(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 August 2002 (29.08.2002)

PCT

(10) International Publication Number
WO 02/066918 A1

(51) International Patent Classification⁷: **F28F 3/08**, 3/04

(21) International Application Number: PCT/JP02/01343

(22) International Filing Date: 18 February 2002 (18.02.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2001-41449 19 February 2001 (19.02.2001) JP
60/302,371 3 July 2001 (03.07.2001) US

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

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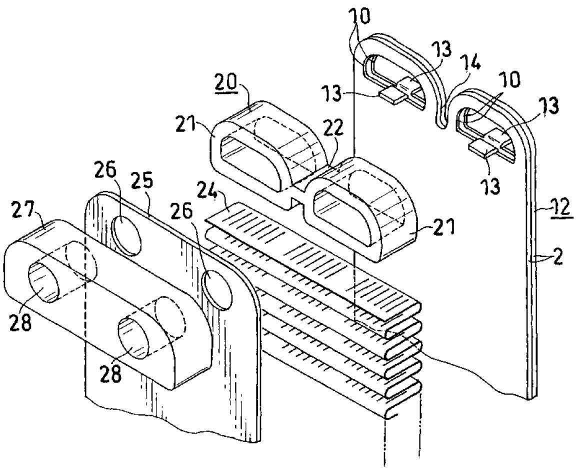
(54) Title: HEAT EXCHANGER



(57) Abstract: The invention relates to heat exchangers for use in motor vehicles or for industrial use, for example, to heat exchangers for use as evaporators, condensers, oil coolers, intercoolers, heater cores, etc. The invention provides a heat exchanger comprising pairs of plates with each plate of the pair having formed on one side thereof a peripheral ridge, central ridge and channel dividing U-shaped ridges which are formed by forging or cutting. Each pair of plates are fitted together and joined, with channel recesses thereof opposed to each other to form a flat tube and a plurality of U-shaped divided fluid passageways in a U-shaped fluid channel inside the tube. Each pair of adjacent flat tubes are joined by spectacle-shaped header members interposed between the upper ends of the tubes and each comprising a front and a rear fluid passing tube portion and a connecting portion therebetween to provide a front and a rear header in communication with the upper ends of the flat tubes. The flat tubes have a reduced front-to-rear width, diminished wall thickness (thinner layers) and increased heat transfer efficiency to provide a heat exchanger which achieves a higher heat transfer efficiency and greatly improved heat exchange performance.

WO 02/066918 A1

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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 data of Provisional Application No. 60/302,371 filed July 3, 2001 pursuant to 35 U.S.C. §111(b).

TECHNICAL FIELD

The present invention relates to heat exchangers for use in motor vehicles or for industrial use, for example, to heat exchangers for use as evaporators, condensers, oil coolers, intercoolers, heater cores, etc.

Generally aluminum heat exchangers are conventionally in wide use as heat exchangers, especially as evaporators for motor vehicle air conditioners, from the viewpoint of lightweightness and workabiliy.

At present, evaporators for motor vehicle air conditioners are chiefly those of the laminate type (layered type). In fabricating evaporators of this type, heat exchange fins for air and a tube portion for evaporating the refrigerant are joined together by brazing, so that such evaporators are superior to heat exchangers of the fin tube enlarged type which were previously in use, for example, with respect to performance and productivity. These evaporators are exceedingly superior to the fin tube enlarged type especially in performance characteristics since louver fins of high heat transfer efficiency are usable as air fins for this type of evaporators to ensure an increased quantity of heat exchange and low resistance to the flow of air.

Accordingly, more lightweight and compact heat exchangers are made available to meet the market demand for smaller sizes and reduced weight. Especially recently, many evaporators are provided with a filter on the front side in view of problems involved in the vehicle compartment, and it has been strongly required that heat exchangers be reduced in thickness to provide space for the installation of the filter.

For example as shown in FIG. 25, conventional heat exchangers for use as evaporators comprise generally rectangular aluminum plates 62 each having formed in one surface thereof front and rear refrigerant channel forming recessed porions 66 divided by a vertically elongated partition ridge 64, and header forming recessed portions (not shown) respectively continuous with the upper and lower ends of these recessed portions 66 and having a larger depth than these portions 66. Each pair of adjacent plates 62 are fitted together in superposed layers with their recessed surfaces opposed to each other to join the opposed partition ridges 64, 64 of the plates 62, 62 to each other and opposed peripheral edges 63, 63 thereof to each other and to thereby form a flat tube portion 61 having front and rear flat refrigerant channels 68 and upper and lower header portions continuous with the respective channels 68. A multiplicity of such flat tube portions 61 are arranged in parallel with a fin interposed therebetween for air to provide the heat exchanger. Each of the plates 62 is prepared from an aluminum sheet by press forming.

The conventional heat exchanger for use as an evaporator encounters the following problems in fulfilling the commercial demand for a reduced thickness.

(1) The plates 62 for forming the flat tube portion 61 are made from an aluminum sheet by drawing with use of a press, so that the partition ridge 64 and the peripheral edge 63 have an increased width. Accordingly, the joints between the two plates 62, 62, i.e., the joint of the opposed partition ridges of the plates 62, 62 and the joint of the opposed peripheral edges 63, 63 which are useless portions not passing the refrigerant have a relatively great area, which consequently reduces the cross sectional area of the refrigerant channel when the

evaporator has a given volume, offering increased resistance to the flow of the refrigerant and resulting in impaired performance.

To meet this problem, it appears useful to give an increased height to the refrigerant channel and thereby assure the channel of a sufficient cross sectional area, whereas the volume to be occupied by the air-side fin in the given volume will then decrease. Thus, the fin has a smaller area for heat transfer and is impaired in performance, while a diminished air passage produces increased resistance to the flow of air, failing to afford a proper rate of air flow.

(2) On the other hand, the joint between the peripheral edges 63, 63 of the two plates 62, 62 is out of direct contact with the fin for the air side to exhibit a low heat transfer efficiency, so that a reduction in the thickness of the heat exchanger including such useless portions increases the relative ratio in area of the useless portions not participating in the passage of the refrigerant.

(3) The header forming recessed portions of the plate 62 are given a greater depth than the front and rear refrigerant channel forming recessed portions 66, 66 on opposite sides of the partition ridge 64 by being worked by drawing, and are therefore made smaller in wall

thickness than the recessed portions 66. Although the flat tube portion 61 having a great proportion is given an allowance for pressure resistance, the header portions are weakest against pressure. With the conventional heat exchanger, the flat tube portion 61 and the header portions are made from an integral plate material, and that by press work, so that there are limitations in further reducing the header portions in wall thickness and weight.

An object of the present invention is to overcome the foregoing technical problems of the prior art and to provide a heat exchanger which is fabricated from plates having ridges and recessed portions formed in one surface thereof as by forging or cutting work instead of using plates formed by press work and in which headers are formed from a member separate from the plate to make a flat tube having a reduced front-to-rear width, a diminished wall thickness (layer of diminished thickness) and an increased heat transfer area, the heat exchanger thus being adapted to achieve a higher heat transfer efficiency and greatly improved heat exchange performance.

DISCLOSURE OF THE INVENTION

First, the present invention provides a heat exchanger which is characterized in that the heat exchanger comprises pairs of plates with each plate of the pairs having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending downward from an upper end of the plate to a position where a return channel can be formed, the ridges being formed by forging or cutting, each plate of said pairs having a U-shaped channel recess formed inwardly of the peripheral ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, the channel recess having one of two fluid inlet-outlet through holes formed at one end thereof and the other through hole formed at the other end thereof, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their U-shaped channel recesses opposed to each other to join the opposed peripheral ridges to each other end-to-end and the opposed central ridges to each other end-to-end and to thereby form a flat tube having a U-shaped fluid channel inside thereof so that a plurality of flat tubes are arranged in parallel with a header member interposed between upper ends of each pair of adjacent flat tubes to provide a front and a rear header in communication with the upper ends of the said pair of adjacent flat tubes, the header member comprising a pair of front and rear fluid passing tube portions in communications with the respective inlet-outlet through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

Second, the present invention provides a heat exchanger which is characterized in that the heat exchanger comprises pairs of plates with each plate of the pairs having an edge ridge U-shaped in its entirety and provided on one side of the plate along opposite side edges and a lower edge thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper end, the central ridge extending from the upper end downward to a position where a return channel can be formed, the ridges being formed by forging or cutting, each plate of said pairs having a U-shaped channel recess formed inwardly of the U-shaped edge ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their U-shaped channel recesses opposed to each other to join the opposed U-shaped edge ridges to each other end-to-end and the opposed central ridges including the bifurcated upper ends to each other end-to-end and to thereby form a flat tube having bifurcated open upper ends and a U-shaped fluid channel inside thereof, a pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated open upper ends thereof into the respective slits in the front and rear header members to join the flat tubes to the header members and to provide a front and a rear header in communication with the bifurcated open upper ends of the flat tubes.

With the heat exchanger having the first or second feature described, a plurality of channel dividing U-shaped ridges are formed in the U-shaped channel recess of each plate by forging or cutting, and a pluralty of U-shaped divided fluid passageways are formed in the U-shaped fluid channel in the interior of each flat tube. The invention provides several modes of channel dividing ridges.

As a first mode, a plurality of channel dividing U-shaped ridges are formed in the U-shaped channel recess of each plate by forging or cutting, and each said pair of plates are fitted together with the recesses thereof opposed to each other and with each of opposed pairs of channel dividing U-shaped ridges joined to each other end-to-end to form a plurality of U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

A second mode of channel dividing ridges is as follows. Each plate of said pairs has formed in the channel recess thereof front and rear channel dividing ridges having a height twice the depth of the channel recess and each comprising a straight portion positioned in the front or rear straight channel recess portion of the channel recess and a quarter circular-arc portion extending from a lower end of the straight portion and positioned in the return portion of the channel recess, the channel dividing ridges being formed by forging or cutting and positioned alternately when each of said pairs of plates are fitted together with their channel recesses opposed to each other, each of said pairs of plates being fitted together with their channel recesses opposed to each other to join top ends of the front and rear channel dividing ridges to a bottom wall flat surface of the plate providing the channel recess and opposed thereto and to thereby form U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

A third mode of channel dividing ridges is as follows. Each plate of said pairs has formed in the channel recess thereof channel dividing ridges having a height twice the depth of the channel recess and formed by forging or cutting so as to be positioned alternately, when each of said pairs fitted together with the recesses thereof opposed to each other, each of said pairs of plates being fitted together to join top ends of the channel dividing ridges on each plate of the pair to a flat surface of bottom wall of the channel recess of the other plate opposed to said each plate and to thereby form U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

A fourth mode of channel dividing ridges is as follows. Each plate of said pairs has formed in a rear half of the channel recess thereof channel dividing ridges having a height twice the depth of the channel recess and formed by forging or cutting, the channel recess of each plate having a front half in the form of a flat surface provided by a bottom wall thereof and having no channel dividing ridges, each of said pairs of plates being fitted together with the recesses thereof opposed to each other to join top ends of the channel dividing ridges thereof to the bottom wall flat surface of the channel recess of the plate opposed to the dividing ridges and to thereby form

U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

With the heat exchanger having the first feature of the invention, one of each pair of plates may be replaced by a flat plate.

More specifically, the heat exchanger in this case comprises ridged plates each having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending downward from an upper end of the plate to a position where a return channel can be formed, the ridges being formed by forging or cutting, each of the ridged plates having a U-shaped channel recess formed inwardly of the peripheral ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, the channel recess having one of two fluid inlet-outlet through holes formed at one end thereof and the other through hole formed at the other end thereof, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate and two fluid inlet-outlet through holes corresponding to said through holes, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having a U-shaped fluid channel inside thereof is formed so that a plurality of flat tubes are arranged in parallel with a header member interposed between upper ends of each pair of adjacent flat tubes to provide a front and a rear header in communication with the upper ends of the said pair of adjacent flat tubes, the header member comprising a pair of front and rear fluid passing tube portions in communications with the respective inlet-outlet through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

With the heat exchanger having the second feature of the invention, one of each pair of plates may be replaced by a flat plate.

Stated more specifically, the heat exchanger in this case comprises ridged plates each having an edge ridge U-shaped in its entirety and provided on one side of the plate along opposite side edges and a lower edge thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper end, the central ridge extending from the upper end downward to a position where a return channel can be formed, the ridges being formed by forging or cutting, each of the ridged plates having a U-shaped channel recess formed inwardly of the U-shaped edge ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate including the bifurcated upper ends having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having bifurcated open upper ends and a U-shaped fluid channel inside thereof is formed, a pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated open upper ends thereof into the respective slits in the front and rear header members to join the flat tubes to the header members and to provide a front and a rear header in communication with the bifurcated open upper ends of the flat tubes.

In a heat exchanger having such flat plates, a plurality of channel dividing U-shaped ridges are formed in the U-shaped channel recess of each ridged plate by forging or cutting, and each ridged plate and each flat plate are fitted together face-to-face with the channel dividing U-shaped ridges of the ridged plate joined to the flat surface of the corresponding central portion of the flat plate to form a plurality of U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

Third, the present invention provides a heat exchanger which is characterized in that the heat exchanger comprises pairs of plates with each plate of the pairs having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending vertically, the ridges being formed by forging or cutting, each plate of said pairs having a front and a rear channel recess portion formed inwardly of the peripheral ridge on opposite sides of the central ridge, each of the front and rear channel recess portions having a through hole formed in each of upper and lower ends thereof, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their channel recess portions opposed to each other to join the opposed peripheral ridges to each other end-to-end and the opposed central ridges to each other end-to-end and to thereby form a flat tube having a front and a rear fluid channel inside thereof so that a plurality of flat tubes are arranged in parallel with an upper and a lower header member interposed respectively between upper ends of each pair of adjacent flat tubes and between lower ends thereof to provide an upper and a lower header in communication with the upper ends and the lower ends of said pair of adjacent flat tubes, each of the header members comprising a pair of front and rear fluid passing tube portions in communications with the corresponding through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

Fourth, the present invention provides a heat exchanger which is characterized in that the heat exchanger comprises pairs of plates with each plate of the pairs having a side edge ridge provided on one side of the plate along each of opposite side edges thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper and a bifurcated lower end, the ridges being formed by forging or cutting, each plate of said pairs having a front and a rear channel recess portion formed inwardly of the side edge ridges on opposite sides of the central ridge, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their channel recess portions opposed to each other to join the opposed side edge ridges to each other end-to-end and the opposed central ridges including the bifurcated upper and lower ends to each other end-to-end and to thereby form a flat tube having bifurcated open upper and lower ends and a front and a rear fluid channel inside thereof, an upper pair of front and rear header members and a lower pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in an upper wall or a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated upper or lower ends thereof into the respective slits in the header members to join the flat tubes to the header members and to provide an upper pair of front and rear headers and a lower pair of front and rear headers in communication with the bifurcated upper and lower ends of the flat tubes respectively.

With the heat exchanger having the third or fourth feature described, a plurality of channel dividing ridges are formed in the front and rear channel recesses of each plate by forging or cutting, and a pluralty of divided fluid passageways are formed in the front and rear fluid channels in the interior of each flat tube. The invention provides several modes of channel dividing ridges.

As a first mode, a plurality of channel dividing ridges are formed in the front and rear channel recess portions of each plate by forging or cutting, and each of said pairs of plates are fitted together with their recess portions opposed to each other to join each of opposed pairs of the channel dividing ridges to each other end-to-end and form divided fluid passageways in the front and rear fluid channels inside thereof.

A second mode of channel dividing ridges is as follows. Each plate has formed in the respective front and rear channel recess portions thereof front and rear channel dividing ridges having a height twice the depth of the recess portion, the front and rear channel dividing ridges being formed by forging or cutting and positioned alternately when each of said pairs of plates are fitted together with their recess portions opposed to each other, each of said pairs of plates being fitted together face-to-face to join top ends of the front and rear channel dividing ridges to a bottom wall flat surface of recess portion of the plate opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

A third mode of channel dividing ridges is as follows. Each plate of the pairs has formed in each of the front and rear channel recess portions thereof a channel dividing ridge having a height twice the depth of the recess portion, the channel dividing ridge being so formed by forging or cutting that the front and rear channel dividing ridges of each pair of plates as fitted together face-to-face are positioned alternately, each pair of plates being fitted together with their recess portions opposed to each other to join top ends of the front and rear channel dividing ridges of each plate of the pair to a bottom wall flat surface of the recess portion of the other plate of the pair opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

A fourth mode of channel dividing ridges is as follows. Each plate has formed in one of the front and rear channel recess portions thereof a plurality of channel dividing ridges having a height twice the depth of the recess portion, the channel dividing ridges being formed by forging or cutting, the other channel recess portion having a bottom wall flat surface having no channel dividing ridges, each of said pairs of plates being fitted together with their recess portions opposed to each other to join top ends of the channel dividing ridges to the bottom wall flat surface of the recess portion of the plate opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

With the heat exchanger having the third feature of the invention, one of each pair of plates may be replaced by a flat plate.

Stated more specifically, the heat exchanger in this case comprises ridged plates each having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending vertically, the ridges being formed by forging or cutting, each the ridged plates having a front and a rear channel recess portion formed inwardly of the peripheral ridge on opposite sides of the central ridge, each of the front and rear channel recess portions having a through hole formed in each of upper and lower ends thereof, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate and fluid inlet-outlet through holes corresponding to said through holes, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having a front and a rear fluid channel inside thereof is formed so that a plurality of flat tubes are arranged in parallel with an upper and a lower header member interposed respectively between upper ends of each pair of adjacent flat tubes and between lower ends thereof to provide an upper and a lower header in communication with the upper ends and the lower ends of said pair of adjacent flat tubes, each of the header members comprising a pair of front and rear fluid passing tube portions in communications with the corresponding through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

In the above heat exchanger, the connecting portion of one of the upper and lower header members interposed between the upper ends and lower ends of each pair of adjacent flat tubes may have a passage interconnecting the fluid passing tube portions of the header member.

With the heat exchanger having the fourth feature of the invention, one of each pair of plates may be replaced by a flat plate.

