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(54) **Heat exchange unit**

(57) A heat exchange unit (1) includes first and second plates (10,20), which is identical to each other in configuration in a peripheral area (50) thereof, but different from each other in a central irregularity pattern section (30,40). The irregularity pattern section (30,40) has a projection-recess pattern on its surface and a recess-projection pattern corresponding thereto on another surface. These patterns are different from each other in configuration. The projection-recess pattern of the first plate (10) has a reverse relationship in projections and recesses to the projection-recess pattern of the second plate (20) so as to be symmetrical to each other. The first and second plates (10,20) are placed alternately one upon another so that the peripheral areas (50) of the first and second plates (10,20) are directed to a same direction and projections of the irregularity pattern section (30) of the first plate (10) come, on peaks thereof, into contact with projections of the irregularity pattern section (40) of the second plate (20).

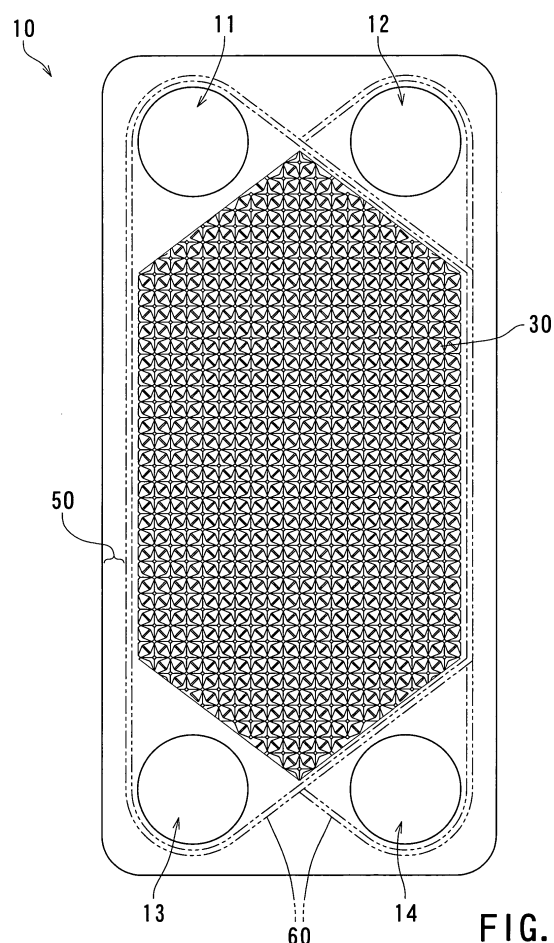


FIG. 1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates a heat exchange unit, which includes a plurality of heat transfer plates, which are formed of a metallic thin sheet and combined in parallel and integrally with each other, and especially to such a heat exchange unit in which fluid passages having different configurations formed between the plates are ensured in the combined state of the plates and an appropriate heat exchange can be made between heat exchange fluids in correspondence with differences in characteristic properties thereof, thus improving a heat exchange effectiveness.

Description of the Related Art

[0002] If there is a demand that heat transfer coefficient is increased to enhance heat exchange effectiveness, utilizing a heat exchanger by which transfer of heat (i.e., heat exchange) is made between a high temperature fluid and a low temperature fluid, a plate-type heat exchanger has conventionally been used widely. The plate-type heat exchanger has a structure in which a plurality of heat transfer plates having a plate-shape are placed parallelly one upon another at prescribed intervals so as to form passages, which are separated by means of the respective heat transfer plate. A high temperature fluid and a low temperature fluid flow alternately in the above-mentioned passages to make heat exchange through the respective heat transfer plates. An example of such a conventional plate-type heat exchanger is discussed as a prior art in Japanese Patent Provisional Publication No. H3-91695, with reference to FIGS. 5 and 6 thereof.

[0003] In the conventional plate-type heat exchanger, gasket members formed of elastic material are placed between the two adjacent plates to make the distance between them constant and define passages for fluid.

[0004] A pattern of irregularity of herringbone type has conventionally and widely applied to the heat transfer plates of the plate-type heat exchanger. However, such a pattern of irregularity could not achieve a balance of decrease in pressure loss and assured resistance to pressure. Accordingly, various kinds of different pattern of irregularities have been proposed. Japanese Patent Provisional Publication No. 2000-257488 describes an example of such different pattern of irregularities.

[0005] The plates for the above-mentioned conventional heat exchanger has a structure in which the plate includes a plurality of heat transfer sections each of which has a mound configuration provided at its top with a flat portion in a thickness direction of the plate (i.e., a cross section thereof) and a rectangular shape in a plan view of the plate, in the inner side of the sealing member (i.e., the gasket member). These plates are combined to each

other so as to be placed one upon another to form a single heat exchanger.

[0006] The conventional heat exchanger has the structure as described in the above-mentioned prior art documents. With respect to the conventional plates described in Japanese Patent Provisional Publication No. 2000-257488, when manufacturing the heat exchanger, the plates are placed one upon another to form a heat exchanger so that alternating plates are turned upside down and upper end portions (i.e., tip ends of projections) of heat transfer sections of the plate faces flowing passage-intersections (i.e., root ends of the projections) of the adjacent plate. The plates are combined to each other so that the heat transfer sections protrude the same direction, with the result that the flowing passages formed between the two adjacent plates have the same pattern.

[0007] Two kinds of liquids used usually in a heat exchanger are different from each other in chemical composition, resulting not only in difference in characteristic property, but also in quite difference in conditions in use such as pressure and flow rate during a heat exchange process. It is therefore theoretically preferable to make heat exchange, with consideration given to heat transfer in accordance with the respective fluids. However, the same pattern of flowing passages formed on the opposite surfaces of the plate leads to substantially the same heat transfer conditions for the plate. Consequently, there is no choice but to make heat exchange under the same heat transfer conditions for the two kinds of liquids flowing the passages. It is therefore difficult to apply optimized heat transfer conditions in accordance with difference in temperature and characteristic properties of the two kinds of heat exchange liquids between which heat exchange is to be made through the plate, thus causing a problem of no achievement of effective heat exchange.

SUMMARY OF THE INVENTION

[0008] An object of the present invention, which was made to solve the above-mentioned problems, is therefore to provide a heat exchange unit, which utilizes two kinds of plates having a symmetrical relationship in configuration of heat transfer sections to cope with a problem of difference in characteristic properties of fluids that flow on the opposite surfaces of the plate, respectively, and ensure sufficient heat transfer performance, thus obtaining a high heat exchange efficiency.

[0009] In order to attain the aforementioned object, a heat exchange unit according to the first aspect of the present invention, comprises a plurality of heat exchange plates having a predetermined pattern of irregularity, which are formed of a metallic thin sheet and combined in parallel and integrally with each other so that first spaces through which a first heat exchange fluid is to pass and second spaces through which a second heat exchange fluid is to pass are provided alternately between respective heat exchange plates, wherein: the heat exchange plates comprises first plates and second plates,

the first and second plates being substantially identical to each other in configuration in a peripheral area thereof, but different from each other in a central irregularity pattern section; the irregularity pattern section of each of the first and second plates has a projection-recess pattern on a surface thereof and a recess-projection pattern corresponding thereto on another surface thereof, the projection-recess pattern being different in configuration from the recess-projection pattern so as to asymmetrical thereto, and the projection-recess pattern of the first plate having a reverse relationship in projections and recesses to the projection-recess pattern of the second plate so as to be symmetrical to each other; and the first and second plates are placed alternately one upon another so that the peripheral areas of the first and second plates are directed to a same direction, and kept apart from each other by a predetermined distance, and projections of the irregularity pattern section of the first plate come, on peaks thereof, into contact with projections of the irregularity pattern section of the second plate.

[0010] According to the first aspect of the present invention, there are used two kinds of plates for the heat exchange plates, i.e., the first and second plates that are substantially identical to each other in configuration in a peripheral area thereof, but provided with the respective central irregularity pattern sections that are symmetrical to each other so as to have the reverse relationship in projection-recess pattern. Assembling such two kinds of plates, i.e., the first and second plates by placing alternately them one upon another so that the peripheral areas of the first and second plates are directed to the same direction, and fastening them, with gasket members placed between the peripheral areas of the plates or brazing them at the contacting peripheral areas thereof provides two kinds of gaps formed between the plates, which gaps are different in configuration and size on the opposite surface sides of the plate in accordance with the adjacently combined two plates having the central irregularity pattern sections. Two adjacent gaps provide flow passages having different characteristics from each other, thus causing different heat transfer performances. Formation of the flow passages in accordance with characteristic properties of heat exchange fluids makes it possible to cause heat transfer between the plates and the heat exchange fluids to effectively progress, thus making an effective heat exchange between the fluids. In the combined states of the plates in which the projections of the adjacent plates come into contact with each other, and in addition, projections formed on the backsides of the recesses come into contact with each other. The plates can be brought into contact with each other not only at the peripheral areas, but also at a number of connecting areas in the irregularity pattern sections of the plates. The irregularity pattern section of the heat exchange plate can be held by the two other adjacent plates, so as to improve remarkably strength of the unit, thus maintain the appropriate configurations of the gaps to perform a proper heat exchange, even when heat ex-

change fluids introduced into the gaps between the plates have high pressure.

