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(54) **HEAT EXCHANGER AND REFRIGERATION AND AIR-CONDITIONING APPARATUS**

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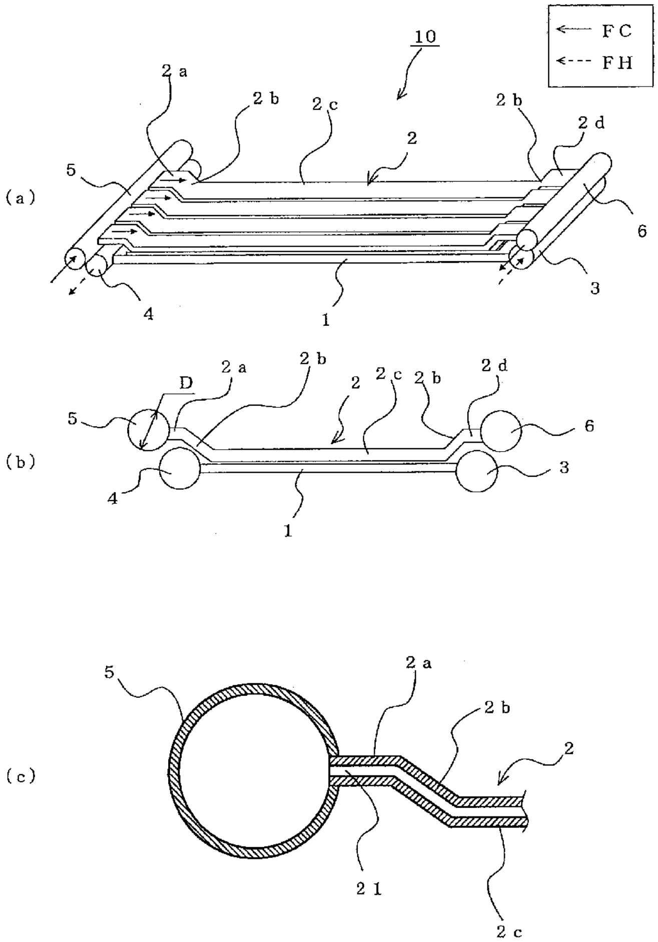
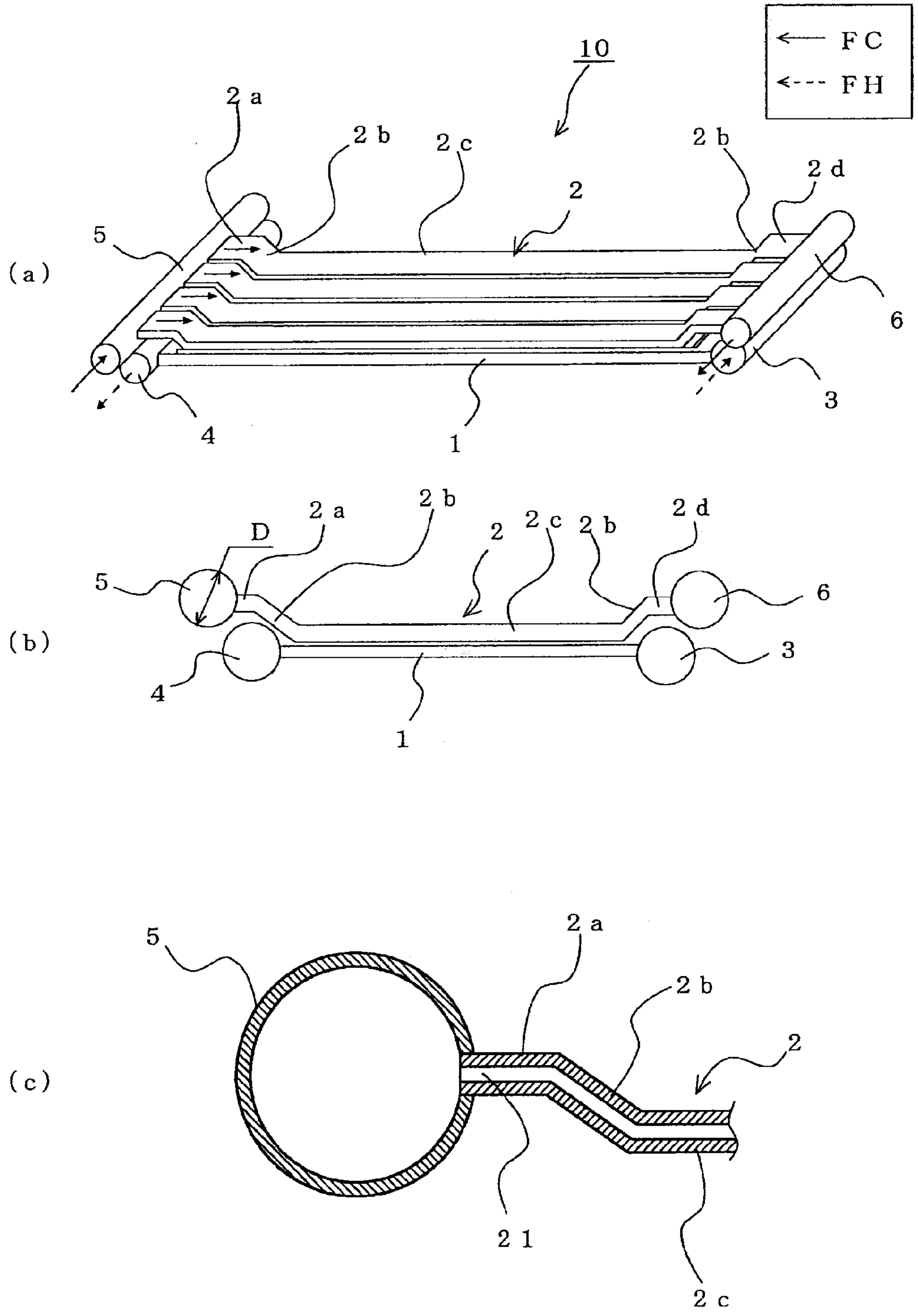
(57) **ABSTRACT**

A heat exchanger includes a first flat pipe including plural through-holes through which a high-temperature fluid flows, a second flat pipe including plural through-holes through which a low-temperature fluid flows, a first tubular shape inlet header connected to one end of the first flat pipe, a first tubular shape outlet header connected to another end of the first flat pipe, a second tubular shape inlet header connected to one end of the second flat pipe, and a second tubular shape outlet header connected to another end of the second flat pipe. The first and second flat pipes are stacked with contacting flat surfaces. The low-temperature fluid flowing into the through-holes in the second flat pipe from the second inlet header is a fluid in a two-phase gas-liquid state, and flows into those through-holes in a substantially horizontal direction or in an upward direction relative to the substantially horizontal direction.



F I G. 1


← FC
←--- FH
10
2a
2b
2c
2b
2d
2
5
(a)
6
4
1
3
D
2a
2b
2
2c
2b
2d
5
6
(b)
4
3
1
5
2a
2b
2
(c)
21
2c

F I G. 2

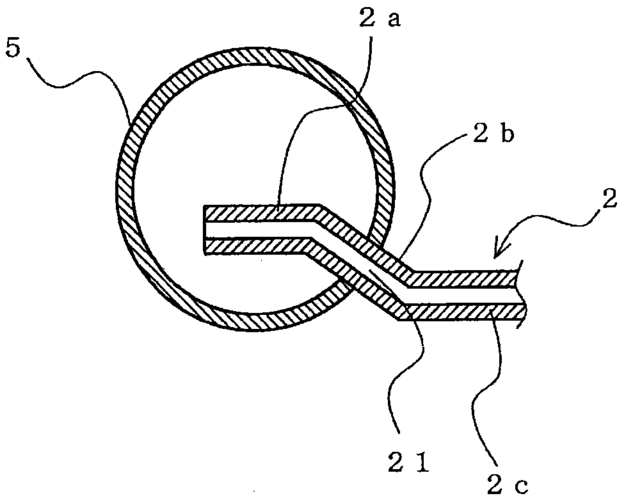


FIG. 3

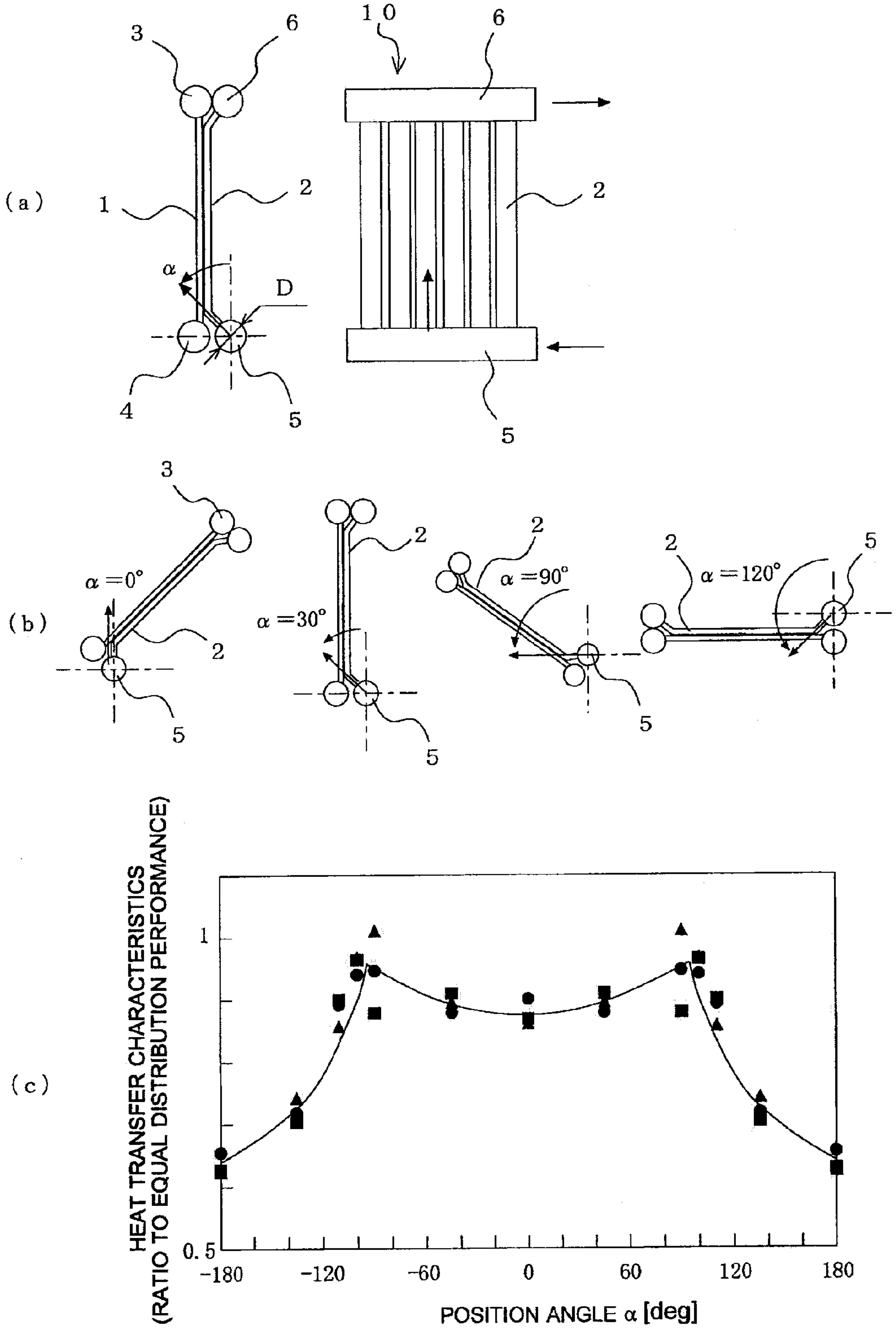
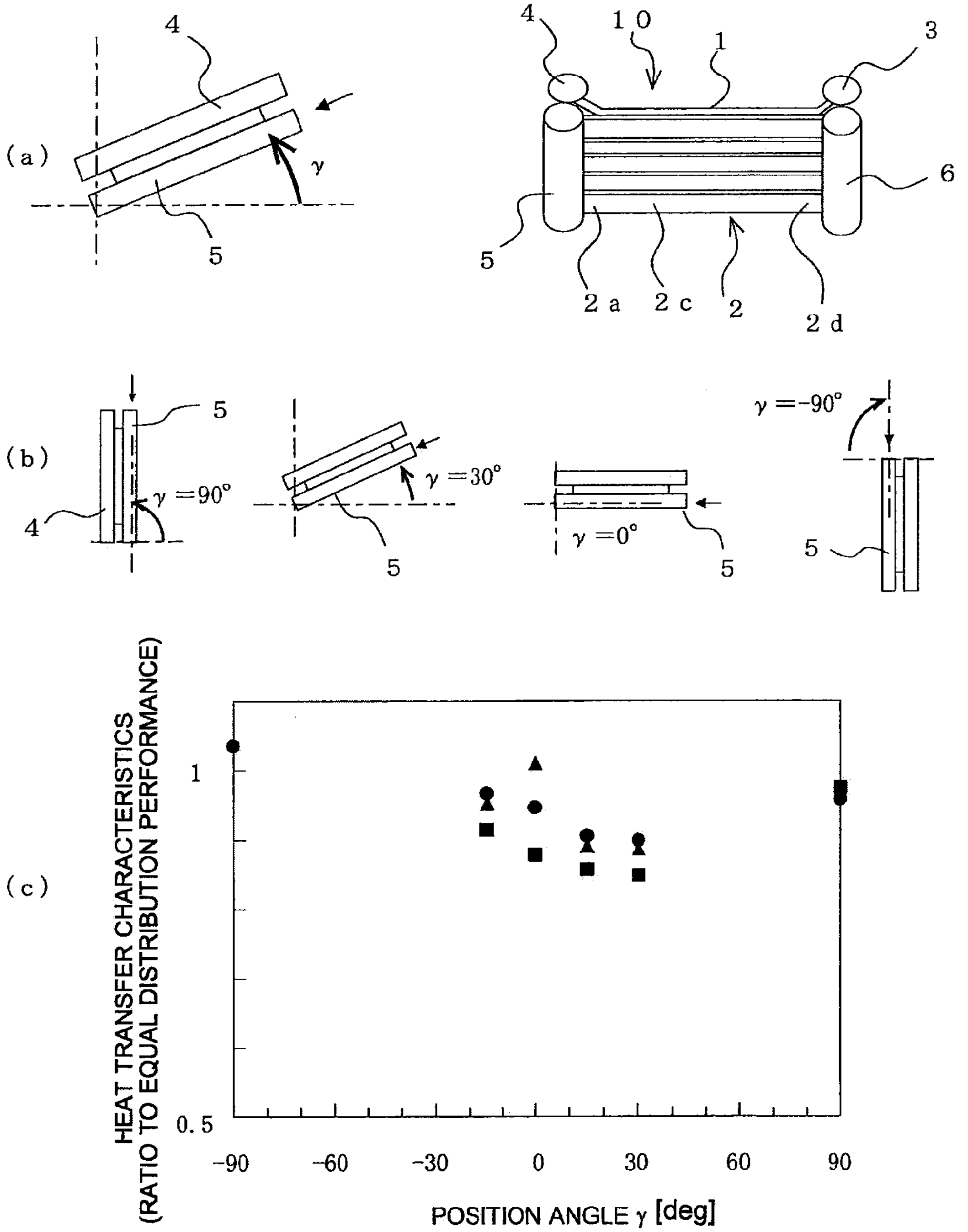