Stated more specifically, the heat exchanger then comprises ridged paltes each having a side edge ridge provided on one side of the plate along each of opposite side edges thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper and a bifurcated lower end, the ridges being formed by forging or cutting, each of the ridged plates having a front and a rear channel recess portion formed inwardly of the side edge ridges on opposite sides of the central ridge, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate, the side edge ridges of the ridged plate having top ends thereof joined to side edges of the flat plate, the central ridge of the ridged plate including the bifurcated upper and lower ends having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having bifurcated open upper and lower ends and a front and a rear fluid channel inside thereof is formed, an upper pair of front and rear header members and a lower pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in an upper wall or a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated upper or lower ends thereof into the respective slits in the header members to join the flat tubes to the header members and to provide an upper pair of front and rear headers and a lower pair of front and rear headers in communication with the bifurcated upper and lower ends of the flat tubes respectively.

In a heat exchanger wherein flat plates are used, each of the ridged plates has channel dividing ridges formed in the respective front and rear channel recess portions thereof by forging or cutting, and each ridged plate is fitted to each flat plate face-to-face to join top ends of the channel dividing ridges to a flat surface of a corresponding portion of the flat plate and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

In a heat exchanger which has the first or third feature, the header member interposed between the ends of each pair of adjacent flat tubes has its fluid passing tube portions joined at their opposite end faces to the flat surfaces on the other sides of the opposed plates of the pair of flat tubes. Preferably, tacks for temporarily holding the header member are provided on respective edges defining the inlet-outlet through holes in the end of each plate.

In a heat exchanger according, a plurality of cutouts are formed in the channel dividing ridges on each plate to cause the adjacent divided fluid passageways inside the flat tube to communicate with each other through the cutouts.

In any of the heat exchangers of the invention described, a fin is provided between each pair of adjacent flat tubes included in the flat tubes arranged in parallel, and the fin has opposite sides edges thereof joined to the flat surfaces on the other sides of the plates of the pair of flat tubes.

For use in any of the heat exchangers of the invention described, the plates are those having recesses and ridges formed on one side thereof by forging or cutting, in place of conventional plates which are formed by press work, and the header members are members separate from the plate for providing headers. These features provide flat tubes having a reduced front-to-rear width, a diminished wall thickness (layer of diminished thickness) and an increased heat transfer area to result in the advantages of a higher heat transfer efficiency and greatly improved heat exchange performance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a heat exchanger according to a first embodiment of the invention.

FIG. 2 is an enlarged front view of a plate of the heat exchanger of FIG. 1.

FIG. 3 is an enlarged fragmentary perspective view of the plate.

FIG. 4 is an enlarged exploded fragmentary perspective view of the heat exchanger of FIG. 1.

FIG. 5 is an enlarged cross sectional view of a plate tube of the heat exchanger.

FIG. 6 is an enlarged fragmentary perspective view partly broken away and showing the heat exchanger.

FIG. 7 is an enlarged fragmentary cross sectional view showing a modification of dividing ridges of plate of the heat exchanger of FIG. 1.

FIG. 8 is an enlarged front view showing a modified plate of the heat exchanger.

FIG. 9 is an enlarged fragmentary perspective view showing another modified plate of the heat exchanger.

FIG. 10 is an enlarged cross sectional view of a flat tube for the heat exchanger wherein the plate of FIG. 9 is used.

FIG. 11 is an enlarged exploded fragmentary perspective view of a heat exchanger according to a second embodiment of the invention.

FIG. 12 is an enlarged fragmentary front view of the plate of the heat exchanger of FIG. 11, with headers also shown.

FIG. 13 is a perspective view of a heat exchanger according to a third embodiment of the invention.

FIG. 14 is an enlarged front view of the plate of the heat exchanger plate shown FIG. 13.

FIG. 15 is an enlarged fragmentary perspective view of the heat exchanger plate.

FIG. 16 is an enlarged exploded perspective view of an upper end portion of the heat exchanger.

FIG. 17 is an enlarged exploded perspective view of a lower end portion of the heat exchanger.

FIG. 18 is an enlarged front view of a plate for use in the heat exchanger of FIG. 1 to show a second modification of diving ridges.

FIG. 19 is an enlarged cross sectional view of a flat tube for the heat exchanger wherein the plate of FIG. 18 is used.

FIG. 20 is an enlarged front view of a plate for use in the heat exchanger of FIG. 1 to show a third modification of diving ridges, the plate being one of a pair of plates in combination.

FIG. 21 is an enlarged front view of the other plate of the pair.

FIG. 22 is an enlarged front view of a plate for use in the heat exchanger of FIG. 1 to show a fourth modification of diving ridges.

FIG. 23 is an enlarged cross sectional view of a flat tube for the heat exchanger wherein the plate of FIG. 22 is used.

FIG. 24 is an enlarged cross sectional view of a flat tube of heat exchanger of the invention, wherein one of a pair of plates in combination is replaced by a flat plate as a modification.

FIG. 25 is an enlarged cross sectional view of a flat tube of an example of conventional heat exchanger.

BEST MODE OF CARRYING OUT THE INVENTION

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

The terms "front," "rear," "left," "right," "upper" and "lower" as used herein are based on FIG. 2; "front" refers to the left-hand side of FIG. 2, "rear" to the right-hand side thereof, "left" to the front side of the plane of the drawing, "right" to the rear side of the plane thereof, "upper" to the upper side of the drawing, and "lower" to the lower side thereof.

The drawings show heat exchangers of the invention for use as evaporators for motor vehicle air conditioners.

FIGS. 1 to 6 show a first embodiment of the present invention. A heat exchanger 1 for use as an evaporator is made from aluminum (including aluminum alloys).

A generally rectangular plate 2 made of an aluminum plate has a peripheral ridge 3 provided on one side of the plate 2 along a periphery thereof and a central ridge 4 provided on the same side of the plate 2 at the center of the width thereof and extending downward from the upper end of the plate to a position where a refrigerant return channel can be formed. Formed in the plate 2 internally of the peripheral ridge 3 is a U-shaped refrigerant channel recess 6 comprising front and rear straight refrigerant channel recess portions 6a, 6b positioned on opposite sides of the central ridge 4 and a refrigerant return channel recess portion 6c positioned under the central ridge.

According to this first embodiment, the plate 2 is provided in the widthwise midportion of its upper end with a notch 14 which is U-shaped when seen from the front. The central ridge 4 is joined at its upper end to the peripheral ridge 3 at the lower end of this notch 14.

The channel recess 6 has one of refrigerant inlet-outlet through holes 10, 10 formed at one end thereof and the other through hole 10 formed at the other end thereof. The plate 2 has a plurality of channel diving U-shaped ridges 5 formed inside the channel recess 6 and extending over the approximate entire length thereof.

The presence of the notch 14 in the widthwise midportion of upper end of the plate 2 positions the though holes 10, 10 as spaced apart from each other by the width of the notch 14. This serves to prevent unnecessary heat exchange between an incoming portion of refrigerant having a low temperature and an outgoing portion of refrigerant having a high temperature, and to prevent the refrigerant introduced into an inlet header to be described later from flowing into an outlet header through a short path.

The corners of return channel recess portion 6c of the channel recess 6 have short circular-arc ridges 9 for achieving an improved heat exchange efficiency at the corner portions.

Each plate 2 is formed, for example, by forging or cutting. Plates 2 are provided in pairs, and each pair of plates 2 are fitted together with their U-shaped channel recesses 6, 6 opposed to each other to join the opposed peripheral ridges 3, 3 of the plates 2, 2 to each other end-to-end, the opposed central ridges 4, 4 thereof to each other end-to-end and each of the opposed pairs of channel dividing rides 5, 5 to each other end-to-end and to thereby form a flat tube 12 having a U-shaped refrigerant channel 8 inside thereof, with a plurality of U-shaped divided refrigerant passageways 7 formed in the refrigerant channel 8 inside the flat tube 12.

A clad material is used for each plate 2 which has a brazing sheet affixed to one surface thereof, preferably each of the inner and outer surfaces thereof. Such components can then be joined together easily.

The evaporator 1 of the present invention has headers 23, 23 which interconnect flat tubes 12, 12 providing a refrigerant circuit and which are formed in the following manner.

A plurality of flat tubes 12 are arranged in parallel, with a spectacle-shaped header member 20 interposed between the upper ends of each pair of adjacent flat tubes 12, 12 to provide front and rear headers 23, 23 in communication with the upper ends of the pair of adjacent flat tubes 12. The header member 20 comprises a pair of front and rear refrigerant passing tube portions 21, 21 in communications with the respective inlet-outlet through holes 10, 10 of the plates 2 and a connecting portion 22 between the tube portions. Opposite end faces of front and rear tube portions 21, 21 of the header member 20 are joined to flat surfaces provided by the other sides of respective opposed plates 2, 2 of the pair of flat tubes 12.

Below the headers 23, 23, a corrugated louver fin 24 for effecting heat exchange with air is provided between the adjacent flat tubes 12, 12. The fin 24 is joined at left and right sides thereof to the flat surfaces of the plates 2, 2.

The corrugated louver fin 24 has louvers formed simultaneously with bending for improved heat transfer.

The bottom of the U-shaped notch 14 formed in the widthwise midportion of the upper end of each plate 2 needs to be positioned below the connecting portion 22 of the spectacle-shaped header member 20 so as to drain condensation water collecting in the notch.

Tacks 13, 13 for temporarily holding the header member 20 are provided at the midportions of the lower edges defining the respective inlet-outlet through holes 10, 10 in the upper end of the plate 2. The header member 20 can be prevented from shifting by these tacks 13, 13 during brazing.

With reference to FIGS. 1 and 4, a pair of side plates 25, 25 are arranged respectively at left and right ends of the evaporator 1. The left side plate 25 of the pair is provided with an inlet-outlet pipe connecting block 27 joined to the upper end thereof. The side plate 25 has a pair of front and rear through holes 26, 26 formed in the upper end thereof and communicating respectively with a pair of front and rear through holes 28, 28 formed in the block 27. The holes 26, 26 of the side plate 25 communicate respectively with the tube portions 21, 21 of the header member 20.

Incidentally, the side plate 25 need not be provided in the case where the block 27 is attached directly to the plate 2 at the left or right outer end of the evaporator 1. The block 17 may alternatively be provided at an intermediate portion of the height of the side plate 25. The block 27 may further be provided at the midportion of length of the evaporator 1, or may comprise an inlet pipe connecting block and an outlet pipe connecting block which are provided respectively at the left and right ends of the evaporator so as to position an inlet and an outlet individually at the left and right ends.

The evaporator components described are assembled and thereafter joined together by brazing to fabricate the essential portion of the evaporator 1.

The assembly is brazed in a vacuum, or in a furnace with use of a fluorine-containing flux.

It is desirable to use a material of relatively high strength for the header member 20 and the side plates 25 in view of pressure resistance. It is especially desirable to use an aluminum alloy containing magnesium added thereto.

In the case where the fluorine-containing flux is used, it is desirable to use an aluminum alloy material having a magnesium content preferably of up to 0.4% since this results in improvements in bondability and strength.

The surfaces of the plate 2 and the corrugated fin 24 are approximately flat so that the fin 24 can be joined to the flat tube 12 nearly 100% to achieve highly efficient heat exchange between the interior of the circuit of flat tubes 12 and the corrugated fins 24.

The header member 20 providing the headers 23, 23 has a generally spectacle-shaped section with two refrigerant channels, one of which has the function of collecting or distributing an incoming portion of refrigerant, with the other serving to collect or distribute an outgoing portion of refrigerant.

When the heat exchanger of the present invention is used as an evaporator 1, the refrigerant is introduced into the flat tubes 12 in the form of a mixture of a liquid and a gas. At this time, the liquid refrigerant has a higher density than the gas and is more readily subjected to an inertial force. The liquid refrigerant has higher properties to advance straight than the gas. For this reason, the liquid refrigerant tends to collect in a greater amount at a header end remote from the inlet header. An uneven flow of the liquid refrigerant upsets the balance of latent heat of vaporization in various portions, contributing greatly to impairment of performance. This can be precluded effectively by causing the flat tube 12 to project into the header 23 to serve as a baffle and diminish the properties of the liquid refrigerant to advance straight.

The present invention is adapted to readily provide a baffle structure, for example, by making the height b1 of the through hole 10 at the inlet side of the flat tube 12 smaller than the inside diameter b2 of the refrigerant passing tube portion 21 of the header member 20. The effect of a baffle is available alternatively by reducing the cross sectional area of the front and rear tube portions 21 of the header member 20 at one location or at a plurality of locations and thereby producing flows of varying cross sectional areas.

Such a procedure diminishes the property of the liquid refrigerant of advancing straight through the headers 23, 23, permitting the refrigerant to flow into the flat tubes 12 in equally divided quantities.

When the percentage of projection of the flat tube 12 into the header 23 in the evaporator 1 of the invention is defined as:

$(b2 - b1)/b2$

wherein b1 is the height of the through hole 10 at the inlet side of the flat tube 12, and b2 is the inside diameter of the tube portion 21 of the header member 20, the percentage of projection is in the range of 10 to 60% to be suitable. If the percentage of projection is less than 10%, no effect of baffle plate is available, readily permitting occurrence of an uneven flow, whereas if the percentage of projection is over 60%, the header 23 offers increased resistance to the flow to entail impaired performance undesirably.

As shown in detail in FIG. 5, it is especially desirable that the U-shaped divided refrigerant passageways 7 formed in the refrigerant channel 8 in the interior of each flat tube 12 be made generally hexagonal in cross section by tapering the peripheral ridges 3, 3 on the pair of the plates 2, 2 of the tube 12 toward inward, tapering the central ridges 4, 4 thereon inward and tapering the channel dividing ridges 5, 5 inward. The reason is that it is advantageous to spread the liquid refrigerant into a thin layer over the inner surface of the refrigerant channel 8 of the flat tube 12 for heat transfer.

Among the U-shaped divided refrigerant passageways 7 formed in the channel 8 inside the flat tube 12, the passageway 7a between the peripheral ridge 3 and the channel dividing U-shaped ridge 5 has a hexagonal cross section with a large width, and the passageways 7b between the ridges 5, 5 have a hexagonal cross section with a small width.

On the other hand, when the U-shaped divided refrigerant passageways 7 formed in the inside refrigerant channel 8 of the flat tube 12 have a rectangular cross section, for example, as shown in FIG. 7, the liquid refrigerant is liable to collect in wall corners of the flat tube 12 if the circuit width is diminished to give an increased surface area to the refrigerant because the liquid refrigerant which flows at a lower rate than the gas is forced toward the passageway ends. With the liquid refrigerant required for evaporation forced toward end portions, the liquid refrigerant will not adhere to the inner walls of the peripheral ridges 3, 3, central ridges 4, 4 and channel dividing ridges 5, 5 in the flat tube 12 and will not be subjected to effective heat exchange, so that the heat exchanger fails to exhibit the desired performance.

When the divided refrigerant passageways 7 are made generally hexagonal in cross section as seen in FIG. 5, the liquid refrigerant collects in the recessed parts of intermediate portions of the passageways 7 with the greatest ease, adhering to the tapered surfaces of the peripheral ridges 3, 3, those of the central ridges 4, 4 and those of the dividing ridges 5, 5 on the pair of plates 2, 2 for effective heat transfer and enabling these ridges to act effectively as interior fins to exhibit improved heat transfer performance. As a result, the heat transfer portions in the interior of the refrigerant passageways 7 are increased in the area of effective parts to cool air to assure comfort.

However, the evaporator 1 of the invention may be so shaped as shown in either one of FIGS. 5 and 7 because the entire width of the channel for passing cold refrigerant is equal to the width of contact of the corrugated fin 24 for the heat exchanger of the invention to achieve a higher heat exchange efficiency than the conventional one.

According to the first embodiment of the invention described, the plate 2 is, for example, 10 to 40 mm in width and 0.25 to 1.0 mm in thickness.

The peripheral ridge 3 on the plate 2 is, for example, 0.25 to 1.0 mm in thickness and 0.5 to 2.0 mm in width. The central ridge 4 on the plate 2 is, for example, 0.25 to 1.0 mm in thickness and 0.5 to 2.0 mm in width. The channel dividing U-shaped ridge 5 on the plate 2 is, for example, 0.25 to 1.0 mm in thickness and 0.25 to 1.0 mm in width.

With the evaporator 1 described above, the refrigerant introduced into the front header 23 through one of the through holes 28, i.e., the inlet hole 28, in the pipe connecting block 27 flows into divided refrigerant passageways 7 from one end of the U-shaped refrigerant channel 8 of each flat tube 12, flows through the U-shaped passageways 7 to the other end of the channel 8, further passes through the rear header 23 and the other through hole 28, i.e., the outlet hole 28, in the block 27 and flows out of the evaporator.

On the other hand, air flows through the evaporator 1 from the front rearward through the spaces each having the corrugated louver fin 24 therein and formed between the adjacent flat tubes 12 and between the tube 12 and each end plate 25 to undergo efficient heat exchange with the refrigerant through the walls of the flat tube 12, the end plates 25 and the louver fins 24.

The evaporator 1 according to the first embodiment is fabricated from plates which have recesses and ridges formed on one side thereof as by forging or cutting and which are used in place of conventional plates formed by press work. The front and rear headers are formed by header members which are separate from the plates. These features give the flat tubes 12 a reduced front-to-rear width and a decreased thickness (thinner layers) and afford a greater area of heat transfer, enabling the evaporator to achieve a higher heat transfer efficiency and exhibit greatly improved heat exchange performance.

To assure the refrigerant of improved heat transfer in the flat tube 12, it is desired that a plurality of cutouts 15 be formed in the channel dividing U-shaped ridges 5 on each plate 2 at a predetermined spacing, for example as shwon in FIG. 8, the cutouts 15 in the adjacent ridges 5 being in a staggered arrangement, so as to cause the divided adjacent refrigerant passageways 7, 7 in the interior of the tube 12 to communicate with each other through the cutouts 15.

Alternatively, the flat tube 12 may have turbulence promoting members (projections) 16 in a staggered arranged for producing turbulent flows of refrigerant for improved heat transfer, for example, as shown in FIGS. 9 and 10.

FIGS. 11 and 12 show a second embodiment of the invention. This embodiment differs from the first in that a pair of front and rear header members 41, 42 each in the form of a pipe having a rectangular cross section are used.

