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• **NAKAMUNE, Hiroaki**
Tokyo 100-8310 (JP)
• **SAKAI, Mizuo**
Tokyo 100-8310 (JP)
• **IKEDA, Soshi**
Tokyo 100-8310 (JP)

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(71) Applicant: **Mitsubishi Electric Corporation**
Tokyo 100-8310 (JP)

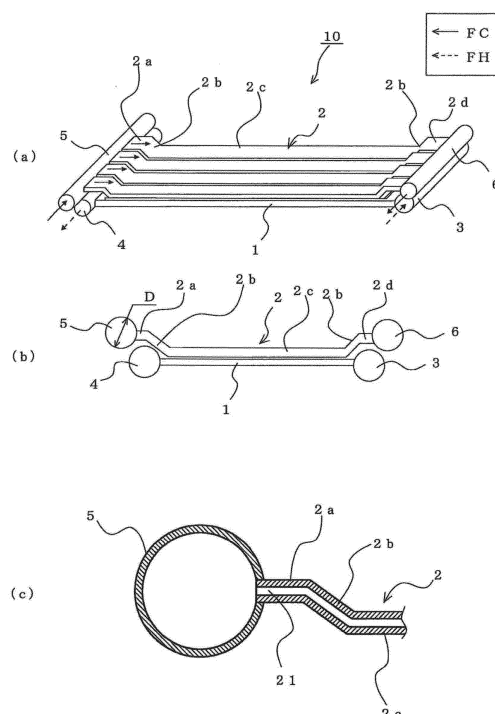
(74) Representative: **Sajda, Wolf E. et al**
Meissner, Bolte & Partner GbR
Postfach 86 06 24
81633 München (DE)

(72) Inventors:
• **YOSHIMURA, Susumu**
Tokyo 100-8310 (JP)

(54) **HEAT EXCHANGER AND REFRIGERATION AND AIR CONDITIONING DEVICE**

(57) A heat exchanger (10) includes a first flat pipe (1) having a plurality of through-holes through which a high-temperature fluid flows, a second flat pipe (2) having a plurality of through-holes (21) through which a low-temperature fluid flows, a first inlet header (3) having a tubular shape and connected to one end of the first flat pipe (1), a first outlet header (4) having a tubular shape and connected to other end of the first flat pipe (1), a second inlet header (5) having a tubular shape and connected to one end of the second flat pipe (2), and a second outlet header (6) having a tubular shape and connected to other end of the second flat pipe (2). The first flat pipe (1) and the second flat pipe (2) are stacked such that flat surfaces thereof are in contact with each other. The low-temperature fluid flowing into the through-holes (21) in the second flat pipe (2) from the second inlet header (5) is a fluid in a two-phase gas-liquid state. The low-temperature fluid flows into the through-holes (21) in the second flat pipe (2) from the second inlet header (5) in a substantially horizontal direction or in an upward direction relative to the substantially horizontal direction.

FIG. 1



DescriptionTechnical Field

[0001] The present invention relates to a heat exchanger that is adapted to exchange 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 such a 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 ListPatent Literature**[0003]**

Patent Literature 1: Japanese Unexamined Patent Application Publication JP-A-2008-141 852 (paragraph [0036], FIG. 1)

Summary of the InventionTechnical 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 the 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 the 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 the Drawings

[0010]

FIG. 1 illustrates a heat exchanger according to Embodiment 1 of the present invention.

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

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

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

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

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

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.

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.

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.

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

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

[0011] 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.

[0012] In Embodiment 1, a substantially-horizontal inflow segment 2a 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°.

[0013] 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 2c 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.

Moreover, 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.

[0014] 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 2a 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 2d 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 2a and the outflow segment 2d are connected to the heat exchanging segment 2c via bent segments 2b. In other words, the through-holes 21 formed in the second flat pipes 2 form parallel passages through which the low-temperature fluid flows.

[0015] 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).

Furthermore, the inflow segments 2a 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 2a) 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.

The first flat pipes 1 correspond to a "first passage section" according to the present invention, and the second flat pipes 2 correspond to a "second passage section" according to the present invention.

[0016] 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 2c).

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.

[0017] 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 2a 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 2a of each second flat pipe 2 may alternatively protrude into the second inlet header 5.

[0018] 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.

[0019] 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.

Furthermore, although the inflow segments 2a are formed by bending the second flat pipes 2 outside the second inlet header 5 in Embodiment 1, the inflow segments 2a 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.

[0020] In the heat exchanger 10 according to Embodiment 1, the inflow segments 2a 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.

[0021] 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.

[0022]

Mathematical Expression 1

$$KA = \frac{M_h C_{p_h} (T_{hi} - T_{ho})}{3600 [LMTD]}$$

[0023]

Mathematical Expression 2

$$[LMTD] = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})}}$$

In this case, M_h denotes a mass flow rate (kg/h) of the high-temperature fluid, C_{p_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.

[0024] In the tests shown in FIGs. 3 to 5, the configuration of the heat exchanger 10 is set as follows.

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.

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

[0025] In the tests shown in FIGs. 3 to 5, the heat transfer characteristics KA (W/K) are measured under the following conditions.

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. 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.

[0026] 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° .

[0027] 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 α 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.

[0028] 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 2a and the outflow segment 2d are directly connected to the heat exchanging segment 2c (without the intervention of the bent segments 2b). Furthermore, when the position angle $\alpha = 0^\circ$, 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 $0^\circ < \text{position angle } \alpha < 90^\circ$, 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 $\alpha = 90^\circ$, 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 $90^\circ < \text{position angle } \alpha < 180^\circ$, 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 $\alpha = 180^\circ$, 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.

[0029] As shown in FIG. 3(c), it is confirmed that, when $-110^\circ < \text{position angle } \alpha < 110^\circ$ (more preferably, $80^\circ < \text{position angle } \alpha < 100^\circ$ or $-80^\circ < \text{position angle } \alpha < -100^\circ$), 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° ($85^\circ < \text{position angle } \alpha < 95^\circ$ or $-85^\circ < \text{position angle } \alpha < -95^\circ$), 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 $-110^\circ < \text{position angle } \alpha < 110^\circ$, 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.

[0030] 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.

[0031] 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 2a, the outflow segment 2d, and the heat exchanging segment 2c are parallel to each other. Furthermore, when the position angle $\gamma = 0^\circ$, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header 5 in a horizontal direction. When $0^\circ < \text{position angle } \gamma < 90^\circ$, 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 $\gamma = 90^\circ$, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header 5 in the vertically downward direction.

When $-90^\circ < \text{position angle } \gamma < 0^\circ$, 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 $\gamma = -90^\circ$, the low-temperature fluid (in the two-phase gas-liquid state) flows into the second inlet header 5 in the vertically upward direction.

[0032] 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.

[0033] 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.

[0034] 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 2a and the outflow segment 2d are directly connected to the heat exchanging segment 2c (without the intervention of the bent segments 2b).

[0035] When the position angle $\beta = 0^\circ$, 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 $0^\circ < \text{position angle } \beta < 90^\circ$, 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 $\beta = 90^\circ$, 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 $90^\circ < \text{position angle } \beta < 180^\circ$, 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 $\beta = 180^\circ$, 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.

