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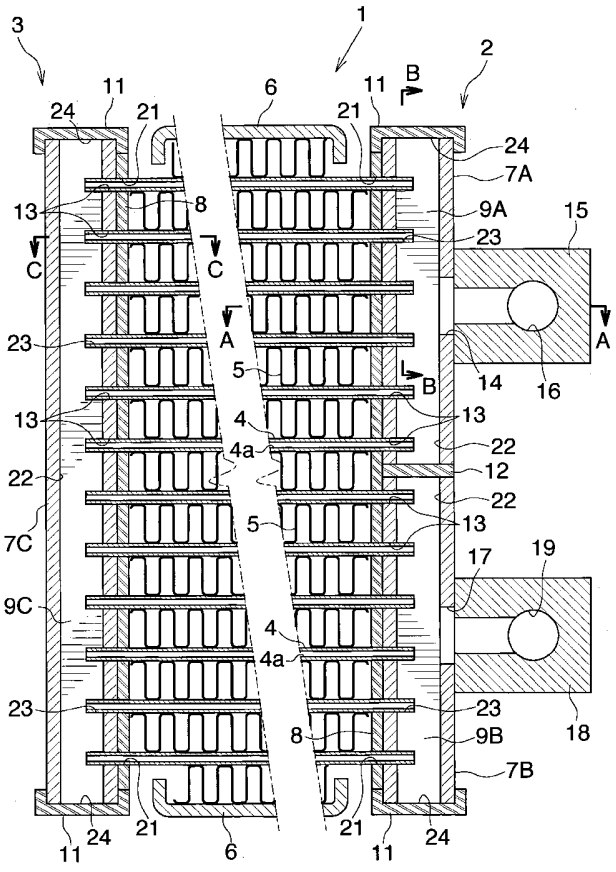
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(54) Title: HEAT EXCHANGER



(57) Abstract: A heat-exchanger header tank 2 (3) of a gas cooler 1, which serves as a heat exchanger, includes a tank formation member 7A (7B, 7C), a tube-connecting plate 8 joined to an outer surface of the tank formation member 7A (7B, 7C), and a partition member 9A (9B, 9C) disposed within and joined to the tank formation member 7A (7B, 7C) and adapted to divide the interior of the tank formation member 7A (7B, 7C) into a plurality of refrigerant channels 22 extending in the longitudinal direction of the tank formation member 7A (7B, 7C) and arranged in the front-rear direction. Tube insertion holes 13 (21) are formed in a wall of the tank formation member 7A (7B, 7C) and in the tube-connecting plate 8 at mutually aligned positions. Tube-end fit cutouts 23 for partially receiving corresponding end portions of heat exchange tubes 4 are formed on the partition member 9A (9B, 9C) in such a manner as to align with the corresponding tube insertion holes 13 (21). With the gas cooler 1, the cross-sectional profile of the header tank 2 (3) can be selected as appropriate in accordance with an installation space for the gas cooler 1, and the cross-sectional shape and area of a refrigerant channel of the header tank 2 (3) can be readily changed.

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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 dates of Provisional Application Nos. 60/580,145 and 60/662,360 filed June 17, 2004 and March 17, 2005, respectively, 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 favorably usable as a gas cooler or an evaporator of a supercritical refrigeration cycle in which a CO_2 (carbon dioxide) refrigerant or a like supercritical refrigerant is used.

Herein and in the appended claims, the downstream side of flow (represented by arrow X in FIGS. 1 and 13) of air in a heat exchanger is referred to as the "front," and the opposite side as the "rear," and the term "aluminum" encompasses aluminum alloys in addition to pure aluminum.

BACKGROUND ART

A conventionally known heat exchanger for use in a supercritical refrigeration cycle includes a pair of header

tanks disposed apart from each other; heat exchange tubes disposed in parallel at intervals between the two header tanks and having opposite ends connected to the respective header tanks; and fins disposed in respective air-passing clearances between adjacent heat exchange tubes (Japanese Patent Application Laid-Open (*kokai*) No. 2001-133189, FIGS. 6 and 7). Each of the two header tanks includes a cylindrical tank formation member formed from an extrudate, and a tube-connecting plate having a minor-arcuate cross section. The tank formation member has an arcuate-segment portion in which a plurality of tube insertion holes are formed and arranged apart from each other in the longitudinal direction thereof. The tube-connecting plate has a plurality of tube insertion holes formed therein and arranged apart from each other in the longitudinal direction thereof, and is joined to the tank formation member while being fitted to the arcuate-segment portion of the tank formation member.

In order to enhance withstand pressure, each of the header tanks of the heat exchanger described in the above-mentioned publication includes the cylindrical tank formation member having a refrigerant channel of a circular cross section. However, the header tanks fail to assume an appropriate cross-sectional profile in accordance with, for example, an installation space for the heat exchanger.

In order to provide, in various applications, appropriate cross-sectional shapes and areas of the refrigerant channel of the header tank so as to enhance heat

exchange performance of the heat exchanger described in the above-mentioned publication, various types of tank formation members having different inside diameters must be prepared beforehand by extrusion, resulting in an increase in cost.

An object of the present invention is to overcome the above problems and to provide a heat exchanger which allows the cross-sectional profile of a header tank thereof to be selected as appropriate in accordance with an installation space therefor and which readily allows a change in the cross-sectional shape and area of a refrigerant channel of the header tank.

DISCLOSURE OF THE INVENTION

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

1) A heat exchanger comprising a pair of header tanks disposed apart from each other, and a plurality of heat exchange tubes disposed in parallel between the two header tanks and each having opposite end portions connected to the respective header tanks,

the two header tanks each comprising a hollow tank formation member, and a partition member disposed within and joined to the tank formation member and adapted to divide the interior of the tank formation member into a plurality of refrigerant channels extending in the longitudinal direction of the tank formation member and arranged in the front-rear direction.

2) A heat exchanger according to par. 1), wherein a plurality of tube insertion holes are formed in the tank formation members; a plurality of tube-end fit cutouts for partially receiving corresponding end portions of heat exchange tubes are formed on the partition members in such a manner as to align with the corresponding tube insertion holes; and the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the corresponding tube insertion holes of the tank formation members and are fitted into the corresponding tube-end fit cutouts of the partition members.

3) A heat exchanger according to par. 1), further comprising tube-connecting plates joined to corresponding outer surfaces of the tank formation members, wherein a plurality of tube insertion holes are formed in the tube-connecting plates in such a manner as to align with the corresponding tube insertion holes of the tank formation members, and the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the tube insertion holes of the tube-connecting plates.

4) A heat exchanger according to par. 1), wherein the partition members assume the form of an elongated plate and are disposed such that the width direction thereof coincides with the height direction of hollow portions of the tank formation members.

5) A heat exchanger according to par. 1), wherein the

partition members have a cross section resembling the letter U, and the partition members are disposed such that the width direction of a pair of opposed walls of each partition member coincides with the height direction of the hollow portions of the tank formation members and such that ends of the opposed walls face the tube insertion holes.

6) A heat exchanger according to par. 1), wherein the partition members assume the form of a corrugated plate comprising a plurality of flat portions in parallel with one another and a plurality of connection portions each connecting adjacent flat portions, and the width direction of the flat portions coincides with the height direction of the hollow portions of the tank formation members.

7) A heat exchanger according to par. 1), wherein a first header tank of the paired header tanks comprises a plurality of tank formation members aligned with one another in a longitudinal direction thereof; a second header tank of the paired header tanks comprises tank formation members numbering one fewer than the tank formation members of the first header tank and is disposed so as to oppose two adjacent tank formation members of the first header tank; and a refrigerant entering one tank formation member of the first header tank flows through all the heat exchange tubes and the tank formation members of the second header tank and enters another tank formation member of the first header tank.

8) A heat exchanger according to par. 7), wherein the number of tank formation members of the first header tank is

two; the two tank formation members are joined together via a separation plate so as to avoid communication between hollow portions thereof; and the number of tank formation members of the second header tank is one.

9) A heat exchanger according to par. 1), wherein the first header tank of the paired header tanks comprises two tank formation members aligned with each other in the longitudinal direction thereof; the second header tank of the paired header tanks is disposed so as to oppose the two tank formation members of the first header tank;

the tank formation members of the two header tanks each have a plurality of hole groups provided in a plurality of rows separated from one another in the front-rear direction, each hole group comprising a plurality of tube insertion holes formed therein apart from one another in the longitudinal direction thereof; a partition member assuming the form of a corrugated plate comprising a plurality of flat portions in parallel with one another and a plurality of connection portions each connecting adjacent flat portions is disposed within each of the tank formation members of the two header tanks such that the width direction of the flat portions coincides with the height direction of a hollow portion of each of the tank formation members and such that at least one flat portion is located between tube insertion holes adjacent to each other in the front-rear direction of the tank formation member; a plurality of tube-end fit cutouts for partially receiving corresponding end portions of

heat exchange tubes are formed on the partition members in such a manner as to align with the corresponding tube insertion holes; the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the corresponding tube insertion holes of the tank formation members and are fitted into the corresponding tube-end fit cutouts of the partition members; no tube-end fit cutouts are formed on the flat portion located between tube insertion holes adjacent to each other in the front-rear direction; and

refrigerant passage holes are formed in the flat portions of the partition member disposed within one of the two tank formation members of the first header tank.

10) 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 a refrigerant from the gas cooler and a refrigerant from the evaporator and in which a supercritical refrigerant is used, the gas cooler comprising a heat exchanger according to any one of pars. 1) to 8).

11) 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 a refrigerant from the gas cooler and a refrigerant from the evaporator and in which a supercritical refrigerant is used, the evaporator comprising a heat exchanger according to any one of pars. 1) to 6) and

9).

12) A vehicle having installed therein a supercritical refrigeration cycle according to par. 10) as a vehicular air conditioner.

13) A vehicle having installed therein a supercritical refrigeration cycle according to par. 11) as a vehicular air conditioner.

With the heat exchanger according to par. 1), the header tank comprises the hollow tank formation member, and the partition member disposed within and joined to the tank formation member and adapted to divide the interior of the tank formation member into a plurality of refrigerant channels extending in the longitudinal direction of the tank formation member and arranged in the front-rear direction, so that the partition member functions to enhance withstand pressure of the header tank. This enables the header tank, or the tank formation member, to assume an appropriate cross-sectional profile in accordance with, for example, an installation space for an associated heat exchanger. Also, by means of changing the shape and cross-sectional area of the partition member, the cross-sectional shape and area of the refrigerant channels in the header tank can be readily changed so as to enhance heat exchange performance of the heat exchanger in various applications. As compared with the case where various types of tank formation members having different cross-sectional sizes are prepared, costs become lower.

With the heat exchanger according to par. 2), a plurality of tube insertion holes are formed in the tank formation member, and a plurality of tube-end fit cutouts for partially receiving corresponding end portions of the heat exchange tubes are formed on the partition member in such a manner as to align with the corresponding tube insertion holes. Accordingly, in the course of assembling the heat exchanger, the heat exchange tubes can be connected to the header tank in a relatively easy manner by utilizing the tube insertion holes of the tank formation member. Further, since the end portions of the heat exchange tubes are fitted into the corresponding tube-end fit cutouts of the partition member, all of the end portions of the heat exchange tubes can readily assume a predetermined length of projection into the header tank, or the tank formation member. Therefore, the length of projection can be set to an appropriate value for enhancing the performance of the heat exchanger.

The heat exchanger according to par. 3) further comprises a tube-connecting plate joined to the outer surface of the tank formation member, and a plurality of tube insertion holes are formed in the tube-connecting plate in such a manner as to align with the corresponding tube insertion holes of the tank formation member. Accordingly, in the course of assembling the heat exchanger by using the header tank, the heat exchange tubes can be connected to the header tank in a relatively easy manner by utilizing the tube insertion holes of the tank formation member and those of the

tube-connecting plate.

With the heat exchanger according to pars. 7) and 8), the flow of refrigerant can be appropriately set for enhancing heat exchange performance. For example, when the heat exchanger is used as a gas cooler of a supercritical refrigeration cycle, the gas cooler exhibits enhanced heat exchange performance.

With the heat exchanger according to par. 9), the flow of refrigerant can be appropriately set for enhancing heat exchange performance. For example, when the heat exchanger is used as an evaporator of a supercritical refrigeration cycle, the evaporator exhibits enhanced heat exchange performance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the overall construction of a gas cooler to which the heat exchanger according to the present invention is applied; FIG. 2 is a fragmentary view in vertical section showing the gas cooler of FIG. 1 as it is seen frontward from rear; FIG. 3 is a perspective view showing a first header tank of the gas cooler of FIG. 1; FIG. 4 is an exploded perspective view of the first header tank of the gas cooler of FIG. 1; FIG. 5 is an enlarged view in section taken along line A—A of FIG. 2; FIG. 6 is an enlarged view in section taken along line B—B of FIG. 2; FIG. 7 is an exploded perspective view of the second header tank of the gas cooler of FIG. 1; FIG. 8 is an

enlarged view in section taken along line C—C of FIG. 2; FIG. 9 is a diagram showing the flow of a refrigerant through the gas cooler of FIG. 1; FIG. 10 is a fragmentary perspective view showing a first modified embodiment of the partition member disposed within a tank formation member of the gas cooler of FIG. 1; FIG. 11 is a fragmentary perspective view showing a second modified embodiment of the partition member disposed within a tank formation member of the gas cooler of FIG. 1; FIG. 12 is a fragmentary perspective view showing a third modified embodiment of the partition member disposed within a tank formation member of the gas cooler of FIG. 1; FIG. 13 is a perspective view showing the overall construction of an evaporator to which the heat exchanger according to the present invention is applied; FIG. 14 is a fragmentary view in vertical section showing the evaporator of FIG. 13 as it is seen frontward from rear; FIG. 15 is an enlarged view in section taken along line D—D of FIG. 14; FIG. 16 is an exploded perspective view showing a first header tank of the evaporator of FIG. 13; FIG. 17 is an enlarged view in section taken along line E—E of FIG. 14; FIG. 18 is an enlarged view in section taken along line F—F of FIG. 14; FIG. 19 is an exploded perspective view showing a second header tank of the evaporator of FIG. 13; FIG. 20 is a diagram showing the flow of a refrigerant through the evaporator of FIG. 13; FIG. 21 is a cross-sectional view showing a first modified embodiment of the heat exchange tube; FIG. 22 is a fragmentary enlarged view of FIG. 21; FIG.

23 is a series of views showing a method of manufacturing the heat exchange tube shown in FIG. 21; FIG. 24 is a cross-sectional view showing a second modified embodiment of the heat exchange tube; FIG. 25 is a cross-sectional view showing a third modified embodiment of the heat exchange tube; FIG. 26 is a fragmentary enlarged view of FIG. 25; and FIG. 27 is a series of views showing a method of manufacturing the heat exchange tube shown in FIG. 25.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below with reference to the drawings.

In the following description, the upper, lower, left-hand, and right-hand sides of FIGS. 1, 2, 13, and 14 will be referred to as "upper," "lower," "left," and "right," respectively.

Embodiment 1

This embodiment is shown in FIGS. 1 to 9 and is implemented by applying a heat exchanger according to the present invention to a gas cooler of a supercritical refrigeration cycle.

With reference to FIGS. 1 and 2, a gas cooler 1 of a supercritical refrigeration cycle wherein a supercritical refrigerant, such as CO_2, is used includes two header tanks 2, 3 extending vertically and separated from each other in the left-right direction; a plurality of flat heat exchange tubes 4 arranged in parallel between the two header tanks 2, 3 and

separated from one another in the vertical direction; corrugated fins 5 arranged in respective air-passing clearances between adjacent heat exchange tubes 4 and at the outside of the upper-end and lower-end heat exchange tubes 4 and each brazed to the adjacent heat exchange tubes 4 or to the upper-end or lower-end heat exchange tube 4; and side plates 6 of bare aluminum material arranged externally of and brazed to the respective upper-end and lower-end corrugated fins 5. In the case of this embodiment, the header tank 2 at the right will be referred to as the "first header tank," and the header tank 3 at the left as the "second header tank."

As shown in FIGS. 3 to 6, the first header tank 2 includes two hollow tank formation members 7A, 7B extending and arranged vertically; a tube-connecting plate 8 opposed to the two tank formation members 7A, 7B and joined to the outer surfaces of the inner side walls with respect to the left-right direction; i.e., the left-hand side walls, of the two tank formation members 7A, 7B; partition members 9A, 9B disposed within and brazed to the tank formation members 7A, 7B, respectively; caps 11 adapted to close the upper end opening of the upper tank formation member 7A, and the lower end opening of the lower tank formation member 7B; and a separation plate 12 disposed between and joined to the upper and lower tank formation members 7A, 7B and adapted to close the lower end opening of the upper tank formation member 7A, and the upper end opening of the lower tank formation member 7B.

The tank formation members 7A, 7B are formed from a hollow aluminum extrudate and have a rectangular cross-sectional shape elongated in the front-rear direction. A plurality of tube insertion holes 13 elongated in the front-rear direction are formed through the inner side walls with respect to the left-right direction; i.e., the left-hand side walls, of the tank formation members 7A, 7B and are vertically separated from one another. A refrigerant inlet 14 is formed in the outer side wall with respect to the left-right direction; i.e., the right-hand side wall, of the upper tank formation member 7A. A refrigerant inlet member 15 of aluminum having a refrigerant inflow channel 16 in communication with the refrigerant inlet 14 is joined to the outer surface of the right-hand side wall of the upper tank formation member 7A by, in the present embodiment, brazing. A refrigerant outlet 17 is formed in the right-hand side wall of the lower tank formation member 7B. A refrigerant outlet member 18 of aluminum having a refrigerant outflow channel 19 in communication with the refrigerant outlet 17 is joined to the outer surface of the right-hand side wall of the lower tank formation member 7B by, in the present embodiment, brazing. The tank formation members 7A, 7B are formed, by press work, from a hollow aluminum extrudate such that the tube insertion holes 13 and the refrigerant inlet 14 or the refrigerant outlet 17 are formed. An upper end portion of the upper tank formation member 7A and a lower end portion of the lower tank formation member 7B project outward beyond the

tube-connecting plate 8.

The tube-connecting plate 8 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof and is brazed to the two tank formation members 7A, 7B by utilizing the brazing material layer on one side thereof. A plurality of tube insertion holes 21 elongated in the front-rear direction are formed through the tube-connecting plate 8 in such a manner as to align with the corresponding tube insertion holes 13 of the two tank formation members 7A, 7B and are vertically separated from one another. The tube-connecting plate 8 has a projecting wall 8a formed at each of the front and rear side edges and projecting outward with respect to the left-right direction. By utilizing the brazing material layer of the tube-connecting plate 8, the two projecting walls 8a are brazed to the outer surfaces of the front and rear side walls of the two tank formation members 7A, 7B while opposing the two tank formation members 7A, 7B. The tube-connecting plate 8 is formed, by press work, from an aluminum brazing sheet such that the tube insertion holes 21 and the projecting walls 8a are formed.