Stated more specifically, an evaporator 1 is fabricated from generally rectangular plates 2 which are aluminum plates. Each of these plates 2 has an edge ridge 33 provided on one side of the plate along opposite side edges and a lower edge thereof and U-shaped in its entirety, and a central ridge 34 provided on the same side of the plate 2 at the center of the width thereof and having a bifurcated upper end 34a, the central ridge 34 extending from the upper end 34a downward to a position where a refrigerant return channel can be formed. The plate 2 has a U-shaped refrigerant channel recess 36 formed internally of the U-shaped edge ridge 33 and comprising front and rear straight refrigerant channel recess portion 36a, 36a formed on opposite sides of the central ridge 34 and a refrigerant return channel recess portion 36c positioned under the central ridge. The plate 2 has a plurality of channel diving U-shaped ridges 35 formed inside the channel recess 36 and extending over the approximate entire length thereof.

The corners of return channel recess portion 36c of the channel recess 36 has short circular-arc ridges 39 for achieving an improved heat exchange efficiency at the corner portions.

According to this second embodiment, the plate 2 is provided in the widthwise midportion of its upper end with a notch 37 which is U-shaped when seen from the front. The central ridge 34 has the bifurcated upper end 34a.

Each plate 2 is formed, for example, by forging or cutting. Plates 2 are provided in pairs, and each pair of plates 2 are fitted together with their U-shaped channel recesses 36, 36 opposed to each other to join the opposed U-shaped edge ridges 33, 33 of the plates 2, 2 to each other end-to-end, the opposed central ridges 34, 34 including the bifurcated upper ends 34a to each other end-to-end and each of the opposed pairs of channel dividing rides 5, 5 each other end-to-end and to thereby form a flat tube 32 having upper ends 32a, 32a which are bifurcated and opened, with a plurality of U-shaped divided refrigerant passageways formed inside the flat tube 32.

On the other hand, a pair of front and rear header members 41, 42 are each in the form of a pipe rectangular in cross section and having a lower wall 43, front wall 45, rear wall 46 and upper wall 47. The header members 41, 42 have slits 44, 44 formed in the respective lower walls 43, 43 thereof and arranged at a predetermined spacing. Flat tubes 32 are arranged in parallel laterally, with a front and a rear header provided in communication with the bifurcated open upper ends 32a, 32a of the flat tubes 32, by inserting the bifurcated open upper ends 32a, 32a thereof into the respective slits 44, 44 of the juxtaposed header members 41, 42 and thereby joining the flat tubes to the header members. At this time, the rear wall 46 and the front wall 45 of the respective juxtaposed front and rear header members 41, 42 are fitted as joined together into U-shaped notches 37, 37 in the upper ends of the opposed plates 2, 2 of each flat tube 32.

Below the headers, a corrugated fin 24 is provided between the adjacent flat tubes 32, 32. The fin 24 is joined at left and right sides thereof to the flat surfaces provided by the other sides of the plates 2, 2.

The evaporator 1 of the second embodiment is fabricated in the same manner as the first in that the assembly of components is brazed in a vacuum, or in a furnace with use of a fluorine-containing flux, so that throughout the drawings concerned, like parts are designated by like reference numerals.

Although not shown, the pair of front and rear header members 41, 42 each in the form of rectangular pipe may be replaced by a single aluminum extrudate having two refrigerant channels generally rectangular in cross section and partitioned by a central wall for use in the evaporator 1 according to the second embodiment described. The extrudate has slits 44, 44 formed in the respective portions of a lower wall thereof which define the refrigerant channels and arranged at a predetermined spacing. A front and a rear header are provided in communication with the bifurcated open upper ends 32a, 32a of the juxtaposed flat tubes 32 by inserting the bifurcated open upper ends 32a, 32a the tubes into the respective slits 44, 44 and thereby joining the tubes to the lower wall.

FIGS. 13 to 17 show a third embodiment of the present invention, which differs from the first in that headers 57 and headers 58 are provided respectively at the top and bottom of an evaporator 1.

With reference to these drawings, a generally rectangular plate 2 made of an aluminum plate has a peripheral ridge 3 provided on one side of the plate 2 along a periphery thereof and a central ridge 4 provided on the same side of the plate 2 at the center of the width thereof and extending vertically. Formed in the plate 2 internally of the peripheral ridge 3 are front and rear refrigerant channel recess portions 6a, 6b positioned on opposite sides of the central ridge 4 and through holes 10, 10 formed in the upper and lower ends of the recess portions 6a, 6b. The plate 2 has straight channel diving ridges 5 formed inside the channel recess portions 6a, 6b and extending over the approximate entire length of the portions 6a, 6b.

The plate 2 is formed, for example, by forging or cutting. Such plates 2 are provided in pairs, and each pair of plates 2 are fitted together with their recess portions 6a, 6b opposed to each other to join the opposed peripheral ridges 3, 3 of the plates 2, 2 to each other end-to-end, the opposed central ridges 4, 4 thereof to each other end-to-end and each of the opposed pairs of channel dividing rides 5, 5 to each other end-to-end and to thereby form a flat tube 12 having a U-shaped refrigerant channel 8 inside thereof, with parallel divided refrigerant passageways 7 formed in the inside the flat tube 12 (see FIG. 7 of the first embodiment).

A required number of flat tubes 12 are arranged side by side. Spectacle-shaped upper and lower header members 51, 52, each comprising a pair of front and rear refrigerant passing tube portions 53, 53 or 54, 54 and a connecting portion 55 or 56 therebetween, are interposed respectively between the upper ends of each pair of adjacent flat tubes and between the lower ends thereof, the tube portions 53 or 54 being in communication with the corresponding through holes 10 of the opposed plates 2.

As shown in detail in FIG. 14, of the pairs of front and rear through holes 10, 10 formed in the upper and lower ends of the plate 2, the pair of front and rear through holes 10a, 10a in the upper end of the plate 2 are each in the form of a circle which is elongated horizontally. In corresponding relation with these holes, the front and rear tube portions 53, 53 of the upper header member 51 provided between the upper ends of the flat tubes 12, 12 have a circular cross section which is similarly elongated horizontally. On the other hand, the pair of front and rear through holes 10b, 10b in the lower end of the plate 2 are each in the form of a circle which is elongated as inclined forwardly downward or rearwardly downward. In corresponding relation with these holes, the front and rear tube portions 54, 54 of the lower header member 52 provided between the lower ends of the flat tubes 12, 12 have a circular cross section which is similarly elongated as inclined forwardly downward or rearwardly downward.

With reference to FIGS. 16 and 17, opposite end faces of the tube portions 53, 53 and 54, 54 of the upper and lower header members 51, 52 are joined to flat surfaces on the other sides of the plates of the flat tubes 12, 12 which surfaces are opposed to the end faces, whereby upper and lower headers 57, 58 are formed in communication respectively with the upper ends and lower ends of the flat tubes 12, 12.

Between the upper and lower headers 57, 58, a corrugated louver fin 24 for effecting heat exchange with air is interposed between each pair of adjacent flat tubes 12, 12. The fin 24 is joined at opposite side edges thereof to the other sides, i.e., the flat surfaces of the plates 2, 2 of the flat tubes 12, 12.

Of the upper and lower header members 51, 52 between the adjacent flat tubes 12, 12 in the evaporator 1 of the third embodiment, the lower header member 52 has passages 59, 59 formed at opposite sides of the intermediate connecting portion 56 for interconnecting the front and rear tube portions 54, 54 of the header member 52.

With the evaporator 1 of the third embodiment described, the refrigerant is introduced from an inlet through hole 18 in an inlet-outlet pipe connecting block 27 into the front tube portion 53 of each upper header member 51 providing the front upper header 57, from which the refrigerant flows into the front upper end of refrigerant channel 8 of each flat tube 12, further flows down the straight divided refrigerant passageways 7 to reach the front lower end of the channel 8, from which the refrigerant temporarily flows into the front tube portion 54 of the lower header member 52 providing the front lower header 58, then passes through the interconnecting passages 59, 59 in the lower header member 52 and flows into the rear tube portion 54 providing the rear lower header 58. Subsequently, the refrigerant flows into the rear lower end of the refrigerant channel 8 of the flat tube 12, further ascends the straight divided refrigerant passageways 7 to reach the rear upper end of the channel

8, passes through the rear tube portion 53 of the upper header member 51 providing the rear upper header 57 and flows out of an outlet through hole 28 in the block 27.

With the evaporator 1 of the third embodiment, the front and rear tube portions 54, 54 of the lower header member 52 between the lower ends of the flat tubes 12, 12 have a circular cross section which is elongated as inclined forwardly downward or rearwardly downward so as to cause the water produced upon condensation on the outer surface of the evaporator 1 during due to be drained smoothly.

Although not shown, the evaporator 1 of the third embodiment may also be modified like the modification of FIG. 8, by forming a plurality of cutouts 15 in the channel dividing ridges 5 on each plate so that the adjacent divided refrigerant passageways 7, 7 inside the flat tube 12 communicate with each other through the cutouts 15.

Of the upper and lower header members 51, 52 provided between the adjacent flat tubes 12, 12 at their upper ends and lower ends in the evaporator 1 of the third embodiment, the upper header member 51 may have passages 59, 59 formed at opposite sides of the intermediate connecting portion 55 for interconnecting the front and rear tube portions 53, 53 of the header member 51, in converse relation with the illustrated case so as to cause the refrigerant to flow in the opposite direction to the illustrated case.

The evaporator 1 of the third embodiment otherwise has the same construction as the first embodiment described, so that like parts are designated by like reference numerals throughout the drawings concerned.

FIGS. 18 and 19 show a second modification of channel dividing ridges 5 on the plate 2 for use in the evaporator according to the first embodiment of the invention, i.e., channel dividing ridges 5a, 5b formed in the refrigerant channel recess 6 of each plate 2, which differ from the channel dividing U-shaped ridges 5 shown in FIGS. 2, 3 and 5 showing the first embodiment in configuration and arrangement. Another difference is that the ridges 5a, 5b on each plate 2 have top ends joined to the flat bottom wall of the plate 2 opposed thereto and providing the refrigerant channel recess 6 thereof.

With reference to FIGS. 18 and 19, each plate 2 of the evaporator 1 has on one side thereof a peripheral ridge 3 along the periphery thereof and a central ridge 4 at the center of the width of the plate and extending downward from the upper end of the plate to a position where a return channel can be formed. More specifically, each pair of plates 2a, 2b have formed in a refrigerant channel recess 6 thereof a multiplicity of front and rear channel dividing ridges 5a, 5b having a height twice the depth of the channel recess 6. These ridges 5a, 5b are so provided as to form independent parallel U-shaped divided refrigerant passageways 7 in a U-shaped refrigerant channel 8 of a flat tube 12 when the pair of plates 2a, 2b are fitted together.

With reference to FIG. 18, these ridges 5a, 5b each comprise a straight portion 5a1 or 5b1 positioned in the front or rear straight channel recess portion 6a or 6b of the refrigerant channel recess 6 and a quarter circular-arc portion 5a2 or 5b2 extending from the straight portion and positioned in the return portion 6c of the recess 6. The ridges 5a, 5b correspond to exactly half of a U-shape in configuration.

When the pair of plates 2a, 2b are fitted together with the recesses 6, 6 opposed to each other, the straight portions 5a1, 5b1 and quarter circular-arcs 5a2, 5b2 of these ridges 5a, 5b are alternately arranged at a predetermined spacing.

With the pair of plates 2a, 2b fitted together, the opposed central ridges 4, 4 are butted against and joined to each other, with the peripheral ridges 3, 3 similarly joined to each other, and the straight portions 5a1, 5b1 and the quarter circular-arcs 5a2, 5b2 of the channel dividing ridges 5a, 5b on each of the plates 2a, 2b are joined at their top ends to the bottom wall flat surface of the other plate 2a or 2b opposed thereto and providing the channel recess 6, whereby a flat tube 12 is formed with a U-shaped refrigerant channel 8 formed therein. In the channel 8 of the flat tube 12, the front channel dividing ridges 5a on the plate 2a of the pair 2a, 2b are joined in a U-form to the rear ridges 5b on the other plate 2b, providing divided parallel U-shaped refrigerant passageways 7. The divided passageways 7 in the return portion are in the form of semicircular arcs.

The return channel recess portion 6c of the U-shaped channel recess 6 is provided at the corners on front and rear sides with short circular-arc ridges 9a, 9b to ensure improved heat exchange performance of this portion. These circular-arc ridges 9a, 9b are so arranged as to be positioned alternately at a predetermined spacing when the pair of plates 2a, 2b are fitted together with the recesses 6, 6 thereof opposed to each other.

The above modification is the same as the first embodiment otherwise; for example, each plate 2 is made by forging or cutting. Throughout the drawings concerned, therefore, like parts are designated by like reference numerals.

With the evaporator 1 described above, the front and rear channel dividing ridges 5a, 5b on the pair of plates 2a, 2b comprise straight portions 5a1, 5b1 and quarter circular-arc portions 5a2, 5b2 and are shaped to correspond to exactly half of a U-shape. These ridges 5a, 5b are so arranged that when the pair of plates 2a, 2b are fitted together with the recesses 6, 6 opposed to each other, the ridges 5a, 5b are positioned alternately at a predetermined spacing. Accordingly, the number of dividing ridges 5a, 5b to be made as by forging or cutting can be diminished, while the ridges 5a, 5b on the plates 2a, 2b can be spaced apart by an increased interval and can be shaped to have exactly half of the U-shape, hence the advantage that the plates 2a, 2b are easy to produce.

FIGS. 20 and 21 show a third modification of channel dividing ridge 5 on the plate 2 for use in the evaporator 1 according to the first embodiment of the invention. The modification differs from the first embodiment in that two kinds of plates 2a, 2b have channel dividing U-shaped ridges 5a, 5b which are different in arrangement in refrigerant channel recesses 6, 6, and that the ridges 5a, 5b on the plates 2a, 2b have their top ends joined to the bottom wall flat surface of the recesses 6 of the plates 2b, 2a opposed thereto.

With reference to the same drawings, the channel dividing U-shaped ridges 5a, 5b having a height twice the depth of recesses 6, 6 are provided in the U-shaped recesses 6, 6 of the pair of plates 2a, 2b so as to be alternately positioned at a predetermined spacing when these plates 2a, 2b are fitted together face-to-face.

With these plates 2a, 2b fitted together face-to-face, the opposed central ridges 4, 4, as well as the opposed plate peripheral ridges 3, 3, are butted against and joined to each other, and the channel dividing U-shaped ridges 5a, 5b on the plates 2a, 2b have their top ends joined to the bottom wall flat surfaces of the recesses 6, 6 of the plates 2b, 2a opposed thereto, whereby a flat tube 12 is formed which has parallel U-shaped refrigerant passageways 7 divided by the ridges 5a, 5b and provided in the U-shaped refrigerant channel 8.

In the front and rear corners of the refrigerant return channel recess portions 6c of the U-shaped refrigerant channel recesses 6, 6, short circular-arc ridges 9a, 9b are provided for these portions to exhibit improved heat exchange performance. These front and rear short circular-arc ridges 9a, 9b are alternately positioned at a predetermined spacing when the pair of plates 2a, 2b are fitted together face-to-face.

The above modification is the same as the first embodiment otherwise; for example, each plate 2 is made by forging or cutting. Throughout the drawings concerned, therefore, like parts are designated by like reference numerals.

With the evaporator 1 wherein the two kinds of plates 2a, 2b are used, the channel dividing U-shaped ridges 5a, 5b on the two plates 2a, 2b are so arranged that when these plates 2a, 2b are fitted together face-to-face, the ridges 5a, 5b are positioned alternately at a predetermined spacing. Accordingly, the number of dividing ridges 5a, 5b to be made as by forging or cutting can be smaller, while the ridges 5a, 5b on the plates 2a, 2b can be spaced apart by an increased interval, hence the advantage that the plates 2a, 2b are easy to produce.

FIGS. 22 and 23 show a fourth modification of channel dividing ridge 5 on the plate 2 for use in the evaporator 1 according to the first embodiment of the invention. The modification differs from the first embodiment in that a multiplicity of channel dividing ridges 5 are provided only in the rear half of the refrigerant channel recess 6 of each plate 2, with no ridges 5 whatever provided in the front half of the recess 6 and with the front half made flat-surfaced, in that the ridges 5 are shaped to have exactly half of a U-shape, and in that the ridges 5 on each plate 2 have their top ends joined to the bottom wall flat surface of the recess 6 of the other plate 6 opposed thereto.

With reference to the same drawings, each plate 2 of the evaporator 1 has a peripheral ridge 3 provided on one side of the plate along a periphery thereof and a central ridge 4 provided on the same side of the plate at the center of the width thereof and extending downward from an upper end of the plate to a position where a return channel can be formed. A multiplicity of channel dividing ridges 5b having a height twice the depth of the recess 6 are provided in the rear half of the refrigerant channel recess 6 of each plate 2, with no ridges 5 whatever provided in the front half of the recess 6 and with the front half made flat-surfaced.

Stated more specifically with reference to FIG. 22, the channel dividing ridges 5b provided in the rear half of the refrigerant channel recess 6 of each plate 2 each comprise a straight portion 5b1 formed in a rear straight channel recess portion 6b and a quarter circular-arc portion 5b2 extending from the straight portion and provided in a return portion 6c of the recess 6, the ridges 5b being shaped to have exactly half of a U-shape.

With a pair of plates 2a, 2b fitted together face-to-face, the opposed central ridges 4, 4, as well as the opposed plate peripheral ridges 3, 3, are butted against and joined to each other, and the channel dividing U-shaped ridges 5, 5 on the plates 2a, 2b have their top ends joined to the bottom wall flat surfaces of the refrigerant channel recesses 6, 6 of the plates 2b, 2a opposed thereto, whereby a flat tube 12 is formed which has a U-shaped refrigerant channel 8. The front ridges 5a on one plate 2a of the two 2a, 2b are made continuous with the rear ridges 5b on the other plate 2b, whereby parallel U-shaped divided refrigerant passageways 7 are formed in the U-shaped refrigerant channel 8 of the flat tube 12. The passageways 7 have semicircular-arc return portions.

Short circular-arc ridges 9 are provided on the rear corner portion of the return channel recess portion 6c of the recess 6 for this portion to exhibit improved heat exchange performance.

The above modification is the same as the first embodiment otherwise; for example, each plate 2 is made by forging or cutting. Throughout the drawings concerned, therefore, like parts are designated by like reference numerals.

