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(54) **HEAT EXCHANGER**

(57) Provided is a heat exchanger that suppresses leakage of a refrigerant when water freezes and expands in volume. A heat exchanger (100) is a heat exchanger that causes heat exchange between water and a refrigerant. The heat exchanger (100) includes a first flow path (111) through which the water flows and a second flow path (121) through which the refrigerant flows. A member forming the first flow path (111) or a portion where members forming the first flow path (111) are joined to each other functions as a fragile portion (190) with a lower strength than the other portions. In the heat exchanger (100), when the water freezes and expands in volume, the member forming the first flow path (111) or the portion where members forming the first flow path (111) are joined to each other, functioning as the fragile portion (190), breaks before the other portions. Therefore, according to the heat exchanger (100), when the water freezes and expands in volume, the leakage of the refrigerant due to the breakage of members or joining portions forming the second flow path (121) is suppressed.

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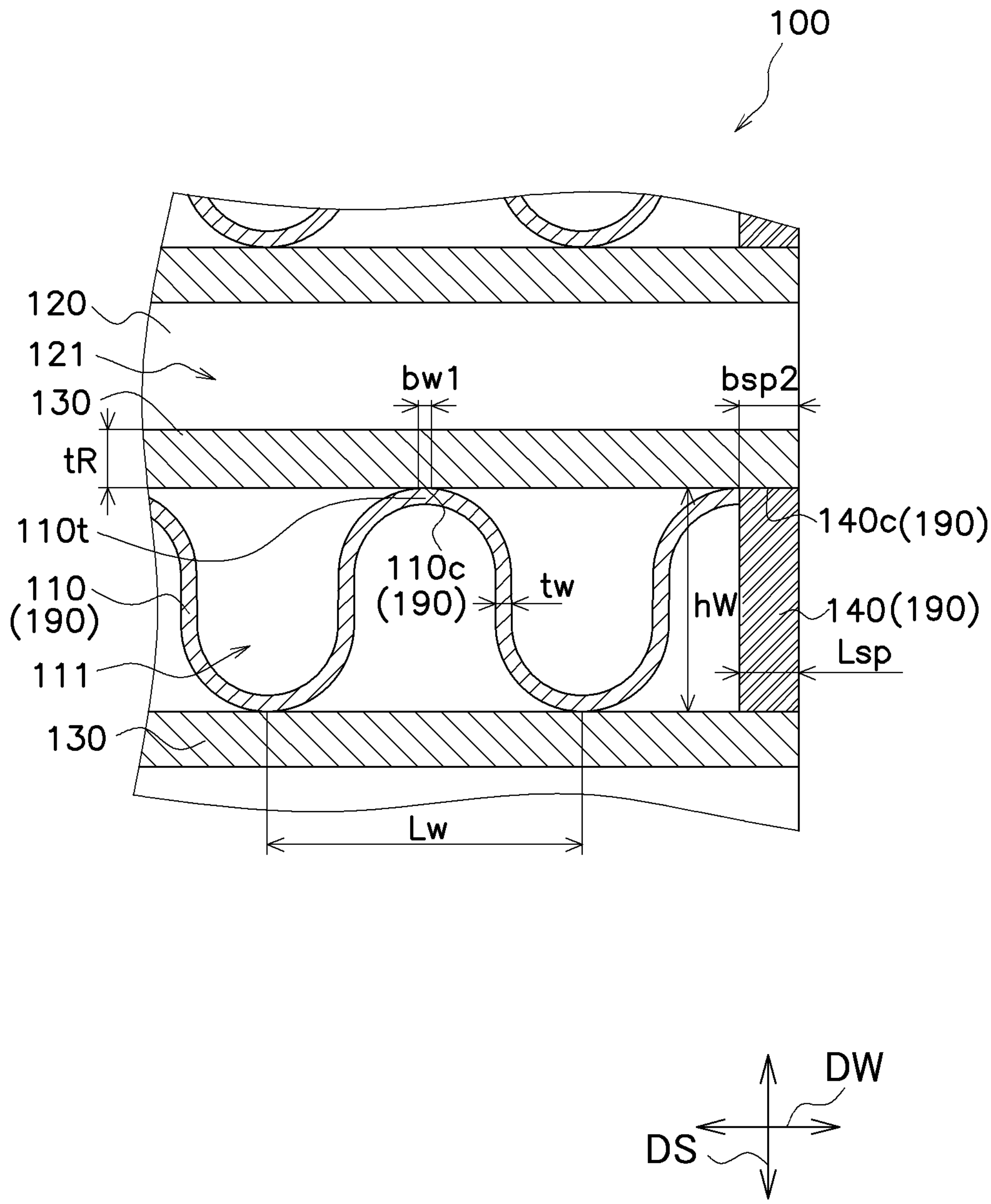

100
120
121
130
bw1
bsp2
tR
110t
110c
(190)
tw
140c(190)
110
(190)
hW
140(190)
Lsp
111
130
Lw
DW
DS

FIG. 6

Description

Technical Field

[0001] The present disclosure relates to a heat exchanger.

Background Art

[0002] There has been known a plate-type heat exchanger in which a plurality of heat transfer plates are stacked at a predetermined interval to alternately form a flow path through which a first fluid flows and a flow path through which a second fluid flows in a stacking direction, and heat is exchanged between the two fluids.
[0003] In the plate-type heat exchanger, when a refrigerant and water are used as the fluids, the heat transfer plates may break due to volume expansion of the frozen water, and the refrigerant may leak. PTL 1 (Japanese Unexamined Patent Application Publication No. 10-132476) discloses, as a fifth embodiment, a heat exchanger including heat transfer plates capable of absorbing stress by elastic deformation to suppress breakage even when the volume expansion of the frozen water occurs.

Summary of Invention

Technical Problem

[0004] Even with the heat transfer plates disclosed in PTL 1, the stress absorbable range (elastically deformable range) is limited. Thus, damage to the heat transfer plates cannot be sufficiently suppressed, meaning that there is a risk of refrigerant leakage.
[0005] The present disclosure provides a heat exchanger that suppresses leakage of a refrigerant when water freezes and expands in volume.

Solution to Problem

[0006] A heat exchanger of a first aspect is a heat exchanger that causes heat exchange between water and a refrigerant, and includes a first flow path through which the water flows and a second flow path through which the refrigerant flows. Any one of members forming the first flow path other than a partition wall partitioning the first flow path and the second flow path or any one of joining portions where members forming the first flow path are joined to each other functions as a fragile portion with a lower strength than the other members forming the first flow path.
[0007] In the heat exchanger, when the water freezes and expands in volume, any one of the members forming the first flow path other than the partition wall partitioning the first flow path and the second flow path or any one of the joining portions where members forming the first flow path are joined to each other, functioning as the fragile portion, breaks before the other portions. Therefore, according to the heat exchanger, when the water freezes and expands in volume, the leakage of the refrigerant due to the breakage of members forming the second flow path, joining portions forming the second flow path, or the partition wall is suppressed.
[0008] A heat exchanger of a second aspect is the heat exchanger of the first aspect, wherein the first flow path is formed using two partition walls, inner fins, and separation members. The inner fins are stacked between the two partition walls and each have a corrugated cross section. The separation members are disposed at end edges of the two partition walls and each separate the two partition walls from each other.
[0009] A heat exchanger of a third aspect is the heat exchanger of the second aspect, wherein the fragile portion is the inner fins.
[0010] According to the heat exchanger, when water freezes and expands in volume, the inner fins forming the first flow path breaks before other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.
[0011] A heat exchanger of a fourth aspect is the heat exchanger of the third aspect, wherein the following relationship is satisfied with tw representing a thickness of the inner fin, Lw representing an interval between top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hw representing a height of the inner fin in a stacking direction:

$$tw/Lw < tR/hw.$$

[0012] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the inner fins when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the inner fins, which break before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0013] A heat exchanger of a fifth aspect is the heat exchanger of the second aspect, wherein the fragile portion is the separation members.

[0014] According to the heat exchanger, when the water freezes and expands in volume, the separation members forming the first flow path break before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0015] A heat exchanger of a sixth aspect is the heat exchanger of the fifth aspect, wherein the following relationship is satisfied with Lsp representing a width of the separation member in plan view, tw representing a thickness of the inner fin, Lw representing an interval between top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hw representing a height of the inner fin in a stacking direction:

$$((\mathrm{Lsp} + \mathrm{tw})/\mathrm{Lw}) < \mathrm{tR}/\mathrm{hw}.$$

[0016] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the separation members when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the separation members, which break before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0017] A heat exchanger of a seventh aspect is the heat exchanger of the first aspect, wherein the first flow path is formed using two partition walls, inner fins, and separation members. The inner fins are stacked between the two partition walls and each have a corrugated cross section. The separation members are disposed at end edges of the two partition walls and each separate the two partition walls from each other. The heat exchanger includes a first joining portion and a second joining portion. The first joining portion is a portion where the partition wall and top portions of the inner fin are joined. The second joining portion is a portion where the partition wall and the separation member are joined.

[0018] A heat exchanger of an eighth aspect is the heat exchanger of the seventh aspect, wherein the fragile portion is the first joining portion.

[0019] According to the heat exchanger, when the water freezes and expands in volume, the first joining portion where members forming the first flow path are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0020] A heat exchanger of a ninth aspect is the heat exchanger of the eighth aspect, wherein joining in the first joining portion is joined by brazing. The following relationship is satisfied with bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$0.35 \times \mathrm{bw1}/(2 \times \mathrm{Lw}) < \mathrm{tR}/\mathrm{hw}.$$

[0021] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the first joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first joining portion, which breaks before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0022] A heat exchanger of a tenth aspect is the heat exchanger of the eighth aspect, wherein joining in the first joining portion is implemented by diffusion joining. The following relationship is satisfied with bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$\mathrm{bw1}/(2 \times \mathrm{Lw}) < \mathrm{tR}/\mathrm{hw}.$$

[0023] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the first joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first joining portion, which breaks before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0024] A heat exchanger of an eleventh aspect is the heat exchanger of the seventh aspect, wherein the fragile portion is the second joining portion.

[0025] According to the heat exchanger, when the water freezes and expands in volume, the second joining portion where members forming the first flow path are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0026] A heat exchanger of a twelfth aspect is the heat exchanger of the eleventh aspect, wherein joining in the second joining portion is joined by brazing. The following relationship is satisfied with bsp2 representing a width of the second joining portion, bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:
$0.35 \times (2 \times bsp2 + bw1)/Lw < 2 \times tR/hw$.

$$0.35 \times (2 \times \mathrm{bsp2} + \mathrm{bw1})/\mathrm{Lw} < 2 \times \mathrm{tR}/\mathrm{hw}.$$

[0027] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the second joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the second joining portion, which breaks before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0028] A heat exchanger of a thirteenth aspect is the heat exchanger of the eleventh aspect, wherein joining in the second joining portion is implemented by diffusion joining. The following relationship is satisfied with bsp2 representing a width of the second joining portion, bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$(2 \times \mathrm{bsp2} + \mathrm{bw1})/\mathrm{Lw} < 2 \times \mathrm{tR}/\mathrm{hw}.$$

[0029] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition walls smaller than the stress generated in the second joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the second joining portion, which breaks before the partition walls. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0030] A heat exchanger of a fourteenth aspect is the heat exchanger of the first aspect, wherein the first flow path is formed using two heat transfer plates. The heat exchanger includes a third joining portion and a fourth joining portion. The two heat transfer plates are stacked on each other and each have a corrugated cross section. The third joining portion is a portion where top portions of the two heat transfer plates are joined. The fourth joining portion is a portion where end edges of the two heat transfer plates are joined.

[0031] A heat exchanger of a fifteenth aspect is the heat exchanger of the fourteenth aspect, wherein the fragile portion is the third joining portion.

[0032] According to the heat exchanger, when the water freezes and expands in volume, the third joining portion 210d where members forming the first flow path are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0033] A heat exchanger of a sixteenth aspect is the heat exchanger of the fifteenth aspect, wherein joining in the third joining portion is joined by brazing. The following relationship is satisfied with bw3 presenting a width of the third joining portion as viewed along a normal direction and t representing a thickness of the heat transfer plate:

$$0.35 \times \mathrm{bw3} < 2 \times \mathrm{t}.$$

[0034] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the heat transfer plates smaller than the stress generated in the third joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the third joining portion, which breaks before the heat transfer plates. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.

[0035] A heat exchanger of a seventeenth aspect is the heat exchanger of the fifteenth aspect, wherein joining in the third joining portion is implemented by diffusion joining. The following relationship is satisfied with bw3 presenting a width of the third joining portion as viewed along a normal direction and t representing a thickness of the heat transfer plate:

$$bw3 < 2 \times t.$$

[0036] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the heat transfer plates smaller than the stress generated in the third joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the third joining portion, which breaks before the heat transfer plates. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.
[0037] A heat exchanger of an eighteenth aspect is the heat exchanger of the fourteenth aspect, wherein the fragile portion is the fourth joining portion.
[0038] According to the heat exchanger, when the water freezes and expands in volume, the fourth joining portion 210e where members forming the first flow path are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.
[0039] A heat exchanger of a nineteenth aspect is the heat exchanger of the eighteenth aspect, wherein joining in the fourth joining portion is joined by brazing. The following relationship is satisfied with bsp4 representing a width of the fourth joining portion as viewed along a normal direction,bw3 presenting a width of the third joining portion as viewed along the normal direction, and t representing a thickness of the heat transfer plate:

$$0.35 \times (bsp4 + bw3/2) <2 \times t.$$

[0040] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the heat transfer plates smaller than the stress generated in the fourth joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fourth joining portion, which breaks before the heat transfer plates. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.
[0041] A heat exchanger of a twentieth aspect is the heat exchanger of the eighteenth aspect, wherein joining in the fourth joining portion is implemented by diffusion joining. The following relationship is satisfied with bsp4 representing a width of the fourth joining portion as viewed along a normal direction, bw3 presenting a width of the third joining portion as viewed along the normal direction, and t representing a thickness of the heat transfer plate:

$$(bsp4 + bw3/2) < 2 \times t.$$

[0042] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the heat transfer plates smaller than the stress generated in the fourth joining portion when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fourth joining portion, which breaks before the heat transfer plates. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path is suppressed.
[0043] A heat exchanger of a twenty-first aspect is the heat exchanger of the first aspect, including a first heat transfer plate and a second heat transfer plate. The first heat transfer plate has the first flow path formed therein. The second heat transfer plate has the second flow path formed therein. The fragile portion is the first heat transfer plate.
[0044] According to the heat exchanger, when the water freezes and expands in volume, the first heat transfer plate forming the first flow path breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the second heat transfer plate forming the second flow path is suppressed.
[0045] A heat exchanger of a twenty-second aspect is the heat exchanger of the twenty-first aspect, wherein the first heat transfer plate is formed by stacking two plate-shaped members in which grooves forming the first flow path are formed. The fragile portion is a portion where the two plate-shaped members are joined.
[0046] According to the heat exchanger, when the water freezes and expands in volume, the portion where the two plate-shaped members forming the first heat transfer plate are joined breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the second heat transfer plate forming the second flow path is suppressed.
[0047] A heat exchanger of a twenty-third aspect is the heat exchanger of any of the first to twenty-second aspects, wherein the refrigerant is flammable or toxic.
[0048] According to the heat exchanger, even when the flammable or toxic refrigerant is used, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 can be

suppressed.

[0049] A heat exchanger of a twenty-fourth aspect is the heat exchanger of any of the first to twenty-third aspects, wherein the fragile portion is formed with such a strength that the fragile portion breaks when the water freezes.

Brief Description of Drawings

[0050]

[Fig. 1] Fig. 1 is a schematic configuration diagram illustrating a refrigerant cycle apparatus 1 including a heat exchanger 100.

[Fig. 2] Fig. 2 is a perspective view of the heat exchanger 100.

[Fig. 3] Fig. 3 is an enlarged view of a portion A in Fig. 2.

[Fig. 4] Fig. 4 is a cross-sectional view illustrating a first inner fin 110 accommodated in the heat exchanger 100.

[Fig. 5] Fig. 5 is a cross-sectional view illustrating a second inner fin 120 accommodated in the heat exchanger 100.

[Fig. 6] Fig. 6 is a cross-sectional view of the heat exchanger 100 taken along line B-B' in Fig. 3.

[Fig. 7] Fig. 7 is an exploded perspective view of a heat exchanger 200.

[Fig. 8] Fig. 8 is a cross-sectional view of the heat exchanger 200.