The partition members 9A, 9B are formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof and assume the form of an elongated plate. The partition members 9A, 9B are disposed within the tank formation members 7A, 7B, respectively, at the respective centers with respect to the front-rear direction

such that the width direction thereof coincides with the left-right direction (the height direction of the hollow portions of the tank formation members 7A, 7B) and in such a manner as to extend along the entire lengths of the tank formation members 7A, 7B. By utilizing the brazing material layers on the opposite surfaces of the partition members 9A, 9B, the partition members 9A, 9B are brazed to the inner surfaces of the left-hand and right-hand side walls of the two tank formation members 7A, 7B. The partition members 9A, 9B disposed within the tank formation members 7A, 7B, respectively, partially define refrigerant channels 22 arranged in the front-rear direction and extending in the longitudinal direction thereof. The refrigerant inlet 14 and the refrigerant outlet 17 of the tank formation members 7A, 7B, respectively, have such a size as to oppose the front and rear refrigerant channels 22. End portions oriented toward the tube insertion holes 13 of the tank formation members 7A, 7B; i.e., left-hand end portions, of the partition members 9A, 9B have a plurality of tube-end fit cutouts 23 formed thereon in such a manner as to be vertically separated from one another and to align with the corresponding tube insertion holes 13, 21 of the tank formation members 7A, 7B and the tube-connecting plate 8. The partition members 9A, 9B are formed, by press work, from an aluminum brazing sheet such that the tube-end fit cutouts 23 are formed.

A cap 11 is formed from an aluminum brazing sheet that has a brazing material layer on at least one side thereof. A

recess 24 is formed on the side of the cap 11 on which the brazing material layer is present, for receiving a portion of the tank formation member 7A or 7B that projects beyond the tube-connecting plate 8. By utilizing the brazing material layers of the caps 11, the caps 11 are brazed to the corresponding tank formation members 7A, 7B while the projecting portion of the upper tank formation member 7A and the projecting portion of the lower tank formation member 7B are fitted into the corresponding recesses 24 of the caps 11. The cap 11 is formed, by press work, from an aluminum brazing sheet such that the recess 24 is formed.

The separation plate 12 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. By utilizing the brazing material layers on the opposite surfaces, the separation plate 12 is brazed to the lower end surfaces of the upper tank formation member 7A and the upper partition member 9A and to the upper end surfaces of the lower tank formation member 7B and the lower partition member 9B.

As shown in FIGS. 7 and 8, the second header tank 3 has substantially the same construction as the first header tank 2 and is in the mirror image of the first header tank 2. The two header tanks 2, 3 are disposed such that the respective tube-connecting plates 8 face each other. In description of the two header tanks 2, 3, like features and parts are designated by like reference numerals. The second header tank 3 differs from the first header tank 2 in that in place

of the two tank formation members 7A, 7B, one tank formation member 7C is used which extends along the entire length of the second header tank 3; one partition member 9C is disposed within the tank formation member 7C and extends along the entire length of the tank formation member 7C; neither the refrigerant inlet 14 nor the refrigerant outlet 17 is formed on the tank formation member 7C; and the separation plate 12 is not provided.

Each of the heat exchange tubes 4 is formed from an aluminum extrudate; is in the form of a flat tube having an increased width in the front-rear direction; and has inside thereof a plurality of refrigerant channels 4a extending in the longitudinal direction thereof and arranged in parallel. Opposite end portions of the heat exchange tubes 4 are inserted through the corresponding tube insertion holes 21 of the tube-connecting plates 8 for the two header tanks 2, 3 and through the tube insertion holes 13 of the tank formation members 7A, 7B, 7C, and central portions with respect to the front-rear direction of the opposite end portions of the heat exchange tubes 4 are fitted into the cutouts 23 of the partition members 9A, 9B, 9C. In this condition, the opposite end portions of the heat exchange tubes 4 are brazed to the tube-connecting plates 8 and to the tank formation members 7A, 7B, 7C by utilizing the brazing material layers of the tube-connecting plates 8. The opposite end faces of the heat exchange tubes 4 abut the corresponding bottoms of the cutouts 23 of the partition members 9A, 9B, 9C.

Each of the corrugated fins 5 is made in a wavy form from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof.

The gas cooler 1 is manufactured by subjecting an assembly of all members to batch brazing.

The gas cooler 1, together with a compressor, an evaporator, a pressure-reducing device, and an intermediate heat exchanger for performing heat exchange between a refrigerant from the gas cooler and a refrigerant from the evaporator, constitutes a supercritical refrigeration cycle. The refrigeration cycle is installed in a vehicle, for example, in a motor vehicle, as a vehicular air conditioner.

As shown in FIG. 9, in the gas cooler 1 described above, CO_2 having passed through a compressor flows through the refrigerant inflow channel 16 of the refrigerant inlet member 15 and enters the two refrigerant channels 22 of the upper tank formation member 7A of the first header tank 2 through the refrigerant inlet 14. Then, the CO_2 flows through the two refrigerant channels 22 and flows into the refrigerant channels 4a of all the heat exchange tubes 4 in communication with the upper tank formation member 7A. The CO_2 in the refrigerant channels 4a flows leftward through the refrigerant channels 4a and enters the tank formation member 7C of the second header tank 3. The CO_2 in the tank formation member 7C flows downward through the two refrigerant channels 22; flows into the refrigerant channels 4a of all the heat exchange tubes 4 in communication with the

lower tank formation member 7B; changes its course; flows rightward through the refrigerant channels 4a; and enters the two refrigerant channels 22 of the lower tank formation member 7B of the first header tank 2. Subsequently, the CO_2 flows through the two refrigerant channels 22 and flows out of the gas cooler 1 via the refrigerant outlet 17 and the refrigerant outflow channel 19 of the refrigerant outlet member 18. While flowing through the refrigerant channels 4a of the heat exchange tubes 4, the CO_2 is subjected to heat exchange with the air flowing through the air-passing clearances in the direction of arrow X shown in FIG. 9, thereby being cooled.

FIGS. 10 to 13 show modified embodiments of the partition member disposed within the tank formation member of the gas cooler.

In the modified embodiment shown in FIG. 10, a plurality of, two in the present modified embodiment, partition members 9A (9B, 9C) of Embodiment 1 are disposed within the tank formation member 7A (7B, 7C) and are separated from each other in the front-rear direction. The refrigerant channels 22 numbering one greater than the partition members 9A (9B, 9C) are formed within the tank formation member 7A (7B, 7C). FIG. 10(a) shows the tank formation member 7A (7B) of the first header tank 2, and FIG. 10(b) shows the tank formation member 7C of the second header tank 3. In this case, in the first header tank 2, the refrigerant inlet 14 and the refrigerant outlet 17 of the

tank formation members 7A, 7B, respectively, have such a size as to oppose all the refrigerant channels 22.

In the modified embodiment shown in FIG. 11, a partition member 30A (30B, 30C) has a cross section resembling the letter U; is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof; and is disposed within the tank formation member 7A (7B, 7C) such that the width direction of a pair of opposed walls 30a thereof coincides with the height direction (left-right direction) of the hollow portion of the tank formation member 7A (7B, 7C) and such that the ends of the opposed walls 30a face the tube insertion holes 13 of the tank formation member 7A (7B, 7C) (inward with respect to the left-right direction). The partition member 30A (30B, 30C) is brazed to the inner surfaces of the left-hand and right-hand side walls of the tank formation member 7A (7B, 7C) by utilizing the brazing material layers provided on the opposite surfaces thereof. FIG. 11(a) shows the tank formation member 7A (7B) of the first header tank 2, and FIG. 11(b) shows the tank formation member 7C of the second header tank 3. Tube-end fit cutouts 32 are formed on end portions of the opposed walls 30a of the partition members 30A, 30B, 30C. The opposed walls 30a of the partition members 30A, 30B, 30C disposed within the tank formation members 7A, 7B, 7C, respectively, partially define the refrigerant channels 22 arranged in the front-rear direction. The partition members 30A, 30B, 30C are formed, by press work, from an aluminum

brazing sheet in such a manner as to assume a cross section resembling the letter U and to have the tube-end fit cutouts 32.

In the case of disposition of the partition members 30A, 30B within the two tank formation members 7A, 7B, respectively, of the first header tank of Embodiment 1, a refrigerant passage through-hole 34 is formed in a connection wall 30b connecting the opposed walls 30a of the partition member 30A (30B) at a position aligned with the refrigerant inlet 14 (refrigerant outlet 17). The refrigerant inlet 14 and the refrigerant outlet 17 of the tank formation members 7A, 7B, respectively, have such a size as to oppose all the refrigerant channels 22.

In the modified embodiment shown in FIG. 12, a partition member 35A (35B, 35C) is formed from an aluminum brazing sheet having a brazing material layer on opposite surfaces thereof and assumes the form of a corrugated plate. The corrugated plate is composed of a plurality of, three in the present modified embodiment, flat walls 35a in parallel with one another, and connection portions 35b each connecting the adjacent flat walls 35a in a staggered manner with respect to the height direction of a hollow portion of the tank formation member 7A (7B, 7C) (with respect to the left-right direction). The partition member 35A (35B, 35C) is disposed within the tank formation member 7A (7B, 7C) such that the width direction of the flat walls 35a coincides with the height direction of the hollow portion of the tank

formation member 7A (7B, 7C) (left-right direction). The partition member 35A (35B, 35C) is brazed to the inner surfaces of the left-hand and right-hand side walls of the tank formation member 7A (7B, 7C) by utilizing the brazing material layers provided on the opposite surfaces thereof. FIG. 12(a) shows the tank formation member 7A (7B) of the first header tank 2, and FIG. 12(b) shows the tank formation member 7C of the second header tank 3. Tube-end fit cutouts 36 are formed on the connection portions 35b of the partition members 35A, 35B, 35C located on the side toward the tube insertion holes 13 of the tank formation members 7A, 7B, and 7C and on the flat walls 35a connected by said connection portions 35b. Also, the tube-end fit cutouts 37 are formed on end portions of other flat walls 35a located on the side toward the tube insertion holes 13. The flat walls 35a of the partition members 35A, 35B, 35C disposed within the tank formation members 7A, 7B, 7C, respectively, partially define the refrigerant channels 22 arranged in the front-rear direction. The partition members 35A, 35B, 35C are formed, by press work, from an aluminum brazing sheet in such a manner as to assume the form of a corrugated plate and to have the tube-end fit cutouts 36, 37.

In the case of disposition of the partition members 35A, 35B within the two tank formation members 7A, 7B, respectively, of the first header tank of Embodiment 1, a refrigerant passage through-hole 38 is formed in the connection portion 35b of the partition member 35A (35B)

located outward with respect to the left-right direction at a position aligned with the refrigerant inlet 14 (refrigerant outlet 17). The refrigerant inlet 14 and the refrigerant outlet 17 of the tank formation members 7A, 7B, respectively, have such a size as to oppose all the refrigerant channels 22.

Embodiment 2

This embodiment is shown in FIGS. 13 to 20 and is implemented by applying a heat exchanger according to the present invention to an evaporator of a supercritical refrigeration cycle.

With reference to FIGS. 13 and 15, an evaporator 40 of a supercritical refrigeration cycle wherein a supercritical refrigerant, such as CO_2, is used includes two header tanks 41, 42 extending in the left-right direction and separated from each other in the vertical direction; a plurality of flat heat exchange tubes 43 arranged in parallel between the two header tanks 41, 42 and separated from one another in the left-right direction; corrugated fins 44 arranged in respective air-passing clearances between adjacent heat exchange tubes 43 and at the outside of the left-end and right-end heat exchange tubes 43 and each brazed to the adjacent heat exchange tubes 43 or to the left-end or right-end heat exchange tube 43; and side plates 45 of bare aluminum material arranged externally of and brazed to the respective left-end and right-end corrugated fins 44. In the case of this embodiment, the upper header tank 41 will be referred to as the "first header tank," and the lower header

tank 42 as the "second header tank."

As shown in FIGS. 16 to 18, the first header tank 41 includes a right-hand tank formation member 46A and a left-hand tank formation member 46B each extending in the left-right direction and assuming a hollow form; a tube-connecting plate 47 opposed to the two tank formation members 46A, 46B and joined to the outer surfaces of the lower walls of the two tank formation members 46A, 46B; partition members 48A, 48B disposed within and brazed to the tank formation members 46A, 46B, respectively; a refrigerant inlet-outlet member 49 joined to a right end portion of the right-hand tank formation member 46A; a cap 51 adapted to close the left end opening of the left-hand tank formation member 46B; and a separation plate 52 disposed between and joined to the two tank formation members 46A, 46B and adapted to close the left end opening of the right-hand tank formation member 46A and the right end opening of the left-hand tank formation member 46B.

The tank formation members 46A, 46B are formed from a hollow aluminum extrudate and have a rectangular cross-sectional shape elongated in the front-rear direction. A plurality of tube insertion holes 53 elongated in the front-rear direction are formed, in front and rear rows, through the lower walls of the tank formation members 46A, 46B and are separated from one another in the left-right direction. The tube insertion holes 53 in the front row and the tube insertion holes 53 in the rear row are aligned with each

other with respect to the left-right direction. The tank formation members 46A, 46B are formed, by press work, from a hollow aluminum extrudate such that the tube insertion holes 53 are formed. A left end portion of the left-hand tank formation member 46B and a right end portion of the right-hand tank formation member 46A project outward beyond the tube-connecting plate 47.

The tube-connecting plate 47 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof and is brazed to the two tank formation members 46A, 46B by utilizing the brazing material layer on one side thereof. A plurality of tube insertion holes 54 elongated in the front-rear direction are formed in front and rear rows through the tube-connecting plate 47 in such a manner as to align with the corresponding tube insertion holes 53 of the two tank formation members 46A, 46B and are separated from one another in the left-right direction. The tube-connecting plate 47 has a projecting wall 47a integrally formed at each of the front and rear side edges and projecting outward with respect to the vertical direction (upward in the present embodiment). By utilizing the brazing material layer of the tube-connecting plate 47, the two projecting walls 47a are brazed to the outer surfaces of the front and rear side walls of the two tank formation members 46A, 46B while opposing the two tank formation members 46A, 46B. The tube-connecting plate 47 is formed, by press work, from an aluminum brazing sheet such that the tube insertion

holes 54 and the projecting walls 47a are formed.

The partition members 48A, 48B are formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof and assumes the form of a corrugated plate. The corrugated plate is composed of a plurality of, five in the present embodiment, flat walls 48a in parallel with one another, and connection portions 48b each connecting the adjacent flat walls 48a in a staggered manner with respect to the height direction of a hollow portion of the tank formation member 46A (46B) (with respect to the vertical direction). The partition member 48A (48B) is disposed within the tank formation member 46A (46B) along the entire length of the tank formation member 46A (46B) such that the width direction of the flat walls 48a coincides with the vertical direction. The partition member 48A (48B) is brazed to the inner surfaces of the upper and lower walls of the tank formation member 46A (46B) by utilizing the brazing material layers provided on the opposite surfaces thereof. The flat walls 48a of the partition members 48A, 48B disposed within the tank formation members 46A, 46B, respectively, partially define the refrigerant channels 55 arranged in the front-rear direction. A plurality of tube-end fit cutouts 56 are formed on the front-side connection portions 48b of the partition members 48A, 48B located on the side toward the tube insertion holes 53 of the tank formation members 46A, 46B and on the flat walls 48a connected by said connection portions 48b in such a manner as to be separated from one

another in the left-right direction so as to be aligned with the front-side tube insertion holes 53 of the tank formation members 46A, 46B and the front-side tube insertion holes 54 of the tube-connecting plate 47. Also, a plurality of tube-end fit cutouts 57 are formed on the rear-side connection portions 48b of the partition members 48A, 48B located on the side toward the tube insertion holes 53 of the tank formation members 46A, 46B and on the flat walls 48a located on the rear side of said connection portions 48b in such a manner as to be separated from one another in the left-right direction so as to be aligned with the rear-side tube insertion holes 53 of the tank formation members 46A, 46B and the rear-side tube insertion holes 54 of the tube-connecting plate 47. Further, a plurality of tube-end fit cutouts 58 are formed on end portions of rearmost flat walls 48a of the partition members 48A, 48B located on the side toward the tube insertion holes 53 of the tank formation members 46A, 46B in such a manner as to be separated from one another in the left-right direction so as to be aligned with the rear-side tube insertion holes 53 of the tank formation members 46A, 46B and the rear-side tube insertion holes 54 of the tube-connecting plate 47. A plurality of refrigerant passage holes 59 are formed through all the flat walls 48a of the partition member 48B disposed within the left-hand tank formation member 46B in such a manner as to be separated from one another in the left-right direction. The right-hand partition member 48A is formed, by press work, from an

aluminum brazing sheet in such a manner as to assume the form of a corrugated plate and to have the tube-end fit cutouts 56, 57, 58. The left-hand partition member 48B is formed, by press work, from an aluminum brazing sheet in such a manner as to assume the form of a corrugated plate and to have the tube-end fit cutouts 56, 57, 58 and the refrigerant passage holes 59.

The refrigerant inlet-outlet member 49 has a recess 61 formed on its left-hand side surface for receiving a portion of the right-hand tank formation member 46A that projects beyond the tube-connecting plate 47. By use of an unillustrated appropriate aluminum brazing sheet or brazing material sheet, the refrigerant inlet-outlet member 49 is brazed to the right-hand tank formation member 46A while the projecting portion of the right-hand tank formation member 46A is fitted into the recess 61. The refrigerant inlet-outlet member 49 has a refrigerant inflow channel 62 formed therein in communication with the front-side three refrigerant channels 55 in the tank formation member 46A, and a refrigerant outflow channel 63 formed therein in communication with the rear-side three refrigerant channels 55 in the tank formation member 46A. A refrigerant inlet pipe (not shown) to communicate with the refrigerant inflow channel 62 and a refrigerant outlet pipe (not shown) to communicate with the refrigerant outflow channel 63 are connected to the refrigerant inlet-outlet member 49.

The cap 51 is formed from an aluminum brazing sheet

that has a brazing material layer on at least one side thereof. A recess 64 is formed on the side of the cap 51 on which the brazing material layer is present, for receiving a portion of the left-hand tank formation member 46B that projects beyond the tube-connecting plate 47. By utilizing the brazing material layer of the cap 51, the cap 51 is brazed to the left-hand tank formation member 46B while the projecting portion of the left-hand tank formation member 46B is fitted into the recess 64 of the cap 51. The cap 51 is formed, by press work, from an aluminum brazing sheet such that the recess 64 is formed.

The separation plate 52 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. By utilizing the brazing material layers on the opposite surfaces, the separation plate 52 is brazed to the left end surfaces of the right-hand tank formation member 46A and the right-hand partition member 48A and to the right end surfaces of the left-hand tank formation member 46B and the left-hand partition member 48B.