[0036] When $-90^\circ < \text{position angle } \beta < 0^\circ$, 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 $\beta = -90^\circ$, 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 $-180^\circ < \text{position angle } \beta < -90^\circ$, 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 $\beta = -180^\circ$, 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.

[0037] As shown in FIG. 5(c), it is confirmed that, when $0^\circ \leq \text{position angle } \beta \leq 180^\circ$, 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 $0^\circ \leq \text{position angle } \beta \leq 180^\circ$, 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

[0038] 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.

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

[0039] 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

[0040] 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.

[0041] FIG. 6 includes side views illustrating examples of a heat exchanger according to Embodiment 2 of the present

invention.

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

[0042] 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.

[0043] 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 1a, a heat exchanging segment 1c, an outflow segment 1d, and bent segments 1b. The inflow segment 1a is connected to the first inlet header 3 and has a substantially horizontal passage. The outflow segment 1d is connected to the first outlet header 4 and has a substantially horizontal passage.

The heat exchanging segment 1c and the heat exchanging segment 2c of the second flat pipe 2 are stacked such that flat surfaces thereof are in contact with each other. The bent segments 1b connect between the inflow segment 1a and the heat exchanging segment 1c, as well as between the heat exchanging segment 1c and the outflow segment 1d.

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.

[0044] 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.

[0045] 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 2A disposed above the first flat pipes 1 each have an inflow segment 2Aa, a heat exchanging segment 2Ac, an outflow segment 2Ad, and bent segments 2Ab. The inflow segment 2Aa is connected to a second inlet header 5A and has a substantially horizontal passage. The outflow segment 2Ad is connected to a second outlet header 6A and has a substantially horizontal passage.

The heat exchanging segment 2Ac and the corresponding first flat pipe 1 are stacked such that flat surfaces thereof are in contact with each other. The bent segments 2Ab connect between the inflow segment 2Aa and the heat exchanging segment 2Ac, as well as between the heat exchanging segment 2Ac and the outflow segment 2Ad. The ends of each second flat pipe 2A are bent so as to extend upon the first inlet header 3 and the first outlet header 4.

[0046] Second flat pipes 2B disposed below the first flat pipes 1 each have an inflow segment 2Ba, a heat exchanging segment 2Bc, an outflow segment 2Bd, and bent segments 2Bb. The inflow segment 2Ba is connected to a second inlet header 5B and has a substantially horizontal passage. The outflow segment 2Bd is connected to a second outlet header 6B and has a substantially horizontal passage.

The heat exchanging segment 2Bc and the corresponding first flat pipe 1 are stacked such that flat surfaces thereof are in contact with each other. The bent segments 2Bb connect between the inflow segment 2Ba and the heat exchanging segment 2Bc, as well as between the heat exchanging segment 2Bc and the outflow segment 2Bd. The ends of each second flat pipe 2B are bent so as to extend under the first inlet header 3 and the first outlet header 4.

[0047] 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 2A and 2B 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 2A 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 2B 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

[0048] 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.

[0049] 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.

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.

[0050] 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.

[0051] 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.

[0052] 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 become 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.

[0053] 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.

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.

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.

[0054] 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.

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.

[0055] 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.

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.

[0056] 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.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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

[0061] 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.

[0062] 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).

As shown in FIG. 10, a plurality of first refrigerant passages 101a 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 101a in parallel to each other, a first refrigerant path 101 is formed. Moreover, a plurality of second refrigerant passages 102a 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 102a 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 101a and the parallel-arranged direction of the second refrigerant passages 102a 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 101a) and the second refrigerant path 102 (i.e., the second refrigerant passages 102a) are vertically disposed. The expression "aligned" used here does not imply that the parallel-arranged direction of the first refrigerant passages 101a is exactly parallel to the parallel-arranged direction of the second refrigerant passages 102a, 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 101a and the parallel-arranged direction of the second refrigerant passages 102a are somewhat tilted.

[0063] 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.

[0064] One of two ends of the main body 110 in the refrigerant flowing direction is provided with a second inlet communication hole 105a that extends in the parallel-arranged direction of the second refrigerant passages 102a and communicates with all of the second refrigerant passages 102a. The other end is provided with a second outlet communication hole 106a that extends in the parallel-arranged direction of the second refrigerant passages 102a and communicates with all of the second refrigerant passages 102a. In other words, in the heat exchanger 10 shown in FIG. 10, the second inlet communication hole 105a and the second outlet communication hole 106a are horizontally disposed.

[0065] 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 106a is provided with a first inlet communication hole 103a that extends in the parallel-arranged direction of the first refrigerant passages 101a and communicates with all of the first refrigerant passages 101a.

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 105a is provided with a first outlet communication hole 104a that extends in the parallel-arranged direction of the first refrigerant passages 101a 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 103a and the first outlet communication hole 104a are horizontally disposed.

[0066] Furthermore, the first inlet communication hole 103a and the second outlet communication hole 106a are slightly displaced relative to each other in the refrigerant flowing direction of the first refrigerant passages 101a (in other words, the second refrigerant passages 102a). Moreover, the first outlet communication hole 104a and the second inlet communication hole 105a are slightly displaced relative to each other in the refrigerant flowing direction of the first refrigerant passages 101a (in other words, the second refrigerant passages 102a).

[0067] The extending direction of the first inlet communication hole 103a and the first outlet communication hole 104a do not necessarily need to be orthogonal to the direction of the first refrigerant passages 101a. Furthermore, the extending direction of the second inlet communication hole 105a and the second outlet communication hole 106a do not necessarily need to be orthogonal to the direction of the second refrigerant passages 102a.

[0068] The first inlet communication hole 103a, the first outlet communication hole 104a, the second inlet communication hole 105a, and the second outlet communication hole 106a 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 103a, the first outlet communication hole 104a, the second inlet communication hole 105a, and the second outlet communication hole 106a is closed by a sealing member or the like.

In FIG. 10, the open (or closed) ends of the first inlet communication hole 103a, the first outlet communication hole 104a, the second inlet communication hole 105a, and the second outlet communication hole 106a are all located at the same side. However, the open (or closed) ends of the first inlet communication hole 103a, the first outlet communication hole 104a, the second inlet communication hole 105a, and the second outlet communication hole 106a 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.

[0069] Both ends of each of the plurality of first refrigerant passages 101a and second refrigerant passages 102a 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).

[0070] 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 102a of the second refrigerant path via the second inlet connection pipe 105 and the second inlet communication hole 105a.

Therefore, in the heat exchanger 10 according to Embodiment 4, the second inlet communication hole 105a 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.

[0071] Specifically, when the second inlet communication hole 105a is observed in the central-axis direction of the second inlet communication hole 105a, the central axis of the second inlet communication hole 105a is disposed at a position that is aligned with a connection section between the second inlet communication hole 105a and the second refrigerant path 102 (i.e., the second refrigerant passages 102a), or at a position away from the first refrigerant path 101 (i.e., the first refrigerant passages 101a) relative to the connection section.

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 $0^\circ \leq \alpha < 110^\circ$ (or $-110^\circ < \alpha \leq 0$ if the positive direction is the same as in FIG. 3).

[0072] The first refrigerant path 101, the second refrigerant path 102, the first inlet communication hole 103a, the first outlet communication hole 104a, the second inlet communication hole 105a, and the second outlet communication hole 106a respectively correspond to the "first passage section", the "second passage section", the "first inlet header", the "first outlet header", the "second inlet header", and the "second outlet header" according to the present invention.