(a)
3
6
1
2
α
D
4
5
10
6
2
5
(b)
3
α = 0°
2
5
2
α = 30°
5
2
α = 90°
5
2
α = 120°
5
(c)
HEAT TRANSFER CHARACTERISTICS (RATIO TO EQUAL DISTRIBUTION PERFORMANCE)
1
0.5
-180
-120
-60
0
60
120
180
POSITION ANGLE α [deg]

FIG. 4


(a)
4
γ
5
4
10
1
3
6
5
2a
2c
2
2d
(b)
5
γ =90°
4
γ =30°
5
γ =0°
5
γ =-90°
5
(c)
HEAT TRANSFER CHARACTERISTICS
(RATIO TO EQUAL DISTRIBUTION PERFORMANCE)
1
0.5
-90
-60
-30
0
30
60
90
POSITION ANGLE γ [deg]

F I G. 5

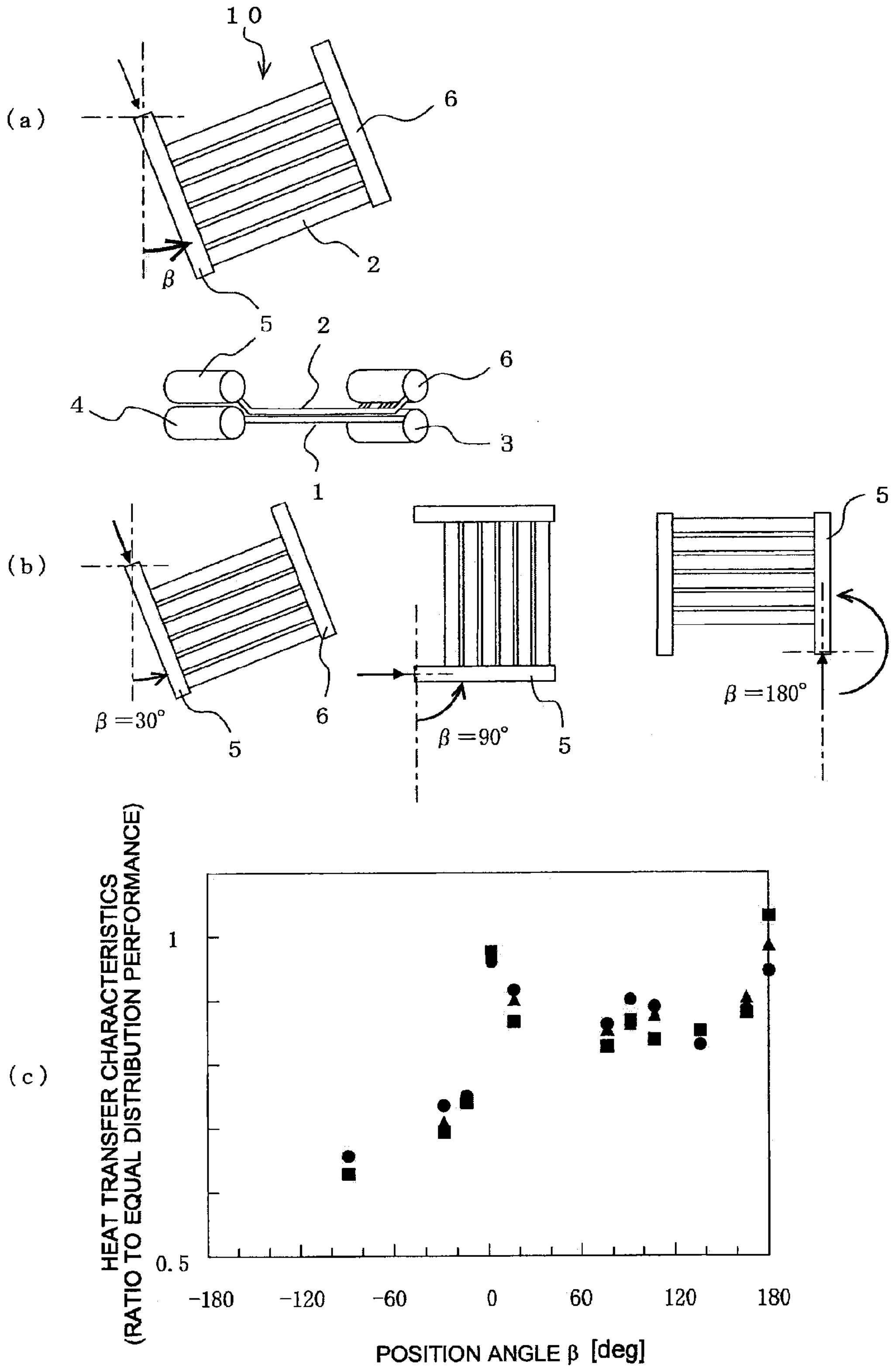
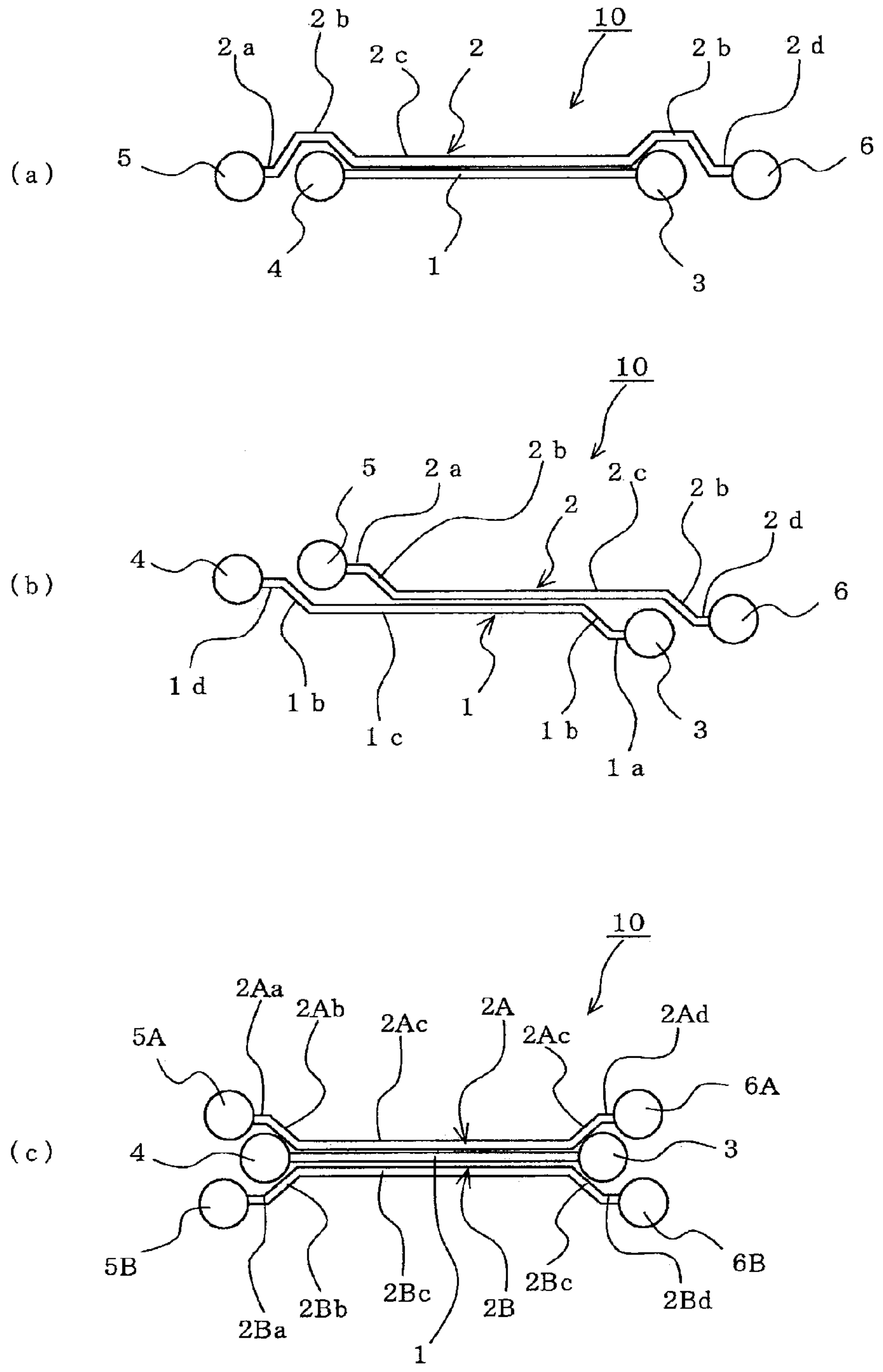
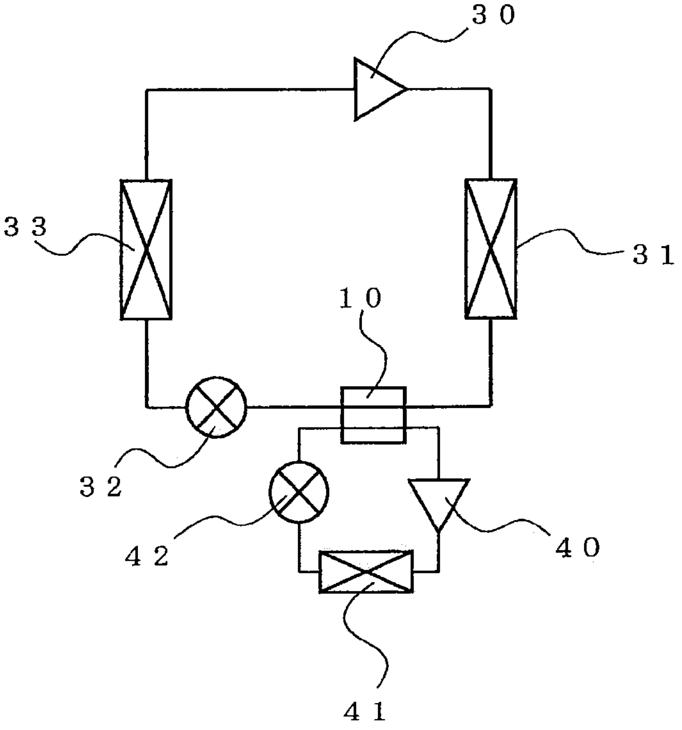