As shown in FIG. 19, the second header tank 42 has substantially the same construction as the first header tank 41 and is in the upside-down image of the first header tank 42. The two header tanks 41, 42 are disposed such that the respective tube-connecting plates 47 face each other. In description of the two header tanks 41, 42, like features and parts are designated by like reference numerals. The second header tank 42 differs from the first header tank 41 in that

in place of the two tank formation members 46A, 46B, one tank formation member 46C is used which extends along the entire length of the second header tank 42; one partition member 48C is disposed within the tank formation member 46C and extends along the entire length of the tank formation member 46C; the refrigerant inlet-outlet member 49 is not attached to a right end portion of the tank formation member 46C, but the cap 51 is brazed to the right end portion as in the case of the left end portion; the refrigerant passage holes 59 are not formed in the partition member 48C; and the separation plate 52 is not provided.

A portion of the right-hand tank formation member 46A of the first header tank 41 that is located on the front side with respect to the central flat wall 48a of the partition member 48A serves as an inlet header portion 65, and a portion on the rear side serves as an outlet header portion 66. A portion of the tank formation member 46C of the second header tank 42 that is located on the front side with respect to the central flat wall 48a of the partition member 48C serves as a first intermediate header portion 67. A portion of the left-hand tank formation member 46B of the first header tank 41 that is located on the front side with respect to the central flat wall 48a of the partition member 48B serves as a second intermediate header portion 68, and a portion on the rear side serves as a third intermediate header portion 69. A portion of the tank formation member 46C of the second header tank 42 that is located on the rear

side with respect to the central flat wall 48a of the partition member 48C serves as a fourth intermediate header portion 70.

Each of the heat exchange tubes 43 is formed from an aluminum extrudate; is in the form of a flat tube having an increased width in the front-rear direction; and has inside thereof a plurality of refrigerant channels 43a extending in the longitudinal direction thereof and arranged in parallel. Opposite end portions of the heat exchange tubes 43 are inserted through the corresponding tube insertion holes 54 of the tube-connecting plates 47 for the two header tanks 41, 42 and through the tube insertion holes 53 of the tank formation members 46A, 46B, 46C and are fitted into the cutouts 56, 57, 58 of the partition members 48A, 48B, 48C. In this condition, the opposite end portions of the heat exchange tubes 43 are brazed to the tube-connecting plates 47 and to the tank formation members 46A, 46B, 46C by utilizing the brazing material layers of the tube-connecting plates 47. Between the two header tanks 41, 42, a plurality of heat-exchange-tube groups 43A, each consisting of a plurality of heat exchange tubes 43 arranged in parallel and separated from one another in the left-right direction, are arranged in a plurality of rows, in two rows in the present embodiment, separated from each other in the front-rear direction. The heat exchange tubes 43 positioned in the right half of the front heat-exchange-tube group 43A communicate with the inlet header portion 65 and the first intermediate header portion

67, and the heat exchange tubes 43 positioned in the left half of the front heat-exchange-tube group 43A communicate with the first intermediate header portion 67 and the second intermediate header portion 68. The heat exchange tubes 43 positioned in the right half of the rear heat-exchange-tube group 43A communicate with the outlet header portion 66 and the fourth intermediate header portion 70, and the heat exchange tubes 43 positioned in the left half of the rear heat-exchange-tube group 43A communicate with the third intermediate header portion 69 and the fourth intermediate header portion 70.

Each of the corrugated fins 44 is made in a wavy form from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. Connecting portions interconnecting crest portions and trough portions of the fin are provided with a plurality of louvers arranged in parallel in the front-rear direction. The corrugated fin 44 is used in common for the front and rear heat-exchange-tube groups 43A and has a front-to-rear width which is substantially equal to the distance between the front edge of the heat exchange tube 43 of the front heat-exchange-tube group 43A and the rear edge of the corresponding heat exchange tube 43 of the rear heat-exchange-tube group 43A. Instead of using one corrugated fin 44 for the front and rear heat-exchange-tube groups 43A in common, a corrugated fin may be provided between each adjacent pair of heat exchange tubes 43 in each of the heat-exchange-tube groups 43A.

The evaporator 1 is manufactured by subjecting an assembly of all members to batch brazing.

The evaporator 1, together with a compressor, a gas cooler, a pressure-reducing device, and an intermediate heat exchanger for performing heat exchange between a refrigerant from the gas cooler and a refrigerant from the evaporator, constitutes a supercritical refrigeration cycle. The refrigeration cycle is installed in a vehicle, for example, in a motor vehicle, as a vehicular air conditioner.

As shown in FIG. 20, with the evaporator 40 described above, CO_2 passing through a pressure-reducing device and undergoing pressure reduction therein flows through the refrigerant inflow channel 62 of the refrigerant inlet-outlet member 49 into the inlet header portion 65 of the first header tank 41 and thereafter flows through the refrigerant channels 55 into the refrigerant channels 43a of all the heat exchange tubes 43 of the front heat-exchange-tube group 43A in communication with the inlet header portion 65. The CO_2 in the refrigerant channels 43a flows downward through the refrigerant channels 43a and enters the first intermediate header portion 67 of the second header tank 42. The CO_2 in the first intermediate header portion 67 flows leftward through the refrigerant channels 55; flows into the refrigerant channels 43a of all the heat exchange tubes 43 of the front heat-exchange-tube group 43A in communication with the second intermediate header portion 68; changes its course and flows upward through the refrigerant channels 43a; and

enters the second intermediate header portion 68 of the first header tank 41. Subsequently, the CO_2 flows through the refrigerant passage holes 59 of the flat walls 48a of the partition member 48B in the left-hand tank formation member 46B into the third intermediate header portion 69; dividedly flows into the refrigerant channels 43a of all the heat exchange tubes 43 of the rear heat-exchange-tube group 43A in communication with the third intermediate header portion 69; changes its course and flows downward through the refrigerant channels 43a and enters the fourth intermediate header portion 70 of the second header tank 42. Then, the CO_2 in the fourth intermediate header portion 70 flows rightward through the refrigerant channels 55; dividedly flows into the refrigerant channels 43a of all the heat exchange tubes 43 of the rear heat-exchange-tube group 43A in communication with the outlet header portion 55; changes its course and flows upward through the refrigerant channels 43a; and enters the outlet header portion 66 of the first header tank 41. The CO_2 thereafter flows through the refrigerant channels 55 and flows out of the evaporator 40 via the refrigerant outflow channel 63 of the refrigerant inlet-outlet member 49. While flowing through the refrigerant channels 43a of the heat exchange tubes 43, the CO_2 is subjected to heat exchange with the air flowing through the air-passing clearances in the direction of arrow X shown in FIGS. 13 and 20 and flows out from the evaporator 40 in a vapor phase.

Although CO_2 is used as a supercritical refrigerant of a

supercritical refrigeration cycle in the above-described embodiments, the refrigerant is not limited thereto, but ethylene, ethane, nitrogen oxide, or the like is alternatively used.

FIGS. 21 to 27 show modified embodiments of a heat exchange tube for use in the above-described gas cooler 1 and evaporator 40. In the following description, the upper, lower, left-hand, and right-hand sides of FIGS. 21 to 27 will be referred to as "upper," "lower," "left," and "right," respectively.

A heat exchange tube 160 shown in FIGS. 21 and 22 includes mutually opposed flat upper and lower walls 161, 162 (a pair of flat walls); left and right side walls 163, 164 that extend over left and right side ends, respectively, of the upper and lower walls 161, 162; and a plurality of reinforcement walls 165 that are provided at predetermined intervals between the left and right side walls 163, 164 and extend longitudinally and between the upper and lower walls 161, 162. By virtue of this structure, the heat exchange tube 160 internally has a plurality of refrigerant channels 166 arranged in the width direction thereof. The reinforcement walls 165 serve as partition walls between adjacent refrigerant channels 166. The width of each refrigerant channel 166 remains unchanged along the entire height of the refrigerant channel 166.

The left side wall 163 has a dual structure and includes an outer side-wall-forming elongated projection 167

that is integrally formed with the left side end of the upper wall 161 in a downward raised condition and extends along the entire height of the heat exchange tube 160; an inner side-wall-forming elongated projection 168 that is located inside the outer side-wall-forming elongated projection 167 and is integrally formed with the upper wall 161 in a downward raised condition; and an inner side-wall-forming elongated projection 169 that is integrally formed with the left side end of the lower wall 162 in an upward raised condition. The outer side-wall-forming elongated projection 167 is brazed to the two inner side-wall-forming elongated projections 168, 169 and the lower wall 162 while a lower end portion thereof is engaged with a left side edge portion of the lower surface of the lower wall 162. The two inner side-wall-forming elongated projections 168, 169 are brazed together while butting against each other. A right side wall 164 is integrally formed with the upper and lower walls 161, 162. A projection 169a is integrally formed on the tip end face of the inner side-wall-forming projection 169 of the lower wall 162 and extends in the longitudinal direction of the inner side-wall-forming projection 169 along the entire length thereof. A groove 168a is formed on the tip end face of the inner side-wall-forming elongated projection 168 of the upper wall 161 and extends in the longitudinal direction of the inner side-wall-forming elongated projection 168 along the entire length thereof. The projection 169a is press-fitted into the groove 168a.

Each of the reinforcement walls 165 is formed such that a reinforcement-wall-forming elongated projection 170, which is integrally formed with the upper wall 161 in a downward raised condition, and a reinforcement-wall-forming elongated projection 171, which is integrally formed with the lower wall 162 in an upward raised condition, are brazed together while butting against each other.

The heat exchange tube 160 is manufactured by use of a tube-forming metal sheet 175 as shown in FIG. 23(a). The tube-forming metal sheet 175 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. The tube-forming metal sheet 175 includes a flat upper-wall-forming portion 176 (flat-wall-forming portion); a lower-wall-forming portion 177 (flat-wall-forming portion); a connection portion 178 connecting the upper-wall-forming portion 176 and the lower-wall-forming portion 177 and adapted to form the right side wall 164; the inner side-wall-forming elongated projections 168, 169, which are integrally formed with the side ends of the upper-wall-forming and lower-wall-forming portions 176, 177 opposite the connection portion 178 in an upward raised condition and which are adapted to form an inner portion of the side wall 163; an outer side-wall-forming-elongated-projection forming portion 179, which extends in the left-right direction (rightward) from the side end (right side end) of the upper-wall-forming portion 176 opposite the connection portion 178; and a plurality of reinforcement-wall-forming elongated

projections 170, 171, which are integrally formed with the upper-wall-forming and lower-wall-forming portions 176, 177 in an upward raised condition and which are arranged at predetermined intervals in the left-right direction. The reinforcement-wall-forming elongated projections 170 of the upper-wall-forming portion 176 and the reinforcement-wall-forming elongated projections 171 of the lower-wall-forming portion 177 are located symmetrically with respect to the centerline of the width direction of the tube-forming metal sheet 175. The projection 169a is formed on the tip end face of the inner side-wall-forming elongated projection 169 of the lower wall 162, and the groove 168a is formed on the tip end face of the inner side-wall-forming elongated projection 168 of the upper wall 161. The two inner side-wall-forming elongated projections 168, 169 and all the reinforcement-wall-forming elongated projections 170, 171 have the same height. The vertical thickness of the connection portion 178 is greater than the thickness of the upper-wall-forming and lower-wall-forming portions 176, 177. The top end face of the connection portion 178 is substantially flush with the top end faces of the inner side-wall-forming elongated projections 168, 169 and the reinforcement-wall-forming elongated projections 170, 171.

The inner side-wall-forming elongated projections 168, 169 and the reinforcement-wall-forming elongated projections 170, 171 are integrally formed 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 168, 169, on those of the reinforcement-wall-forming elongated projections 170, 171, and on the vertically opposite surfaces of the upper-wall-forming and lower-wall-forming portions 176, 177. The brazing material layer on the tip end faces of the inner side-wall-forming elongated projections 168, 169 and the reinforcement-wall-forming elongated projections 170, 171 is greater in thickness than the brazing material layer on other portions of the tube-forming metal sheet 175.

The tube-forming metal sheet 175 is gradually folded at left and right side edges of the connection portion 178 by a roll forming process (see FIG. 23(b)) until a hairpin form is assumed. The inner side-wall-forming elongated projections 168, 169 are caused to butt against each other; the reinforcement-wall-forming elongated projections 170, 171 are caused to butt against each other; and the projection 169a is caused to be press-fitted into the groove 168a.

Next, the outer side-wall-forming-elongated-projection forming portion 179 is folded along the outer surfaces of the inner side-wall-forming elongated projections 168, 169, and a tip end portion thereof is deformed so as to be engaged with the lower-wall-forming portion 177, thereby yielding a folded member 180 (see FIG. 23(c)).

Subsequently, the folded member 180 is heated at a predetermined temperature so as to braze together tip end

portions of the inner side-wall-forming elongated projections 168, 169; to braze together tip end portions of the reinforcement-wall-forming elongated projections 170, 171; and to braze the outer side-wall-forming-elongated-projection forming portion 179 to the inner side-wall-forming elongated projections 168, 169 and to the lower-wall-forming portion 177. Thus is manufactured the heat exchange tube 160. The heat exchange tubes 160 are manufactured in the course of manufacture of the gas cooler 1 or the evaporator 40.

In the case of a heat exchange tube 185 shown in FIG. 24, a projection 186 extending along the entire length thereof and a groove 187 extending along the entire length thereof are alternately formed on the tip end faces of all the reinforcement-wall-forming elongated projections 170 of the upper wall 161. A groove 188 into which the corresponding projection 186 of the reinforcement-wall-forming elongated projection 170 of the upper wall 161 is fitted and a projection 186 to be fitted into the corresponding groove 187 of the reinforcement-wall-forming elongated projection 170 of the upper wall 161 are alternately formed on the tip end faces of all the reinforcement-wall-forming elongated projections 171 of the lower wall 162, along the entire length thereof. Other structural features are similar to those of the heat exchange tube 160 shown in FIGS. 21 and 22. The heat exchange tube 185 is manufactured in a manner similar to that for the heat exchange tube 160 shown in FIGS. 21 and 22.

In a heat exchange tube 190 shown in FIGS. 25 and 26, the reinforcement wall 165 formed such that a reinforcement-wall-forming elongated projection 191 formed integrally with the upper wall 161 and in a downward raised condition is brazed to the lower wall 162, and the reinforcement wall 165 formed such that a reinforcement-wall-forming elongated projection 192 formed integrally with the lower wall 162 and in an upward raised condition is brazed to the upper wall 161, are alternately provided in the left-right direction; the upper and lower walls 161, 162 have projections 193 extending along the entire length thereof and formed integrally at portions thereof that abut the corresponding reinforcement-wall-forming elongated projections 192, 191; recesses 194 are formed on the corresponding tip end faces of the projections 193 so as to allow corresponding tip end portions of the reinforcement-wall-forming elongated projections 191, 192 to be fitted thereinto; and the tip end portions of the reinforcement-wall-forming elongated projections 191, 192 are brazed to the corresponding projections 193 while being fitted into the recesses 194 of the projections 193. The thickness of the projection 193 as measured in the left-right direction is slightly greater than that of the reinforcement-wall-forming elongated projections 191, 192. Other structural features of the heat exchange tube 190 are similar to those of the heat exchange tube 160 shown in FIGS. 21 and 22.

The heat exchange tube 190 is manufactured by use of a

tube-forming metal sheet 195 as shown in FIG. 27(a). The tube-forming metal sheet 195 is formed from an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. The tube-forming metal sheet 195 includes a plurality of reinforcement-wall-forming elongated projections 191, 192, which are integrally formed with the upper-wall-forming and lower-wall-forming portions 176, 177 in an upward raised condition and which are arranged at predetermined intervals in the left-right direction. The reinforcement-wall-forming elongated projections 191 of the upper-wall-forming portion 176 and the reinforcement-wall-forming elongated projections 192 of the lower-wall-forming portion 177 are located asymmetrically with respect to the centerline of the width direction of the tube-forming metal sheet 195. The reinforcement-wall-forming elongated projections 191, 192 have the same height, which is about two times the height of the inner side-wall-forming elongated projections 168, 169. The projections 193 are integrally formed, in such a manner as to extend along the entire length of the upper-wall-forming and lower-wall-forming portions 176, 177, at those portions of the upper-wall-forming and lower-wall-forming portions 176, 177 which the corresponding reinforcement-wall-forming elongated projections 192, 191 of the lower-wall-forming and upper-wall-forming portions 177, 176 abut. The recesses 194 are formed on the corresponding tip end faces of the projections 193 so as to allow corresponding tip end portions of the reinforcement-wall-

forming elongated projections 191, 192 to be fitted thereinto. Other structural features of the tube-forming metal sheet 195 are similar to those of the tube-forming metal sheet 175 shown in FIG. 23.

The tube-forming metal sheet 195 is gradually folded at left and right side edges of the connection portion 178 by a roll forming process (see FIG. 27(b)) until a hairpin form is assumed. The inner side-wall-forming elongated projections 168, 169 are caused to butt against each other, and the projection 169a is caused to be press-fitted into the groove 168a. Also, tip end portions of the reinforcement-wall-forming elongated projections 191 of the upper-wall-forming portion 176 are caused to be fitted into the corresponding grooves 194 of the projections 193 of the lower-wall-forming portion 177, and tip end portions of the reinforcement-wall-forming elongated projections 192 of the lower-wall-forming portion 177 are caused to be fitted into the corresponding grooves 194 of the projections 193 of the upper-wall-forming portion 176.

Next, the outer side-wall-forming-elongated-projection forming portion 179 is folded along the outer surfaces of the inner side-wall-forming elongated projections 168, 169, and a tip end portion thereof is deformed so as to be engaged with the lower-wall-forming portion 177, thereby yielding a folded member 196 (see FIG. 27(c)).

Subsequently, the folded member 196 is heated at a predetermined temperature so as to braze together tip end

portions of the inner side-wall-forming elongated projections 168, 169; to braze tip end portions of the reinforcement-wall-forming elongated projections 191, 192 to the corresponding projections 193; and to braze the outer side-wall-forming-elongated-projection forming portion 179 to the inner side-wall-forming elongated projections 168, 169 and to the lower-wall-forming portion 177. Thus is manufactured the heat exchange tube 190. The heat exchange tubes 190 are manufactured in the course of manufacture of the gas cooler 1 or the evaporator 40.

INDUSTRIAL APPLICABILITY

The heat exchanger of the present invention is favorably used as a gas cooler or an evaporator of a supercritical refrigeration cycle in which a CO_2 (carbon dioxide) refrigerant or a like supercritical refrigerant is used.

CLAIMS

1. A heat exchanger comprising a pair of header tanks disposed apart from each other, and a plurality of heat exchange tubes disposed in parallel between the two header tanks and each having opposite end portions connected to the respective header tanks,

the two header tanks each comprising a hollow tank formation member, and a partition member disposed within and joined to the tank formation member and adapted to divide the interior of the tank formation member into a plurality of refrigerant channels extending in the longitudinal direction of the tank formation member and arranged in the front-rear direction.

