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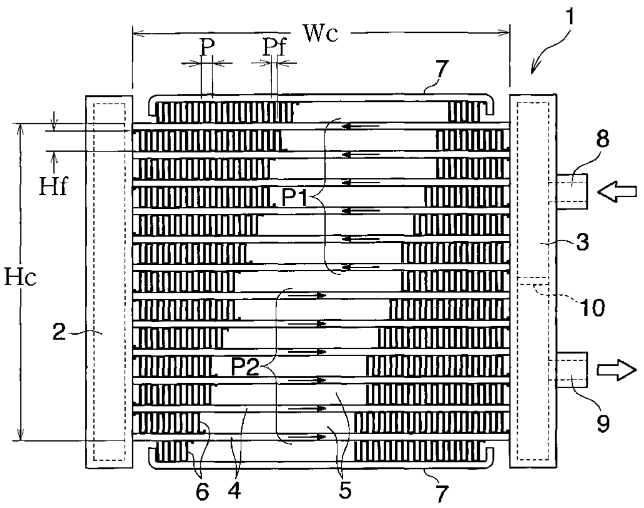
(54) Title: HEAT EXCHANGER




(57) **Abstract:** A heat exchanger 1 includes a pair of headers 2, 3 arranged apart from each other, and a plurality of flat tubes 4 arranged between the two headers 2, 3 at predetermined intervals along the longitudinal direction of the headers 2, 3 and each having opposite end portions connected to the respective headers 2, 3, all the flat tubes 4 having the same cross-sectional shape. All the flat tubes 4 are divided into two passes P1, P2 each consisting of a plurality of flat tubes 4 continuously arranged in the vertical direction. When the quotient produced by dividing the number of the flat tubes 4 constituting each of the passes P1, P2 by the number of all the flat tubes 4 is defined as "tube ratio," each of the passes P1, P2 has a tube ratio of 0.45 to 0.55, preferably 0.48 to 0.52. This heat exchanger 1, when used as a gas cooler of a supercritical refrigeration cycle, exhibits improved heat radiation performance and allows a reduction in size and weight.

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DESCRIPTION

# HEAT EXCHANGER

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is an application filed under 35 U.S.C. § 111(a) claiming the benefit pursuant to 35 U.S.C. § 119(e)(1) of the filing date of Provisional Application No. 60/640,063 filed December 30, 2004 pursuant to 35 U.S.C. § 111(b).

## TECHNICAL FIELD

The present invention relates to a heat exchanger, and more particularly to a heat exchanger suitable for use as a gas cooler of a supercritical refrigeration cycle which employs a supercritical refrigerant such as $CO_2$ and in which the pressure of the refrigerant on a high-pressure side is equal to or higher than the critical pressure of the refrigerant.

Herein and in the appended claims, the term "aluminum" encompasses aluminum alloys in addition to pure aluminum. Further, herein and in the appended claims, the term "supercritical refrigeration cycle" refers to a refrigeration cycle in which the pressure of refrigerant exceeds the critical pressure and enters a supercritical state on a high-pressure side, and the term "supercritical refrigerant" refers to a refrigerant used in the supercritical refrigeration cycle.

BACKGROUND ART

A conventionally known heat exchanger of a supercritical refrigeration cycle in which a supercritical refrigerant such as $CO_2$ is used includes, for example, a pair of headers arranged in parallel with and apart from each other; a plurality of flat tubes of aluminum arranged in parallel between the two headers and each having opposite end portions connected to the respective headers; corrugate fins of aluminum arranged in corresponding air-passing clearances between adjacent flat tubes; a refrigerant inlet connected to an upper end portion of a circumferential wall of a first header; a refrigerant outlet connected to a lower end portion of a circumferential wall of a second header; a first partition wall provided in the interior of the first header at a vertically intermediate position; and a second partition wall provided in the interior of the second header at a position located below a vertically intermediate position of the second header. All the flat tubes are divided into a tube group consisting of a plurality of flat tubes located above the first partition wall, a tube group consisting of a plurality of flat tubes located between the first and second partition walls, and a tube group consisting of a plurality of flat tubes located below the second partition wall, thereby being divided into first to third passes (refrigerant channel groups). Within each pass, the refrigerant flows in the same direction through the flat tubes which constitute the pass. Two adjacent passes differ in the flow direction of the refrigerant flowing through the flat tubes thereof. The number of flat tubes is reduced in sequence from the first pass to the third pass. In the course of flow from inflow from the refrigerant inlet to outflow from the refrigerant outlet, the refrigerant flows in the heat exchanger in a meandering manner on the basis of the passes (refer to, for example, Japanese Patent No. 3313086).

The heat exchanger described in the patent provides a certain degree of heat radiation performance. However, various studies conducted by the inventors of the present invention have revealed that a further improvement in heat radiation performance and a reduction in size and weight by virtue of the improved heat radiation performance cannot be expected from the heat exchanger described in the patent, for the reason described below.

In the case of a gas cooler of a supercritical refrigeration cycle which employs a supercritical refrigerant such as $CO_2$, condensation of the refrigerant is not involved. Thus, when the number of flat tubes which constitute a pass is reduced in sequence from an inlet-side pass to an outlet-side pass, pressure loss generated in refrigerant channels of flat tubes increases toward the outlet-side pass, and thus the flow rate of refrigerant drops accordingly, resulting in an impairment in heat radiation performance. In order to obtain desired heat radiation performance, the size of the heat exchanger must be increased, which is accompanied by an increase in weight.

An object of the present invention is to overcome the above problems and to provide a heat exchanger which, when used as a gas cooler of a supercritical refrigeration cycle, exhibits improved heat radiation performance and allows a reduction in size and weight.

DISCLOSURE OF THE INVENTION

To fulfill the above object, the present invention comprises the following modes.

1) A heat exchanger including a pair of headers arranged apart from each other, and a plurality of flat tubes arranged between the two headers at predetermined intervals along the longitudinal direction of the headers and each having opposite end portions connected to the respective headers,

wherein all the flat tubes are divided into two passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction; and when the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.45 to 0.55.

2) A heat exchanger according to par. 1), wherein each of the passes has a tube ratio of 0.48 to 0.52.

3) A heat exchanger including a pair of headers

arranged apart from each other, and a plurality of flat tubes arranged between the two headers at predetermined intervals along the longitudinal direction of the headers and each having opposite end portions connected to the respective headers,

wherein all the flat tubes are divided into three passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction; and when the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.3 to 0.4.

4) A heat exchanger according to par. 3), wherein each of the passes has a tube ratio of 0.32 to 0.34.

5) A heat exchanger according to par. 1) or 3), wherein each of the flat tubes has a plurality of refrigerant channels arranged therein along the width direction thereof; each of the refrigerant channels has a vertically elongated cross section; and when the quotient produced by dividing a channel height Hp (mm) of the refrigerant channel by a minimum channel width Wp (mm) of the refrigerant channel is defined as "aspect ratio," the aspect ratio (Hp/Wp) is 1.05 to 2.

In the case where the channel width of the refrigerant channel remains unchanged along the entire height of the refrigerant channel, the minimum channel width Wp of the refrigerant channel means the width of the refrigerant channel. In the case where the channel width of the refrigerant channel is not uniform along the entire height of the refrigerant channel, the minimum channel width Wp means the width of the refrigerant channel as measured at a certain height where the refrigerant channel is the narrowest.

6) A heat exchanger according to par. 1) or 3), satisfying a relation $0.5 \leq Tw/Wp \leq 1.5$, where Tw (mm) is the thickness of a partition wall between the adjacent refrigerant channels of each of the flat tubes, and Wp (mm) is the minimum channel width of each of the refrigerant channels.

7) A heat exchanger according to par. 1) or 3), satisfying a relation $0.3 \leq Hp/Ht \leq 0.7$, where Hp (mm) is the channel height of each of the refrigerant channels of each of the flat tubes, and Ht (mm) is the tube height of each of the flat tubes.

8) A heat exchanger according to par. 1) or 3), satisfying a relation $3 \leq Sp \leq 5$, where Sp ($mm^2$) is the total channel cross-sectional-area of all the refrigerant channels of each of the flat tubes.

9) A heat exchanger according to par. 1) or 3), satisfying a relation $Sp/Sb \leq 0.5$, where Sp ($mm^2$) is the total channel cross-sectional-area of all the refrigerant channels of each of the flat tubes, and Sb ($mm^2$) is the remaining area (cross-sectional area of a bulk portion) after subtracting the total channel cross-sectional-area Sp ($mm^2$) from the entire cross-sectional area of each of the flat

tubes.

10) A heat exchanger according to par. 1) or 3), satisfying a relation $(Wt \times Ht)/3 \geq Sp$, where Sp ($mm^2$) is the total channel cross-sectional-area of all the refrigerant channels of each of the flat tubes; Ht (mm) is the tube height of each of the flat tubes; and Wt (mm) is the tube width of each of the flat tubes.

11) A heat exchanger according to par. 1) or 3), satisfying a relation $Ht \leq 4$, where Ht (mm) is the tube height of each of the flat tubes.

12) A heat exchanger according to par. 1) or 3), wherein each of the flat tubes includes two flat walls in parallel with each other; first and second side walls extending over corresponding side ends of the two flat walls; and reinforcement walls provided between the first and second side walls and extending between the two flat walls and in the longitudinal direction of the two flat walls; and

each of the flat tubes is formed from a single metal sheet including two flat-wall-forming portions; a connection portion connecting the two flat-wall-forming portions and adapted to form the first side wall; two side-wall-forming elongated projections provided integrally with and in such a manner as to project from corresponding side ends of the flat-wall-forming portions opposite the connection portion, and adapted to form the second side wall; a plurality of reinforcement-wall-forming elongated projections provided integrally with each of the flat-wall-forming portion in such a manner as to project in the same direction as the side-wall-forming elongated projections; and the flat tube is formed by folding the metal sheet at the connection portion into a hairpin form such that the side-wall-forming elongated projections butt against each other and such that the reinforcement-wall-forming elongated projections butt against each other, and by brazing the mutually butting side-wall-forming elongated projections together and the mutually butting reinforcement-wall-forming elongated projections together, the mutually brazed reinforcement-wall-forming elongated projections forming the reinforcement walls.

13) A heat exchanger according to par. 12), wherein of two reinforcement-wall-forming elongated projections which form each reinforcement wall, one reinforcement-wall-forming elongated projection has a groove which is formed on the tip end face thereof so as to receive a tip end portion of the other reinforcement-wall-forming elongated projection.

14) A heat exchanger according to par. 1) or 3), wherein corrugate fins each including wave crest portions, wave trough portions, and connection portions each connecting together a wave crest portion and a wave trough portion are each arranged between the adjacent flat tubes; and each corrugate fin has a fin height of 5 mm to 8 mm, a fin pitch of 1.0 mm to 1.5 mm, and a thickness of 0.05 mm to 0.1 mm.

15) A supercritical refrigeration cycle which comprises a compressor, a gas cooler, an evaporator, a pressure-reducing device, and an intermediate heat exchanger for

performing heat exchange between refrigerant flowing out from the gas cooler and refrigerant flowing out from the evaporator and in which a supercritical refrigerant is used, wherein the gas cooler is a heat exchanger according to par. 1) or 3).

According to the heat exchanger described in par. 1) or 2), all the flat tubes are divided into two passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction. Thus, while the refrigerant velocity in the refrigerant channels of the flat tubes is increased, there can be prevented an increase in pressure loss generated in the refrigerant channels, as well as a drop in refrigerant flow rate which could otherwise result from an increase in pressure loss. When the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.45 to 0.55, preferably 0.48 to 0.52. Thus, even when the heat exchanger is used as a gas cooler of a supercritical refrigeration cycle, there can be prevented an increase in pressure loss generated in the refrigerant channels of the flat tubes of either pass, as well as a drop in refrigerant flow rate in either pass which could otherwise result from an increase in pressure loss. Accordingly, when the heat exchanger is used as a gas cooler of a supercritical refrigeration cycle, the heat exchanger exhibits improved heat radiation performance as compared with the heat exchanger described in the above-mentioned patent and thus allows a reduction in size and weight.