(a)
10
6
2
β
5
5
2
6
4
3
1
(b)
β =30°
5
6
β =90°
5
5
β =180°
(c)
HEAT TRANSFER CHARACTERISTICS (RATIO TO EQUAL DISTRIBUTION PERFORMANCE)
1
0.5
-180
-120
-60
0
60
120
180
POSITION ANGLE β [deg]

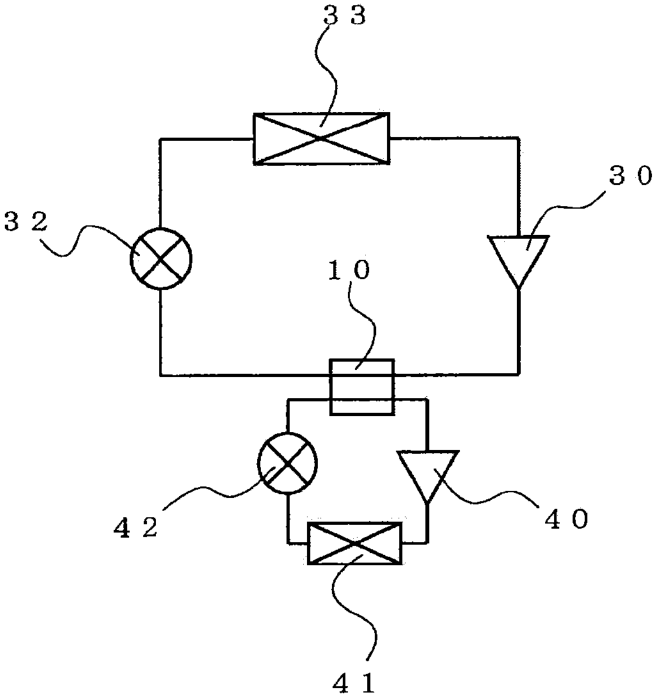
FIG. 6


(a)
10
2 a
2 b
2 c
2
2 b
2 d
5
6
4
1
3
(b)
10
5
2 a
2 b
2 c
2
2 b
2 d
4
6
1 d
1 b
1 c
1
1 b
3
1 a
(c)
10
2Aa
2Ab
2Ac
2A
2Ac
2Ad
5A
6A
4
3
5B
6B
2Ba
2Bb
2Bc
1
2B
2Bc
2Bd

F I G. 7



F I G. 8



F I G. 9

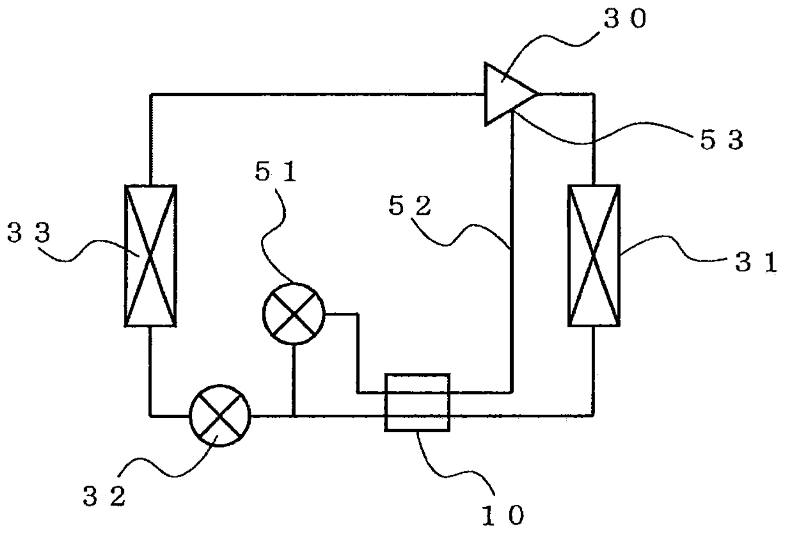


FIG. 10

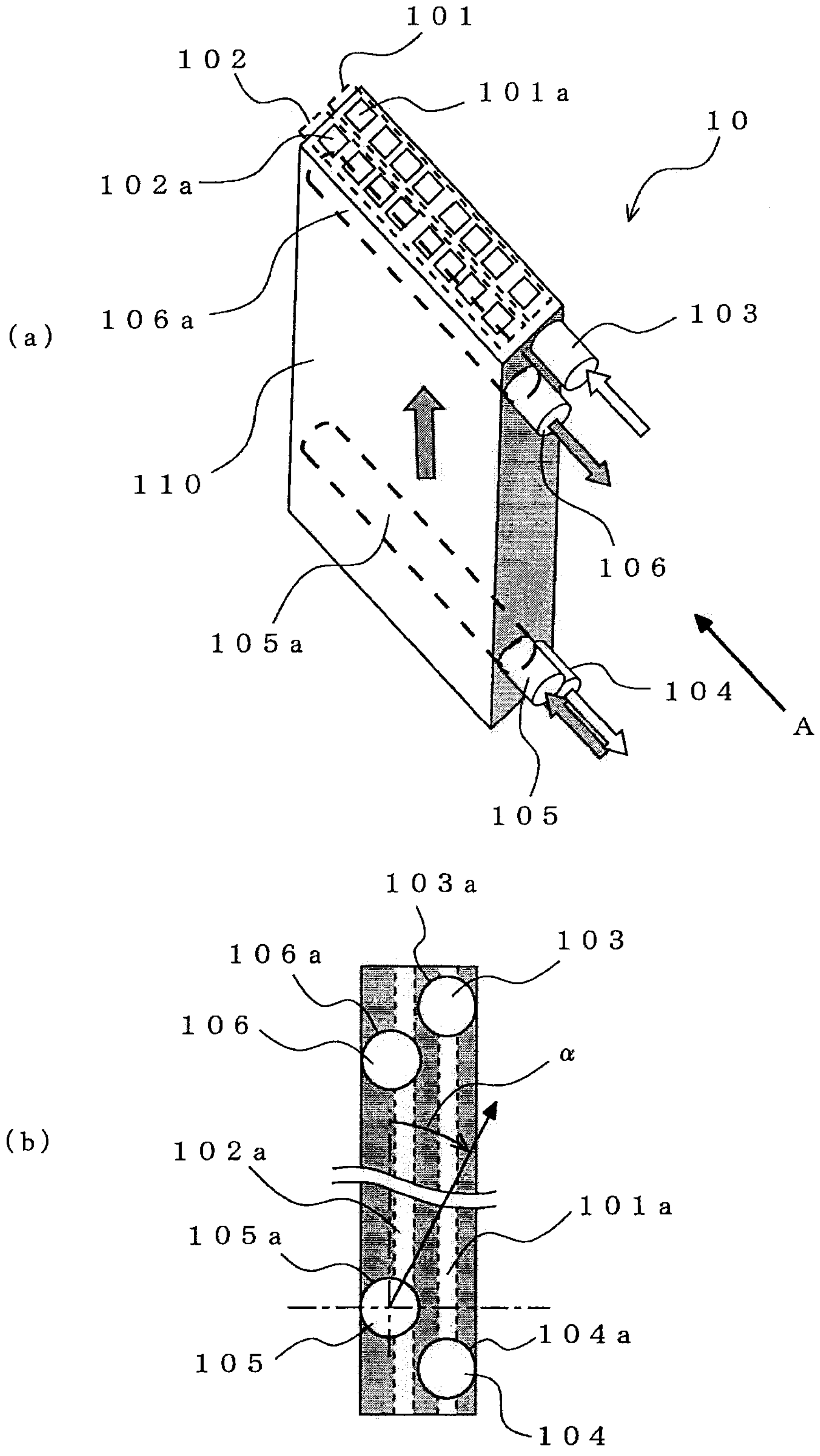
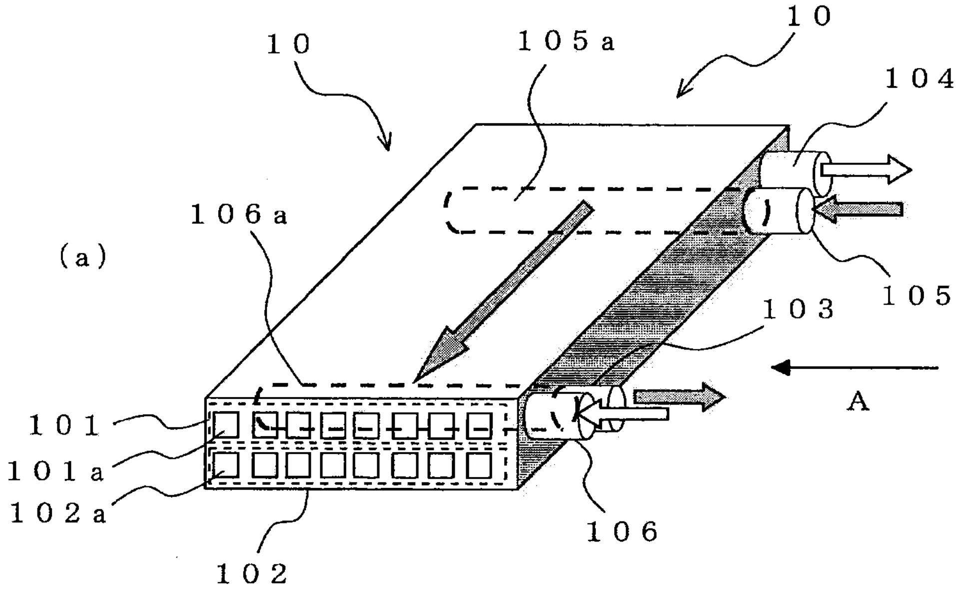
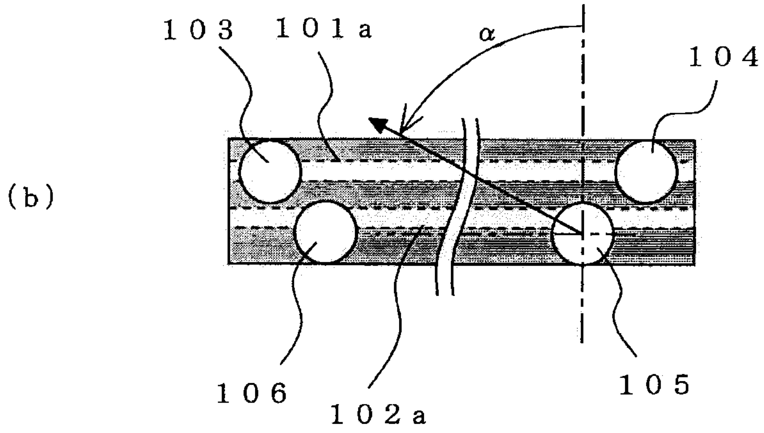

(a)
101
102
101a
10
102a
106a
103
110
106
105a
104
A
105
(b)
103a
103
106a
106
α
102a
101a
105a
104a
105
104

FIG. 11


(a)
10
105a
10
104
106a
105
103
A
101
101a
102a
106
102


(b)
103
101a
α
104
106
102a
105

HEAT EXCHANGER AND REFRIGERATION AND AIR-CONDITIONING APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger that exchanges heat between a low-temperature fluid and a high-temperature fluid so as to transfer the heat from the high-temperature fluid to the low-temperature fluid. Moreover, the present invention relates to a refrigeration and air-conditioning apparatus equipped with the heat exchanger.

BACKGROUND ART

[0002] A heat exchanger in the related art includes a first passage section having a plurality of through-holes through which a low-temperature fluid flows, a second passage section having a plurality of through-holes through which a high-temperature fluid flows, first headers connected to both ends of the first passage section, and second headers connected to both ends of the second passage section. The first passage section and the second passage section are stacked with surfaces thereof in contact with each other such that longitudinal directions (i.e., fluid flowing directions) thereof are parallel to each other. Moreover, at least one of the high-temperature fluid and the low-temperature fluid is a fluid in a two-phase gas-liquid state. An inlet header through which the fluid in the two-phase gas-liquid state flows has an inner diameter that is smaller than the inner diameter of the other headers. Thus, the gas and the liquid are made uniform by mixing of the gas and the liquid within a pipe due to an increase in gas flow velocity, so that the low-temperature fluid is distributed to the through-holes with a uniform gas-to-liquid ratio, thereby maximizing the temperature efficiency of the fluid and achieving high heat exchanging performance (for example, see Patent Literature 1).