2. A heat exchanger according to claim 1, wherein a plurality of tube insertion holes are formed in the tank formation members; a plurality of tube-end fit cutouts for partially receiving corresponding end portions of heat exchange tubes are formed on the partition members in such a manner as to align with the corresponding tube insertion holes; and the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the corresponding tube insertion holes of the tank formation members and are fitted into the corresponding tube-end fit cutouts of the partition members.

3. A heat exchanger according to claim 1, further comprising tube-connecting plates joined to corresponding outer surfaces

of the tank formation members, wherein a plurality of tube insertion holes are formed in the tube-connecting plates in such a manner as to align with the corresponding tube insertion holes of the tank formation members, and the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the tube insertion holes of the tube-connecting plates.

4. A heat exchanger according to claim 1, wherein the partition members assume the form of an elongated plate and are disposed such that the width direction thereof coincides with the height direction of hollow portions of the tank formation members.

5. A heat exchanger according to claim 1, wherein the partition members have a cross section resembling the letter U, and the partition members are disposed such that the width direction of a pair of opposed walls of each partition member coincides with the height direction of the hollow portions of the tank formation members and such that ends of the opposed walls face the tube insertion holes.

6. A heat exchanger according to claim 1, wherein the partition members assume the form of a corrugated plate comprising a plurality of flat portions in parallel with one another and a plurality of connection portions each connecting adjacent flat portions, and the width direction of the flat portions coincides with the height direction of the hollow portions of the tank formation members.

7. A heat exchanger according to claim 1, wherein a first

header tank of the paired header tanks comprises a plurality of tank formation members aligned with one another in a longitudinal direction thereof; a second header tank of the paired header tanks comprises tank formation members numbering one fewer than the tank formation members of the first header tank and is disposed so as to oppose two adjacent tank formation members of the first header tank; and a refrigerant entering one tank formation member of the first header tank flows through all the heat exchange tubes and the tank formation members of the second header tank and enters another tank formation member of the first header tank.

8. A heat exchanger according to claim 7, wherein the number of tank formation members of the first header tank is two; the two tank formation members are joined together via a separation plate so as to avoid communication between hollow portions thereof; and the number of tank formation members of the second header tank is one.

9. A heat exchanger according to claim 1, wherein the first header tank of the paired header tanks comprises two tank formation members aligned with each other in the longitudinal direction thereof; the second header tank of the paired header tanks is disposed so as to oppose the two tank formation members of the first header tank;

the tank formation members of the two header tanks each have a plurality of hole groups provided in a plurality of rows separated from one another in the front-rear direction, each hole group comprising a plurality of tube insertion

holes formed therein apart from one another in the longitudinal direction thereof; a partition member assuming the form of a corrugated plate comprising a plurality of flat portions in parallel with one another and a plurality of connection portions each connecting adjacent flat portions is disposed within each of the tank formation members of the two header tanks such that the width direction of the flat portions coincides with the height direction of a hollow portion of each of the tank formation members and such that at least one flat portion is located between tube insertion holes adjacent to each other in the front-rear direction of the tank formation member; a plurality of tube-end fit cutouts for partially receiving corresponding end portions of heat exchange tubes are formed on the partition members in such a manner as to align with the corresponding tube insertion holes; the heat exchange tubes are connected to the two header tanks such that end portions thereof are inserted through the corresponding tube insertion holes of the tank formation members and are fitted into the corresponding tube-end fit cutouts of the partition members; no tube-end fit cutouts are formed on the flat portion located between tube insertion holes adjacent to each other in the front-rear direction; and

refrigerant passage holes are formed in the flat portions of the partition member disposed within one of the two tank formation members of the first header tank.

10. 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 a refrigerant from the gas cooler and a refrigerant from the evaporator and in which a supercritical refrigerant is used, the gas cooler comprising a heat exchanger according to any one of claims 1 to 8.

11. 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 a refrigerant from the gas cooler and a refrigerant from the evaporator and in which a supercritical refrigerant is used, the evaporator comprising a heat exchanger according to any one of claims 1 to 6 and 9.

12. A vehicle having installed therein a supercritical refrigeration cycle according to claim 10 as a vehicular air conditioner.

13. A vehicle having installed therein a supercritical refrigeration cycle according to claim 11 as a vehicular air conditioner.

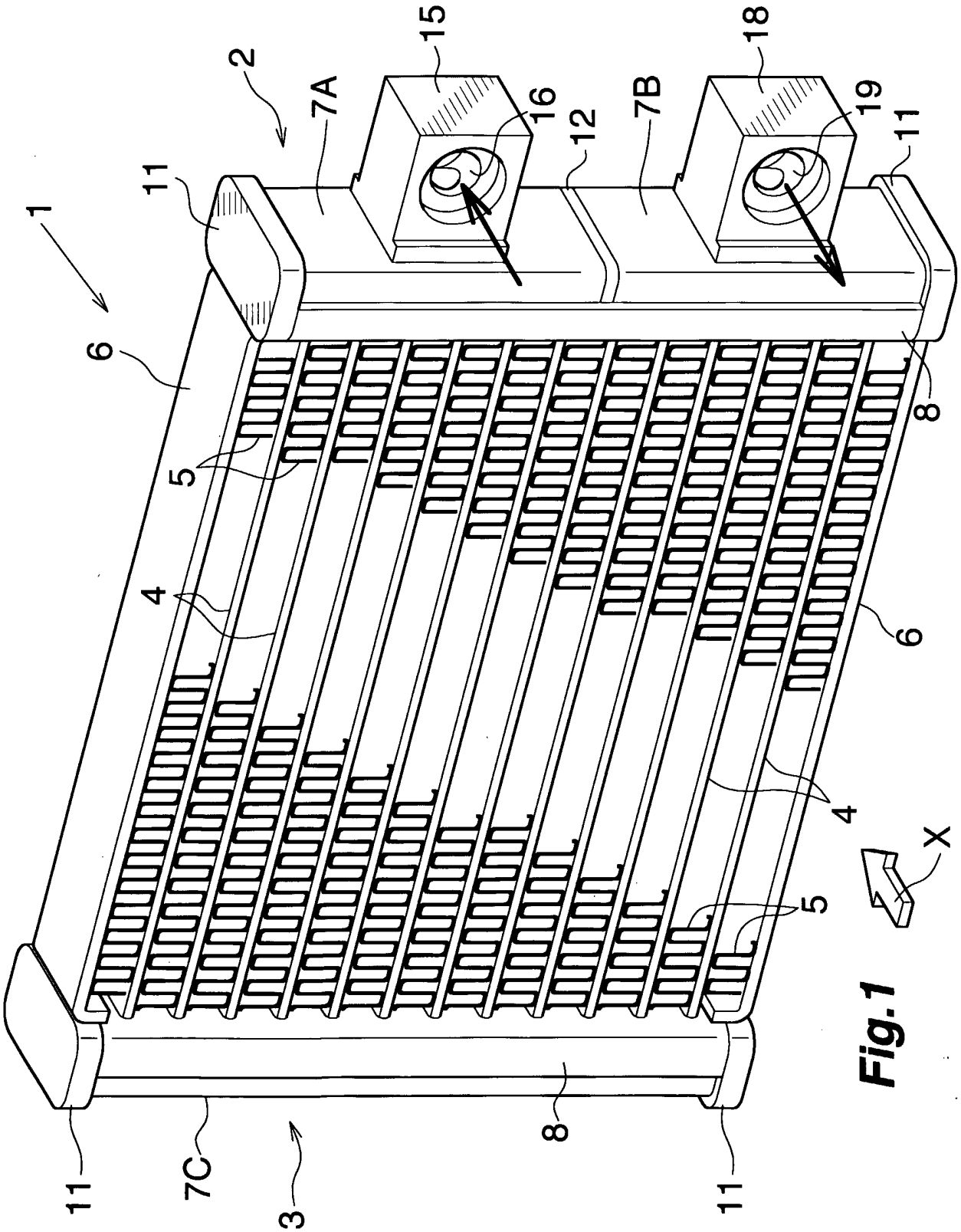


Fig.1

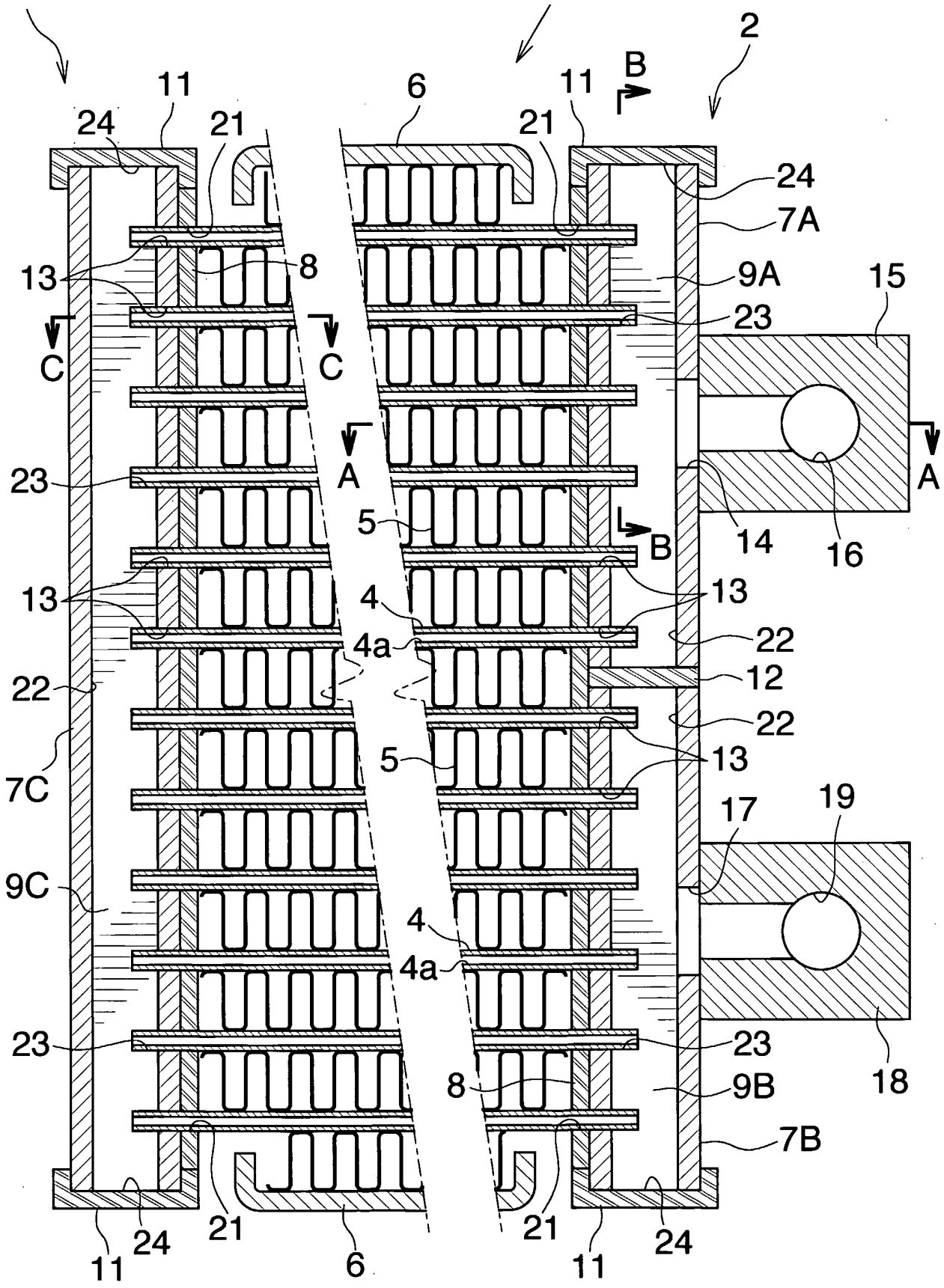

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Fig.2

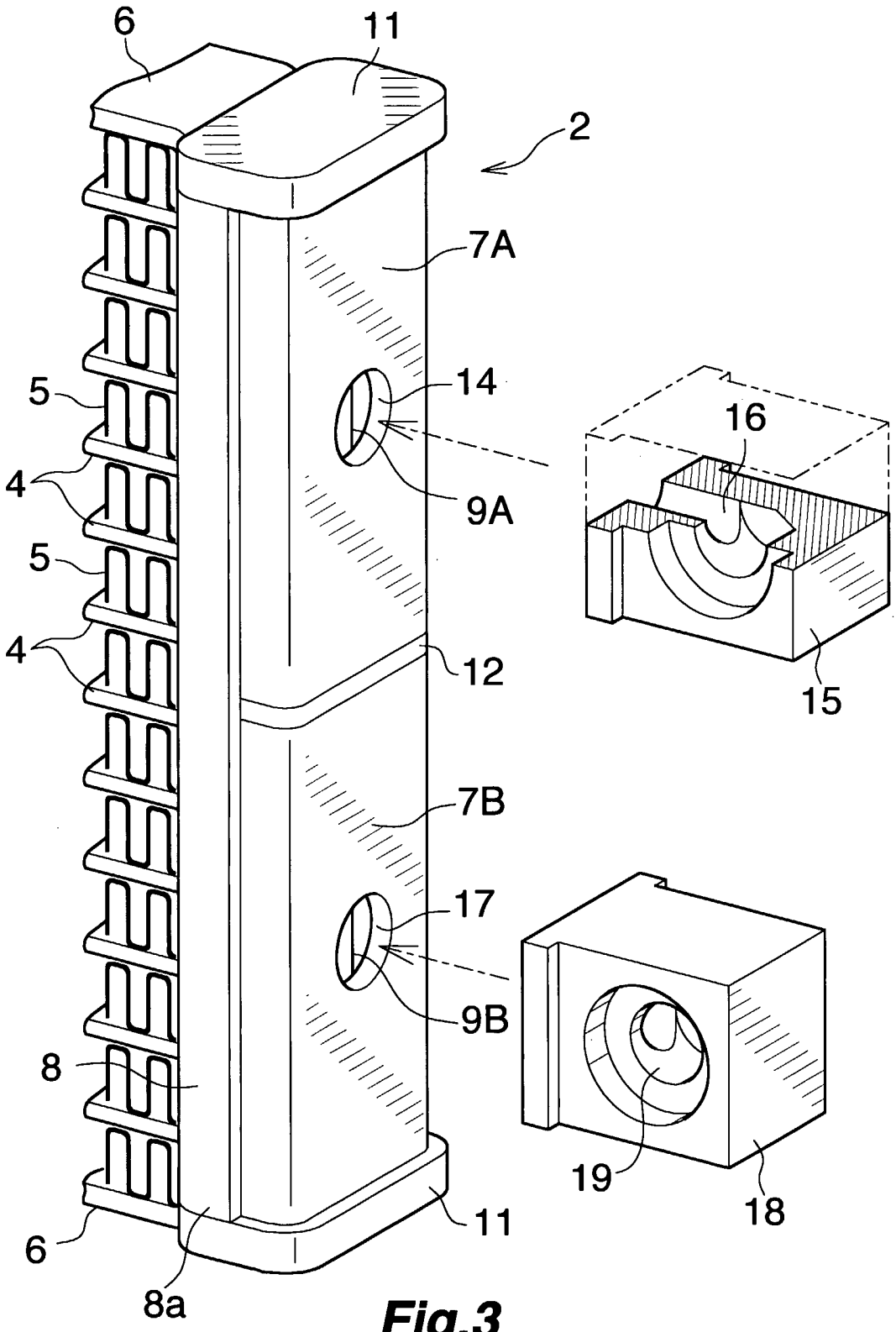


Fig.3

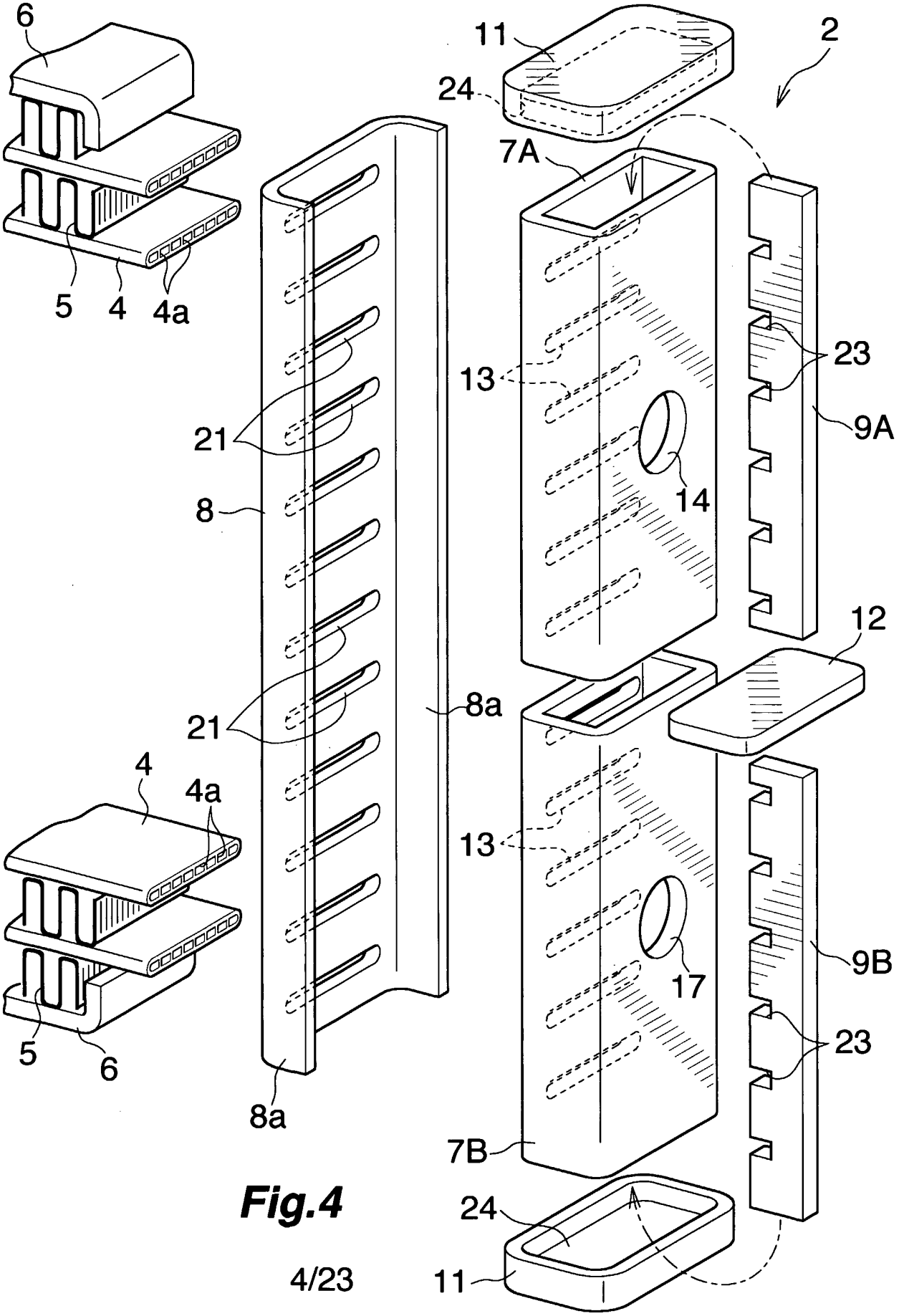

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9B
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Fig.4