With the evaporator 1, the channel dividing ridges 5 on each plate 2 each comprise a straight portion 5b1 and a quarter circular-arc portion 5b2 extending therefrom and are shaped to have exactly half of a U-shape, while the front half of the recess 6 of each plate 2 has a flat surface provided with no channel dividing ridges 5. Accordingly, the ridges 5 to be formed on the plate 2 as by forging or cutting can be half, hence the advantage that the plates 2a, 2b are easy to make.

FIG. 24 shows a pair of plates for use in the evaporator 1 of the first embodiment of the invention, with one of the plates replaced by a flat plate.

With reference to the drawing, the ridged plate 2 of the first embodiment, i.e., the plate 2b comprises, as will be apparent from FIG. 2, a peripheral ridge 3 provided on one side of the plate along a periphery thereof and a central ridge 4 provided on the same side of the plate at the center of the width thereof and extending downward from the upper end of the plate to a position where a refrigerant return channel can be formed. Formed in the plate internally of the peripheral ridge 3 is a U-shaped refrigerant channel recess 6 comprising front and rear straight refrigerant channel recess portions 6a, 6b positioned on opposite sides of the central ridge 4 and a refrigerant return channel recess portion 6c positioned under the central ridge. The plate has a plurality of channel diving U-shaped ridges 5 formed inside the channel recess 6 and extending over the approximate entire length thereof. The plate 2b is provided in the widthwise midportion of its upper end with a notch 14 which is U-shaped when seen from the front. The central ridge 4 is joined at its upper end to the peripheral ridge 3 at the lower end of this notch 14. The channel recess 6 of the plate 2b has one of refrigerant inlet-outlet through holes 10, 10 formed at one end thereof and the other through hole 10 formed at the other end thereof.

The flat plate 2a, on the other hand, has no U-shaped recess nor any channel dividing U-shaped ridge but has a flat surface and the same contour as the ridge plate 2b. The plate 2a is provided at the widthwise midportion of its upper end with a notch which is U-shaped when seen from the front. The flat plate 2a further has refrigerant inlet-outlet through holes formed in its upper end at front and rear sides thereof (not shown).

Such flat plates 2a and ridged plates 2b are provided in pairs, with each pair of plates fitted together face-to-face. The peripheral ridge 3 on the ridged plate 2b has its top end joined to the flat surface of the peripheral edge portion of the flat plate 2a, with the top end of the central ridge 4 joined to the flat surface of the central portion of the flat plate 2a, and with the top ends of the ridges 5 joined to the corresponding flat surface portions of the flat plate 2a, whereby a flat tube 12 is formed which has a U-shaped refrigerant channel 8, with a plurality of divided refrigerant passageways 7 formed in the channel 8.

The evaporator 1 comprising flat plates 2a described is the same as the first embodiment otherwise; for example, the ridged plate 2b is made as by forging or cutting. Throughout the drawings concerned, therefore, like parts are designated by like reference numerals.

The evaporator 1 comprises ridged plates 2b having a peripheral ridge 3, central ridge 4 and channel dividing ridges 5, and flat plates 2a having the same contour as the plate 2b. This serves to halve the number of ridged plates 2b used which are prepared as by forging or cutting, consequently entailing the advantage of making the evaporator 1 easy to fabricate.

The evaporator 1 can be modified as will be described below which is the second embodiment of the invention shown in FIGS. 11 and 12 and wherein a pair of front and rear header members 41, 42 used are each in the form of a pipe of rectangular cross section.

Like the modification shown in FIGS. 18 and 19, the first of modifications has a multiplicity of channel diving ridges 5a, 5b formed in the channel recess 6 of each plate 2, comprising straight portions 5a1, 5b1 and quarter circular-arc portions 5a2, 5b2 extending therefrom, and having exactly half of a U-shape and a height twice the depth of the recess 6. When a pair of plates 2a, 2b are fitted together face-to-face, a flat tube 12 is formed wherein the ridges 5a, 5b form independent parallel U-shaped divided refrigerant passageways 7 in a U-shaped refrigerant channel 8. The ridges 5a, 5b of each plate 2 have their top ends joined to the bottom wall flat surface of the recess 6 of the other plate 2 opposed to the ridges.

Like the modification shown in FIGS. 20 and 21, two kinds of plates 2a, 2b can be used in the second modification to be described below. The plates 2a, 2b have channel dividing U-shaped ridges 5a, 5b which are different in arrangement in refrigerant channel recesses 6, 6, and have a height twice the depth of the recesses 6, 6. In this case, the ridges 5a, 5b on each of the plates 2a, 2b have their top ends joined to the bottom wall flat surface of the recesses 6 the other of these plates 2b, 2a opposed thereto.

As is the case with the embodiment shown in FIGS. 22 and 23, usable in a third modification are plates 2 which have a multiplicity of channel dividing ridges 5 formed only in the rear half of the refrigerant channel recess 6. The front half of the recess 6 has no ridges whatever and is flat-surfaced. In this case, the ridges 5 on each plate 2 have their top ends joined to the bottom wall flat surface of the recess 6 of the other plate 2 opposed thereto.

As is the case with the flat tube shown in FIG. 24, usable in a fourth modification in combination with a ridged plate 2b which is the plate 2 of the second embodiment of FIG. 12 is a flat plate 2a having the same contour as the plate 2b. In this case, the peripheral ridge 3 on the ridged plate 2b has its top end joined to the flat surface of the peripheral edge portion of the flat plate 2a, with the top end of the central ridge 4 joined to the flat surface of the central portion of the flat plate 2a and with the top ends of the channel dividing ridges 5 joined to the corresponding flat surface portions of the flat plate 2a, whereby a flat tube 12 is provided wherein a plurality of U-shaped divided refrigerant passageways 7 are formed in a refrigerant channel 8.

Although not shown, the evaporator 1 of the third embodiment of the invention wherein the upper and lower headers 57, 58 are provided may comprise the pair of front and rear header members 41, 42 each in the form of a rectangular pipe and shown in FIGS. 11 and 12, in place of the spectacle-shaped upper and lower header members 51, 52 shown in FIGS. 16 and 17.

The evaporator thus modified will be referred to a fourth embodiment of the invention. The evaporator 1 according to the fourth embodiment of the invention will be described using reference numerals of FIGS. 11 and 12.

Each of plates 2 in pairs has straight side edge ridges 33, 33 provided on one side of the plate along opposite side edges thereof and a central ridge 34 provided on the same side of the plate at the center of the width thereof and having bifurcated upper and lower ends 34a, 34a, the ridges being formed by forging or cutting, each plate 2 having front and rear straight channel recess portions 36a, 36a formed inwardly of the side edge ridges on opposite sides of the central ridge 34, each plate 2 having a flat surface on the other side thereof, each of the pairs of plates being fitted together with their front and rear channel recess portions 36a, 36b opposed to each other to join the opposed straight side edge ridges 33, 33 to each other end-to-end and the opposed central ridges 34, 34 including the bifurcated upper and lower ends 34a, 34a to each other end-to-end and to thereby form a flat tube 32 having bifurcated open upper and lower ends and front and rear straight fluid channels 38, 38 inside thereof, an upper and a lower pair of front and rear header members 41, 42 being each in the form of a pipe having a rectangular cross section, each of the header members 41, 42 having slits 44, 44 formed in an upper wall 47 or a lower wall thereof 43 and arranged at a predetermined spacing, a plurality of flat tubes 32 being arranged in parallel by inserting the bifurcated upper or lower ends thereof into the respective slits 44, 44 in the header members 41, 42 to join the flat tubes to the header members and to provide an upper and a lower pair of front and rear headers in communication with the bifurcated upper and lower ends of the flat tubes 32 respectively. At this time, the rear wall 46 and the front wall 45 of the respective juxtaposed front and rear header members 41, 42 are fitted as joined together into U-shaped notches 37, 37 in the upper ends of the opposed plates 2, 2 of each flat tube 32.

Described below are modifications of the evaporator 1 of the third embodiment of the invention wherein the upper and lower headers 57, 58 are provided by the spectacle-shaped upper and lower header members 51, 52 and the evaporator 1 of the fourth embodiment of the invention wherein the upper and lower headers are provided by pairs of front and rear header members 41, 42 in the form of rectangular pipes.

Like the embodiment shown in FIGS. 18 and 19, usable for a first modification are plates 2, 2a, 2b each having formed in respective front and rear refrigerant channel recess portions 6a, 6b thereof many front and rear channel dividing ridges 5a, 5b having a height twice the depth of the recess portions 6a, 6b. These ridges 5a, 5b are so provided as to form parallel divided independent refrigerant passageways 7 in a refrigerant channel 8 in a flat tube 12 when each of pairs of plates 2a, 2b are fitted together face-to-face. In this case, the channel dividing ridges 5a, 5b of each of the plates 2a, 2b have their top ends joined to the bottom wall flat surface of recess portions 6a, 6b of the other plate 2a or 2b opposed thereto.

Like the embodiment shown in FIGS. 20 and 21, two kinds of plates 2a, 2b are usable for a second modification. These plates 2a, 2b are different in the arrangement of straight channel dividing ridges 5a, 5b which are provided in refrigerant channel recesses 6, 6 and which have a height twice the depth of the recesses 6, 6. In this case, the straight channel dividing ridges 5a, 5b on each of the plates 2a, 2b have their top ends joined to the bottom wall flat surface of recess portion of the other plate 2a or 2b opposed thereto.

As is the case with the embodiment shown in FIGS. 22 and 23, usable in a third modification are plates 2 which have a multiplicity of channel dividing straight ridges 5 formed only in the rear half of the refrigerant channel recess 6. The front half of the recess 6 has no ridges whatever and is flat-surfaced. In this case, the straight ridges 5 on one plate 2 have their top ends joined to the bottom wall flat surface of the recess 6 of the other plate 2 opposed thereto.

As in the case of the flat tube shown in FIG. 24, usable in a fourth modification in combination with a ridged plate 2b is a flat plate 2a having the same contour as the plate 2b. In this case, the side edge ridges 3, 33 on the ridged plate 2b have their top ends joined to the flat surface of the side edge portions of the flat plate 2a, with the top end of the central ridge 4, 34 joined to the flat surface of the central portion of the flat plate 2a and with the top ends of the channel dividing straight ridges 5 joined to the corresponding flat surface portions of the flat plate 2a, whereby a flat tube 12, 32 is provided which has front and rear straight refrigerant channel 8, 38 formed in the tube and a plurality of divided refrigerant passageways 7 formed in the refrigerant channel 8, 38.

Although the heat exchanger 1 of the present invention has been described with reference to embodiments for use as evaporators for motor vehicle air conditioners, the present invention can be applied also to heat changers for use in motor vehicles or in industries, such as evaporators, condensers, oil coolers, intercoolers, heater cores, etc.

In the case where the heat exchanger 1 of the invention is to be used, for example, as a heater heat exchanger for heating systems, efficient heat exchange is available since the entire width of the channel for the fluid is equal to the contact width of the radiator fin 24. Furthermore, the internal fluid can be passed in a counterflow relation with air. This results in an increased temperature efficiency to achieve higher heat exchanger effectiveness and realize a compacted device.

CLAIMS

1. A heat exchanger comprising pairs of plates with each plate of the pairs having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending downward from an upper end of the plate to a position where a return channel can be formed, the ridges being formed by forging or cutting, each plate of said pairs having a U-shaped channel recess formed inwardly of the peripheral ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, the channel recess having one of two fluid inlet-outlet through holes formed at one end thereof and the other through hole formed at the other end thereof, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their U-shaped channel recesses opposed to each other to join the opposed peripheral ridges to each other end-to-end and the opposed central ridges to each other end-to-end and to thereby form a flat tube having a U-shaped fluid channel inside thereof so that a plurality of flat tubes are arranged in parallel with a header member interposed between upper ends of each pair of

adjacent flat tubes to provide a front and a rear header in communication with the upper ends of the said pair of adjacent flat tubes, the header member comprising a pair of front and rear fluid passing tube portions in communications with the respective inlet-outlet through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

2. A heat exchanger comprising pairs of plates with each plate of the pairs having an edge ridge U-shaped in its entirety and provided on one side of the plate along opposite side edges and a lower edge thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper end, the central ridge extending from the upper end downward to a position where a return channel can be formed, the ridges being formed by forging or cutting, each plate of said pairs having a U-shaped channel recess formed inwardly of the U-shaped edge ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their U-shaped channel recesses opposed to each other to join the opposed U-shaped edge ridges to each other end-

to-end and the opposed central ridges including the bifurcated upper ends to each other end-to-end and to thereby form a flat tube having bifurcated open upper ends and a U-shaped fluid channel inside thereof, a pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated open upper ends thereof into the respective slits in the front and rear header members to join the flat tubes to the header members and to provide a front and a rear header in communication with the bifurcated open upper ends of the flat tubes.

3. A heat exchanger according to claim 1 or 2 wherein a plurality of channel dividing U-shaped ridges are formed in the U-shaped channel recess of each plate by forging or cutting, and each said pair of plates are fitted together with the recesses thereof opposed to each other and with each of opposed pairs of channel dividing U-shaped ridges joined to each other end-to-end to form a plurality of U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

4. A heat exchanger according to claim 1 or 2 wherein each plate of said pairs has formed in the channel recess

thereof front and rear channel dividing ridges having a height twice the depth of the channel recess and each comprising a straight portion positioned in the front or rear straight channel recess portion of the channel recess and a quarter circular-arc portion extending from a lower end of the straight portion and positioned in the return portion of the channel recess, the channel dividing ridges being formed by forging or cutting and positioned alternately when each of said pairs of plates are fitted together with their channel recesses opposed to each other, each of said pairs of plates being fitted together with their channel recesses opposed to each other to join top ends of the front and rear channel dividing ridges to a bottom wall flat surface of the plate providing the channel recess and opposed thereto and to thereby form U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

5. A heat exchanger according to claim 1 or 2 wherein each plate of said pairs has formed in the channel recess thereof channel dividing ridges having a height twice the depth of the channel recess and formed by forging or cutting so as to be positioned alternately, when each of said pairs fitted together with the recesses thereof opposed to each other, each of said pairs of plates being fitted together to join top ends of the channel dividing

ridges on each plate of the pair to a flat surface of bottom wall of the channel recess of the other plate opposed to said each plate and to thereby form U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

6. A heat exchanger according to claim 1 or 2 wherein each plate of said pairs has formed in a rear half of the channel recess thereof channel dividing ridges having a height twice the depth of the channel recess and formed by forging or cutting, the channel recess of each plate having a front half in the form of a flat surface provided by a bottom wall thereof and having no channel dividing ridges, each of said pairs of plates being fitted together with the recesses thereof opposed to each other to join top ends of the channel dividing ridges thereof to the bottom wall flat surface of the channel recess of the plate opposed to the dividing ridges and to thereby form U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

7. A heat exchanger comprising ridged plates each having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending downward from an upper end of the plate to a position where a return channel can be

formed, the ridges being formed by forging or cutting, each of the ridged plates having a U-shaped channel recess formed inwardly of the peripheral ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, the channel recess having one of two fluid inlet-outlet through holes formed at one end thereof and the other through hole formed at the other end thereof, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate and two fluid inlet-outlet through holes corresponding to said through holes, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having a U-shaped fluid channel inside thereof is formed so that a plurality of flat tubes are arranged in parallel with a header member interposed between upper ends of each pair of adjacent flat tubes to provide a front and a rear header in communication with the upper ends of the said pair of adjacent flat tubes, the header member comprising a pair of front and rear fluid passing tube portions in communications with the respective inlet-outlet through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

8. A heat exchanger comprising ridged plates each having an edge ridge U-shaped in its entirety and provided on one side of the plate along opposite side edges and a lower edge thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper end, the central ridge extending from the upper end downward to a position where a return channel can be formed, the ridges being formed by forging or cutting, each of the ridged plates having a U-shaped channel recess formed inwardly of the U-shaped edge ridge and comprising a front and a rear channel recess portion formed on opposite sides of the central ridge and a return channel recess portion positioned under the central ridge, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate including the bifurcated upper ends having a top end thereof joined to a flat

surface of a corresponding central portion of the flat plate, whereby a flat tube having bifurcated open upper ends and a U-shaped fluid channel inside thereof is formed, a pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated open upper ends thereof into the respective slits in the front and rear header members to join the flat tubes to the header members and to provide a front and a rear header in communication with the bifurcated open upper ends of the flat tubes.

9. A heat exchanger according to claim 7 or 8 wherein a plurality of channel dividing U-shaped ridges are formed in the U-shaped channel recess of each ridged plate by forging or cutting, and each ridged plate and each flat plate are fitted together face-to-face with the channel dividing U-shaped ridges of the ridged plate joined to the flat surface of the corresponding central portion of the flat plate to form a plurality of U-shaped divided fluid passageways in the U-shaped fluid channel inside the flat tube.

10. A heat exchanger comprising pairs of plates with each plate of the pairs having a peripheral ridge provided

on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending vertically, the ridges being formed by forging or cutting, each plate of said pairs having a front and a rear channel recess portion formed inwardly of the peripheral ridge on opposite sides of the central ridge, each of the front and rear channel recess portions having a through hole formed in each of upper and lower ends thereof, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their channel recess portions opposed to each other to join the opposed peripheral ridges to each other end-to-end and the opposed central ridges to each other end-to-end and to thereby form a flat tube having a front and a rear fluid channel inside thereof so that a plurality of flat tubes are arranged in parallel with an upper and a lower header member interposed respectively between upper ends of each pair of adjacent flat tubes and between lower ends thereof to provide an upper and a lower header in communication with the upper ends and the lower ends of said pair of adjacent flat tubes, each of the header members comprising a pair of front and rear fluid passing tube portions in communications with the corresponding through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

11. A heat exchanger comprising pairs of plates with each plate of the pairs having a side edge ridge provided on one side of the plate along each of opposite side edges thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper and a bifurcated lower end, the ridges being formed by forging or cutting, each plate of said pairs having a front and a rear channel recess portion formed inwardly of the side edge ridges on opposite sides of the central ridge, each plate of said pairs having a flat surface on the other side thereof, each of said pairs of plates being fitted together with their channel recess portions opposed to each other to join the opposed side edge ridges to each other end-to-end and the opposed central ridges including the bifurcated upper and lower ends to each other end-to-end and to thereby form a flat tube having bifurcated open upper and lower ends and a front and a rear fluid channel inside thereof, an upper pair of front and rear header members and a lower pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in an upper wall or a lower wall thereof and arranged at a predetermined

spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated upper or lower ends thereof into the respective slits in the header members to join the flat tubes to the header members and to provide an upper pair of front and rear headers and a lower pair of front and rear headers in communication with the bifurcated upper and lower ends of the flat tubes respectively.

