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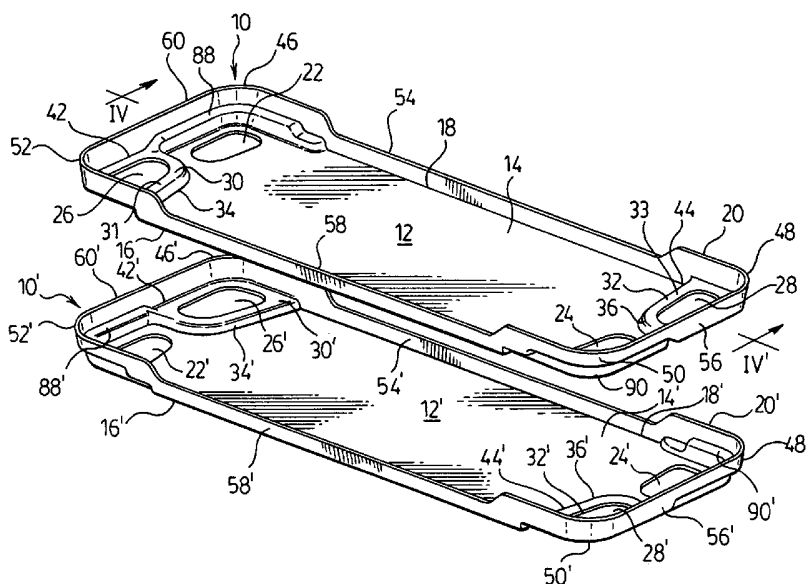
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(54) Title: STACKED PLATE HEAT EXCHANGERS AND HEAT EXCHANGER PLATES



(57) Abstract: A plate-type heat exchanger is comprised of a stack of dished plates, with the plates being sealed at their margins by nesting sidewalls and the plate bottoms being spaced from one another to define a plurality of flow passages. Each of the plates has two pairs of openings. In each of the preferred embodiments, at least one pair of openings is formed in bosses which are joined to the sidewall along a portion of their length, thereby avoiding formation of a bypass channel between the bosses and the sidewall and maximizing the plate area available for heat transfer. The bosses may either be raised or depressed relative to the plate bottom. In some preferred embodiments, one pair of openings is provided with ribs which support the bosses of upwardly adjacent plates in the stack and which provide channels to provide transverse distribution of fluid across the plate.

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STACKED PLATE HEAT EXCHANGERS AND HEAT EXCHANGER PLATES**FIELD OF THE INVENTION**

The present invention relates to plate-type heat exchangers, and more particularly to heat exchangers comprising a stack of dished plates. The
5 present invention also relates to plates for such heat exchangers.

BACKGROUND OF THE INVENTION

Plate-type heat exchangers comprising a stack of heat exchanger plates are well known. The individual plates making up the stack may preferably have a generally planar plate bottom with a sloped peripheral sidewall (i.e. dish or tub
10 shaped) which nests with adjacent plates in the stack. During assembly, the sidewalls are sealed together, for example by brazing, to form sealed flow passages for heat exchange fluids.

There is a need for improved heat exchangers of this type having improved flow distribution and efficiency.

15 SUMMARY OF THE INVENTION

In one aspect, the present invention provides a heat exchanger comprising a plurality of plates arranged in a stack, with fluid flow passages being provided between adjacent plates in the stack. Each of the plates comprises: (a) a plate bottom having a top surface and a bottom surface, the top surface facing
20 upwardly and the bottom surface facing downwardly, the plate bottom having a peripheral edge; (b) a continuous plate wall extending upwardly and outwardly from the peripheral edge of the plate bottom; (c) a first inlet hole and a first outlet hole provided through the plate bottom, the first inlet and outlet holes being spaced from one another and spaced from the peripheral edge of the
25 plate bottom; (d) a second inlet hole and a second outlet hole provided through the plate bottom, the second inlet and outlet holes being spaced from one

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another, spaced from the first inlet and outlet holes, and spaced from the peripheral edge of the plate bottom, wherein the second inlet and outlet holes are spaced upwardly relative to the first inlet and outlet holes; and (e) a pair of raised bosses having upper surfaces in which the second inlet and outlet holes
5 are provided, the upper surface of each said boss surrounding one of the second inlet and outlet holes and having an outer edge which, for a first part of its length, is joined directly to the plate wall; wherein the plates in said stack are in nested, sealed engagement with one another, with the plate bottoms of adjacent plates being spaced from one another to form said fluid flow
10 passages, with the first inlet and outlet holes in each plate being aligned with the second inlet and outlet holes, respectively, of an adjacent plate, and with the upper surfaces of the bosses in each plate sealingly engaging the bottom surface of an adjacent plate; wherein directly joining the upper surfaces of the bosses to the plate wall prevents fluid from flowing between the outer edge of
15 each of the bosses and the plate wall.