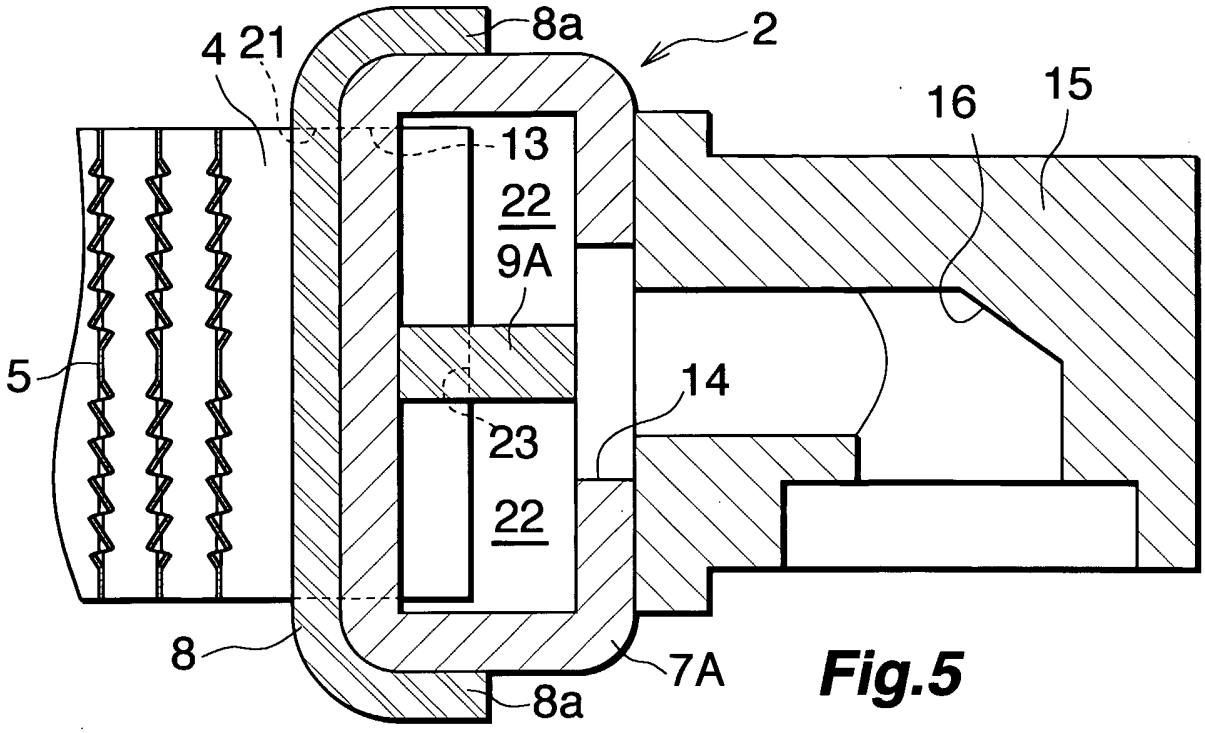

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Fig.5

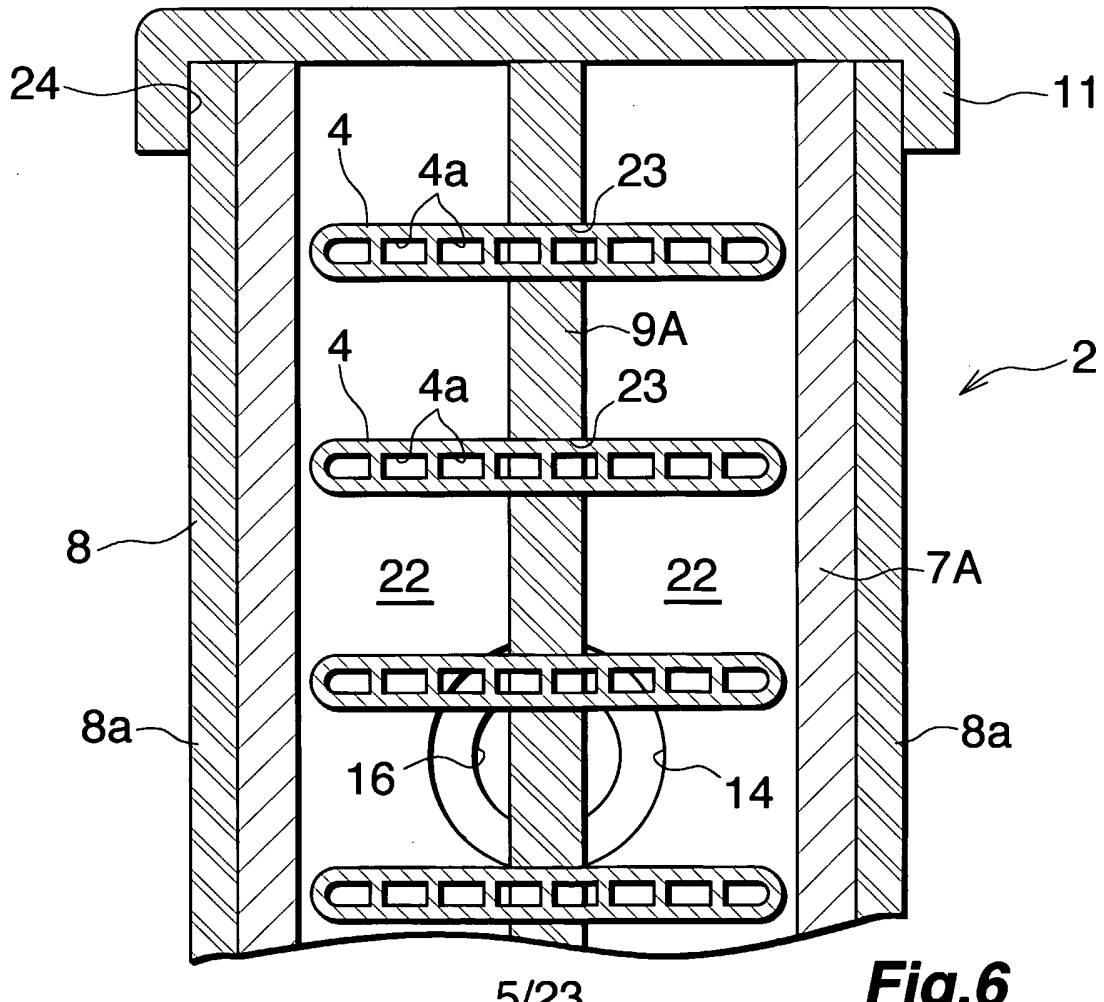

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Fig.6

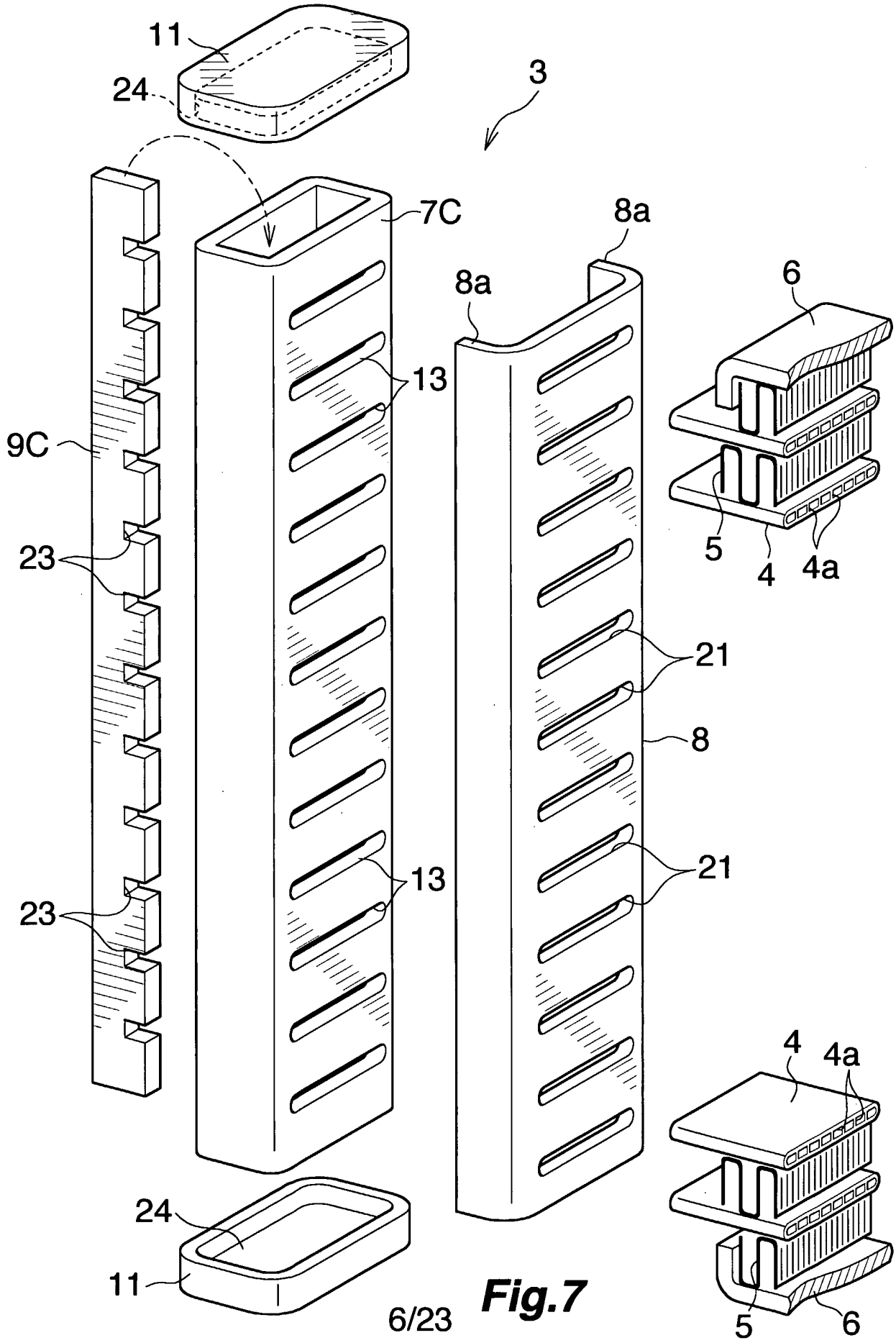


Fig.7

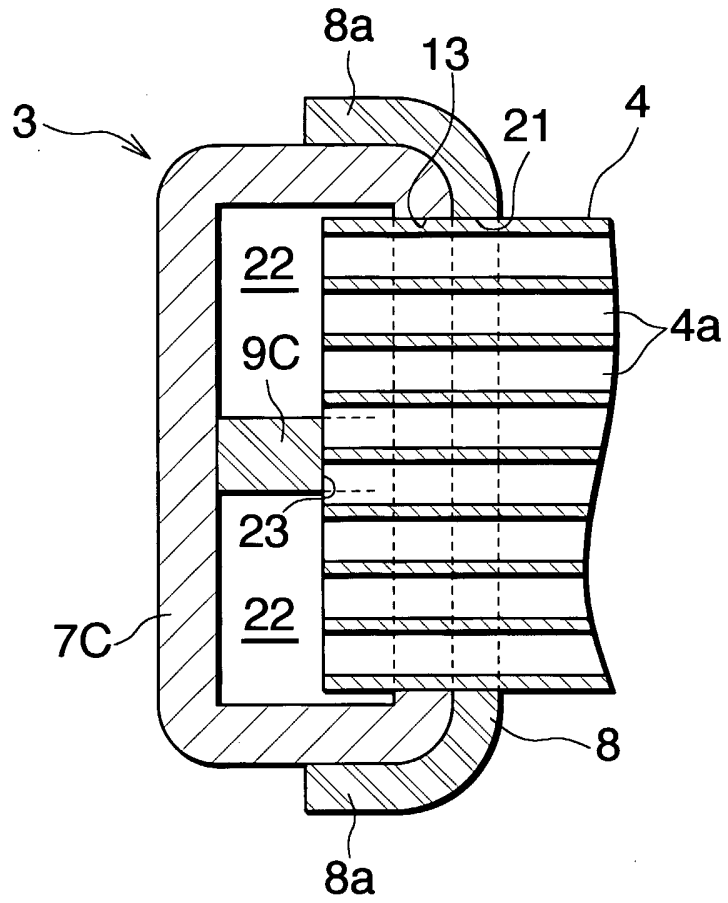


Fig.8

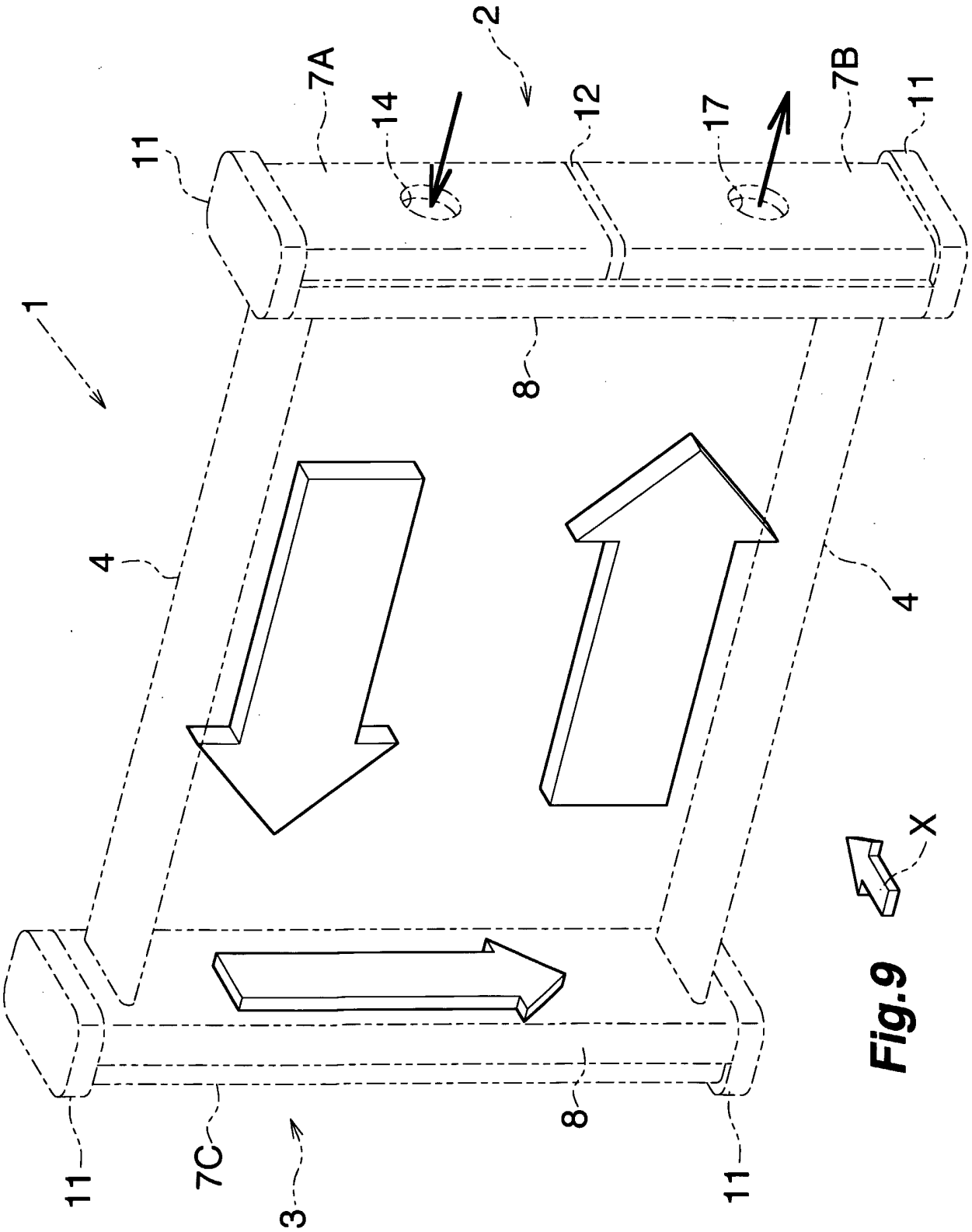


Fig.9

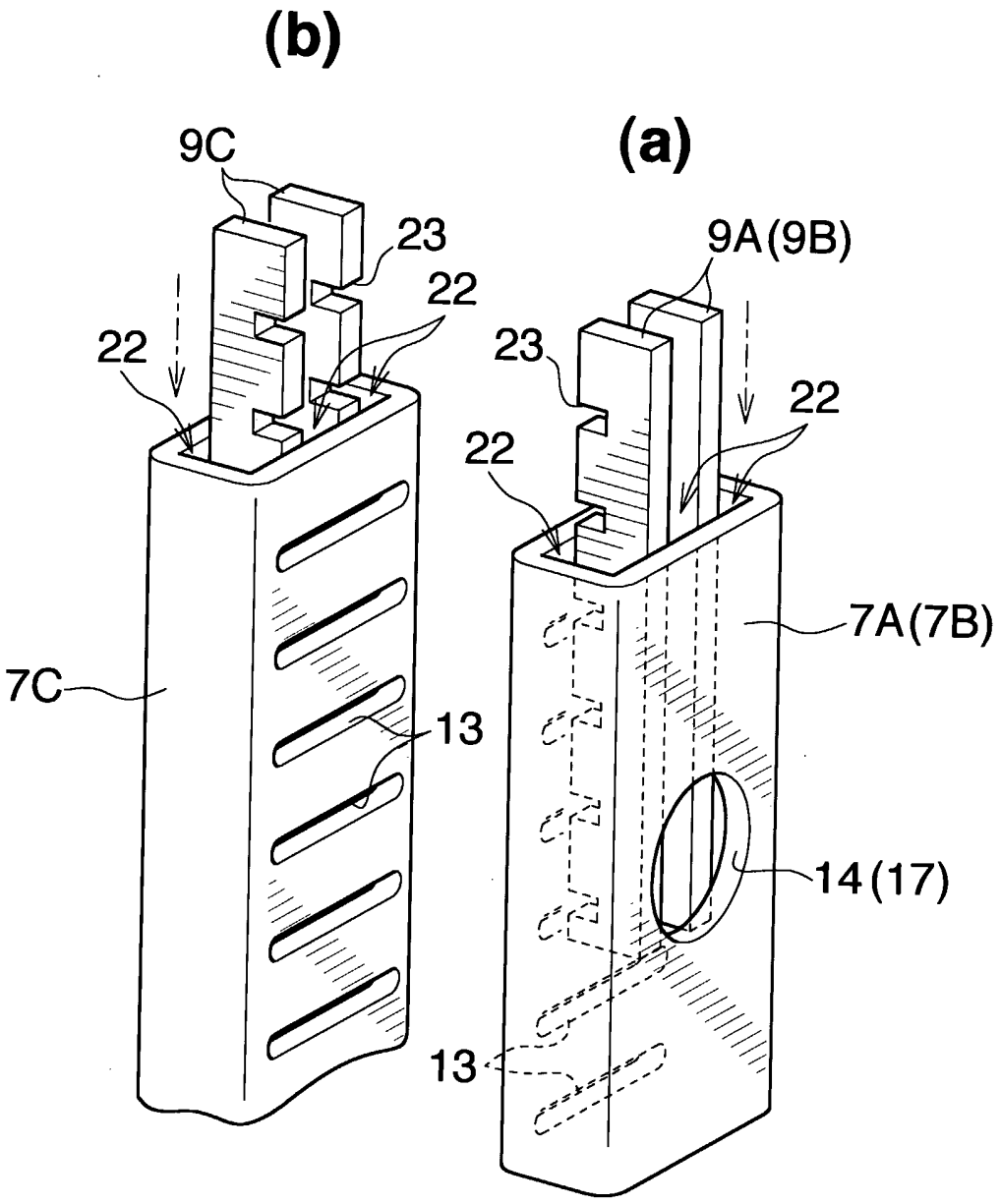


Fig.10

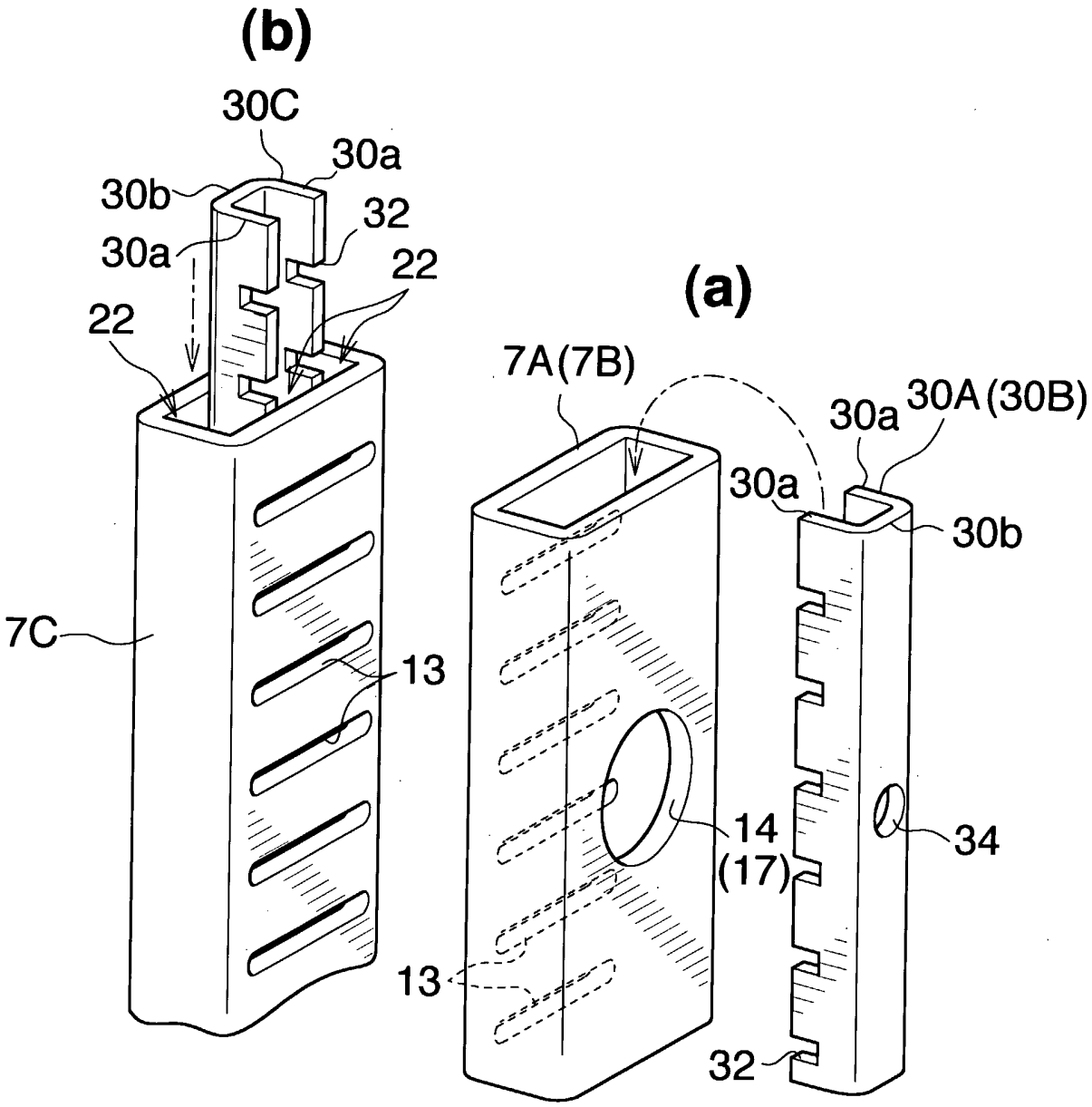

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30b
14
(17)
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13
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Fig.11

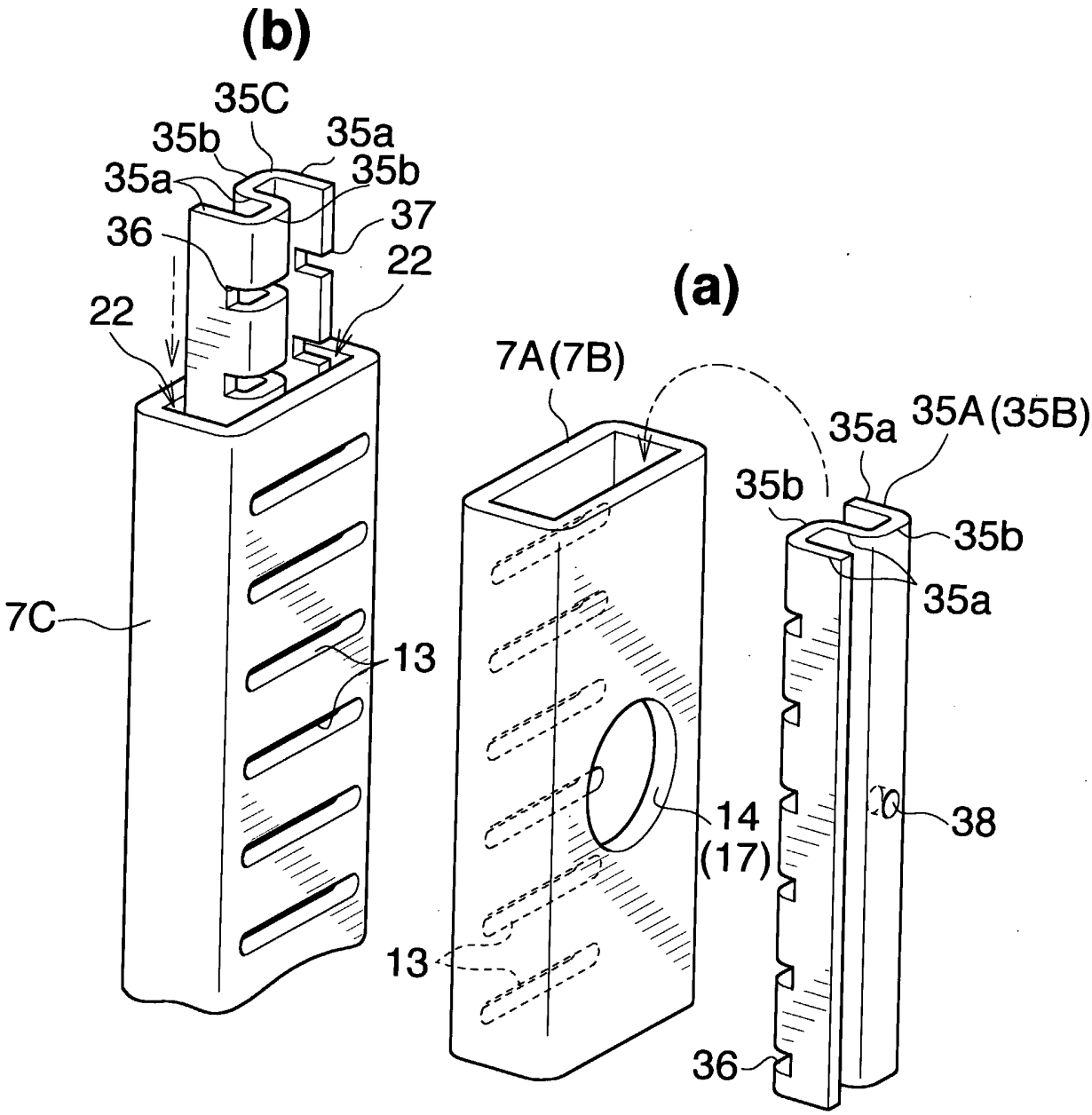

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(17)
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Fig.12