[Fig. 9] Fig. 9 is a perspective view of a heat exchanger 300.

[Fig. 10] Fig. 10 is an enlarged view of a portion C in Fig. 9.

[Fig. 11] Fig. 11 is a cross-sectional view of the heat exchanger 300 taken along line D-D' in Fig. 10.

Description of Embodiments

<First embodiment>

(1) Refrigerant cycle apparatus 1

[0051] First, a refrigerant cycle apparatus 1 including a heat exchanger 100 according to a first embodiment of the present disclosure will be described. The refrigerant cycle apparatus 1 heats or cools water supplied from the outside of the refrigerant cycle apparatus 1, such as city water (tap water), and supplies the water. The refrigerant cycle apparatus 1 includes a water intake unit 1a, a water supply unit 1b, the heat exchanger 100, a refrigerant circuit 10, a water circuit 20, a water supply unit 30, and a control unit 40. Although not limited thereto, in the present embodiment, the water supply unit 30 is installed indoors, and the water circuit 20 and the refrigerant circuit 10 are installed outdoors. As will be described in detail below, a refrigerant circulates in the refrigerant circuit 10, and water circulates in the water circuit 20.

[0052] The water intake unit 1a takes in water supplied from the outside into the refrigerant cycle apparatus 1. The water supply unit 1b supplies to the outside, water heated or cooled in the refrigerant cycle apparatus 1.

(1-1) Heat exchanger 100

[0053] The heat exchanger 100 causes heat exchange between the refrigerant circulating in the refrigerant circuit 10 and the water circulating in the water circuit 20. The heat exchanger 100 includes first flow pipes 170a and 170b, second flow pipes 180a and 180b, a first flow path 111, and a second flow path 121.

[0054] The first flow path 111 is a flow path through which water flows. The first flow path 111 is provided between the first flow pipe 170a and the first flow pipe 170b.

[0055] The second flow path 121 is a flow path through which the refrigerant flows. The second flow path 121 is formed between the second flow pipe 180a and the second flow pipe 180b. A detailed structure of the heat exchanger 100 will be described below.

(1-2) Refrigerant circuit 10

[0056] In the refrigerant circuit 10, the refrigerant is heated or cooled. The refrigerant circuit 10 includes a compressor 11, a four-way switching valve 12, a heat source heat exchanger 13, an expansion valve 14, and the second flow path 121 of the heat exchanger 100. The compressor 11, the four-way switching valve 12, the heat source heat exchanger 13, the expansion valve 14, and the second flow path 121 of the heat exchanger 100 are connected by pipes, and the refrigerant circulates therein. In the present embodiment, the refrigerant is propane.

[0057] The compressor 11 takes in a low-pressure refrigerant in the refrigerant circuit 10 through an intake portion 11a, compresses the refrigerant, and discharges the refrigerant as a high-pressure refrigerant through a discharge portion 11b.

[0058] The four-way switching valve 12 has a first port P1, a second port P2, a third port P3, and a fourth port P4. The four-way switching valve 12 is switched between a first state and a second state different from each other in a communication state of the first port P1, the second port P2, the third port P3, and the fourth port P4, based on an instruction from the control unit 40. In the first state, the first port P1 and the second port P2 communicate with each other, and the third port P3 and the fourth port P4 communicate with each other. In the second state, the first port P1 and the fourth port P4 communicate with each other, and the second port P2 and the third port P3 communicate with each other.

[0059] The first port P1 is connected to the discharge portion 11b of the compressor 11. The second port P2 is connected to the second flow pipe 180a of the heat exchanger 100. The third port P3 is connected to the intake portion 11a of the compressor 11. The fourth port P4 is connected to one end of the heat source heat exchanger 13.

[0060] The heat source heat exchanger 13 causes heat exchange between the refrigerant circulating in the refrigerant circuit 10 and a heat source (for example, outdoor air).

[0061] The expansion valve 14 functions as a pressure reducing device that adjusts the flow rate of the refrigerant circulating in the refrigerant circuit 10 and reduces the pressure of the refrigerant.

[0062] One end of the expansion valve 14 is connected to the other end of the heat source heat exchanger 13. The other end of the expansion valve 14 is connected to the second flow pipe 180b of the heat exchanger 100.

(1-3) Water circuit 20

[0063] In the water circuit 20, the water after the heat exchange with the refrigerant circulates. The water circuit 20 includes the first flow path 111 of the heat exchanger 100, a water circulation pump 21, a flow rate adjustment valve 22, and a utilization heat exchanger 23. The first flow path 111 of the heat exchanger 100, the water circulation pump 21, the flow rate adjustment valve 22, and the utilization heat exchanger 23 are connected to each other by pipes, and water circulates therein.

[0064] The water circulation pump 21 makes the water circulate inside the water circuit 20. The water circulation pump 21 takes in water in the water circuit 20 through an intake portion 21a and discharges the water through a discharge portion 21b.

[0065] The intake portion 21a is connected to the first flow pipe 170a of the heat exchanger 100. The discharge portion 21b is connected to one end of the flow rate adjustment valve 22.

[0066] The flow rate adjustment valve 22 adjusts the flow rate of water circulating in the water circuit 20.

[0067] The utilization heat exchanger 23 causes heat exchange between the water circulating in the water circuit 20 and water stored in a water storage tank 31 (described below) of the water supply unit 30. The utilization heat exchanger 23 is disposed inside the water storage tank 31 so that water passing therethrough can exchange heat with the water stored in the water storage tank 31.

[0068] One end of the utilization heat exchanger 23 is connected to the other end of the flow rate adjustment valve 22. The other end of the utilization heat exchanger 23 is connected to the first flow pipe 170b of the heat exchanger 100.

[0069] The water circuit 20 may further include a heat exchanger for heating or cooling indoor air using the circulating water.

(1-4) Water supply unit 30

[0070] The water supply unit 30 causes heat exchange between the water supplied from the outside of the refrigerant cycle apparatus 1 and the water circulating in the water circuit 20, and then supplies the water to the outside of the refrigerant cycle apparatus 1. The water supply unit 30 includes the water storage tank 31, a water supply pump 32, and a mixing valve 33. The water storage tank 31, the water supply pump 32, and the mixing valve 33 are connected by a pipe.

[0071] The water storage tank 31 stores the water supplied from the outside. The stored water exchanges heat with the water passing through the utilization heat exchanger 23. The water storage tank 31 takes in water supplied from the outside through a water intake portion 31a and stores the water. The stored water exchanges heat with water passing through the utilization heat exchanger 23, and is discharged from a water discharge portion 81b.

[0072] The water intake portion 31a is connected to the water intake unit 1a to which water is supplied from the outside.

[0073] The water supply pump 32 takes in water stored in the water storage tank 31 and supplies the water to the mixing valve 33. The water supply pump 32 takes in water inside the water storage tank 31 through an intake portion 32a, and discharges the water through a discharge portion 32b.

[0074] The intake portion 32a is connected to a water discharge portion 31b. The discharge portion 32b is connected to a second port 33b (described below) of the mixing valve 33.

[0075] The mixing valve 33 mixes water supplied from the outside and water stored in the water storage tank 31. The mixing valve 33 has a first port 33a, the second port 33b, and a third port 33c.

[0076] The first port 33a is connected to the water intake unit 1a to which water is supplied from the outside. The second port 33b is connected to the discharge portion 32b of the water supply pump 32. The third port 33c is connected to the water supply unit 1b that communicates with the outside of the refrigerant cycle apparatus 1.

(1-5) Control unit 40

[0077] The control unit 40 controls the compressor 11, the four-way switching valve 12, the expansion valve 14, the water circulation pump 21, the flow rate adjustment valve 22, the water supply pump 32, and the mixing valve 33. Although not illustrated in the drawings, the control unit 40 is electrically connected to the compressor 11, the four-way switching valve 12, the expansion valve 14, the water circulation pump 21, the flow rate adjustment valve 22, the water supply pump 32, and the mixing valve 33 in such a manner that a control signal can be transmitted and received therebetween.

(1-6) Operation of refrigerant cycle apparatus 1

[0078] The refrigerant cycle apparatus 1 performs a heating operation, a cooling operation, and a defrosting operation.

(1-6-1) Heating operation

[0079] The heating operation is an operation in which the refrigerant cycle apparatus 1 heats water that is supplied from the outside to the water intake unit 1a and supplies the heated water through the water supply unit 1b. In the heating operation, the control unit 40 sets the four-way switching valve 12 to the first state, drives the compressor 11, the water circulation pump 21, and the water supply pump 32, and controls the opening degrees of the expansion valve 14, the flow rate adjustment valve 22, and the mixing valve 33.

(1-6-1-1) Refrigerant circuit 10

[0080] The compressor 11 takes in a low-pressure gas-phase refrigerant in the refrigerant circuit 10 through the intake portion 11a, and discharges the refrigerant as a high-pressure gas-phase refrigerant through the discharge portion 11b. The high-pressure gas-phase refrigerant passes through the four-way switching valve 12 in the order of the first port P1 and the second port P2, and reaches the second flow path 121 of the heat exchanger 100. In the second flow path 121 of the heat exchanger 100, the high-pressure gas-phase refrigerant is condensed into a high-pressure liquid-phase refrigerant. In this process, the refrigerant releases heat to the water passing through the first flow path 111. The high-pressure liquid-phase refrigerant reaches the expansion valve 14. The expansion valve 14 set to an appropriate opening degree decompresses the high-pressure liquid-phase refrigerant into a low-pressure gas-liquid two phase refrigerant. The low-pressure gas-liquid two phase refrigerant evaporates in the heat source heat exchanger 13 to become a low-pressure gas-phase refrigerant. In this process, the refrigerant absorbs heat from the heat source (outside air). The low-pressure gas-phase refrigerant passes through the four-way switching valve 12 in the order of the fourth port P4 and the third port P3, and is then taken into the compressor 11 through the intake portion 11a.

(1-6-1-2) Water circuit 20

[0081] The water circulation pump 21 takes in water circulating in the water circuit 20 through the intake portion 21a and discharges the water through the discharge portion 21b. The discharged water reaches the utilization heat exchanger 23 through the flow rate adjustment valve 22. The water that has reached the utilization heat exchanger 23 releases heat to the water stored in the water storage tank 31 in the utilization heat exchanger 23. In other words, the water that has reached the utilization heat exchanger 23 heats the water stored in the water storage tank 31 in the utilization heat exchanger 23. The water that has released heat in the utilization heat exchanger 23 reaches the first flow path 111 of the heat exchanger 100. The water that has reached the first flow path 111 of the heat exchanger 100 absorbs heat from the refrigerant passing through the second flow path 121. The water that has absorbed heat is taken into the water circulation pump 21 through the intake portion 21a.

(1-6-1-3) Water supply unit 30

[0082] The water stored in the water storage tank 31 is heated by absorbing heat from the water passing through the utilization heat exchanger 23. The water supply pump 32 takes in the water heated in the water storage tank 31 through the intake portion 32a. The water taken into the water supply pump 32 is discharged through the discharge portion 32b to the mixing valve 33. The water discharged from the water supply pump 32 passes through the second port 33b and is then mixed with the water from the outside that has reached the first port 33a through the water intake unit 1a. The mixed water from the mixing valve 33 passes through the third port 33c and is then supplied to the outside of the refrigerant cycle apparatus 1 from the water supply unit 1b.

(1-6-2) Cooling operation

[0083] The cooling operation is an operation in which the refrigerant cycle apparatus 1 cools water that is supplied from the outside to the water intake unit 1a and supplies the cooled water from the water supply unit 1b. In the cooling operation, the control unit 40 sets the four-way switching valve 12 to the second state, drives the compressor 11, the water circulation pump 21, and the water supply pump 32, and controls the opening degrees of the expansion valve 14, the flow rate adjustment valve 22, and the mixing valve 33.

(1-6-2-1) Refrigerant circuit 10

[0084] The compressor 11 takes in a low-pressure gas-phase refrigerant in the refrigerant circuit 10 through the intake portion 11a, and discharges the refrigerant as a high-pressure gas-phase refrigerant through the discharge portion 11b. The high-pressure gas-phase refrigerant passes through the four-way switching valve 12 in the order of the first port P1 and the fourth port P4, and reaches the heat source heat exchanger 13. In the heat source heat exchanger 13, the high-pressure gas-phase refrigerant is condensed into a high-pressure liquid-phase refrigerant. In this process, the refrigerant releases heat to a heat source (outside air). The high-pressure liquid-phase refrigerant reaches the expansion valve 14. The expansion valve 14 set to an appropriate opening degree decompresses the high-pressure liquid-phase refrigerant into a low-pressure gas-liquid two phase refrigerant. The low-pressure gas-liquid two phase refrigerant evaporates in the second flow path 121 of the heat exchanger 100 to become a low-pressure gas-phase refrigerant. In this process, the refrigerant absorbs heat from the water passing through the first flow path 111. The low-pressure gas-phase refrigerant passes through the four-way switching valve 12 in the order of the second port P2 and the third port P3, and is then taken into the compressor 11 through the intake portion 11a.

(1-6-2-2) Water circuit 20

[0085] The water circulation pump 21 takes in water circulating in the water circuit 20 through the intake portion 21a and discharges the water through the discharge portion 21b. The discharged water reaches the utilization heat exchanger 23 through the flow rate adjustment valve 22. The water that has reached the utilization heat exchanger 23 absorbs heat from the water stored in the water storage tank 31 in the utilization heat exchanger 23. In other words, the water that has reached the utilization heat exchanger 23 cools the water stored in the water storage tank 31 in the utilization heat exchanger 23. The water that has absorbed heat in the utilization heat exchanger 23 reaches the first flow path 111 of the heat exchanger 100. The water that has reached the first flow path 111 of the heat exchanger 100 releases heat to the refrigerant passing through the second flow path 121. The water that has released heat is taken into the water circulation pump 21 through the intake portion 21a.

(1-6-2-3) Water supply unit 30

[0086] The water stored in the water storage tank 31 is cooled by releasing heat to the water passing through the utilization heat exchanger 23. The water supply pump 32 takes in water cooled in the water storage tank 31 through the intake portion 32a. The water taken into the water supply pump 32 is discharged through the discharge portion 32b to the mixing valve 33. The water discharged from the water supply pump 32 passes through the second port 33b and is then mixed with the water from the outside that has reached the first port 33a through the water intake unit 1a. The mixed water from the mixing valve 33 passes through the third port 33c and is then supplied to the outside of the refrigerant cycle apparatus 1 from the water supply unit 1b.

(1-6-3) Defrosting operation

[0087] The defrosting operation is an operation in which frost that has adhered to the surface of the heat source heat exchanger 13 during the heating operation is melted and removed by the heat of the refrigerant condensed in the heat source heat exchanger 13. The operation of each part of the refrigerant cycle apparatus 1 in the defrosting operation is the same as that in the cooling operation described above. Therefore, a detailed description of the defrosting operation will be omitted.

(2) Heat exchanger

(2-1) Overall configuration

[0088] The heat exchanger 100 is a heat exchanger including a plurality of first inner fins 110, a plurality of second inner fins 120, a plurality of partition walls 130, a first separation member 140, a second separation member 150, a casing 160, the first flow pipe 170a, the first flow pipe 170b, the second flow pipe 180a, and the second flow pipe 180b. The first flow path 111 through which water flows and the second flow path 121 through which a refrigerant flows are formed inside the heat exchanger 100. As will be described in detail below, the heat exchanger 100 has a fragile portion 190 that prevents the refrigerant flowing through the second flow path 121 from flowing into the first flow path 111 when water freezes.

[0089] The first inner fins 110, the second inner fins 120, and the partition walls 130 are plate-shaped members made of metal and formed in the same rectangular outer shape. In the present embodiment, as illustrated in Fig. 2, the outer shapes of the first inner fins 110, the second inner fins 120, and the partition walls 130 are formed in a rectangular shape elongated in a first direction.

[0090] The first inner fins 110 and the second inner fins 120 are alternately stacked with the partition wall 130 interposed therebetween and are accommodated in the casing 160. The number of each of the first inner fins 110 and the second inner fins 120 is not limited, and is appropriately set according to the required performance.

[0091] In the following description, for the sake of simplicity, the first direction may be referred to as a longitudinal direction DL. A direction orthogonal to the first direction may be referred to as a width direction DW. Further, a direction in which the first inner fins 110, the partition wall 130, and the second inner fins 120 are stacked may be referred to as a stacking direction DS. The longitudinal direction DL, the width direction DW, and the stacking direction DS correspond to the directions indicated by the arrows in the drawing. The back, front, left, and right directions used in the following description correspond to the directions indicated by the arrows in Figs. 2 to 5.