CITATION LIST

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2008-101852 (paragraph [0036], FIG. 1)

SUMMARY OF INVENTION

Technical Problem

[0004] A refrigeration and air-conditioning apparatus that uses the aforementioned heat exchanger in the related art has a refrigerant circuit in which a compressor, a radiator, flow control means, and an evaporator are connected by a refrigerant pipe, and a refrigerant, such as an HFC (hydrofluorocarbon) based refrigerant, hydrocarbon, or carbon dioxide, circulates through this refrigerant circuit. In order to increase the efficiency of the refrigeration and air-conditioning apparatus, it is important to increase the heat exchanging performance of the heat exchanger.

[0005] However, in the aforementioned heat exchanger in the related art, when the refrigerant in the two-phase gas-liquid state flows through the inlet header in a low flow-rate range, the mixing of the gas and the liquid is insufficient, causing the gas and the liquid to flow separately from each other. Thus, the ratio of the gas and the liquid distributed to the through-holes in the passage section becomes non-uniform. This results in an excess or insufficient amount of fluid that can effectively exchange heat in each of the through-holes in the passage section. Therefore, in the aforementioned heat exchanger in the related art, there is a problem in that the temperature efficiency significantly decreases, causing the heat exchanging performance to deteriorate. There is another problem in that the heat exchanger needs to be increased in size more than necessary to compensate for the deterioration in the heat exchanging performance. On the other hand, if the header diameter is reduced too much in accordance with the low flow-rate range, when the refrigerant in the two-phase gas-liquid state flows through the inlet header in a high flow-rate range, a pressure loss increases, which is a problem in that it leads to an increase in power used by a driving device that transports the fluid to the heat exchanger. Accordingly, with the aforementioned heat exchanger in the related art, it is difficult to make the heat exchanger operate efficiently while achieving uniform gas-liquid distribution over a wide operating range.

[0006] The present invention has been made to solve the aforementioned problems, and an object thereof is to obtain a compact, high-performance heat exchanger and a compact, high-performance refrigeration and air-conditioning apparatus.

Solution to Problem

[0007] A heat exchanger according to the present invention includes a first passage section having a plurality of through-holes through which a high-temperature fluid flows; a second passage section having a plurality of through-holes through which a low-temperature fluid flows; a first inlet header having a tubular shape and connected to one end of the first passage section; a first outlet header having a tubular shape and connected to other end of the first passage section; a second inlet header having a tubular shape and connected to one end of the second passage section; and a second outlet header having a tubular shape and connected to other end of the second passage section. The first passage section and the second passage section are disposed in a heat exchangeable manner via a partition wall provided therebetween. At least one of the high-temperature fluid flowing into the through-holes in the first passage section from the first inlet header and the low-temperature fluid flowing into the through-holes in the second passage section from the second inlet header is a fluid in a two-phase gas-liquid state. A direction in which the fluid in the two-phase gas-liquid state flows into the passage section from the inlet header is a substantially horizontal direction or an upward direction relative to the substantially horizontal direction.

[0008] A refrigeration and air-conditioning apparatus according to the present invention is equipped with the heat exchanger according to the present invention.

Advantageous Effects of Invention

[0009] According to the present invention, a compact, high-performance heat exchanger can be provided. Furthermore, according to the present invention, a compact, high-performance refrigeration and air-conditioning apparatus can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** illustrates a heat exchanger according to Embodiment 1 of the present invention.

[0011] FIG. **2** is a vertical sectional view illustrating another example of second flat pipes according to Embodiment 1 of the present invention.

[0012] FIG. **3** illustrates the heat transfer characteristics of the heat exchanger according to Embodiment 1 of the present invention.

[0013] FIG. **4** illustrates another example of the heat transfer characteristics of the heat exchanger according to Embodiment 1 of the present invention.

[0014] FIG. **5** illustrates another example of the heat transfer characteristics of the heat exchanger according to Embodiment 1 of the present invention.

[0015] FIG. **6** includes side views illustrating examples of a heat exchanger according to Embodiment 2 of the present invention.

[0016] FIG. **7** is a refrigerant circuit diagram illustrating an example of a refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0017] FIG. **8** is a refrigerant circuit diagram illustrating another example of the refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0018] FIG. **9** is a refrigerant circuit diagram illustrating another example of the refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0019] FIG. **10** includes structural diagrams of a heat exchanger according to Embodiment 4 of the present invention.

[0020] FIG. **11** includes structural diagrams illustrating another example of the heat exchanger according to Embodiment 4 of the present invention.

DESCRIPTION OF EMBODIMENTS

Embodiment 1

[0021] FIG. **1** illustrates a heat exchanger according to Embodiment 1 of the present invention, and includes FIG. **1**(*a*) showing a perspective view, FIG. **1**(*b*) showing a side view, and FIG. **1**(*c*) showing a sectional view of the vicinity of a connection area between a second inlet header and each second flat pipe. FH shown in FIG. **1**(*a*) denotes the flow of a high-temperature fluid, and FC shown in FIG. **1**(*a*) denotes the flow of a low-temperature fluid. Embodiment 1 is directed to a case where the low-temperature fluid in a two-phase gas-liquid state flows into the second header. In the following drawings, components given the same reference numerals or characters indicate the same components or equivalent components, and this commonly applies throughout the entire specification.

[0022] In Embodiment 1, a substantially-horizontal inflow segment **2***a* is provided at an end of each second flat pipe **2** shown in FIG. **1** on the basis of information obtained from tests shown in FIGS. **3** to **5**, that is, the ranges of position angles α, β, and γ, to be described later, providing excellent heat transfer characteristics, whereby a heat exchanger **10** having excellent heat transfer characteristics is achieved. Specifically, in FIG. **1**, the second flat pipes **2** are connected to a second inlet header **5** with a position angle α of 90°.

[0023] First flat pipes **1** each have a plurality of through-holes extending in the longitudinal direction (i.e., the left-right direction in FIG. **1**(*b*)) and through which the high-temperature fluid flows. The through-holes are arranged parallel to each other in the width direction of the first flat pipe **1** (i.e., a direction orthogonal to the plane of FIG. **1**(*b*)). The second flat pipes **2** each have a plurality of through-holes **21** extending in the longitudinal direction (i.e., the left-right direction in FIG. **1**(*b*)) and through which the low-temperature fluid flows. The through-holes **21** are arranged parallel to each other in the width direction of the second flat pipe **2** (i.e., the direction orthogonal to the plane of FIG. **1**(*b*)). The first flat pipes **1** and the second flat pipes **2** are stacked such that flat surfaces of the first flat pipes **1** and flat surfaces of heat exchanging segments **2***c* of the second flat pipes **2** are in contact with each other. Furthermore, the first flat pipes **1** and the second flat pipes **2** are stacked such that the flowing directions of the fluids flowing through the flat pipes **1** and **2** are parallel to each other. The first flat pipes **1** and the second flat pipes **2** are joined to each other by, for example, soldering or bonding. For example, if the first flat pipes **1** and the second flat pipes **2** are both composed of aluminum or an aluminum alloy, the solder or flux used for soldering is composed of aluminum/silicon-based material, fluoride-based material, or the like. Furthermore, for example, if the group of first flat pipes **1** or second flat pipes **2** are composed of aluminum or an aluminum alloy while the other group of first flat pipes **1** or second flat pipes **2** are composed of copper, the solder or flux used for soldering is composed of zinc/aluminum-based material, aluminum/cesium/fluoride-based material or the like. With regard to a combination of solder and flux, a combination in which the melting point of the former is close to the activation temperature of the latter is preferable since the solderability improves due to, for example, better flowability of the solder.

[0024] One longitudinal end of each first flat pipe **1** is connected to a side surface of a first inlet header **3** having a tubular shape, while the other end is connected to a side surface of a first outlet header **4** having a tubular shape. In other words, the through-holes formed in the first flat pipes **1** form parallel passages through which the high-temperature fluid flows. The inflow segment **2***a* serving as one longitudinal end of each second flat pipe **2** is connected to a side surface of the second inlet header **5** having a tubular shape. An outflow segment **2***d* serving as the other longitudinal end of each second flat pipe **2** is connected to a side surface of a second outlet header **6** having a tubular shape. The inflow segment **2***a* and the outflow segment **2***d* are connected to the heat exchanging segment **2***c* via bent segments **2***b*. In other words, the through-holes **21** formed in the second flat pipes **2** form parallel passages through which the low-temperature fluid flows.

[0025] The first inlet header **3**, the first outlet header **4**, the second inlet header **5**, and the second outlet header **6** are disposed such that axial directions thereof are parallel to the flat surfaces of the flat pipes **1** and **2** (specifically, the parallel-arranged direction of the through-holes formed in the flat pipes **1** and **2**).

[0026] Furthermore, the inflow segments **2***a* of the second flat pipes **2**, through which the low-temperature fluid in the two-phase gas-liquid state flows, connected to the second inlet header **5** are substantially horizontal. Specifically, the passages (in other words, the through-holes **21** in the inflow segments **2***a*) for the low-temperature fluid in the two-phase gas-liquid state flowing into the second flat pipes **2** from the second inlet header **5** are substantially horizontal.

[0027] The first flat pipes **1** correspond to "first passage section" according to the present invention, and the second flat pipes **2** correspond to "second passage section" according to the present invention.

[0028] The high-temperature fluid flows through the first inlet header **3**, the first flat pipes **1**, and the first outlet header **4** in that order, the low-temperature fluid flows through the second inlet header **5**, the second flat pipes **2**, and the second outlet header **6** in that order, and the two fluids exchange heat via contact sections between the first flat pipes **1** and the second flat pipes **2** (more specifically, the heat exchanging segments **2***c*). In other words, the high-temperature fluid flowing through the through-holes in the first flat pipes **1** and the low-temperature fluid flowing through the through-holes in the second flat pipes **2** exchange heat via outer hulls, serving as partition walls between the through-holes, of the first flat pipes **1** and the second flat pipes **2**.

[0029] Although the heat exchanger **10** is constituted of several first flat pipes **1** and several second flat pipes **2** in Embodiment 1, the number of flat pipes **1** and the number of flat pipes **2** are not limited to the numbers in Embodiment 1. The parallel passages may be formed by alternately arranging one first flat pipe **1** and one second flat pipe **2** along a flat plane. Furthermore, although the first flat pipes **1** and the second flat pipes **2** in Embodiment 1 are disposed in contact with each other such that the flowing directions of the fluids flowing therethrough are parallel to each other, the flat pipes may alternatively be disposed in contact with each other such that the flowing directions are orthogonal to each other. As a further alternative, the first flat pipes **1** and the second flat pipes **2** may be stacked while folding the first flat pipes **1** and the second flat pipes **2**. Furthermore, although the end of the inflow segment **2***a* of each second flat pipe **2** is substantially aligned with the inner surface of the second inlet header **5** in FIG. **1**(*c*), the end of the inflow segment **2***a* of each second flat pipe **2** may alternatively protrude into the second inlet header **5**.

[0030] In the heat exchanger **10** according to Embodiment 1, the ends of the second flat pipes **2**, through which the two-phase gas-liquid fluid flows, connected to the second inlet header **5** are substantially horizontal. In other words, the outflowing direction of the two-phase gas-liquid fluid flowing out from the second inlet header **5** toward the through-holes **21** (in other words, the inflowing direction of the two-phase gas-liquid fluid flowing into the through-holes **21**) is substantially horizontal. More specifically, in Embodiment 1, even when the refrigerant flow velocity within the second inlet header **5** decreases to cause the gas and the liquid to flow separately through the upper side and the lower side therein, the liquid accumulates from the bottom of the second inlet header **5** to near the inflow segments of the second flat pipes **2** so that a gas-liquid interface is formed exactly near the inflow segments of the second flat pipes **2**, whereby favorable gas-liquid distribution is achieved. In other words, for example, if the refrigerant flows vertically downward from the horizontally-disposed second inlet header **5** toward the second flat pipes **2**, the gas-liquid distribution would deteriorate since the liquid alone tends to selectively flow out toward the second flat pipes **2** located at the upstream side before a liquid surface is formed within the second inlet header **5**. In contrast, this does not occur in the heat exchanger **10** according to Embodiment 1 because the ends of the second flat pipes **2** connected to the second inlet header **5** are substantially horizontal. Therefore, the low-temperature fluid can be distributed to the through-holes **21** in the second flat pipes **2** with a uniform gas-to-liquid ratio so that the temperature efficiency of the fluid can be maximized and the pressure loss can be minimized, thereby allowing for improved heat exchanging performance of the heat exchanger **10**. Consequently, with the heat exchanger **10** according to Embodiment 1, a compact, high-performance heat exchanger can be obtained.