[0011] In the second aspect of the heat exchange unit of the present invention, there may be adopted a structure in which each of the first and second plates has a shape of rectangular or square; and at least the irregularity pattern section of each of the first and second plates has a symmetrical shape with respect to a central position between a pair of opposite sides of the plate or another pair of opposite sides thereof.

[0012] According to the second aspect of the present invention, the irregularity pattern section of each of the first and second plates has a symmetrical shape with respect to a central position between a pair of opposite sides of the plate or another pair of opposite sides thereof. Turning the plate inside out provides a reverse relationship in projection-recess pattern with respect to that of the plate as not turned, with the positions of the projections and recesses unchanged, thus permitting to provide the same configuration of the irregularity pattern section as the other plate not turned. It is therefore possible to use the same press-forming die for at least the irregularity pattern section in a press-forming method so as to manufacture the heat exchange plates. As a result, the same die can be applied to the irregularity pattern section having a complicated configuration in manufacture of two kinds of different plates, thus reducing costs and remarkably improving production efficiency.

[0013] In the third aspect of the heat exchange unit of the present invention, there may be adopted a structure in which the irregularity pattern section of each of the heat exchange plates has the projections that project outward from the surface of the heat exchange plate in a form of a truncated cone or a truncated pyramid, and a plurality of intermediate protrusions each of which is placed between two projections that are adjacent to each other at a shortest distance, each of the intermediate protrusions being defined by one or more flat or curved portions that extend to opposing surfaces of the two projection, and each of the intermediate protrusions having one or more peak portions that are placed in a lower position than a top of the projection; there is made arrangement providing simultaneously a plurality of combinations of the projection and another projection adjacent thereto at the shortest distance between which the intermediate protrusion is placed; and a plurality of non-protruded portions each of which is placed between adjacent intermediate protrusions, each of the non-protruded portions being placed in a lowest position relative to a projecting direction of the projections, the non-protruded portions providing the recesses surrounded by the projections and the intermediate protrusions.

[0014] According to the third aspect of the present invention, the irregularity pattern section of each of the heat exchange plates has the projections that project outward from one surface of the heat exchange plate in a form of a truncated cone or a truncated pyramid, and the plurality of intermediate protrusions each of which is placed be-

tween two projections that are adjacent to each other at a shortest distance. When the heat exchange plates are arranged in parallel with each other, there is provided between the two adjacent plates a gap in which a unit of the similar pattern of irregularity is repeated in aligning directions of the projections, thus providing linear passages extending in the above-mentioned directions so as to cross each other. More specifically, each of the linear passages extending in a reticulation shape includes expanded areas and throat areas that are placed alternately in the same direction, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. Using the thus assembled plates can impart substantially the same behavior to the heat exchange fluid, irrespective the flowing system of the heat exchange fluid, i.e., any one of the parallel flowing system, the counter-flowing system and the cross flowing system. As a result, it is possible to perform a smooth heat transfer at a low pressure loss to make an effective heat exchange, even when the heat exchange fluids are combined in any manner in their flowing directions, thus providing a high degree of freedom in design of the heat exchanger and becoming excellent in general purpose use. In addition, the heat exchange fluid can flow freely in the above-mentioned two directions along the plate, and the constant heat transfer property can be obtained, irrespective of the flowing direction of the heat exchange fluid. It is therefore possible to cause the heat exchange fluid to spread over the entire area of the plate so that such an entire area can serve as an effective heat transfer section, and vary flowing conditions through the intermediate protrusions in comparison with a simple combination of cones or pyramids so as to provide an improved heat transfer, thus increasing remarkably an amount of heat transfer per area and achieving a high performance. Further, the projections of the plate, which come into contact with the other plate, are provided in the form of the truncated cone or truncated pyramid so as to disperse force applied to the projections in the direction on the surface the truncated cone or truncated pyramid. As a result, the strength of the assembled plates can be improved remarkably in comparison with the conventional heat exchange plate, and it is therefore possible to keep the distance between the two adjacent plates constant, even when there exists a large difference in pressure between the heat exchange fluids, thus enhancing a pressure-resistant property.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a plan view illustrating a schematic structure of the first plate of a heat exchange unit according to an embodiment of the present invention;
FIG. 2 is a plan view illustrating a schematic structure

of the second plate of a heat exchange unit according to an embodiment of the present invention;
FIG. 3 is a perspective view illustrating a state in which the heat exchange plates for the heat exchange unit according to the embodiment of the present invention are arranged;
FIG. 4 is a side view illustrating a state in which the heat exchange plates are assembled into the heat exchange unit according to the embodiment of the present invention;
FIG. 5 is an enlarged partial view of the first plate of the heat exchange unit according to the embodiment of the present invention;
FIG. 6 is a cross-sectional view cut along the line VI-VI in FIG. 5;
FIG. 7 is a cross-sectional view cut along the line VII-VII in FIG. 5;
FIG. 8 is a cross-sectional view cut along the line VIII-VIII in FIG. 5;
FIG. 9 is an enlarged partial view of the second plate of the heat exchange unit according to the embodiment of the present invention;
FIG. 10 is a cross-sectional view cut along the line X-X in FIG. 9;
FIG. 11 is a cross-sectional view cut along the line XI-XI in FIG. 9;
FIG. 12 is a cross-sectional view cut along the line XII-XII in FIG. 9; and
FIG. 13 is an enlarged partial cross-sectional view illustrating the irregularity pattern sections of the heat exchange plates for the heat exchange unit according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Now, the embodiment of the present invention will be described in detail below with reference to FIGS. 1 to 13. FIG. 1 is a plan view illustrating a schematic structure of the first plate of a heat exchange unit according to an embodiment of the present invention; FIG. 2 is a plan view illustrating a schematic structure of the second plate of a heat exchange unit according to an embodiment of the present invention; FIG. 3 is a perspective view illustrating a state in which the heat exchange plates for the heat exchange unit according to the embodiment of the present invention are arranged; FIG. 4 is a side view illustrating a state in which the heat exchange plates are assembled into the heat exchange unit according to the embodiment of the present invention; FIG. 5 is an enlarged partial view of the first plate of the heat exchange unit according to the embodiment of the present invention; FIG. 6 is a cross-sectional view cut along the line VI-VI in FIG. 5; FIG. 7 is a cross-sectional view cut along the line VII-VII in FIG. 5; FIG. 8 is a cross-sectional view cut along the line VIII-VIII in FIG. 5; FIG. 9 is an enlarged partial view of the second plate of the heat exchange unit according to the embodiment of the present

invention; FIG. 10 is a cross-sectional view cut along the line X-X in FIG. 9; FIG. 11 is a cross-sectional view cut along the line XI-XI in FIG. 9; FIG. 12 is a cross-sectional view cut along the line XII-XII in FIG. 9; and FIG. 13 is an enlarged partial cross-sectional view illustrating the irregularity pattern sections of the heat exchange plates for the heat exchange unit according to the embodiment of the present invention.

[0017] The heat exchange unit 1 according to the embodiment of the present invention is composed of two kinds of heat exchange plates 10, 20, which serve as the first and second plates, respectively, and are placed in parallel with each other through gasket members 60 and combined together. The heat exchange plates 10, 20 have irregularity pattern sections 30, 40 and peripheral areas 50 with which the irregularity pattern sections 30, 40 are surrounded, respectively. Each of the plates 10, 20 has opposite surfaces, which are to be come into contact with heat exchange fluids, respectively.

[0018] The heat exchange plates 10, 20, which are formed of a metallic thin sheet having a rectangular shape, are subjected to a press forming process to form irregularity pattern sections 30, 40 in a central portion thereof and the peripheral areas 50 by which the irregularity pattern sections 30, 40 are surrounded, respectively. The irregularity pattern section 30 of the first heat exchange plate 10 has a reverse relationship in projections and recesses to the irregularity pattern section 40 of the second heat exchange plate 20 so as to be symmetrical to each other. As a result, the heat exchange plates 10, 20 are provided in the form of two different kinds of plates that are identical to each other in configuration of the peripheral area 50, but different from each other in configuration in the central irregularity pattern sections 30, 40 having the reverse relationship in projections and recesses therein to each other.

