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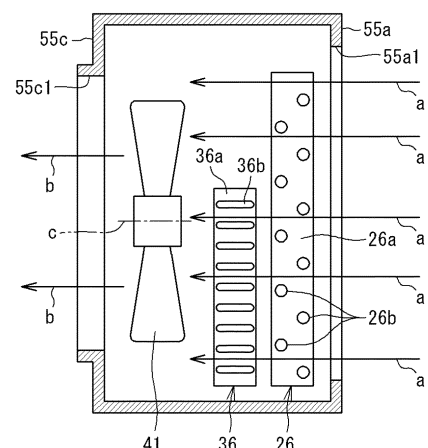
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(54) **REFRIGERATION DEVICE**

(57) A refrigeration apparatus (10) includes: a first refrigerant circuit (21) including a first heat exchanger (26) configured to release heat from carbon dioxide serving as a first refrigerant; a second refrigerant circuit (22) including a second heat exchanger (36) configured to release heat from a second refrigerant having combustibility or toxicity or a second refrigerant having a global warming potential equal to four or more, and a decompressor (38) configured to decompress the second refrigerant; and a third heat exchanger (27) configured to cause heat exchange between the first refrigerant having radiated heat in the first heat exchanger (26) and the second refrigerant having radiated heat in the second heat exchanger (36) and then decompressed in the decompressor (38); in which the second heat exchanger (36) includes a plurality of flat multi-hole tubes (36b).

FIG. 3



Description**TECHNICAL FIELD**

[0001] The present disclosure relates to a refrigeration apparatus. 5

BACKGROUND ART

[0002] PATENT LITERATURE 1 discloses a binary refrigeration apparatus including a lower-stage refrigeration cycle and a higher-stage refrigeration cycle. The lower-stage refrigeration cycle is used to adjust temperature of an indoor loading device such as a showcase. The lower-stage refrigeration cycle includes a refrigerant circuit that may thus be opened for rearrangement or the like of the showcase and a refrigerant may leak. Accordingly, examples of the refrigerant include carbon dioxide having a low global warming potential. In contrast, the higher-stage refrigeration cycle is used to further cool the refrigerant cooled in a radiator in the lower-stage refrigeration cycle. The higher-stage refrigeration cycle includes a refrigerant circuit that is not opened unlike the refrigerant circuit in the lower-stage refrigeration cycle, and thus adopts a refrigerant such as R32 having high heat exchange efficiency though having a higher global warming potential in comparison to the refrigerant in the lower-stage refrigeration cycle. 10 20 25

CITATION LIST

[PATENT LITERATURE]

[0003] PATENT LITERATURE 1: WO 2014/181399 A 30 35

SUMMARY OF THE INVENTION

[TECHNICAL PROBLEM]

[0004] The refrigerant such as R32 used in the higher-stage refrigeration cycle may have combustibility or toxicity and is thus desired to have used quantity as small as possible. 40

[0005] It is an object of the present disclosure to reduce used quantity of a refrigerant having combustibility or toxicity in a refrigeration apparatus including two refrigerant circuits adopting refrigerants different from each other. 45

[SOLUTION TO PROBLEM]

[0006]

(1) A refrigeration apparatus according to the present disclosure includes: a first refrigerant circuit including a first heat exchanger configured to release heat from carbon dioxide serving as a first refrigerant; a second refrigerant circuit including a second 50

heat exchanger configured to release heat from a second refrigerant having combustibility or toxicity or a second refrigerant having a global warming potential (GWP) of four or more, and a decompressor configured to decompress the second refrigerant; and a third heat exchanger configured to cause heat exchange between the first refrigerant having radiated heat in the first heat exchanger and the second refrigerant having radiated heat in the second heat exchanger and then decompressed in the decompressor; in which the second heat exchanger includes a plurality of flat multi-hole tubes.

[0007] In this configuration, the second heat exchanger including the flat multi-hole tubes achieves more efficient heat exchange in comparison to a heat exchanger including a heat transfer tube having a general circular tube shape, and can thus reduce used quantity of the refrigerant. This can lower a leakage risk of the second refrigerant having combustibility or toxicity or the second refrigerant having a GWP equal to four or more. 15 20

[0008] (2) Preferably, the refrigeration apparatus according to (1) described above further includes a control device configured to control operation of the first refrigerant circuit and the second refrigerant circuit, and a fan configured to generate an air flow to be supplied to the first heat exchanger and the second heat exchanger, in which the first heat exchanger and the second heat exchanger are aligned in a direction of the air flow generated by the fan, and the control device executes a first mode of operating both the first refrigerant circuit and the second refrigerant circuit to cause the first heat exchanger to release heat from the first refrigerant and cause the second heat exchanger to release heat from the second refrigerant, and a second mode of solely operating the first refrigerant circuit to cause the first heat exchanger to evaporate the first refrigerant. 25 30 35

[0009] Each of the flat multi-hole tubes of the second heat exchanger has a transverse section long and narrow in the air flow direction and is hard to cause resistance to the air flow, so as to inhibit deterioration in heat exchange efficiency in the first heat exchanger in the second mode of solely operating the first refrigerant circuit. 40

[0010] (3) In the refrigeration apparatus according to (1) or (2) described above, the second heat exchanger preferably includes the plurality of flat multi-hole tubes, and a fin meanderingly disposed between the flat multi-hole tubes adjacent to each other. 45

[0011] The second heat exchanger including the meandering fin (the so-called corrugated fin) has low drainability for water entered the corrugated fin. In the refrigeration apparatus according to the present disclosure, the second heat exchanger functions as a radiator configured to release heat from the refrigerant and can thus inhibit entered water from freezing. 50

[0012] (4) In the refrigeration apparatus according to any one of (1) to (3) described above, the second refrig-

erant circuit preferably uses the second refrigerant in the quantity of 1000 g or less.

[0013] This configuration includes the flat multi-hole tubes and can thus reduce the used quantity of the second refrigerant to 1000 g or less so as to lower the leakage risk.

[0014] (5) In the refrigeration apparatus according to (4) described above, the second refrigerant circuit preferably uses the second refrigerant in the quantity of 150 g or less.

[0015] This configuration includes the flat multi-hole tubes and can thus reduce the used quantity of the second refrigerant to 150 g or less so as to further lower the leakage risk.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

FIG. 1 is a refrigerant circuit diagram of a refrigeration apparatus according to an embodiment of the present disclosure.

FIG. 2 is a plan view depicting the interior of an outdoor unit in the refrigeration apparatus.

FIG. 3 is a side view depicting the interior of the outdoor unit in the refrigeration apparatus.

FIG. 4 is a schematic explanatory view of a first outdoor heat exchanger in the refrigeration apparatus.

FIG. 5 is a schematic explanatory view of a second outdoor heat exchanger in the refrigeration apparatus.

FIG. 6 is an enlarged sectional view of the second outdoor heat exchanger.

FIG. 7 is an explanatory Mollier diagram on a refrigeration cycle of a first refrigerant circuit during cooling operation.

DETAILED DESCRIPTION

[0017] Embodiments of the present disclosure will be described in detail hereinafter with reference to the accompanying drawings.

(Entire configuration of refrigeration apparatus)

[0018] FIG. 1 is a refrigerant circuit diagram of a refrigeration apparatus according to an embodiment of the present disclosure.

[0019] As depicted in FIG. 1, a refrigeration apparatus 10 according to the present embodiment is an air conditioner configured to adjust, to predetermined target temperature, air temperature in an indoor space as an air conditioning target space. The refrigeration apparatus 10 according to the present embodiment is configured to cool and heat the indoor space. The refrigeration apparatus 10 may alternatively be dedicated to cooling operation. Examples of the refrigeration apparatus 10 may

include a refrigerator and a freezer configured to cool air in the apparatus.

[0020] The refrigeration apparatus 10 includes an outdoor unit 11 (heat source unit) and an indoor unit 12 (utilization unit). The refrigeration apparatus 10 exemplarily includes the single outdoor unit 11 and the single indoor unit 12 connected to the outdoor unit 11. The refrigeration apparatus 10 may alternatively include a plurality of indoor units 12 connected in parallel with the outdoor unit 11. The refrigeration apparatus 10 may still alternatively include a plurality of outdoor units 11.

