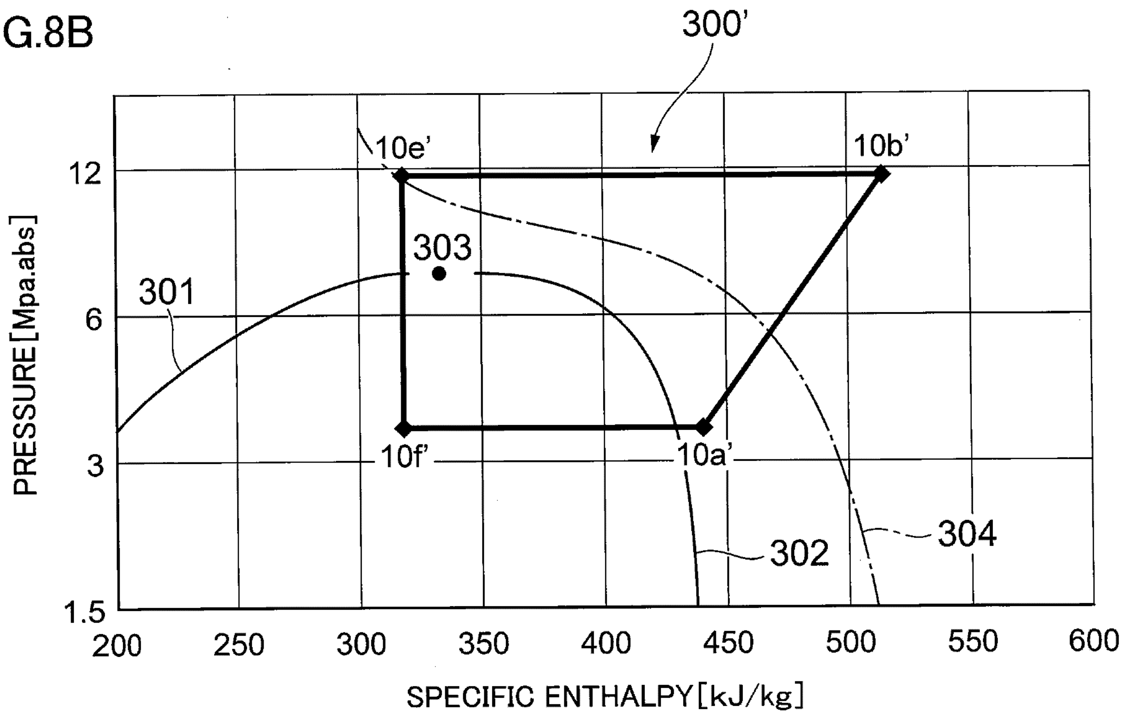
13'
12'
19'
10f'
10a'
30

FIG.8B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301
6
3
1.5
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300
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400
450
500
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SPECIFIC ENTHALPY[kJ/kg]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/011724

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i; ***F25B 6/02***(2006.01)i
FI: F25B1/00 331F; F25B1/00 396D; F25B1/00 361J; F25B1/00 361L; F25B1/00 304Q; F25B6/02 Z

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; F25B6/02

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 1971-2024
Registered utility model specifications of Japan 1996-2024
Published registered utility model applications of Japan 1994-2024

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 2013-124820 A (IWATANI, Ryohei) 24 June 2013 (2013-06-24) paragraphs [0028]-[0041], fig. 1-2	1-2
Y	paragraphs [0028]-[0041], fig. 1-2	2-6
A	paragraphs [0028]-[0041], fig. 1-2	7-8
X	JP 2009-539058 A (CARRIER CORP.) 12 November 2009 (2009-11-12) paragraphs [0007]-[0019], [0060], fig. 1	1, 6
Y	paragraphs [0007]-[0019], [0060], fig. 1	2-6
A	paragraphs [0007]-[0019], [0060], fig. 1	7-8
X	JP 2000-329416 A (DENSO CORPORATION) 30 November 2000 (2000-11-30) paragraphs [0032]-[0043], fig. 1-2	1, 6
Y	paragraphs [0032]-[0043], fig. 1-2	2-6
A	paragraphs [0032]-[0043], fig. 1-2	7-8

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

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Date of the actual completion of the international search	Date of mailing of the international search report
21 May 2024	**04 June 2024**

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2024/011724

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0017240 A1 (HUSSMANN CORPORATION) 25 January 2007 (2007-01-25) paragraphs [0015]-[0021], fig. 1	1
Y	paragraphs [0015]-[0021], fig. 1	2-6
A	paragraphs [0015]-[0021], fig. 1	7-8
Y	JP 59-041746 A (MITSUBISHI ELECTRIC CORPORATION) 08 March 1984 (1984-03-08) claims, sections 1-2, p. 2, lower left column, line 1 to lower right column, line 9, fig. 5	3-4
Y	JP 03-294754 A (DAIKIN INDUSTRIES, LTD.) 25 December 1991 (1991-12-25) p. 3, upper right column, line 9 to lower left column, line 12, fig. 1	5
Y	JP 05-346267 A (DAIKIN INDUSTRIES, LTD.) 27 December 1993 (1993-12-27) paragraphs [0014]-[0016], fig. 1-2	5
A	JP 2005-061784 A (YANMAR CO., LTD.) 10 March 2005 (2005-03-10) entire text, all drawings	1-8
A	WO 2010/137120 A1 (MITSUBISHI ELECTRIC CORPORATION) 02 December 2010 (2010-12-02) entire text, all drawings	1-8

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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