(2-2) Detailed configuration

(2-2-1) First inner fin 110

[0092] The first inner fin 110 is a corrugated fin having a corrugated cross section. The corrugated shape of the first inner fin 110 is formed such that a top portion 110t of the corrugated shape extends along the longitudinal direction DL in plan view. The first inner fin 110 forms the first flow path 111 together with the partition walls 130 adjacently stacked and the first separation member 140 separating the partition walls 130 from each other. The first inner fin 110 is formed by, for example, but not limited to, pressing.

[0093] Regarding the shape of the first inner fin 110, "corrugated" is not limited to a shape in which semicircular recesses and protrusions are periodically arranged as illustrated in Fig. 6, and may be a periodically changing shape such as a sine wave, a rectangular wave, or a triangular wave shape. The same applies to the second inner fin 120.

(2-2-2) Second inner fin 120

[0094] The second inner fin 120 is a corrugated fin having a corrugated cross section. The corrugated shape of the second inner fin 120 is formed such that a top portion 120t of the corrugated shape extends along the width direction DW in plan view. The second inner fin 120 forms the second flow path 121 together with the partition walls 130 adjacently stacked. The second inner fin 120 is formed by, for example, but not limited to, pressing.

(2-2-3) Partition wall 130

[0095] The partition wall 130 is a flat plate that separates the first inner fin 110 and the second inner fin 120 in the stacking direction DS.

(2-2-4) First separation member 140

[0096] The first separation member 140 is a member that separates two partition walls 130 from each other in order to dispose the first inner fin 110 between the partition walls 130 adjacent to each other in the stacking direction DS. The first separation member 140 is a strip-shaped member extending along the longitudinal direction DL. The first separation members 140 are disposed along both end edges of the partition wall 130 in the width direction DW. The height of the first separation member 140 in the stacking direction DS is set to be the same as the height of the first inner fin 110 in the stacking direction DS. The first inner fin 110 is disposed between the first separation members 140 disposed along both end edges of the partition wall 130 in the width direction DW.

(2-2-5) Second separation member 150

[0097] The second separation member 150 is a member that separates two partition walls 130 from each other in order to dispose the second inner fin 120 between the partition walls 130 adjacent to each other in the stacking direction DS. The second separation member 150 is a strip-shaped member extending along the width direction DW. The second separation members 150 are disposed along both end edges of the partition wall 130 in the longitudinal direction DL. The height of the second separation member 150 in the stacking direction DS is set to be the same as the height of the second inner fin 120 in the stacking direction DS. The first inner fin 110 is disposed between the second separation members 150 disposed along both end edges of the partition wall 130 in the longitudinal direction DL.

(2-2-6) Casing 160

[0098] The casing 160 is a substantially rectangular parallelepiped member that accommodates the first inner fins 110, the second inner fins 120, the partition walls 130, the first separation members 140, and the second separation members 150. The casing 160 has two main surfaces 160a orthogonal to the stacking direction DS, two first side surfaces 160b, and two second side surfaces 160c. The main surfaces 140a are surfaces orthogonal to the stacking direction DS. The first side surfaces 160b are surfaces orthogonal to the longitudinal direction DL. The second side surfaces 160c are surfaces orthogonal to the width direction DW. A first header 141, a second header 142, a third header 143, a fourth header 144, and a fifth header 145 are formed inside the casing 160.

[0099] The first header 141 is a space in which water flowing into the casing 160 is distributed to a plurality of first flow paths 111. The first header 141 is formed along the first side surface 160b on the back side.

[0100] The second header 142 is a space in which the water that has passed through the first flow paths 111 merges. The second header 142 is formed along the first side surface 160b on the front side.

[0101] The third header 143 is a space in which the refrigerant flowing into the casing 160 is distributed to a plurality of second flow paths 121. The third header 143 is formed along the back side of the second side surface 160c on the right side.

[0102] The fourth header 144 is a space in which the refrigerant that has passed through the second flow paths 121 merges. The fourth header 144 is formed along the front side of the second side surface 160c on the right side.

[0103] The fifth header 145 is a space in which the refrigerant that has passed through the second flow paths 121 is merged, and then the flow direction is changed, and the flow of the refrigerant is branched again to the second flow paths 121. The fifth header 145 includes a fifth header 145a, a fifth header 145b, and a fifth header 145c. As illustrated in Fig. 5, the fifth header 145a is formed along the back side of the second side surface 160c on the left side. The fifth header 145b is formed along the second side surface 160c on the right side between the fourth header 144 and the fifth header 145. The fifth header 145c is formed along the front side of the second side surface 160c on the left side.

(2-2-7) First flow pipe 170a and first flow pipe 170b

[0104] The first flow pipe 170a is a pipe for making water flow through the first flow paths 111. The first flow pipe 170a is provided, in the casing 160, through the first side surface 160b on the front side and communicates with the first header 141.

[0105] The first flow pipe 170b is a pipe for making water flow through the first flow paths 111. The first flow pipe 170b is provided, in the casing 160, through the first side surface 160b on the back side and communicates with the second header 142.

(2-2-8) Second flow pipe 180a and second flow pipe 180b

[0106] The second flow pipe 180a is a pipe for making the refrigerant flow through the second flow paths 121. The second flow pipe 180a is provided, in the casing 160, through the second side surface 160c on the right side and communicates with the third header 143.

[0107] The second flow pipe 180b is a pipe for making water flow through the second flow paths 121. The second flow pipe 180b is provided, in the casing 160, through the second side surface 160c on the right side and communicates with the fourth header 144.

(2-2-9) First flow path 111 and second flow path 121

[0108] The first inner fin 110 is accommodated in a space surrounded by two partition walls 130 adjacent to each other in the stacking direction DS and two first separation members 140 disposed between these partition walls 130, whereby the plurality of first flow paths 111 arranged in the width direction DW are formed. The first flow path 111 is a space surrounded by the first inner fin 110 and the partition wall 130 and extending in the longitudinal direction DL, and a space surrounded by the first inner fin 110, the partition wall 130, and the first separation member 140 and extending in the longitudinal direction DL.

[0109] In the present embodiment, the first inner fin 110, the partition wall 130, and the first separation member 140 are joined by brazing. More specifically, the first inner fin 110 has the top portion 110t of the corrugated shape joined to the partition wall 130 by brazing. A surface of the first separation member 140 orthogonal to the stacking direction DS is joined to the partition wall 130 by brazing. Hereinafter, for the sake of simplicity, a portion where the top portion 110t and the partition wall 130 are joined is referred to as a first joining portion 110c, and a portion where the partition wall 130 and the first separation member 140 are joined is referred to as a second joining portion 140c. The first joining portion 110c and the second joining portion 140c are examples of joining portions.

[0110] The second inner fin 120 is accommodated in a space surrounded by two partition walls 130 adjacent to each other in the stacking direction DS and two second separation members 150 disposed between these partition walls 130, whereby the plurality of second flow paths 121 arranged in the longitudinal direction DL are formed. The second flow path 121 is a space surrounded by the second inner fin 120 and the partition wall 130 and extending in the width direction DW, and a space surrounded by the second inner fin 120, the partition wall 130, and the second separation member 150 and extending in the width direction DW.

[0111] The plurality of first inner fins 110 and the plurality of second inner fins 120 are alternately stacked with the partition wall 130 interposed therebetween, whereby the plurality of first flow paths 111 arranged in the width direction DW and the plurality of second flow paths 121 arranged in the longitudinal direction DL are stacked in a parallel cross form in the stacking direction DS.

(2-2-10) Fragile portion 190

[0112] The heat exchanger 100 has the fragile portion 190 that has lower strength than other portions and breaks when the water freezes and expands in volume. The fragile portion 190 is a member that forms the first flow path 111 and is any member other than the partition wall 130 separating the first flow path 111 and the second flow path 121. In the present embodiment, the first inner fin 110 and the first separation member 140 function as the fragile portion 190. In this case, it is preferable that the first inner fin 110 and the first separation member 140 are formed such that the first inner fin 110 breaks first and then the first separation member 140 breaks when the volume expansion of the water reaches or exceeds a certain level.

[0113] In order to make the first inner fin 110 function as the fragile portion 190, it is preferable that the sizes of the respective parts forming the first flow path 111 satisfy the relationship described in (Formula 1) below. Here, it is assumed that tw represents the thickness of the first inner fins 110, Lw represents the interval of the top portions 110t in contact with the same partition wall 130, tR represents the thickness of the partition wall 130, and hw represents the height of the first inner fins in the stacking direction DS.

$$tw/Lw < tR/hw \ldots \text{(Formula 1)}$$

[0114] Note that tw is, for example, 0.15 mm. For example, Lw is 2 mm, tR is 0.15 mm, and Hw is 1 mm.

[0115] In addition, in order to make the first separation member 140 function as the fragile portion 190, it is preferable that the sizes of the portions forming the first flow path 111 satisfy the relationship described in (Formula 2) below. Here, Lsp represents the width of the first separation members 140 in plan view.

$$((Lsp + tw)/Lw) < tR/hw \ldots \text{(Formula 2)}$$

[0116] For example, Lsp is 0.1 mm.

(2-3) Flow of refrigerant and water

[0117] The water introduced from the first flow pipe 170a of the heat exchanger 100 passes through the first header 141 and flows into the first flow path 111. The water that has flowed into the first flow path 111 flows through the first flow path 111 toward the back side along the longitudinal direction DL. The water that has reached the back side passes through the second header 142 and is led out from the first flow pipe 170b. In addition, the water introduced from the first flow pipe 170b of the heat exchanger 100 passes through the second header 142 and flows into the first flow path 111. The water that has flowed into the first flow path 111 flows through the first flow path 111 toward the front side along the longitudinal direction DL. The water that has reached the front side passes through the first header 141 and is led out from the first flow pipe 170a. In either case, the water flowing through the first flow path 111 exchanges heat with the refrigerant in the adjacent second flow path 121 via the partition wall 130.

[0118] On the other hand, the refrigerant introduced from the second flow pipe 180a of the heat exchanger 100 passes through the third header 143 and flows into the second flow path 121. The refrigerant that has flowed into the second flow path 121 flows through the second flow path 121 from the right side toward the left side along the width direction DW. The refrigerant that has reached the left side merges in the fifth header 145a, then flows toward the front side along the longitudinal direction DL, and is again divided into the plurality of second flow paths 121. The refrigerant that has flowed into the second flow path 121 from the fifth header 145a flows through the second flow path 121 from the left side toward the right side along the width direction DW. Thereafter, similarly, the refrigerant flows through the fifth header 145b, the second flow path 121, the fifth header 145c, and the second flow path 121 in this order while repeatedly branching and merging, then passes through the fourth header 144, and is led out from the second flow pipe 180b. The refrigerant introduced from the second flow pipe 180b of the heat exchanger 100 passes through the fourth header 144 and flows into the second flow path 121. The refrigerant that has flowed into the second flow path 121 flows through the second flow path 121 from the right side toward the left side along the width direction DW. The refrigerant that has reached the left side merges in the fifth header 145c, then flows toward the back side and the front side along the longitudinal direction DL, and is again divided into the plurality of second flow paths 121. The refrigerant that has flowed into the second flow path 121 from the fifth header 145c flows through the second flow path 121 from the left side toward the right side along the width direction DW. Thereafter, similarly, the refrigerant flows through the fifth header 145b, the second flow path 121, the fifth header 145a, and the second flow path 121 in this order while repeatedly branching and merging, then passes through the third header 143, and is led out from the second flow pipe 180a. In either case, the water flowing through the second flow path 121 is condensed (during the heating operation) or evaporated (during the cooling operation and the defrosting operation) by exchanging heat with the water in the adjacent first flow path 111 via the partition wall 130.

(3) Features

[0119] (3-1) The heat exchanger 100 is a heat exchanger that causes heat exchange between water and a refrigerant, and includes the first flow path 111 through which water flows and the second flow path 121 through which the refrigerant flows. Any of the members forming the first flow path 111 other than the partition wall 130 separating the first flow path 111 and the second flow path 121 functions as the fragile portion 190 having a lower strength than the other members forming the first flow path 111.

[0120] In the heat exchanger 100, when the water passing through the first flow path 111 freezes and expands in volume, any of the members forming the first flow path 111 functioning as the fragile portion 190 other than the partition wall 130 separating the first flow path 111 and the second flow path 121 breaks before the other portions. Therefore, according to the heat exchanger 100, when water freezes and expands in volume, the leakage of the refrigerant due to the breakage of the members forming the second flow path 121, the joining portions forming the second flow path 121, or the partition wall 130 is suppressed.

[0121] Although not limited, in the refrigerant cycle apparatus 1, for example, it is assumed that the water passing through the first flow path 111 freezes due to the cooling operation, the defrosting operation, and a temperature drop in the installation location of the refrigerant circuit 10. During the cooling operation and the defrosting operation, in the heat exchanger 100, the refrigerant passing through the second flow path 121 evaporates and absorbs heat from the water passing through the first flow path 111 (cools the water), and thus the water may freeze. In addition, when the air temperature at the installation location of the refrigerant circuit 10 drops, the heat exchanger 100 is cooled by the drop in the ambient temperature, and thus the water may freeze.

[0122] (3-2) In the heat exchanger 100, the first flow path 111 is formed using the two partition walls 130, the first inner fins 110, and the first separation members 140. The first inner fins 110 are stacked between the two partition walls 130 and each have a corrugated cross section. The first separation members 140 are disposed at the end edges of the two partition walls 130 and each separate the two partition walls 130.

[0123] (3-3) The fragile portion 190 is the first inner fin 110.

[0124] According to the heat exchanger 100, when the water freezes and expands in volume, the first inner fin 110 forming the first flow path 111 breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0125] (3-4) The following relationship is satisfied with tw representing the thickness of the first inner fins 110, Lw representing the interval of the top portions 110t of the first inner fins 110 in contact with the same partition wall 130, tR representing the thickness of the partition wall 130, and hw representing the height of the first inner fins 110 in the stacking direction DS.

$$tw/Lw < tR/hw \text{ ... (Formula 1)}$$

[0126] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the first inner fin 110 when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first inner fin 110, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0127] (3-5) The fragile portion 190 is the first separation member 140.

[0128] According to the heat exchanger 100, when the water freezes and expands in volume, the first separation member 140 forming the first flow path 111 breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0129] (3-6) The following relationship is satisfied with Lsp representing the width of the first separation members 140 in plan view, tw representing the thickness of the first inner fins 110, Lw representing the interval of the top portions 110t of the first inner fins 110 in contact with the same partition wall 130, tR representing the thickness of the partition wall 130, and hw representing the height of the first inner fins 110 in the stacking direction.

$$((Lsp + tw)/Lw) < tR/hw \text{ ... (Formula 2)}$$

[0130] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the first separation member 140 when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first separation member 140, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

(4) Modifications

(4-1) Modification 1A

[0131] In the above embodiment, the first inner fin 110 and the first separation member 140 function as the fragile portion 190, but only one of the first inner fin 110 and the first separation member 140 may be formed so as to function as the fragile portion 190 as long as the breakage of the members forming the second flow path 121 can be prevented.

(4-2) Modification 1B

[0132] In the above embodiment, a member forming the first flow path 111 functions as the fragile portion 190, but the fragile portion 190 may be any one of joining portions where members forming the first flow path 111 are joined to each other. Specifically, the fragile portion 190 may be the first joining portion 110c. Further, the fragile portion 190 may be the first joining portion 110c and the second joining portion 140c. In this case, it is preferable that the first joining portion 110c breaks first and then the second joining portion 140c breaks when the volume expansion of the water reaches or exceeds a certain level.

[0133] The heat exchanger 100 according to Modification 1B is a heat exchanger that causes heat exchange between water and a refrigerant, and includes the first flow path 111 through which water flows, and the second flow path 121 through which the refrigerant flows. The first joining portion 110c or the second joining portion 140c, which is a joining portion where members forming the first flow path 111 are joined to each other, functions as a fragile portion having a lower strength than the other members forming the first flow path 111.

[0134] In the heat exchanger 100 according to Modification 1B, the first joining portion 110c or the second joining portion 140c, which functions as the fragile portion 190, breaks before the other portions when the water freezes and expands in volume. Therefore, in the heat exchanger 100 according to Modification 1B, when the water freezes and expands in volume, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0135] In order to make the first joining portion 110c function as the fragile portion 190, it is preferable that the sizes of the respective parts forming the first flow path 111 satisfy the relationship described in (Formula 3) below. Here, it is assumed that bw1 represents the width of the first joining portion 110c in plan view.

$$0.35 \times bw1/(2 \times Lw) < tR/hw \ldots \text{(Formula 3)}$$

[0136] For example, bw1 is 0.035 mm.