[0073] 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.

[0074] The high-temperature fluid flows into the first inlet communication hole 103a via the first inlet connection pipe 103, flows through the first refrigerant path 101 and the first outlet communication hole 104a 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 105a via the second inlet connection pipe 105, flows through the second refrigerant path 102 and the second outlet communication hole 106a 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.

[0075] In the heat exchanger 10 having the configuration as in Embodiment 4, when the second inlet communication hole 105a is observed in the central-axis direction of the second inlet communication hole 105a, the central axis of the second inlet communication hole 105a is disposed at a position that is aligned with the connection section between the second inlet communication hole 105a and the second refrigerant path 102 (i.e., the second refrigerant passages 102a), or at a position away from the first refrigerant path 101 (i.e., the first refrigerant passages 101a) 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 105a is in a range of $0^\circ \leq \alpha < 110^\circ$. Therefore, the low-temperature fluid in the two-phase gas-liquid state is readily distributed to the second refrigerant passages 102a 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.

[0076] 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 $80^\circ < \alpha < 100^\circ$. 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 105a is formed so as to satisfy $80^\circ < \alpha < 100^\circ$, thereby further suppressing heat resistance in the main body 110 due to heat conductivity and further improving the performance of the heat exchanger 10.

[0077] 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.

[0078] 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.

[0079] Furthermore, because the first inlet communication hole 103a and the first outlet communication hole 104a 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 105a and the second outlet communication hole 106a with respect to the second refrigerant path 102.

[0080] Furthermore, since the first inlet communication hole 103a and the second outlet communication hole 106a are slightly displaced relative to each other in the fluid flowing direction, and the first outlet communication hole 104a

and the second inlet communication hole 105a 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.

[0081] In the heat exchanger 10 according to Embodiment 4, although the first refrigerant passages 101a and the second refrigerant passages 102a 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 101a and the second refrigerant passages 102a may be polygonal, or circular for enhancing the pressure resisting performance, for example.

The first refrigerant passages 101a and the second refrigerant passages 102a 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 101a and the cross-sectional shape of the second refrigerant passages 102a 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 101a and the second refrigerant passages 102a. 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.

[0082] Although the number of first refrigerant passages 101a in the first refrigerant path 101 and the number of second refrigerant passages 102a 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.

[0083] 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.

[0084] 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.

[0085] 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).

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 101a) and the second refrigerant path 102 (i.e., the second refrigerant passages 102a) 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.

[0086] In the heat exchanger 10 having the configuration shown in FIG. 11, when the second inlet communication hole 105a is observed in the central-axis direction of the second inlet communication hole 105a, the central axis of the second inlet communication hole 105a may similarly be disposed at a position that is aligned with the connection section between the second inlet communication hole 105a and the second refrigerant path 102 (i.e., the second refrigerant passages 102a), or at a position away from the first refrigerant path 101 (i.e., the first refrigerant passages 101a) 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 105a can be set in a range of $0^\circ < \alpha \leq 90^\circ$. Therefore, the low-temperature fluid in the two-phase gas-liquid state is readily distributed to the second refrigerant passages 102a 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 $80^\circ < \alpha < 100^\circ$ 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 105a 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 $0^\circ \leq \alpha \leq 90^\circ$.

[0087] 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 106a is observed in the central-axis direction of the second outlet communication hole 106a, the central axis of the second outlet communication hole 106a is disposed at a position aligned with a connection section between the second outlet communication hole 106a and the second refrigerant path 102 (i.e., the second refrigerant passages 102a), or at a position away from the first refrigerant path 101 (i.e., the first refrigerant passages 101a) relative to the connection section.

List of Reference Signs

[0088]

1	= first flat pipe
1a	= inflow segment
1b	= bent segment
1c	= heat exchanging segment
1d	= outflow segment
2	= second flat pipe
2a	= inflow segment
2b	= bent segment
2c	= heat exchanging segment
2d	= outflow segment
2A	= second flat pipe
2Aa	= inflow segment
2Ab	= bent segment
2Ac	= heat exchanging segment
2Ad	= outflow segment
2B	= second flat pipe
2Ba	= inflow segment
2Bb	= bent segment
2Bc	= heat exchanging segment
2Bd	= outflow segment
3	= first inlet header
4	= first outlet header
5	= second inlet header
5A	= second inlet header
5B	= second inlet header
6	= second outlet header
6A	= second outlet header
6B	= 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
101a	= first refrigerant passage

(continued)

102	= second refrigerant path
102a	= second refrigerant passage
103	= first inlet connection pipe
103a	= first inlet communication hole
104	= first outlet connection pipe
104a	= first outlet communication hole
105	= second inlet connection pipe
105a	= second inlet communication hole
106	= second outlet connection pipe
106a	= second outlet communication hole
110	= main body.

Claims**1.** A heat exchanger comprising:

- 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,

wherein the first passage section and the second passage section are disposed in a heat exchangeable manner via a partition wall provided therebetween,

wherein 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, and

wherein a direction in which the fluid in the two-phase gas-liquid state flows into the corresponding passage section from the corresponding inlet header is in a range of $-110^\circ < \text{position angle } \alpha < 110^\circ$, assuming that an angle α in a downward direction from a vertical direction is positive.

2. The heat exchanger of claim 1,

wherein the direction in which the fluid in the two-phase gas-liquid state flows into the passage section from the inlet header is in a range of $-80^\circ < \text{position angle } \alpha < -100^\circ$ or $80^\circ < \text{position angle } \alpha < 100^\circ$, assuming that the angle α in the downward direction from the vertical direction is positive.

3. The heat exchanger of claim 1,

wherein the fluid in the two-phase gas-liquid state flows into the passage section from the inlet header in a substantially horizontal direction or in an upward direction relative to the substantially horizontal direction.

4. The heat exchanger of claim 1,

wherein the direction in which the fluid in the two-phase gas-liquid state flows into the passage section from the inlet header is in a positive range, assuming that an angle in an upward direction from a horizontal direction is positive.

5. The heat exchanger of claim 1,

wherein the fluid in the two-phase gas-liquid state flows into the passage section from the inlet header in a substantially horizontal direction, assuming that an angle in an upward direction from a horizontal direction is positive.

6. The heat exchanger of any one of claims 1 to 5,

wherein an end of the passage section connected to the inlet header through which the fluid in the two-phase gas-liquid state flows is bent inside the inlet header through which the fluid in the two-phase gas-liquid state flows.

7. The heat exchanger of any one of claims 1 to 5,

wherein an end of the passage section connected to the inlet header through which the fluid in the two-phase gas-liquid state flows is bent outside the inlet header through which the fluid in the two-phase gas-liquid state flows.