[0019] The first heat exchange plate 10 has openings 11, 12, 13, 14 formed at four corners of the plate on the inside of the peripheral area 50, respectively in the same manner as the conventional plate, so as to enable a heat exchange fluid to pass through therein. The second heat exchange plate 20 also has openings 21, 22, 23, 24 formed in the same manner.

[0020] The above-mentioned irregularity pattern sections 30, 40 have a common fundamental configuration in projection-recess pattern. The above-mentioned irregularity pattern section 30 includes a plurality of projections 31, a plurality of intermediate protrusions 33 and a plurality of recesses 34. The projections 31 are formed on the basis of a matrix arrangement in which the projections 31 project in the form of truncated pyramid from the surface of the plate so that four pyramidal surfaces of the projection faces the respective surrounding pyramidal surfaces of the adjacent projections and are aligned at regular intervals in four directions corresponding to the four pyramidal surfaces of the projection. Each of the intermediate protrusions 33 is placed in the form of a mound portion between the opposing pyramidal surfaces

of the two adjacent projections 31 so that a pair of foot portions of the intermediate protrusion is located in the lowest positions at which corresponding ridgelines of the opposing pyramidal surfaces intersect and a peak portion of the intermediate protrusion is located between the intersecting points of the above-mentioned ridgelines. The peak portion of the intermediate protrusion 33 is placed in a lower position than the top 32 of the projection 31. Each of the recesses 34 is provided in the form of a non-protruded portion in a central position between the projections that are placed adjacently to each other without placing the intermediate protrusion 33 therebetween. The recess 34 is surrounded by the pyramidal surfaces of the projections 31 and inclines surfaces of the intermediate protrusions 33 so as to be placed in the lowest position in the direction perpendicular to the plane of the plate.

[0021] The irregularity pattern section 40, which is symmetrical to the irregularity pattern section 30 on assumption that the peripheral areas of the heat exchange plates 10, 20 face to the same direction, includes a plurality of recesses 41, a plurality of intermediate valley portions 42 and a plurality of projections 43. The recesses 41 are formed on the basis of a matrix arrangement so as to dent in the form of a truncated pyramid. Each of the intermediate valley portion 42 is placed in the form of a dent portion between the opposing pyramidal surfaces of the two adjacent recesses 41 so that a bottom of the intermediate valley portion 42 is located in an upper position than the bottom of the recess 41. Each of the projections 43 is provided, in the highest place in the direction perpendicular to the plane of the plate, between the recesses 41 that are placed adjacently to each other without placing the intermediate valley portion 42 therebetween. The recesses 41 of the irregularity pattern section 40 match with the configuration just on the backside of the projections 31 of the irregularity pattern section 30. The intermediate valley portions 42 match with the configuration on the backside of the intermediate protrusions. The projections 43 match with the configuration on the backside of the recesses 34.

[0022] The projection 31 and the recess 34 are placed so as to deviate from each other by a half of a distance between two adjacent projections in the alignment direction thereof. The recess 41 and the projection 43 are also placed so as to deviate from each other by a half of a distance between two adjacent projections in the alignment direction thereof. The projections 31, 43 and the recesses 34, 41 are formed at regular intervals based on a matrix arrangement. However, in the above-mentioned irregularity pattern sections 30, 40, recess portions formed on the backsides of the projections 31, 42 are different in configuration from the recesses 34, 41 and projections portions formed on the backsides of the recesses 34, 41 are different in configuration from the projections 31, 43. The opposite surfaces of each of the plates having the irregularity pattern section are asymmetrical to each other.

[0023] In addition, not only the direction along which the two adjacent projections 31 of the irregularity pattern section 30 are aligned so as to place the recess 34 therebetween, but also the direction along which the two adjacent recesses 41 of the irregularity pattern section 40 are aligned so as to place the projection 43 therebetween are in parallel with or perpendicular to the side of the rectangular plate. The irregularity pattern sections 30, 40 may have a structure in which the above-mentioned directions are inclined by an angle of 45 degrees or a desired angle relative to the side of the plate.

[0024] The peripheral area 50 of each of the heat exchange plates 10, 20 is provided in the form of a flat portion along the respective side edges. The plates are placed one upon another so as to face to the same direction, with gasket members 60 placed between the peripheral areas 50 of the plates. The surface of the heat exchange plate 10, from which the projections 31 project, serves as a front surface, and the surface of the heat exchange plate 20, from which the projections 43 project, serves as a front surface.

[0025] The heat exchange plates 10, 20 are placed one upon another with the front surfaces thereof directed to the same direction and combined together into a heat exchange unit 1. In such an assembled state, the peripheral areas 50 of the adjacent two plates 10, 20 come into contact with each other, the projections 31 of the irregularity pattern section 30 of the heat exchange plate 10 come into contact with the projection portions formed on the backsides of the recesses 41 of the irregularity pattern section 40 of the heat exchange plate 20, and the projection portions formed on the backsides of the recesses 34 of the irregularity pattern section 30 of the heat exchange plate 10 come into contact with the projections 43 of the irregularity pattern section 40 of the other heat exchange plate 20. As a result, a gap in which a heat exchange fluid is to flow is formed between the two adjacent plates 10, 20, excluding the contacting portions thereof.

[0026] In the first gap section 61 in which the projections 31 of the irregularity pattern section 30 project, the intermediate protrusions 33 having a smaller height than the projections 31 face the backsides of the corresponding intermediate valley portions 42, with a constant distance kept therebetween, and the recesses 34 having a further smaller height than the intermediate valley portions 42 face the backsides of the corresponding projections 43, with another constant distance kept therebetween. The gap section formed on the front surface side of the intermediate protrusions 33 communicates with the gap section formed on the front surface side of the recesses 34 to form linear passages. Each of the linear passages, which has a passage opening increasing from the intermediate protrusion 33 toward the recess 34, includes expanded areas and throat areas that are placed alternately to extend linearly, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded ar-

reas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. The first gap section 61 communicates with the other first gap section 61 and the outside at the openings 11, 13, 21, 23 provided at two corners on the same side of the heat exchange plates 10, 20.

[0027] In the second gap section 62 in which the projections 43 of the irregularity pattern section 40 project, a tunnel-shaped gap section formed between the intermediate valley portion 42 and the backside of the corresponding intermediate protrusion 33 connects spaces provided between the recesses 41 and the backsides of the corresponding projections 31 to each other, so as to form linear passages. Each of the linear passages, which has a passage opening increasing from the intermediate protrusion 42 toward the recess 41, includes expanded areas and throat areas that are placed alternately to extend linearly in the direction along which the recesses 41 are aligned, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. The second gap section 62 communicates with the other second gap section 62 and the outside at the openings 12, 14, 22, 24 provided at the other corners than those provided with the above-mentioned openings 11, 13, 21, 23.

[0028] The opposite surfaces of each of the first and second plates having the projection-recess pattern are asymmetrical from each other and the first and second plates are placed alternately one upon another so that the corresponding surfaces of these plates, which are symmetrical to each other, face to each other, and combined together into a unit. As a result, the first gap section 61 and the second gap section 62 are different from each other in configuration and size. Differences between the first gap section 61 and the second gap section 62 in configuration and size impart these sections different heat transfer properties. Previously forming of the projection-recess patterns of the plates to determine the configuration and size of the gap sections taking into consideration characteristic properties of two kinds of fluids between which heat exchange is to be made makes it possible to provide suitable flowing conditions and heat transfer properties for these fluids. The heat exchanger is designed so that the heat exchange fluids having the respective characteristic properties are introduced into the corresponding first and second gap sections 61, 62, respectively.

[0029] The heat exchange plates 10, 20 have further additional features that each of these plates is symmetrical in areas of the opening and the irregularity pattern sections 30, 40 with respect to a center of the short sides of the plate. Accordingly, turning the first heat exchange plate 10 inside out by an angle of 180 degrees so that the long sides of the plate change their places provides a state in which only a relationship in projections and recesses is reversed relative to the plate as not-turned,

with places of the projection and recesses kept unchanged. The thus turned plate 10 and the other plate 20 as not-turned are identical to each other in an area inside the peripheral areas 50.