According to the heat exchanger described in par. 3) or 4), all the flat tubes are divided into three passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction. Thus, while the refrigerant velocity in the refrigerant channels of the flat tubes is increased, there can be prevented an increase in pressure loss generated in the refrigerant channels, as well as a drop in refrigerant flow rate which could otherwise result from an increase in pressure loss. When the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.3 to 0.4, preferably 0.32 to 0.34. Thus, even when the heat exchanger is used as a gas cooler of a supercritical refrigeration cycle, there can be prevented an increase in pressure loss generated in the refrigerant channels of the flat tubes of any one of the passes, as well as a drop in refrigerant flow rate in any one of the passes which could otherwise result from an increase in pressure loss. Accordingly, when the heat exchanger is used as a gas cooler of a supercritical refrigeration cycle, the heat exchanger exhibits improved heat radiation performance as compared with the heat exchanger described in the above-mentioned patent and thus allows a reduction in size and weight.

The heat exchanger described in any one of pars. 5) to

11) exhibits improved heat radiation performance, and enhanced withstand pressure of the flat tubes.

The heat exchanger described in par. 14) exhibits improved heat radiation performance while suppressing an increase in pressure loss of air flowing through clearances between adjacent flat tubes, thereby maintaining good balance therebetween.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general front view showing Embodiment 1 of a heat exchanger according to the present invention. FIG. 2 is a cross-sectional views showing a flat tube of the heat exchanger of FIG. 1. FIG. 3 is a fragmentary enlarged view of FIG. 2. FIG. 4 is a general front view showing Embodiment 2 of a heat exchanger according to the present invention. FIG. 5 is a graph showing the results of Experiment Examples 1 and 2 and Comparative Experiment Examples 3 and 4. FIG. 6 is a graph showing the results of Experiment Example 1 and Comparative Experiment Example 1. FIG. 7 is a graph showing the results of Experiment Example 2 and Comparative Experiment Example 2. FIG. 8 is a cross-sectional view showing a first modified embodiment of the flat tube. FIG. 9 is a fragmentary enlarged view of FIG. 8. FIG. 10 is a set of views showing a method of manufacturing the flat tube shown in FIG. 8. FIG. 11 is a cross-sectional view showing a second modified embodiment of the flat tube. FIG. 12 is a cross-sectional view showing a third modified embodiment of the flat tube. FIG. 13 is a fragmentary enlarged view of FIG. 12. FIG. 14 is a set of views showing a method of manufacturing the flat tube shown in FIG. 12. FIG. 15 is a cross-sectional view showing a fourth modified embodiment of the flat tube. FIG. 16 is a fragmentary enlarged view of FIG. 15. FIG. 17 is a set of views showing a method of manufacturing the flat tube shown in FIG. 15.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below with reference to the drawings. Notably, in the following description, the upper, lower, left-hand, and right-hand sides of FIGS. 1 and 4 will be referred to as "upper," "lower," "left," and "right," respectively.

Embodiment 1

This embodiment is shown in FIGS. 1 to 3.

FIG. 1 shows the overall structure of a heat exchanger according to the present invention, and FIGS. 2 and 3 show the structures of essential portions thereof.

In FIG. 1, a heat exchanger 1 includes a pair of left-hand and right-hand headers 2, 3 of aluminum arranged apart from and in parallel with each other and extending vertically; a plurality of flat tubes 4 of aluminum arranged in parallel between the two headers 2, 3, separated from one another in the vertical direction, and each having opposite end portions connected to the respective headers 2, 3; corrugated fins 6 of aluminum arranged in respective air passage clearances 5 between adjacent flat tubes 4 and outside the uppermost and lowermost flat tubes 4, and brazed to the flat tubes 4; side plates 7 of aluminum arranged externally of and brazed to the respective uppermost and lowermost corrugate fins 6; a refrigerant inlet 8 provided on a side wall of the right-hand header 3 and located above a vertically intermediate position; a refrigerant outlet 9 provided on the side wall of the right-hand header 3 and located below the vertically intermediate position; and a partition wall 10 provided in the interior of the right-hand header 3 and located between the refrigerant inlet 8 and the refrigerant outlet 9 and at the vertically intermediate position.

All the flat tubes 4 are divided into a tube group consisting of a plurality of the flat tubes 4 located above the partition wall 10, and a tube group consisting of a plurality of the flat tubes 4 located below the partition wall 10, thereby being divided into first and second passes P1, P2 (refrigerant channel groups). Within each pass P1, P2, the refrigerant flows in the same direction through the flat tubes 4 which constitute the pass P1, P2. The two passes P1, P2 differ in the flow direction of the refrigerant flowing through the flat tubes 4 thereof.

When the quotient produced by dividing the number of the flat tubes 4 constituting each of the passes P1, P2 by the number of all the flat tubes 4 is defined as "tube ratio," each of the passes P1, P2 has a tube ratio of 0.45 to

0.55. Notably, the total of the tube ratio of the first pass P1 and the tube ratio of the second pass P2 is 1. In the case where the heat exchanger 1 is used as a gas cooler of a supercritical refrigeration cycle which employs a supercritical refrigerant such as $CO_2$, a tube ratio less than 0.45 or in excess of 0.55 causes an increase in pressure loss generated in the flat tubes 4 in either pass P1, P2 and a drop in refrigerant flow rate in either pass P1, P2, resulting in an impairment in heat radiation performance. As a result, in order to obtain desired heat radiation performance, the size of the heat exchanger 1 must be increased, which is accompanied by an increase in weight. Preferably, the passes P1, P2 each have a tube ratio of 0.48 to 0.52. Even in this case, the total of the tube ratio of the first pass P1 and the tube ratio of the second pass P2 is 1.

As shown in FIGS. 2 and 3, each of the flat tubes 4 is formed from an extrudate; all the flat tubes 4 have the same cross-sectional shape; and a plurality of refrigerant channels 11 are formed in the flat tubes 4 and are arranged in a row in the width direction of flat tubes 4. Each of the refrigerant channels 11 has an identical cross-sectional shape of a rectangle standing on its shorter side, except for those at the opposite ends.

Preferably, when Hp (mm) represents the channel height of each of the refrigerant channels 11; Wp (mm) represents the minimum channel width of each of the refrigerant channels

11; Tw (mm) represents the thickness of a partition wall 12 between the adjacent refrigerant channels 11 of each of the flat tubes 4; Ht (mm) represents the tube height of each of the flat tubes 4, Sp ($mm^2$) represents the total channel cross-sectional-area of all the refrigerant channels 11 of each of the flat tubes 4 (the total area of hatched portions in FIG. 2(b)); Sb ($mm^2$) represents the remaining area (the area of a hatched bulk portion in FIG. 2(a)) after subtracting the total channel cross-sectional-area Sp ($mm^2$) from the entire cross-sectional area T ($mm^2$) of each of the flat tubes 4 (= T - Sp); and Wt (mm) represents the tube width of each of the flat tubes 4, the following relations are satisfied.

Relation 1

When the quotient produced by dividing Hp (mm) by Wp (mm) is defined as "aspect ratio," 1.05 ≤ aspect ratio (Hp/Wp) ≤ 2

Relation 2

$0.5 \leq Tw/Wp \leq 1.5$

Relation 3

$03 \leq Hp/Ht \leq 0.7$

Relation 4

$3 \leq Sp \leq 5$

Relation 5

$Sp/Sb \leq 0.5$

Relation 6

$(Wt \times Ht)/3 \geq Sp$

Relation 7

$$Ht \leq 4$$

When the above relations 1 to 7 are satisfied, the heat radiation performance of the heat exchanger 1 is improved, and the withstand pressure of the flat tubes 4 is increased. In the present embodiment, the width of each of the refrigerant channels 11 of each flat tube 4 remains unchanged along the entire height of the refrigerant channel 11, except for the refrigerant channels 11 at the opposite ends. Thus, the width of each of the refrigerant channels 11 is the minimum channel width Wp. The width of each of the refrigerant channels 11 at the opposite ends changes in the height direction, and needless to say, the minimum channel width Wp is the width of the narrowest potion.

The corrugate fins 6 each include wave crest portions, wave trough portions, and connection portions each connecting together a wave crest portion and a wave trough portion. The fin height Hf of each corrugate fin 6 is the direct distance between the wave crest portion and the wave trough portion, and the fin height Hf is preferably 5 mm to 8 mm. Further, the fin pitch Pf of each corrugate fin 6 is the distance between the central portions (with respect to the left-right direction) of a wave crest portion and a wave trough portion adjacent thereto; i.e., half the interval P between the central portions (with respect to the left-right direction) of the adjacent wave crest portions or the adjacent wave trough portions (i.e., Pf = P/2), and the fin pitch Pf is preferably 1.0 mm to 1.5 mm. Moreover, the thickness of each corrugate fin 6 is 0.05 mm to 0.1 mm.

Embodiment 2

This embodiment is shown in FIG. 4.

FIG. 4 shows the overall structure of a heat exchanger according to the present invention.

In the case of a heat exchanger 20 of the present embodiment, the refrigerant inlet 8 is provided at an upper end portion of a side wall of the left-hand header 2, and the refrigerant outlet 9 is provided at a lower end portion of a side wall of the right-hand header 3. A first partition wall 21 is provided in the interior of the left-hand header 2 and is located above a vertically intermediate position. A second partition wall 22 is provided in the interior of the right-hand header 3 and is located below a vertically intermediate position.

All the flat tubes 4 are divided into a tube group consisting of a plurality of the flat tubes 4 located above the first partition wall 21, a tube group consisting of a plurality of the flat tubes 4 located between the two partition walls 21, 22, and a tube group consisting of a plurality of the flat tubes 4 located below the second partition wall 22, thereby being divided into first to third passes P1, P2, P3 (refrigerant channel groups). Within each pass P1, P2, P3, the refrigerant flows in the same direction through the flat tubes 4 which constitute the pass P1, P2, P3. The two adjacent passes P1, P2 as well as the two adjacent passes P2, P3 differ in the flow direction of the refrigerant flowing through the flat tubes 4 thereof.

When the quotient produced by dividing the number of the flat tubes 4 constituting each of the passes P1, P2, P3 by the number of all the flat tubes 4 is defined as "tube ratio," each of the passes P1, P2, P3 has a tube ratio of 0.3 to 0.4. In the case where the heat exchanger 20 is used as a gas cooler of a supercritical refrigeration cycle which employs a supercritical refrigerant such as $CO_2$, a tube ratio less than 0.3 or in excess of 0.4 causes an increase in pressure loss generated in the flat tubes 4 in any one of the passes P1, P2, P3 and a drop in refrigerant flow rate in any one of the passes P1, P2, P3, resulting in an impairment in heat radiation performance. As a result, in order to obtain desired heat radiation performance, the size of the heat exchanger 20 must be increased, which is accompanied by an increase in weight. Preferably, the passes P1, P2, P3 each have a tube ratio of 0.32 to 0.34.

Other structural features are similar to those of Embodiment 1 described above; like parts are denoted by like reference numerals; and repeated description thereof is omitted. In other words, also, in the present embodiment, dimensions of the flat tubes 4 satisfy the above-mentioned Relations 1 to 7, and the fin height Hf, the fin pitch Pf, and the thickness of the corrugate fins 6 conform to the dimensional specifications of Embodiment 1.

Each of the heat exchangers 1, 20 of Embodiments 1 and

2, respectively, is suitable for use as a gas cooler in a supercritical refrigeration cycle which includes a compressor, a gas cooler, an evaporator, an accumulator serving as a gas-liquid separator, an expansion valve serving as a pressure-reducing device, and an intermediate heat exchanger for performing heat exchange between a high-temperature, high-pressure refrigerant flowing out from the gas cooler and a low-temperature, low-pressure refrigerant flowing out from the evaporator and passing through the accumulator and which employs $CO_2$ as a supercritical refrigerant. The supercritical refrigeration cycle is mounted on a vehicle such as an automobile as a car air conditioner. Although $CO_2$ is used as a supercritical refrigerant of a supercritical refrigeration cycle, the refrigerant is not limited thereto, but ethylene, ethane, nitrogen oxide, or the like may also be used.

Next will be described Experiment Examples concerning experiments which were conducted by use of the heat exchangers of Embodiments 1 and 2, as well as Comparative Experiment Examples.