[0031] With regard to the ends of the flat pipes connected to the remaining headers **3**, **4**, and **6**, the ends do not particularly need to be horizontal unless a two-phase gas-liquid fluid flows therethrough.

[0032] Furthermore, although the inflow segments **2***a* are formed by bending the second flat pipes **2** outside the second inlet header **5** in Embodiment 1, the inflow segments **2***a* may alternatively be formed by bending the second flat pipes **2** inside the second inlet header **5** to an extent that the gas-liquid flow within the second inlet header **5** is not disturbed, as shown in FIG. **2**.

[0033] In the heat exchanger **10** according to Embodiment 1, the inflow segments **2***a* of the second flat pipes **2** connected to the second inlet header **5** are maintained in a substantially horizontal state even if the heat exchanger **10** is positionally inverted. Therefore, the gas-liquid distribution does not deteriorate. Consequently, the heat exchanger **10** according to Embodiment 1 is advantageous in that the degree of freedom in terms of installation and the degree of freedom in terms of connection and routing of pipes are increased.

[0034] Generally, the distribution characteristics of the two-phase gas-liquid fluid toward the through-holes in the flat pipes change significantly depending on the outflowing direction of the fluid flowing out from the header toward the through-holes (in other words, the inflowing direction of the fluid flowing into the through-holes). Therefore, an effect that this direction has on the heat transfer characteristics (i.e., the distribution characteristics of the two-phase gas-liquid fluid) in the heat exchanger **10** is examined by performing tests (FIGS. **3** to **5**). In the tests shown in FIGS. **3** to **5**, hot water is made to flow as the high-temperature fluid through the first flat pipes **1**, and a low-temperature fluorocarbon refrigerant in a two-phase gas-liquid state is made to flow as the low-temperature fluid through the second flat pipes **2**. Then, heat transfer characteristics KA (W/K) of the heat exchanger **10** are measured by using the inlet and outlet temperatures of each fluid and mathematical expressions 1 and 2.

$$KA = \frac{M_h Cp_h (T_{hi} - T_{ho})}{3600[LMTD]} \qquad \text{[Mathematical Expression 1]}$$

$$[LMTD] = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})}} \qquad \text{[Mathematical Expression 2]}$$

[0035] In this case, M_h denotes a mass flow rate (kg/h) of the high-temperature fluid, Cp_h denotes isobaric specific heat (J/kgK) of the high-temperature fluid, T_{hi} denotes an inlet temperature of the high-temperature fluid, T_{ho} denotes an outlet temperature of the high-temperature fluid, T_{co} denotes an outlet temperature of the low-temperature fluid, and T_{ci} denotes an inlet temperature of the low-temperature fluid.

[0036] In the tests shown in FIGS. **3** to **5**, the configuration of the heat exchanger **10** is set as follows.

[0037] The second inlet header **5** has an inner diameter D of 6 mm. The through-holes formed in the first flat pipes **1** are rectangular holes with about 1 mm sides, and a total of 60 through-holes are formed in each first flat pipe **1**. Furthermore, these through-holes are arranged in the width direction of the first flat pipe **1**. The through-holes **21** formed in the second flat pipes **2** are also rectangular holes with about 1 mm sides, and a total of 60 through-holes **21** are formed in each second flat pipe **2**. Furthermore, these through-holes **21** are arranged in the width direction of the second flat pipe **2**.

[0038] The protruding length of the ends of each first flat pipe **1** from the inner surfaces of the headers is 2 mm.

[0039] In the tests shown in FIGS. **3** to **5**, the heat transfer characteristics KA (W/K) are measured under the following conditions.

[0040] The mass flow rate M_h of the high-temperature fluid is 600 kg/h. A mass flow rate M_c of the low-temperature fluid ranges between 80 kg/h and 100 kg/h. A ratio of the mass flow rate of the gas to the overall mass flow rate of the gas and the liquid in the low-temperature fluid (i.e., quality X) is adjusted between 0.1 and 0.2. This range of the quality X is a generally used range for the inlet quality in the heat exchanger **10** used in a common refrigeration and air-conditioning apparatus.

[0041] The triangles, squares, and circles shown in FIG. **3**(*c*), FIG. **4**(*c*), and FIG. **5**(*c*) express the heat transfer characteristics under the following conditions. The squares express the heat transfer characteristics when the mass flow rate M_c of the low-temperature fluid is 80 kg/h. The triangles express the heat transfer characteristics when the mass flow rate M_c of the low-temperature fluid is 90 kg/h. The circles express the heat transfer characteristics when the mass flow rate M_c of the low-temperature fluid is 100 kg/h.

[0042] In FIGS. **3** to **5**, when the second inlet header **5** is in a near horizontal state, the refrigerant within the second inlet header **5** tends to flow such that the gas and the liquid flow separately through the upper side and the lower side therein due to mass velocity. When the second inlet header **5** is in a near vertical state, the refrigerant within the second inlet header **5** tends to flow such that the gas and the liquid flow annularly due to mass velocity. For example, a difference in properties between when the header is in a horizontal state and when the header is in a vertical state begins to occur near a position angle γ or β of 45°.

[0043] FIG. **3** illustrates the heat transfer characteristics obtained when the second inlet header **5** is horizontally disposed and the position angle α, which corresponds to the outflowing direction of the low-temperature fluid in the two-phase gas-liquid state flowing out toward the through-holes **21** in the second flat pipes **2** (in other words, the inflowing direction of the low-temperature fluid flowing into the through-holes **21**), is changed. Specifically, FIG. **3**(*a*) is a diagram for explaining the position angle α. FIG. **3**(*b*) illustrates the positions of the heat exchanger **10** at main position angles α. FIG. **3**(*c*) shows a test result and illustrates the relationship between the position angle a and the heat transfer characteristics (relative value). The heat transfer characteristics (relative value) of the heat exchanger **10** indicated on the ordinate axis in FIG. **3**(*c*) are expressed by relative values, with 1 as the heat transfer characteristics obtained under a condition in which the low-temperature fluid is distributed to the through-holes **21** in the second flat pipes **2** with a uniform gas-to-liquid ratio.

[0044] Unlike the heat exchanger **10** shown in FIG. **1**, the ends of the second flat pipes **2** shown in FIG. **3** each have one folded section. In other words, in each of the second flat pipes **2** shown in FIG. **3**, the inflow segment **2***a* and the outflow segment **2***d* are directly connected to the heat exchanging segment **2***c* (without the intervention of the bent segments **2***b*). Furthermore, when the position angle α=0°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in a vertically upward direction. When 0°<position angle α<90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** upward relative to the horizontal direction. When the position angle α=90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the horizontal direction. When 90°<position angle α<180°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** downward relative to the horizontal direction. When the position angle α=180°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in a vertically downward direction.

[0045] As shown in FIG. **3**(*c*), it is confirmed that, when −110°<position angle α<110° (more preferably, 80°<position angle α<100° or −80°<position angle α<−100°), the heat transfer characteristics can be maintained at a high level. In particular, it is confirmed that, when the position angle α is close to 90° (85°<position angle α<95° or −85°<position angle α<−95°), the heat transfer characteristics are at the maximum level. It is also confirmed that, when the position angle α is smaller than or equal to 110°, the heat transfer characteristics decrease sharply. In other words, it is confirmed from this result that, when −110°<position angle α<110°, the gas-to-liquid ratio of the low-temperature fluid distributed to the through-holes **21** is substantially made uniform. Furthermore, it is confirmed that, by setting the position angle α to substantially −90° or substantially 90°, the gas-to-liquid ratio of the low-temperature fluid distributed to the through-holes **21** can be made more uniform. Accordingly, by setting the position angle α to substantially −90° or substantially 90°, even when the flow velocity within the second inlet header **5** decreases to cause the gas and the liquid to flow separately through the upper side and the lower side therein, the inflow segments extending from the second inlet header **5** to the second flat pipes **2** are prevented from being constantly filled with the liquid, thereby preventing deterioration in the gas-liquid distribution caused by the liquid alone flowing out selectively to the second flat pipes **2** located at the upstream side. When the position angle α is close to 0°, the liquid tends to flow into the second flat pipes **2** located toward the far side as viewed from the inlet side of the second inlet header **5** due to, for example, inertia of the liquid. However, since the flow is suppressed by gravity acting on the liquid, deterioration in the distribution is minimized to a certain extent.

[0046] FIG. **4** illustrates the heat transfer characteristics obtained when the outflowing direction of the low-temperature fluid in the two-phase gas-liquid state flowing out toward the through-holes **21** in the second flat pipes **2** is set to be horizontal and the position angle γ of the second inlet header **5** is changed. Specifically, FIG. **4**(*a*) is a diagram for explaining the position angle γ. FIG. **4**(*b*) illustrates the positions of the heat exchanger **10** at main position angles γ. FIG. **4**(*c*) shows a test result and illustrates the relationship between the position angle γ and the heat transfer characteristics (relative value). The heat transfer characteristics (relative value) of the heat exchanger **10** indicated on the ordinate axis in FIG. **4**(*c*) are expressed by relative values, with 1 as the heat transfer characteristics obtained under a condition in which the low-temperature fluid is distributed to the through-holes **21** in the second flat pipes **2** with a uniform gas-to-liquid ratio.

[0047] Unlike the heat exchanger **10** shown in FIG. **1**, the ends of the second flat pipes **2** shown in FIG. **4** do not have folded sections. In other words, in each of the second flat pipes **2** shown in FIG. **4**, the inflow segment **2***a,* the outflow segment **2***d,* and the heat exchanging segment **2***c* are parallel to each other. Furthermore, when the position angle γ=0°, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in a horizontal direction. When 0°<position angle γ<90°, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** downward relative to the horizontal direction. When the position angle γ=90°, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the vertically downward direction. When −90°<position angle γ<0°, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** upward relative to the horizontal direction. When the position angle γ=−90°, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the vertically upward direction.

[0048] As shown in FIG. **4**(*c*), it is confirmed that the heat transfer characteristics of the heat exchanger **10** tend to be slightly higher when the second inlet header **5** is set in a vertical position, but the effect of the position angle γ against the position of the second inlet header **5** is relatively small.

[0049] FIG. **5** illustrates the heat transfer characteristics obtained when both the position of the second inlet header **5** and the outflowing direction of the low-temperature fluid in the two-phase gas-liquid state flowing out toward the through-holes **21** in the second flat pipes **2** are changed. Specifically, FIG. **5**(*a*) is a diagram for explaining the position angle β. FIG. **5**(*b*) illustrates the positions of the heat exchanger **10** at main position angles β. FIG. **5**(*c*) shows a test result and illustrates the relationship between the position angle β and the heat transfer characteristics (relative value). The heat transfer characteristics (relative value) of the heat exchanger **10** indicated on the ordinate axis in FIG. **5**(*c*) are expressed by relative values, with 1 as the heat transfer characteristics obtained under a condition in which the low-temperature fluid is distributed to the through-holes **21** in the second flat pipes **2** with a uniform gas-to-liquid ratio.

[0050] Unlike the heat exchanger **10** shown in FIG. **1**, the ends of the second flat pipes **2** shown in FIG. **5** each have one folded section. In other words, in each of the second flat pipes **2** shown in FIG. **5**, the inflow segment **2***a* and the outflow segment **2***d* are directly connected to the heat exchanging segment **2***c* (without the intervention of the bent segments **2***b*).

[0051] When the position angle β=0°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the vertically downward direction. When 0°<position angle β<90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** upward relative to the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** downward relative to the horizontal direction. When the position angle β=90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the vertically upward direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the horizontal direction. When 90°<position angle β<180°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** upward relative to the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** upward relative to the horizontal direction. When the position angle β=180°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the vertically upward direction.

[0052] When −90°<position angle β<0°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** downward relative to the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** downward relative to the horizontal direction. When the position angle β=−90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the vertically downward direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the horizontal direction. When −180°<position angle β<−90°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** downward relative to the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** downward relative to the horizontal direction. When the position angle β=−180°, the low-temperature fluid (in the two-phase gas-liquid state) flows out toward the through-holes **21** in the second flat pipes **2** in the horizontal direction, and the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header **5** in the vertically downward direction.