12. A heat exchanger according to claim 10 or 11 wherein a plurality of channel dividing ridges are formed in the front and rear channel recess portions of each plate by forging or cutting, and each of said pairs of plates are fitted together with their recess portions opposed to each other to join each of opposed pairs of the channel dividing ridges to each other end-to-end and form divided fluid passageways in the front and rear fluid channels inside thereof.

13. A heat exchanger according to claim 10 or 11 wherein each plate has formed in the respective front and rear channel recess portions thereof front and rear channel dividing ridges having a height twice the depth of the recess portion, the front and rear channel dividing ridges being formed by forging or cutting and positioned alternately when each of said pairs of plates are fitted together with their recess portions opposed to each other,

each of said pairs of plates being fitted together face-to-face to join top ends of the front and rear channel dividing ridges to a bottom wall flat surface of recess portion of the plate opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

14. A heat exchanger according to claim 10 or 11 wherein each plate of the pairs has formed in each of the front and rear channel recess portions thereof a channel dividing ridge having a height twice the depth of the recess portion, the channel dividing ridge being so formed by forging or cutting that the front and rear channel dividing ridges of each pair of plates as fitted together face-to-face are positioned alternately, each pair of plates being fitted together with their recess portions opposed to each other to join top ends of the front and rear channel dividing ridges of each plate of the pair to a bottom wall flat surface of the recess portion of the other plate of the pair opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

15. A heat exchanger according to claim 10 or 11 wherein each plate has formed in one of the front and rear channel recess portions thereof a plurality of channel dividing ridges having a height twice the depth of the

recess portion, the channel dividing ridges being formed by forging or cutting, the other channel recess portion having a bottom wall flat surface having no channel dividing ridges, each of said pairs of plates being fitted together with their recess portions opposed to each other to join top ends of the channel dividing ridges to the bottom wall flat surface of the recess portion of the plate opposed thereto and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

16. A heat exchanger comprising ridged plates each having a peripheral ridge provided on one side of the plate along a periphery thereof and a central ridge provided on said one side of the plate at a center of the width thereof and extending vertically, the ridges being formed by forging or cutting, each the ridged plates having a front and a rear channel recess portion formed inwardly of the peripheral ridge on opposite sides of the central ridge, each of the front and rear channel recess portions having a through hole formed in each of upper and lower ends thereof, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate and fluid inlet-outlet through holes corresponding

to said through holes, the peripheral ridge of the ridged plate having a top end thereof joined to a peripheral edge of the flat plate, the central ridge of the ridged plate having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having a front and a rear fluid channel inside thereof is formed so that a plurality of flat tubes are arranged in parallel with an upper and a lower header member interposed respectively between upper ends of each pair of adjacent flat tubes and between lower ends thereof to provide an upper and a lower header in communication with the upper ends and the lower ends of said pair of adjacent flat tubes, each of the header members comprising a pair of front and rear fluid passing tube portions in communications with the corresponding through holes of the plates of said pair of adjacent flat tubes and a connecting portion between the tube portions.

17. A heat exchanger according to claim 16 wherein the connecting portion of one of the upper and lower header members interposed between the upper ends and lower ends of each pair of adjacent flat tubes has a passage interconnecting the fluid passing tube portions of the header member.

18. A heat exchanger comprising ridged plates each having a side edge ridge provided on one side of the plate

along each of opposite side edges thereof and a central ridge provided on said one side of the plate at a center of the width thereof and having a bifurcated upper and a bifurcated lower end, the ridges being formed by forging or cutting, each of the ridged plates having a front and a rear channel recess portion formed inwardly of the side edge ridges on opposite sides of the central ridge, each of the ridged plates having a flat surface on the other side thereof and being fitted to each of flat plates face-to-face, each of said flat plates having the same contour and the same size as the ridged plate, the side edge ridges of the ridged plate having top ends thereof joined to side edges of the flat plate, the central ridge of the ridged plate including the bifurcated upper and lower ends having a top end thereof joined to a flat surface of a corresponding central portion of the flat plate, whereby a flat tube having bifurcated open upper and lower ends and a front and a rear fluid channel inside thereof is formed, an upper pair of front and rear header members and a lower pair of front and rear header members being each in the form of a pipe having a rectangular cross section, each of the header members having slits formed in an upper wall or a lower wall thereof and arranged at a predetermined spacing, a plurality of flat tubes being arranged in parallel by inserting the bifurcated upper or lower ends thereof into the respective slits in the header members to join the flat tubes to the header members and to provide an upper pair of front and rear headers and a lower pair of front and rear headers in communication with the bifurcated upper and lower ends of the flat tubes respectively.

19. A heat exchanger according to claim 16 or 18 wherein each of the ridged plates has channel dividing ridges formed in the respective front and rear channel recess portions thereof by forging or cutting, and each ridged plate is fitted to each flat plate face-to-face to join top ends of the channel dividing ridges to a flat surface of a corresponding portion of the flat plate and to thereby form divided fluid passageways in the front and rear fluid channels inside the flat tube.

20. A heat exchanger according to any one of claims 1, 7, 10 and 16 wherein the header member interposed between the ends of each pair of adjacent flat tubes has its fluid passing tube portions joined at their opposite end faces to the flat surfaces on the other sides of the opposed plates of the pair of flat tubes.

21. A heat exchanger according to in any one of claims 1, 7, 10 and 16 wherein tacks for temporarily holding the header member are provided respective edges defining the inlet-outlet through holes in the end of each plate.

22. A heat exchanger according to any one of claims 3 to 6, 9, 12 to 15 and 19 wherein a plurality of cutouts are formed in the channel dividing ridges on each plate to cause the adjacent divided fluid passageways inside the flat tube to communicate with each other through the cutouts.

23. A heat exchanger according to any one of claims 1, 2, 7, 8, 10, 11,16 and 18 wherein a fin is provided between each pair of adjacent flat tubes included in the flat tubes arranged in parallel, and the fin has opposite sides edges thereof joined to the flat surfaces on the other sides of the plates of the pair of flat tubes.

Fig.1

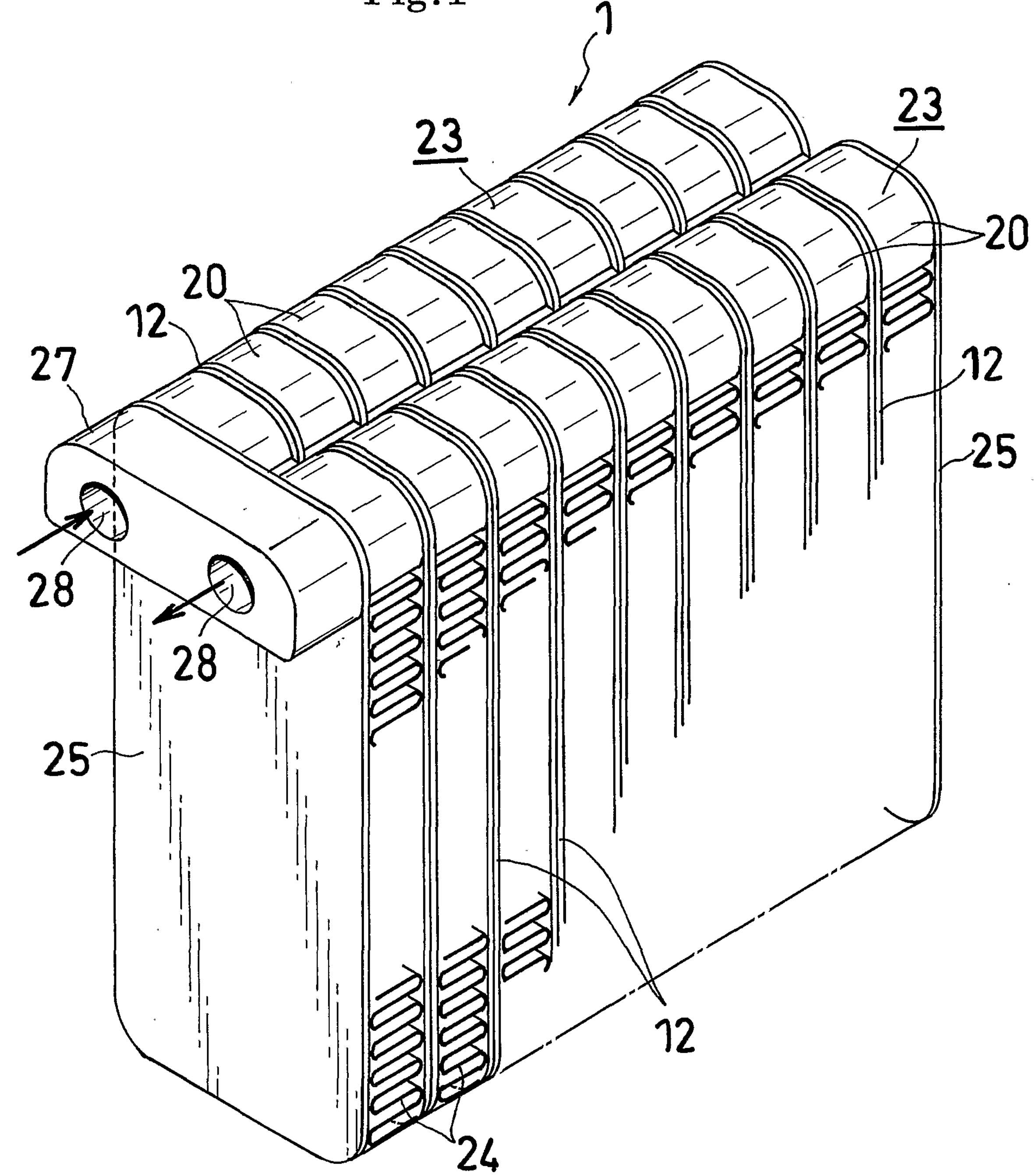


Fig.2

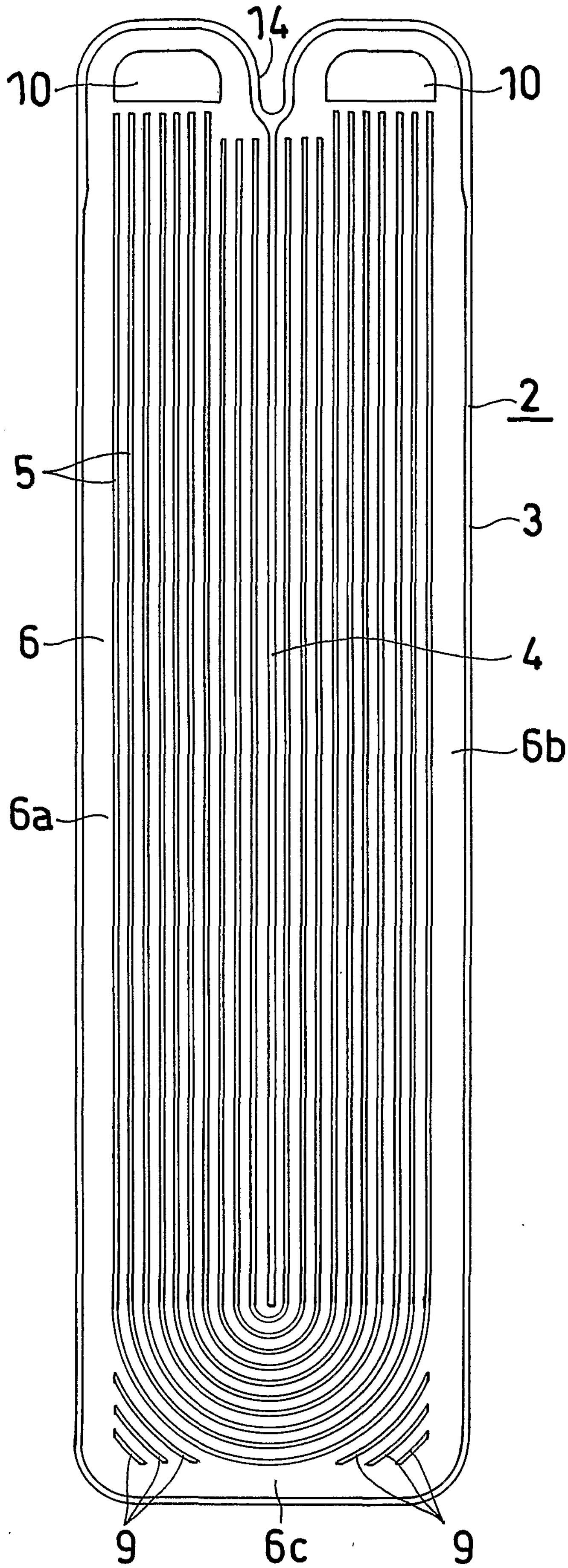


Fig.3

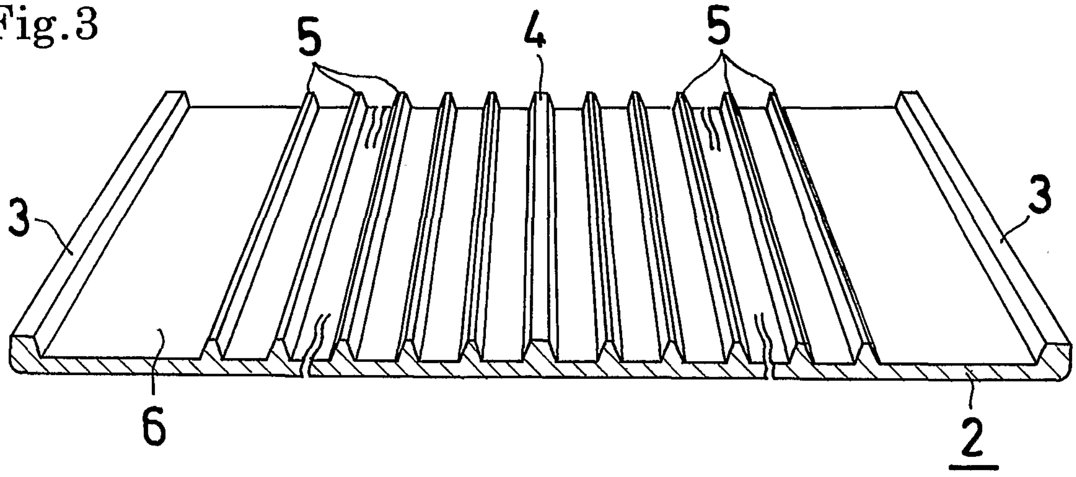
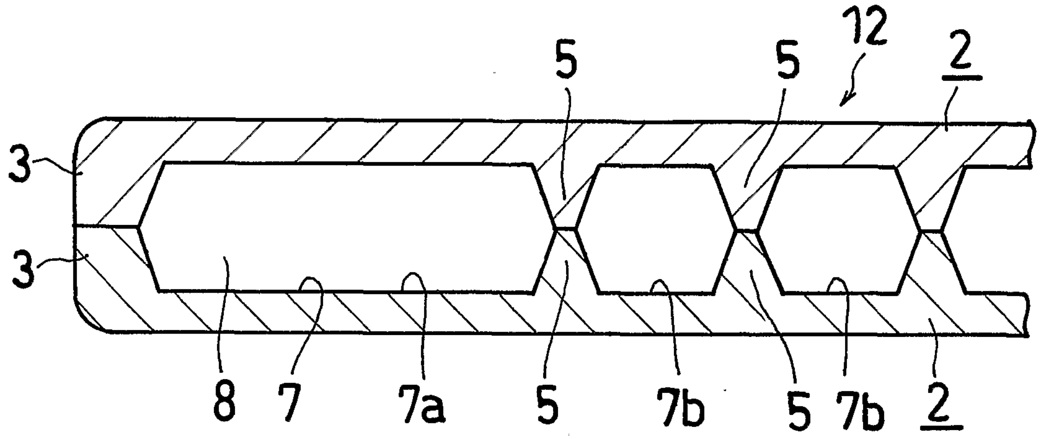