Experiment Example 1

The present Experiment Example is of an experiment which was conducted by use of the heat exchanger 1 of Embodiment 1. Specifications of heat exchanger: height Hc of heat exchange core section composed of flat tubes 4 and corrugate fins 6: 380 mm; width Wc of heat exchange core section: 660 mm; total number of flat tubes 4: 51; number of flat tubes 4 of first pass P1: 26 (tube ratio 0.51); and number of flat tubes 4 of second pass P2: 25 (tube ratio 0.49). Specifications of flat tube 4: channel height Hp of refrigerant channel 11: 0.44 mm; minimum channel width Wp of refrigerant channel 11: 0.32 mm; thickness Tw of partition wall 12 between adjacent refrigerant channels 11: 0.38 mm; tube height Ht: 1.3 mm; total channel cross-sectional-area of all refrigerant channels 11: 3.1 $mm^2$; remaining area Sb after subtracting total channel cross-sectional-area Sp ($mm^2$) from entire cross-sectional area of flat tube 4: 17.3 $mm^2$; and tube width Wt: 16 mm. Accordingly, aspect ratio (Hp/Wp) = 1.38; Tw/Wp = 1.19; Hp/Ht = 0.34; Sp/Sb = 0.18; and (Wt × Ht)/3 = 6.93. These values satisfy above-mentioned Relations 1 to 7.

By use of a car air conditioner bench test apparatus, the heat exchanger was measured for heat radiation performance and pressure loss generated in the refrigerant channels 11 of the flat tubes 4 under the following conditions: front air velocity (inlet air velocity): 2.0 m/s; air temperature: 40°C; circulation rate of $CO_2$ refrigerant: 100 kg/h; refrigerant inlet pressure: 11 MPa; and refrigerant inlet temperature: 120°C.

Experiment Example 2

The present Experiment Example is of an experiment which was conducted by use of the heat exchanger 20 of Embodiment 2. Dimensions of the heat exchange core section, the total number of flat tubes 4, dimensions (Ht, Sp) of the flat tube 4, the aspect ratio, Tw/Wp, Hp/Ht, Sp/Sb, and (Wt × Ht)/3 are identical with those of Experiment Example 1. Three passes P1, P2, P3 each have 17 flat tubes 4 and a tube ratio of 0.33.

Heat radiation performance and pressure loss were measured in a manner similar to that of Experiment Example 1.

Comparative Experiment Example 1

The present comparative experiment was conducted by use of a 2-pass heat exchanger which was similar to that of Experiment Example 1 except for the following: number of flat tubes 4 of first pass: 38 (tube ratio 0.75); and number of flat tubes 4 of second pass: 13 (tube ratio 0.25). The heat exchanger was measured for heat radiation performance and pressure loss generated in the refrigerant channels 11 of the flat tubes 4 in a manner similar to that of Experiment Example 1.

Comparative Experiment Example 2

The present comparative experiment was conducted by use of a 3-pass heat exchanger which was similar to that of Experiment Example 2 except for the following: number of flat tubes 4 of first pass: 29 (tube ratio 0.57); number of flat tubes 4 of second pass: 14 (tube ratio 0.27); and number of flat tubes 4 of third pass: 8 (tube ratio 0.16). The heat exchanger was measured for heat radiation performance and pressure loss generated in the refrigerant channels 11 of the flat tubes 4 in a manner similar to that of Experiment Example 1.

Comparative Experiment Example 3

The present comparative experiment was conducted by use of a heat exchanger which was similar to that of Experiment Example 1 except that the number of passes was 1; i.e., refrigerant flowed in the same direction through the refrigerant channels 11 of all of 51 flat tubes 4. The heat exchanger was measured for heat radiation performance and pressure loss generated in the refrigerant channels 11 of the flat tubes 4 in a manner similar to that of Experiment Example 1.

Comparative Experiment Example 4

The present comparative experiment was conducted by use of a heat exchanger which was similar to that of Experiment Example 1 except that all the flat tubes 4 were divided into four passes and except for the following: number of flat tubes 4 of first pass: 13 (tube ratio 0.25); number of flat tubes 4 of second pass: 13 (tube ratio 0.25); number of flat tubes 4 of third pass: 13 (tube ratio 0.25); and number of flat tubes 4 of fourth pass: 12 (tube ratio 0.24). The heat exchanger was measured for heat radiation performance and pressure loss generated in the refrigerant channels 11 of the flat tubes 4 in a manner similar to that of Experiment Example 1.

FIG. 5 shows the results of Experiment Examples 1 and 2 and Comparative Experiment Examples 3 and 4. In FIG. 5, the bar graph shows heat radiation performance, and the line graph shows pressure loss. Heat radiation performance and pressure loss are represented with those of Experiment Example 1 taken as 100%.

The results shown in FIG. 5 show that the heat exchanger of Comparative Experiment Example 3 exhibits insufficient heat radiation performance and that the heat exchanger of Comparative Experiment Example 4 exhibits significantly increased pressure loss.

FIG. 6 shows the results of Experiment Example 1 and Comparative Experiment Example 1. In FIG. 6, the bar graph shows heat radiation performance, and the line graph shows pressure loss. Heat radiation performance and pressure loss are represented with those of Experiment Example 1 taken as 100%.

The results shown in FIG. 6 show that the two heat exchangers do not make much difference in heat radiation performance, but the heat exchanger of Comparative Experiment Example 1 exhibits significantly increased pressure loss.

FIG. 7 shows the results of Experiment Example 2 and Comparative Experiment Example 2. In FIG. 7, the bar graph shows heat radiation performance, and the line graph shows pressure loss. Heat radiation performance and pressure loss are represented with those of Experiment Example 2 taken as 100%.

The results shown in FIG. 7 show that the two heat exchangers do not make much difference in heat radiation performance, but the heat exchanger of Comparative Experiment Example 2 exhibits significantly increased pressure loss.

Next will be described modified embodiments of a flat tube for use in the heat exchangers of Embodiment 1 and 2. In the following description of modified embodiments of the flat tube, the upper, lower, left-hand, and right-hand sides of the relevant drawings will be referred to as "upper," "lower," "left," and "right," respectively.

A flat tube 30 shown in FIGS. 8 and 9 includes mutually opposed flat upper and lower walls 31, 32 (a pair of flat walls); left and right side walls 33, 34 which extend over left and right side ends, respectively, of the upper and lower walls 31, 32; and a plurality of reinforcement walls 35 which are provided at predetermined intervals between the left and right side walls 33, 34 and extend longitudinally and between the upper and lower walls 31, 32. By virtue of this structure, the flat tube 30 internally has a plurality of refrigerant channels 36 arranged in the width direction thereof. The reinforcement walls 35 serve as partition walls between adjacent refrigerant channels 36. The width of each refrigerant channel 36 remains unchanged along the entire height of the refrigerant channel 36. Further, the width of the refrigerant channel 36 at the right end is smaller than those of the remaining refrigerant channels 36, and the remaining refrigerant channels 36 have the same width.

The left side wall 33 has a dual structure and includes an outer side-wall-forming elongated projection 37 which is integrally formed with the left side end of the upper wall 31 in a downward raised condition and extends along the entire height of the flat tube 30; an inner side-wall-forming elongated projection 38 which is located inside the outer side-wall-forming elongated projection 37 and is integrally formed with the upper wall 31 in a downward raised condition; and an inner side-wall-forming elongated projection 39 which is integrally formed with the left side end of the lower wall 32 in an upward raised condition. The outer side-wall-forming elongated projection 37 is brazed to the two inner side-wall-forming elongated projections 38, 39 and to the lower wall 32 while a lower end portion thereof is engaged with a left side edge portion of the lower surface of the lower wall 32. The two inner side-wall-forming elongated projections 38, 39 are brazed together while butting against each other. A right side wall 34 is integrally formed with the upper and lower walls 31, 32. A projection 39a is integrally formed on the tip end face of the inner side-wall-forming projection 39 of the lower wall 32 and extends in the longitudinal direction of the inner side-wall-forming projection 39 along the entire length thereof. A groove 38a is formed on the tip end face of the inner side-wall-forming elongated projection 38 of the upper wall 31 and extends in the longitudinal direction of the inner side-wall-forming elongated projection 38 along the entire length thereof. The projection 39a is press-fitted into the groove 38a.

Each of the reinforcement walls 35 is formed such that a reinforcement-wall-forming elongated projection 40, which is integrally formed with the upper wall 31 in a downward raised condition, and a reinforcement-wall-forming elongated projection 41, which is integrally formed with the lower wall 32 in an upward raised condition, are brazed together while butting against each other.

The flat tube 30 is manufactured by use of a flat-tube-forming metal sheet 45 as shown in FIG. 10(a). The flat-tube-forming metal sheet 45 is formed by performing rolling on an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. The flat-tube-forming metal sheet 45 includes a flat upper-wall-forming portion 46 (flat-wall-forming portion); a flat lower-wall-forming portion 47 (flat-wall-forming portion); a connection portion 48 connecting the upper-wall-forming portion 46 and the lower-wall-forming portion 47 and adapted to form the right side wall 34; the inner side-wall-forming elongated projections 38, 39, which are integrally formed with the side ends of the upper-wall-forming and lower-wall-forming portions 46, 47 opposite the connection portion 48 in an upward raised condition and which are adapted to form an inner portion of the left side wall 33; an outer side-wall-forming-elongated-projection forming portion 49, which extends outward (rightward) with respect to the left-right direction from the side end (right side end) of the upper-wall-forming portion 46 opposite the connection portion 48; and a plurality of reinforcement-wall-forming elongated projections 40, 41, which are integrally formed with the upper-wall-forming and lower-wall-forming portions 46, 47 in an upward raised condition and which are arranged at predetermined intervals in the left-right direction. The reinforcement-wall-forming elongated projections 40 of the upper-wall-forming portion 46 and the reinforcement-wall-forming elongated projections 41 of the lower-wall-forming portion 47 are located symmetrically with respect to the centerline of the connection portion in the width direction. The projection 39a is formed on the tip end face of the inner side-wall-forming elongated projection 39 of the lower-wall-forming projection 47, and the groove 38a is formed on the tip end face of the inner side-wall-forming elongated projection 38 of the upper-wall-forming portion 46. The two inner side-wall-forming elongated projections 38, 39 and all the reinforcement-wall-forming elongated projections 40, 41 have the same height.

The inner side-wall-forming elongated projections 38, 39 and the reinforcement-wall-forming elongated projections 40, 41 are integrally formed, through rolling, on one side of the aluminum brazing sheet whose opposite sides are clad with a brazing material, whereby a brazing material layer (not shown) is formed on the opposite side surfaces and tip end faces of the inner side-wall-forming elongated projections 38, 39, on those of the reinforcement-wall-forming elongated projections 40, 41, and on the vertically opposite surfaces of the upper-wall-forming and lower-wall-forming portions 46, 47, and the side-wall-forming-elongated-projection forming portion 49.

The flat-tube-forming metal sheet 45 is gradually folded at left and right side edges of the connection portion 48 by a roll forming process (see FIG. 10(b)) until a hairpin form is assumed. The inner side-wall-forming elongated projections 38, 39 are caused to butt against each other; the reinforcement-wall-forming elongated projections 40, 41 are caused to butt against each other; and the projection 39a is caused to be press-fitted into the groove 38a.

Next, the outer side-wall-forming-elongated-projection forming portion 49 is folded along the outer surfaces of the inner side-wall-forming elongated projections 38, 39, and a tip end portion thereof is deformed so as to be engaged with the lower-wall-forming portion 47, thereby yielding a folded member 50 (see FIG. 10(c)).

Subsequently, the folded member 50 is heated at a predetermined temperature so as to braze together tip end portions of the inner side-wall-forming elongated projections 38, 39; to braze together tip end portions of the reinforcement-wall-forming elongated projections 40, 41; and to braze the outer side-wall-forming-elongated-projection forming portion 49 to the inner side-wall-forming elongated projections 38, 39 and to the lower-wall-forming portion 47. Thus is manufactured the flat tube 30. The flat tubes 30 are manufactured in the course of manufacture of the heat exchanger 1, 20.