[0021] The refrigeration apparatus 10 includes a first refrigerant circuit 21 and a second refrigerant circuit 22. The first refrigerant circuit 21 causes circulation of a first refrigerant whereas the second refrigerant circuit 22 causes circulation of a second refrigerant. The present embodiment adopts carbon dioxide as the first refrigerant. The present embodiment adopts, as the second refrigerant, a refrigerant having combustibility or toxicity, or a refrigerant having a high global warming potential (GWP). Examples of the second refrigerant include R290 (propane). The refrigeration apparatus 10 further includes an auxiliary heat exchanger 27, a control device 51, an outdoor fan 41, and an indoor fan 42.

(Configuration of first refrigerant circuit 21)

[0022] The first refrigerant circuit 21 causes circulation of the first refrigerant between the indoor unit 12 and the outdoor unit 11. The first refrigerant circuit 21 includes a first compressor 24, a four-way switching valve 25, a first outdoor heat exchanger (heat source heat exchanger; first heat exchanger) 26, a first expansion valve 28, a first shutoff valve 29, an indoor heat exchanger (utilization heat exchanger) 30, a second shutoff valve 31, a first accumulator 32, a refrigerant pipe 40 connecting these components, and the like.

[0023] The outdoor unit 11 includes the first compressor 24, the four-way switching valve 25, the first outdoor heat exchanger 26, the first expansion valve 28, the first shutoff valve 29, the second shutoff valve 31, and the first accumulator 32, which constitute the first refrigerant circuit 21. The indoor unit 12 includes the indoor heat exchanger 30 constituting the first refrigerant circuit 21. The outdoor unit 11 is provided with the outdoor fan 41 configured to import outdoor air into the outdoor unit 11 and supply the first outdoor heat exchanger 26 with the outdoor air thus imported. The indoor unit 12 is provided with the indoor fan 42 configured to import indoor air into the indoor unit 12 and supply the indoor heat exchanger 30 with the indoor air thus imported.

[0024] The first compressor 24 sucks the first refrigerant in a low-pressure gas state and discharges the first refrigerant in a high-pressure gas state. The first compressor 24 includes a motor having a number of operating revolutions adjustable in accordance with inverter control. The first compressor 24 is of a variable capacity type

(performance variable type) having capacity (performance) variable in accordance with inverter control of the motor. The first compressor 24 may alternatively be of a constant capacity type. There may alternatively be provided a plurality of first compressors 24. In this case, the first compressors 24 may include both a compressor of the variable capacity type and a compressor of the constant capacity type.

[0025] The four-way switching valve 25 reverses a flow of the first refrigerant in the refrigerant pipe 40, and switchingly supplies one of the first outdoor heat exchanger 26 and the indoor heat exchanger 30 with the first refrigerant discharged from the first compressor 24. The refrigeration apparatus 10 can thus switchingly execute cooling operation and heating operation.

[0026] The first outdoor heat exchanger 26 is of a cross-fin tube type. The first outdoor heat exchanger 26 causes heat exchange between outdoor air imported by the outdoor fan 41 and the first refrigerant to release heat from or evaporate the first refrigerant. The first outdoor heat exchanger 26 may be of a microchannel type similarly to a second outdoor heat exchanger 36 to be described later.

[0027] The first expansion valve 28 is a decompressor configured to decompress to expand the first refrigerant. The first expansion valve 28 is constituted by a motor valve configured to adjust a refrigerant flow rate or the like. The first expansion valve 28 decompresses to expand the first refrigerant in a high-pressure gas state having radiated heat in the first outdoor heat exchanger 26 and the auxiliary heat exchanger 27 to be described later, to obtain a low-pressure refrigerant in a gas-liquid two-phase state. The first expansion valve 28 functioning as a decompressor may be replaced with a capillary tube.

[0028] The first shutoff valve 29 is a manually operated on-off valve. The first shutoff valve 29 is closed to block the flow of the first refrigerant in the refrigerant pipe 40, and is opened to allow the flow of the first refrigerant in the refrigerant pipe 40.

[0029] The indoor heat exchanger 30 is of the cross-fin tube type, the microchannel type, or the like. The indoor heat exchanger 30 causes heat exchange between indoor air imported by the indoor fan 42 and the first refrigerant to release heat from or evaporate the first refrigerant.

[0030] The second shutoff valve 31 is a manually operated on-off valve. The second shutoff valve 31 is closed to block the flow of the first refrigerant in the refrigerant pipe 40, and is opened to allow the flow of the first refrigerant in the refrigerant pipe 40.

[0031] The first accumulator 32 is provided on a suction pipe of the first compressor 24. The first accumulator 32 temporarily reserves the first refrigerant in the low pressure state to be sucked into the first compressor 24 and separates the first refrigerant into a gas refrigerant and a liquid refrigerant. The first refrigerant as the gas refrigerant thus separated in the first accumulator 32 is sucked into the first compressor 24.

(Configuration of second refrigerant circuit 22)

[0032] The second refrigerant circuit 22 causes refrigerant circulation in the outdoor unit 11. The second refrigerant circuit 22 adopts R290 (propane) as the second refrigerant. The second refrigerant circuit 22 includes a second compressor 34, the second outdoor heat exchanger (second heat exchanger) 36, a second expansion valve 38, a second accumulator 39, a refrigerant pipe 50 connecting these components, and the like.

[0033] The second compressor 34 sucks the second refrigerant in a low-pressure gas state and discharges the second refrigerant in a high-pressure gas state. The second compressor 34 includes a motor having a number of operating revolutions adjustable in accordance with inverter control. The second compressor 34 is of the variable capacity type (performance variable type) having capacity (performance) variable in accordance with inverter control of the motor. The second compressor 34 may alternatively be of the constant capacity type. There may alternatively be provided a plurality of second compressors 34. In this case, the second compressors 34 may include both a second compressor of the variable capacity type and a second compressor of the constant capacity type.

[0034] The second outdoor heat exchanger 36 is of the microchannel type. The second outdoor heat exchanger 36 causes heat exchange between outdoor air supplied by the outdoor fan 41 and a refrigerant to release heat from (condense) the refrigerant.

[0035] The second expansion valve 38 is a decompressor configured to decompress to expand the second refrigerant. The second expansion valve 38 according to the present embodiment is constituted by a motor valve configured to adjust a refrigerant flow rate or the like. The second expansion valve 38 decompresses to expand the second refrigerant in a high pressure state having radiated heat in the second outdoor heat exchanger 36 to obtain a low-pressure refrigerant in a gas-liquid two-phase state. The second expansion valve 38 functioning as a decompressor may be replaced with a capillary tube.

[0036] The second accumulator 39 is provided on a suction pipe of the second compressor 34. The second accumulator 39 temporarily reserves the second refrigerant in the low pressure state to be sucked into the second compressor 34 and separates the second refrigerant into a gas refrigerant and a liquid refrigerant. The second refrigerant as the gas refrigerant thus separated in the second accumulator 39 is sucked into the second compressor 34.

(Configuration of auxiliary heat exchanger 27)

[0037] The auxiliary heat exchanger (third heat exchanger) 27 causes further heat radiation from the first refrigerant having radiated heat in the first outdoor heat exchanger 26. The auxiliary heat exchanger 27 evaporates the second refrigerant having radiated heat in the

second outdoor heat exchanger 36 and having been decompressed in the second expansion valve 38. The auxiliary heat exchanger 27 is exemplarily configured as a plate heat exchanger.

[0038] Specifically, the auxiliary heat exchanger 27 includes a first heat transfer tube (first heat transfer flow path) 27a and a second heat transfer tube (second heat transfer flow path) 27b. The first heat transfer tube 27a has a first end connected to a refrigerant pipe extending to the first outdoor heat exchanger 26. The first heat transfer tube 27a has a second end connected to a refrigerant pipe extending to the first expansion valve 28. The second heat transfer tube 27b has a first end connected to a refrigerant pipe extending to the second expansion valve 38. The second heat transfer tube 27b has a second end connected to a refrigerant pipe extending to the second accumulator 39.