[0030] A design is made so that, when the first plate is turned inside out, the same configuration as the second plate in the predetermined area containing the irregularity pattern sections 30, 40 can be obtained. It is therefore possible to form the irregularity pattern sections 30, 40 for the two kinds of heat exchange plates 10, 20 in the same manner. In this case, it is possible to form such sections 30, 40 by using a press-forming apparatus in which portions of a die of the press-forming apparatus corresponding to the peripheral areas 50 of the plate can be adjusted in position relative to the other portions, for example a press-forming apparatus an invention of which was made by the inventors of the present invention and described in Japanese Patent Provisional Publication No. 2003-275824. In use of such an apparatus, a positional adjustment of auxiliary die sections for forming the peripheral areas 50 relative to a central main die section for forming the irregularity pattern sections 30, 40 in a pressing direction is made in the pressing apparatus and then, a press forming process is carried out. In such a case, it is possible to manufacture the two different kinds of plates with the use of the same dies, thus providing a remarkably enhanced manufacturing efficiency.

[0031] Now, assembling steps for the heat exchange unit according to the present invention will be described below. It is assumed that the two kinds of heat exchange plates 10, 20, i.e., a plurality of plates 10 and a plurality of plates 20, which have the same configuration in the peripheral area 50, but the symmetrical irregularity pattern sections 30, 40 in the central portion thereof have previously been prepared by a press-forming method.

[0032] The heat exchange plates 10, 20 in a predetermined number are alternately one upon another, with gasket members 60 placed between the peripheral areas 50 of the plates and peripheries of the openings, and then fastened from the opposing directions in the aligning direction of the plates to prepare a heat exchange unit 1 in which all the plates are water-tightly combined together, in the same manner as the conventional plate-type heat exchanger, except that the heat exchange plates 10, 20 are alternately one upon another so that the plates 10 are turned inside out relative to the plates 20 and the long sides of each plates 10 change their places, as a result that the surfaces for defining the irregularity pattern sections 30, 40, respectively face each other.

[0033] In the thus obtained heat exchange unit 1, the first gap section 61 is formed on the side of the projections 31 of each heat exchange plate 10 and the openings 11, 13, 21, 23 communicate with this first gap section 61. The second gap section 62 is formed on each sides placed adjacently to the first gap section 61 through the heat exchange plates 10, 20 and the openings 12, 14, 22, 24 communicate with this second gap section 62. When the heat exchange unit 1 composed of the plates

as combined in a manner as described above is placed in use so that one of the both sides of each plate is placed horizontally or vertically, the main passages in the gap sections 61, 62 between the plates, i.e., the gaps continuously extending along the recesses 34 and the intermediate protrusions 33 of the heat exchange plate 10, and the gaps continuously extending along the recesses 41 and the intermediate valley portions 42 of the heat exchange plate 20 are kept in an inclined state.

[0034] Now, an operation of the heat exchange unit according to the embodiment of the present invention serving as the heat exchanger will be described below. A heat exchange fluid is introduced into the first gap section 61 through the two openings 11, 13, 21, 23 of the respective heat exchange plates 10, 20 for forming the heat exchange unit 1, and discharged therefrom, on the one hand, and another heat exchange fluid is introduced into the second gap section 62 through the remaining two openings 12, 14, 22, 24 of the respective heat exchange plates 10, 20, and discharged therefrom, on the other hand.

[0035] In the gap sections 61, 62 in which the heat exchange fluids flow, the passages linearly extend in the oblique direction along which the projections 31, 42 and the recesses 34, 41 are aligned, mainly around the recesses and the intermediate protrusions 33 or the intermediate valley portions 42. The heat exchange fluids flow in the above-mentioned passages. As a result, the heat exchange fluids flows in the oblique direction in the passages that have specific configurations with the repeated expanded areas and throat areas in the gap sections 61, 62, and naturally repeats divergence and confluence to smoothly spread over every areas on the upper and lower surfaces of the plate of the irregularity pattern sections 30, 40 of the heat exchange plates 10, 20. Even when a flowing relationship of the two kinds of heat exchange fluids is based on any one of a parallel flowing system, a counter-flowing system and a cross flowing system, it is therefore possible to impart substantially the same conditions to the heat exchange fluids and reduce pressure loss and achieve smooth flow of the heat exchange fluids.

[0036] The heat exchange fluids spread over every area in the gap sections 61, 62 formed between the plates, to improve heat transfer between the plates and the heat exchange fluids. In addition, the heat exchange fluids spread over every area in the gap sections 61, 62 that are formed between the plates and have the specific shapes in which expanded areas and throat areas are placed alternately, thus providing the opposite surfaces of each plate with the respective passages having the different configurations from each other for heat transfer properties in full consideration of the characteristic properties of the heat transfer fluids. It is therefore possible to cause an effective heat transfer to progress between the respective heat exchange fluids flowing through the gap sections and the respective heat exchange plates 10, 20, with the result that heat exchange can be made smoothly between the heat exchange fluids through the

heat exchange plates 10, 20.

[0037] According to the heat exchange unit of the embodiment of the present invention, there are used two kinds of plates for the heat exchange plates 10, 20, i.e., the first and second plates that are substantially identical to each other in configuration in a peripheral area thereof, but provided with the respective central irregularity pattern sections 30, 40 that are symmetrical to each other so as to have the reverse relationship in projection-recess pattern. Assembling such two kinds of plates, i.e., the first and second plates by placing alternately them one upon another so that the peripheral areas 50 of the first and second plates are directed to the same direction, and fastening them, with gasket members 60 placed between the peripheral areas 50 of the plates 10, 20 two kinds of gaps 61, 62 formed between the plates, which gaps are different in configuration and size on the opposite surface sides of the plate in accordance with the adjacently combined two plates having the central irregularity pattern sections. Two adjacent gaps provide flow passages having different characteristics from each other, thus causing different heat transfer performances. Formation of the flow passages in accordance with characteristic properties of heat exchange fluids makes it possible to cause heat transfer between the plates and the heat exchange fluids to effectively progress, thus making an effective heat exchange between the fluids.

[0038] In the heat exchange unit according to the embodiment of the present invention, the irregularity pattern section 30 has a basic structure in which the projection 31 is surrounded by four adjacent projections 31 through the intermediate protrusions 33 and the recesses 34 are placed so as to deviate from the projections by a half of the distance between the two adjacent projections and the irregularity pattern sections 40 also have the similar arrangement. However, the present invention is not limited only to such an embodiment. Any desired structure may be adopted, except for the specific design in which the irregularity pattern sections 30, 40 of the heat exchange plates 10, 20 have the symmetrical configurations to each other, and for example, there may be made adjustment in shape of the projections of the irregularity pattern section, existence or inexistence of the intermediate protrusions between the projections, the number of the other projections by which the projection is surrounded. Such a modified structure permits adjustment to cope appropriately with the characteristic properties of the heat exchange fluids introduced into the gaps between the plates.

[0039] In the heat exchange unit according to the embodiment of the present invention, each of the projections 31 of the irregularity pattern section 30 has a truncated pyramid shape. However, the projection may have a shape of prismoid such as a pentagonal prismoid or a hexagonal prismoid, or a shape of truncated cone so as to be adapted to the desired performance of the heat exchanger.

[0040] In the heat exchange unit according to the em-

bodiment of the present invention, the two kinds of plates having the irregularity pattern sections 30, 40 that are symmetrical in configuration to each other are used in the type of the heat exchange unit in which the heat exchange plates 10, 20 are placed alternately one upon another, with the gasket members 60 placed between the plates. However, the present invention is not limited only to such an embodiment. In case where the plates are placed in parallel with each other and brazed in a water-tight manner, it is also possible to use two kinds of plates, which are identical to each other in configuration in the peripheral areas thereof, but symmetrical to each other in the irregularity pattern sections thereof, thus providing the heat exchange unit having the same heat exchange properties as the heat exchange unit as described above and a high pressure proof property.

Claims

1. A heat exchange unit (1), comprising a plurality of heat exchange plates having a predetermined pattern of irregularity, which are formed of a metallic thin sheet and combined in parallel and integrally with each other so that first spaces through which a first heat exchange fluid is to pass and second spaces through which a second heat exchange fluid is to pass are provided alternately between respective heat exchange plates, wherein:

said heat exchange plates comprises first plates (10) and second plates (20), said first and second plates (10,20) being substantially identical to each other in configuration in a peripheral area (50) thereof, but different from each other in a central irregularity pattern section (30,40); said irregularity pattern section (30,40) of each of said first and second plates (10,20) has a projection-recess pattern on a surface thereof and a recess-projection pattern corresponding thereto on another surface thereof, said projection-recess pattern being different in configuration from said recess-projection pattern so as to be asymmetrical thereto, and the projection-recess pattern of the first plate (10) having a reverse relationship in projections and recesses to the projection-recess pattern of the second plate (20) so as to be symmetrical to each other; and

said first and second plates (10,20) are placed alternately one upon another so that the peripheral areas (50) of the first and second plates (50) are directed to a same direction, and kept apart from each other by a predetermined distance, and projections of the irregularity pattern section (30) of the first plate (10) come, on peaks thereof, into contact with projections of the irregularity

pattern section (40) of the second plate (20).