[0137] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the first joining portion 110c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first joining portion 110c, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0138] In order to make the second joining portion 140c function as the fragile portion 190, it is preferable that the sizes of the respective parts forming the first flow path 111 satisfy the relationship described in (Formula 4) below. Here, it is assumed that bsp2 represents the width of the second joining portion 140c in plan view.

$$0.35 \times (2 \times bsp2 + bw1)/Lw < 2 \times tR/hw \ldots \text{(Formula 4)}$$

[0139] For example, bsp2 is 0.1 mm.

[0140] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the second joining portion 140c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the second joining portion 140c, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

(4-3) Modification 1C

[0141] In the above embodiment, joining in the first joining portion 110c and the second joining portion 140c is joined by brazing, but the joining in the first joining portion 110c and the second joining portion 140c may be joined by diffusion joining.

[0142] As in the case of the heat exchanger 100 according to Modification 1B, in the heat exchanger 100 according to Modification 1C, in which the joining in the first joining portion 110c and the second joining portion 140c is implemented by diffusion joining, the first joining portion 110c or the second joining portion 140c, which functions as the fragile portion 190, breaks before the other portions when the water freezes and expands in volume. Therefore, in the heat exchanger 100 according to Modification 1B, when the water freezes and expands in volume, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0143] In order to make the first joining portion 110c function as the fragile portion 190, it is preferable that the sizes of the respective parts forming the first flow path 111 satisfy the relationship described in (Formula 5) below.

$$bw1/(2 \times Lw) < tR/hw \ldots \text{Formula 5}$$

[0144] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the first joining portion 110c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the first joining portion 110c, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

[0145] In order to make the second joining portion 140c function as the fragile portion 190, it is preferable that the sizes of the respective parts forming the first flow path 111 satisfy the relationship described in (Formula 6) below.

$$(2 \times bsp2 + bw1)/Lw < 2 \times tR/hw \ldots \text{(Formula 6)}$$

[0146] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the partition wall 130 smaller than the stress generated in the second joining portion 140c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the second joining portion 140c, which breaks before the partition wall 130. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 is suppressed.

(4-4) Modification 1D

[0147] In the above embodiment, the refrigerant used is propane, but the refrigerant used is not limited to this, and it is possible to use a known refrigerant such as HC, HFC (such as R410A), HCFC (such as R22 or R32), or a natural refrigerant.

[0148] According to the heat exchanger 100, even when a flammable or toxic refrigerant is used, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 121 can be suppressed. The flammable refrigerant refers to a refrigerant classified as 2L or higher in the standard of ANSI/ASHRAE34 in the United States.

<Second embodiment>

(1) Heat exchanger

[0149] A heat exchanger 200 according to a second embodiment of the present disclosure will be described. The main difference between the heat exchanger 100 and the heat exchanger 200 is that the heat exchanger 100 has flow paths formed by stacking inner fins and partition walls, whereas the heat exchanger 200 has flow paths formed by stacking two heat transfer plates.

[0150] The refrigerant cycle apparatus 1 may include the heat exchanger 200 instead of the heat exchanger 100. Since the configuration and operation of the refrigerant cycle apparatus 1 including the heat exchanger 200 are the same as those of the heat exchanger 100, detailed description thereof will be omitted.

[0151] The longitudinal direction DL, the width direction DW, and the stacking direction DS correspond to the directions indicated by the arrows in the drawings. The back, front, up, down, left, and right directions used in the following description correspond to the directions indicated by the arrows in Fig. 7 and Fig. 8.

(1-1) Overall configuration

[0152] The heat exchanger 200 is a heat exchanger including a plurality of first heat transfer plates 210, a plurality of second heat transfer plates 220, a first frame 230, a second frame 240, a first flow pipe 250a, a first flow pipe 250b, a second flow pipe 260a, and a second flow pipe 260b.

[0153] A first flow path 211 and a second flow path 221 are provided inside the heat exchanger 200. As will be described in detail below, the heat exchanger 200 has a fragile portion 290 that prevents the refrigerant flowing through the second flow path 221 from flowing into the first flow path 211 when water freezes.

[0154] The first heat transfer plates 210 and the second heat transfer plates 220 are plate-shaped members made of metal and formed in the same rectangular outer shape. The first heat transfer plates 210 and the second heat transfer plates 220 have the same thickness. In the present embodiment, as illustrated in Fig. 7, the first heat transfer plates 210, the second heat transfer plates 220, the first frame 230, and the second frame 240 are formed in a rectangular outer shape elongated in the first direction (longitudinal direction DL).

[0155] The plurality of first heat transfer plates 210 and the plurality of second heat transfer plates 220 are alternately stacked. The number of each of the plurality of first heat transfer plates 210 and the plurality of second heat transfer plates 220 is not limited, and is appropriately set according to the required performance.

(1-2) Detailed configuration

(1-2-1) First heat transfer plate 210

[0156] The first heat transfer plate 210 is a corrugated fin having a corrugated cross section. In the present embodiment, the corrugated shape of the first heat transfer plate 210 is formed such that a top portion 210t draws a herring bone pattern that is convex upward in plan view. The first heat transfer plate 210 forms the first flow path 211 and the second flow path 221 together with the second heat transfer plate 220 stacked adjacent thereto. The first heat transfer plate 210 has a first joining region 210a, two first flow holes 210b, two first through holes 210c, a first surface 210sa, and a second surface 210sb.

[0157] The first joining region 210a is a region where the first heat transfer plate 210 and the second heat transfer plate 220 are joined to each other. The first joining region 210a is a strip-shaped region with an end edge of a predetermined width bent toward the front side.

[0158] The first flow holes 210b are holes for making water flow to the first flow path 211. The first flow holes 210b are formed on the upper right side and the lower left side.

[0159] The first through holes 210c are holes through which the refrigerant passes in the stacking direction DS. The first through holes 210c are formed on the upper left side and the lower right side.

[0160] The first surface 210sa is a surface on the front side of the first heat transfer plate 210. The first surface 210sa is a surface that faces a second surface 220sb of the second heat transfer plate 220, which will be described below, when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked.

[0161] The second surface 210sb is a surface on the back side of the first heat transfer plate 210. The second surface 210sb is a surface that faces a first surface 220sa of the second heat transfer plate 220, which will be described below, when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked.

[0162] The first heat transfer plate 210 is formed by, for example, but not limited to, pressing.

[0163] Regarding the shape of the first heat transfer plate 210, "corrugated" is not limited to a shape in which semicircular recesses and protrusions are periodically arranged as illustrated in Fig. 8, and may be a periodically changing shape such as a sine wave, a rectangular wave, or a triangular wave shape. The same applies to the second heat transfer plate 220.

(1-2-2) Second heat transfer plate 220

[0164] The second heat transfer plate 220 is a corrugated fin having a corrugated cross section. In the present embodiment, the corrugated shape of the second heat transfer plate 220 is formed such that a top portion 220t draws a herring bone pattern that is convex downward in plan view. The second heat transfer plate 220 forms the first flow path 211 and the second flow path 221 together with the first heat transfer plate 210 stacked adjacent thereto. The second heat transfer plate 220 has a second joining region 220a, two second flow holes 220b, two second through holes 220c, the first surface 220sa, and the second surface 220sb.

[0165] The second joining region 220a is a region where the first heat transfer plate 210 and the second heat transfer plate 220 are joined to each other. The second joining region 220a is a strip-shaped region with an end edge of a predetermined width bent toward the front side.

[0166] The second flow holes 220b are holes for making the refrigerant flow through the second flow path 221. The second flow holes 220b are formed on the upper right side and the lower left side. The second flow holes 220b are formed at positions overlapping and communicating with the first through holes 210c when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked. The size and shape of the second flow holes 220b are the same as those of the first through holes 210c.

[0167] The second through holes 220c are holes through which the water passes in the stacking direction DS. The second through holes 220c are formed on the upper left side and the lower right side. The second through holes 220c are formed at positions overlapping and communicating with the first flow holes 210b when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked. The size and shape of the second through holes 220c are the same as those of the first flow holes 210b.

[0168] The first surface 220sa is a surface on the front side of the second heat transfer plate 220. The first surface 220sa is a surface that faces the second surface 210sb of the first heat transfer plate 210 when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked.

[0169] The second surface 220sb is a surface on the back side of the second heat transfer plate 220. The second surface 220sb is a surface that faces the first surface 210sa of the first heat transfer plate 210 when the first heat transfer plate 210 and the second heat transfer plate 220 are stacked.

[0170] The second heat transfer plate 220 is formed by, for example, but not limited to, pressing.

(1-2-3) First frame 230 and second frame 240

[0171] The first frame 230 and the second frame 240 are plate-shaped members made of metal that sandwich the plurality of first heat transfer plates 210 and the plurality of second heat transfer plates 220, which are alternately stacked, at both ends in the stacking direction DS.

(1-2-4) First flow pipe 250a and first flow pipe 250b

[0172] The first flow pipe 250a is a pipe for making water flow through the first flow path 211. The first flow pipe 250a is provided through the upper left side of the first frame 230 to communicate with the first flow path 211. More specifically, the first flow pipe 250a is formed so as to communicate with the first flow hole 210b and the second through hole 220c formed on the upper left side, which communicate with each other when the first heat transfer plate 210, the second heat transfer plate 220, and the first frame 230 are stacked.

[0173] The first flow pipe 250b is a pipe for making water flow through the first flow path 211. The first flow pipe 250a is provided through the lower right side of the first frame 230 to communicate with the first flow path 211. More specifically, the first flow pipe 250a is formed so as to communicate with the first flow hole 210b and the second through hole 220c formed on the lower right side, which communicate with each other when the first heat transfer plate 210, the second heat transfer plate 220, and the first frame 230 are stacked.

[0174] Note that the first flow pipe 250a corresponds to the first flow pipe 170a of the heat exchanger 100. The first flow pipe 250b corresponds to the first flow pipe 170b of the heat exchanger 100.

(1-2-5) Second flow pipe 260a and second flow pipe 260b

[0175] The second flow pipe 260a is a pipe for making the refrigerant flow through the second flow path 221. The second flow pipe 260a is provided through the upper right side of the first frame 230 to communicate with the second flow path 221. More specifically, the second flow pipe 260a is formed so as to communicate with the second flow hole 220b and the first through hole 210c formed on the upper right side, which communicate with each other when the first heat transfer plate 210, the second heat transfer plate 220, and the first frame 230 are stacked.

[0176] The second flow pipe 260b is a pipe for making the refrigerant flow through the second flow path 221. The second flow pipe 260a is provided through the lower left side of the first frame 230 to communicate with the second flow path 221. More specifically, the second flow pipe 260a is formed so as to communicate with the second flow hole 220b and the first through hole 210c formed on the lower left side, which communicate with each other when the first heat transfer plate 210, the second heat transfer plate 220, and the first frame 230 are stacked.

[0177] The second flow pipe 260a corresponds to the second flow pipe 180a of the heat exchanger 100. The second flow pipe 260b corresponds to the second flow pipe 180b of the heat exchanger 100.

(1-2-6) First flow path 211 and second flow path 221

[0178] The first flow paths 211 and the second flow paths 221 are alternately formed in the stacking direction DS by alternately stacking the first heat transfer plates 210 and the second heat transfer plates 220. More specifically, by alternately stacking the first heat transfer plates 210 and the second heat transfer plates 220, a space in which the first surface 210sa of the first heat transfer plate 210 and the second surface 220sb of the second heat transfer plate 220 face each other is formed to be the first flow path 211. Furthermore, by alternately stacking the first heat transfer plates 210 and the second heat transfer plates 220, a space in which the second surface 210sb of the first heat transfer plate 210 and the first surface 220sa of the second heat transfer plate 220 face each other is formed to be the first flow path 211.

[0179] The first flow path 211 corresponds to the first flow path 111 of the heat exchanger 100. The second flow path 221 corresponds to the second flow path 121 of the heat exchanger 100.

[0180] In the present embodiment, the first heat transfer plate 210 and the second heat transfer plate 220 are joined by brazing. More specifically, the first heat transfer plate 210 and the second heat transfer plate 220 are joined to each other by brazing in the first joining region 210a and the second joining region 220a, and the top portion 210t of the first heat transfer plate 210 and the top portion 220t of the second heat transfer plate 220 are joined to each other by brazing. Hereinafter, for the sake of simplicity, a portion where the first surface 210sa side of the top portion 210t of the first heat transfer plate 210 and the second surface 220sb side of the top portion 220t of the second heat transfer plate 220 are joined is referred to as a third joining portion 210d, and a portion where the first surface 210sa side of the first joining region 210a and the second surface 220sb side of the second joining region 220a are joined is referred to as a fourth joining portion 210e.

(1-2-7) Fragile portion 290

[0181] The heat exchanger 200 has the fragile portion 290 that has lower strength than other portions and breaks when the water freezes and expands in volume. The fragile portion 290 is any one of joining portions where members forming the first flow path 211 are joined to each other. In the present embodiment, the third joining portion 210d and the fourth joining portion 210e function as the fragile portion 290. In this case, it is preferable that the third joining portion 210d and the fourth joining portion 210e are formed such that the third joining portion 210d breaks first and then the fourth joining portion 210e breaks when the volume expansion of the water reaches or exceeds a certain level.

[0182] In order to make the third joining portion 210d function as the fragile portion 290, it is preferable that the sizes of the respective parts forming the first flow path 211 satisfy the relationship described in (Formula 7) below. Here, it is assumed that bw3 represents the width of the third joining portion 210d as viewed along the normal direction, and t represents the thickness of the first heat transfer plate 210 and the second heat transfer plate.

$$0.35 \times bw3 < 2 \times t \text{ ... (Formula 7)}$$

[0183] For example, bw3 is 1 mm, and t is 2 mm.

[0184] In order to make the fourth joining portion 210e function as the fragile portion 290, it is preferable that the sizes of the respective parts forming the first flow path 211 satisfy the relationship described in (Formula 8) below. Here, it is assumed that bsp4 represents the width of the fourth joining portion 210e as viewed along the normal direction.

$$0.35 \times (bsp4 + bw3/2) < 2 \times t \ldots \text{(Formula 8)}$$

[0185] For example, bsp4 is 1 mm.

(1-3) Flow of refrigerant and water

[0186] The water introduced from the first flow pipe 250a of the heat exchanger 200 passes through the second through hole 220c and the first flow hole 210b on the upper side and flows into the first flow path 211. The water that has flowed into the first flow path 211 flows through the first flow path 211 toward the first flow hole 210b on the lower side. The water that has reached the first flow hole 210b on the lower side passes through the second through hole 220c on the lower side and is led out from the first flow pipe 250b. The water introduced from the first flow pipe 250b of the heat exchanger 200 passes through the second through hole 220c and the first flow hole 210b on the lower side and flows into the first flow path 211. The water that has flowed into the first flow path 211 flows through the first flow path 211 toward the first flow hole 210b on the upper side. The water that has reached the first flow hole 210b on the upper side passes through the second through hole 220c on the upper side and is led out from the first flow pipe 250a. In either case, the water flowing through the first flow path 211 exchanges heat with the refrigerant in the adjacent second flow path 221 via the first heat transfer plate 210 or the second heat transfer plate 220.

[0187] On the other hand, the refrigerant introduced from the second flow pipe 260a of the heat exchanger 200 passes through the first through hole 210c and the second flow hole 220b on the upper side and flows into the second flow path 221. The refrigerant that has flowed into the second flow path 221 flows through the second flow path 221 toward the second flow hole 220b on the lower side. The refrigerant that has reached the second flow hole 220b on the lower side passes through the first through hole 210c on the lower side and is led out from the second flow pipe 260b. In addition, the refrigerant introduced from the second flow pipe 260b of the heat exchanger 200 passes through the first through hole 210c and the second flow hole 220b on the lower side and flows into the second flow path 221. The refrigerant that has flowed into the second flow path 221 flows through the second flow path 221 toward the second flow hole 220b on the upper side. The refrigerant that has reached the second flow hole 220b on the upper side passes through the first through hole 210c on the upper side and is led out from the second flow pipe 260a. In either case, the water flowing through the second flow path 221 is condensed (during the heating operation) or evaporated (during the cooling operation and the defrosting operation) by exchanging heat with the water in the adjacent first flow path 211 via the first heat transfer plate 210 or the second heat transfer plate 220.