Fig.5



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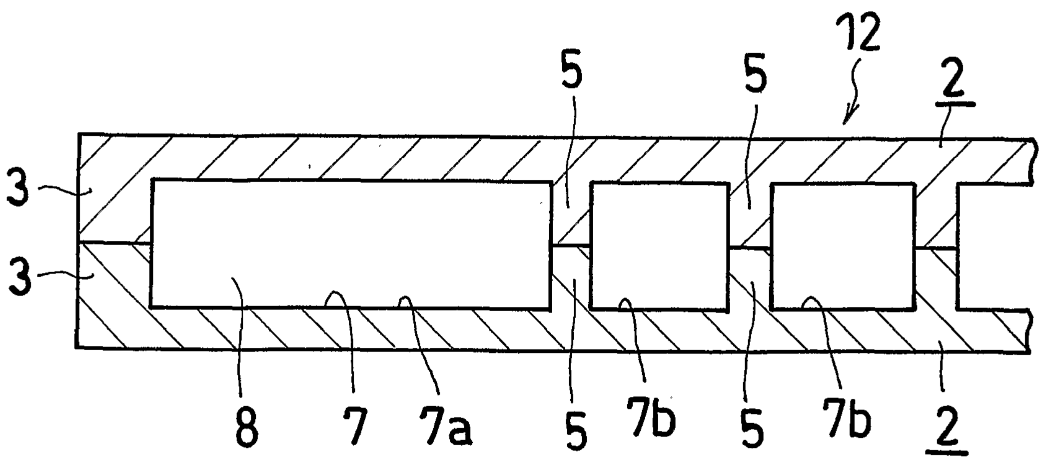
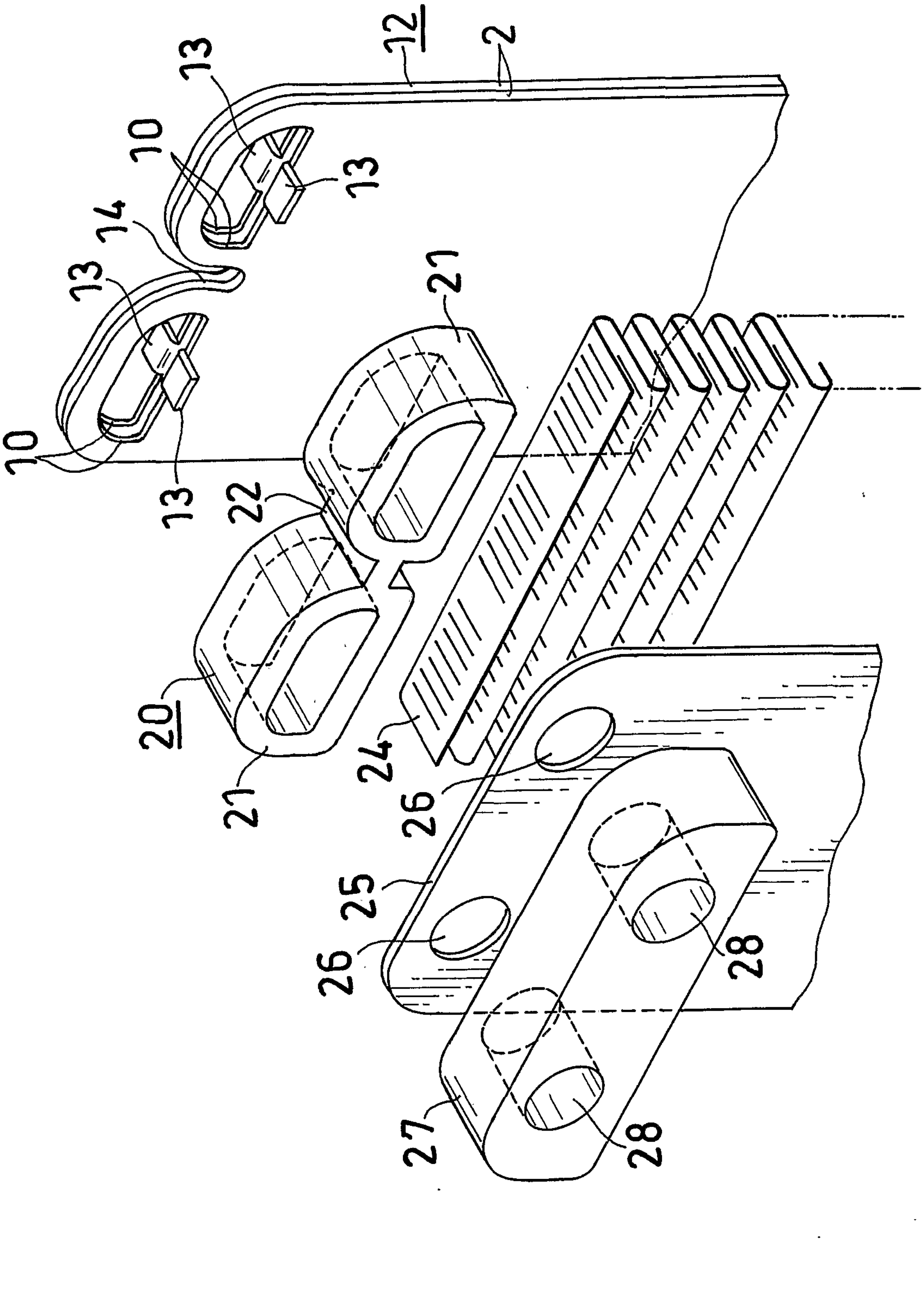


Fig.4



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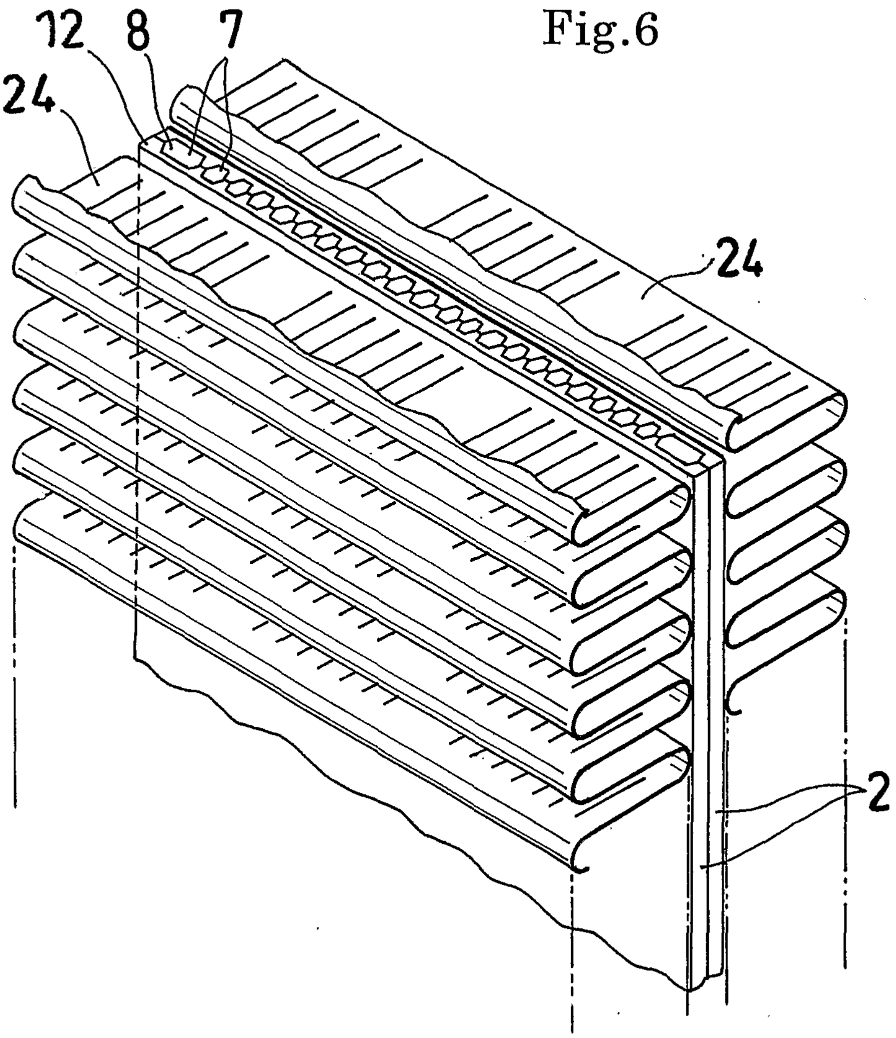

Fig.9

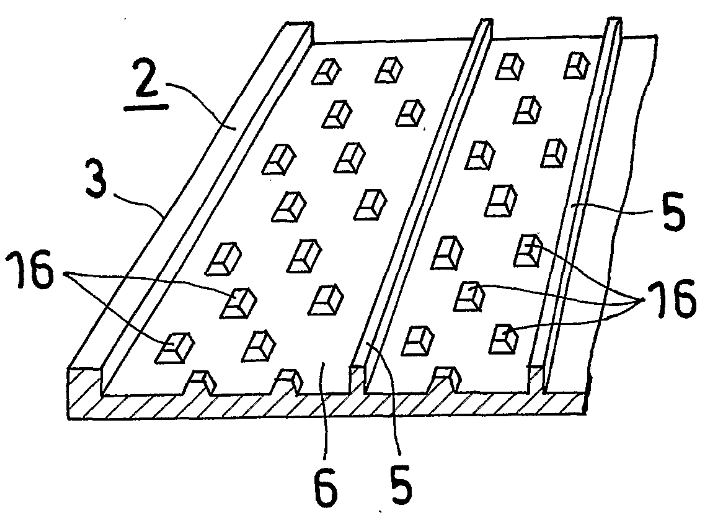

Fig.8

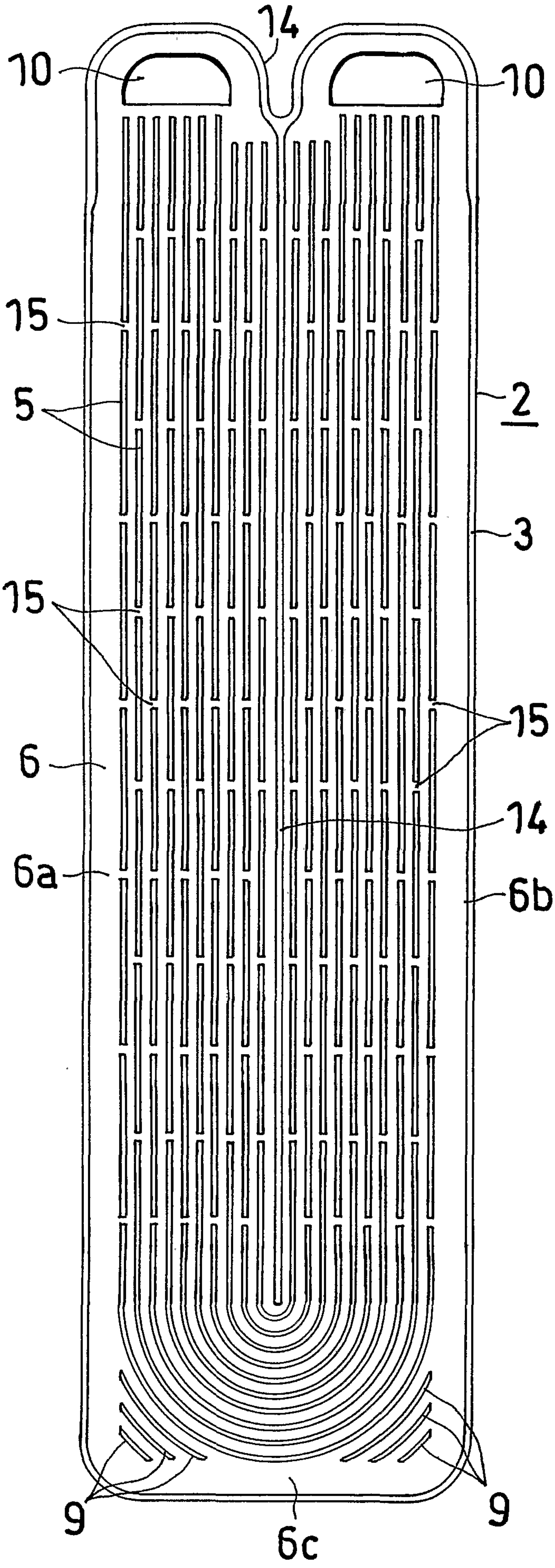

Fig.10

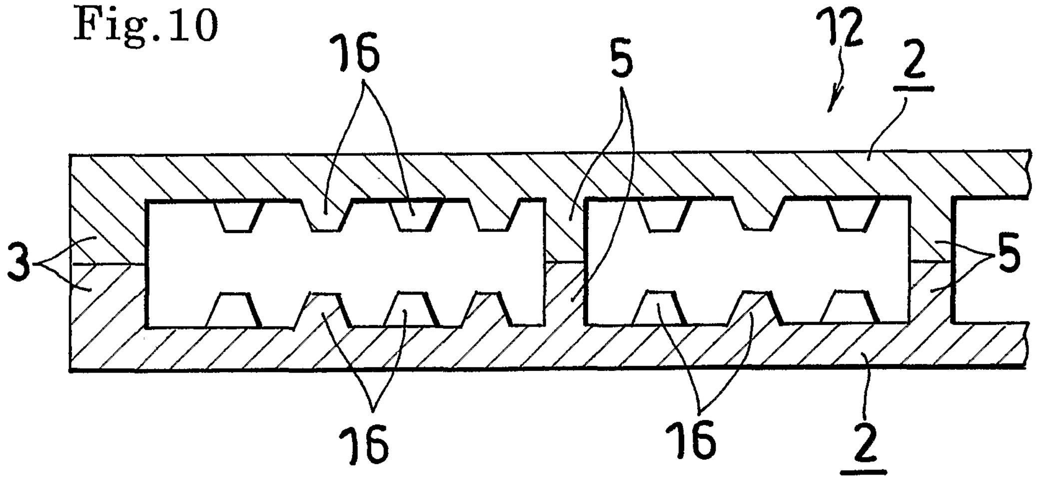
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Fig.11

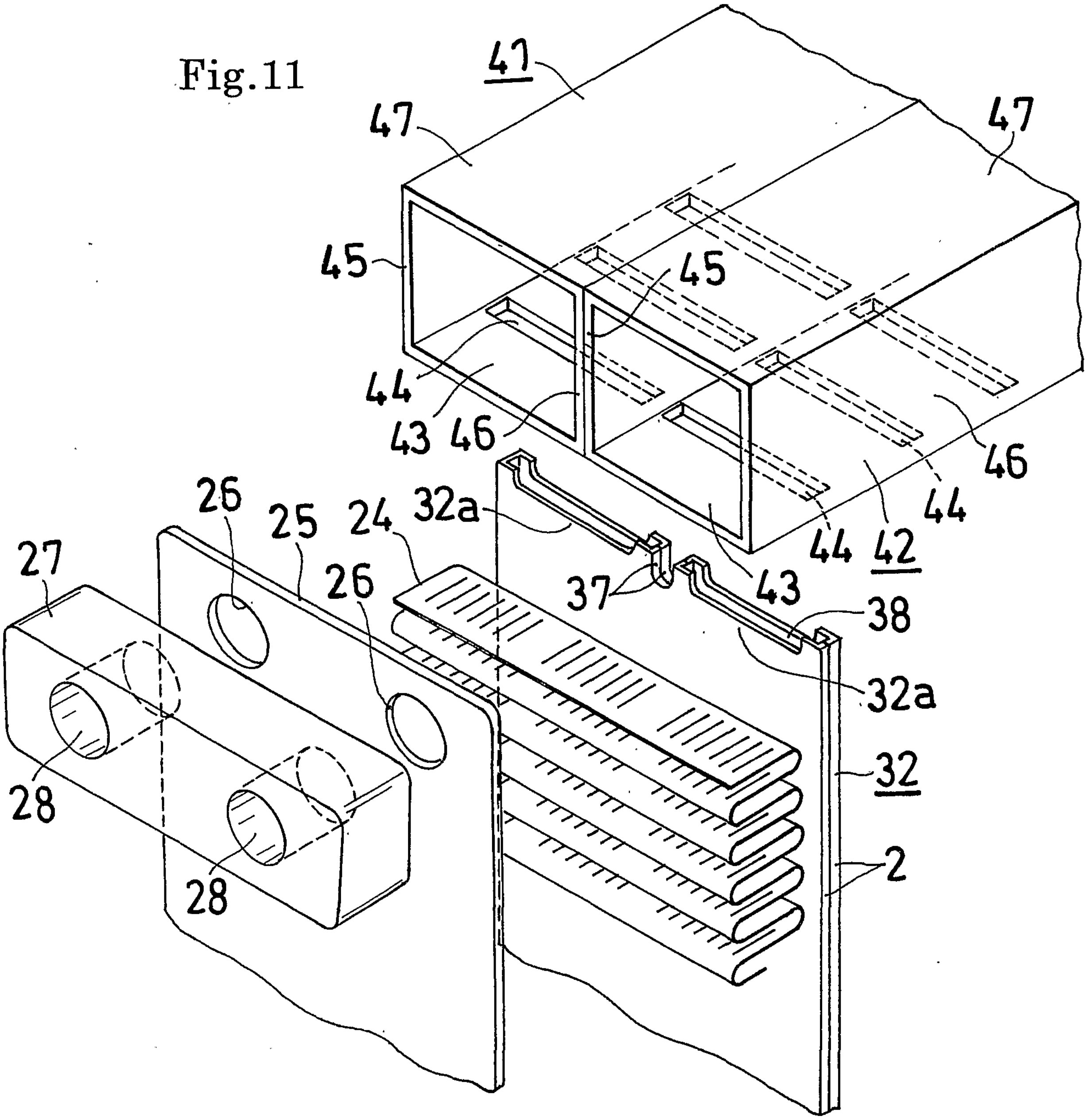
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Fig.12