In another aspect, the present invention provides a heat exchanger plate comprising: (a) a plate bottom having a top surface and a bottom surface, the top surface facing upwardly and the bottom surface facing downwardly, the
20 plate bottom having a peripheral edge; (b) a continuous plate wall extending upwardly and outwardly from the peripheral edge of the plate bottom; (c) a first pair of holes provided through the plate bottom, the first pair of holes being spaced from one another and from the peripheral edge of the plate bottom; (d)
a second pair of holes provided through the plate bottom, the second
25 pair of holes being spaced from one another, spaced from the first pair of holes, and spaced from the peripheral edge of the plate bottom, wherein the second pair of holes are spaced upwardly relative to the first pair of holes; and (e) a pair of raised bosses having upper surfaces in which the second pair of holes are provided, the upper surface of each said boss surrounding one of the
30 second pair of holes and having an outer edge which, for a first part of its length, is joined directly to the plate wall.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a perspective view showing a heat exchanger plate according to the
5 prior art;

Figure 2 is a cross-sectional side elevation along line II – II' of Figure 1 showing a pair of stacked heat exchanger plates according to the prior art;

Figure 3 is a perspective view showing a pair of heat exchanger plates according to a first preferred embodiment of the present invention;

10 Figure 4 is a cross-section along line IV – IV' of Figure 3;

Figure 5 is a close-up perspective view of a corner of a plate of Figure 3;

Figure 6 is a close-up perspective view one end of a plate of Figure 3;

Figure 7 is a perspective view of a stack comprising the heat exchanger plates of Figure 3;

15 Figure 8 is a cross-section along line VIII – VIII' of Figure 7;

Figure 9 is a cross-section along line IX – IX' of Figure 7;

Figure 10 is a cross-section along line X – X' of Figure 7;

Figure 11 is a cross-section along line XI – XI' of Figure 7;

Figure 12 is a cross-section along line XII – XII' of Figure 7;

20 Figure 13 is a cross-section along line XIII – XIII' of Figure 7;

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Figure 14 is a cross-section along line XIV – XIV' of Figure 7

Figure 15 is a perspective view showing a pair of heat exchanger plates according to a second preferred embodiment of the present invention;

Figure 16 is a cross-section along line XVI – XVI of Figure 15, illustrating a
5 portion of a stack incorporating the plates of Figure 15;

Figure 17 is a perspective view showing a pair of heat exchanger plates according to a third preferred embodiment of the present invention;

Figure 18 is a perspective view showing a pair of heat exchanger plates according to a fourth preferred embodiment of the present invention;

10 Figure 19 is a cross-section along line XIX – XIX of Figure 18, illustrating a portion of a stack incorporating the plates of Figure 18;

Figure 20 is a perspective view showing a pair of heat exchanger plates according to a fifth preferred embodiment of the present invention; and

Figure 21 is a perspective view showing a heat exchanger plate according to a
15 sixth preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The first preferred embodiment of the present invention is now described with reference to Figures 1 to 14.

Figure 1 is a perspective view of a conventional heat exchanger plate 300
20 according to the prior art comprising a rectangular plate bottom 302 surrounded on all sides by an upwardly and outwardly sloping plate wall 304. Heat exchanger plates of this type are commonly known as "dished" plates. The plate bottom 302 is provided with four holes 306, 308, 310 and 312 at its

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corners, each of the holes serving as an inlet or outlet for a heat exchange fluid. Diagonally opposed holes 306 and 310 are raised relative to the plate bottom 302 and are in the form of raised bosses having flat upper surfaces 314, 316 and circumferential side walls 318, 320. As can be seen from Figure 1, the raised holes 306, 310 are spaced from the plate wall 304. The other two holes 308, 312 are coplanar with the bottom wall 302.