[0039] The auxiliary heat exchanger 27 causes heat exchange between the first refrigerant flowing in the first heat transfer tube 27a and the second refrigerant flowing in the second heat transfer tube 27b. The first heat transfer tube 27a receives the first refrigerant (gas refrigerant) having radiated heat in the first outdoor heat exchanger 26. The second heat transfer tube 27b receives the second refrigerant (gas-liquid two-phase refrigerant) decompressed and expanded in the second expansion valve 38.

[0040] The auxiliary heat exchanger 27 thus causes heat exchange between the first refrigerant having passed through the first outdoor heat exchanger 26 and flowing in the first heat transfer tube 27a and the second refrigerant having passed through the second expansion valve (decompressor) 38 and flowing in the second heat transfer tube 27b. The auxiliary heat exchanger 27 radiates heat from the first refrigerant flowing in the first heat transfer tube 27a and evaporates the second refrigerant flowing in the second heat transfer tube 27b.

[0041] As described above, the auxiliary heat exchanger 27 is included in the first refrigerant circuit 21 and the second refrigerant circuit 22. The auxiliary heat exchanger 27 is thus regarded as a constituent element of both the first refrigerant circuit 21 and the second refrigerant circuit 22.

(Configuration of control device 51)

[0042] The control device 51 controls behavior of the first compressor 24, the four-way switching valve 25, the first expansion valve 28, the outdoor fan 41, the indoor fan 42, the second compressor 34, the second expansion valve 38, and the like. The control device 51 includes a processor and a memory. The processor of the control device 51 is constituted by a central processing unit (CPU), an application specific integrated circuit (ASIC), a gate array, a field programmable gate array (FPGA), or the like. A programmable logic device such as the ASIC, the gate array, or the FPGA is configured to execute

processing similarly to a control program. The memory of the control device 51 includes a volatile memory such as a static random access memory (SRAM) or a dynamic random access memory (DRAM), or a nonvolatile memory such as a flash memory, a hard disk, or a read only memory (ROM). The nonvolatile memory stores a control program as a computer program, and control data.

[0043] The control device 51 exhibits various functions when the processor executes the control program. Specifically, the control device 51 executes a first mode for cooling operation and a second mode for heating operation.

(Cooling operation)

[0044] When the refrigeration apparatus 10 executes cooling operation, the control device 51 drives both the first refrigerant circuit 21 and the second refrigerant circuit 22. The four-way switching valve 25 is kept in a state indicated by solid lines in FIG. 1. The first compressor 24 in the first refrigerant circuit 21 discharges the first refrigerant in a high-temperature high-pressure gas state. The first refrigerant flows into the first outdoor heat exchanger 26 by way of the four-way switching valve 25. The first refrigerant according to the present embodiment is carbon dioxide and is pressurized by the first compressor 24 to have pressure exceeding a critical point. The first refrigerant is caused by the outdoor fan 41 to exchange heat with outdoor air and radiate heat. The first refrigerant further flows into the auxiliary heat exchanger 27.

[0045] Meanwhile, the second compressor 34 in the second refrigerant circuit 22 discharges the second refrigerant in a high-temperature high-pressure gas state. The second refrigerant flows into the second outdoor heat exchanger 36 and is caused by the outdoor fan 41 to exchange heat with outdoor air and release heat (condense). The second refrigerant further flows into the second expansion valve 38 to be decompressed to have predetermined low pressure. The second refrigerant thereafter flows into the auxiliary heat exchanger 27.

[0046] In the auxiliary heat exchanger 27, the first refrigerant in the first refrigerant circuit 21 exchanges heat with the second refrigerant in the second refrigerant circuit 22 to radiate heat. The first refrigerant is then decompressed to be expanded in the first expansion valve 28, and flows into the indoor heat exchanger 30 of the indoor unit 12. In the indoor unit 12, the first refrigerant exchanges heat with indoor air to evaporate in the indoor heat exchanger 30. The indoor fan 42 causes the indoor air cooled due to evaporation of the first refrigerant to blow indoors and cool the indoor space. The first refrigerant evaporated in the indoor heat exchanger 30 passes through the refrigerant pipe 40 to return to the outdoor unit 11, and is sucked into the first compressor 24 by way of the four-way switching valve 25 and the first accumulator 32.

[0047] In the auxiliary heat exchanger 27, the second

refrigerant in the second refrigerant circuit 22 exchanges heat with the first refrigerant in the first refrigerant circuit 21 to evaporate. The second refrigerant is then sucked into the second compressor 34 by way of the second accumulator 39.

(Heating operation)

[0048] When the refrigeration apparatus 10 executes heating operation, the control device 51 drives the first refrigerant circuit 21 and stops the second refrigerant circuit 22. The four-way switching valve 25 is kept in a state indicated by broken lines in FIG. 1. The first compressor 24 discharges the first refrigerant in the high-temperature high-pressure gas state, which passes through the four-way switching valve 25 and flows into the indoor heat exchanger 30 of the indoor unit 12. In the indoor heat exchanger 30, the first refrigerant exchanges heat with indoor air to radiate heat. The indoor fan 42 causes the indoor air heated due to heat radiation of the first refrigerant to blow indoors and heat the indoor space.

[0049] The first refrigerant then passes through the refrigerant pipe 40, returns to the outdoor unit 11, is decompressed to have predetermined low pressure in the first expansion valve 28, passes through the auxiliary heat exchanger 27, and flows into the first outdoor heat exchanger 26. The second refrigerant circuit 22 not being driven does not substantially cause heat exchange between the first refrigerant and the second refrigerant in the auxiliary heat exchanger 27. The first refrigerant having flowed into the first outdoor heat exchanger 26 exchanges heat with outdoor air to evaporate. The first refrigerant evaporated and gasified in the first outdoor heat exchanger 26 is sucked into the first compressor 24 by way of the four-way switching valve 25.

(Defrosting operation)

[0050] The refrigeration apparatus 10 is configured to execute defrosting operation for removal of frost adhering to the first outdoor heat exchanger 26 due to heating operation. Similarly to cooling operation described above or the like, defrosting operation can be achieved by causing the first refrigerant having high temperature and high pressure to flow into the first outdoor heat exchanger 26.

(Refrigeration cycle of first refrigerant circuit during cooling operation)

[0051] FIG. 7 is an explanatory Mollier diagram on a refrigeration cycle of the first refrigerant circuit during cooling operation. FIG. 7 includes reference sign L denoting an isothermal line at outdoor air temperature in summer or the like.

[0052] The first refrigerant used in the first refrigerant circuit 21 is carbon dioxide and is pressurized to have pressure exceeding a critical point P by the first com-

pressor 24. The first refrigerant radiates heat only enough to reach around outdoor air temperature in the first outdoor heat exchanger 26 during cooling operation, and can secure only an enthalpy difference Δh_1 indicated in FIG. 7. In the present embodiment, the auxiliary heat exchanger 27 causes heat exchange between the first refrigerant and the second refrigerant lower in temperature than outdoor air temperature, so that the first refrigerant further radiates heat to secure a further enthalpy difference Δh_2 . This enhances refrigerating capacity H of the refrigeration apparatus 10 adopting carbon dioxide as a refrigerant.

[0053] The refrigerant pipe 40 may be detached from the first refrigerant circuit 21 for replacement of the indoor unit 12 or the like. The first refrigerant circuit 21 is opened in this case to possibly cause refrigerant leakage. The first refrigerant circuit 21 adopts carbon dioxide as the first refrigerant and is thus less affected by such leakage. In contrast, the second refrigerant circuit 22 is rarely opened because the second refrigerant circulates only in the outdoor unit 11. The present embodiment adopts R290 (propane) having combustibility as the second refrigerant, but is less likely to have leakage because the second refrigerant circuit 22 is rarely opened.