In the case of a flat tube 55 shown in FIG. 11, a projection 56 extending along the entire length thereof and a groove 57 extending along the entire length thereof are alternately formed on the tip end faces of all the reinforcement-wall-forming elongated projections 40 of the upper wall 31. A groove 58 into which the corresponding projection 56 of the reinforcement-wall-forming elongated projection 40 of the upper wall 31 is fitted, and a projection 59 to be fitted into the corresponding groove 57 of the reinforcement-wall-forming elongated projection 40 of the upper wall 31 are alternately formed on the tip end faces of all the reinforcement-wall-forming elongated projections 41 of the lower wall 32, along the entire length thereof. Other structural features are similar to those of the flat tube 30 shown in FIGS. 8 and 9. The flat tube 55 is manufactured in a manner similar to that for the flat tube 30 shown in FIGS. 8 and 9.

In a flat tube 60 shown in FIGS. 12 and 13, the reinforcement wall 35 formed such that a reinforcement-wall-forming elongated projection 61 formed integrally with the upper wall 31 and in a downward raised condition is brazed to the lower wall 32, and the reinforcement wall 35 formed such that a reinforcement-wall-forming elongated projection 62 formed integrally with the lower wall 32 and in an upward raised condition is brazed to the upper wall 31, are alternately provided in the left-right direction; the upper and lower walls 31, 32 have projections 63 extending along the entire length thereof and formed integrally at portions thereof which abut the corresponding reinforcement-wall-forming elongated projections 62, 61; grooves 64 are formed on the corresponding tip end faces of the projections 63 so as to allow corresponding tip end portions of the reinforcement-wall-forming elongated projections 61, 62 to be fitted thereinto; and the tip end portions of the reinforcement-wall-forming elongated projections 61, 62 are brazed to the corresponding projections 63 while being fitted into the grooves 64 of the projections 63. The thickness of the projection 63 as measured in the left-right direction is slightly greater than that of the reinforcement-wall-forming elongated projections 61, 62. Other structural features of the flat tube 60 are similar to those of the flat tube 30 shown in FIGS. 8 and 9. In the flat tube 60, the width of each of the refrigerant channels 36, except for the refrigerant channel 36 at the right end, is not uniform along the height of the refrigerant channel 36. The minimum channel width Wp of these refrigerant channels 36 means the width of the refrigerant channel 36 as measured at a certain height where the refrigerant channel 36 is the narrowest; i.e., the distance between the reinforcement-wall-forming elongated projection 61 or 62 and the projection 63 to which the adjacent reinforcement-wall-forming elongated projection 62 or 61 is brazed. The thickness of each of the reinforcement-wall-forming elongated projections 61, 62 serving as the reinforcement walls 35 is the thickness of a partition wall between the adjacent refrigerant channels 36.

The flat tube 60 is manufactured by use of a flat-tube-forming metal sheet 65 as shown in FIG. 14(a). The flat-tube-forming metal sheet 65 is formed by performing rolling on an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. The flat-tube-forming metal sheet 65 includes a plurality of reinforcement-wall-forming elongated projections 61, 62, which are integrally formed with the upper-wall-forming and lower-wall-forming portions 46, 47 in an upward raised condition and which are arranged at predetermined intervals in the left-right direction. The reinforcement-wall-forming elongated projections 61 of the upper-wall-forming portion 46 and the reinforcement-wall-forming elongated projections 62 of the lower-wall-forming portion 47 are located asymmetrically with respect to the centerline of the connection portion 48 in the width direction. The reinforcement-wall-forming elongated projections 61, 62 have the same height, which is about two times the height of the inner side-wall-forming elongated projections 38, 39. The projections 63, which extend along the entire length of the upper-wall-forming and lower-wall-forming portions 46, 47, are integrally formed on the upper-wall-forming and lower-wall-forming portions 46, 47 at positions which are symmetrical, with respect to the centerline of the connection portion 48 in the width direction, with the positions of the reinforcement-wall-forming elongated projections 62, 61 of the lower-wall-forming and upper-wall-forming portions 47, 46. The grooves 64 are formed on the corresponding tip end faces of the projections 63 so as to allow corresponding tip end portions of the reinforcement-wall-forming elongated projections 62, 61 to be fitted thereinto. Other structural features of the flat-tube-forming metal sheet 65 are similar to those of the flat-tube-forming metal sheet 45 shown in FIG. 10.

The flat-tube-forming metal sheet 65 is gradually folded at left and right side edges of the connection portion 48 by a roll forming process (see FIG. 14(b)) until a hairpin form is assumed. The inner side-wall-forming elongated projections 38, 39 are caused to butt against each other, and the projection 39a is caused to be press-fitted into the groove 38a. Also, tip end portions of the reinforcement-wall-forming elongated projections 61 of the upper-wall-forming portion 46 are caused to be fitted into the corresponding grooves 64 of the projections 63 of the lower-wall-forming portion 47, and tip end portions of the reinforcement-wall-forming elongated projections 62 of the lower-wall-forming portion 47 are caused to be fitted into the corresponding grooves 64 of the projections 63 of the upper-wall-forming portion 46.

Next, the outer side-wall-forming-elongated-projection forming portion 49 is folded along the outer surfaces of the inner side-wall-forming elongated projections 38, 39, and a tip end portion thereof is deformed so as to be engaged with the lower-wall-forming portion 47, thereby yielding a folded member 66 (see FIG. 14(c)).

Subsequently, the folded member 66 is heated at a predetermined temperature so as to braze together tip end portions of the inner side-wall-forming elongated projections 38, 39; to braze tip end portions of the reinforcement-wall-forming elongated projections 61, 62 to the corresponding projections 63; and to braze the outer side-wall-forming-elongated-projection forming portion 49 to the inner side-wall-forming elongated projections 38, 39 and to the lower-wall-forming portion 47. Thus is manufactured the flat tube 60. The flat tubes 60 are manufactured in the course of manufacture of the heat exchanger 1, 20.

The reinforcement walls 35 of a flat tube 70 shown in FIGS. 15 and 16 are formed such that reinforcement-wall-forming elongated projections 71, 72 formed integrally with the upper wall 31 and in a downward raised condition are caused to butt against and brazed to reinforcement-wall-forming elongated projections 73, 74 formed integrally with the lower wall 32 and in an upward raised condition. The high and low reinforcement-wall-forming elongated projections 71 and 72, which differ in projection height, are alternately provided in the left-right direction on the upper wall 31, and the high and low reinforcement-wall-forming elongated projections 73 and 74, which differ in projection height, are alternately provided in the left-right direction on the lower wall 32. The reinforcement-wall-forming elongated projections 71 of large projection height on the upper wall 31 are brazed to the reinforcement-wall-forming elongated projections 74 of small projection height on the lower wall

32; and the reinforcement-wall-forming elongated projections 72 of small projection height on the upper wall 31 are brazed to the reinforcement-wall-forming elongated projections 73 of large projection height on the lower wall 32. Hereinbelow, the reinforcement-wall-forming elongated projections 71, 73 of large projection height provided on the upper and lower walls 31 and 32, respectively, are called "first reinforcement-wall-forming elongated projections," and the reinforcement-wall-forming elongated projections 72, 74 of small projection height provided on the upper and lower walls 31 and 32, respectively, are called "second reinforcement-wall-forming elongated projections." Grooves 75, 76, which extend along the longitudinal direction, are formed on the corresponding tip end faces of the second reinforcement-wall-forming elongated projections 72, 74 of the upper and lower walls 31, 32 over the entire length so as to receive the corresponding tip end portions of the first reinforcement-wall-forming elongated projections 73, 71 of the lower and upper walls 32, 31. The reinforcement-wall-forming elongated projections 71 74, and the reinforcement-wall-forming elongated projections 72, 73 are brazed together in a state in which the corresponding tip end portions of the first reinforcement-wall-forming elongated projections 71, 73 of the upper and lower walls 31 and 32 are fitted into the grooves 76, 75. Other structural features of the flat tube 70 are similar to those of the flat tube 30 shown in FIGS. 8 and 9.

In the flat tube 70, the width of each of the refrigerant channels 36, except for the refrigerant channel 36 at the right end, is not uniform along the height of the refrigerant channel 36. The minimum channel width Wp of these refrigerant channels 36 means the width of the refrigerant channel 36 as measured at a certain height where the refrigerant channel 36 is the narrowest; i.e., the distance between the first reinforcement-wall-forming elongated projection 71 or 73 and the second reinforcement-wall-forming elongated projection 72 or 74 adjacent thereto. The thickness of each of the first reinforcement-wall-forming elongated projections 71, 73 is the thickness of a partition wall between the adjacent refrigerant channels 36.

In the flat tube 70, the grooves 75, 76 extent over the entire height of the second reinforcement-wall-forming elongated projections 72 and 74; however, the present invention is not limited thereto, and the depth of the grooves 75, 76 may be smaller than the height of the second reinforcement-wall-forming elongated projections 72 and 74.

The flat tube 70 is manufactured by use of a flat-tube-forming metal sheet 80 as shown in FIG. 17(a). The flat-tube-forming metal sheet 80 is formed by performing rolling on an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. The flat-tube-forming metal sheet 80 includes a plurality of reinforcement-wall-forming elongated projections 71, 72, 73, 74, which are integrally formed with the upper-wall-forming and lower-wall-forming portions 46, 47 in an upward raised condition and which are arranged at predetermined intervals in the left-right direction. The first reinforcement-wall-forming elongated projections 71 of the upper-wall-forming portion 46 and the second reinforcement-wall-forming elongated projections 74 of the lower-wall-forming portion 47 are located symmetrically with respect to the centerline of the connection portion 48 in the width direction. Similarly, the second reinforcement-wall-forming elongated projections 72 of the upper-wall-forming portion 46 and the first reinforcement-wall-forming elongated projections 73 of the lower-wall-forming portion 47 are located symmetrically with respect to the centerline of the connection portion 48 in the width direction. The grooves 75, 76 are formed on the corresponding tip end faces of the second reinforcement-wall-forming elongated projections 72, 74 of the upper-wall-forming and lower-wall-forming portions 46, 47 so as to allow corresponding tip end portions of the first reinforcement-wall-forming elongated projections 73, 71 of the lower-wall-forming and upper-wall-forming portions 47, 46 to be fitted thereinto. Other structural features of the flat-tube-forming metal sheet 80 are similar to those of the flat-tube-forming metal sheet 45 shown in FIG. 10.

The flat-tube-forming metal sheet 80 is gradually folded at left and right side edges of the connection portion 48 by a roll forming process (see FIG. 17(b)) until a hairpin form is assumed. The inner side-wall-forming elongated projections 38, 39 are caused to butt against each other. Also, tip end portions of the first reinforcement-wall-forming elongated projections 71, 73 are caused to be fitted into the corresponding grooves 76, 75 of the second reinforcement-wall-forming elongated projections 74, 72. Further, the projection 39a is caused to be press-fitted into the groove 38a.

Next, the outer side-wall-forming-elongated-projection forming portion 49 is folded along the outer surfaces of the inner side-wall-forming elongated projections 38, 39, and a tip end portion thereof is deformed so as to be engaged with the lower-wall-forming portion 47, thereby yielding a folded member 85 (see FIG. 17(c)).

Subsequently, the folded member 85 is heated at a predetermined temperature so as to braze together tip end portions of the inner side-wall-forming elongated projections 38, 39; to braze tip end portions of the first reinforcement-wall-forming elongated projections 71, 73 to tip end portions of the second reinforcement-wall-forming elongated projections 74, 72; and to braze the outer side-wall-forming-elongated-projection forming portion 49 to the inner side-wall-forming elongated projections 38, 39 and to the lower-wall-forming portion 47. Thus is manufactured the flat tube 70. The flat tubes 70 are manufactured in the course of manufacture of the heat exchanger 1, 20.

The flat tubes 30, 55, 60, 70 of modified embodiments described above also satisfy the above-mentioned Relations 1 to 7.

## INDUSTRIAL APPLICABILITY

The heat exchanger according to the present invention is preferably used as a gas cooler of a supercritical refrigeration cycle which uses a supercritical refrigerant such as $CO_2$ and in which the pressure of the refrigerant on a high-pressure side becomes equal to or higher than the critical pressure of the refrigerant.