(2) Features

[0188] (2-1) In the heat exchanger 200, the first flow path 211 includes the first heat transfer plate 210, the second heat transfer plate 220, the third joining portion 210d, and the fourth joining portion 210e. The first heat transfer plate 210 and the second heat transfer plate 220 are stacked on each other. Each of the first heat transfer plate 210 and the second heat transfer plate 220 has a corrugated cross section. The third joining portion is a portion where the top portions 210t and 220t of the first heat transfer plate 210 and the second heat transfer plate 220 are joined. The fourth joining portion 210e is a portion where the end edges of the first heat transfer plate 210 and the second heat transfer plate 220 are joined.

[0189] (2-2) The fragile portion 290 is the third joining portion 210d.

[0190] According to the heat exchanger 200, when the water freezes and expands in volume, the third joining portion 210d where members forming the first flow path 211 are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

[0191] (2-3) The joining in the third joining portion 210d is joined by brazing. The following relationship is satisfied with bw3 representing the width of the third joining portion 210d as viewed along the normal direction, and t representing the thickness of the first heat transfer plate 210 and the second heat transfer plate 220.

$$0.35 \times bw3 < 2 \times t \ldots \text{(Formula 7)}$$

[0192] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the first heat transfer plate 210 and the second heat transfer plate 220 smaller than the stress generated in the third joining portion 210d when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the third joining portion 210d, which breaks before the first heat transfer plate 210 and the second heat transfer plate 220. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

[0193] (2-4) The fragile portion 290 is the fourth joining portion 210e.

[0194] According to the heat exchanger 200, when the water freezes and expands in volume, the fourth joining portion 210e where members forming the first flow path 211 are joined to each other breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

[0195] (2-5) The joining in the fourth joining portion 210e is joined by brazing. The following relationship is satisfied with bsp4 representing the width of the fourth joining portion 210e as viewed along the normal direction, bw3 representing the width of the third joining portion as viewed along the normal direction, and t representing the thickness of the first heat transfer plate 210 and the second heat transfer plate 220.

$$0.35 \times (bsp4 + bw3/2) < 2 \times t \ldots \text{(Formula 8)}$$

[0196] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the first heat transfer plate 210 and the second heat transfer plate 220 smaller than the stress generated in the fourth joining portion 210e when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fourth joining portion 210e, which breaks before the first heat transfer plate 210 and the second heat transfer plate 220. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

(3) Modifications

(3-1) Modification 2A

[0197] In the above embodiment, the third joining portion 210d and the fourth joining portion 210e function as the fragile portion 290, but only one of the third joining portion 210d and the fourth joining portion 210e may be formed so as to function as the fragile portion 290 as long as the breakage of the members forming the second flow path 121 can be prevented.

(3-2) Modification 2B

[0198] In the above embodiment, joining in the third joining portion 210d and the fourth joining portion 210e are joined by brazing, but the joining in the third joining portion 210d and the fourth joining portion 210e may be joined by diffusion joining.

[0199] As in the case of the heat exchanger 200 according to the second embodiment, in the heat exchanger 200 according to Modification 2B, the third joining portion 210d or the fourth joining portion 210e, which functions as the fragile portion 290, breaks before the other portions when the water freezes and expands in volume. Therefore, in the heat exchanger 200 according to Modification 2B, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed when water freezes and expands in volume.

[0200] In order to make the third joining portion 210d function as the fragile portion 290, it is preferable that the sizes of the respective parts forming the first flow path 211 satisfy the relationship described in (Formula 9) below.

$$bw3 < 2 \times t \ldots \text{(Formula 9)}$$

[0201] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the first heat transfer plate 210 and the second heat transfer plate 220 smaller than the stress generated in the third joining portion 210d when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the third joining portion 210d, which breaks before the first heat transfer plate 210 and the second heat transfer plate 220. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

[0202] In order to make the fourth joining portion 210e function as the fragile portion 290, it is preferable that the sizes of the respective parts forming the first flow path 211 satisfy the relationship described in (Formula 10) below.

$$(bsp4 + bw3/2) < 2 \times t \text{ (Formula 10)}$$

[0203] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated in the first heat transfer plate 210 and the second heat transfer plate 220 smaller than the stress generated in the fourth joining portion 210e when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fourth joining portion 210e, which breaks before the first heat transfer plate 210 and the second heat transfer plate 220. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 221 is suppressed.

<Third embodiment>

(1) Heat exchanger

[0204] A heat exchanger 300 according to a third embodiment of the present disclosure will be described. The main difference between the heat exchanger 100 and the heat exchanger 300 is that the heat exchanger 100 has flow paths formed by stacking inner fins and partition walls, whereas the heat exchanger 300 has flow paths formed by stacking two heat transfer plates.

[0205] The refrigerant cycle apparatus 1 may include the heat exchanger 300 instead of the heat exchanger 100. Since the configuration and operation of the refrigerant cycle apparatus 1 including the heat exchanger 300 are the same as those of the heat exchanger 100, detailed description thereof will be omitted.

[0206] The longitudinal direction DL, the width direction DW, and the stacking direction DS correspond to the directions indicated by the arrows in the drawings. The back, front, up, down, left, and right directions used in the following description correspond to the directions indicated by the arrows in Fig. 9 and Fig. 10. Note that features similar to or corresponding to those of the first embodiment are denoted by the same reference numerals, and description thereof is omitted as appropriate.

(1-1) Overall configuration

[0207] The heat exchanger 300 is a heat exchanger including a plurality of first heat transfer plates 310, a plurality of second heat transfer plates 320, the casing 160, the first flow pipe 170a, the first flow pipe 170b, the second flow pipe 180a, and the second flow pipe 180b. In other words, the heat exchanger 300 includes the first heat transfer plates 310 and the second heat transfer plates 320 instead of the first inner fins 110, the second inner fins 120, the partition walls 130, the first separation members 140, and the second separation members 150 of the heat exchanger 100. A first flow path 311 through which water flows and a second flow path 321 through which a refrigerant flows are formed inside the heat exchanger 300. As will be described in detail below, the heat exchanger 300 includes a fragile portion 390 that prevents the refrigerant flowing through the second flow path 321 from flowing into the first flow path 311 when water freezes.

[0208] The first heat transfer plates 310 and the second heat transfer plates 320 are plate-shaped members made of metal and formed in the same rectangular outer shape. In the present embodiment, as illustrated in Figs. 9 and 10, the first heat transfer plate 310 and the second heat transfer plate 320 are formed in a rectangular shape elongated in the first direction (longitudinal direction DL), similarly to the first inner fins 110, the second inner fins 120, and the partition walls 130.

[0209] The first heat transfer plates 310 and the second heat transfer plates 320 are alternately stacked along the stacking direction DS and accommodated in the casing 160. The number of each of the first heat transfer plates 310 and the second heat transfer plates 320 is not limited, and is appropriately set according to the required performance.

(1-2) Detailed configuration

(1-2-1) First heat transfer plate 310 and first flow path 311

[0210] The first heat transfer plate 310 is a plate-shaped member in which a plurality of first flow paths 311 are formed. The first flow path 311 is formed to extend along the longitudinal direction DL in plan view. The plurality of first flow paths 311 are formed side by side at a predetermined interval in the width direction DW. In the present embodiment, the first flow path 311 has a rectangular cross-sectional shape taken along a plane perpendicular to the direction in which water flows. The first flow path 311 is formed by, for example, but not limited to, etching.

[0211] More specifically, the first heat transfer plate 310 is formed by stacking a plate-shaped member 310a and a plate-shaped member 310b in the stacking direction DS. In the plate-shaped members 310a and 310b, grooves 311a and 311b are formed by etching so as to face each other to form the first flow path 311 when the plate-shaped members are stacked.

[0212] In the present embodiment, the plate-shaped member 310a and the plate-shaped member 310b are joined by brazing. Hereinafter, for the sake of simplicity, a portion at which the plate-shaped member 310a and the plate-shaped member 310b are joined to each other and which is located between the adjacent first flow paths 311 in plan view is referred to as a fifth joining portion 310c. In addition, a portion where the plate-shaped member 310a and the plate-shaped member 310b are joined to each other and which is located between the end portion of the first heat transfer plate 310 in the width direction DW and the first flow path 311 formed closest to the end portion is referred to as a sixth joining portion 310d. The fifth joining portion 310c and the sixth joining portion 310d are examples of joining portions.

[0213] The first flow path 311 corresponds to the first flow path 111 of the heat exchanger 100.

(1-2-2) Second heat transfer plate 320 and second flow path 321

[0214] The second heat transfer plate 320 is a plate-shaped member in which a plurality of second flow paths 321 are formed. The second flow path 321 is formed so as to extend along the width direction DW in plan view. The plurality of second flow paths 321 are formed side by side at a predetermined interval in the longitudinal direction DL. The second flow path 321 is formed by, for example, but not limited to, etching.

[0215] The second flow path 321 corresponds to the second flow path 121 of the heat exchanger 100.

(1-2-3) Fragile portion 390

[0216] The heat exchanger 300 has the fragile portion 390 that has lower strength than other portions and breaks when the water freezes and expands in volume. In the present embodiment, the first heat transfer plate 310, which is a member forming the first flow path 311, functions as the fragile portion 390.

[0217] In order to make the first heat transfer plate 310 function as the fragile portion 390, it is preferable that the sizes of the respective parts of the first heat transfer plate 310 satisfy the relationship described in (Formula 11) below. Here, it is assumed that tw3 represents the interval, in the width direction DW, of the first flow paths 311 formed in the first heat transfer plate 310, Lw3 represents the sum of the interval tw3 and the width of the first flow path 311 in the width direction DW, tR3 represents the interval between the first flow path 311 and the second flow path 321 in the stacking direction DS, and hw3 represents the height of the first flow path 311 in the stacking direction DS.

$$tw3/(2 \times Lw3) < tR3/hw3 \text{ ... (Formula 11)}$$

[0218] For example, tw3 is 0.15 mm. For example, Lw3 is 2 mm, tR3 is 0.15 mm, and hw3 is 1 mm.

[0219] Further, in order to make the first heat transfer plate 310 function as the fragile portion 390, it is preferable that the sizes of the respective parts forming the first heat transfer plate 310 further satisfy the relationship described in (Formula 12) below. Here, it is assumed that Lsp3 represents the interval in the width direction DW between an end portion of the first heat transfer plate 310 in the width direction DW and the first flow path 311 formed closest to the end portion.

$$((Lsp3 + tw3/2)/Lw3) < tR3/hw3 \text{ ... (Formula 12)}$$

[0220] For example, Lsp3 is 0.1 mm.

(2) Features

[0221] (2-1) The heat exchanger 300 includes the first heat transfer plate 310 and the second heat transfer plate 320. The first heat transfer plate 310 has the first flow path 311 formed therein. The second heat transfer plate 320 has the second flow path 321 formed therein. The fragile portion 390 is the first heat transfer plate 310.

[0222] According to the heat exchanger 300, when the water freezes and expands in volume, the first heat transfer plate 310 forming the first flow path 311 breaks before the other portions. Thus, the leakage of the refrigerant due to the breakage of the second heat transfer plate 320 forming the second flow path 321 is suppressed.

(3) Modifications

(3-1) Modification 3A

[0223] In the above embodiment, a member forming the first flow path 311 functions as the fragile portion 390, but the fragile portion 390 may be a portion where members forming the first flow path 311 are joined to each other. Specifically, the fragile portion 390 may be the fifth joining portion 310c. Further, the fragile portion 190 may be the fifth joining portion 310c and the sixth joining portion 310d. In this case, it is preferable that the fifth joining portion 310c breaks first and then the sixth joining portion 310d breaks when the volume expansion of the water reaches or exceeds a certain level.

[0224] In the heat exchanger 300 according to Modification 3A, the fifth joining portion 310c or the sixth joining portion 310d, which functions as the fragile portion 390, breaks before the other portions when the water freezes and expands in volume. Therefore, in the heat exchanger 300 according to Modification 3A, when the water freezes and expands in volume, the leakage of the refrigerant due to the breakage of the member (second heat transfer plate 320) forming the second flow path 321 is suppressed.

[0225] In order to make the fifth joining portion 310c function as the fragile portion 390, it is preferable that the sizes of the respective parts of the first heat transfer plate 310 forming the first flow path 311 satisfy the relationship described in (Formula 13) below. Here, it is assumed that bw5 represents the width of the fifth joining portion 310c in plan view.

$$0.35 \times bw5/(2 \times Lw3) < tR3/hw3 \text{ ... (Formula 13)}$$

[0226] For example, bw5 is 0.035 mm.

[0227] Through the formation with the sizes of the respective parts of the first heat transfer plate 310 satisfying the above-described relationship, it is possible to make the stress generated between the first flow path 311 and the second flow path 321 smaller than the stress generated in the fifth joining portion 310c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fifth joining portion 310c, which breaks before the portion between the first flow path 311 and the second flow path 321. Thus, the leakage of the refrigerant due to the breakage of the member forming the second flow path 321 is suppressed.

[0228] In order to make the sixth joining portion 310d function as the fragile portion 390, it is preferable that the sizes of the respective parts of the first heat transfer plate 310 forming the first flow path 311 satisfy the relationship described in (Formula 14) below. Here, it is assumed that bsp6 represents the width of the sixth joining portion 310d in plan view.

$$0.35 \times (2 \times bsp6 + bw5)/Lw3 < 2 \times tR3/hw3 \text{ ... (Formula 14)}$$

[0229] For example, bsp6 is 0.1 mm.

[0230] Through the formation with the sizes of the respective parts of the first heat transfer plate 310 satisfying the above-described relationship, it is possible to make the stress generated between the first flow path 311 and the second flow path 321 smaller than the stress generated in the sixth joining portion 310d when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the sixth joining portion 310d, which breaks before the portion between the first flow path 311 and the second flow path 321. Thus, the leakage of the refrigerant due to the breakage of the member (second heat transfer plate 320) forming the second flow path 321 is suppressed.

[0231] In the heat exchanger 300, the first heat transfer plate 310 is formed by stacking the two plate-shaped members 310a and 310b in which the grooves 311a and 312b forming the first flow path 311 are formed. The fragile portion 390 is a portion where the two plate-shaped members 310a and 310b are joined.

[0232] According to the heat exchanger 300, when the water freezes and expands in volume, the portions (fifth joining portion 310c, sixth joining portion 310d) where the two plate-shaped members 310a and 310b forming the first heat transfer plate 310 are joined break before the other portions. Thus, the leakage of the refrigerant due to the breakage of the second heat transfer plate 320 forming the second flow path is suppressed.

(3-2) Modification 3B

[0233] In the above embodiment, joining in the fifth joining portion 310c and the sixth joining portion 310d is joined by brazing, but the joining in the fifth joining portion 310c and the sixth joining portion 310d may be joined by diffusion joining.

[0234] As in the case of the heat exchanger 300 according to Modification 3A, in the heat exchanger 300 according to Modification 3B, in which the joining in the fifth joining portion 310c and the sixth joining portion 310d is implemented by diffusion joining, the fifth joining portion 310c or the sixth joining portion 310d, which functions as the fragile portion 390, breaks before the portion between the first flow path 311 and the second flow path 321 when the water freezes and expands in volume. Therefore, in the heat exchanger 300 according to Modification 3B, when the water freezes and expands in volume the leakage of the refrigerant due to the breakage of the member (second heat transfer plate 320) forming the second flow path 321 is suppressed.

[0235] In order to make the fifth joining portion 310c function as the fragile portion 390, it is preferable that the sizes of the respective parts of the first heat transfer plate 310 forming the first flow path 311 satisfy the relationship described in (Formula 15) below.

$$bw5/(2 \times Lw3) < tR3/hw3 \ldots \text{(Formula 15)}$$

[0236] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated between the first flow path 311 and the second flow path 321 smaller than the stress generated in the fifth joining portion 310c when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the fifth joining portion 310c, which breaks before the portion between the first flow path 311 and the second flow path 321. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 321 is suppressed.

[0237] In order to make the sixth joining portion 310d function as the fragile portion 190, it is preferable that the sizes of the respective parts of the first heat transfer plate 310 forming the first flow path 111 satisfy the relationship described in (Formula 16) below.

$$(2 \times bsp6 + bw5)/Lw3 < 2 \times tR3/hw3 \ldots \text{(Formula 16)}$$

[0238] Through the formation with the sizes of the respective parts satisfying the above-described relationship, it is possible to make the stress generated between the first flow path 311 and the second flow path 321 smaller than the stress generated in the sixth joining portion 310d when the water freezes and expands in volume. With this configuration, the force generated by the volume expansion can be absorbed by the sixth joining portion 310d, which breaks before the portion between the first flow path 311 and the second flow path 321. Thus, the leakage of the refrigerant due to the breakage of the members or the joining portions forming the second flow path 321 is suppressed.