A plurality of plates of the type shown in Figure 1 may be stacked on top of one another to form a stacked plate heat exchanger. Figure 2 is a partial cross-sectional view through a pair of stacked plates, one of which is plate 300 of Figure 1 and the other of which is its identical mirror image, identified as plate 300'. The plates 300 and 300' are stacked with their plate walls 304, 304' in nested, sealed engagement. The raised holes 306, 310 of plate 300 align with flat holes 308', 312' of plate 300', and the flat upper surfaces 314, 316 of raised holes 306, 310 are sealed to the bottom 302' of plate 300' around the peripheries of holes 308', 312'. As shown in Figure 2, a flow passage 321 for heat exchange fluid is formed between the plate bottoms 302, 302' of plates 300, 300'. In order to enhance heat exchange efficiency, a fin or turbulizer (not shown) may be provided in the flow passage 321.

It can be seen from Figure 2 that a bypass channel 322 is formed between the raised hole 306 and the plate wall 304. The top and bottom of the channel 322 is defined by the plate bottoms 302 of the adjacent plates 300, and the sides of the channel 322 are defined by the plate wall 304 and the side wall 318 of raised hole 306. Since there is no driving force to cause fluid to flow through channel 322, this channel is considered a "dead space" which lowers the overall efficiency of the heat exchanger.

Figure 3 illustrates a pair of plates 10 and 10' according to a first preferred embodiment of the present invention. Plates 10 and 10' are mirror images of one another and are therefore substantially identical. For this reason, only plate 10 is described in detail below. Unless otherwise noted, the description of

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plate 10 also applies to plate 10', and vice versa, and like elements of plates 10 and 10' are identified by like reference numerals.

Plate 10 comprises a plate bottom 12 having a top surface 14 and an opposed bottom surface 16. The top surface 14 faces upwardly and the bottom surface 16 faces downwardly. It will be appreciated that the terms "upwardly" and "downwardly" are used herein as terms of reference only, and that heat exchangers and heat exchanger plates according to the invention can have any desired orientation when in use. The plate bottom 12 has a continuous peripheral edge 18 at which it is joined to a continuous plate wall 20. The plate wall 20 extends upwardly and outwardly from the peripheral edge 18 of the plate bottom 12, preferably being slightly angled relative to the upward direction.

Plate 10 is provided with four holes for passage of fluids, including a first pair of holes 22 and 24 (also referred to herein as first inlet hole 22 and first outlet hole 24). The first inlet and outlet holes 22, 24 extend through the plate bottom 12 and are spaced from one another and from the peripheral edge 18 of the plate bottom 12. In the preferred embodiment shown in the drawings, the first inlet and outlet holes 22, 24 are coplanar with one another. It will, however, be appreciated that holes 22 and 24 are not necessarily coplanar.

The plate 10 also has a second pair of holes 26 and 28 (also referred to herein as the second inlet hole 26 and the second outlet hole 28). The second inlet and outlet holes 26, 28 are also spaced from one another, spaced from the first inlet and outlet holes 22, 24 and spaced from the peripheral edge 18 of the plate bottom 12. In the preferred embodiment shown in the drawings, the second inlet and outlet holes 26, 28 are coplanar with one another. It will, however, be appreciated that holes 26 and 28 are not necessarily coplanar.

Although the holes of plate 10 may be identified herein as "inlets" or "outlets", this is done for ease of reference only. It will be appreciated that the heat

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exchange fluid may flow from inlet to outlet, or in the reverse direction from the outlet to the inlet.

The relative heights of holes 22, 24, 26 and 28 are illustrated in the cross-section of Figure 4. The plate bottom 12 and the first inlet and outlet holes 22, 24 are located in a first plane P1. The second inlet and outlet holes 26, 28 are located in a plane P2 which is spaced upwardly relative to the plane P1. That is, the second inlet and outlet holes 26, 28 are raised relative to the first inlet and outlet holes 22, 24 for reasons which will be explained below. As mentioned above, the respective holes 22, 24 and/or 26, 28 are not necessarily coplanar. In this case, the planes in which holes 26, 28 are located are spaced upwardly relative to the planes in which holes 22, 24 are located.

As shown in Figure 3, the plate 10 further comprises a pair of bosses 30, 32 protruding upwardly from the plate bottom 12 and surrounding the second inlet and outlet holes 26, 28 respectively. The bosses 30 and 32 have flat upper surfaces 31 and 33 which, in the preferred embodiment shown in the drawings, are coplanar with the second inlet and outlet holes 26, 28 respectively, i.e. they are located in plane P2 shown in Figure 4. It will, however, be appreciated that the upper surfaces 31, 33 of bosses 30, 32 are not necessarily flat and are not necessarily coplanar with the holes 26, 28. For example, it may be preferred to provide ribs or other protrusions (not shown) on the upper surfaces 31, 33 which are concentric with holes 26, 28 and may assist in brazing the heat exchanger plates together.