2. The heat exchange unit (1) as claimed in Claim 1, wherein:

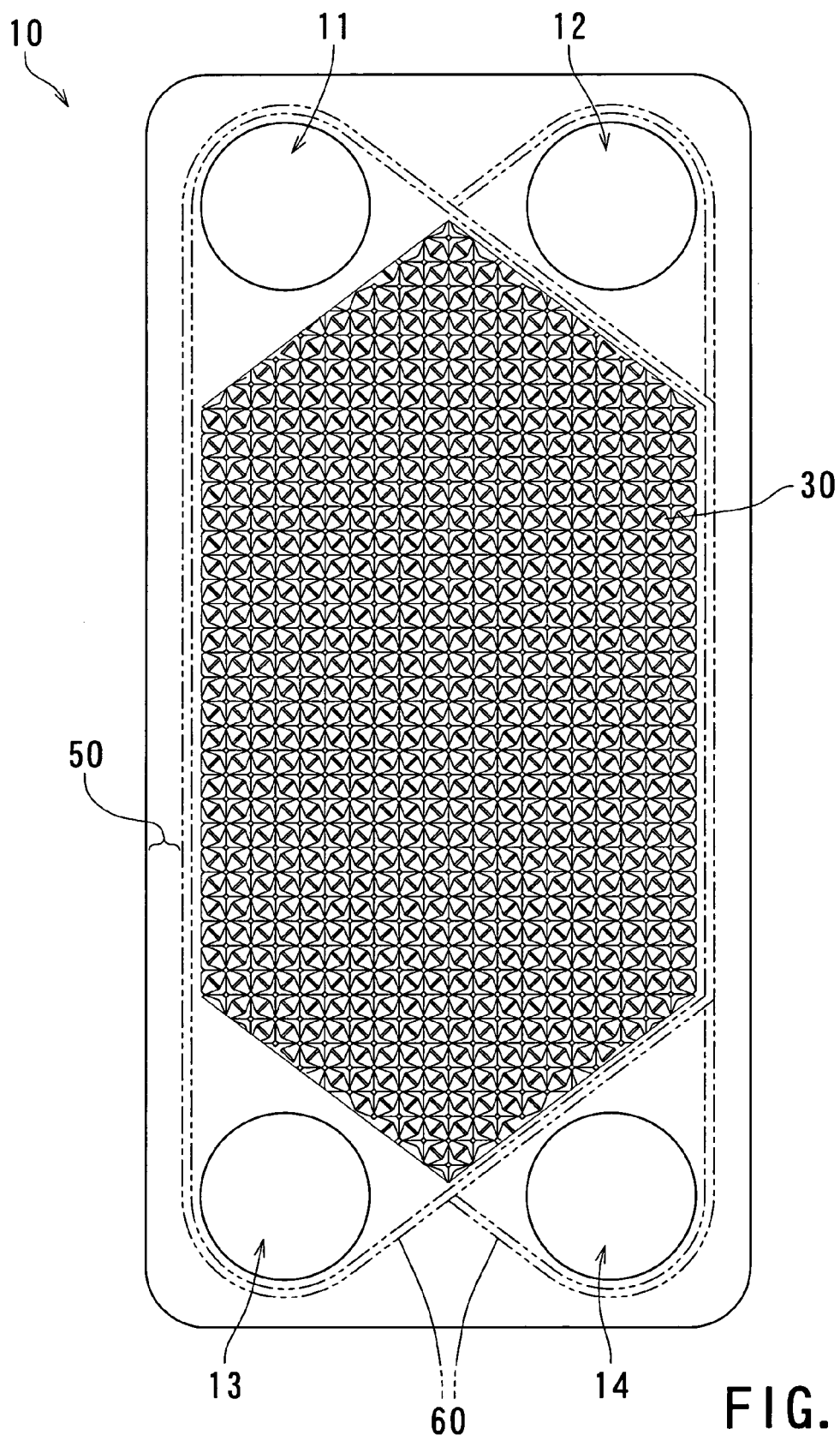
each of said first and second plates (10,20) has a shape of rectangular or square; and at least the irregularity pattern section (30,40) of each of the first and second plates (10,20) has a symmetrical shape with respect to a central position between a pair of opposite sides of the plate or another pair of opposite sides thereof.

3. The heat exchange unit (1) as claimed in Claim 1 or 2, wherein:

the irregularity pattern section (30,40) of each of the heat exchange plates (10,20) has said projections that project outward from the surface of the heat exchange plate in a form of a truncated cone or a truncated pyramid, and a plurality of intermediate protrusions (33) each of which is placed between two projections (31) that are adjacent to each other at a shortest distance, each of the intermediate protrusions (33) being defined by one or more flat or curved portions that extend to opposing surfaces of the two projection (31), and each of the intermediate protrusions (33) having one or more peak portions that are placed in a lower position than a top (32) of the projection (31); there is made arrangement providing simultaneously a plurality of combinations of the projection and another projection adjacent thereto at the shortest distance between which the intermediate protrusion (33) is placed; and a plurality of non-protruded portions each of which is placed between adjacent intermediate protrusions (33), each of the non-protruded portions being placed in a lowest position relative to a projecting direction of the projections (31), the non-protruded portions providing said recesses (34) surrounded by the projections (31) and the intermediate protrusions (33).

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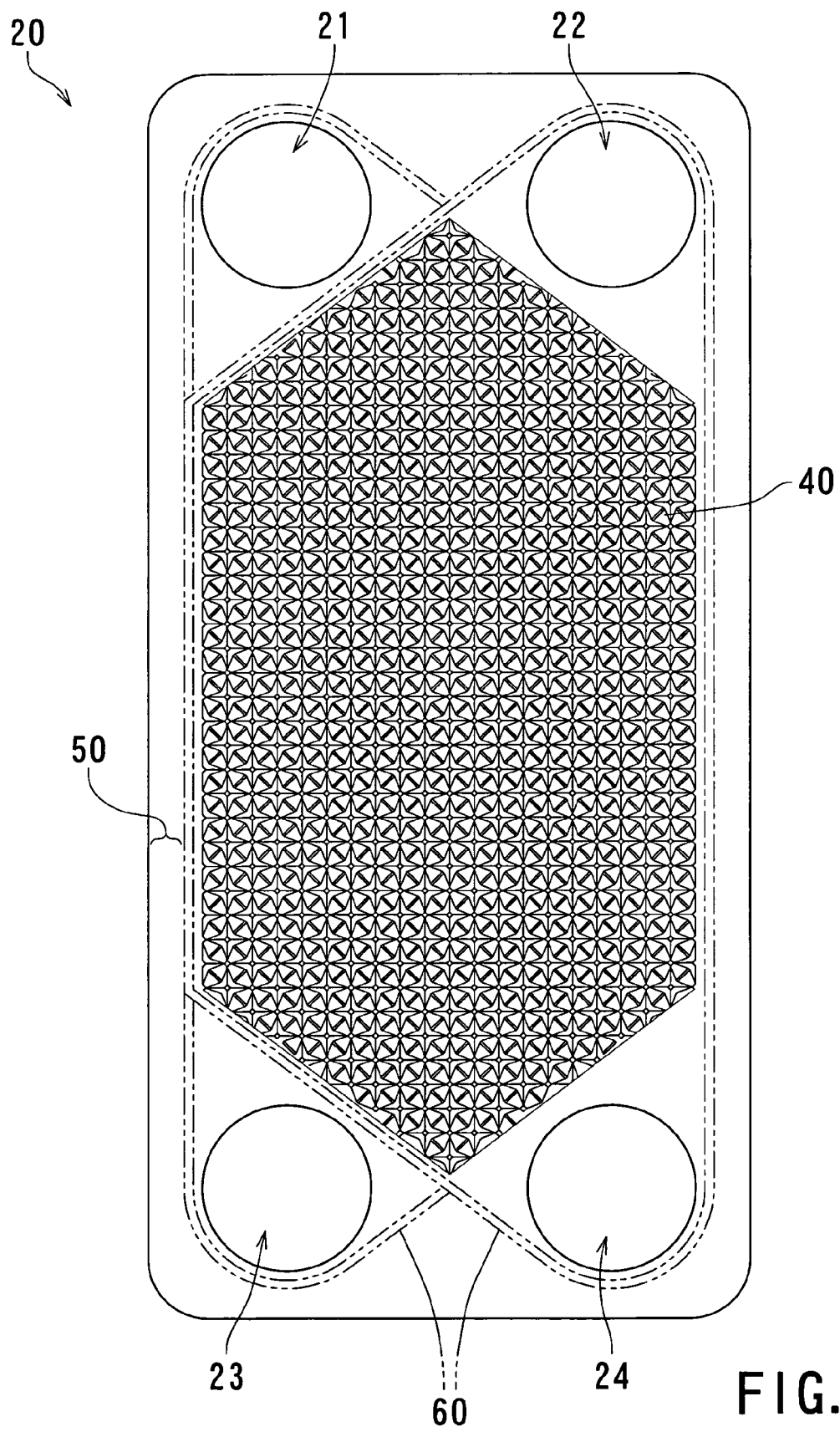