[0054] FIG. 2 is a plan view depicting the interior of the outdoor unit in the refrigeration apparatus. FIG. 3 is a side view depicting the interior of the outdoor unit in the refrigeration apparatus.

[0055] The outdoor unit 11 includes a casing 55. The casing 55 has a rectangular parallelepiped shape. As depicted in FIG. 2, the casing 55 has the interior provided with a sectioning wall 56 zoning a machine chamber S1 and a heat exchange chamber S2. The casing 55 includes two adjacent side walls 55a and 55b disposed at the heat exchange chamber S2 and provided with air intake ports 55a1 and 55b1, respectively. There is provided another side wall 55c that is disposed adjacent to the side wall 55b having the air intake port 55b1 and is provided with an air blow-out port 55c1.

[0056] The machine chamber S1 in the casing 55 accommodates the first compressor 24, the second compressor 34, the first accumulator 32, the second accumulator 39, the auxiliary heat exchanger 27, and the like. The heat exchange chamber S2 in the casing 55 accommodates the first outdoor heat exchanger 26, the second outdoor heat exchanger 36, the outdoor fan 41, and the like. The outdoor fan 41 rotates about a shaft c. The outdoor fan 41 imports air into the casing 55 via the air intake ports 55a1 and 55b1, and discharges air out of the casing 55 via the air blow-out port 55c1. FIG. 2 and FIG. 3 include an arrow a indicating a flow direction of air imported to the casing 55 via the air intake ports 55a1 and 55b1 and passing through the first and second outdoor heat exchangers 26 and 36, and an arrow b indicating a flow direction of air discharged out of the casing 55 via the air blow-out port 55c1.

[0057] As depicted in FIG. 2, the first outdoor heat exchanger 26 has a substantially L shape in a top view.

The first outdoor heat exchanger 26 is bent near a corner d between the two side walls 55a and 55b provided with the air intake ports 55a1 and 55b1, and is disposed along the two side walls 55a and 55b.

[0058] As depicted in FIG. 2, the second outdoor heat exchanger 36 has a substantially linear shape in a top view. The second outdoor heat exchanger 36 is disposed substantially along the side wall 55a of the casing 55. In a top view, the second outdoor heat exchanger 36 is shorter than the first outdoor heat exchanger 26.

[0059] As depicted in FIG. 3, the second outdoor heat exchanger 36 is shorter in vertical length than the first outdoor heat exchanger 26. A lower end of the second outdoor heat exchanger 36 and a lower end of the first outdoor heat exchanger 26 are set on a bottom plate of the casing 55 to be disposed substantially equally in height. The first outdoor heat exchanger 26 thus protrudes upward from the second outdoor heat exchanger 36. Accordingly, the first outdoor heat exchanger 26 is larger in air passage area than the second outdoor heat exchanger 36.

[0060] The first outdoor heat exchanger 26 and the second outdoor heat exchanger 36 are supplied with air by the common outdoor fan 41. The second outdoor heat exchanger 36 is disposed downstream of the first outdoor heat exchanger 26 in an air flow direction a of the outdoor fan 41. The second outdoor heat exchanger 36 is thus supplied with air having passed through the first outdoor heat exchanger 26.

[0061] FIG. 4 is a schematic explanatory view of the first outdoor heat exchanger in the refrigeration apparatus.

[0062] The first outdoor heat exchanger 26 includes a large number of fins 26a and a heat transfer tube 26b. The large number of fins 26a each have a rectangular plate shape in a side view, and are aligned parallel to one another. The large number of fins 26a have plate surfaces extending vertically.

[0063] The heat transfer tube 26b is a cylindrical tube having a circular section. The heat transfer tube 26b is made of a material principally containing copper. The heat transfer tube 26b is made of copper or a copper alloy. The heat transfer tube 26b includes a plurality of linear tube portions 26b1 each having a linear shape and a curved tube portion 26b2 having a U shape. The linear tube portions 26b1 extend in a direction in which the large number of fins 26a are aligned and penetrate the fins 26a. The curved tube portion 26b2 is disposed at each end portion of the first outdoor heat exchanger 26 in a top view, and connects the two linear tube portions 26b1 adjacent to each other. The plurality of linear tube portions 26b1 is disposed in a staggered arrangement in a vertical direction and in the air flow direction a as depicted in FIG. 3. In a top view, the end portions of the first outdoor heat exchanger 26 are respectively provided with tube plates 26c. The tube plates 26c keep the shape of the first outdoor heat exchanger 26.

[0064] FIG. 5 is a schematic explanatory view of the

second outdoor heat exchanger in the refrigeration apparatus. FIG. 6 is an enlarged sectional view of the second outdoor heat exchanger.

[0065] The second outdoor heat exchanger 36 includes a large number of fins 36a, a plurality of heat transfer tubes 36b, and headers 36c and 36d. The heat transfer tubes 36b are made of a material principally containing aluminum. The heat transfer tubes 36b are made of aluminum or an aluminum alloy. The plurality of heat transfer tubes 36b is aligned vertically in parallel with each other. The heat transfer tubes 36b are disposed substantially horizontally.

[0066] The headers 36c and 36d are coupled respectively to first end portions and second end portions in a longitudinal direction of the heat transfer tubes 36b. The headers 36c and 36d include a liquid header 36c for a flow of a liquid refrigerant and a gas header 36d for a flow of a gas refrigerant. The headers 36c and 36d divide a flow of the second refrigerant from outside the second outdoor heat exchanger 36 into the heat transfer tubes 36b, and merge the second refrigerant from the heat transfer tubes 36b to send out of the second outdoor heat exchanger 36.

[0067] As depicted in FIG. 6, the heat transfer tubes 36b according to the present embodiment are constituted by porous tubes each provided therein with a plurality of refrigerant flow paths 36b1. The plurality of refrigerant flow paths 36b1 is aligned linearly in the air flow direction a. The heat transfer tubes 36b each have a transverse section that is taken in a direction perpendicular to the longitudinal direction and lengthens in the air flow direction a in which the plurality of refrigerant flow paths 36b1 is aligned. In other words, each of the heat transfer tubes 36b is a flat tube having a transverse section having a length L2 in the air flow direction a (horizontal direction) larger than a vertical length (thickness) L1. Hereinafter, the heat transfer tubes 36b of the second outdoor heat exchanger 36 will also be referred to as "flat multi-hole tubes". Each of the flat multi-hole tubes 36b has an upper surface and a lower surface disposed substantially horizontally.

[0068] The flat multi-hole tubes 36b each have the vertical length L1 exemplarily set to 1 mm to 3 mm. The flat multi-hole tubes 36b each have the length L2 in the air flow direction a exemplarily set to 10 mm to 30 mm. In contrast, the heat transfer tube 26b of the first outdoor heat exchanger 26 has an outer diameter exemplarily set to 5 mm to 10 mm. Therefore, when viewed from the air flow direction a, the flat multi-hole tube 36b has a smaller vertical length than the heat transfer tube 26b and has less resistance to the air flow. Each of the flat multi-hole tubes 36b has the transverse section having the length L1 in the air flow direction a (horizontal direction) larger than the vertical length L2, and therefore water is likely to be accumulated on the upper surface.

[0069] Meanwhile, the heat transfer tube 26b of the first outdoor heat exchanger 26 is larger in vertical length and thus higher in strength than the flat multi-hole tubes 36b of the second outdoor heat exchanger 36. The first out-

door heat exchanger 26 according to the present embodiment is disposed closer to the outside (closer to the side walls 55a and 55b) of the outdoor unit 11 than the second outdoor heat exchanger 36. The first outdoor heat exchanger 26 higher in strength is disposed closer to the outside to inhibit damage to the first and second outdoor heat exchangers 26 and 36 caused by external impact to the outdoor unit 11.