8. A heat exchanger comprising:

- a first passage section, disposed vertically or horizontally, in which a plurality of through-holes through which a high-temperature fluid flows are arranged parallel to each other;
- a second passage section, disposed vertically or horizontally in which a plurality of through-holes through which a low-temperature fluid flows are arranged parallel to each other;
- a first inlet header disposed horizontally, having a tubular shape and connected to one end of the first passage section;
- a first outlet header disposed horizontally, having a tubular shape and connected to other end of the first passage section;
- a second inlet header disposed horizontally, having a tubular shape and connected to one end of the second passage section; and
- a second outlet header disposed horizontally, having a tubular shape and connected to other end of the second passage section;

wherein the first passage section, the second passage section, the first inlet header, the first outlet header, the second inlet header, and the second outlet header are integrally formed,

wherein the first passage section and the second passage section are disposed with aligning parallel-arranged directions of the through-holes thereof each other so as to be capable to exchange heat via a partition wall provided therebetween,

wherein 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, and

wherein, in a state where the inlet header through which the fluid in the two-phase gas-liquid state flows is observed in a central-axis direction of the inlet header, a central axis of the inlet header through which the fluid in the two-phase gas-liquid state flows is disposed at a position that is aligned with a connection section between the inlet header and the passage section connected to the inlet header, or at a position away from the passage section not connected to the inlet header relative to the connection section.