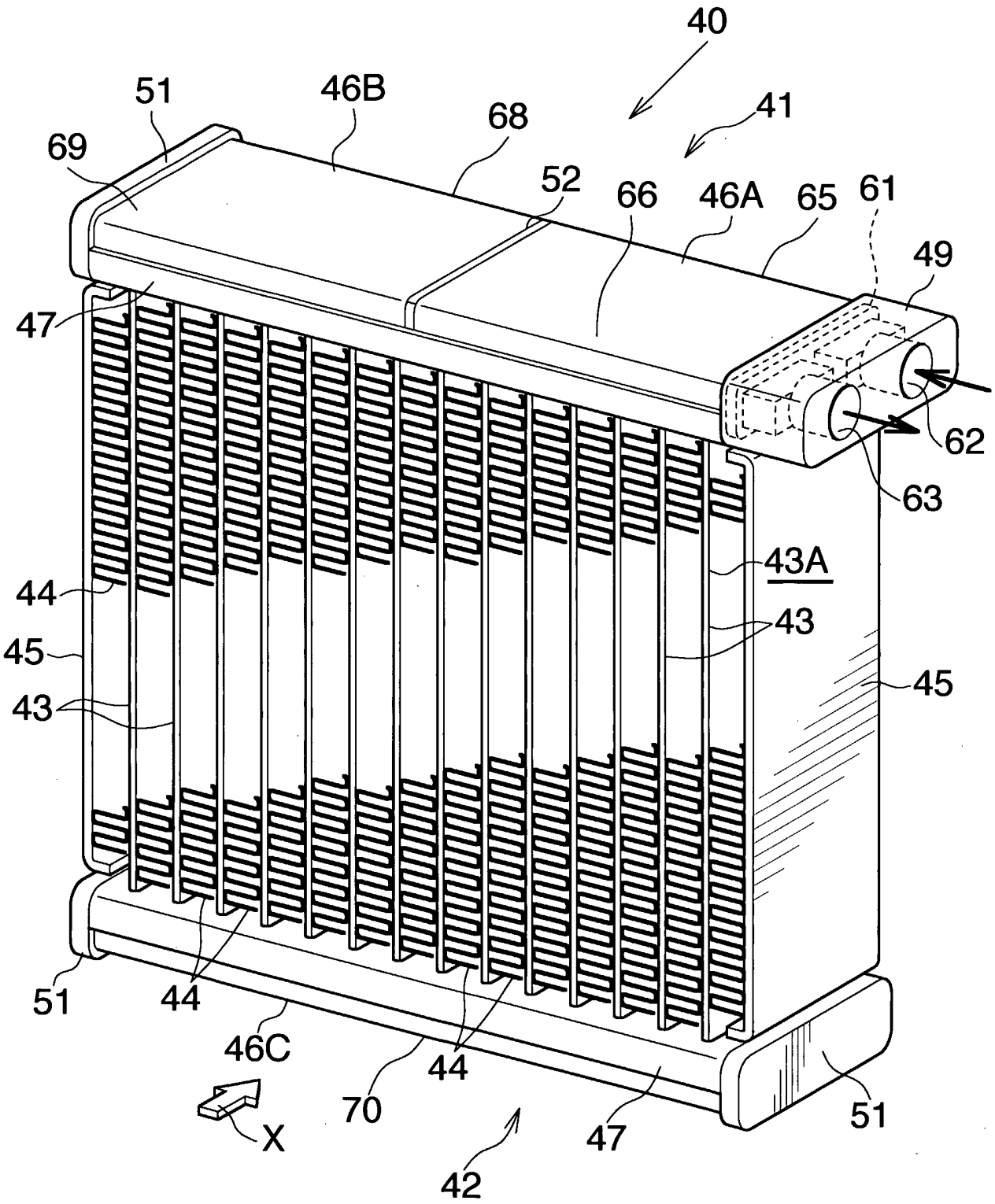

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Fig.13

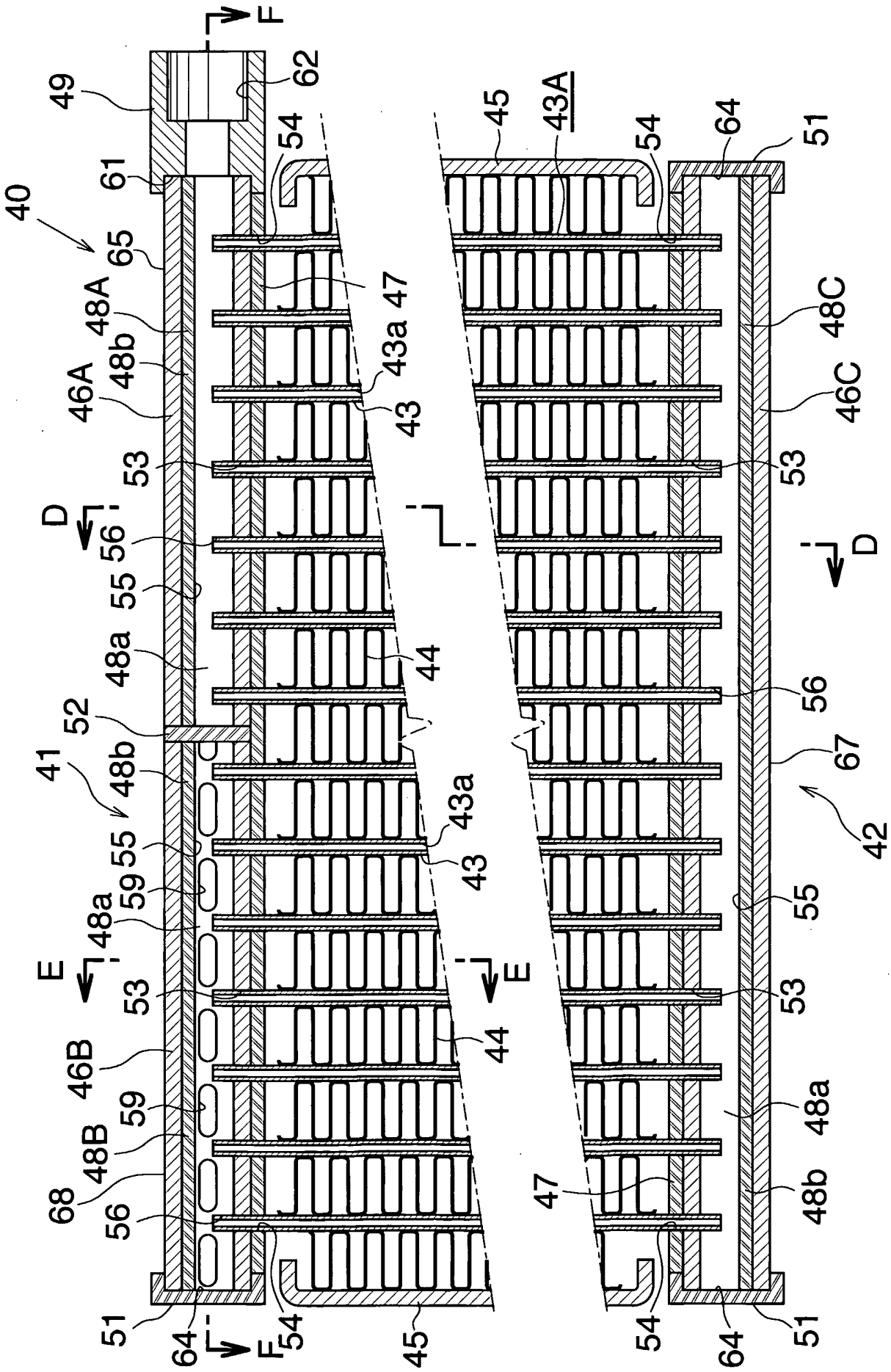

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Fig.14

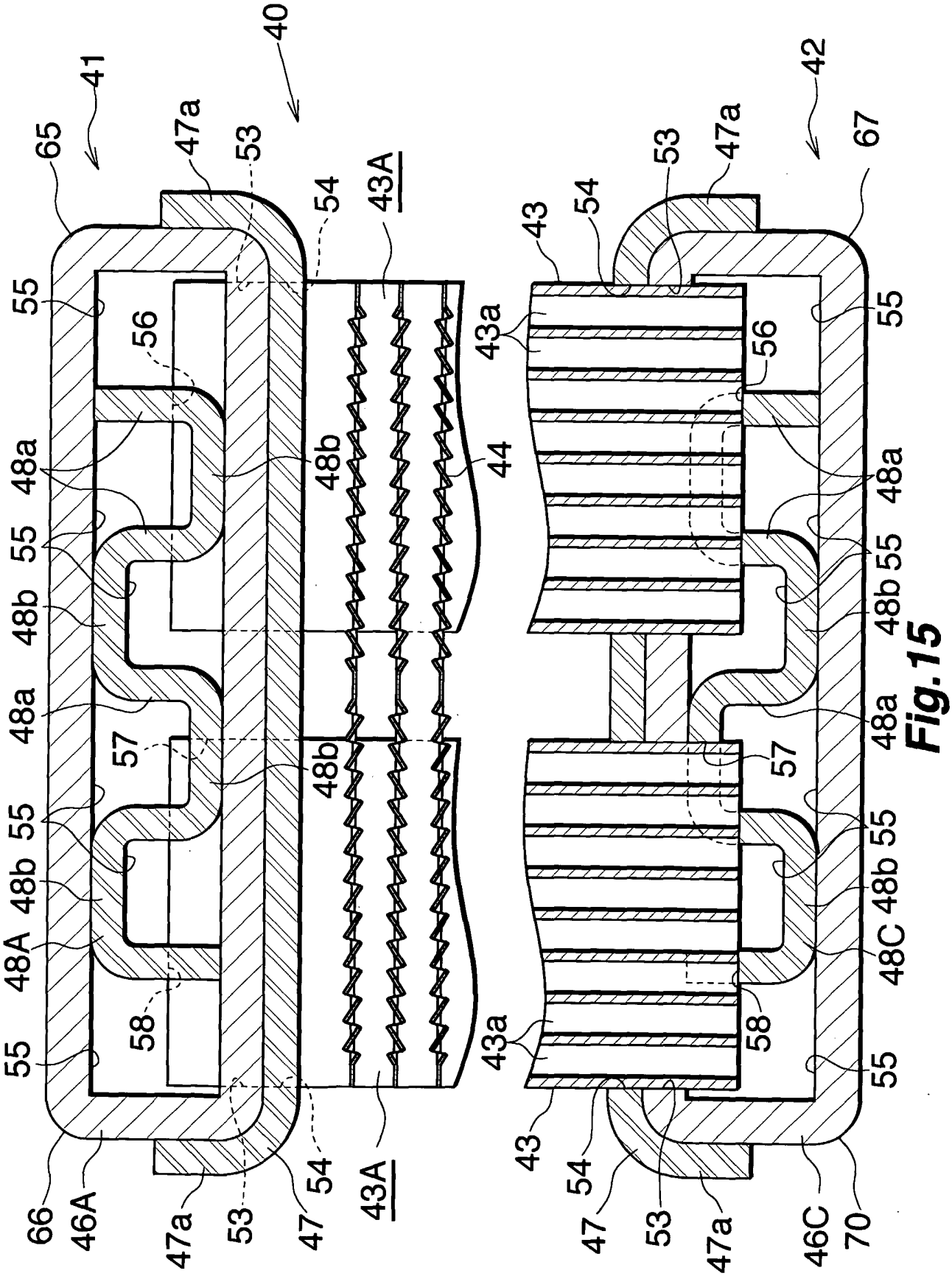

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Fig.15

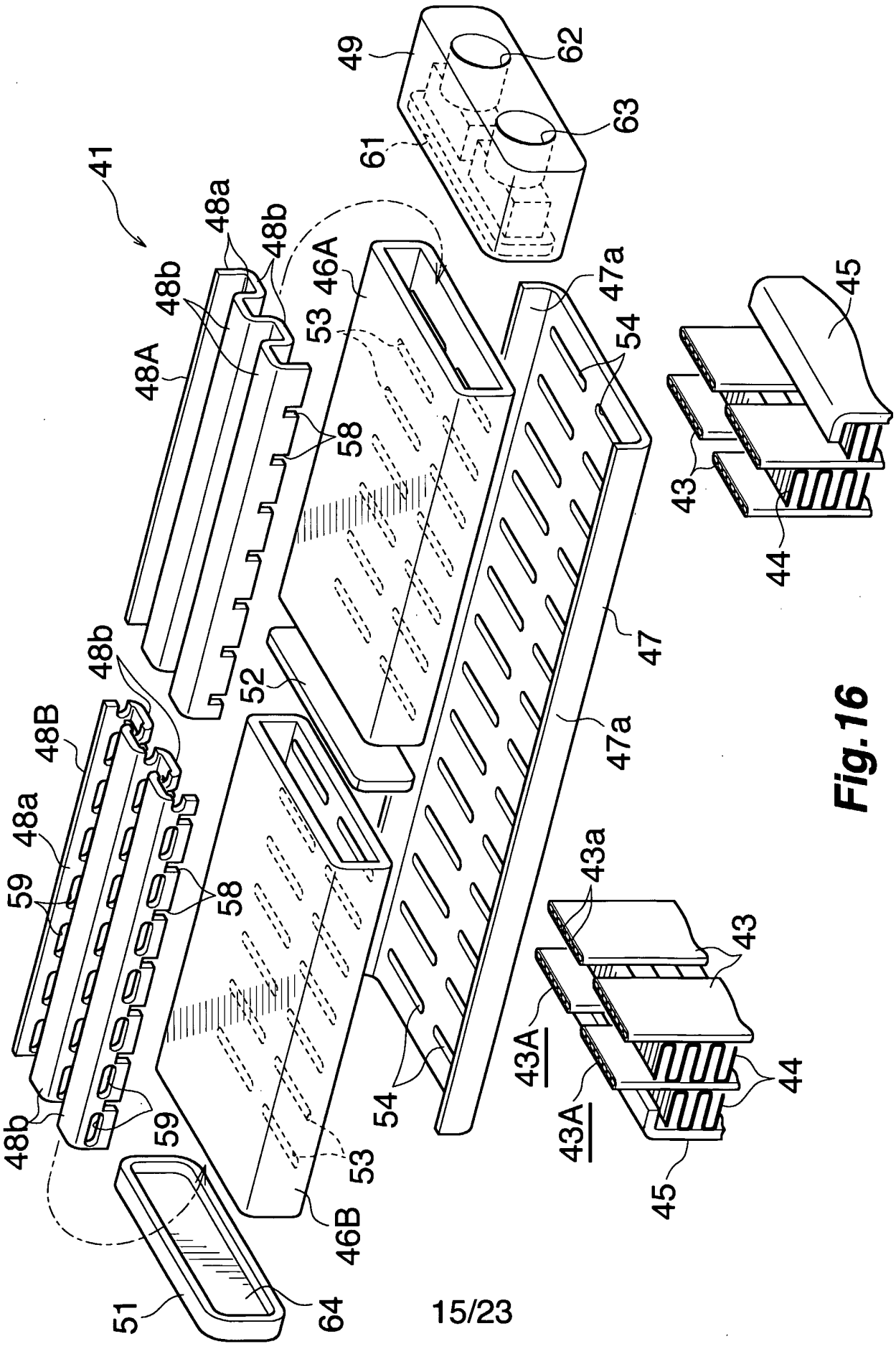

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Fig.16

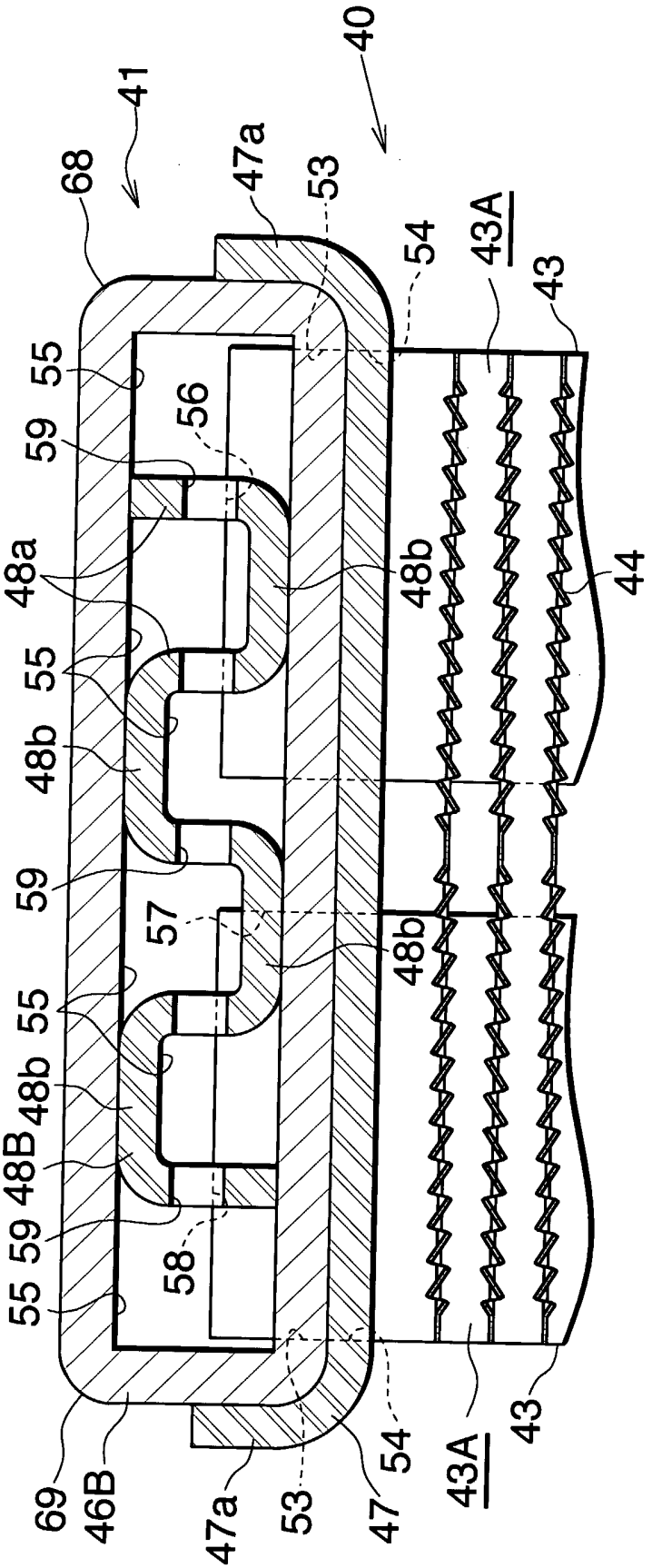

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Fig.17

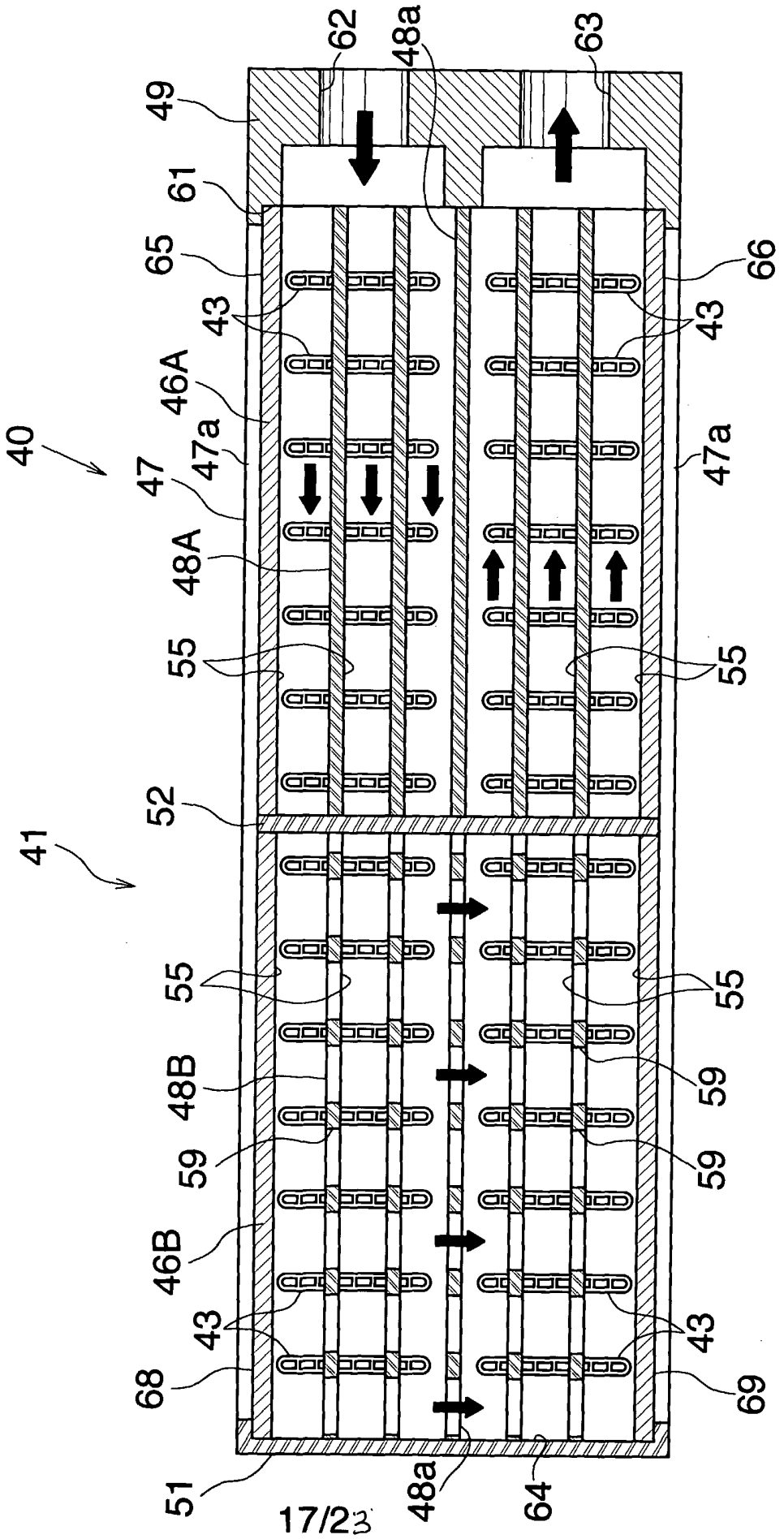

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Fig.18

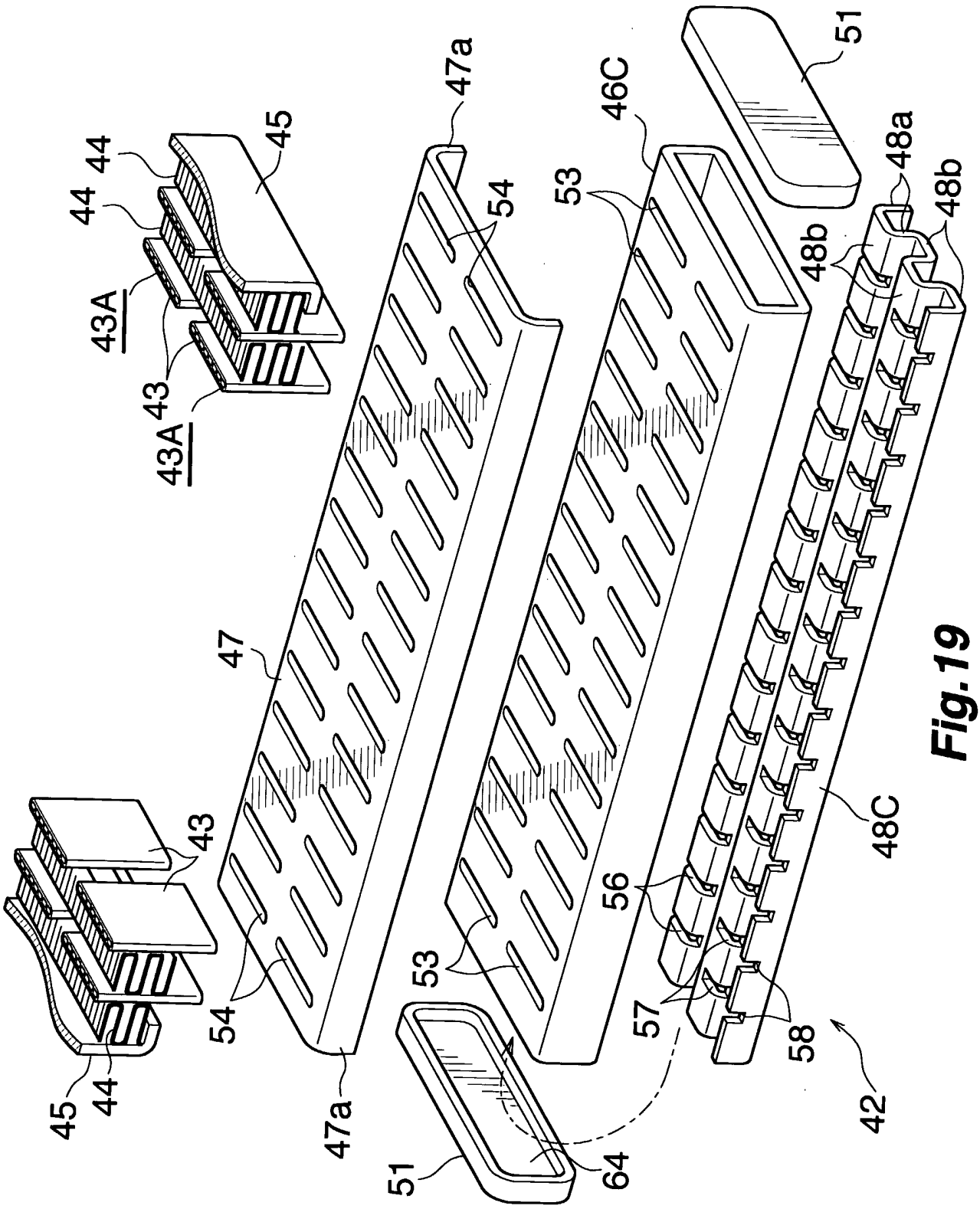

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Fig.19

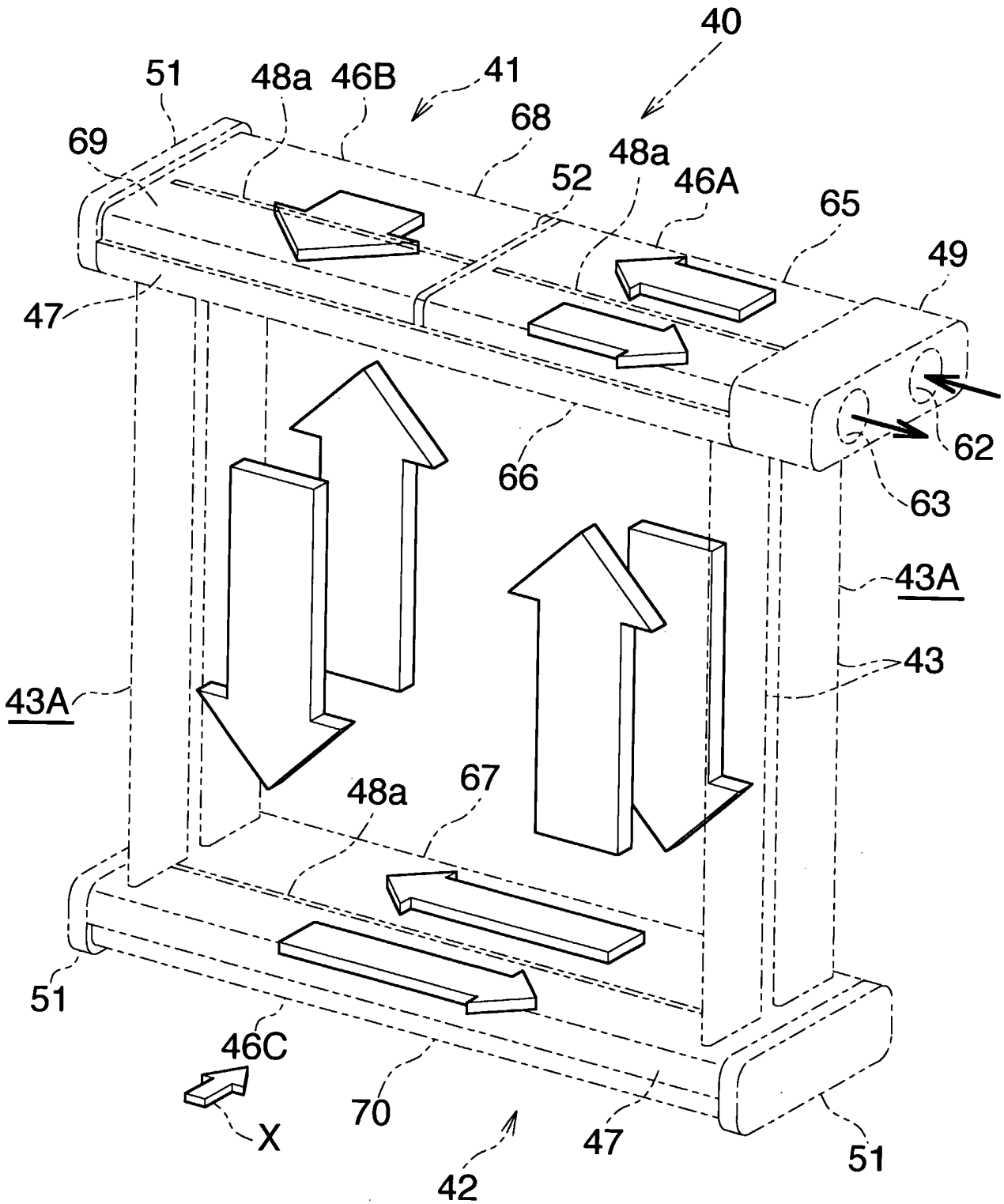

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Fig.20

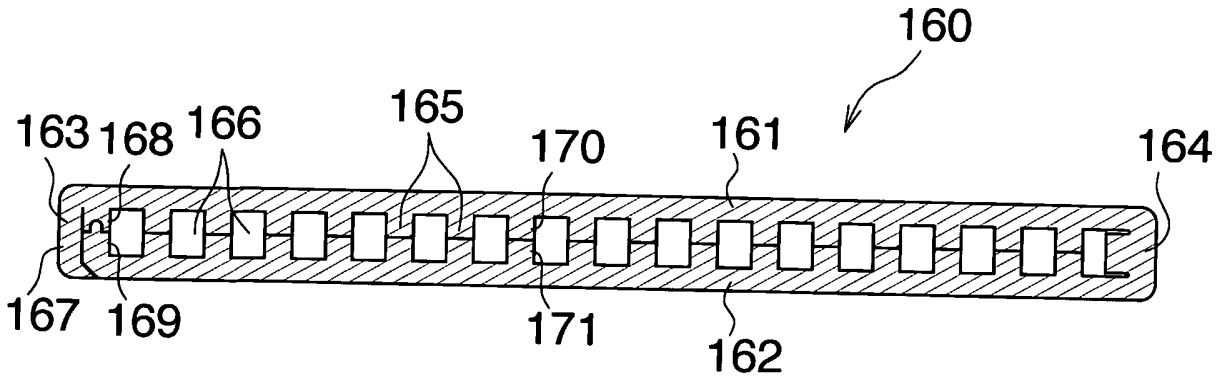

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Fig.21