[0070] The refrigerant flow paths 36b1 in each of the flat multi-hole tubes 36b of the second outdoor heat exchanger 36 is smaller in area than a refrigerant flow path in the heat transfer tube (cylindrical tube) 26b of the first outdoor heat exchanger 26. The second outdoor heat exchanger 36 thus has more opportunities of contact between the second refrigerant and the flat multi-hole tubes 36b to achieve more efficient heat exchange in comparison to the first outdoor heat exchanger 26. This enables minimization of used quantity of the second refrigerant. The present embodiment adopts R290 (propane) having combustibility as the second refrigerant, and such a reduction of the second refrigerant is thus quite effective for a lower leakage risk. The used quantity of the second refrigerant can exemplarily be 1000 g or less. The used quantity of the second refrigerant can preferably be 150 g or less.

[0071] The fins 36a of the second outdoor heat exchanger 36 are so-called corrugated fins. The fins 36a are disposed between the flat multi-hole tubes 36b vertically adjacent to each other. Each of the fins 36a is formed by bending a board into a wavy state. Each of the fins 36a thus extends in the longitudinal direction of the flat multi-hole tubes 36b while being meandering upward and downward between the flat multi-hole tubes 36b disposed above and below. Each of the fins 36a has an upper end and a lower end joined by brazing to the flat multi-hole tubes 36b. The corrugated fins 36a each meander between the flat multi-hole tubes 36b disposed above and below, and water once entered is hard to be drained.

[0072] The refrigeration apparatus 10 according to the present embodiment operates only the first refrigerant circuit 21 and stops the second refrigerant circuit 22 during heating operation. Accordingly, the air flow generated by the outdoor fan 41 exchanges heat with the first refrigerant flowing in the first outdoor heat exchanger 26 and simply passes through the second outdoor heat exchanger 36. Each of the flat multi-hole tubes 36b of the second outdoor heat exchanger 36 has the transverse section long and narrow in the air flow direction and has small resistance to the air flow, so as to inhibit deterioration in heat exchange efficiency in the first outdoor heat exchanger 26.

[0073] The second outdoor heat exchanger 36 is not used for heating operation and is thus unlikely to generate frost in the second outdoor heat exchanger 36. Accordingly, water as molten frost is unlikely to be accumulated on the flat multi-hole tubes 36b or in the corrugated fins 36a or is unlikely to freeze. This can inhibit

damage to bonded portions (brazed portions) between the flat multi-hole tubes 36b and the corrugated fins 36a by water entered the corrugated fins 36a and frozen. Although the first outdoor heat exchanger 26 may generate frost during heating operation, water as molten frost due to defrosting operation or the like is thus hard to be accumulated on the heat transfer tube 26b. This can accordingly inhibit such water from refreezing.

10 [Other embodiments]

[0074] The embodiment described above exemplifies R290 (propane) as the second refrigerant used in the second refrigerant circuit 22. However, the present disclosure is not limited to this case. Any other refrigerant having combustibility or toxicity can be adopted as the second refrigerant. Alternatively, any refrigerant having a relatively high global warming potential (GWP) (such as a refrigerant having a higher GWP from 4 to 675 inclusive in comparison to a natural refrigerant) can be adopted as the second refrigerant. Examples of the refrigerant having combustibility can include R290 (propane) as mentioned above, as well as R32, R1234yf, R474a, and R600a (isobutane). Examples of the refrigerant having toxicity can include NH₃ (ammonia). Examples of the refrigerant having a high GWP can include R32, R454B, and R454C. Among these, R32 has the largest GWP equal to 675.

[0075] The second outdoor heat exchanger 36 may alternatively include the flat multi-hole tubes 36b disposed vertically. For example, the second outdoor heat exchanger 36 depicted in FIG. 5 may be rotated by 90 degrees. Although water entered the corrugated fins 36a is hard to be drained even in such a case, the second outdoor heat exchanger 36 functions as a radiator configured to release heat from the second refrigerant and does not function as an evaporator. This inhibits generation of frost, accumulation of water as molten frost, and freezing of water.

[0076] The second outdoor heat exchanger 36 may alternatively include, instead of the corrugated fins 36a, fins having a rectangular flat plate shape similarly to the fins 26a of the first outdoor heat exchanger 26. In this case, a large number of fins can be aligned along vertical direction and the flat multi-hole tubes 36b can penetrate the plurality of fins. In this case, the fins may be cut off to expose an end portion in the air flow direction of each of the flat multi-hole tubes 36b.

50 [Action and effects of embodiments]

[0077]

(1) The refrigeration apparatus 10 according to the above embodiment includes: the first refrigerant circuit 21 including the first heat exchanger (first outdoor heat exchanger) 26 configured to release heat from carbon dioxide serving as the first refrigerant;

the second refrigerant circuit 22 including the second heat exchanger (second outdoor heat exchanger) 36 configured to release heat from the second refrigerant having combustibility or toxicity or the second refrigerant having the global warming potential (GWP) of four or more, and the decompressor (second expansion valve) 38 configured to decompress the second refrigerant; and the third heat exchanger (auxiliary heat exchanger) 27 configured to cause heat exchange between the first refrigerant having radiated heat in the first heat exchanger 26 and the second refrigerant having radiated heat in the second heat exchanger 36 and then decompressed in the decompressor 38. The second heat exchanger 36 includes the plurality of flat multi-hole tubes 36b.

[0078] A heat exchanger including a flat multi-hole tube typically achieves more efficient heat exchange in comparison to a heat exchanger including a heat transfer tube having a general circular tube shape, and can thus reduce refrigerant used quantity. The second heat exchanger 36 according to the above embodiment includes the flat multi-hole tubes 36b and can thus be reduced in the used quantity of the second refrigerant having combustibility or toxicity or the second refrigerant having a GWP equal to four or more, for a lower leakage risk of the second refrigerant.

[0079] (2) The refrigeration apparatus 10 according to the above embodiment further includes the control device 51 configured to control operation of the first refrigerant circuit 21 and the second refrigerant circuit 22, and the fan (outdoor fan) 41 configured to generate an air flow to be supplied to the first heat exchanger 26 and the second heat exchanger 36. The first heat exchanger 26 and the second heat exchanger 36 are aligned in the direction a of the air flow generated by the fan 41. The control device 51 executes the first mode (operating mode for cooling operation) of operating both the first refrigerant circuit 21 and the second refrigerant circuit 22 to cause the first heat exchanger 26 to release heat from the first refrigerant and cause the second heat exchanger 36 to release heat from the second refrigerant, and the second mode (operating mode for heating operation) of solely operating the first refrigerant circuit 21 to cause the first heat exchanger 26 to evaporate the first refrigerant.

[0080] In the second mode of solely operating the first refrigerant circuit 21, the air flow generated by the fan 41 exchanges heat with the first refrigerant flowing in the first heat exchanger 26 and simply passes through the second heat exchanger 36. Each of the flat multi-hole tubes 36b of the second heat exchanger 36 has the transverse section long and narrow in the air flow direction a and is hard to cause resistance to the air flow, so as to inhibit deterioration in heat exchange efficiency in the first heat exchanger 26.

[0081] (3) In the refrigeration apparatus 10 according to the above embodiment, the second heat exchanger 36 includes the plurality of flat multi-hole tubes 36b and the

fin (corrugated fin) 36a meanderingly disposed between the flat multi-hole tubes 36b adjacent to each other.

[0082] In the second heat exchanger 36 including the fin 36a meandering between the adjacent flat multi-hole tubes 36b, water entered the fin 36a is hard to be drained and accumulated water may be frozen to damage the bonded portions (brazed portions) between the corrugated fin 36a and the flat multi-hole tubes 36b. In the refrigeration apparatus 10 according to the present embodiment, the second heat exchanger 36 functions as a radiator and thus inhibits generation of frost and accumulation of water as molten frost. The corrugated fin has high heat exchange efficiency and can further reduce the refrigerant used quantity.

[0083] (4) The refrigeration apparatus 10 according to the above embodiment uses the second refrigerant in the quantity of 1000 g or less in the second refrigerant circuit 22. The second heat exchanger 36 including the flat multi-hole tubes 36b described above achieves more efficient heat exchange in comparison to the first heat exchanger 26 including the heat transfer tube 26b having the circular tube shape, and can thus reduce the refrigerant used quantity to 1000 g or less. This can lower the leakage risk for the second refrigerant.