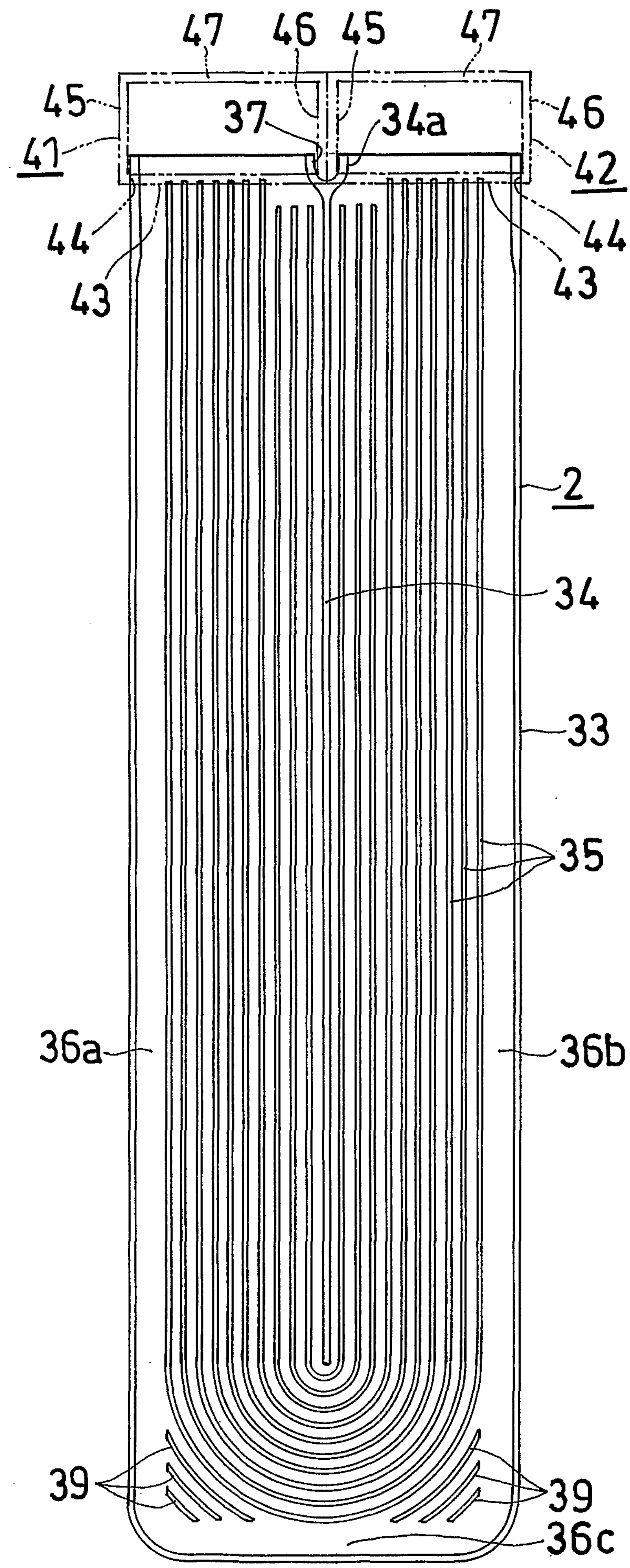


Fig.13

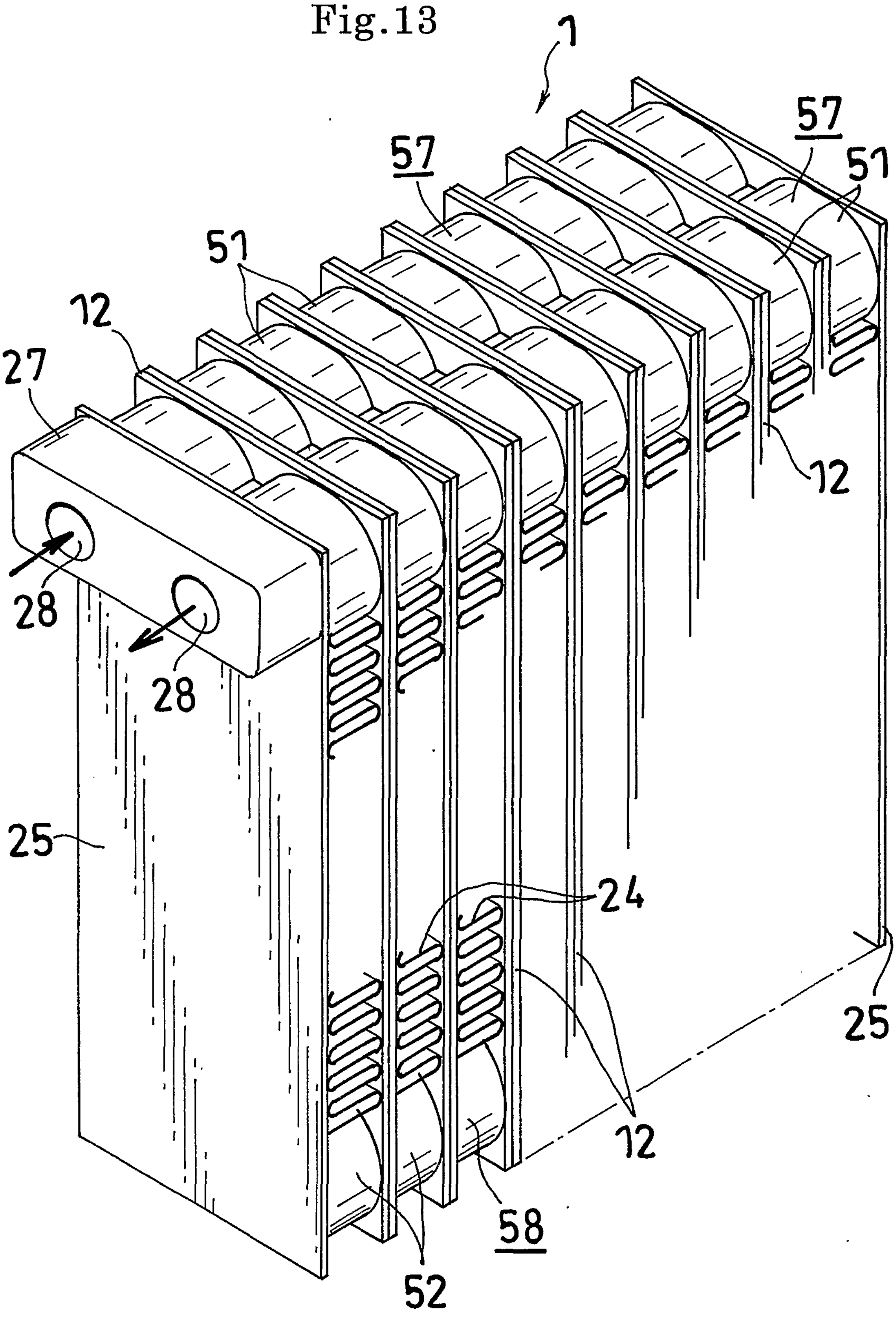


Fig.14

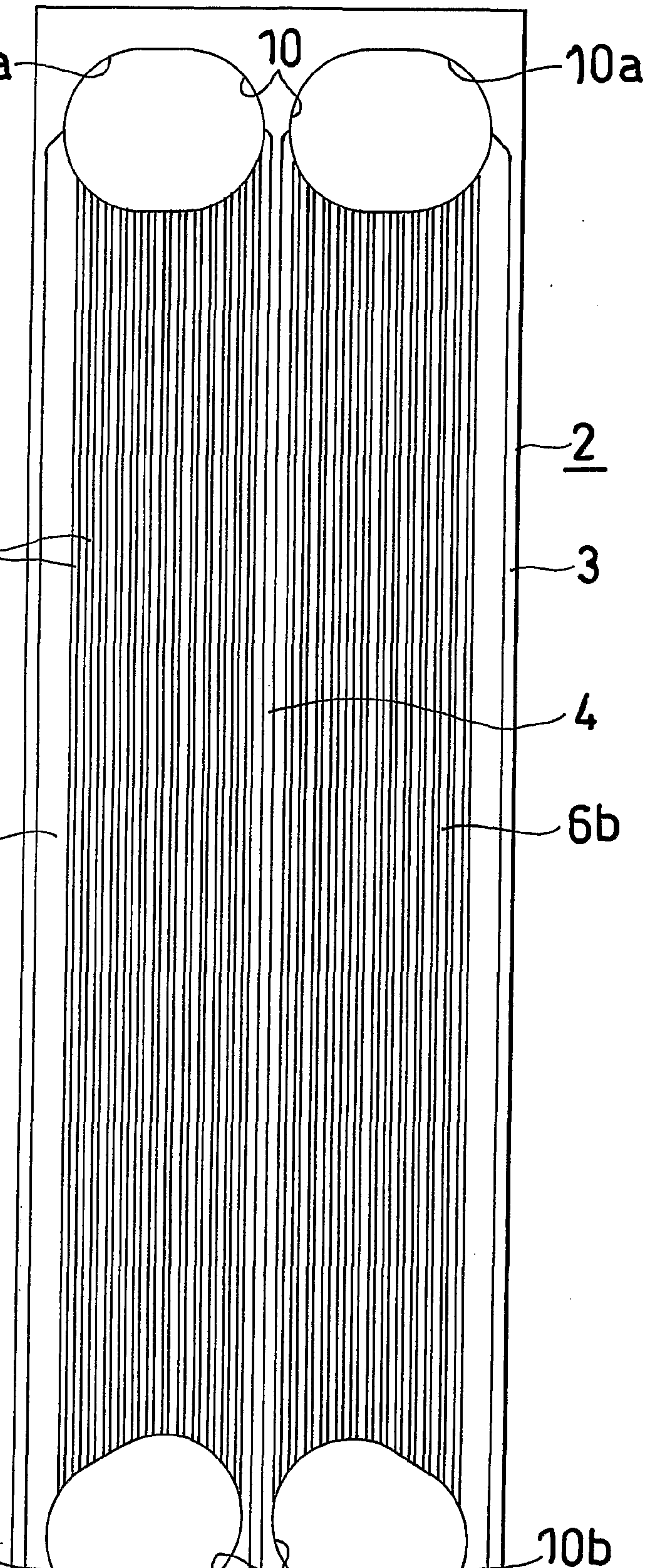


Fig.15

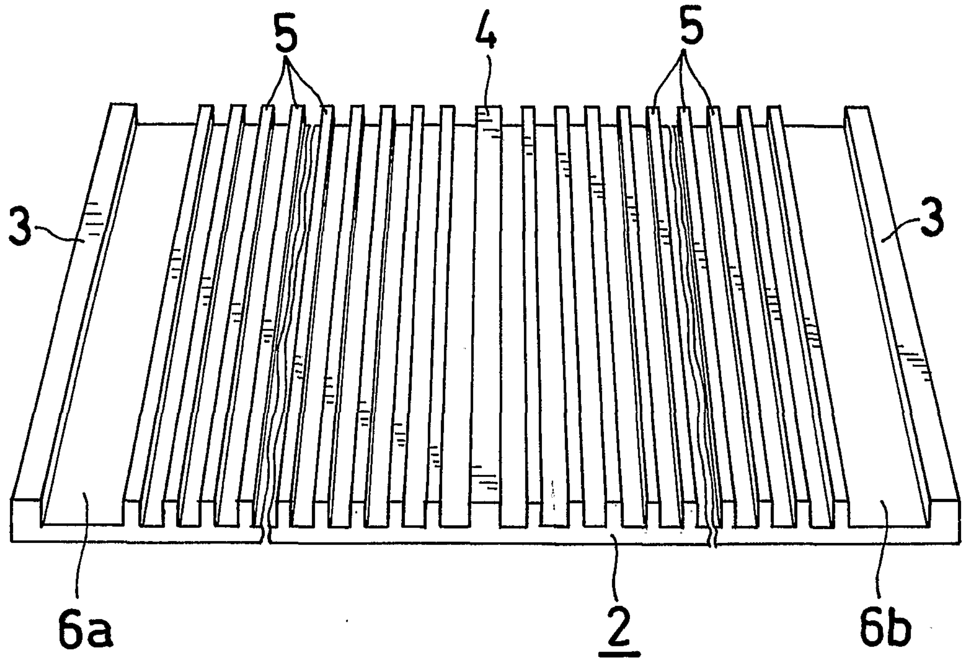


Fig.19

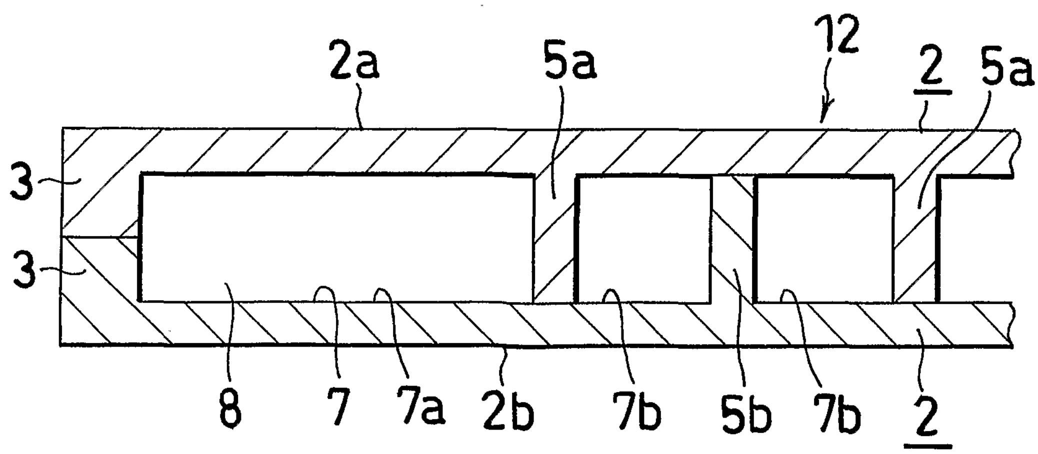


Fig.16

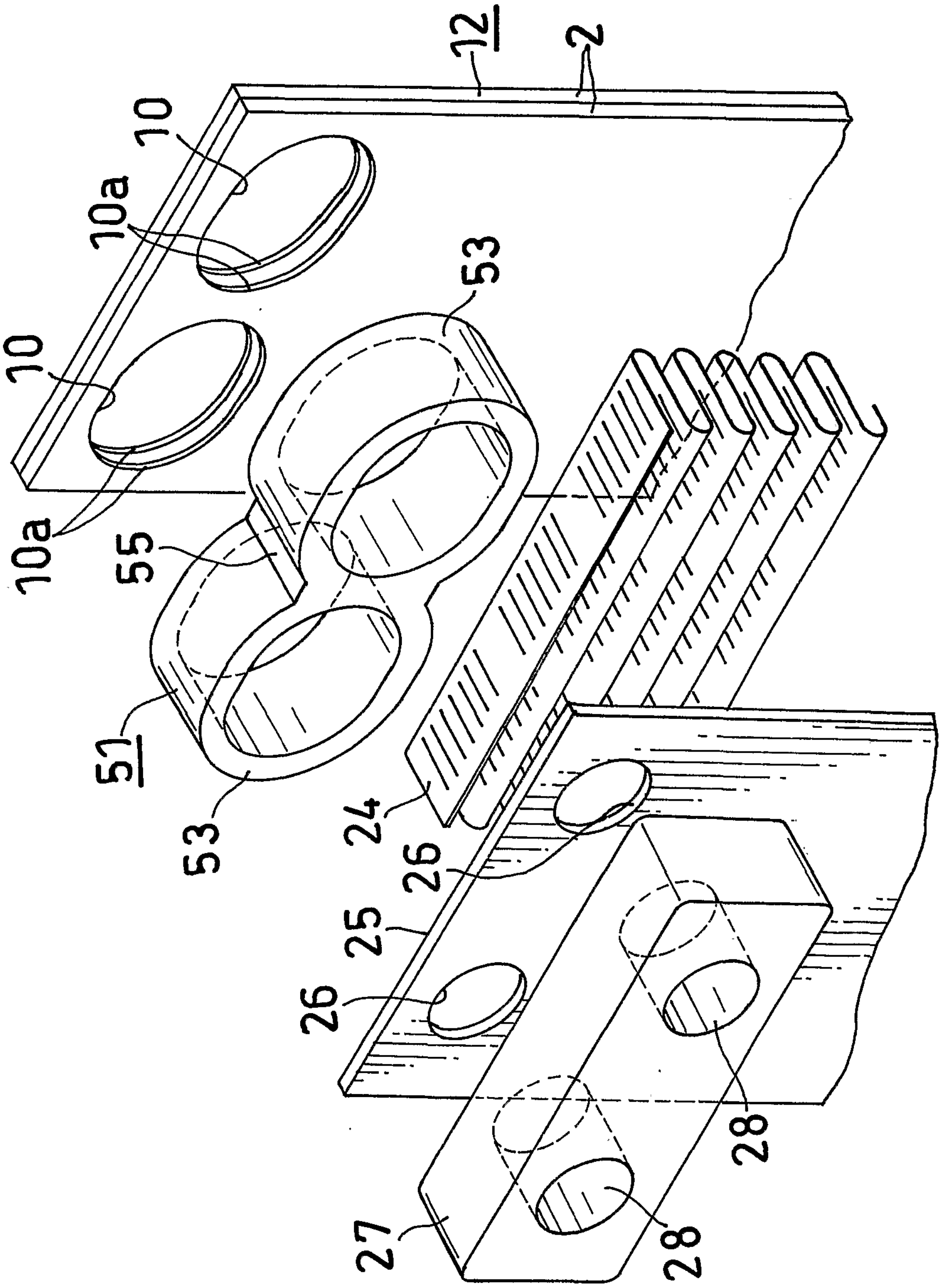


Fig.17

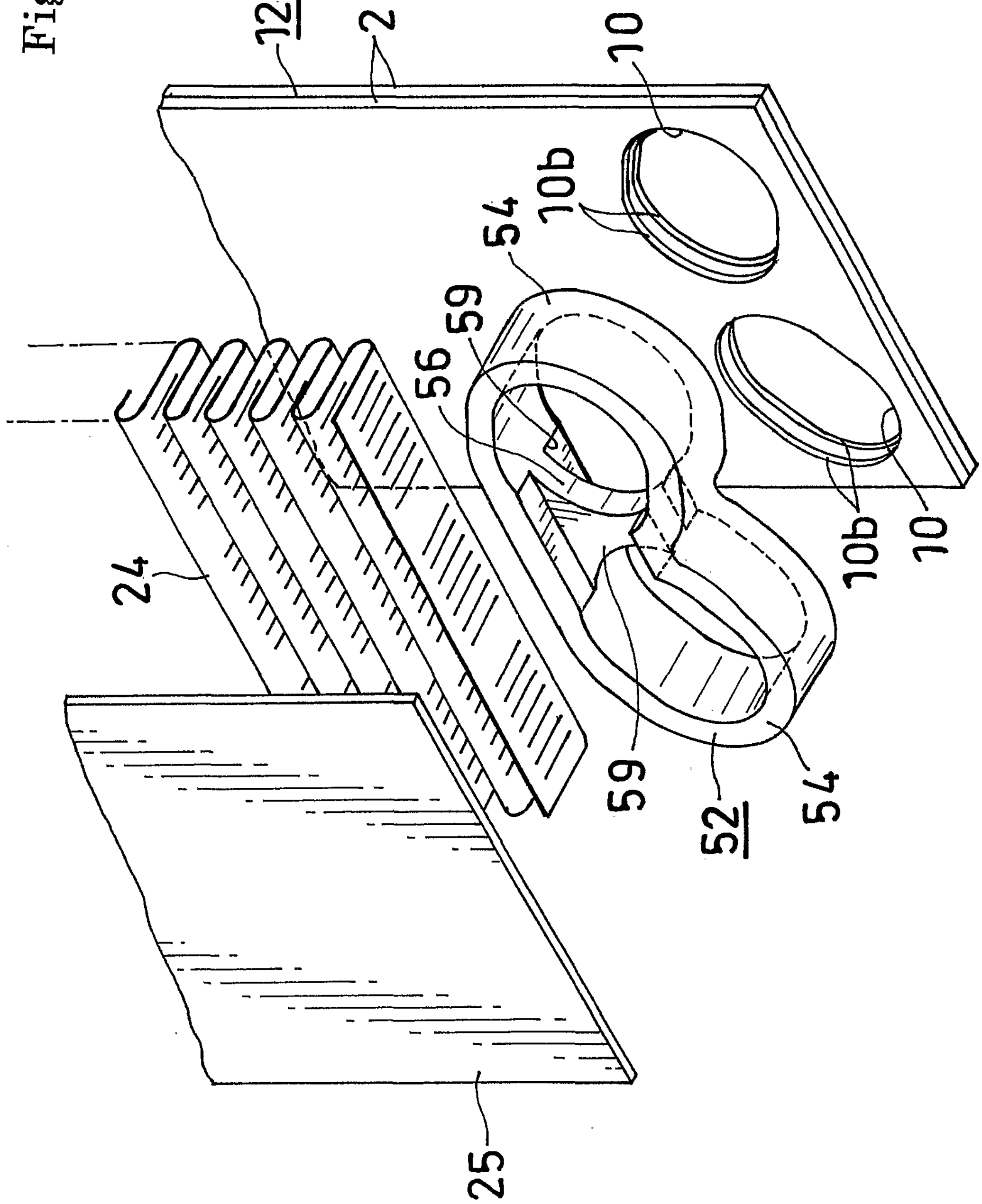


Fig.18

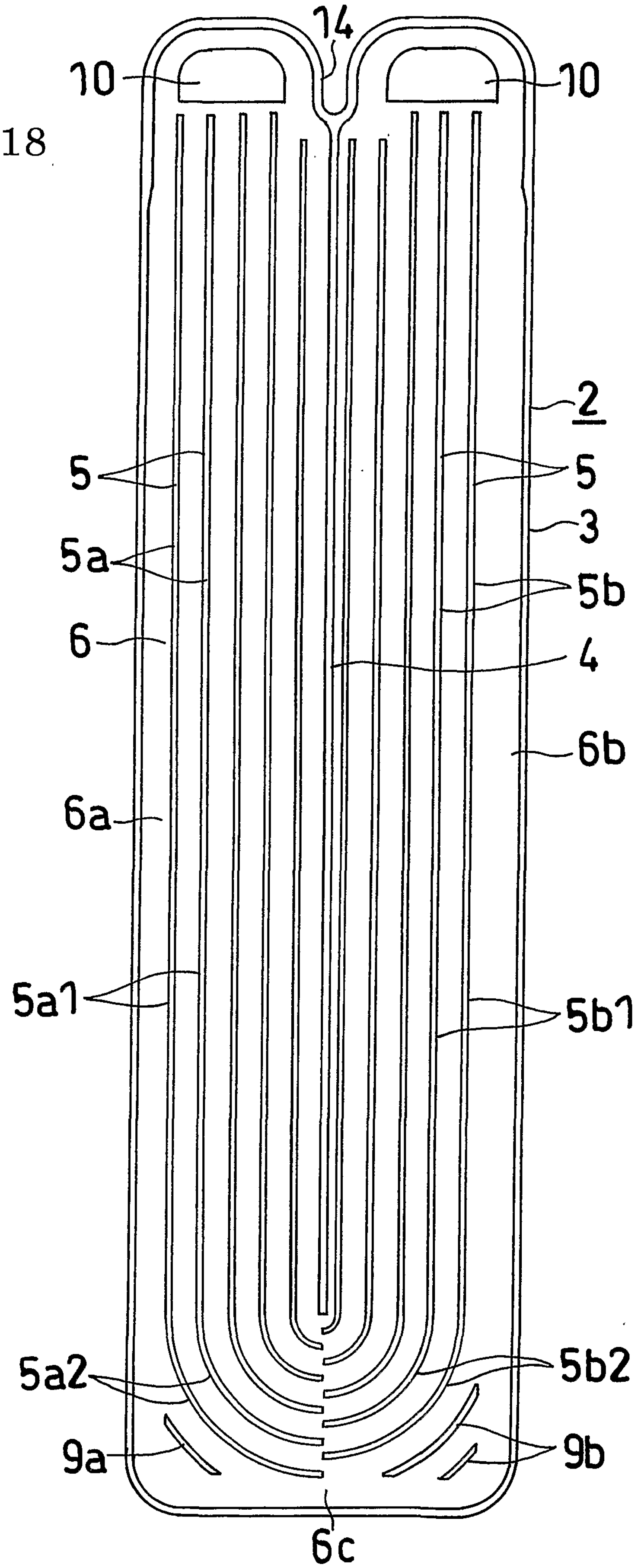


Fig.20

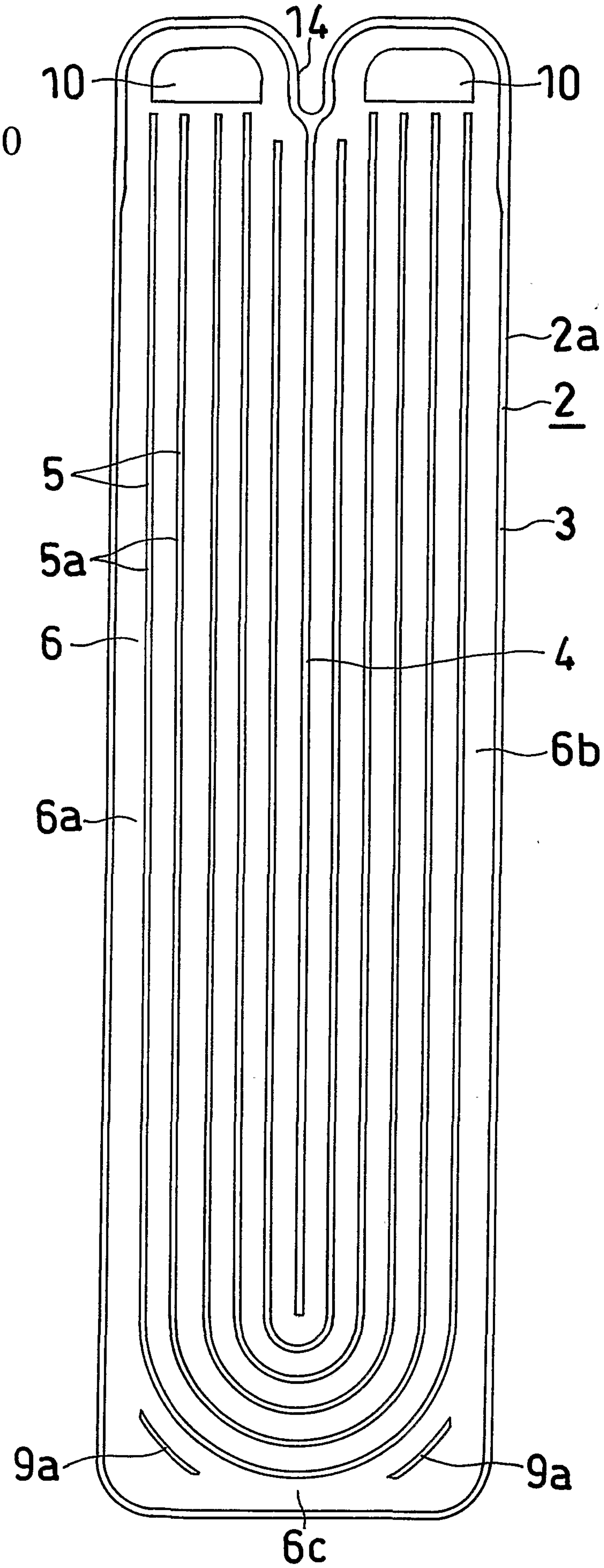


Fig.21

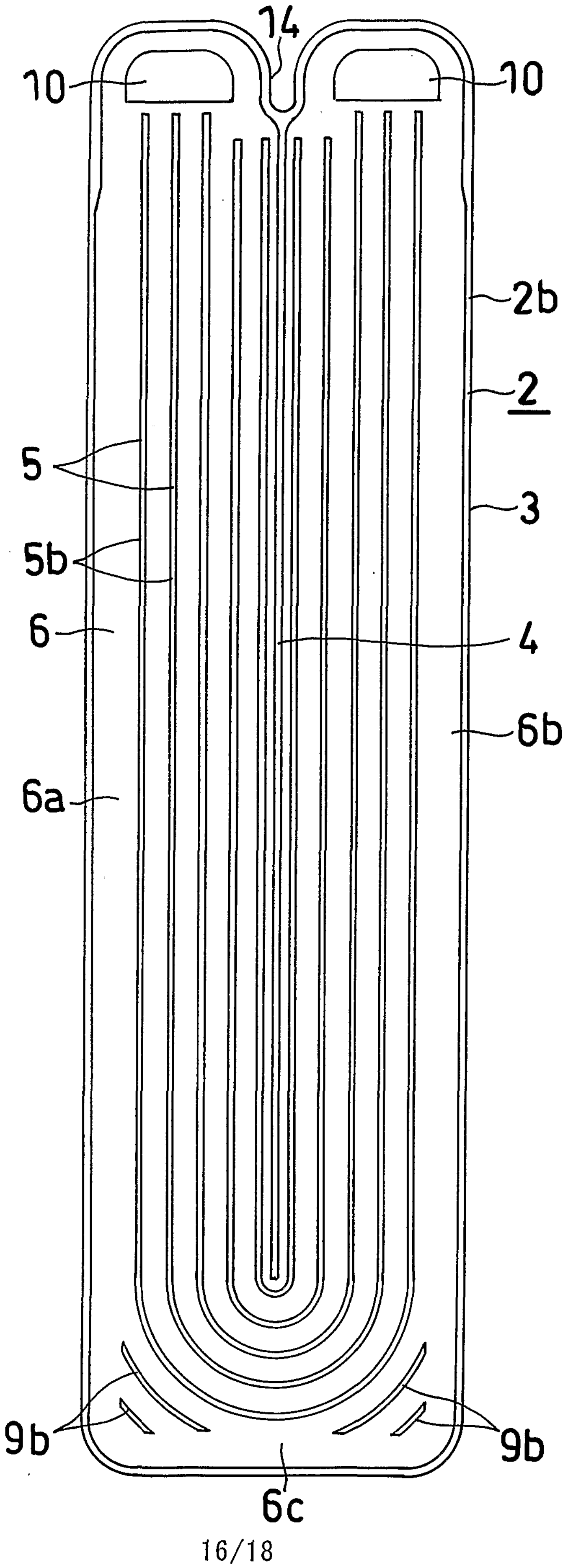


Fig.22

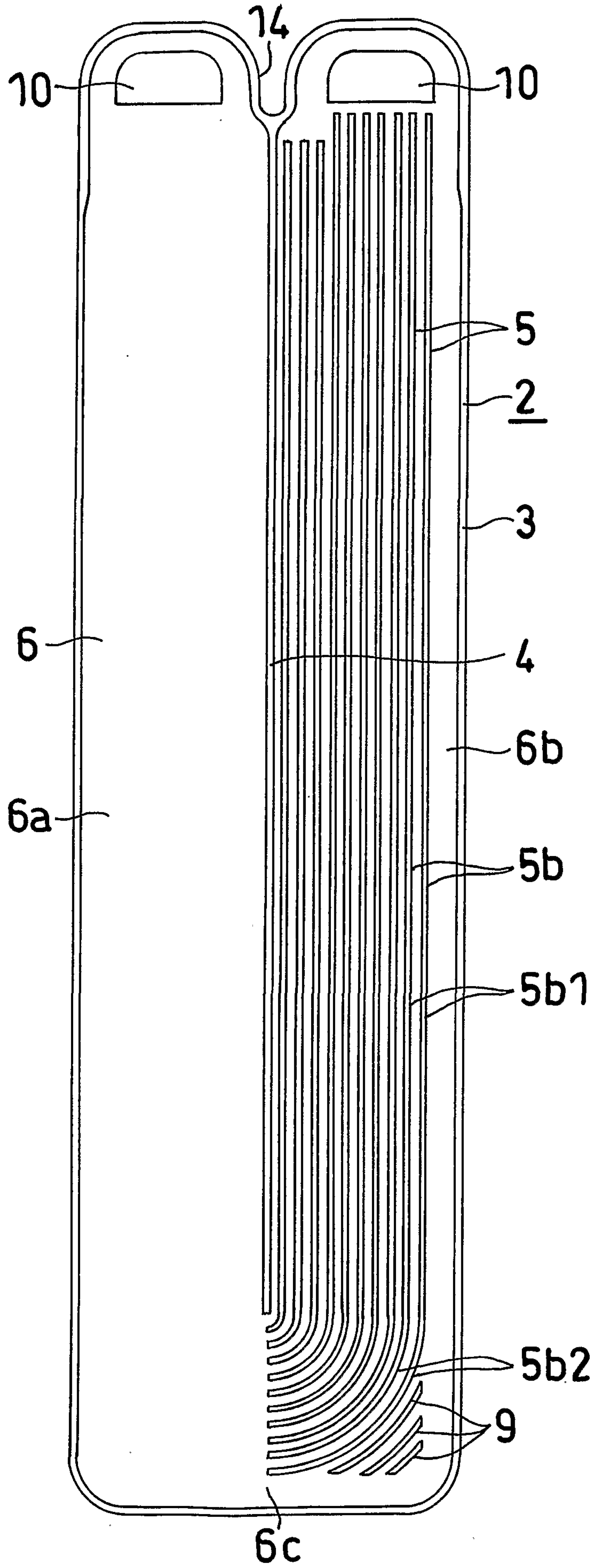


Fig.23

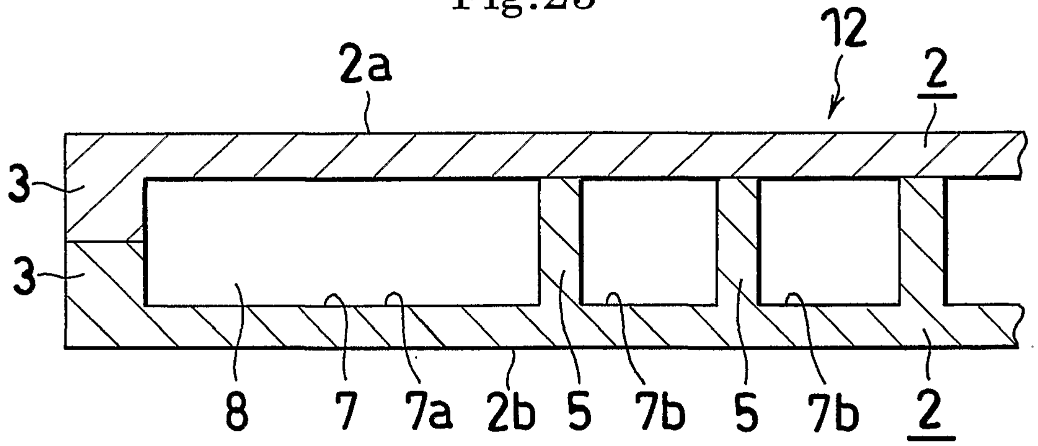


Fig.24

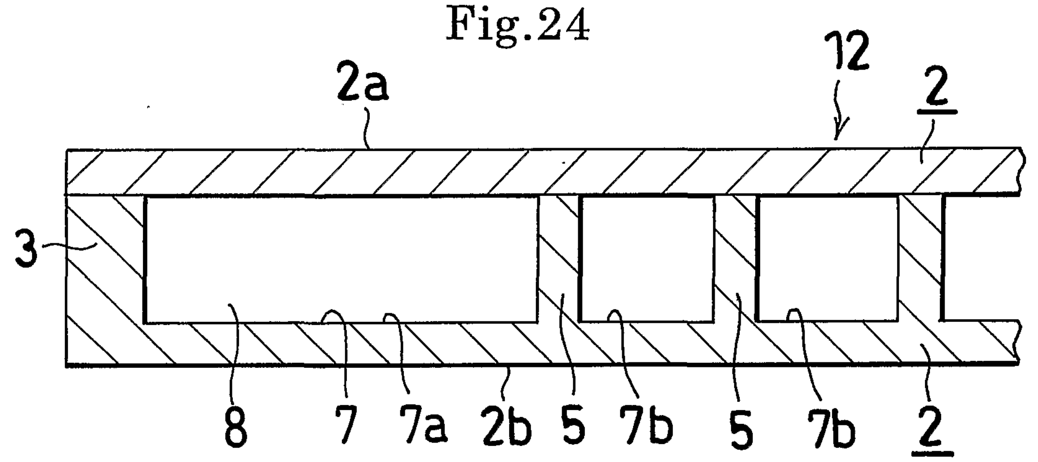
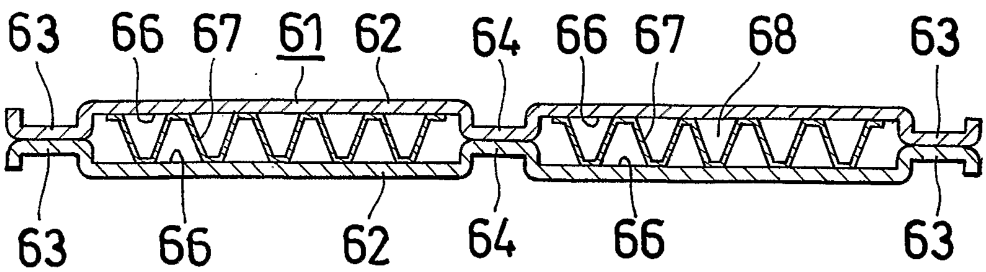


Fig.25



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/01343

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl[7] F28F3/08, F28F3/04

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] F28F3/08, F28F3/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Japanese Utility Model Gazette 1926-1996, Japanese Publication of Unexamined Utility Model Applications 1971-2001, Japanese Registered Utility Model Gazette 1994-2001, Japanese Gazette Containing the Utility Model 1996-2001