[0053] As shown in FIG. **5**(*c*), it is confirmed that, when 0°≦position angle β≦180°, the heat transfer characteristics can be maintained at a high level. In particular, it is confirmed that, when the position angle β is close to 90° or close to 180°, the heat transfer characteristics are at the maximum level. It is also confirmed that, when the position angle β is smaller than 0°, the heat transfer characteristics decrease sharply. In other words, it is confirmed from this result that, when 0°≦position angle β≦180°, the gas-to-liquid ratio of the low-temperature fluid distributed to the through-holes **21** is substantially made uniform. Furthermore, it is confirmed that, by setting the position angle β close to 90° or close to 180°, the gas-to-liquid ratio of the low-temperature fluid distributed to the through-holes **21** can be made more uniform.

(Advantages)

[0054] Accordingly, in the heat exchanger **10** according to Embodiment 1, at least one of the high-temperature fluid flowing into the through-holes in the first flat pipes **1** from the first inlet header **3** and the low-temperature fluid flowing into the through-holes **21** in the second flat pipes **2** from the second inlet header **4** is a fluid in a two-phase gas-liquid state. The two-phase gas-liquid fluid flows into the flat pipes from the inlet header in a substantially horizontal direction or in an upward direction relative to the substantially horizontal direction. Therefore, even when the flow velocity within the second inlet header **5** decreases to cause the gas and the liquid to flow separately through the upper side and the lower side therein, the inflow segments extending from the second inlet header **5** to the second flat pipes **2** are prevented from being constantly filled with the liquid, thereby preventing deterioration in the gas-liquid distribution caused by the liquid alone flowing out selectively to the second flat pipes **2** located at the upstream side. Therefore, the two-phase gas-liquid fluid can be distributed to the through-holes with a uniform gas-to-liquid ratio so that the temperature efficiency of the fluid can be maximized and the pressure loss can be minimized. In other words, the heat exchanging performance of the heat exchanger **10** can be improved.

[0055] Consequently, with the heat exchanger **10** according to Embodiment 1, a compact, high-performance heat exchanger can be obtained.

[0056] The description of Embodiment 1 is directed to a case where the low-temperature fluid flowing through the second inlet header **5** turns into a two-phase gas-liquid state. If the high-temperature fluid flowing through the first inlet header **3** turns into a two-phase gas-liquid state, similar advantages can be achieved by making the high-temperature fluid flow into the through-holes in the first flat pipes **1** from the first inlet header **3** in a substantially horizontal direction.

Embodiment 2

[0057] The configuration of the heat exchanger **10** according to Embodiment 1 is merely an example; for example, the heat exchanger **10** may be configured as follows. The following description will mainly be focused on the differences from the heat exchanger **10** according to Embodiment 1.

[0058] FIG. **6** includes side views illustrating examples of a heat exchanger according to Embodiment 2 of the present invention.

[0059] In a heat exchanger **10** shown in FIG. **6**(*a*), the bent segments **2***b* of each second flat pipe **2** are substantially U-shaped in cross section. In other words, the bent segment **2***b* that connects the inflow segment **2***a* and the heat exchanging segment **2***c* of the second flat pipe **2** is disposed so as to overpass the first outlet header **4** through which the high-temperature fluid flows. Moreover, the bent segment **2***b* that connects the heat exchanging segment **2***c* and the outflow segment **2***d* of the second flat pipe **2** is disposed so as to overpass the first inlet header **3** through which the high-temperature fluid flows.

[0060] In addition to achieving the advantages of Embodiment 1, the heat exchanger **10** having such a configuration achieves compactness since the height of the flat pipes **1** and **2** is reduced in the stacked direction thereof.

[0061] In each of the second flat pipes **2** in a heat exchanger **10** shown in FIG. **6**(*b*), the end thereof at the second inlet header **5** side and the end thereof at the second outlet header **6** side are bent in opposite directions. Moreover, each first flat pipe **1** has an inflow segment **1***a*, a heat exchanging segment **1***c*, an outflow segment **1***d*, and bent segments **1***b*. The inflow segment **1***a* is connected to the first inlet header **3** and has a substantially horizontal passage. The outflow segment **1***d* is connected to the first outlet header **4** and has a substantially horizontal passage. The heat exchanging segment **1***c* and the heat exchanging segment **2***c* of the second flat pipe **2** are stacked such that flat surfaces thereof are in contact with each other. The bent segments **1***b* connect between the inflow segment **1***a* and the heat exchanging segment **1***c*, as well as between the heat exchanging segment **1***c* and the outflow segment **1***d*. The end of each first flat pipe **1** at the first inlet header **3** side is bent in the same direction as the end of each second flat pipe **2** at the second outlet header **6** side. The end of each first flat pipe **1** at the first outlet header **4** side is bent in the same direction as the end of each second flat pipe **2** at the second inlet header **5** side.

[0062] In addition to achieving the advantages of Embodiment 1, the heat exchanger **10** having such a configuration is advantageous in that the installation space can be made compact in the height direction when a plurality of heat exchangers **10** are installed. In other words, when a plurality of heat exchangers **10** are installed by stacking them in the stacked direction of the flat pipes **1** and **2** for increasing the heat exchanging capability, gaps between the heat exchangers **10** in the height direction can be reduced while interference between the headers **3**, **4**, **5**, and **6** is prevented.

[0063] In a heat exchanger **10** shown in FIG. **6**(*c*), the second flat pipes are provided above the first flat pipes **1** and also below the first flat pipes **1**. Second flat pipes **2**A disposed above the first flat pipes **1** each have an inflow segment **2**Aa, a heat exchanging segment **2**Ac, an outflow segment **2**Ad, and bent segments **2**Ab. The inflow segment **2**Aa is connected to a second inlet header **5**A and has a substantially horizontal passage. The outflow segment **2**Ad is connected to a second outlet header **6**A and has a substantially horizontal passage. The heat exchanging segment **2**Ac and the corresponding first flat pipe **1** are stacked such that flat surfaces thereof are in contact with each other. The bent segments **2**Ab connect between the inflow segment **2**Aa and the heat exchanging segment **2**Ac, as well as between the heat exchanging segment **2**Ac and the outflow segment **2**Ad. The ends of each second flat pipe **2**A are bent so as to extend upon the first inlet header **3** and the first outlet header **4**.

[0064] Second flat pipes **2**B disposed below the first flat pipes **1** each have an inflow segment **2**Ba, a heat exchanging segment **2**Bc, an outflow segment **2**Bd, and bent segments **2**Bb. The inflow segment **2**Ba is connected to a second inlet header **5**B and has a substantially horizontal passage. The outflow segment **2**Bd is connected to a second outlet header **6**B and has a substantially horizontal passage. The heat exchanging segment **2**Bc and the corresponding first flat pipe **1** are stacked such that flat surfaces thereof are in contact with each other. The bent segments **2**Bb connect between the inflow segment **2**Ba and the heat exchanging segment **2**Bc, as well as between the heat exchanging segment **2**Bc and the outflow segment **2**Bd. The ends of each second flat pipe **2**B are bent so as to extend under the first inlet header **3** and the first outlet header **4**.

[0065] When increasing the heat exchanging capability, optimizing the heat transfer and flow characteristics of the second flat pipes **2** or the like, there is a case where two second flat pipes **2**A and **2**B are disposed for each first flat pipe **1**. In the heat exchanger **10** having such a configuration, the low-temperature fluid in the two-phase gas-liquid state is made to flow out toward the through-holes **21** in the second flat pipes **2**A in a substantially horizontal direction. Furthermore, in the heat exchanger **10** having such a configuration, the low-temperature fluid in the two-phase gas-liquid state is made to flow out toward the through-holes **21** in the second flat pipes **2**B in a substantially horizontal direction. Therefore, similar to Embodiment 1, the gas-to-liquid ratio of the low-temperature fluid distributed to the through-holes **21** can be made uniform, whereby a compact, high-performance heat exchanger **10** can be obtained.

Embodiment 3

[0066] The heat exchanger **10** according to each of Embodiment 1 and Embodiment 2 is installed in, for example, a refrigeration and air-conditioning apparatus, such as an air-conditioning apparatus, a hot-water storage apparatus, or a refrigeration apparatus. An example of a refrigeration and air-conditioning apparatus equipped with the heat exchanger **10** according to Embodiment 1 or Embodiment 2 will be described below.

[0067] FIG. **7** is a refrigerant circuit diagram illustrating an example of a refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0068] The refrigeration and air-conditioning apparatus shown in FIG. **7** has a first refrigerant circuit in which a first compressor **30**, a first radiator **31**, a first pressure reducing device **32**, and a first cooling unit **33** are connected in that order with pipes. The first refrigerant circuit makes a first refrigerant serving as a high-temperature fluid circulate therethrough and operates based on a vapor compression refrigeration cycle. The heat exchanger **10** is disposed between the first radiator **31** and the first pressure reducing device **32** in the first refrigerant circuit. The first inlet header **3** of the heat exchanger **10** is connected to the first radiator **31**, and the first outlet header **4** is connected to the first pressure reducing device **32**.

[0069] The refrigeration and air-conditioning apparatus also has a second refrigerant circuit in which the heat exchanger **10**, a second compressor **40**, a second radiator **41**, and a second pressure reducing device **42** are connected in that order with pipes. The second outlet header **6** of the heat exchanger **10** is connected to the second compressor **40**, and the second inlet header **5** is connected to the second pressure reducing device **42**. The second refrigerant circuit makes a second refrigerant serving as a low-temperature fluid circulate therethrough and operates based on a vapor compression refrigeration cycle. The first refrigerant and the second refrigerant used are a refrigerant such as carbon dioxide, an HFC-based refrigerant, an HC-based refrigerant, an HFO-based refrigerant, and ammonia. In Embodiment 3, carbon dioxide is used as the first refrigerant.

[0070] The first refrigerant is compressed by the first compressor **30** and is discharged therefrom as a high-temperature high-pressure supercritical fluid. The first refrigerant having become a high-temperature high-pressure supercritical fluid is transported to the first radiator **31** and is decreased in temperature by exchanging heat with air or the like at the first radiator **31**, thereby becoming a high-pressure supercritical fluid. The first refrigerant having become a high-pressure supercritical fluid is decreased in temperature by being cooled by the heat exchanger **10**, flows into the first pressure reducing device **32** where the first refrigerant is decompressed so as to change into a low-temperature low-pressure two-phase gas-liquid state, and is then transported to the first cooling unit **33**. The first refrigerant in the low-temperature low-pressure two-phase gas-liquid state evaporates by exchanging heat with air or the like at the first cooling unit **33** and then returns to the first compressor **30**.

[0071] On the other hand, the second refrigerant is compressed by the second compressor **40** and is discharged therefrom as high-temperature high-pressure vapor. The second refrigerant having becoming high-temperature high-pressure vapor is transported to the second radiator **41** and is decreased in temperature by exchanging heat with air or the like at the second radiator **41**, thereby becoming a high-pressure liquid. The second refrigerant having become a high-pressure liquid is decompressed by the second pressure reducing device **42** so as to change into a low-temperature two-phase gas-liquid state, and is transported to the heat exchanger **10**. The second refrigerant in the low-temperature two-phase gas-liquid state becomes vapor by being heated at the heat exchanger **10** and then returns to the second compressor **40**.

[0072] In the refrigeration and air-conditioning apparatus having such a configuration, a large degree of subcooling for the refrigerant flowing out from the first radiator **31** can be ensured so that the efficiency of the refrigeration and air-conditioning apparatus can be significantly improved.

[0073] Even if an HFC-based refrigerant, an HC-based refrigerant, an HFO-based refrigerant, or ammonia is used as the first refrigerant flowing through the first refrigerant circuit, the efficiency of the refrigeration and air-conditioning apparatus is improved by ensuring a large degree of subcooling for the refrigerant flowing out from the first radiator **31**. The efficiency of the refrigeration and air-conditioning apparatus is improved especially when the first refrigerant in the first refrigerant circuit is carbon dioxide and transfers heat at a critical point or higher.

[0074] Although the second refrigerant circuit is described as being a vapor compression refrigeration cycle in Embodiment 3, the second refrigerant may alternatively be water or brine (antifreeze), such as an ethylene glycol aqueous solution, and the second compressor **40** may alternatively be a pump.

[0075] FIG. **8** is a refrigerant circuit diagram illustrating another example of the refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0076] In the refrigeration and air-conditioning apparatus shown in FIG. **8**, the first radiator **31** is omitted from the configuration of the refrigeration and air-conditioning apparatus shown in FIG. **7**, and the first refrigerant, which is high-temperature high-pressure vapor, discharged from the first compressor **30** is entirely cooled at the heat exchanger **10**. In other words, the refrigeration and air-conditioning apparatus shown in FIG. **8** is a so-called secondary-loop refrigeration and air-conditioning apparatus. In this case, the heat exchanger **10** is used as the first radiator **31**. In the refrigeration and air-conditioning apparatus shown in FIG. **8**, the amount of heat exchange required in the heat exchanger **10** is increased, and the percentage of volume occupying the overall refrigeration and air-conditioning apparatus becomes larger than in the case where the first radiator **31** is provided. With the heat exchanger **10** made compact, the advantage in which the entire refrigeration and air-conditioning apparatus is made compact is further increased.