[0239] While embodiments of the present disclosure have been described above, it should be understood that various changes in mode and detail may be made without departing from the spirit and scope of the present disclosure as set forth in the claims.

Reference Signs List

[0240]

1 Refrigerant cycle apparatus
100, 200, 300 Heat exchanger
110 First inner fin
110c First joining portion
110t Top portion
111, 211, 311 First flow path
130 Partition wall
140 Separation member
140c Second joining portion
210, 310 First heat transfer plate
210d Third joining portion
210e Fourth joining portion
220, 320 Second heat transfer plate
121, 221, 321 Second flow path
190, 290, 390 Fragile portion
310a, 310b Plate-shaped member
310c Fifth joining portion
310d Sixth joining portion
311a, 311b Groove

Citation List

Patent Literature

[0241] PTL 1: Japanese Unexamined Patent Application Publication No. H10-132476

Claims

1. A heat exchanger (100, 200, 300) that causes heat exchange between water and a refrigerant, the heat exchanger comprising:

   a first flow path (111, 211, 311) through which the water flows; and
   a second flow path (121, 221, 321) through which the refrigerant flows, wherein
   any one of members (110, 140) forming the first flow path other than a partition wall (130) partitioning the first flow path and the second flow path or any one of joining portions (110c, 140c, 210d, 210e) where members forming the first flow path are joined to each other functions as a fragile portion (190, 290, 390) with a lower strength than the other members forming the first flow path.

2. The heat exchanger according to claim 1, wherein the first flow path is formed using

   two partition walls,
   inner fins (110) stacked between the two partition walls and each having a corrugated cross section, and
   separation members (140) disposed at end edges of the two partition walls and each separating the two partition walls from each other.

3. The heat exchanger according to claim 2, wherein the fragile portion is the inner fins.

4. The heat exchanger according to claim 3, wherein the following relationship is satisfied with tw representing a thickness of the inner fin,

   Lw representing an interval between top portions (110t) of the inner fin in contact with the same partition wall,
   tR representing a thickness of the partition wall, and
   hw representing a height of the inner fin in a stacking direction:

$$tw/Lw < tR/hw.$$

5. The heat exchanger according to claim 2, wherein the fragile portion is the separation members.

6. The heat exchanger according to claim 5, wherein the following relationship is satisfied with Lsp representing a width of the separation member in plan view,

   tw representing a thickness of the inner fin,
   Lw representing an interval between top portions of the inner fin in contact with the same partition wall,
   tR representing a thickness of the partition wall, and
   hw representing a height of the inner fin in a stacking direction:

$$((Lsp + tw)/Lw) < tR/hw.$$

7. The heat exchanger according to claim 1, wherein the first flow path is formed using

   two partition walls,
   inner fins (110) stacked between the two partition walls and each having a corrugated cross section, and
   separation members (140) disposed at end edges of the two partition walls and each separating the two partition walls from each other,
   the heat exchanger comprising:

      a first joining portion (110c) where the partition wall and top portions of the inner fin are joined; and
      a second joining portion (140c) where the partition wall and the separation member are joined.

8. The heat exchanger according to claim 7, wherein the fragile portion is the first joining portion.

9. The heat exchanger according to claim 8, wherein

joining in the first joining portion is joined by brazing, and the following relationship is satisfied with bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$0.35 \times \mathrm{bw1}/(2 \times \mathrm{Lw}) < \mathrm{tR}/\mathrm{hw}.$$

10. The heat exchanger according to claim 8, wherein

joining in the first joining portion is implemented by diffusion joining, and the following relationship is satisfied with bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$\mathrm{bw1}/(2 \times \mathrm{Lw}) < \mathrm{tR}/\mathrm{hw}.$$

11. The heat exchanger according to claim 7, wherein the fragile portion is the second joining portion.

12. The heat exchanger according to claim 11, wherein

joining in the second joining portion is joined by brazing, and the following relationship is satisfied with bsp2 representing a width of the second joining portion, bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$0.35 \times (2 \times \mathrm{bsp2} + \mathrm{bw1})/\mathrm{Lw} < 2 \times \mathrm{tR}/\mathrm{hw}.$$

13. The heat exchanger according to claim 11, wherein

joining in the second joining portion is implemented by diffusion joining, and the following relationship is satisfied with bsp2 representing a width of the second joining portion, bw1 representing a width of the first joining portion, Lw representing an interval between the top portions of the inner fin in contact with the same partition wall, tR representing a thickness of the partition wall, and hW representing a height of the inner fin in a stacking direction:

$$(2 \times \mathrm{bsp2} + \mathrm{bw1})/\mathrm{Lw} < 2 \times \mathrm{tR}/\mathrm{hw}.$$

14. The heat exchanger according to claim 1, wherein the first flow path is formed using

two heat transfer plates (210, 220) stacked on each other and each having a corrugated cross section,
the heat exchanger comprising:

a third joining portion (210d) where top portions of the two heat transfer plates are joined; and
a fourth joining portion (210e) where end edges of the two heat transfer plates are joined.

15. The heat exchanger according to claim 14, wherein the fragile portion is the third joining portion.

16. The heat exchanger according to claim 15, wherein

the third joining portion is
joined by brazing, and
the following relationship is satisfied with bw3 presenting a width of the third joining portion as viewed along a normal direction and
t representing a thickness of the heat transfer plate:

$$0.35 \times bw3 < 2 \times t.$$

17. The heat exchanger according to claim 15, wherein

the third joining portion is
implemented by diffusion joining, and
the following relationship is satisfied with bw3 presenting a width of the third joining portion as viewed along a normal direction
and t representing a thickness of the heat transfer plate:

$$bw3 < 2 \times t.$$

18. The heat exchanger according to claim 14, wherein the fragile portion is the fourth joining portion.

19. The heat exchanger according to claim 18, wherein

the fourth joining portion is
joined by brazing, and
the following relationship is satisfied with bsp4 representing a width of the fourth joining portion as viewed along a normal direction,
bw3 presenting a width of the third joining portion as viewed along the normal direction, and
t representing a thickness of the heat transfer plate:

$$0.35 \times (bsp4 + bw3/2) < 2 \times t.$$

20. The heat exchanger according to claim 18, wherein

the fourth joining portion is
implemented by diffusion joining, and
the following relationship is satisfied with bsp4 representing a width of the fourth joining portion as viewed along a normal direction,
bw3 presenting a width of the third j oining portion as viewed along the normal direction, and
t representing a thickness of the heat transfer plate:

$$(bsp4 + bw3/2) < 2 \times t.$$

21. The heat exchanger according to claim 1, comprising:

a first heat transfer plate (310) having the first flow path formed therein; and
a second heat transfer plate (320) having the second flow path formed therein, wherein
the fragile portion is
the first heat transfer plate.

22. The heat exchanger according to claim 21, wherein

the first heat transfer plate is
formed by stacking two plate-shaped members (310a, 310b) in which grooves (311a, 311b) forming the first flow path are formed, and
the fragile portion is
a portion (310c, 310d) where the two plate-shaped members are joined.

23. The heat exchanger according to any one of claims 1 to 22, wherein the refrigerant is flammable or toxic.

24. The heat exchanger according to any one of claims 1 to 23, wherein the fragile portion is formed with such a strength that the fragile portion breaks when the water freezes.

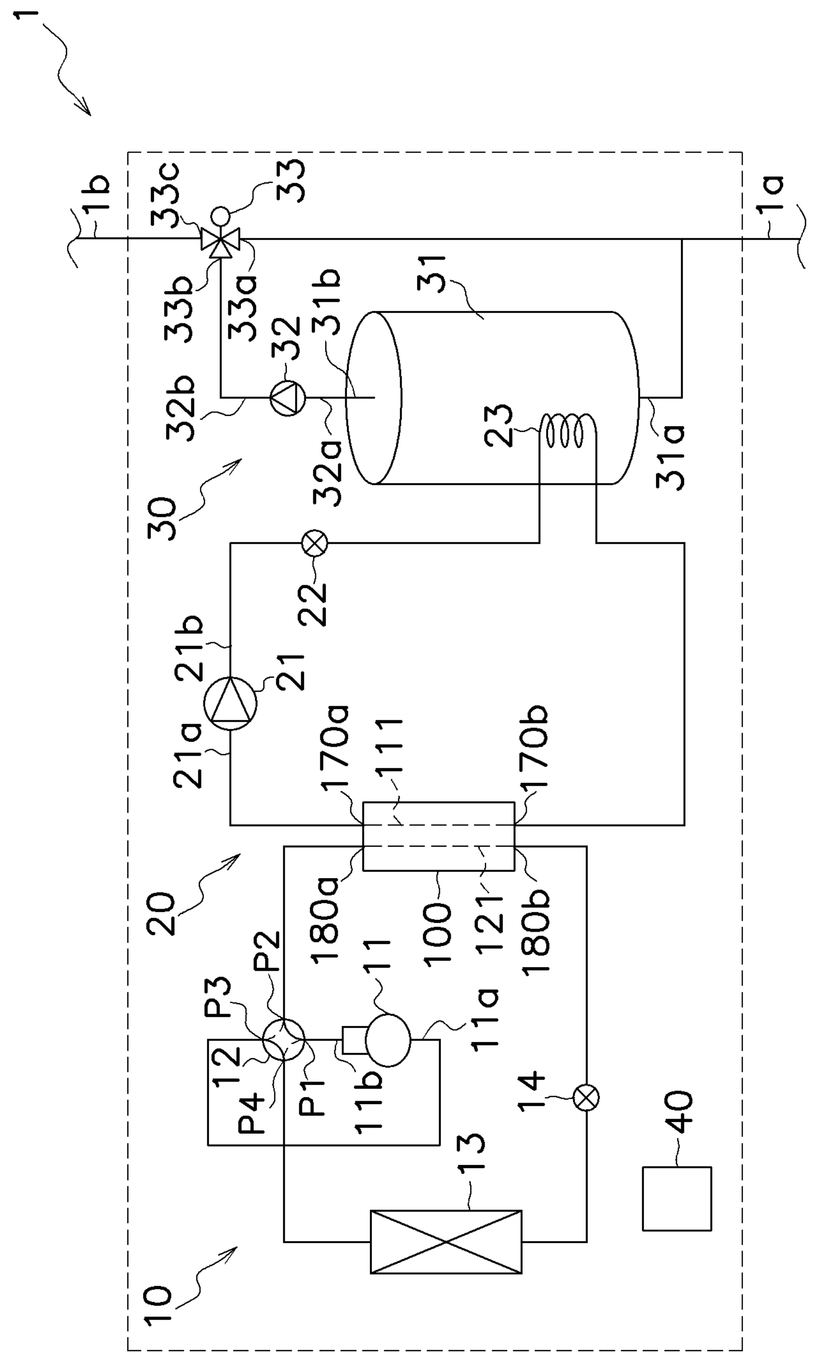

1
1b
33c
33
1a
33b
33a
31b
31
32
32b
23
32a
31a
30
22
21b
21
21a
170a
111
170b
20
180a
100
121
180b
P2
P3
11
12
11a
P4
P1
11b
14
40
13
10

FIG. 1

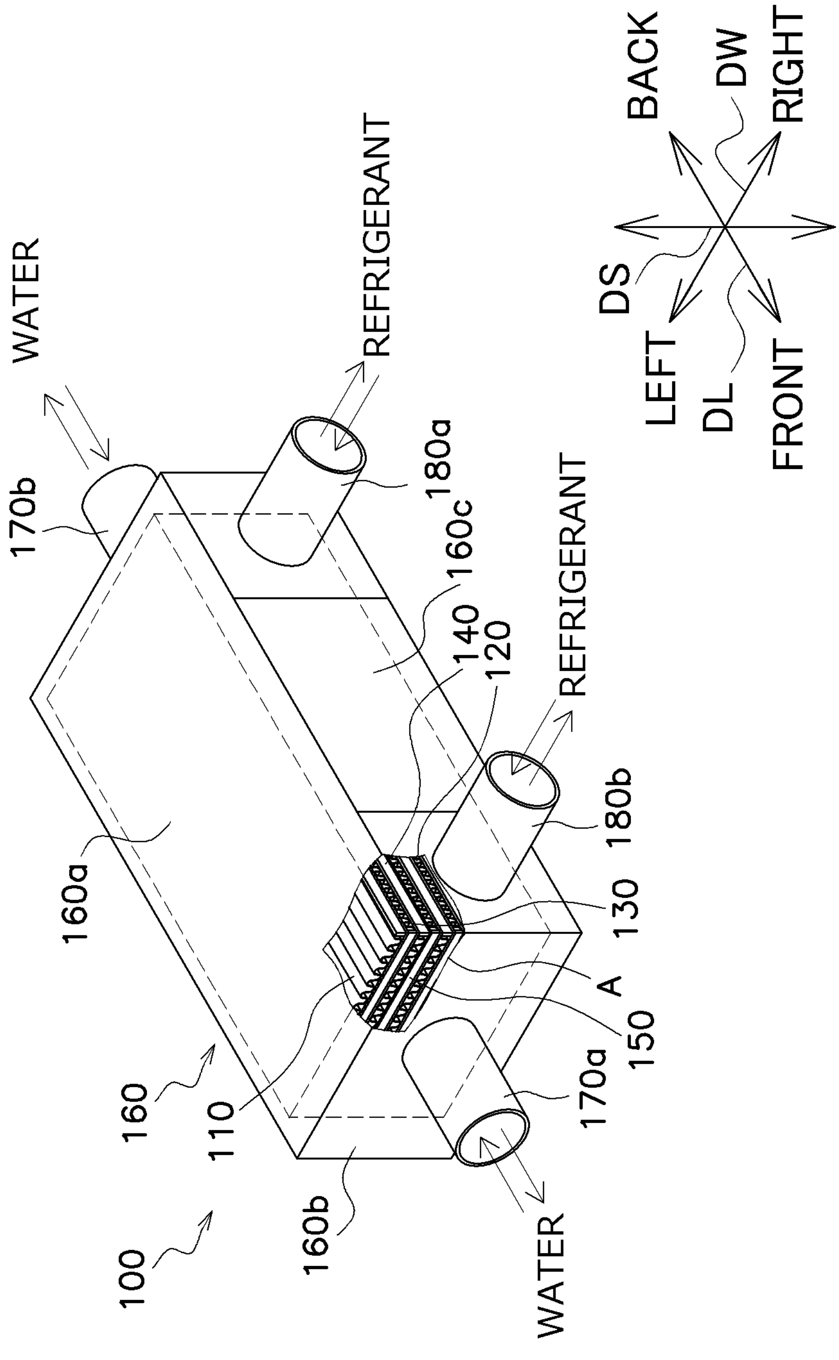
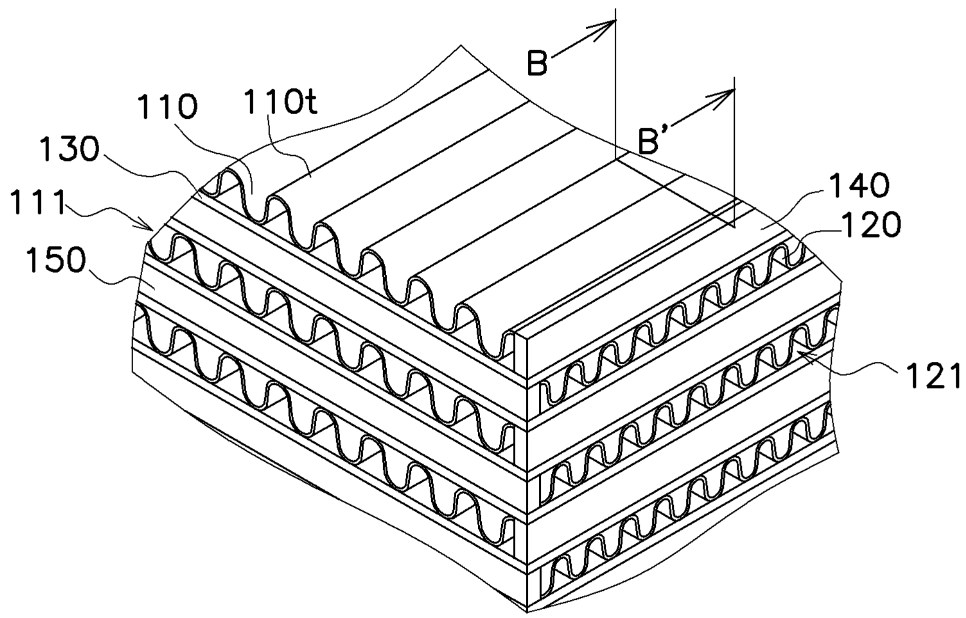