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.
Y	JP 10-332284 A (SHOWA ALUMINUM CORPORATION) 1998.12.15 &WO 98/25093 A &EP 943884 A &US 6170567 B	1, 3-7, 9, 10, 12-17, 19-23
X Y	CD-ROM of the specification and drawings annexed to the written application of Japanese Utility Model Application No.69157/1992(Laid-open No.30680/1994) (CALSONIC CORPORATION) 1994.04.22 (Family:none)	2, 23 3-6, 8, 9, 11-15, 18, 19, 22
Y	JP 6-74677 A (MITSUBISHI HEAVY INDUSTRIES., LTD.) 1994.03.18 &EP 584806 A & US 5417280 A	4, 13
Y	JP 11-63881 A (SHOWA ALUMINUM CORPORATION) 1999.03.05 (Family:None)	4-6, 13-15

☑ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10.05.02	21.05.02

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/01343

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the written application of Japanese Utility Model Application No.42690/1987(Laid-open No.175769/1988) (NIPPON RADIATOR CO., LTD.) 1988.11.15 (Family:None)	6, 15
Y	JP 6-281373 A (SHOWA ALUMINUM CORPORATION) 1994.10.07 &EP 617250 A	7, 8, 16, 18, 22
Y	JP 5-66073 A (SANDEN CORPORATION) 1993.03.19 &US 5318114 A	11, 18
Y	JP 2000-329493 A (TOYO RADIATOR K.K.) 2000.11.30 (Family:None)	20