9. A refrigeration and air-conditioning apparatus equipped with the heat exchanger of any one of claims 1 to 8.

FIG. 1

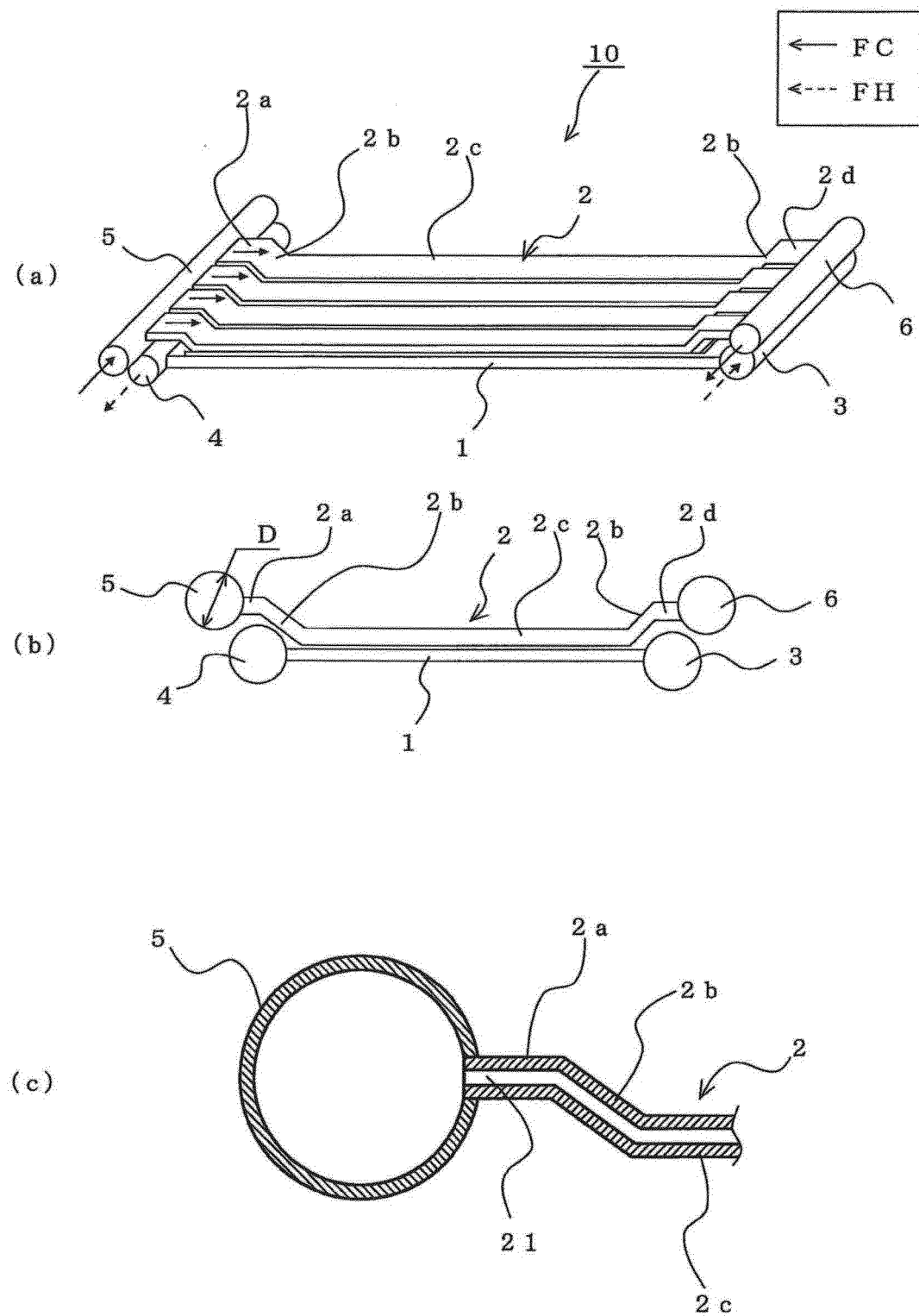


FIG. 2

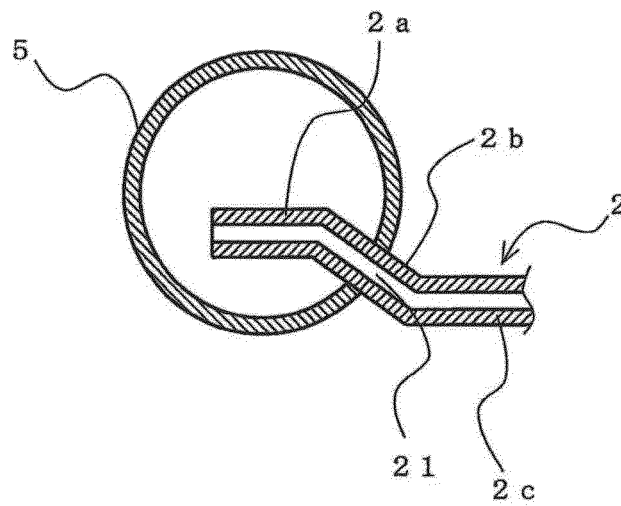


FIG. 3

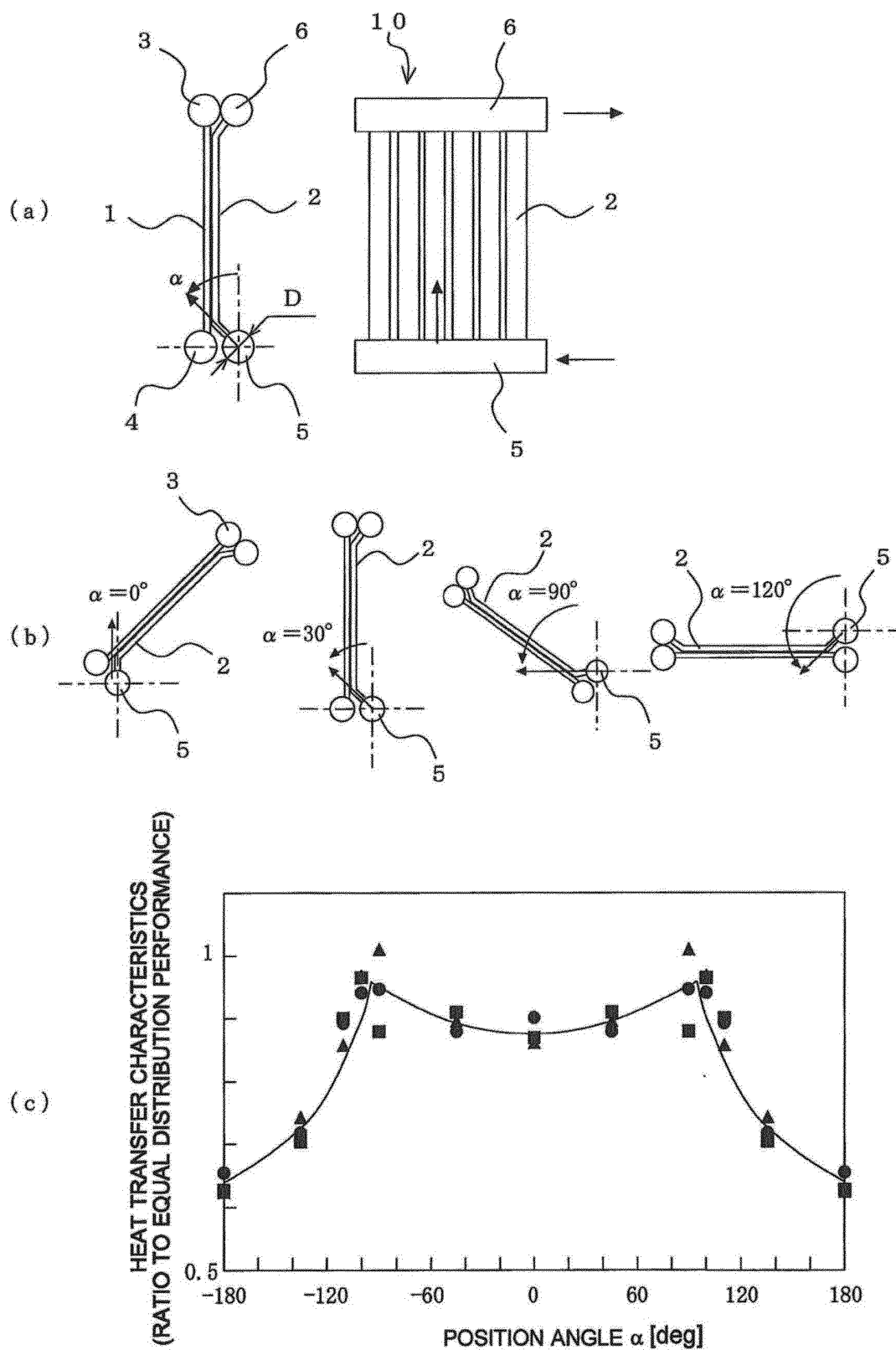


FIG. 4

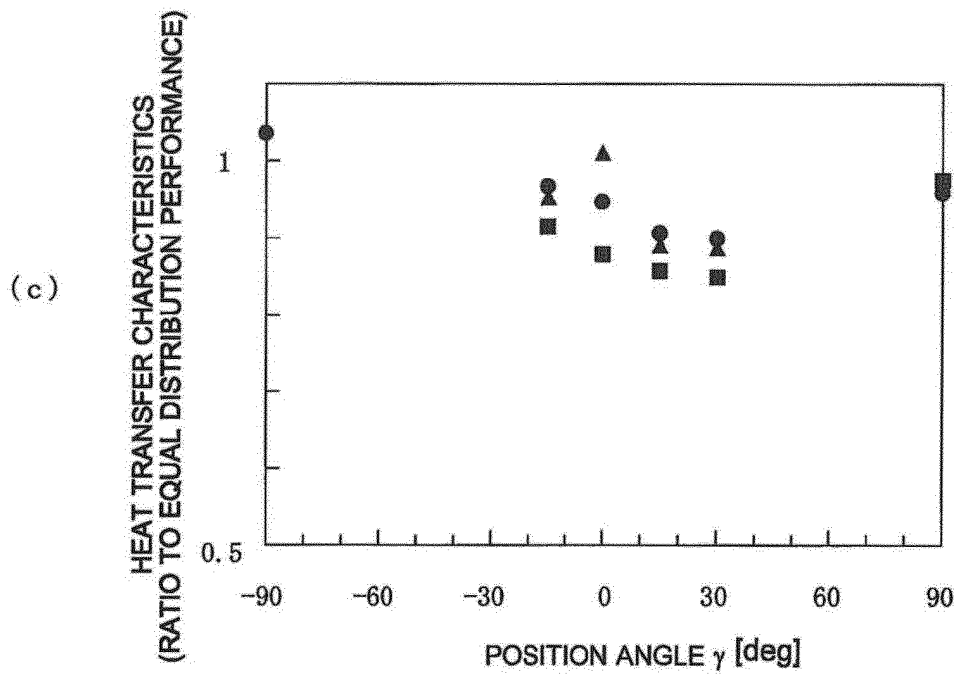
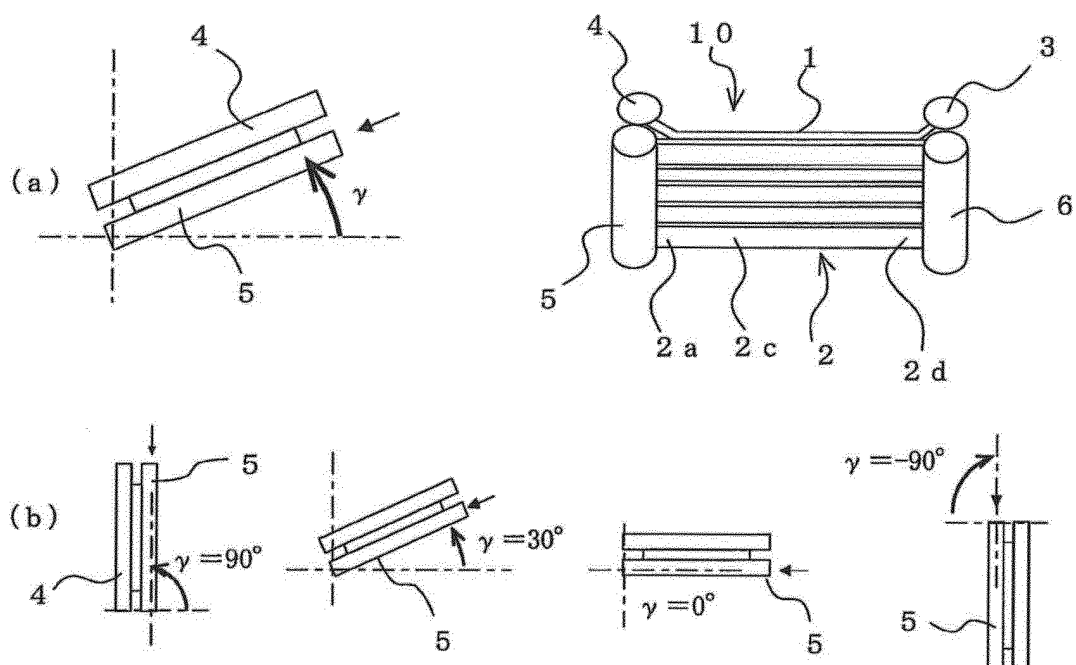