WATER
REFRIGERANT
170b
180a
160c
140
120
REFRIGERANT
160a
180b
130
A
150
170a
160
110
160b
100
WATER
BACK
DW
RIGHT
DS
LEFT
DL
FRONT

FIG. 2



ENLARGED VIEW OF PORTION A

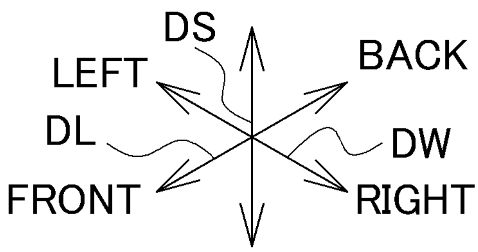


FIG. 3

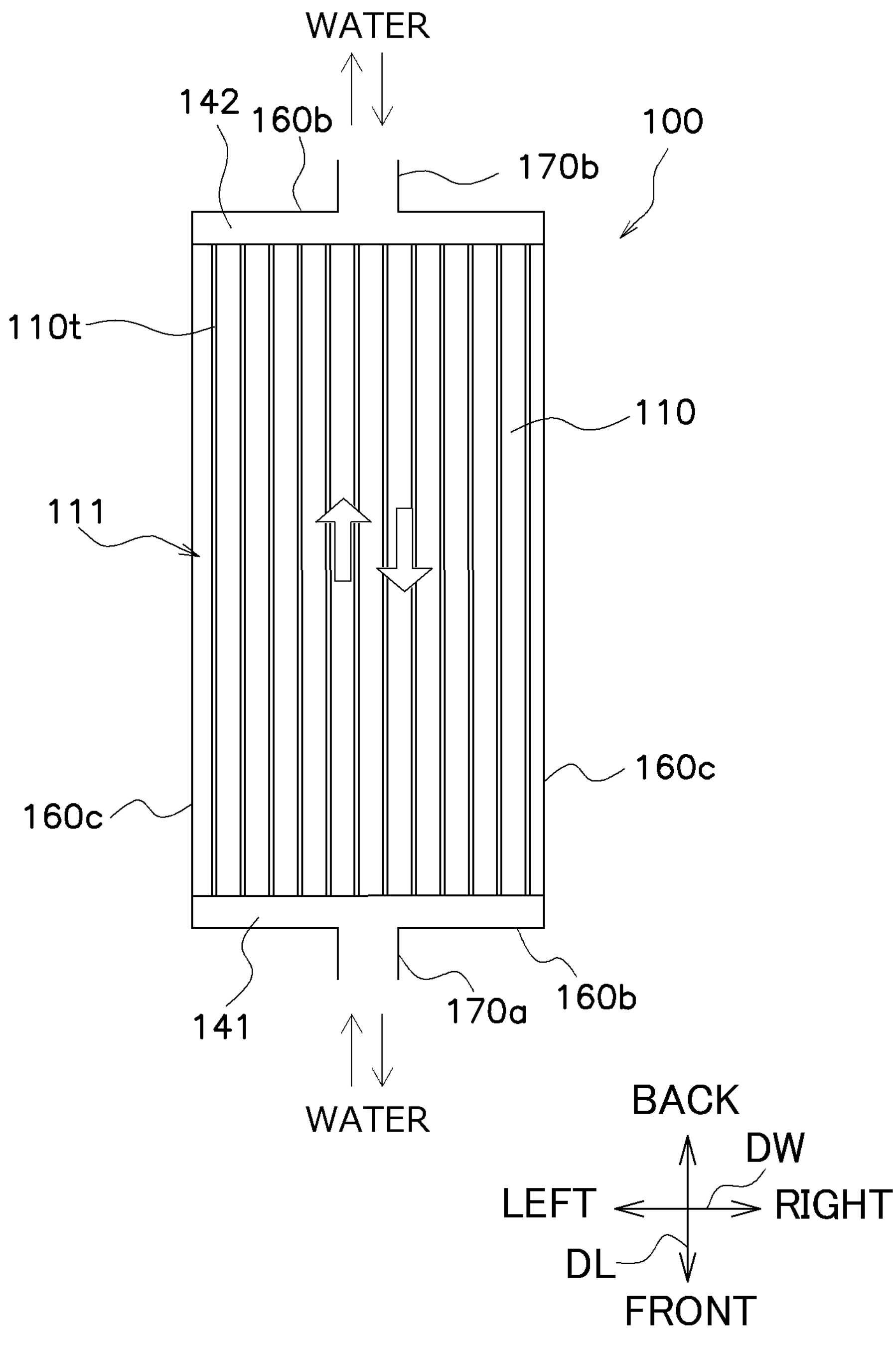

WATER
142
160b
170b
100
110t
110
111
160c
160c
141
170a
160b
WATER
BACK
DW
LEFT
RIGHT
DL
FRONT

FIG. 4

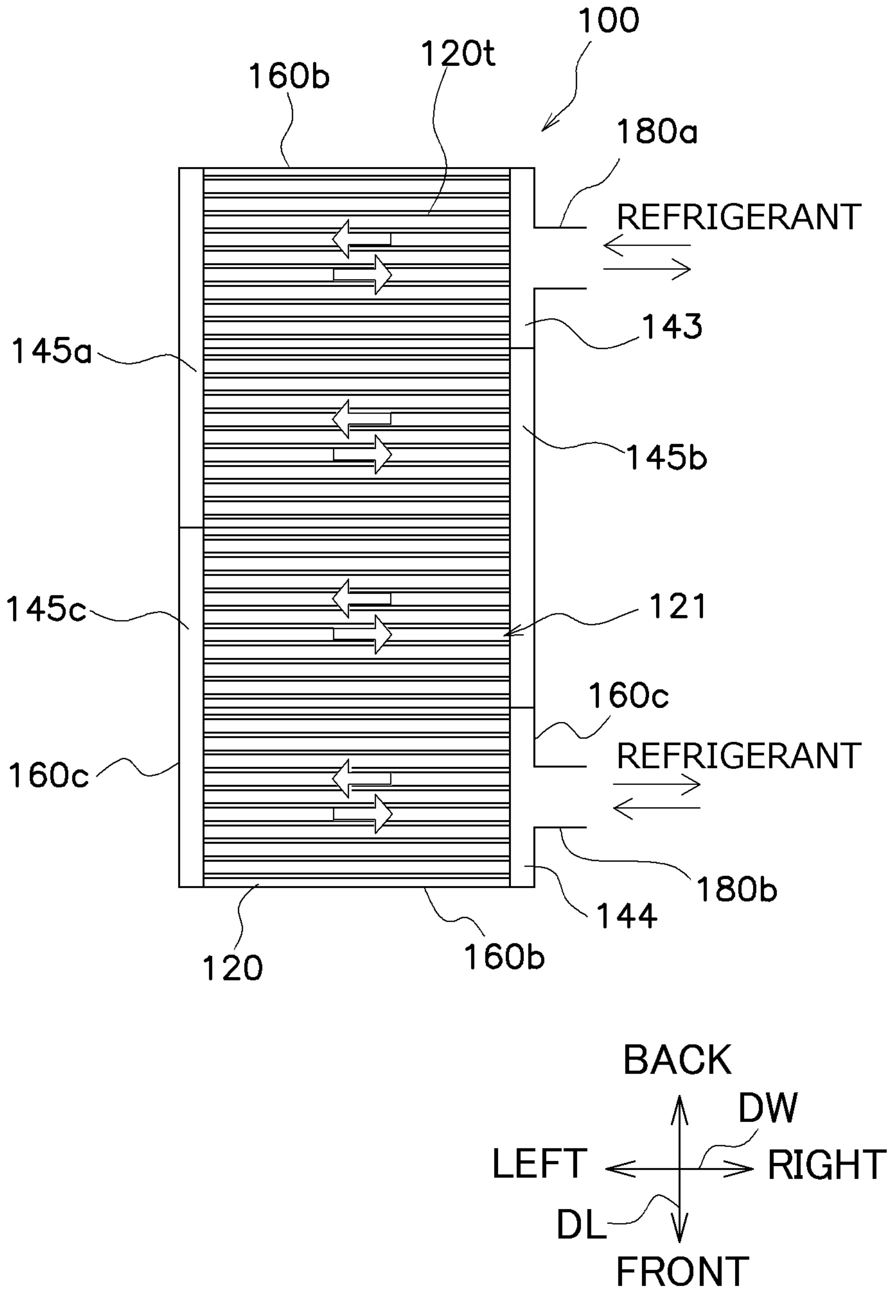

100
120t
160b
180a
REFRIGERANT
143
145a
145b
145c
121
160c
REFRIGERANT
160c
180b
144
120
160b
BACK
DW
LEFT
RIGHT
DL
FRONT

FIG. 5

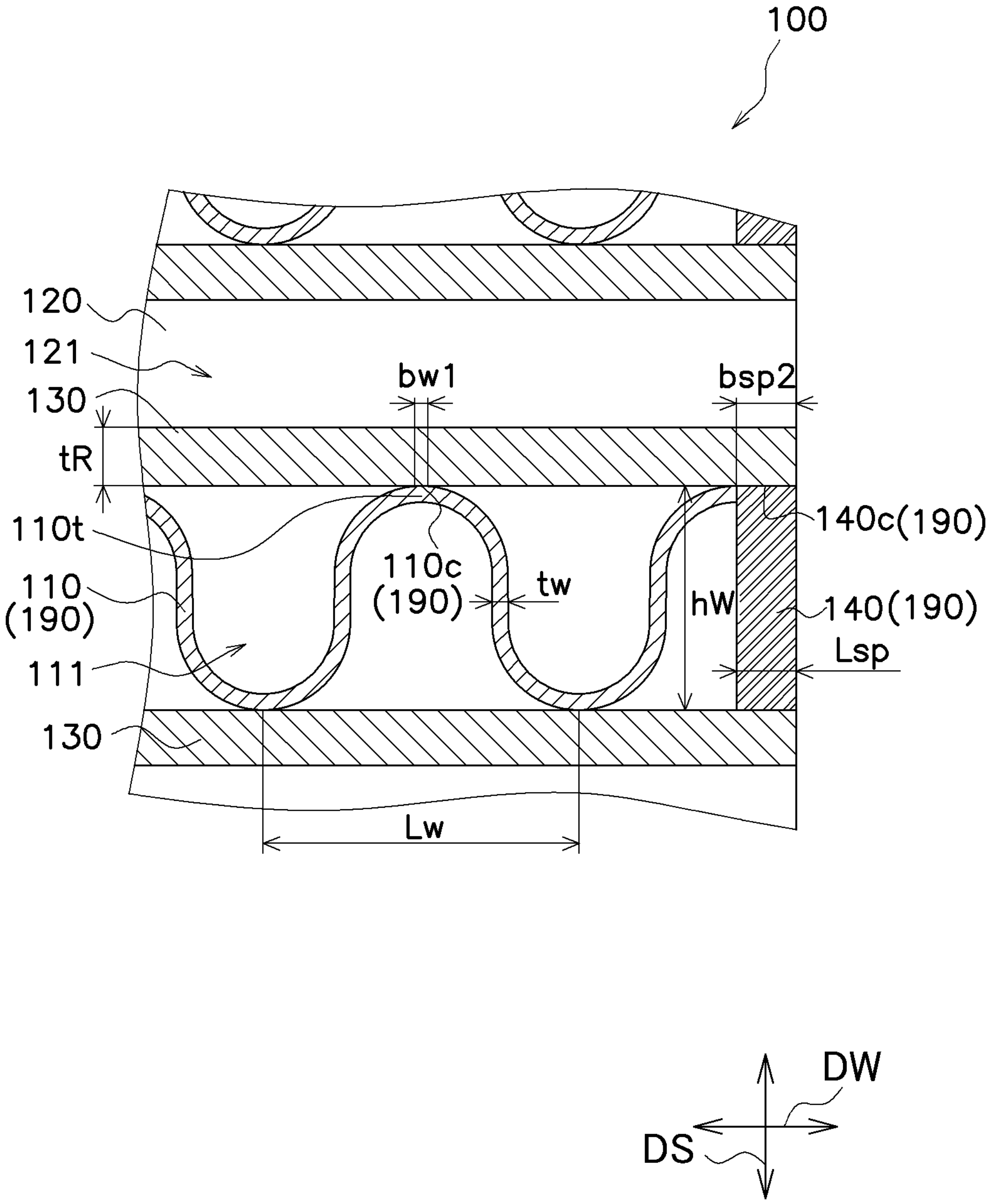

100
120
121
130
bw1
bsp2
tR
110t
110c
(190)
tw
hW
140c(190)
110
(190)
140(190)
Lsp
111
130
Lw
DW
DS

FIG. 6

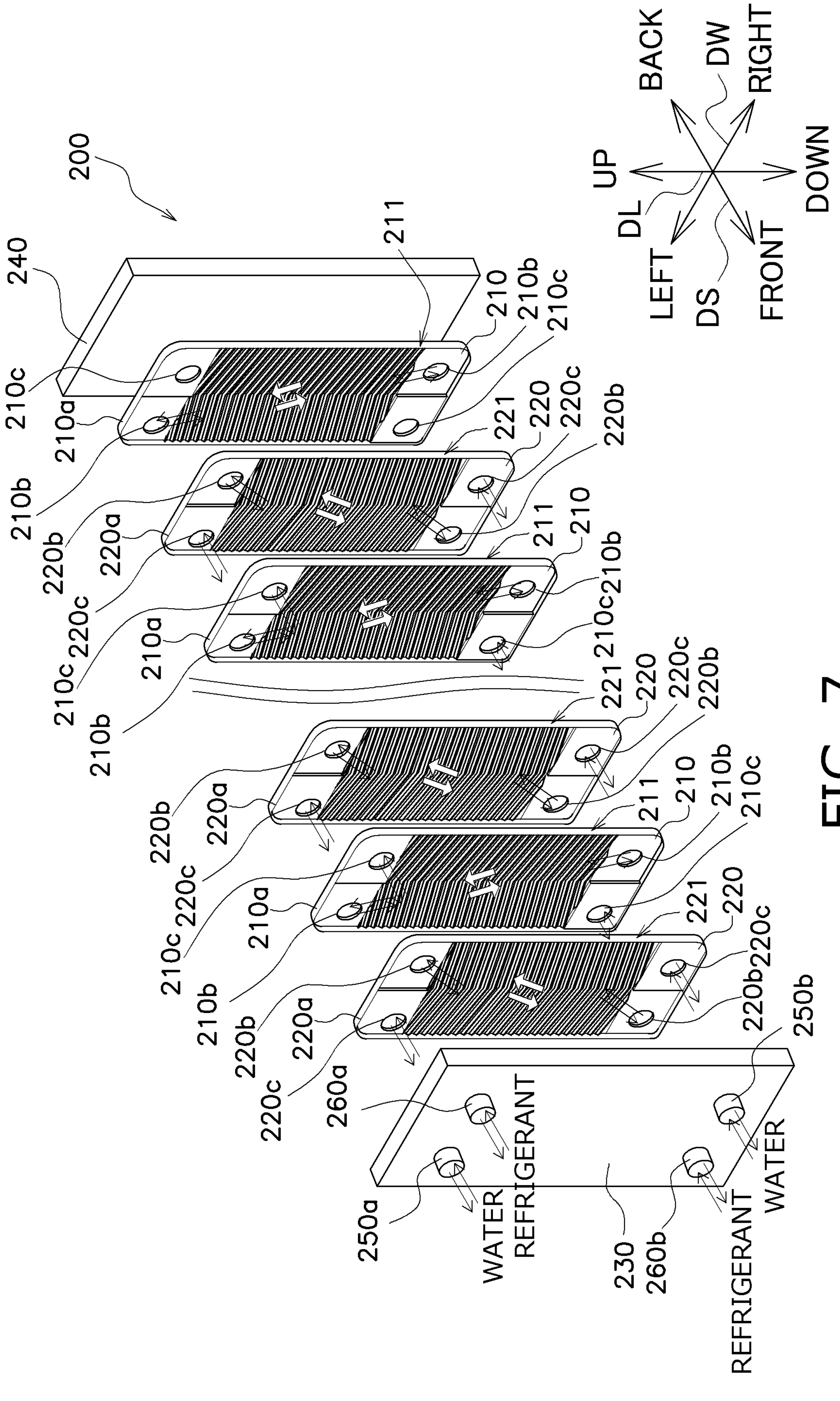

200
240
211
210
210a
210b
210c
220
220a
220b
220c
221
230
250a
250b
260a
260b
WATER
REFRIGERANT
UP
DOWN
BACK
FRONT
LEFT
RIGHT
DL
DW
DS