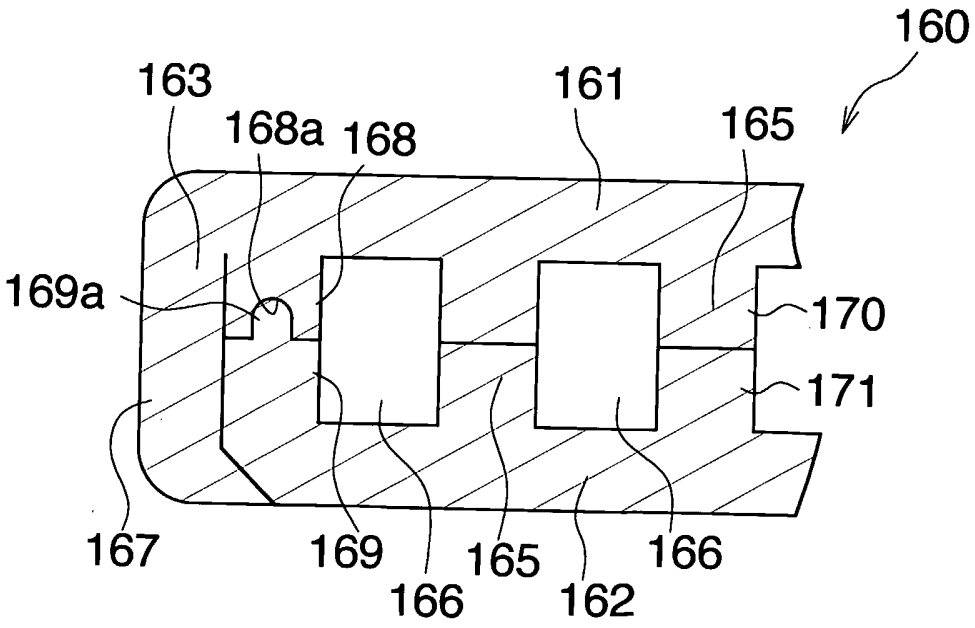

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Fig.22

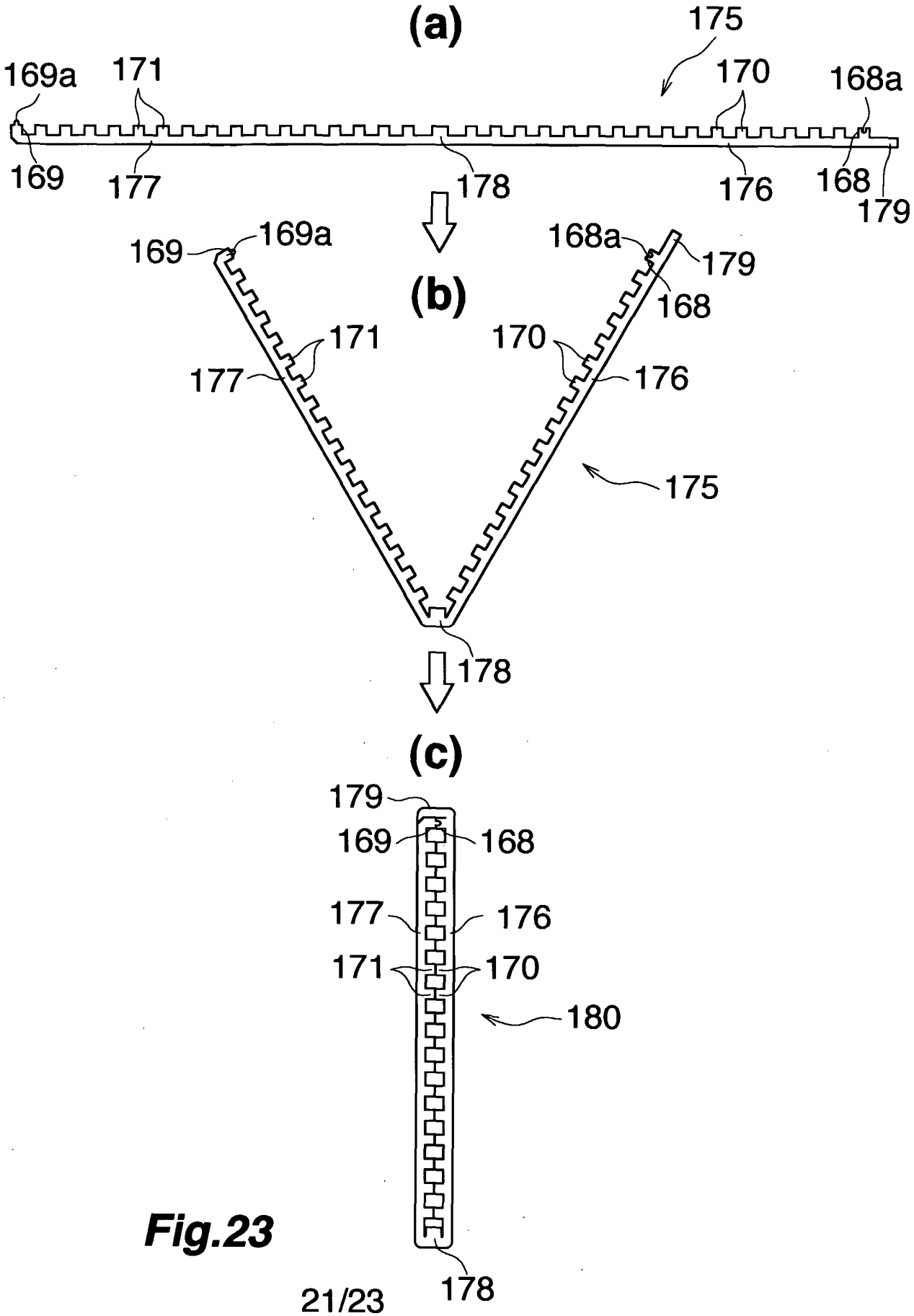

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Fig.23

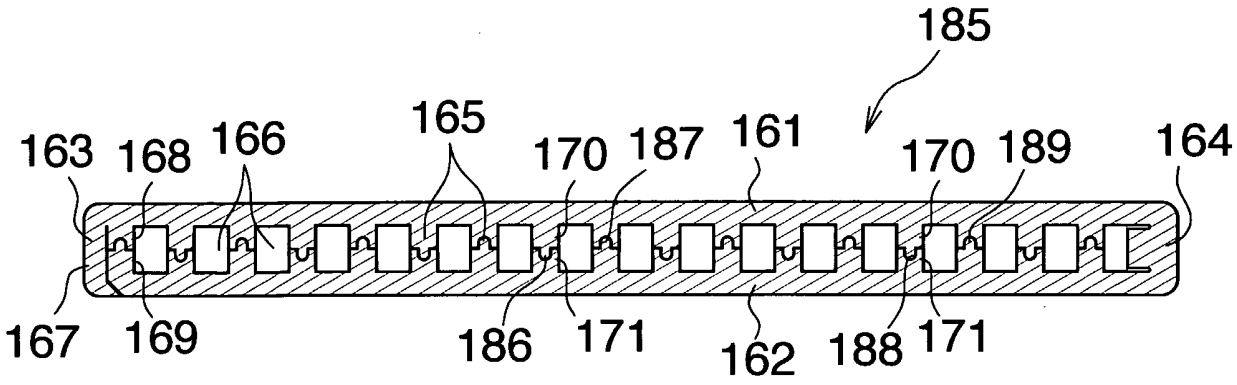


Fig.24

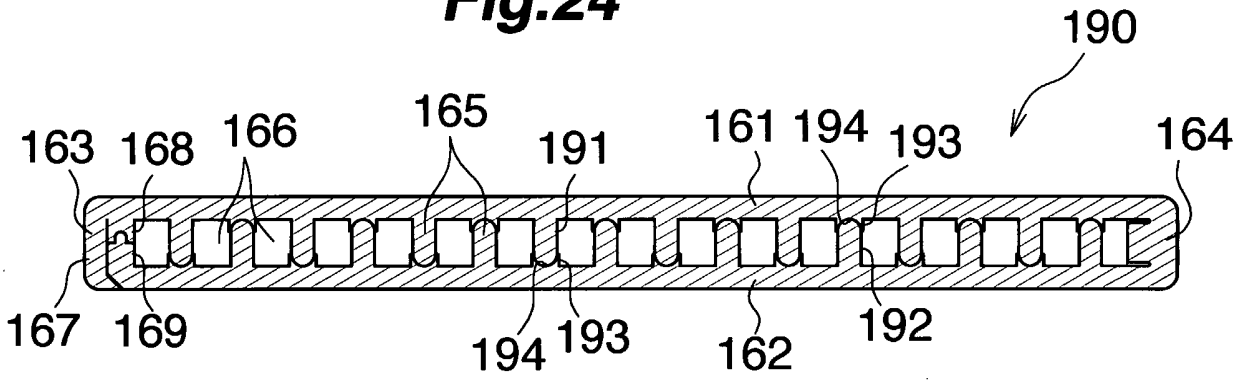


Fig.25

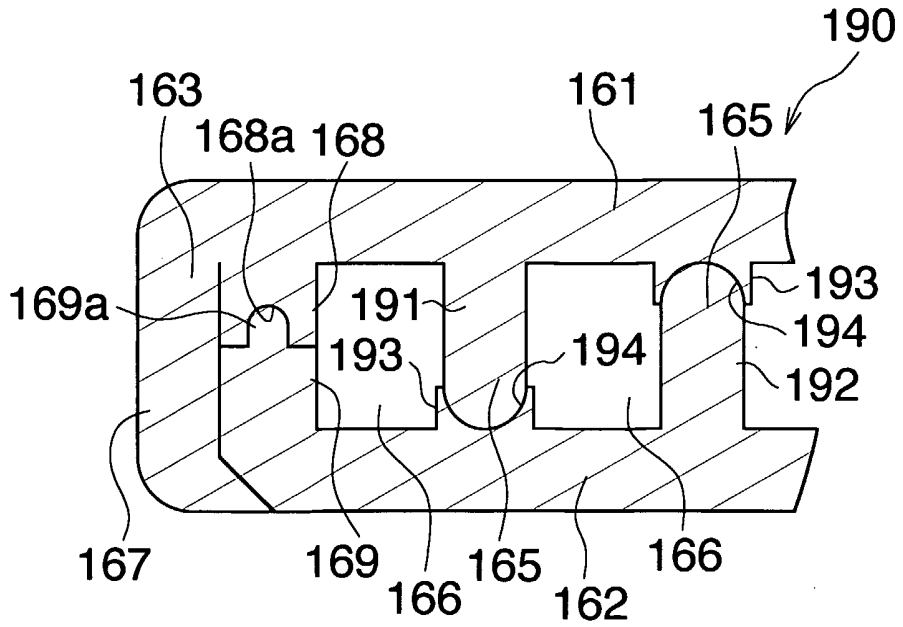


Fig.26

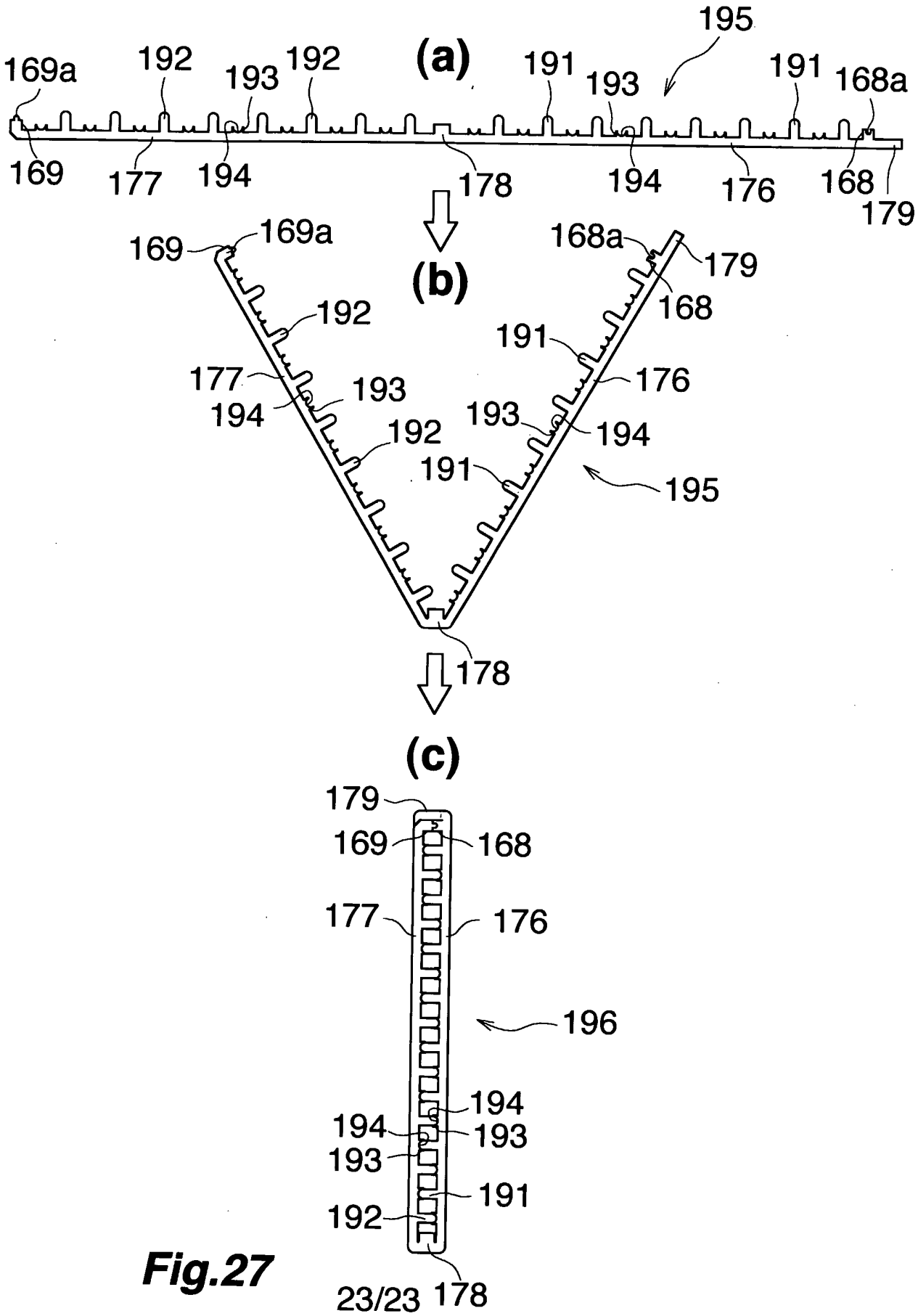

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Fig.27

INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2005/011224

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.[7] ***F28F9/02*** (2006.01), ***F25B1/00*** (2006.01), ***F25B39/00*** (2006.01), ***F28D1/053*** (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.[7] ***F28F9/02*** (2006.01), ***F25B1/00*** (2006.01), ***F25B39/00*** (2006.01), ***F28D1/053*** (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 1971-2005
Registered utility model specifications of Japan 1996-2005
Published registered utility model applications of Japan 1994-2005

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	JP 4-73599 A (Sanden K.K.) 1992.03.09, line 7, left-upper column, - line 18, right-upper column, page4, figures 1, 5 family: none	1,2,4,10-13
Y		3,5-9
Y	JP 2000-39288 A (Showa aluminum K.K.) 2000.02.08, paragraphs 15-41, figures 1-9 family: none	3,5-9
Y	JP 7-19783 A (Sanden K.K.) 1995.01.20, paragraphs 22-27, figures 1-5 family: none	7-9

☐ 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
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"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	Date of mailing of the international search report
07.10.2005	25.10.2005

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office	KANZAKI Takayuki
3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No. +81-3-3581-1101 Ext. 3377

3M 9037