CLAIMS

1. A heat exchanger including a pair of headers arranged apart from each other, and a plurality of flat tubes arranged between the two headers at predetermined intervals along the longitudinal direction of the headers and each having opposite end portions connected to the respective headers,

wherein all the flat tubes are divided into two passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction; and when the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.45 to 0.55.

2. A heat exchanger according to claim 1, wherein each of the passes has a tube ratio of 0.48 to 0.52.

3. A heat exchanger including a pair of headers arranged apart from each other, and a plurality of flat tubes arranged between the two headers at predetermined intervals along the longitudinal direction of the headers and each having opposite end portions connected to the respective headers,

wherein all the flat tubes are divided into three passes each consisting of a plurality of flat tubes continuously arranged in the vertical direction; and when the quotient produced by dividing the number of the flat tubes constituting each of the passes by the number of all the flat tubes is defined as "tube ratio," each of the passes has a tube ratio of 0.3 to 0.4.

4. A heat exchanger according to claim 3, wherein each of the passes has a tube ratio of 0.32 to 0.34.

5. A heat exchanger according to claim 1 or 3, wherein each of the flat tubes has a plurality of refrigerant channels arranged therein along the width direction thereof; each of the refrigerant channels has a vertically elongated cross section; and when the quotient produced by dividing a channel height Hp (mm) of the refrigerant channel by a minimum channel width Wp (mm) of the refrigerant channel is defined as "aspect ratio," the aspect ratio (Hp/Wp) is 1.05 to 2.

6. A heat exchanger according to claim 1 or 3, satisfying a relation $0.5 \leq Tw/Wp \leq 1.5$, where Tw (mm) is the thickness of a partition wall between the adjacent refrigerant channels of each of the flat tubes, and Wp (mm) is the minimum channel width of each of the refrigerant channels.

7. A heat exchanger according to claim 1 or 3, satisfying a relation $0.3 \leq Hp/Ht \leq 0.7$, where Hp (mm) is the channel height of each of the refrigerant channels of each of the flat tubes, and Ht (mm) is the tube height of each of the flat tubes.

8. A heat exchanger according to claim 1 or 3, satisfying a relation $3 \leq Sp \leq 5$, where Sp ($mm^2$) is the total channel cross-sectional-area of all the refrigerant channels of each of the flat tubes.

9. A heat exchanger according to claim 1 or 3, satisfying a relation $Sp/Sb \leq 0.5$, where Sp ($mm^2$) is the total channel

cross-sectional-area of all the refrigerant channels of each of the flat tubes, and Sb ($mm^2$) is the remaining area (cross-sectional area of a bulk portion) after subtracting the total channel cross-sectional-area Sp ($mm^2$) from the entire cross-sectional area of each of the flat tubes.

10. A heat exchanger according to claim 1 or 3, satisfying a relation $(Wt \times Ht)/3 \geq Sp$, where Sp ($mm^2$) is the total channel cross-sectional-area of all the refrigerant channels of each of the flat tubes; Ht (mm) is the tube height of each of the flat tubes; and Wt (mm) is the tube width of each of the flat tubes.

11. A heat exchanger according to claim 1 or 3, satisfying a relation $Ht \leq 4$, where Ht (mm) is the tube height of each of the flat tubes.

12. A heat exchanger according to claim 1 or 3, wherein each of the flat tubes includes two flat walls in parallel with each other; first and second side walls extending over corresponding side ends of the two flat walls; and reinforcement walls provided between the first and second side walls and extending between the two flat walls and in the longitudinal direction of the two flat walls; and

each of the flat tubes is formed from a single metal sheet including two flat-wall-forming portions; a connection portion connecting the two flat-wall-forming portions and adapted to form the first side wall; two side-wall-forming elongated projections provided integrally with and in such a manner as to project from corresponding side ends of the flat-wall-forming portions opposite the connection portion, and adapted to form the second side wall; a plurality of reinforcement-wall-forming elongated projections provided integrally with each of the flat-wall-forming portion in such a manner as to project in the same direction as the side-wall-forming elongated projections; and the flat tube is formed by folding the metal sheet at the connection portion into a hairpin form such that the side-wall-forming elongated projections butt against each other and such that the reinforcement-wall-forming elongated projections butt against each other, and by brazing the mutually butting side-wall-forming elongated projections together and the mutually butting reinforcement-wall-forming elongated projections together, the mutually brazed reinforcement-wall-forming elongated projections forming the reinforcement walls.

13. A heat exchanger according to claim 12, wherein of two reinforcement-wall-forming elongated projections which form each reinforcement wall, one reinforcement-wall-forming elongated projection has a groove which is formed on the tip end face thereof so as to receive a tip end portion of the other reinforcement-wall-forming elongated projection.

14. A heat exchanger according to claim 1 or 3, wherein corrugate fins each including wave crest portions, wave trough portions, and connection portions each connecting together a wave crest portion and a wave trough portion are each arranged between the adjacent flat tubes; and each corrugate fin has a fin height of 5 mm to 8 mm, a fin pitch

of 1.0 mm to 1.5 mm, and a thickness of 0.05 mm to 0.1 mm.

15. A supercritical refrigeration cycle which comprises a compressor, a gas cooler, an evaporator, a pressure-reducing device, and an intermediate heat exchanger for performing heat exchange between refrigerant flowing out from the gas cooler and refrigerant flowing out from the evaporator and in which a supercritical refrigerant is used, wherein the gas cooler is a heat exchanger according to claim 1 or 3.