The boss 30 has a peripheral edge 34 extending about substantially its entire periphery. Similarly, boss 32 has a peripheral edge 36 extending about substantially its entire periphery. As shown in Figure 5, the peripheral edge 36 of boss 32 is joined directly to the plate wall 20 along a first part 38 of its length, i.e. approximately between points A and B in Figure 5. Also shown in Figure 5, the outer edge 36 is joined to the plate bottom 12 through a peripheral side wall

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40 of boss 32 along a second part 41 of its length, i.e. approximately between points B and C.

As discussed in greater detail below, the outer edge 36 of boss 32 is directly joined to the plate wall 20 so as to avoid the formation of a significant bypass
5 channel between the boss 32 and the plate wall 20, thereby avoiding the problems described above in connection with prior art plate 300 shown in Figures 1 and 2. It will be appreciated that the first part 38 of the outer edge 36 of boss upper surface 33 need only be directly joined to the plate wall 20 along a portion of the distance between points A and B in order to effectively prevent
10 fluid from flowing between boss 32 and plate wall 20.

It will be appreciated that the above description of boss 32 shown in Figure 5 also applies to boss 30.

In preferred embodiments of the invention, the bosses 30, 32 are formed in the plate 10 by stamping and punching. As shown in the drawings, the bosses
15 30,32 are preferably formed as close as possible to the plate wall 20 in order to avoid formation of a bypass channel between the holes 26, 28 and the plate wall 20, while providing bosses 30,32 of sufficient width to provide adequate contact for brazing. While the bosses 30, 32 of plate 10 are illustrated in the drawings as being raised bosses which elevate the holes 26, 28 formed therein
20 above the plate bottom 12, it will be appreciated that the bosses 30, 32 may instead be "depressed" bosses similar to those described below in connection with the fourth and fifth preferred embodiments, which would result in holes 26, 28 being located in a plane which is located below the plate bottom 12.

The plate 10 may be of any suitable shape. In the preferred embodiments
25 shown in the drawings, the plate is preferably rectangular, having four corners 46,48,50,52, and such that the plate wall 20 has four sides 54,56,58,60 which intersect at the corners. In some preferred embodiments of the inventions, the plate 10 is square. Although the preferred plates according to the invention are

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square or rectangular, it is also possible to provide heat exchanger plates according to the invention having other polygonal shapes, with hexagonal being a preferred example of a possible shape. The corners of the plates can be angular or, as in the preferred embodiment shown in the drawings, may be
5 rounded. Furthermore, the invention can also be applied to plates having non-polygonal shapes, such as circular or oval plates.

In a rectangular or square plate such as plate 10, the holes 22,24,26,28 are preferably located as close as possible to the corners 46,48,50,52 of the plate bottom 12 in order to maximize the heat exchange area between the holes and
10 to avoid formation of dead spaces between bosses 30, 32 and the plate wall 20. Where the holes are located at the corners, each of the bosses 30,32 is preferably also formed in the corners and is joined to two adjacent sides of the plate wall 20. In the preferred embodiment shown in Figure 3, the boss 30 surrounding hole 26 is located at corner 52 and is joined to sides 58 and 60 of
15 the plate wall 20. Similarly, the boss 32 surrounding hole 28 is located at corner 48 and is joined to sides 54 and 56 of plate wall 20.

In preferred plate 10, the first pair of holes 22,24 are diagonally opposed to one another and the second pair of holes 26,28 are also diagonally opposed to one another. Fluid flowing between the inlets and outlets is therefore forced to
20 follow a generally diagonal path across the plate, thereby enhancing heat exchange. It will, however, be appreciated that holes 22, 24 and holes 26, 28 are not necessarily diagonally opposed, but rather may be directly opposed on the same side of the plate 10.