FIG. 5

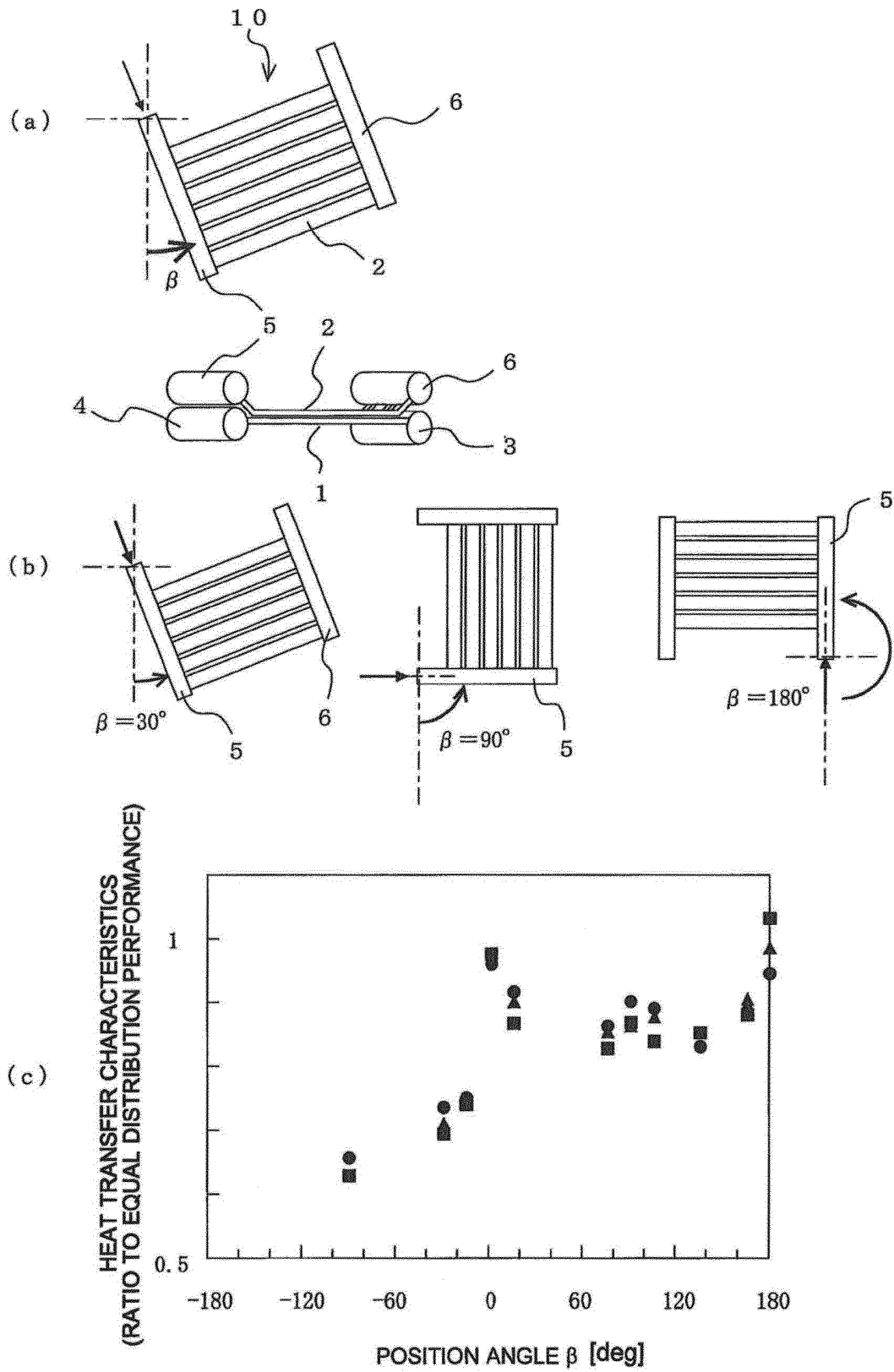


FIG. 6

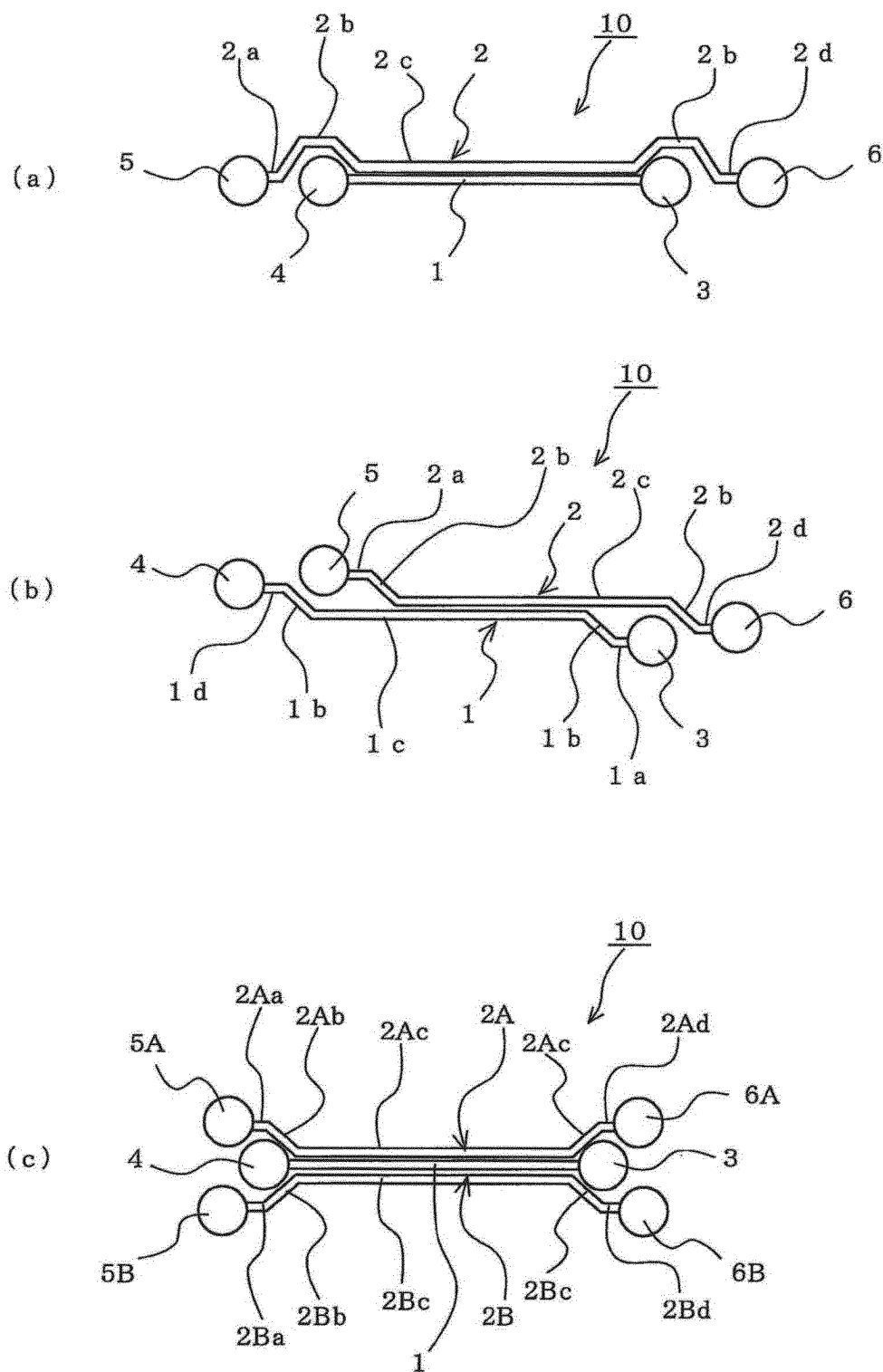


FIG. 7

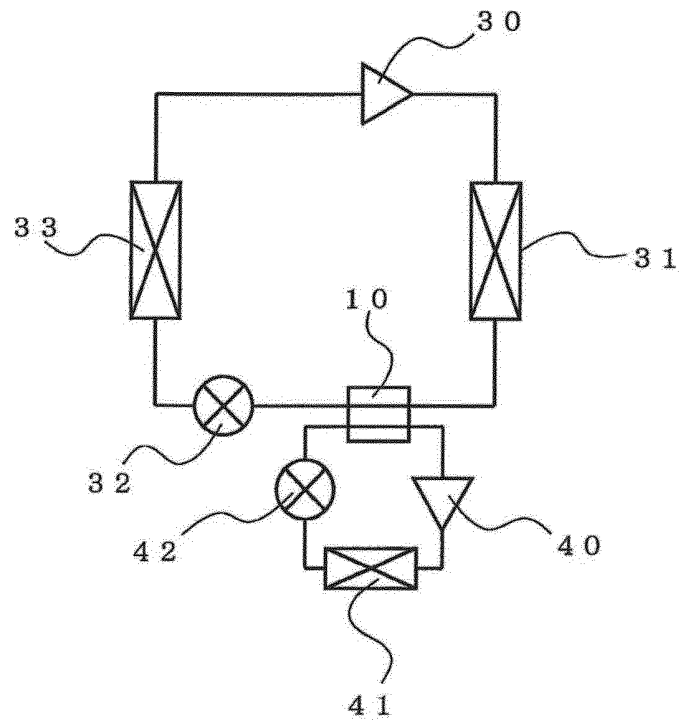


FIG. 8

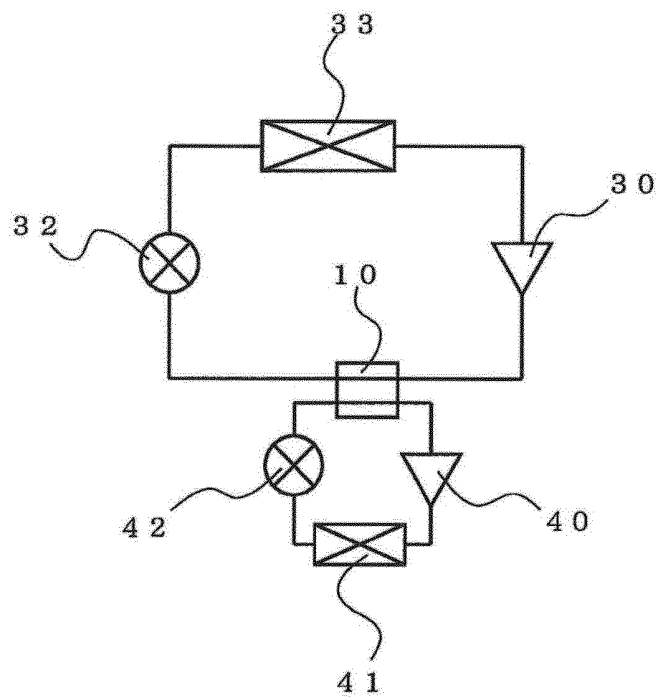


FIG. 9

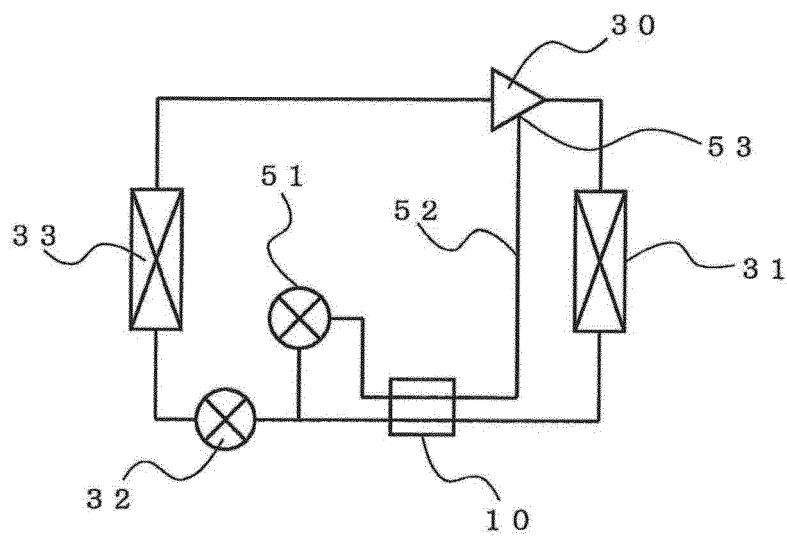


FIG. 10

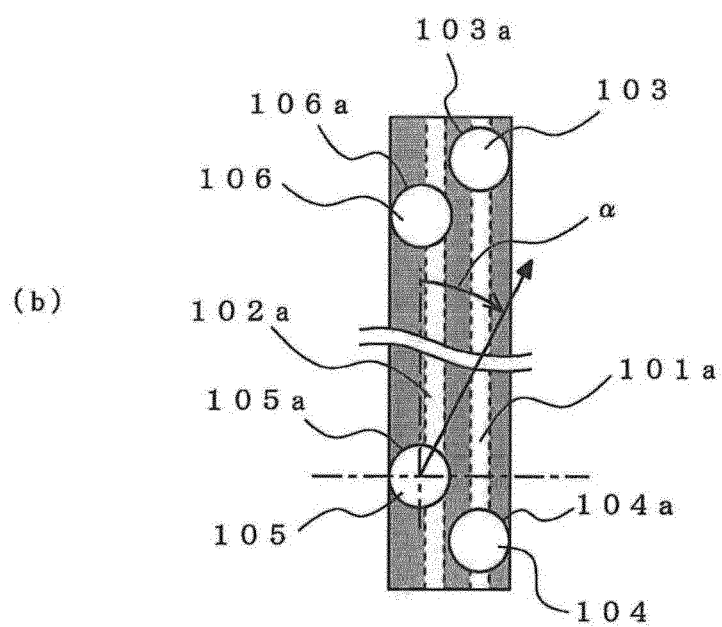
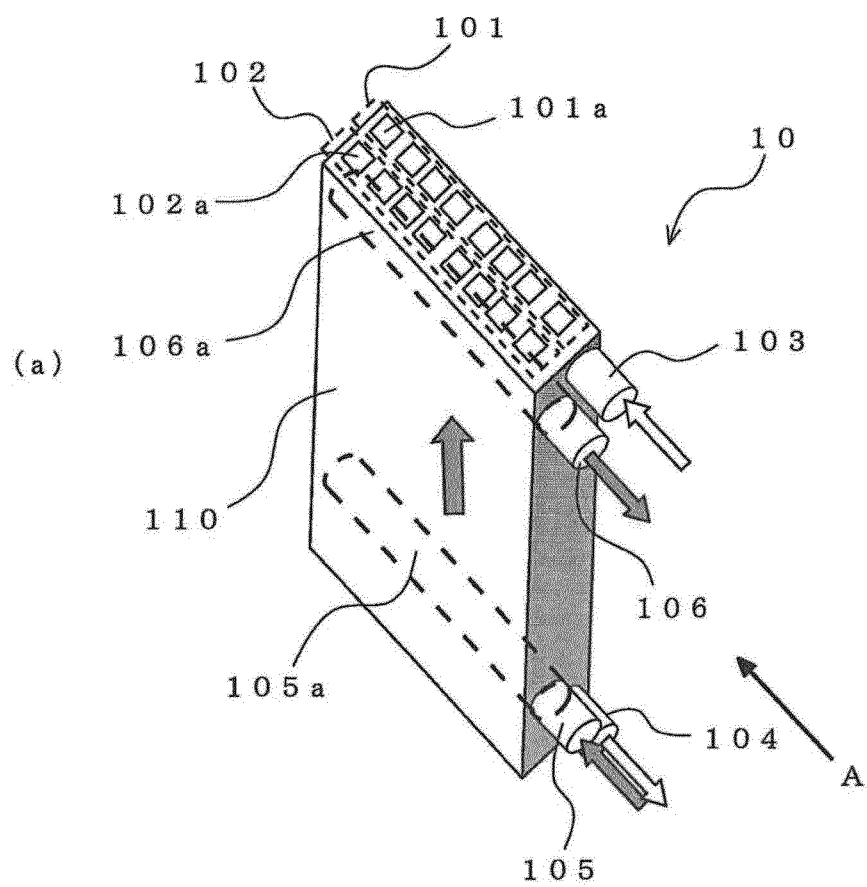
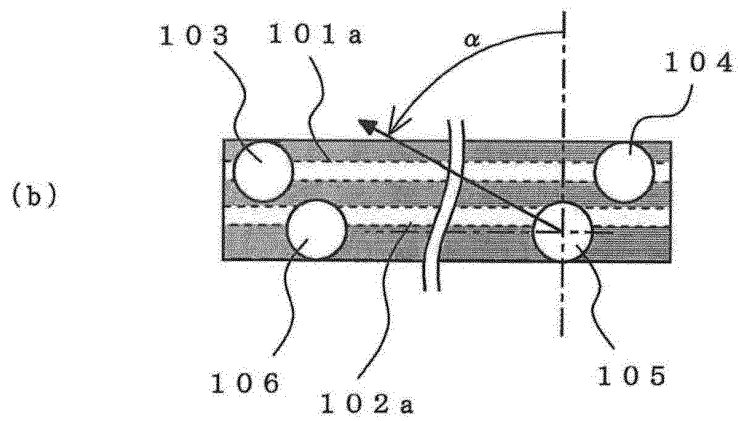
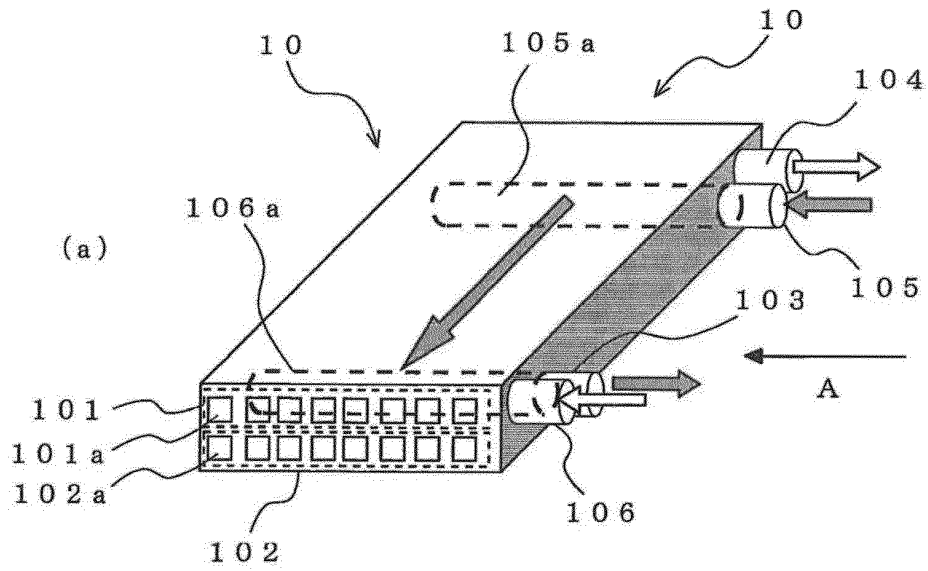


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/004459

A. CLASSIFICATION OF SUBJECT MATTER

F28D7/16(2006.01) i, F25B39/04(2006.01) i, F28D7/00(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28D7/16, F25B39/04, F28D7/00

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2011

Kokai Jitsuyo Shinan Koho 1971-2011 Toroku Jitsuyo Shinan Koho 1994-2011

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 Y	JP 2008-101852 A (Mitsubishi Electric Corp.), 01 May 2008 (01.05.2008), entire text; all drawings (particularly, paragraphs [0012], [0013], [0019], [0023]; fig. 1 to 3) (Family: none)	1-5, 9 6-8
Y	JP 2006-112756 A (Mitsubishi Electric Corp.), 27 April 2006 (27.04.2006), entire text; all drawings (particularly, fig. 1, 6, 7, 10) (Family: none)	6-8