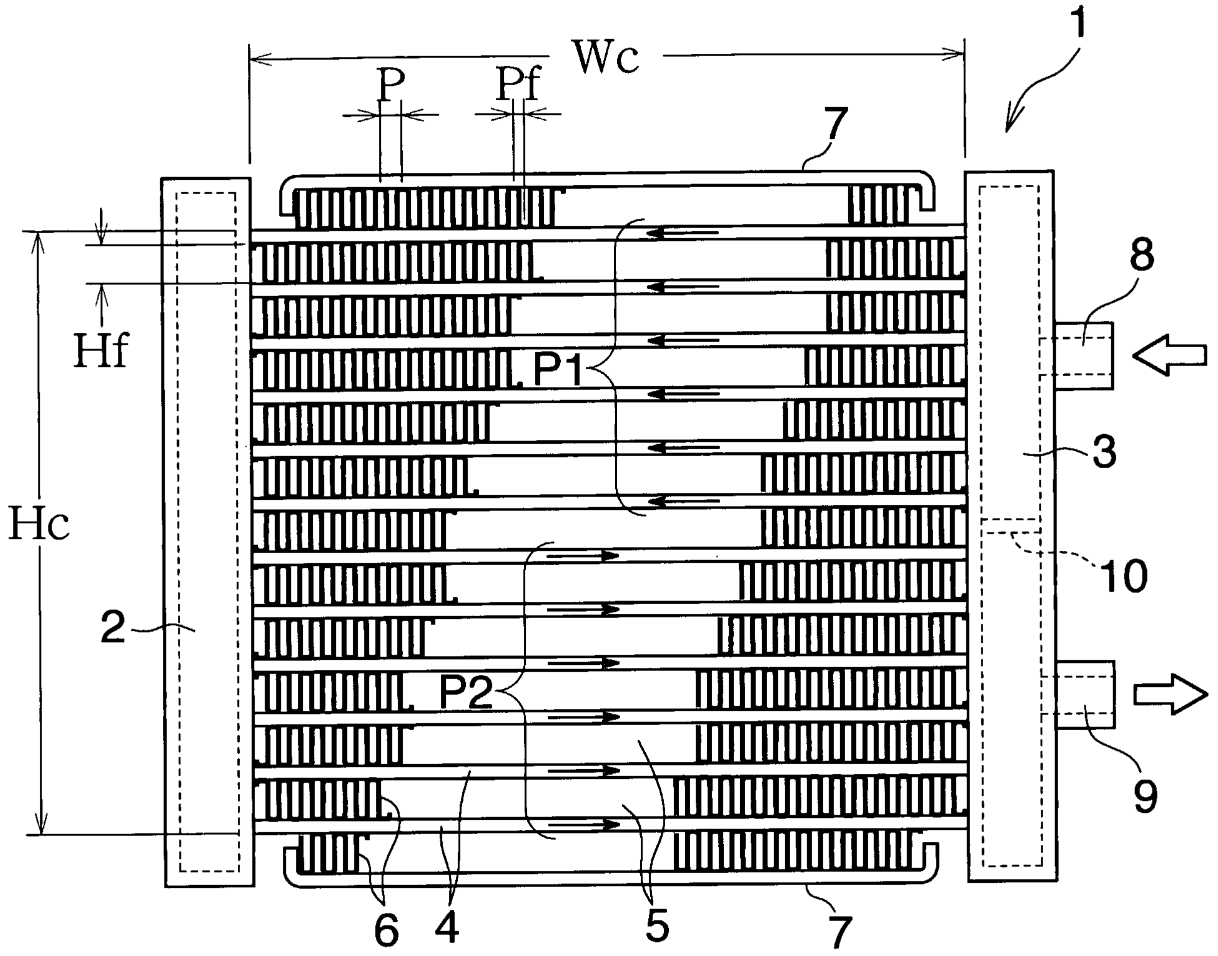



*Fig.1*

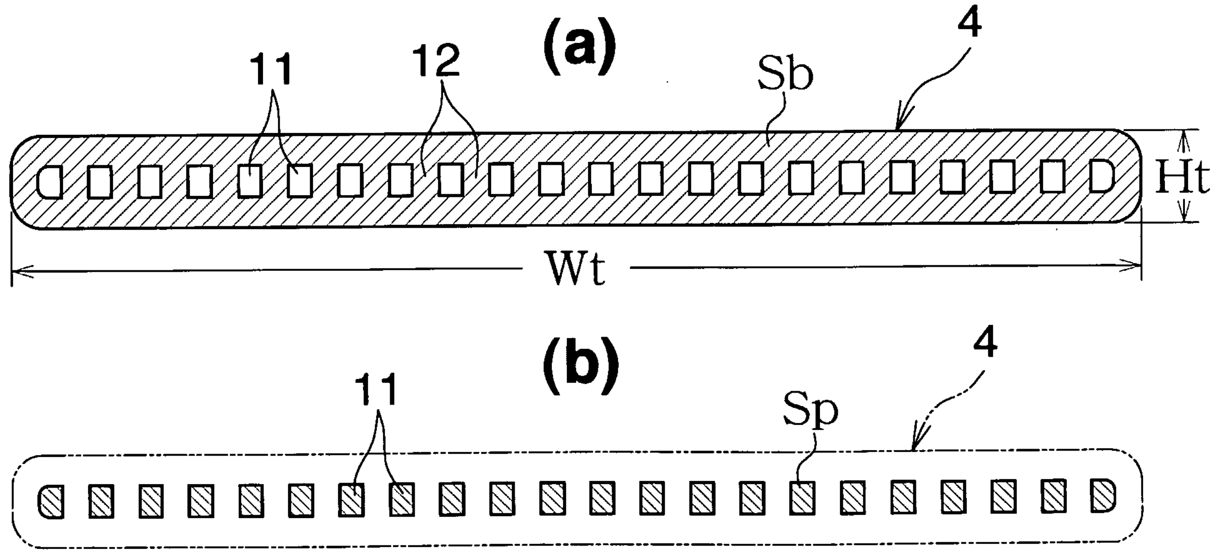



*Fig.2*

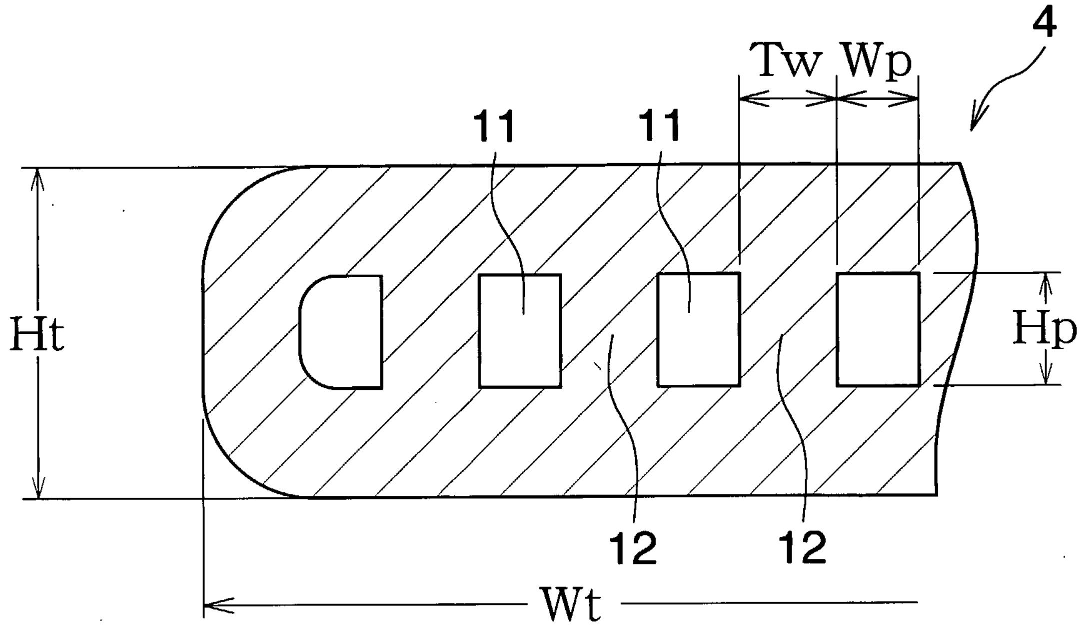



*Fig.3*

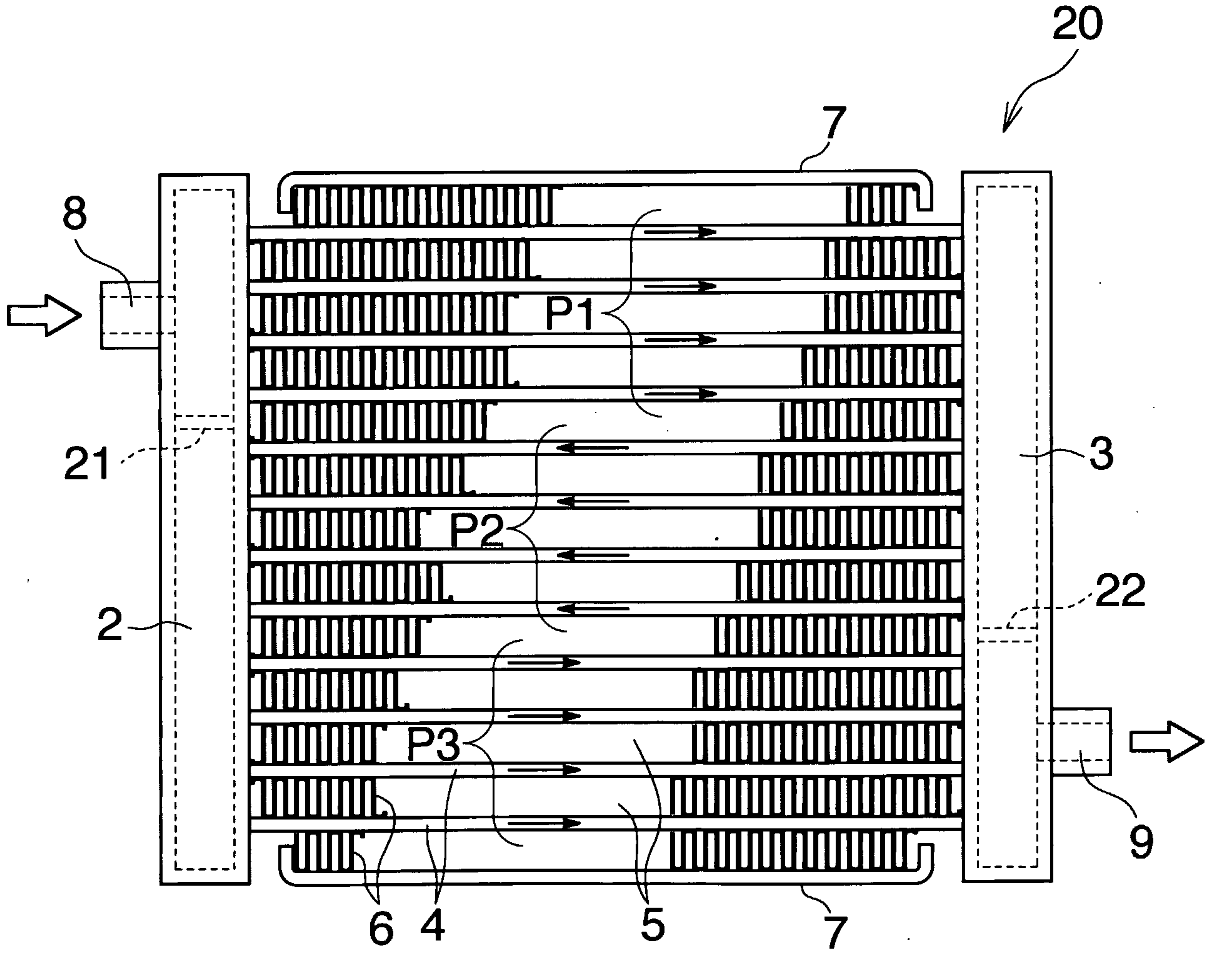



*Fig.4*

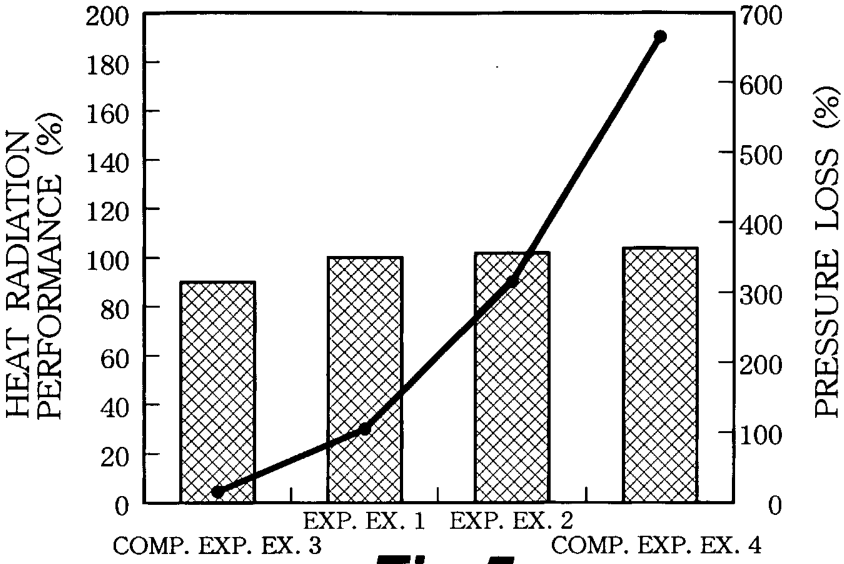



Fig.5

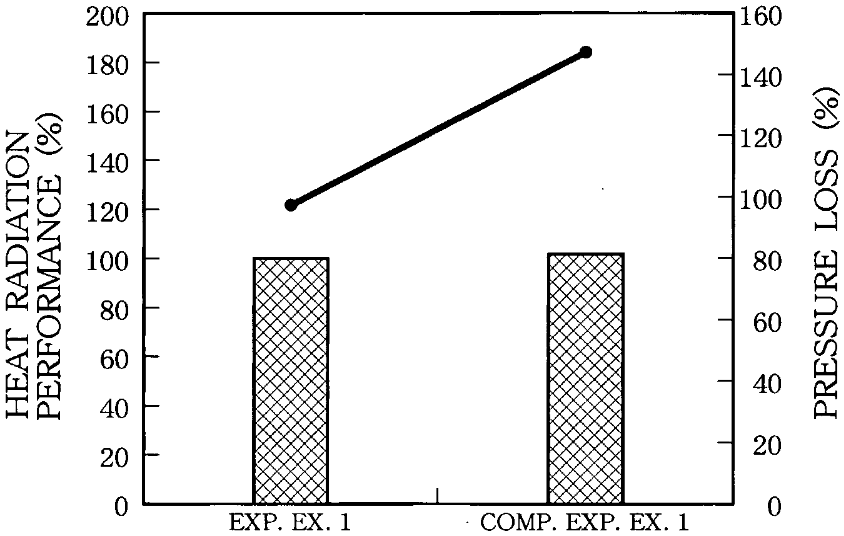



Fig.6

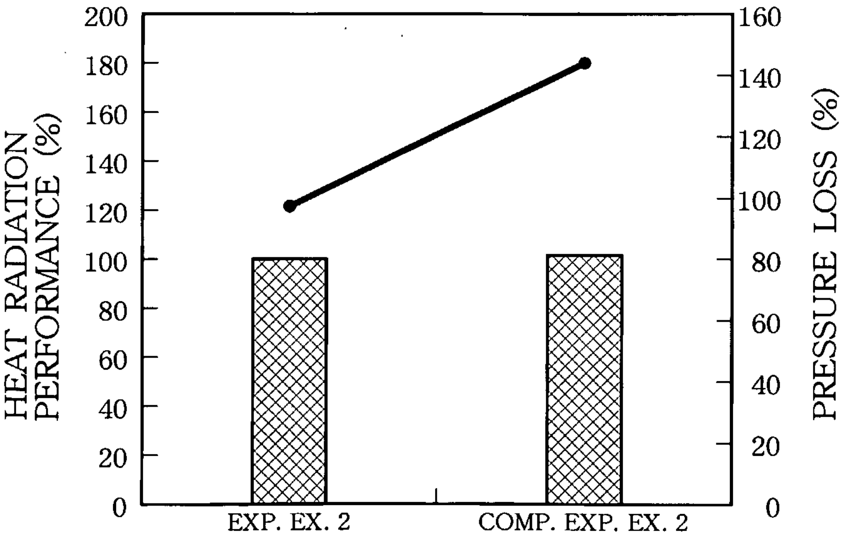



Fig.7

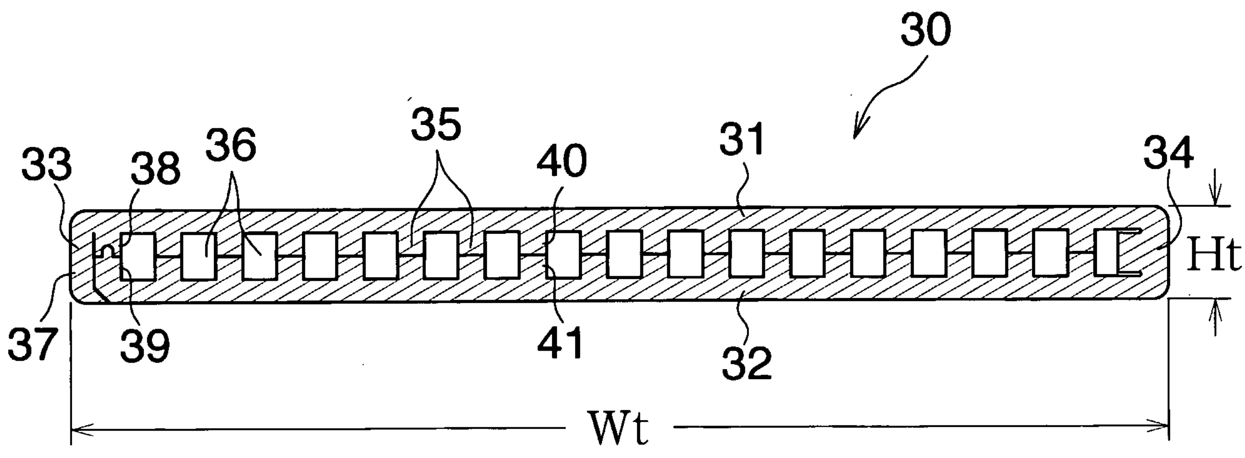

30
33
38
36
35
40
31
34
Ht
37
39
41
32
Wt

*Fig.8*

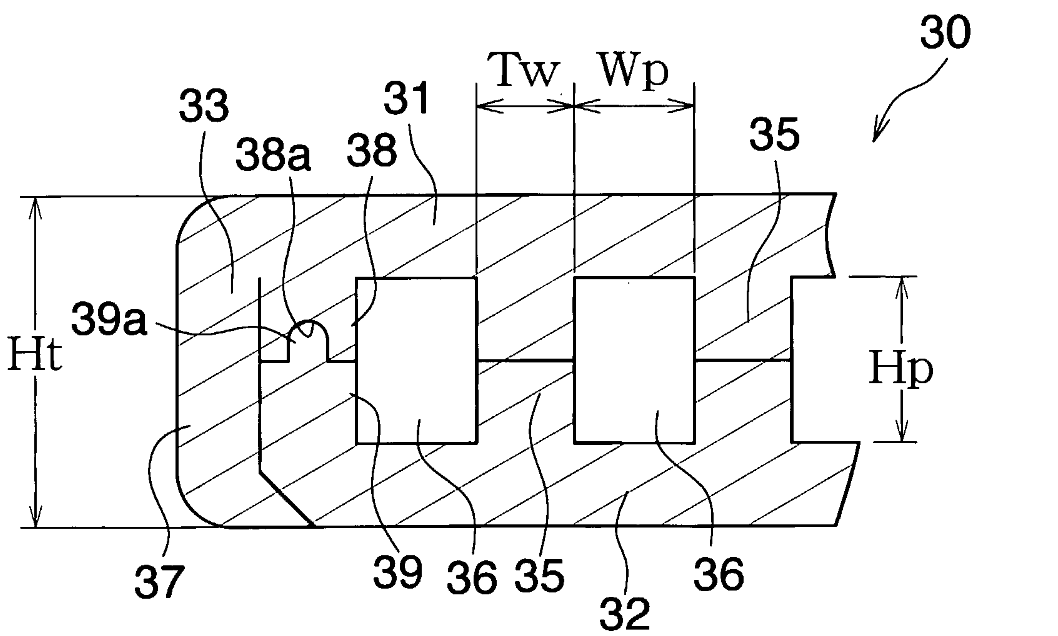