[0077] FIG. **9** is a refrigerant circuit diagram illustrating another example of the refrigeration and air-conditioning apparatus according to Embodiment 3 of the present invention.

[0078] The refrigeration and air-conditioning apparatus shown in FIG. **9** has a refrigerant circuit in which the first compressor **30**, the first radiator **31**, the first pressure reducing device **32**, and the first cooling unit **33** are connected in that order. Furthermore, the refrigeration and air-conditioning apparatus shown in FIG. **9** has a bypass pipe **52**. The bypass pipe **52** has one end connected between the first radiator **31** and the first pressure reducing device **32** and other end connected to an injection port **53**, which is provided at an intermediate position in a refrigerant compression process in the first compressor **30**, or between the compressor **30** and the first cooling unit **33**, although not shown here. The heat exchanger **10** is disposed between the first radiator **31** and the first pressure reducing device **32** in the refrigerant circuit and at an intermediate position of the bypass pipe **52**. With regard to the heat exchanger **10**, the first inlet header **3** is connected to the first radiator **31**, and the first outlet header **4** is connected to the first pressure reducing device **32**. Furthermore, with regard to the heat exchanger **10**, the second inlet header **5** is connected to a bypass pressure reducing device **51**, and the second outlet header **6** is connected to the injection port **53** or between the compressor **30** and the first cooling unit **33**, although not shown here.

[0079] A refrigerant (i.e., low-temperature fluid) decompressed by the bypass pressure reducing device **51** changes into a low-temperature two-phase gas-liquid state, exchanges heat at the heat exchanger **10** with a refrigerant (i.e., high-temperature fluid) flowing out from the first radiator **31**, and is then transported to the injection port **53** of the first compressor **30**. A refrigerant such as an HFC-based refrigerant, an HC-based refrigerant, an HFO-based refrigerant, ammonia, and carbon dioxide is used in the refrigeration and air-conditioning apparatus shown in FIG. **9**.

[0080] In the refrigeration and air-conditioning apparatus having such a configuration, a large degree of subcooling for the refrigerant flowing out from the first radiator **31** can be ensured so that the efficiency of the refrigeration and air-conditioning apparatus can be significantly improved.

[0081] Furthermore, in the refrigeration and air-conditioning apparatus shown in FIG. **9**, the higher the saturation temperature (i.e., gas-liquid equilibrium temperature) of the low-temperature fluid flowing into the injection port **53** from the heat exchanger **10** is, the higher the efficiency of the first compressor **30** is, thus also allowing for a reduction of required power. By cooling the outlet of the first radiator **31** as shown in FIG. **9**, a sufficiently large temperature difference between the high-temperature fluid and the low-temperature fluid can be ensured in the heat exchanger **10** especially when the outdoor air temperature is high and the temperature of the high-temperature fluid at the outlet of the first radiator **31** is relatively high. Therefore, the temperature of the low-temperature fluid flowing into the injection port **53** can be maintained at a higher level, thereby ensuring high efficiency of the first compressor **30**.

[0082] If the second end of the bypass pipe **52** is connected between the first compressor **30** and the first cooling unit **33**, the flow rate of refrigerant flowing through the first cooling unit **33** can be reduced without reducing the refrigeration effect, as compared with a case where the heat exchanger **10** is not used. This is effective especially if the pipe length between the first compressor **30** and the first cooling unit **33** is large since deterioration in performance caused by an increase in pressure loss can be suppressed.

[0083] Accordingly, with the compact, high-performance heat exchanger **10** installed, a refrigeration and air-conditioning apparatus that is compact and has the above-described advantages can be obtained.

Embodiment 4

[0084] In the heat exchanger **10** described in each of Embodiment 1 and Embodiment 2, the first flat pipes **1** through which the high-temperature fluid flows and the second flat pipes **2** through which the low-temperature fluid flows are formed independently of each other, and the first flat pipes **1** and the second flat pipes **2** are stacked such that the flat surfaces thereof are joined together by soldering or the like. In other words, in the heat exchanger **10** described in each of Embodiment 1 and Embodiment 2, the refrigerant passages through which the high-temperature fluid flows and the refrigerant passages through which the low-temperature fluid flows are formed in separate components. Alternatively, in the heat exchanger **10**, the refrigerant passages through which the high-temperature fluid flows and the refrigerant passages through which the low-temperature fluid flows may be formed in the same component (in other words, the first passage section and the second passage section according to the present invention may be integrally formed). The heat exchanger **10** having such a configuration may be installed in the refrigeration and air-conditioning apparatus according to Embodiment 3. In Embodiment 4, items not described in particular are the same as those in Embodiment 1 to Embodiment 3.

[0085] FIG. **10** includes structural diagrams of a heat exchanger according to Embodiment 4 of the present invention. Specifically, FIG. **10**(*a*) is a perspective view of the heat exchanger **10**, and FIG. **10**(*b*) is a diagram as viewed along an arrow A in FIG. **10**(*a*).

[0086] As shown in FIG. **10**, a plurality of first refrigerant passages **101***a* through which a first refrigerant (e.g., a high-temperature fluid) flows extend through a main body **110** of the heat exchanger **10** according to Embodiment 4 in, for example, the longitudinal direction (i.e., the up-down direction in FIG. **10**). By arranging these first refrigerant passages **101***a* in parallel to each other, a first refrigerant path **101** is formed. Moreover, a plurality of second refrigerant passages **102***a* through which a second refrigerant (e.g., a low-temperature fluid) flows extend through the main body **110** in, for example, the longitudinal direction (i.e., the up-down direction in FIG. **10**). By arranging these second refrigerant passages **102***a* in parallel to each other, a second refrigerant path **102** is formed. The first refrigerant path **101** and the second refrigerant **102** are disposed such that the parallel-arranged direction of the first refrigerant passages **101***a* and the parallel-arranged direction of the second refrigerant passages **102***a* are aligned with each other. In the heat exchanger **10** shown in FIG. **10**, the first refrigerant path **101** (i.e., the first refrigerant passages **101***a*) and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*) are vertically disposed.

[0087] The expression “aligned” used here does not imply that the parallel-arranged direction of the first refrigerant passages **101***a* is exactly parallel to the parallel-arranged direction of the second refrigerant passages **102***a*, but indicates that the parallel-arranged directions of the two are substantially aligned with each other. Therefore, the expression “the parallel-arranged directions of the two are aligned with each other” will be used in Embodiment 4 even if the parallel-arranged direction of the first refrigerant passages **101***a* and the parallel-arranged direction of the second refrigerant passages **102***a* are somewhat tilted.

[0088] In other words, in Embodiment 4, the first refrigerant path **101** and the second refrigerant path **102** are integrally formed. The main body **110** having the first refrigerant path

101 and the second refrigerant path **102** is composed of, for example, aluminum or an aluminum alloy, copper or a copper alloy, steel, or a stainless alloy, and is manufactured by extrusion, pultrusion or the like.

[0089] One of two ends of the main body **110** in the refrigerant flowing direction is provided with a second inlet communication hole **105***a* that extends in the parallel-arranged direction of the second refrigerant passages **102***a* and communicates with all of the second refrigerant passages **102***a*. The other end is provided with a second outlet communication hole **106***a* that extends in the parallel-arranged direction of the second refrigerant passages **102***a* and communicates with all of the second refrigerant passages **102***a*. In other words, in the heat exchanger **10** shown in FIG. **10**, the second inlet communication hole **105***a* and the second outlet communication hole **106***a* are horizontally disposed.

[0090] Similarly, of the two ends of the main body **110** in the refrigerant flowing direction, the one end that is provided with the second outlet communication hole **106***a* is provided with a first inlet communication hole **103***a* that extends in the parallel-arranged direction of the first refrigerant passages **101***a* and communicates with all of the first refrigerant passages **101***a*. Moreover, of the two ends of the main body **110** in the refrigerant flowing direction, the other end that is provided with the second inlet communication hole **105***a* is provided with a first outlet communication hole **104***a* that extends in the parallel-arranged direction of the first refrigerant passages **101***a* and communicates with all of the first refrigerant passages **101***a*. In other words, in the heat exchanger **10** shown in FIG. **10**, the first inlet communication hole **103***a* and the first outlet communication hole **104***a* are horizontally disposed.

[0091] Furthermore, the first inlet communication hole **103***a* and the second outlet communication hole **106***a* are slightly displaced relative to each other in the refrigerant flowing direction of the first refrigerant passages **101***a* (in other words, the second refrigerant passages **102***a*). Moreover, the first outlet communication hole **104***a* and the second inlet communication hole **105***a* are slightly displaced relative to each other in the refrigerant flowing direction of the first refrigerant passages **101***a* (in other words, the second refrigerant passages **102***a*).

[0092] The extending direction of the first inlet communication hole **103***a* and the first outlet communication hole **104***a* do not necessarily need to be orthogonal to the direction of the first refrigerant passages **101***a*. Furthermore, the extending direction of the second inlet communication hole **105***a* and the second outlet communication hole **106***a* do not necessarily need to be orthogonal to the direction of the second refrigerant passages **102***a*.

[0093] The first inlet communication hole **103***a*, the first outlet communication hole **104***a*, the second inlet communication hole **105***a*, and the second outlet communication hole **106***a* each have one open end and are respectively connected to a first inlet connection pipe **103**, a first outlet connection pipe **104**, a second inlet connection pipe **105**, and a second outlet connection pipe **106** so as to communicate with the outside. The other end of each of the first inlet communication hole **103***a*, the first outlet communication hole **104***a*, the second inlet communication hole **105***a*, and the second outlet communication hole **106***a* is closed by a sealing member or the like.

[0094] In FIG. **10**, the open (or closed) ends of the first inlet communication hole **103***a*, the first outlet communication hole **104***a*, the second inlet communication hole **105***a*, and the second outlet communication hole **106***a* are all located at the same side. However, the open (or closed) ends of the first inlet communication hole **103***a*, the first outlet communication hole **104***a*, the second inlet communication hole **105***a*, and the second outlet communication hole **106***a* are not limited to the positions shown in FIG. **10** and do not need to be located at the same side so long as each communication hole has an open end and a closed end.

[0095] Both ends of each of the plurality of first refrigerant passages **101***a* and second refrigerant passages **102***a* extending through the main body **110** in the longitudinal direction are sealed by a process such as pinching or sealed by using sealing members (not shown).

[0096] The heat exchanger **10** according to Embodiment 4 is assumed to be used in a position that makes the low-temperature fluid and the high-temperature fluid flow in the up-down direction as shown in FIG. **10**. Furthermore, in the heat exchanger **10** according to Embodiment 4, the low-temperature fluid in a two-phase gas-liquid state is assumed to flow into the second refrigerant passages **102***a* of the second refrigerant path via the second inlet connection pipe **105** and the second inlet communication hole **105***a*. Therefore, in the heat exchanger **10** according to Embodiment 4, the second inlet communication hole **105***a* is disposed at the following position based on the information obtained from the tests shown in FIGS. **3** to **5** in Embodiment 1, that is, the ranges of the aforementioned position angles α, β, and γ providing excellent heat transfer characteristics.

[0097] Specifically, when the second inlet communication hole **105***a* is observed in the central-axis direction of the second inlet communication hole **105***a*, the central axis of the second inlet communication hole **105***a* is disposed at a position that is aligned with a connection section between the second inlet communication hole **105***a* and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*), or at a position away from the first refrigerant path **101** (i.e., the first refrigerant passages **101***a*) relative to the connection section.

[0098] Thus, in the heat exchanger **10** according to Embodiment 4, the second refrigerant path **102** and the second inlet header **5** are connected with a position angle α in a range of $0° \leqq \alpha < 110°$ (or $-110° < \alpha \leqq 0$ if the positive direction is the same as in FIG. **3**).

[0099] The first refrigerant path **101**, the second refrigerant path **102**, the first inlet communication hole **103***a*, the first outlet communication hole **104***a*, the second inlet communication hole **105***a*, and the second outlet communication hole **106***a* respectively correspond to "first passage section", "second passage section", "first inlet header", "first outlet header", "second inlet header", and "second outlet header" according to the present invention.

[0100] Next, a heat exchanging process between the high-temperature fluid and the low-temperature fluid in the heat exchanger **10** according to Embodiment 4 will be described with reference to FIG. **10**.