Plate 10 also preferably comprises a pair of ribs 88,90 adjacent the first inlet
25 and outlet holes 22, 24 respectively. Rib 88, located adjacent first inlet hole 22, is now described below with reference to the close-up of Figure 6. Rib 88 comprises a first end 92, and second end 94 and an intermediate portion 96 extending along the plate wall 20 between the ends 92,94. The intermediate portion 96 preferably comprises an upwardly extending rib side wall 98 which is

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integrally connected to a rib upper surface 100. The first end 92 of rib 88 is joined to the boss 30 of second inlet hole 26. The intermediate portion 96 of rib 88 is located between the plate wall 20 and the first inlet hole 22, is spaced from the inlet hole 22, and extends from a proximal side 102 of the hole 22 to a
5 distal side 104 of hole 22. The second end 94 of rib 88 is located adjacent the distal side 104 of the hole 22 and is joined to the plate bottom 12 and the plate wall 20.

Similarly, the rib 90 (Figs. 9, 10) comprises a first end 106, a second end 108 and an intermediate portion 110, the intermediate portion 110 comprising a rib
10 side wall 112 and a rib upper surface 114. The intermediate portion 110 of rib 90 is located between the plate wall 20 and the first outlet hole 24, is spaced from the first outlet hole 24, and extends from a proximal side 116 of hole 24 to a distal side 118 of hole 24. The second end 108 of rib 90 is located at the distal side 118 of hole 24 and is joined to the plate bottom 12.

15 As shown in the drawings, particularly in Figure 4, the side wall 98 of rib 88 extends upwardly from the plate bottom 12 to the rib upper surface 100 which is joined to the plate wall 20. The upper surface 100, 114 of each rib 88, 90 is spaced upwardly relative to the holes 22, 24, 26 and 28 and lies in a plane P3 shown in Figure 4.

20 The following is a description of a heat exchanger according to the present invention comprising a stack 202 of plates 10, 10'. A portion of stack 202 is illustrated in Figure 7 and the subsequent cross-sectional views. The stack 202 comprises a plurality of plates 10, 10' arranged in alternating layers, the plates 10, 10' being oriented as in the exploded view of Figure 3.

25 As shown in the longitudinal cross sections of Figures 8 and 9, the plate walls 20, 20' of plates 10, 10' have a slight outward slope in order to nest (i.e. overlap) with one another along their entire lengths, thereby forming a seal around the outer peripheries of plates 10, 10' in the stack 202. The amount of

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overlap between adjacent plate walls 20,20' is sufficient so that a reliable braze joint can be provided between adjacent plates 10,10'. Figures 8 and 9 also show that the plate bottoms 12,12' of adjacent plates 10,10' are spaced from each other to define a plurality of fluid flow passages 204, 206 for flow of heat
5 exchange fluids.

As shown in the drawings, fluid flow passages 204 are formed in alternating layers of plate stack 202 between the bottom surface 16 of a plate 10 and a top surface 14' of an adjacent (underlying) plate 10'. As shown in Figure 9, fluid flow passages 204 are in flow communication with the second inlet hole 26 of
10 plate 10 and with the first inlet hole 22' of adjacent plate 10', the holes 26 and 22' being aligned with one another in the stack 202. As shown in Figure 8, flow passages 204 are also in communication with the diagonally opposed second outlet hole 28 of plate 10 and the first outlet hole 24' of adjacent plate 10', the holes 28 and 24' being aligned with one another. Furthermore, the flow
15 passages 204 in alternating layers of heat exchanger 200 are in flow communication with one another through the inlet holes 26, 22' and the outlet holes 28, 24' mentioned above.

Fluid flow passages 206 are formed in alternating layers of heat exchanger 200 between the bottom surface 16' of a plate 10' and the top surface 14 of an
20 adjacent (underlying) plate 10. Fluid flow passages 206 are in flow communication with the first outlet hole 24 of plate 10 and with the second outlet hole 28' of plate 10', with holes 24 and 28' being aligned with one another. Flow passages 206 are also in flow communication with the diagonally opposed first inlet hole 22 of plate 10 and the second inlet hole 26'
25 of plate 10', the holes 22 and 26' being aligned with one another. The flow passages 206 in alternating layers of heat exchanger 200 are in flow communication with one another through the outlet holes 24, 28' and the inlet holes 22, 26' mentioned above.