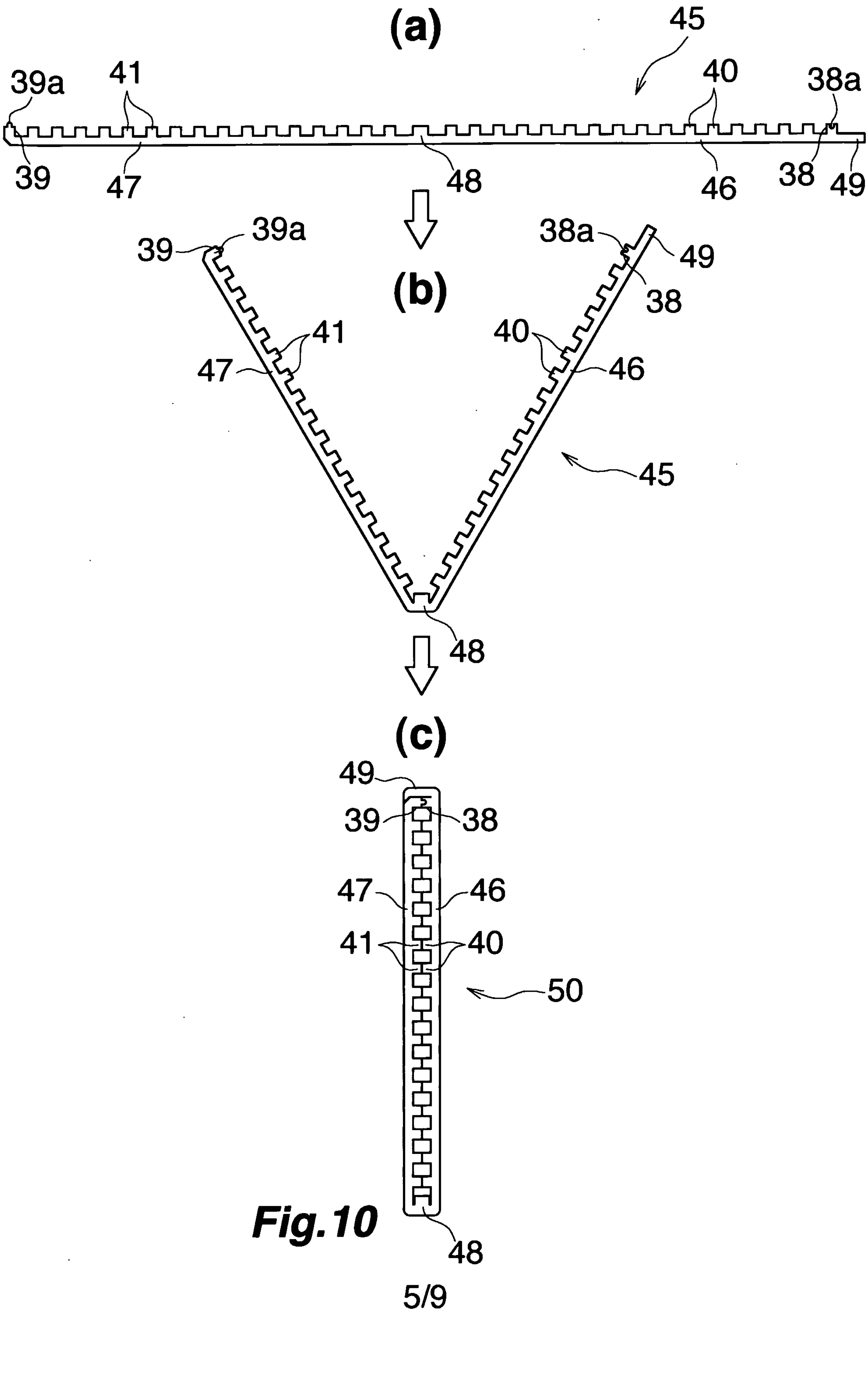

30
Tw
Wp
33
31
38a
38
35
39a
Ht
Hp
37
39
36
35
32
36

*Fig.9*


(a)
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(b)
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38a
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41
40
50
48

Fig.10

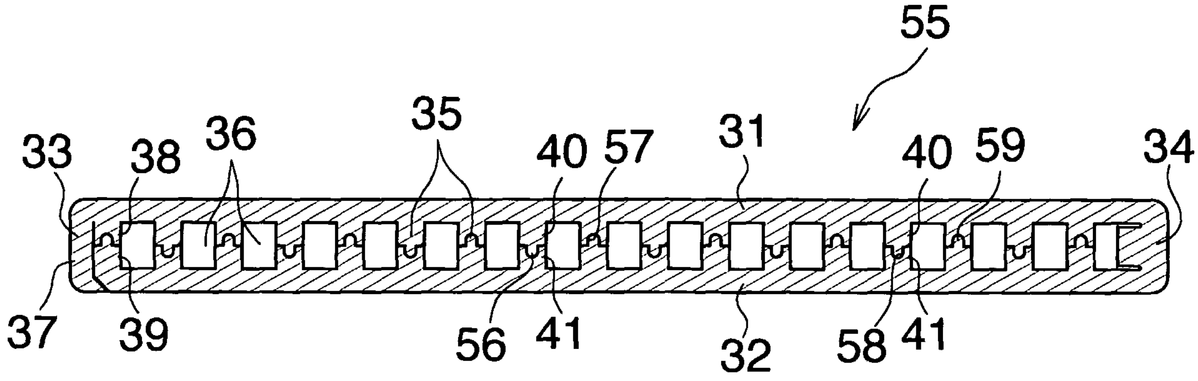



Fig.11

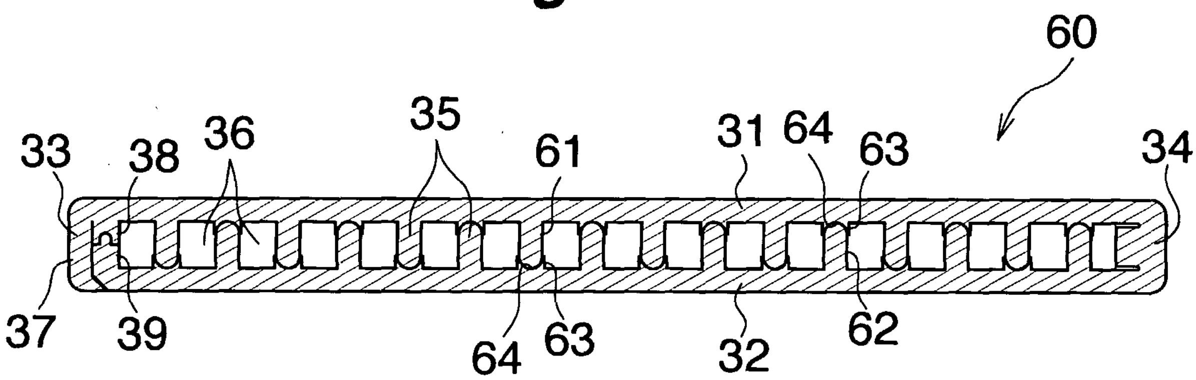



Fig.12

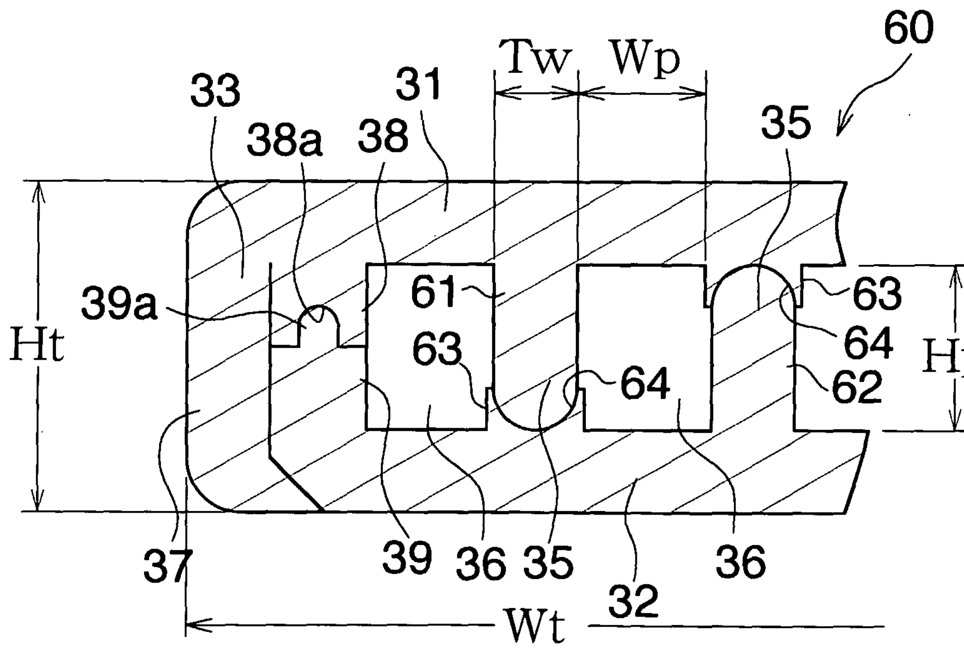
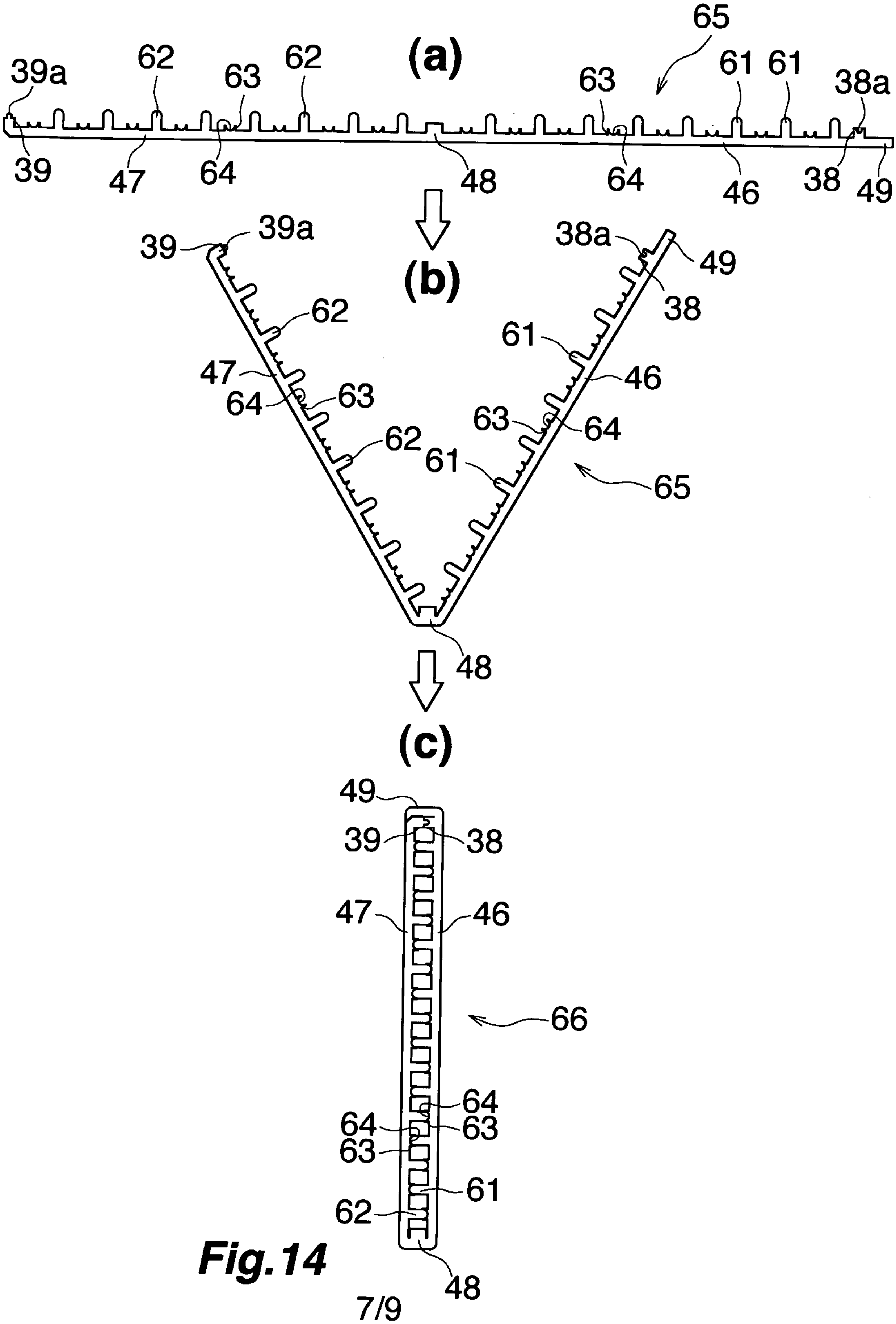