[0101] The high-temperature fluid flows into the first inlet communication hole **103***a* via the first inlet connection pipe **103**, flows through the first refrigerant path **101** and the first outlet communication hole **104***a* in that order, and then flows out from the first outlet connection pipe **104**. On the other hand, the low-temperature fluid in a two-phase gas-liquid state flows into the second inlet communication hole **105***a* via the second inlet connection pipe **105**, flows through the second refrigerant path **102** and the second outlet communication hole **106***a* in that order, and then flows out from the second outlet connection pipe **106**. During this time, the high-temperature fluid flowing through the first refrigerant path **101** and the low-temperature fluid flowing through the second refrigerant path **102** exchange heat in a countercurrent manner via a partition wall between the refrigerant paths.

[0102] In the heat exchanger **10** having the configuration as in Embodiment 4, when the second inlet communication hole **105***a* is observed in the central-axis direction of the second inlet communication hole **105***a*, the central axis of the second inlet communication hole **105***a* is disposed at a position that is aligned with the connection section between the second inlet communication hole **105***a* and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*), or at a position away from the first refrigerant path **101** (i.e., the first refrigerant passages **101***a*) relative to the connection section. Consequently, the position angle α when the low-temperature fluid in the two-phase gas-liquid state flows into the second refrigerant path **102** from the second inlet communication hole **105***a* is in a range of $0° \leqq \alpha < 110°$. Therefore, the low-temperature fluid in the two-phase gas-liquid state is readily distributed to the second refrigerant passages **102***a* of the second refrigerant path **102** with a substantially uniform gas-to-liquid ratio, whereby a heat exchanger **10** with stable performance can be obtained.

[0103] It is apparent from Embodiment 1 that, if the direction indicated by an arrow in FIG. **10**(*b*) is defined as the positive direction, the distribution characteristics of a gaseous phase component and a liquid phase component in the low-temperature fluid are optimal when $80° < \alpha < 100°$. Moreover, the distance between the first refrigerant path **101** and the second refrigerant path **102** located next to each other can be shortened. Therefore, if the direction indicated by the arrow in FIG. **10**(*b*) is defined as the positive direction, the second inlet communication hole **105***a* is formed so as to satisfy $80° < \alpha < 100°$, thereby further suppressing heat resistance in the main body **110** due to heat conductivity and further improving the performance of the heat exchanger **10**.

[0104] With the first refrigerant path **101** and the second refrigerant path **102** formed integrally in the main body **110**, the following various advantages can also be achieved.

[0105] First, heat resistance generated, in case that the passages through which the high-temperature fluid flows and the passages through which the low-temperature fluid flows are formed in separate components, at joint surfaces of these components is suppressed, whereby the heat exchanging performance of the heat exchanger **10** can be improved.

[0106] Furthermore, because the first inlet communication hole **103***a* and the first outlet communication hole **104***a* are provided inside the main body **110** of the heat exchanger **10**, an additional header pipe for connecting to the first refrigerant path **101** is not necessary, thereby achieving compactness of the heat exchanger **10**, as well as simplifying the manufacturing process. The same applies to the second inlet communication hole **105***a* and the second outlet communication hole **106***a* with respect to the second refrigerant path **102**.

[0107] Furthermore, since the first inlet communication hole **103***a* and the second outlet communication hole **106***a* are slightly displaced relative to each other in the fluid flowing direction, and the first outlet communication hole **104***a* and the second inlet communication hole **105***a* are slightly displaced relative to each other in the fluid flowing direction, the distance between the first refrigerant path **101** and the second refrigerant path **102** located next to each other can be shortened, as compared with a case where the holes are not displaced, thereby achieving compactness of the heat exchanger **10**.

[0108] In the heat exchanger **10** according to Embodiment 4, although the first refrigerant passages **101***a* and the second refrigerant passages **102***a* are rectangular in cross section, as shown in FIG. **10**, the cross-sectional shapes thereof are not limited to a rectangular shape. The cross-sectional shape of the first refrigerant passages **101***a* and the second refrigerant passages **102***a* may be polygonal, or circular for enhancing the pressure resisting performance, for example. The first refrigerant passages **101***a* and the second refrigerant passages **102***a* may certainly be elongated or ellipsoidal in cross section. In this case, it is needless to say that the cross-sectional shape of the first refrigerant passages **101***a* and the cross-sectional shape of the second refrigerant passages **102***a* do not need to be the same. Furthermore, in order to enhance the heat transfer performance, the heat transfer area may be increased by providing a groove in the inner surface of each of the first refrigerant passages **101***a* and the second refrigerant passages **102***a*. In this case, these grooves may be processed simultaneously during the extrusion process or the pultrusion process of the main body **10** so that the manufacturing process can be simplified.

[0109] Although the number of first refrigerant passages **101***a* in the first refrigerant path **101** and the number of second refrigerant passages **102***a* in the second refrigerant path **102** are the same in the heat exchanger **10** according to Embodiment 4, as shown in FIG. **10**, the numbers thereof are not limited to this relationship. Specifically, the numbers may be varied in accordance with the operating conditions or the flow property values of the high-temperature fluid and the low-temperature fluid in the heat exchanger **10** so that a preferred heat exchanger **10** with high heat transfer performance and low pressure loss is achieved.

[0110] Although the high-temperature fluid flowing through the first refrigerant path **101** and the low-temperature fluid flowing through the second refrigerant path **102** exchange heat in a countercurrent manner, the two fluids may alternatively exchange heat in a parallel current manner. For example, by making the high-temperature fluid flow in from the first inlet connection pipe **103** and making the low-temperature fluid flow in from the second outlet connection pipe **106**, the high-temperature fluid and the low-temperature fluid are made to flow in parallel to each other.

[0111] Furthermore, although the heat exchanger **10** in FIG. **10** is described as being used in a position that makes the low-temperature fluid and the high-temperature fluid flow in the up-down direction, the installation position of the heat exchanger **10** according to Embodiment 4 in which the first refrigerant path **101** and the second refrigerant path **102** are integrally formed is not limited to the position shown in FIG. **10**.

[0112] FIG. **11** includes structural diagrams illustrating another example of the heat exchanger according to Embodiment 4 of the present invention. Specifically, FIG. **11**(*a*) is a perspective view of the heat exchanger **10**, and FIG. **11**(*b*) is a diagram as viewed along an arrow A in FIG. **11**(*a*).

[0113] The heat exchanger **10** shown in FIG. **11** is assumed to be used in a position that makes the low-temperature fluid and the high-temperature fluid flow in the left-right direction (i.e., substantially horizontal direction). In other words, in the heat exchanger **10** shown in FIG. **11**, the first refrigerant path

101 (i.e., the first refrigerant passages **101***a*) and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*) are horizontally disposed. The remaining configuration is similar to that in the heat exchanger **10** shown in FIG. **10** and exhibits similar advantages. Since components given the same reference numerals in FIGS. **10** and **11** have the same functions and operate in the same manner, descriptions of the functions and operations thereof will be omitted.

[0114] In the heat exchanger **10** having the configuration shown in FIG. **11**, when the second inlet communication hole **105***a* is observed in the central-axis direction of the second inlet communication hole **105***a,* the central axis of the second inlet communication hole **105***a* may similarly be disposed at a position that is aligned with the connection section between the second inlet communication hole **105***a* and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*), or at a position away from the first refrigerant path **101** (i.e., the first refrigerant passages **101***a*) relative to the connection section. Consequently, the position angle α when the low-temperature fluid in the two-phase gas-liquid state flows into the second refrigerant path **102** from the second inlet communication hole **105***a* can beset in a range of $0° < \alpha \leqq 90°$. Therefore, the low-temperature fluid in the two-phase gas-liquid state is readily distributed to the second refrigerant passages **102***a* of the second refrigerant path **102** with a substantially uniform gas-to-liquid ratio, whereby a heat exchanger **10** with stable performance can be obtained. Although a range of $80° < \alpha < 100°$ is the most preferable as the distribution characteristics, in the case of Embodiment 4, as α approaches closer to 0° from 90° (specifically, as the central axis of the second inlet communication hole **105***a* is disposed farther away from the first refrigerant path **101**), the distance between the first refrigerant path **101** and the second refrigerant path **102** located next to each other can be shorter. Therefore, a position angle α that allows for reduced heat resistance by heat conductivity and improved performance may at least be in the range of $0° < \alpha \leqq 90°$.

[0115] As shown in FIGS. **10** and **11**, with regard to the heat exchanger **10** according to Embodiment 4, a usage mode in which the low-temperature fluid in the two-phase gas-liquid state is made to flow in from the second outlet connection pipe **106** and flow out from the second inlet connection pipe **105** may also be assumed. Therefore, when the second outlet communication hole **106***a* is observed in the central-axis direction of the second outlet communication hole **106***a,* the central axis of the second outlet communication hole **106***a* is disposed at a position aligned with a connection section between the second outlet communication hole **106***a* and the second refrigerant path **102** (i.e., the second refrigerant passages **102***a*), or at a position away from the first refrigerant path **101** (i.e., the first refrigerant passages **101***a*) relative to the connection section.

REFERENCE SIGNS LIST

[0116] **1** first flat pipe, **1***a* inflow segment, **1***b* bent segment, **1***c* heat exchanging segment, **1***d* outflow segment, **2** second flat pipe, **2***a* inflow segment, **2***b* bent segment, **2***c* heat exchanging segment, **2***d* outflow segment, **2**A second flat pipe, **2**Aa inflow segment, **2**Ab bent segment, **2**Ac heat exchanging segment, **2**Ad outflow segment, **2**B second flat pipe, **2**Ba inflow segment, **2**Bb bent segment, **2**Bc heat exchanging segment, **2**Bd outflow segment, **3** first inlet header, **4** first outlet header, **5** second inlet header, **5**A second inlet header, **5**B second inlet header, **6** second outlet header, **6**A second outlet header, **6**B second outlet header, **10** heat exchanger, **21** through-hole, **30** first compressor, **31** first radiator, **32** first pressure reducing device, **33** first cooling unit, **40** second compressor, **41** second radiator, **42** second pressure reducing device, **52** bypass pipe, **53** injection port, **101** first refrigerant path, **101***a* first refrigerant passage, **102** second refrigerant path, **102***a* second refrigerant passage, **103** first inlet connection pipe, **103***a* first inlet communication hole, **104** first outlet connection pipe, **104***a* first outlet communication hole, **105** second inlet connection pipe, **105***a* second inlet communication hole, **106** second outlet connection pipe, **106***a* second outlet communication hole, **110** main body.

1-**9**. (canceled)

10. A heat exchanger comprising:

a main body in which a plurality of through-holes are arranged in parallel to each other as a first passage section and a plurality of through-holes aligned with the first passage section are arranged in parallel to each other as a second passage section, the main body being integrally formed with the first passage section and the second passage section, wherein

the main body is formed with a second inlet header as a hole that communicates with the plurality of through-holes of the second passage section,

the second inlet header is formed to shift a position away from the through-holes aligned with the first passage section relative to a connection position between the second inlet header and the plurality of through-holes of the second passage section.

11. A refrigeration and air-conditioning apparatus comprising the heat exchanger of claim **10**.

12. The heat exchanger of claim **10**, wherein

the second inlet header has a central axis, and

in case of observing in a direction of the central axis, the central axis is disposed at the position away from the through-holes aligned with the first passage section relative to the connection position between the second inlet header and the through-holes of the second passage section.

13. The heat exchanger of claim **10**, wherein

the main body includes a first inlet header and a first outlet header as holes that communicate with the plurality of through-holes of the first passage section, and

the main body includes a second outlet header as a hole that communicates with the plurality of through-holes of the second passage section.

14. The heat exchanger of claim **13**, wherein

a hole of the first inlet header, a hole of the second inlet header, a hole of the first outlet header, and a hole of the second outlet header are each a shifted position in an extending direction of through-holes of the first passage section or the second passage section.

15. A method for heat exchange that uses the heat exchanger of claim **10**, comprising:

flowing a two-phase gas-liquid fluid into the second passage section, the two-phase gas-liquid fluid being lower temperature than a fluid flowed into the first passage section.

16. The method for heat exchange of claim **15**, wherein

an extending direction of the plurality of through-holes of the second passage section is set to a vertical direction, and a direction for the second inlet header to communicate is set to a horizontal direction.

17. The method for heat exchange of claim **16**, further comprising:

flowing the fluid into the second passage section upward from the second inlet header.

18. The method for heat exchange of claim **15**, wherein

an extending direction of the plurality of through-holes of the second passage section is set horizontally, and

in case of observing in a central-axis direction of the second inlet header, a direction from a position of a central-axis of the hole of the second inlet header to a connection position between the second inlet header and the through-holes of the first passage section is set upward relative to a horizontal direction.

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