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- As shown in Figures 8 and 9, the upper surfaces 31', 33' of bosses 30', 32' are in sealed engagement with a portion of the bottom surface 16 of plate 10 which surrounds the first inlet and outlet holes 22, 24 respectively. The area of contact between bosses 30', 32' and the bottom surface 16 of plate 10 is
- 5 sufficient to provide a reliable braze joint between the two. It can be seen that the bosses 30', 32' are in sealed engagement with the bottom surface 16 of plate 10 around the entire periphery of inlet holes 26', 22 and outlet holes 28', 24, thereby sealing passages 204, 206 from one another and preventing mixing of the heat exchange fluids flowing through passages 204, 206.
- 10 It will be appreciated that locating holes 22, 24, 26, 28 as close as possible to the corners maximizes the total area of the fluid flow passages 204, 206 which is available for heat exchange, and in which a turbulizer may preferably be provided. Furthermore, directly joining the bosses 30, 32 to the plate wall 20 effectively prevents the formation of a bypass channel as in prior art plates of
- 15 this type. These improvements provided by the present invention provide improved heat exchange efficiency over prior art heat exchangers described above.

- Although not shown in the drawings, the fluid flow passages 204, 206 may preferably be provided with structures which enhance heat exchange efficiency
- 20 by forcing the fluid to follow a tortuous path through passages 204, 206. For example, passages 204, 206 may be provided with corrugated fins or turbulizers which are well known in the art. Alternatively, the plate bottom 12 could be provided with ribs, corrugations, dimples or other protrusions for the same purpose.
- 25 In some preferred embodiments of the invention, it may be preferred to construct a heat exchanger according to the invention from heat exchanger plates identical in all respects to plates 10, but with all four sides 54, 56, 58, 60 being of equal length so that the plates are square. It will be appreciated that provision of square plates will eliminate the need for mirror image plates 10'.

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All the plates of such a heat exchanger would preferably be identical to each other, with the different hole orientations in adjacent layers being provided by 90 degree rotation of each plate relative to adjacent plates in the stack, the rotation taking place about an upwardly directed axis. Such a heat exchanger
5 may be more economical to manufacture than heat exchangers constructed from plates 10 and 10', since the need for separate tooling to produce mirror image plates 10' is eliminated.

As mentioned above, plate 10 is preferably provided with ribs 88 and 90 located between the plate wall 20 and the first inlet and outlet holes 22 and 24,
10 respectively. The ribs 88, 90 fulfill two functions described below.

Firstly, the ribs 88 and 90 are open at their ends to provide flow distribution channels extending transversely across the plate 10. Each of the flow distribution channels extends from the second inlet or outlet hole 26, 28 to a distal side of an adjacent one of the first inlet or outlet holes 22, 24. This
15 enhances flow distribution of the fluid and thereby improves efficiency of the heat exchanger. The transverse flow distribution channels according to the present invention are distinct from the bypass channels of prior art plates described above. Specifically, one end of the flow distribution channel is in direct communication with an inlet or outlet hole, thereby providing a path of
20 reduced flow resistance through which fluid is caused to flow. This enhances distribution of fluid transversely across the plate and also lowers the overall pressure drop of the heat exchanger.

Secondly, the upper surfaces 100, 114 of ribs 88 and 90 engage the undersides of bosses 30, 32 in an upwardly adjacent plate in the assembled
25 heat exchanger, thereby providing support for the bosses 30, 32 and enhancing strength of the heat exchanger. The support function of the ribs 88, 90 can be explained by reference to the cross section of Figure 10, showing alternating layers of ribs 90, 88' and bosses 30, 32'. As shown in this drawing, the rib upper surface 100' of each rib 88' is in direct engagement with the boss 30 of

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an adjacent (overlying) plate 10, and the rib upper surface 114 of each rib 90 is in direct engagement with the boss 32' of an adjacent (overlying) plate 10'.

This engagement between ribs 90, 88' and bosses 30, 32' provides a relatively large surface for brazing and provides support for the bosses 30, 32'.

- 5 As mentioned above, the upper surface 100' of rib 88' is located in plane P3 of Figure 4, whereas the holes 22, 24 are located in plane P1 and holes 26, 28 are located in plane P2. In order to provide engagement between ribs 88' and bosses 30 as in Figure 10, it is preferred that the rib upper surface 100' (plane P3) be about twice as high as the adjacent boss 30 (plane P2) along
- 10 substantially the entire intermediate portion 96' of the rib 88'.

- Figure 10 also shows that the second end 94' of rib 88' has a height such that it engages the lower surface 16 of the plate bottom 12 of overlying plate 10, thereby providing additional support for the plate 10. As shown in Figure 4, the upper surface of the second end 94 of rib 88 preferably lies in plane P2, i.e. it is
- 15 coplanar with the second pair of holes 26, 28 and their surrounding bosses 30, 32.