Fig.13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38a
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39a
38a
49
38
62
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(c)
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Fig.14

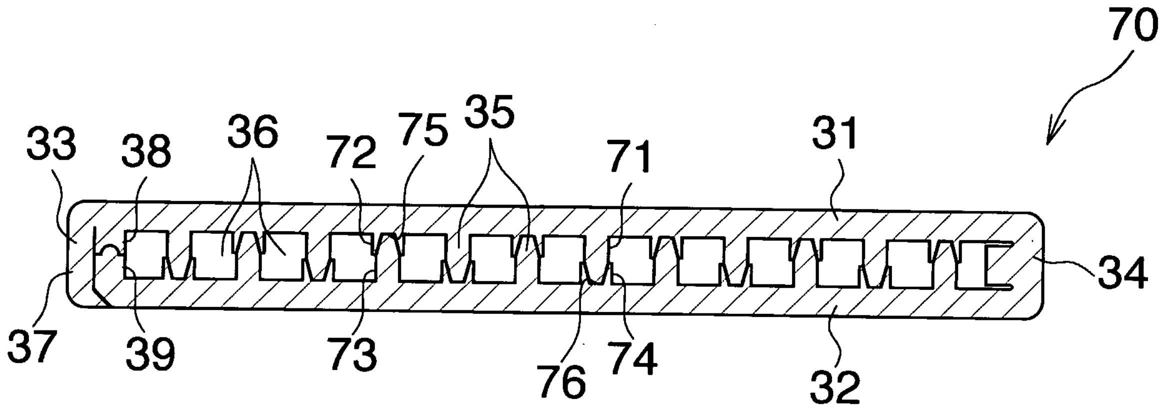
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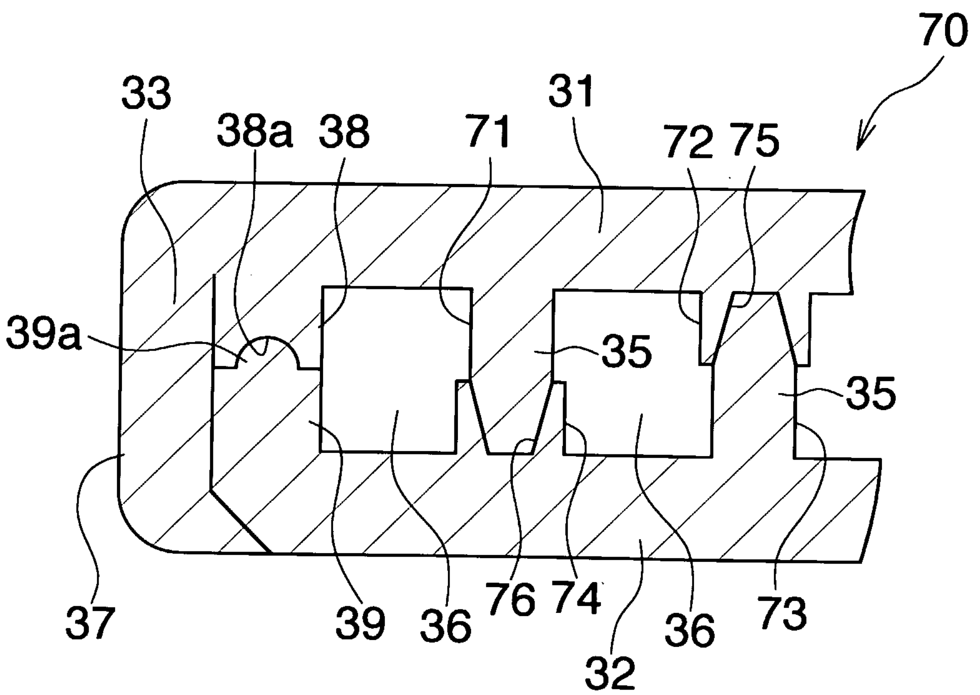
*Fig.15*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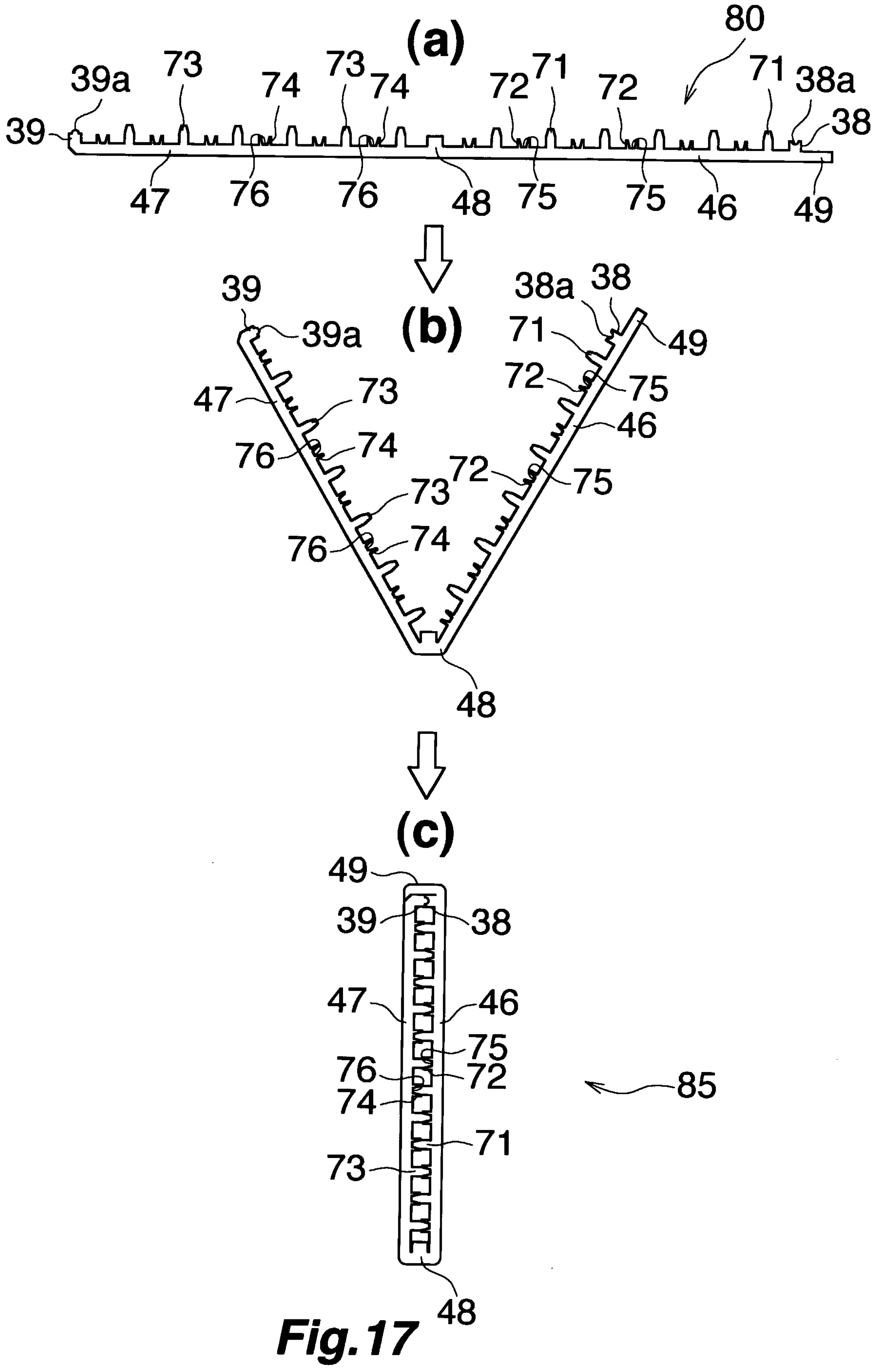
73

*Fig.16*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(b)
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39a
38a
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(c)
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*Fig.17*

**INTERNATIONALSEARCHREPORT**

International application No. PCT/JP2005/023695

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. *F28D1/053(2006.01), F25B39/04(2006.01)*

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)

Int.Cl. *F28D1/053(2006.01), F25B39/04(2006.01)*

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2006
Registered utility model specifications of Japan 1996-2006
Published registered utility model applications of Japan 1994-2006

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<br>Y | JP 2003-166790 A (MITSUBISHI HEAVY INDUSTRYS,LTD.)2003.06.13 Paragraph[0003]-[0004], Fig.5 (Family:None) | 1,2,15<br>5-14 |
| X<br>Y | WO 2002/95302 A1 (MATSUSHITA ELECTRIC INDUSTRIAL CO.,LTD.) 2002.11.28, Page7,Line16-Page10,Line5, Fig.2 & EP 1389721 A1 & US 2004-206109 A1 | 3,4,15<br>5-14 |
| Y | JP 2000-356488 A(SHOWA ALUMINUM CORPORATION) 2000.12.26, Claim1-8, Fig.1-3 (Family:None) | 5-11 |

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

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"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
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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 25.04.2006 | 02.05.2006 |
| Name and mailing address of the ISA/JP<br>**Japan Patent Office**<br>3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan | Authorized officer 3M 3332<br>Masayuki SHINOHARA<br>Telephone No. +81-3-3581-1101 Ext. 3377 |

International application No.
PCT/JP2005/023695

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 2003-53460 A(SHOWA DENKO K.K.)2003.02.26 Paragraph[0041]-[0050], Fig.1-3 & WO 02/100567 A1 & EP 1420910 A & US 2004-244196 A1 | 12,13 |
| Y | JP 2001-27484 A (ZEXEL VALEO CLIMATE CONTROL CORPORATION) 2001.01.30, Claim1, Claim3 & WO 01/6193 A1 & EP 1195569 A1 | 14 |
| Y | JP 2004-271116 A (JAPAN CLIMATE SYSTEMS CORPORATION) 2004.09.30, Claim1-2, Fig.1-2 (Family:None) | 14 |