FIG. 2

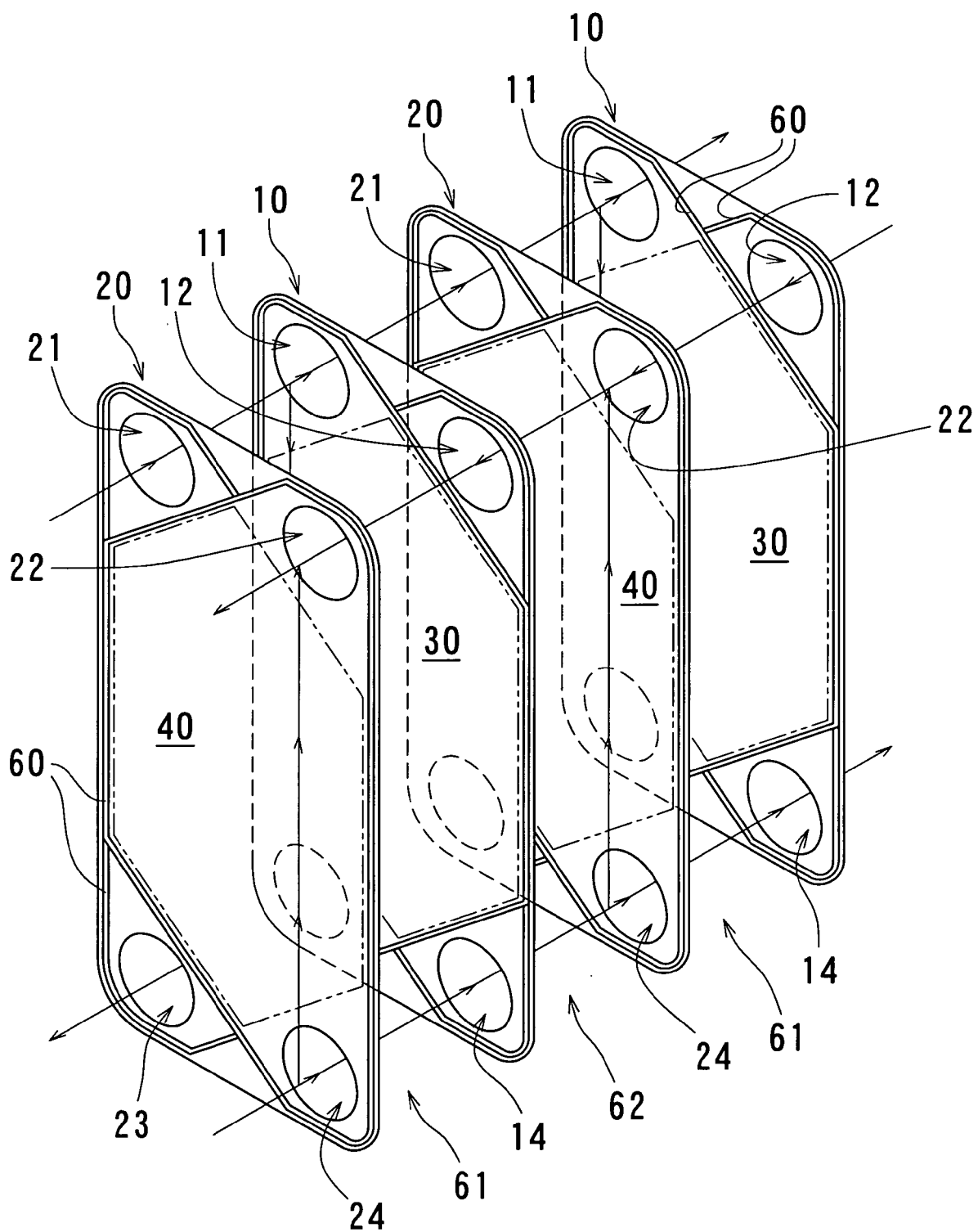


FIG. 3

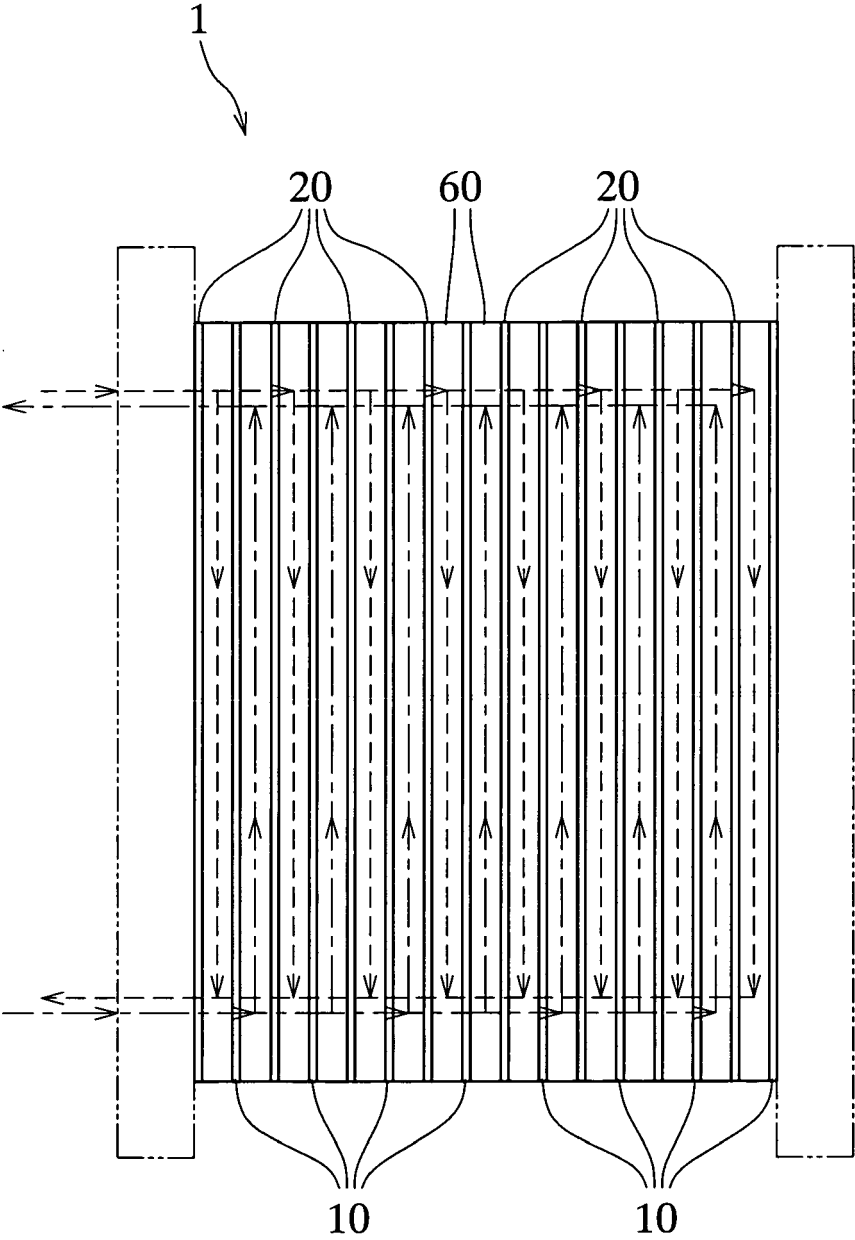


FIG.4

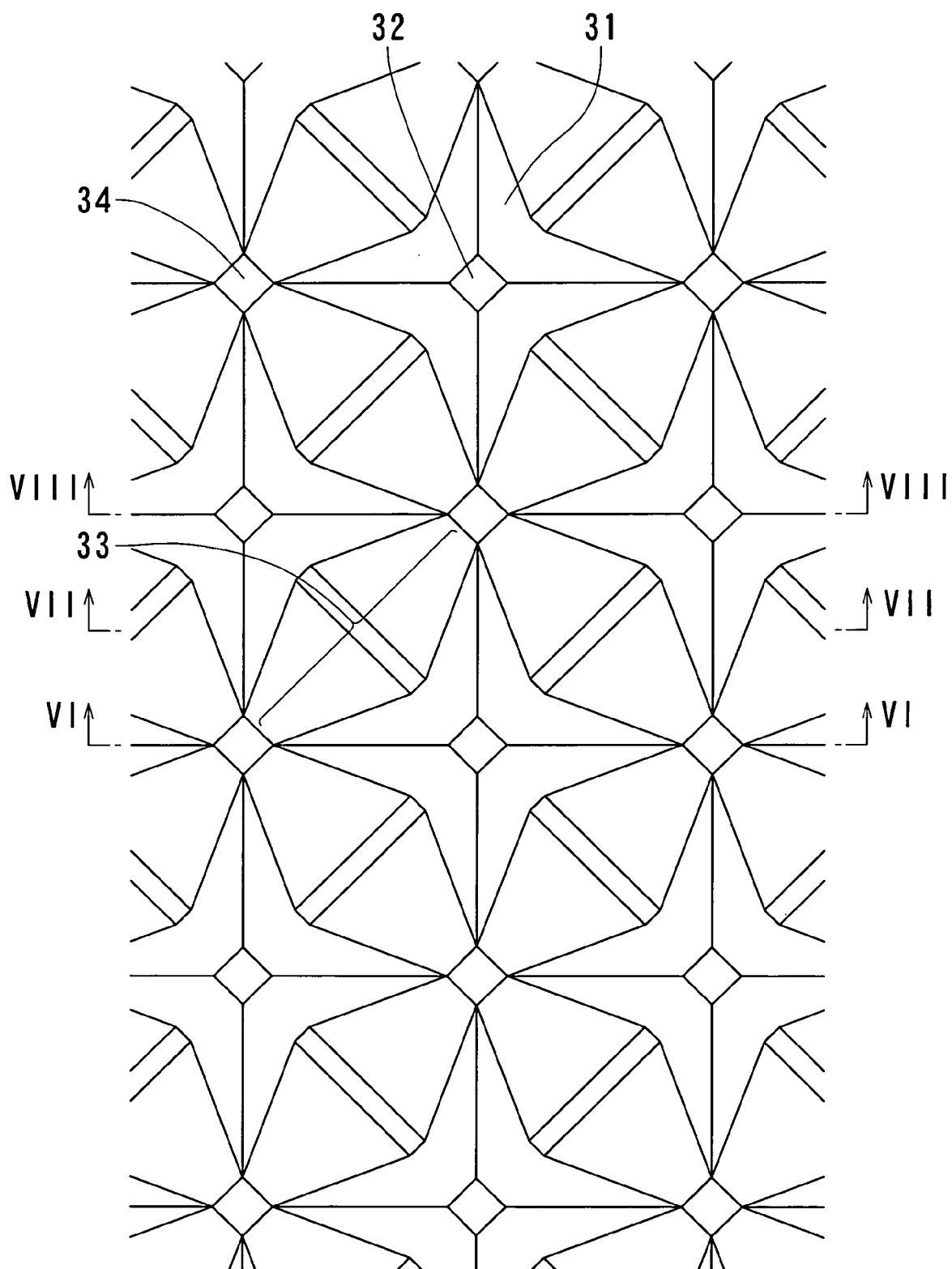


FIG. 5

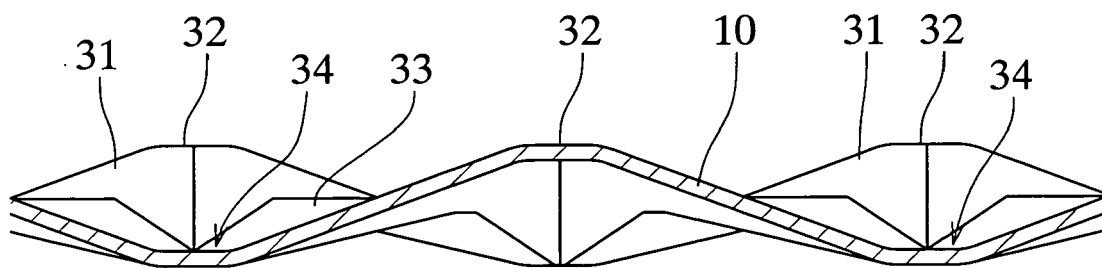


FIG. 6