- The flow distribution channel 208 formed by rib 88 is now described with reference to Figures 8, 9 and 11 to 14. As shown in 8, 9 and 11, the intermediate portion 96 of rib 88 is comprised of the rib side wall 98 and the
- 20 adjoining rib upper surface 100. These form the front and top walls respectively of the flow distribution channel 208. The rear wall of the channel 208 is formed by the plate wall 20' of an adjacent (underlying) plate 10' and the bottom wall of channel 208 is formed by the upper surface of the boss 30' of underlying plate 10'. It will thus be seen that the flow distribution channel 208
- 25 is sealed along the intermediate portion 96 of rib 88, thereby providing a sealed passage for fluid to flow between the first and second ends 92, 94 of rib 88. The fluid flows through channel 208 from the proximal side 116 to the distal side 118 of the first outlet hole 24, thereby distributing a portion of the heat exchange fluid transversely across the plate 10.

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As mentioned above, the first and second ends 92, 94 of rib 88 are open to the flow passage 204. As shown in Figure 6, the first end 92 of rib 88 slopes downwardly and flares away from the plate wall 20 in order to form a smooth transition with the boss 30 and to provide fluid communication with the underside of boss 30 and the fluid flow passage 204. Figure 13 is a longitudinal cross-section bisecting the plate stack 202, extending through the flared transition between the first end 92 of rib 88 and the boss 30. As shown, small gaps 209 are formed between the adjacent plates 10, 10' which allow fluid communication between the flow distribution channels 208 of ribs 88 and the fluid flow passages 204.

The ribs 88' of plates 10' also have flared transitions at their first ends 92' where they join bosses 30'. As shown in Figure 13, the flared transitions at ends 92' of ribs 88' form small gaps 209' which allow fluid communication between the flow distribution channels 208' of ribs 88' and the fluid flow passages 206.

At the opposite end of rib 88, shown in Figure 12, a step 210 is formed between the intermediate portion 96 and the second end 94 of rib 88. As shown, the second end 94 of rib 88 has an open bottom 211 which is in communication with the flow passage 204, thereby fluid communication between fluid distribution channel 208 and the fluid flow passages 206. Similarly, the second end portions 94' have open bottoms 211' which permit fluid communication between fluid distribution channel 208' and the flow passage 206.

In order to provide sufficient brazing surface area between the plate walls 20 of adjacent plates 10 which, as seen in the cross section of Figure 4, would otherwise be reduced by the provision of ribs 88, 90, the plate walls are provided with upward extensions 212 in the regions where ribs 88, 90 are provided.

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Additional preferred embodiments of the invention are now described with reference to Figures 15 to 21. In each of these additional embodiments, ribs such as those adjacent the first inlet and outlet holes of the first preferred plate 10 are eliminated.

- 5 Figures 15 and 16 illustrate a pair of plates 220, 222 according to a second preferred embodiment of the present invention. Plates 220, 222 are mirror images of one another and like elements of plates 220, 222 are identified by like reference numerals, with the elements of plates 222 being primed. Furthermore, most of the elements of plates 220, 222 correspond to elements
10 of plate 10 described above, and are therefore the same reference numerals are used to describe these elements. For convenience, only plate 220 is described in detail below. Unless otherwise noted, the description of plate 220 also applies to plate 222.

Plate 220 comprises a plate bottom 12 having a top surface 14 and an opposed
15 bottom surface 16. The plate bottom 12 has a continuous peripheral edge 18 at which it is joined to a continuous plate wall 20. The plate wall 20 extends upwardly and outwardly from the peripheral edge 18 of the plate bottom 12, preferably being slightly angled relative to the upward direction.

Plate 220 is provided with a first inlet hole 22 and a first outlet hole 24 which
20 extend through the plate bottom 12 and are spaced from one another and from the peripheral edge 18. The holes 22, 24 of plate 220 are coplanar with one another and with the plate bottom 12 and are formed at diagonally opposed corners of the plate 220. The shape of holes 22, 24 differs somewhat from the holes of the first preferred plate 10, being of a generally rounded triangular
25 shape. As noted above, plate 220 does not include ribs adjacent to the first inlet and outlet holes 22, 24.

The plate 220 also has a second inlet hole 26 and a second outlet hole 28 which are spaced from one another, spaced from the first inlet and outlet holes

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22, 24 and spaced from the peripheral edge 18. The holes 26, 28 are shown as being of the same size and shape as holes 22, 24 and are also coplanar with one another and located at diagonally opposed corners of the plate 220.