FIG. 7

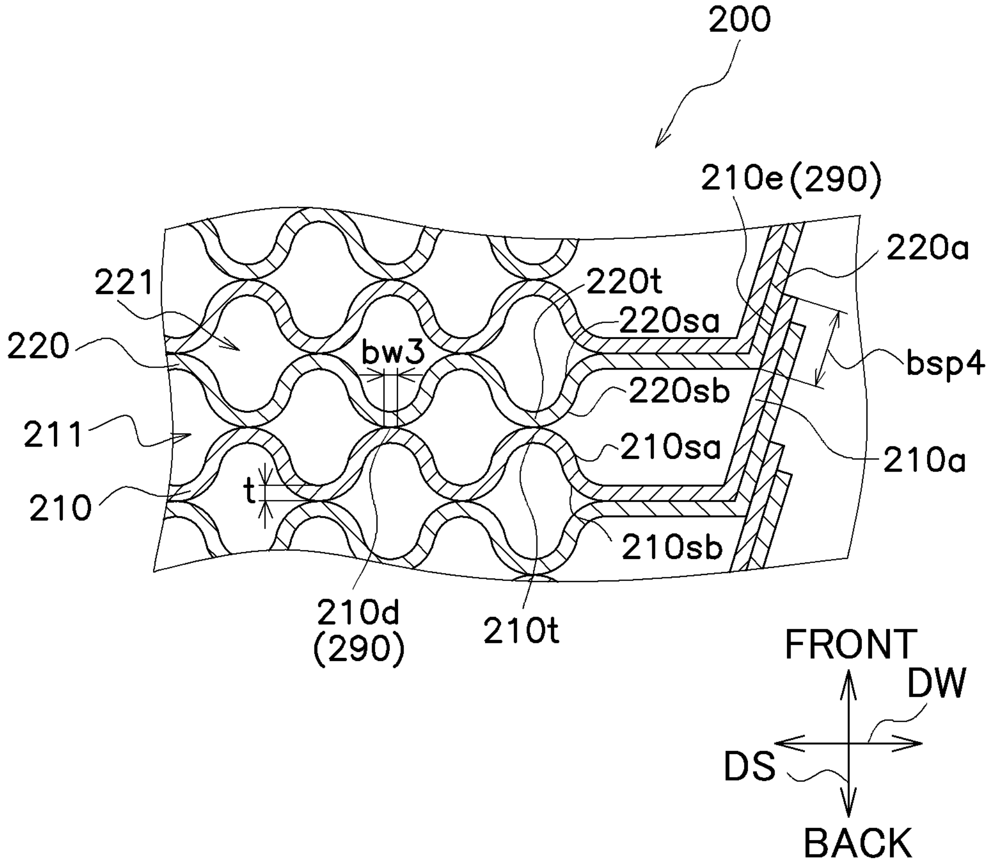

200
210e (290)
220a
221
220t
220sa
220
bw3
bsp4
220sb
211
210sa
210a
210
t
210sb
210d
(290)
210t
FRONT
DW
DS
BACK

FIG. 8

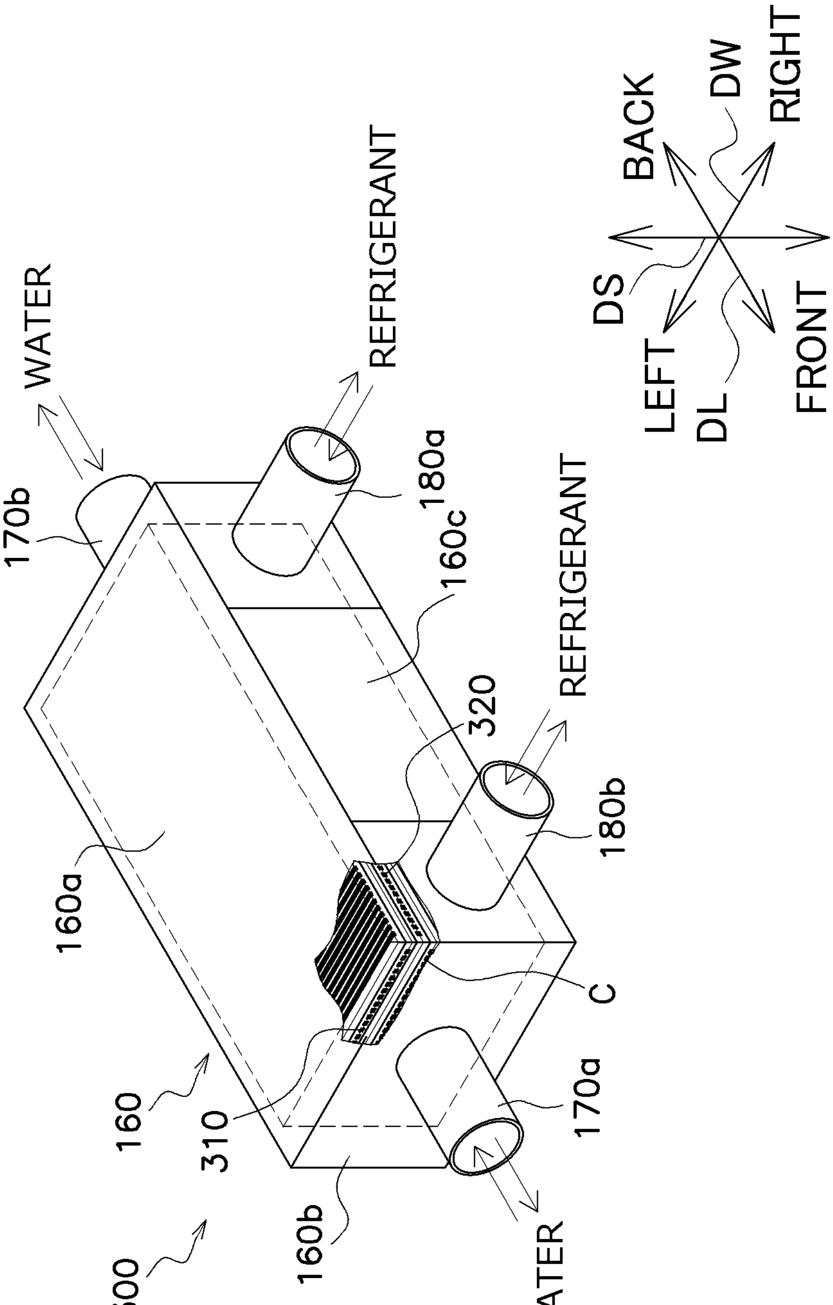

300
160b
WATER
310
160
160a
170a
C
320
180b
REFRIGERANT
160c
180a
170b
WATER
REFRIGERANT
DS
LEFT
DL
FRONT
BACK
DW
RIGHT

FIG. 9

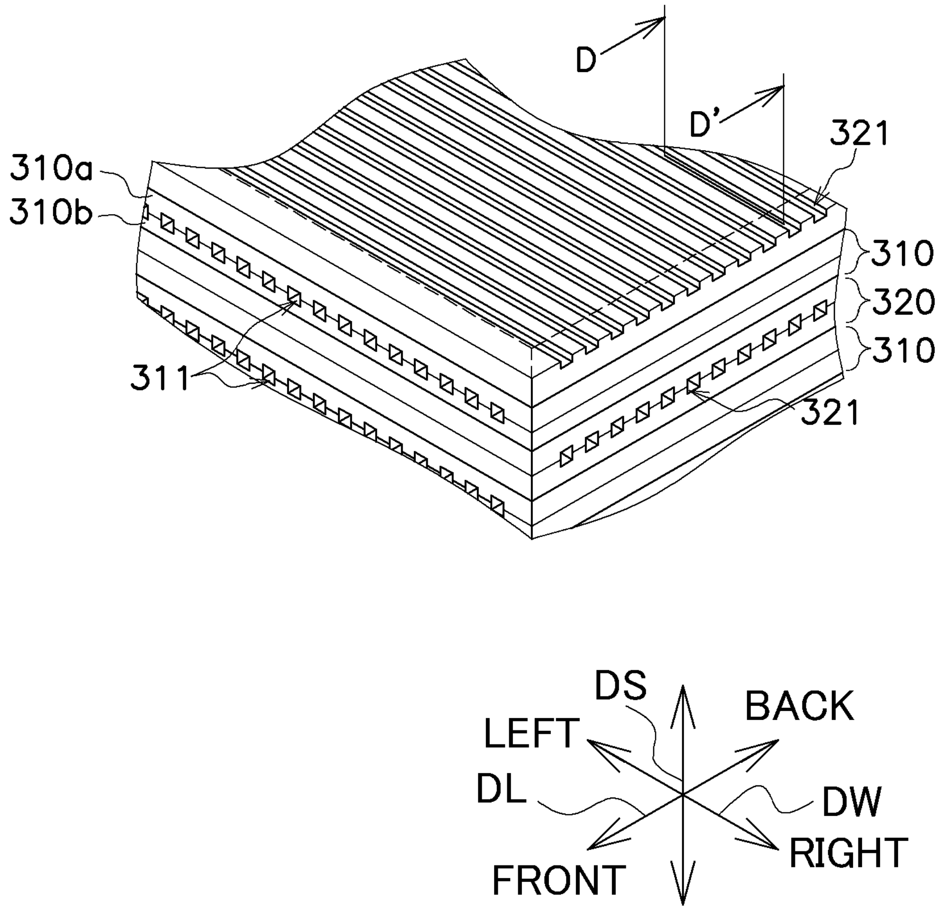

D
D'
321
310a
310b
310
320
310
311
321
DS
BACK
LEFT
DL
DW
RIGHT
FRONT

FIG. 10

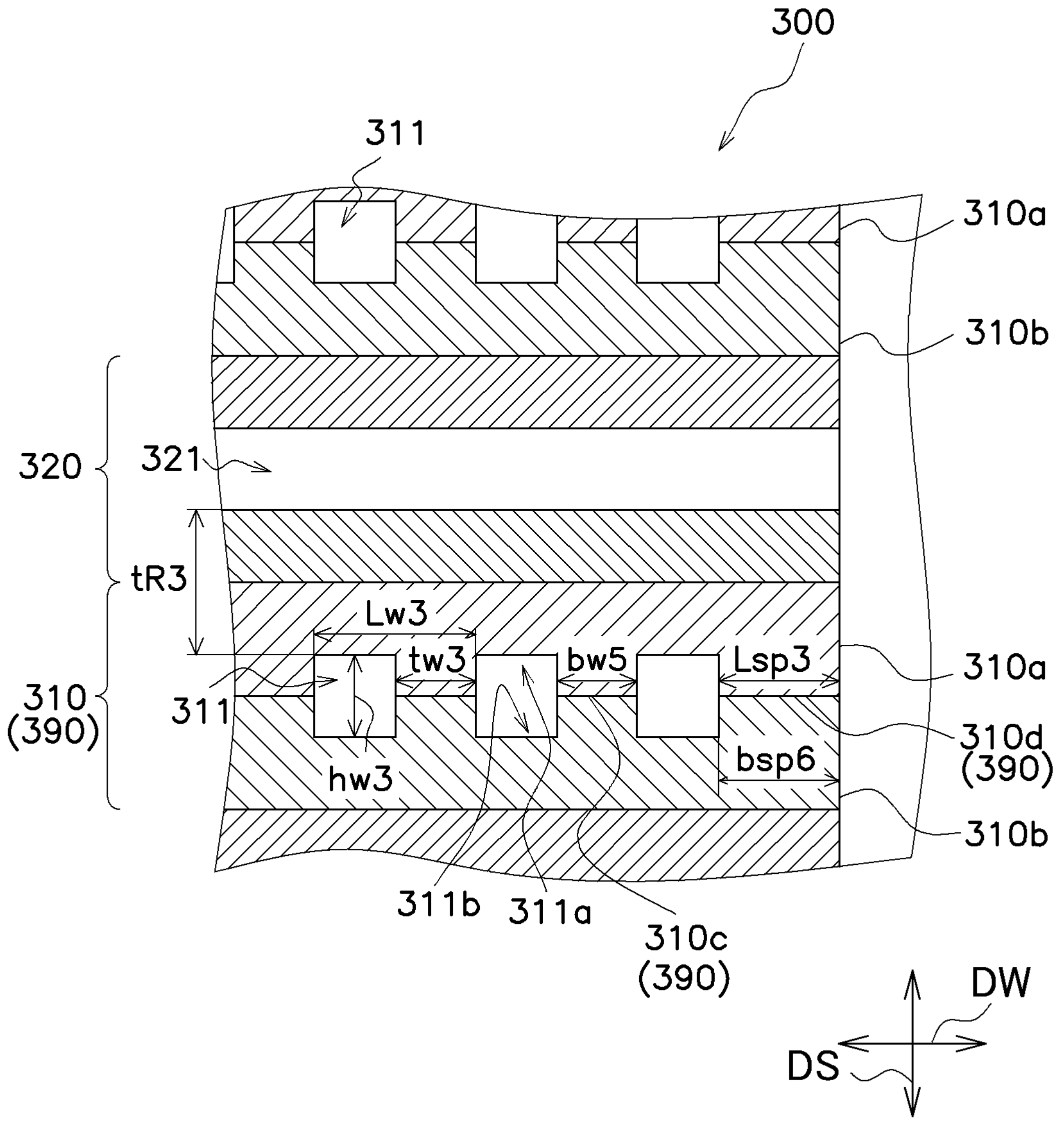

300
311
310a
310b
320
321
tR3
Lw3
tw3
bw5
Lsp3
310a
310
(390)
311
hw3
310d
(390)
bsp6
310b
311b
311a
310c
(390)
DW
DS

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026469

A. CLASSIFICATION OF SUBJECT MATTER

F28F 3/08(2006.01)i; ***F28D 9/02***(2006.01)i; ***F28F 3/00***(2006.01)i
FI: F28F3/08 301A; F28D9/02; F28F3/00 311

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)

F28F1/00-99/00; F28D1/00-13/00; F25B39/00-39/04

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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	CN 113432461 A (JIANGSU YUANZHUO EQUIPMENT MFG CO., LTD.) 24 September 2021 (2021-09-24) particularly, paragraphs [0028]-[0043], fig. 1-7	1, 14-15, 24
Y		2-13, 16-20, 21-22
X	JP 2003-294380 A (HISAKA WORKS LTD.) 15 October 2003 (2003-10-15) in particular, paragraph [0020], fig. 1-4	1, 23-24
Y		2-13, 16-22
X	WO 2019/176566 A1 (MITSUBISHI ELECTRIC CORP.) 19 September 2019 (2019-09-19) in particular, paragraphs [0070], [0095], fig. 17	1, 23-24
Y		2-13, 16-20
Y	JP 2005-61778 A (CALSONIC KANSEI CORP.) 10 March 2005 (2005-03-10) in particular, paragraphs [0015]-[0034], fig. 1-4	2-13
Y	JP 3-500861 A (FORSCHUNGSZENTRUM KARLSRUHE GMBH) 28 February 1991 (1991-02-28) in particular, fig. 4	21-22

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

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 September 2023	**12 September 2023**

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

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026469

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2020/245876 A1 (MITSUBISHI ELECTRIC CORP.) 10 December 2020 (2020-12-10) particularly, paragraph [0060]	1-24

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/026469

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 113432461 A	24 September 2021	(Family: none)	
JP 2003-294380 A	15 October 2003	(Family: none)	
WO 2019/176566 A1	19 September 2019	US 2021/0055057 A1 particularly, paragraphs [0102], [0128], fig. 17 DE 112019001351 T5 CN 111837010 A	
JP 2005-61778 A	10 March 2005	(Family: none)	
JP 3-500861 A	28 February 1991	US 5152060 A in particular, fig. 4 WO 1988/006941 A1 EP 391895 A1 DE 3709278 A1	
WO 2020/245876 A1	10 December 2020	US 2022/0155019 A1 particularly, paragraph [0077] CN 113874674 A	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 10132476 A **[0003]**
- JP H10132476 A **[0241]**