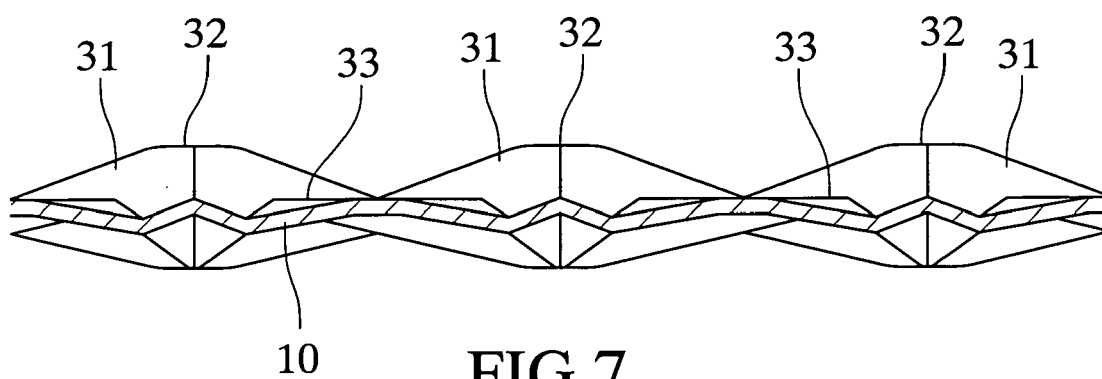


FIG. 7

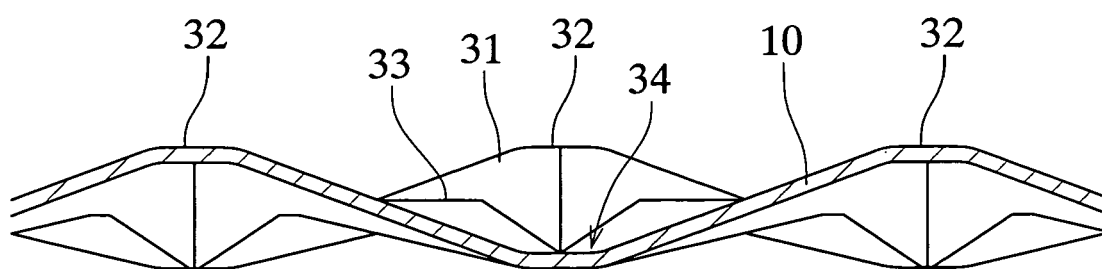


FIG. 8

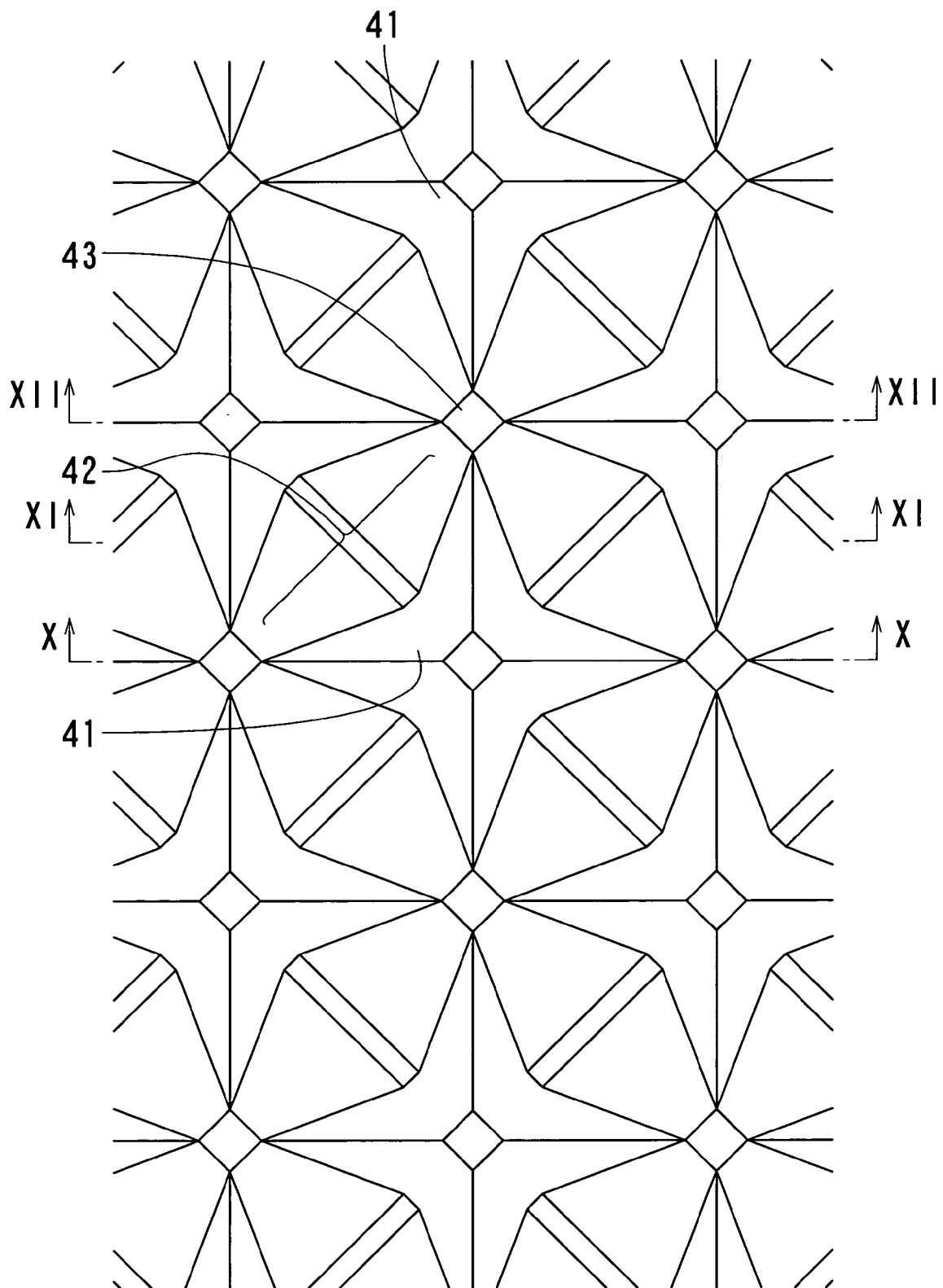


FIG. 9

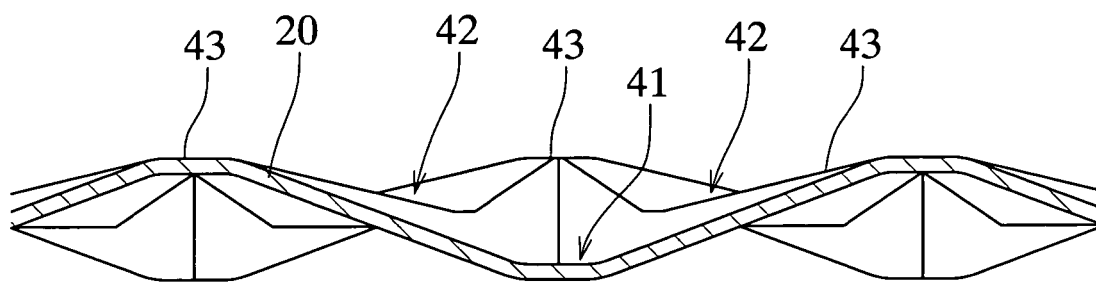


FIG. 10

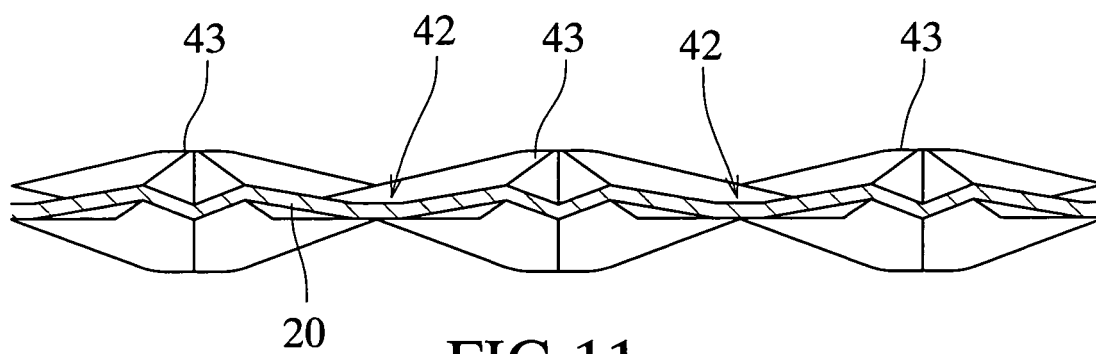