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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
26 October, 2011 (26.10.11)Date of mailing of the international search report
08 November, 2011 (08.11.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/004459

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-340485 A (Mitsubishi Heavy Industries, Ltd.), 27 November 2002 (27.11.2002), entire text; all drawings (particularly, fig. 1, 3) (Family: none)	6-8
Y	JP 2003-202197 A (Denso Corp.), 18 July 2003 (18.07.2003), entire text; all drawings & DE 10300054 A1	8

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/004459

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/004459

Continuation of Box No.III of continuation of first sheet (2)

The matter common to the inventions in claims 1-7 and the inventions in claims 8, 9 is "a heat exchanger provided with a first flow path part, a second flow path part, a first inlet header, a first outlet header, a second inlet header, and a second outlet header, wherein the first flow path part and the second flow path part are disposed to be able to exchange heat with each other via a partition wall provided therebetween, and the high-temperature fluid flowing from the first inlet header into the through-holes of the first flow path part and/or the low-temperature fluid flowing from the second inlet header into the through-holes of the second flow path part is a fluid in a gas-liquid two-phase state".

However, the search has revealed that since this matter makes no contribution over the prior art in the light of the disclosure of document 1 (JP 2008-101852), the abovementioned common matter is not a special technical feature within the meaning of PCT Rule 13.2.

Therefore, none of the inventions in claims 1-9 has the same or corresponding special technical feature. As a result of the investigation of special technical features, the following two inventions are considered to be contained.

Note that "the inventions in claims 1-5" which have no special technical feature, "the inventions in claims 6, 7" which are the mere design variation of the prior art or the addition of the well-known art to the prior art and do not provide a new effect, and "9 referring to these 1-7" are classified as invention 1.

(Invention 1) Claims 1-7, and 9 referring to 1-7

(Invention 2) Claim 8, and 9 referring to claim 8

Thus, the inventions in claims 1-9 clearly do not comply with the unity of invention.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2008141852 A [0003]