[0084] (5) The refrigeration apparatus 10 according to the above embodiment use the second refrigerant in the quantity of 150 g or less in the second refrigerant circuit 22. The second heat exchanger 36 including the flat multi-hole tubes 36b described above achieves more efficient heat exchange in comparison to the first heat exchanger 26 including the heat transfer tube 26b having the circular tube shape, and can thus reduce the refrigerant used quantity to 150 g or less. This can further lower the leakage risk for the second refrigerant.

[0085] The embodiments have been described above. Various changes to modes and details will be available without departing from the object and the scope of the claims.

REFERENCE SIGNS LIST

[0086]

10	refrigeration apparatus
21	first refrigerant circuit
22	second refrigerant circuit
26	first outdoor heat exchanger (first heat exchanger)
27	auxiliary heat exchanger (third heat exchanger)
36	second outdoor heat exchanger (second heat exchanger)
36a	corrugated fin
36b	flat multi-hole tube
38	second expansion valve (decompressor)
41	outdoor fan
51	control device
a	air flow direction

Claims**1.** A refrigeration apparatus comprising:

a first refrigerant circuit (21) including a first heat exchanger (26) configured to release heat from carbon dioxide serving as a first refrigerant; a second refrigerant circuit (22) including a second heat exchanger (36) configured to release heat from a second refrigerant having combustibility or toxicity or a second refrigerant having a global warming potential equal to four or more, and a decompressor (38) configured to decompress the second refrigerant; and a third heat exchanger (27) configured to cause heat exchange between the first refrigerant having radiated heat in the first heat exchanger (26) and the second refrigerant having radiated heat in the second heat exchanger (36) and then decompressed in the decompressor (38); wherein the second heat exchanger (36) includes a plurality of flat multi-hole tubes (36b).

2. The refrigeration apparatus according to claim 1, further comprising

a control device (51) configured to control operation of the first refrigerant circuit (21) and the second refrigerant circuit (22), and a fan (41) configured to generate an air flow to be supplied to the first heat exchanger (26) and the second heat exchanger (36), wherein the first heat exchanger (26) and the second heat exchanger (36) are aligned in a direction (a) of the air flow generated by the fan (41), and the control device (51) executes a first mode of operating both the first refrigerant circuit (21) and the second refrigerant circuit (22) to cause the first heat exchanger (26) to release heat from the first refrigerant and cause the second heat exchanger (36) to release heat from the second refrigerant, and a second mode of solely operating the first refrigerant circuit (21) to cause the first heat exchanger (26) to evaporate the first refrigerant.

3. The refrigeration apparatus according to claim 1 or 2, wherein

the second heat exchanger (36) includes the plurality of flat multi-hole tubes (36b), and a fin (36a) meanderingly disposed between the flat multi-hole tubes (36b) adjacent to each other.

4. The refrigeration apparatus according to any one of claims 1 to 3, wherein the second refrigerant circuit (22) uses the second refrigerant in a quantity of 1000 g or less.**5.** The refrigeration apparatus according to claim 4, wherein the second refrigerant circuit (22) uses the second refrigerant in a quantity of 150 g or less.