FIG. 11

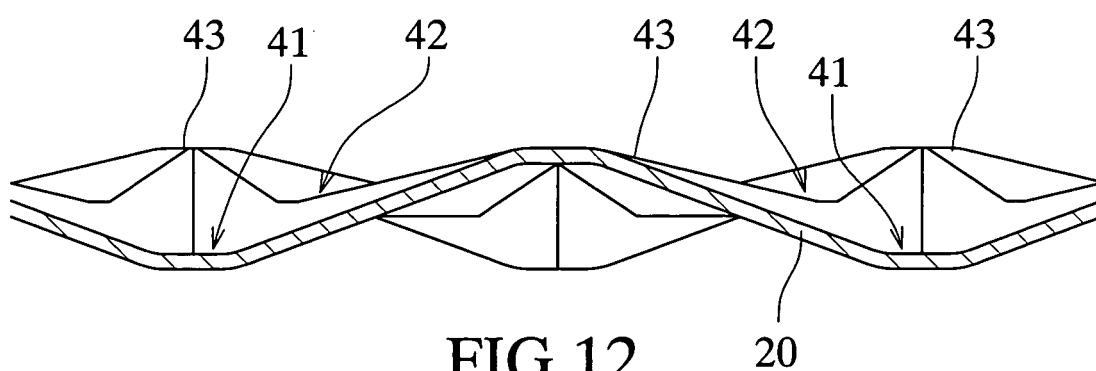


FIG. 12

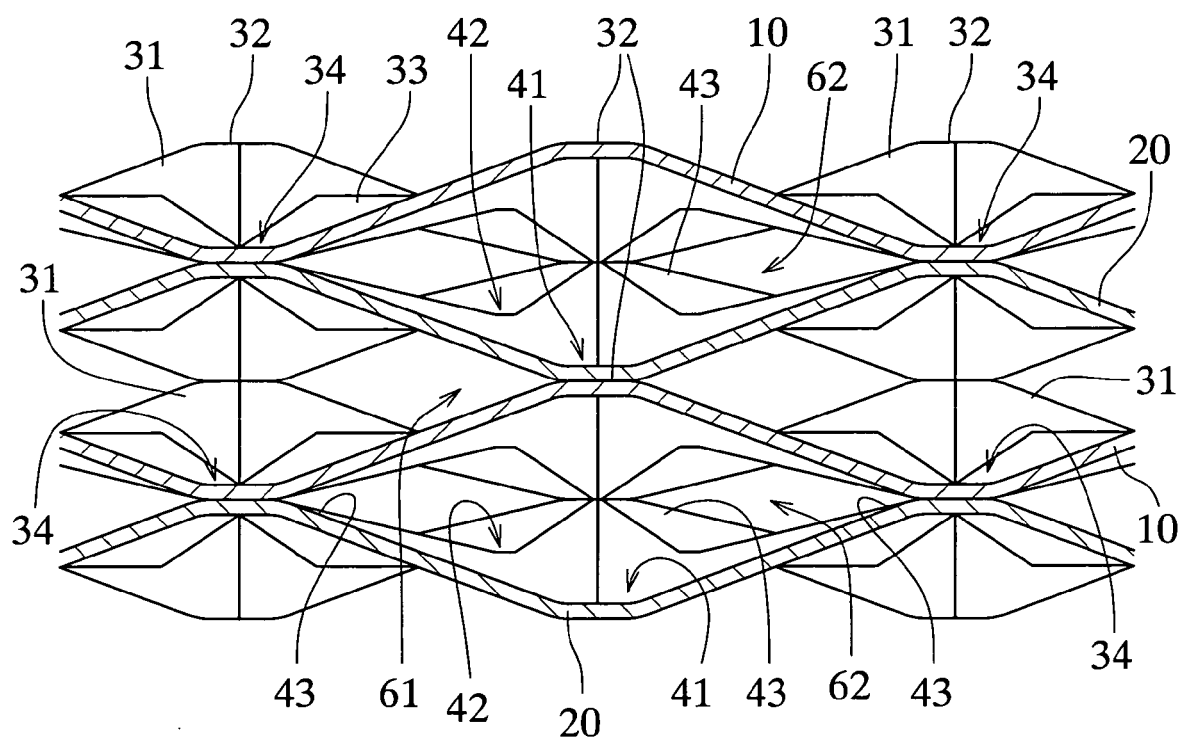


FIG.13

REFERENCES CITED IN THE DESCRIPTION

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