FIG. 1

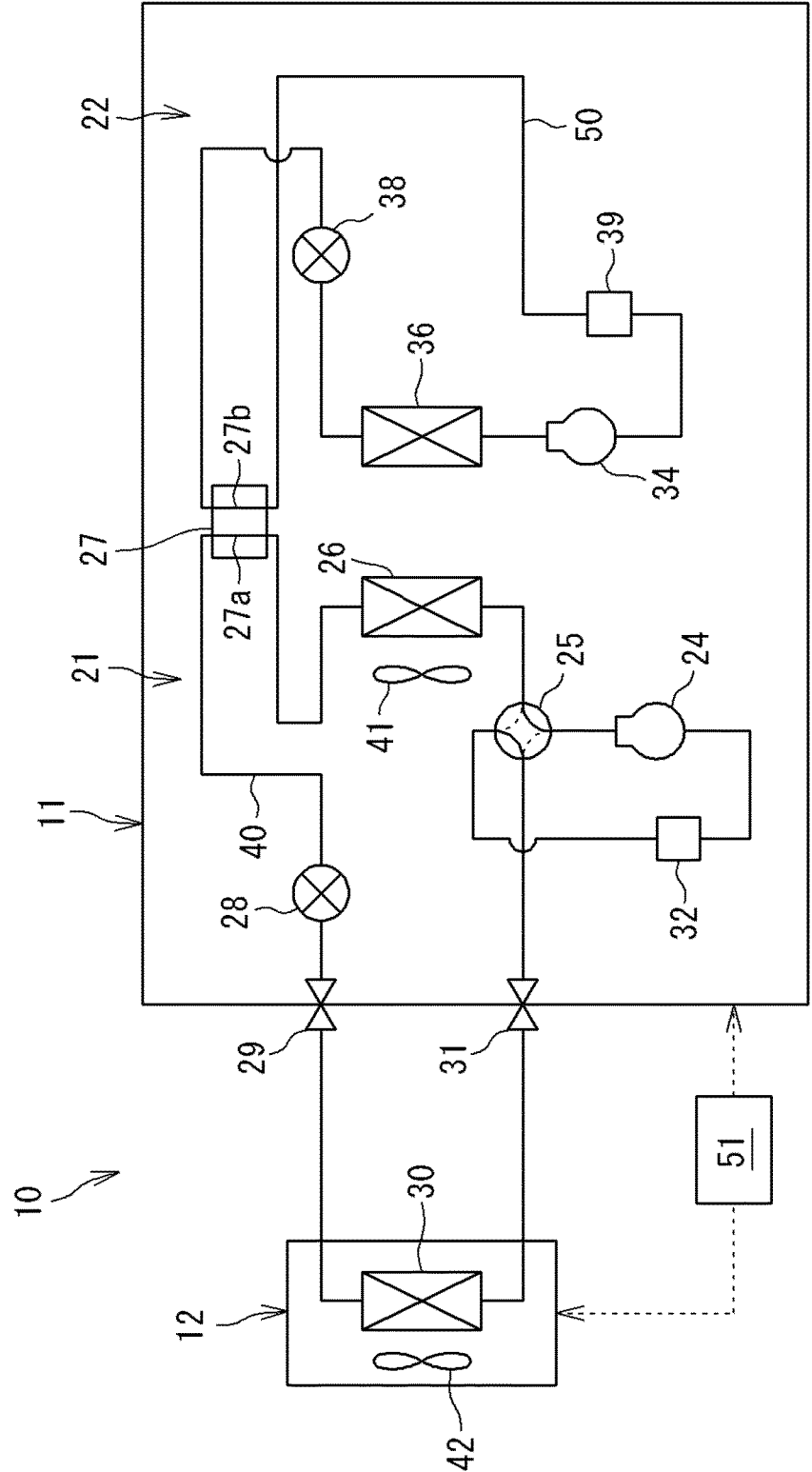


FIG. 2

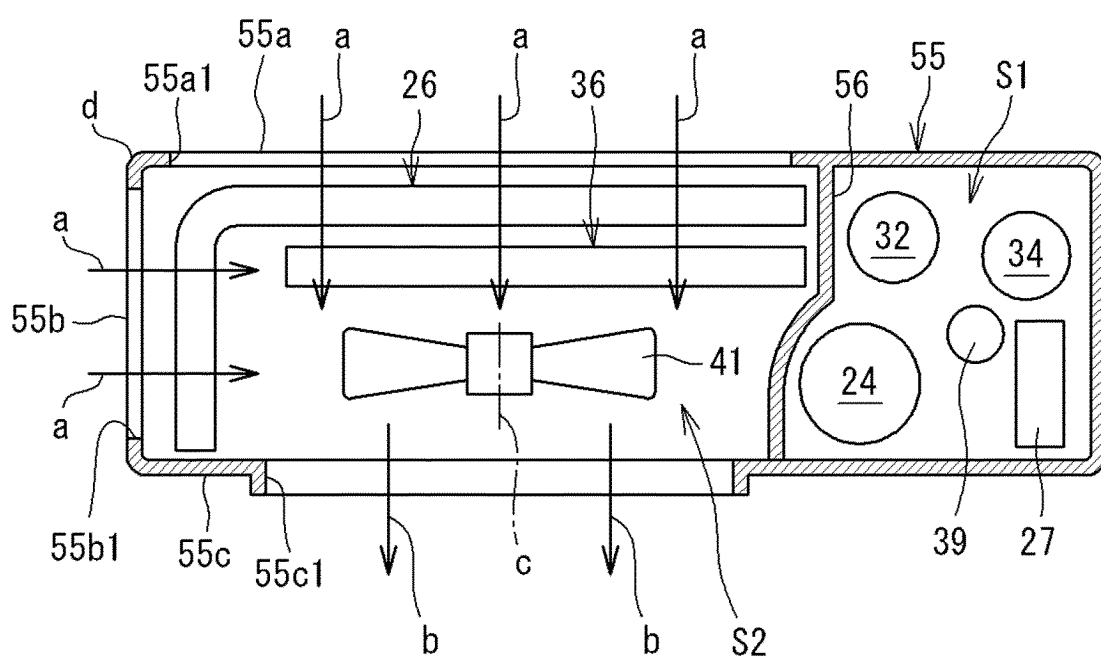


FIG. 3

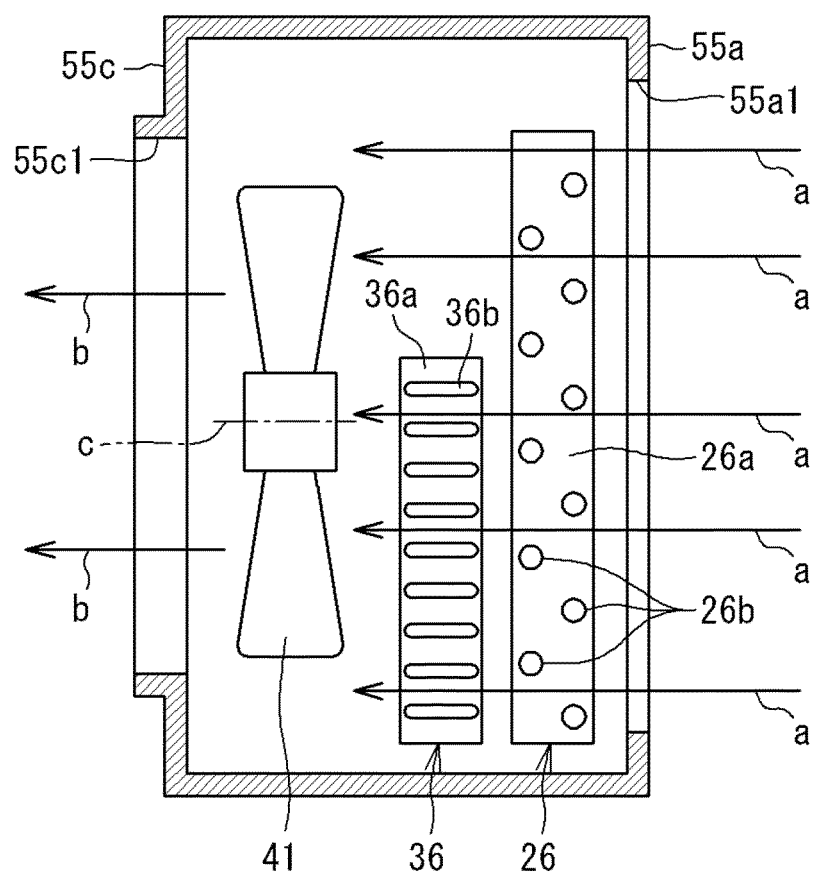


FIG. 4

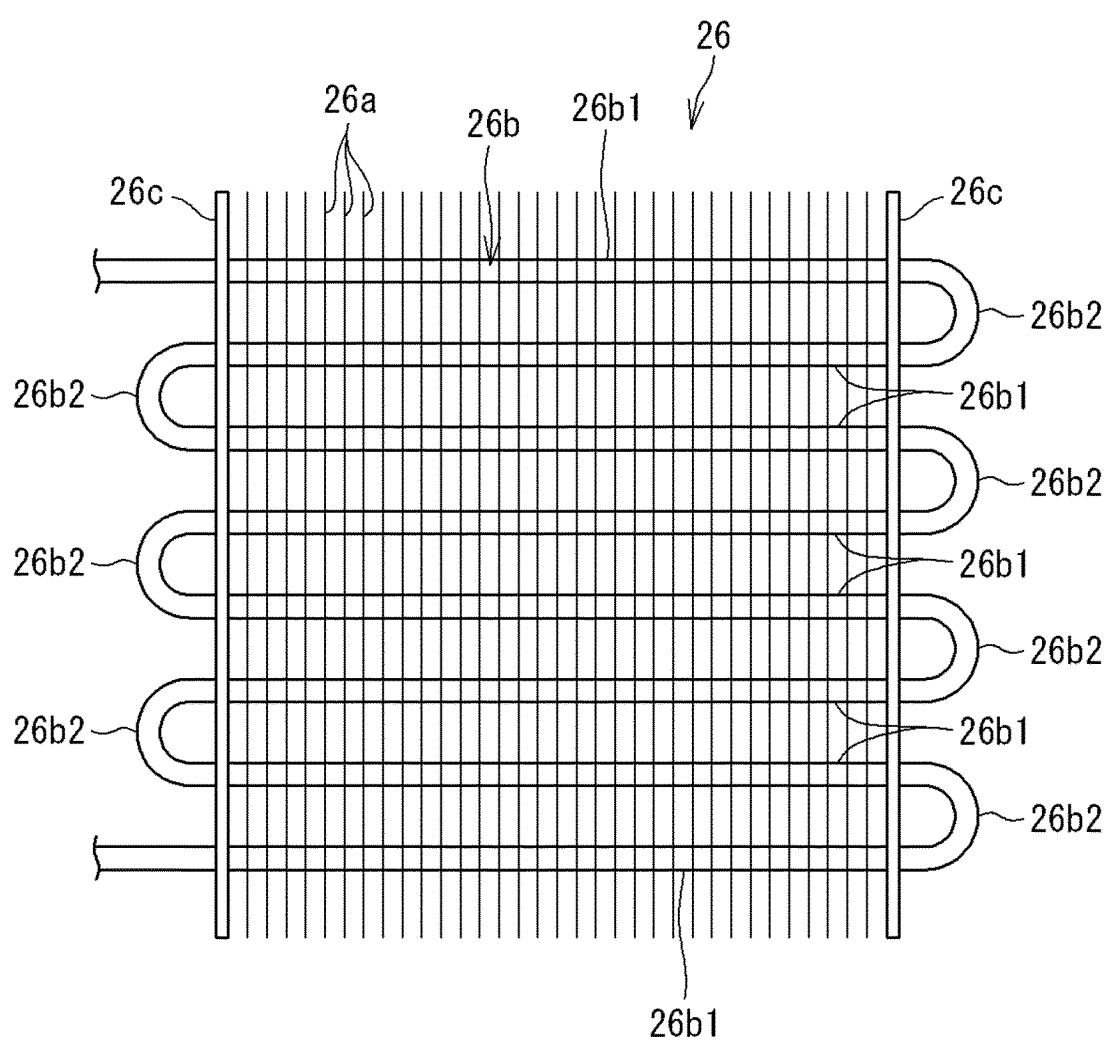


FIG. 5

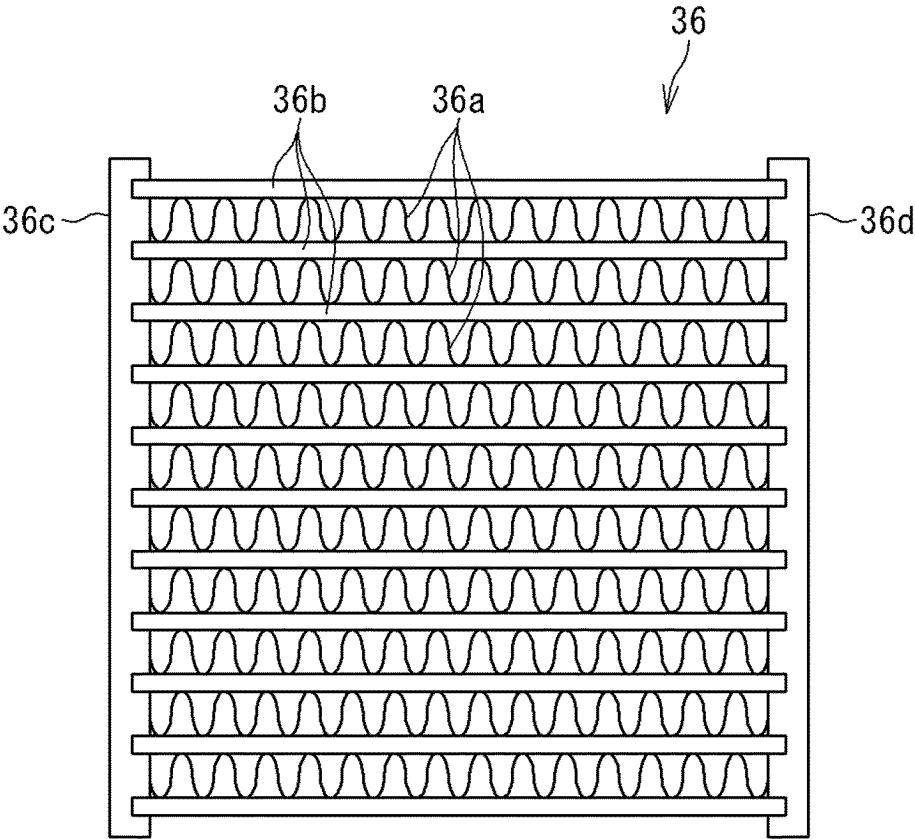


FIG. 6

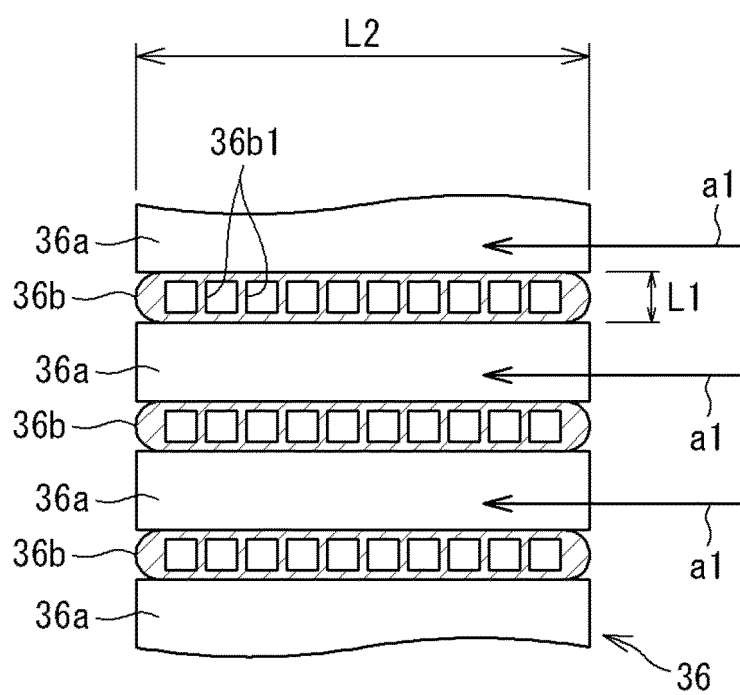
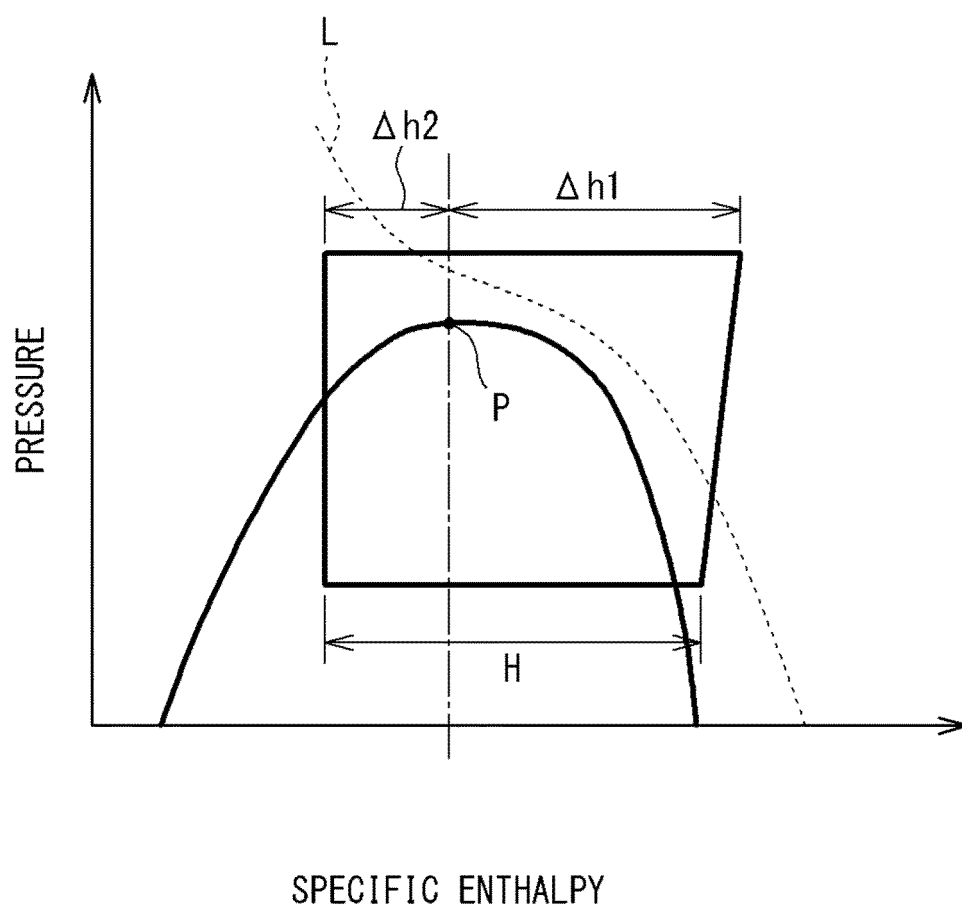


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/020517

A. CLASSIFICATION OF SUBJECT MATTER

F25B 7/00(2006.01)i; **F25B 1/00**(2006.01)i; **F25B 39/04**(2006.01)i; **F28F 1/02**(2006.01)i
 Ft: F25B7/00 D; F25B1/00 396D; F25B1/00 397A; F25B39/04 C; F28F1/02 B

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B7/00; F25B1/00; F25B39/04; F28F1/02

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.
Y	WO 2005/052467 A1 (MITSUBISHI ELECTRIC CORPORATION) 09 June 2005 (2005-06-09) paragraphs [0016]-[0017], fig. 1-25	1-5
Y	WO 2020/250953 A1 (DAIKIN INDUSTRIES, LTD.) 17 December 2020 (2020-12-17) paragraphs [0004]-[0008], [0031]-[0032], fig. 1-2	1-5
Y	JP 2013-181713 A (HITACHI, LTD.) 12 September 2013 (2013-09-12) claims 3, 6, fig. 1	2-5
Y	WO 2021/014865 A1 (PHC HOLDINGS CORP.) 28 January 2021 (2021-01-28) paragraphs [0020]-[0023], fig. 2	2-5
Y	JP 2014-74508 A (SAMSUNG R&D INSTITUTE JAPAN CO., LTD.) 24 April 2014 (2014-04-24) paragraph [0015]	2-5

☒ 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

27 June 2024

Date of mailing of the international search report

06 August 2024

Name and mailing address of the ISA/JP

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/020517

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/020517

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