The plate 220 further comprises a pair of bosses 30, 32 protruding upwardly from the plate bottom 12 and surrounding the second inlet and outlet holes 26, 28, respectively. The bosses 30, 32 have flat upper surfaces 31, 33 in which the second inlet and outlet holes 26, 28 are formed. Boss 30 has a peripheral edge 34 extending about substantially its entire periphery. Similarly, boss 32 has a peripheral edge 36 extending about substantially its entire periphery.

10 The peripheral edges 34, 36 follow the general triangular shape of the openings 26, 28. The peripheral edges 34, 36 are joined directly to the plate wall along a first portion of their length, i.e. the portion located between the openings 26, 28 and the plate wall 20. As in the first preferred embodiment, the joining of peripheral edges 34, 36 of bosses 30, 32 directly to the plate wall 20 avoids the

15 formation of a significant bypass channel between the bosses 30, 32 and the plate wall 20, thereby avoiding the problems described above in connection with prior art plate 300 shown in Figures 1 and 2.

In addition, the peripheral edges 34, 36 are joined to the plate bottom 12 along a second portion of their length, i.e. the substantially straight portion which

20 extends diagonally across the corners of plate 220 and is joined to the plate bottom 12 through a diagonally-extending sloped shoulder 223, 225. These shoulders provide additional advantages which are now discussed below.

As mentioned above, a turbulence-enhancing element such as a fin or turbulizer may be provided within the fluid flow passages between adjacent

25 plates in order to enhance heat transfer. Although these elements may have a positive impact on heat transfer, they do not generally improve fluid flow distribution across the surface area of the plate and may in fact impair the fluid flow distribution. This problem is addressed in the present invention by dividing the fluid flow passages along the top and bottom surfaces 14, 16 of the plates

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220, 222 into a plurality of zones having variations in resistance to transverse flow, i.e. across the short dimension of the plates 220, 222. For example, plate 220 shown in Figure 15 is shown as being divided into three zones, D, E and F. Central area E may preferably be provided with a turbulence-enhancing
5 element such as a fin or turbulizer (not shown) having a relatively high resistance to transverse flow, whereas the ends D and F may preferably be left empty or may be provided with turbulence-enhancing elements such as ribs, dimples or the like which provide less resistance to transverse flow. As will be appreciated, the fin or turbulizer provided of central area E must be prevented
10 from shifting its position in order to maximize the benefit of this flow distribution. As will be appreciated from the drawings, the diagonally-extending shoulders 223, 225 gradually reduce the transverse width dimension of the plate bottom 12 between the dotted lines 227, 229 and the ends of the plate 220. Therefore, a rectangular fin or turbulizer having approximately the same dimensions as
15 area E will be prevented from shifting its position due to abutment of two of its corners against the shoulders 223, 225. This same advantage is also provided by the preferred embodiments of the invention shown in Figures 17 to 21, all of which have diagonally-extending shoulders provided in the plate bottom.

Figure 16 is a transverse cross section through a portion of a stack 224
20 comprised of a plurality of plates 220, 222 arranged in alternating layers, the plates 220, 222 being oriented as in the exploded view of Figure 15.

As shown in Figure 16, the plate walls 20, 20' of plates 220, 222 are nested, thereby sealing the plates around their peripheries. Fluid flow passages 226 are formed in alternating layers of plate stack 224 between the bottom surface
25 16 of a plate 220 and the top surface 14' of an adjacent (underlying) plate 222. Fluid flow passages 226 are in flow communication with the second inlet hole 26 of plate 220 and the first inlet hole 22' of adjacent plate 222, the holes 26, 22' being aligned with one another. Although not shown in Figure 16, flow passages 226 are also in communication with the diagonally opposed second

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outlet hole 28 of plate 220 and the first outlet hole 24' of adjacent plate 222, the holes 28, 24' being aligned with one another.

Fluid flow passages 228 are similarly formed in alternating layers of stack 224 between the bottom surface 16' of a plate 222 and the top surface 14 of an adjacent (underlying) plate 220. Fluid flow passages 228 are in flow communication with the first inlet hole 22 of plate 220 and the second inlet hole 26' of plate 222, the holes 22, 26' being aligned with one another. Although not shown in Figure 16, the flow passages 228 are also in flow communication with the first outlet hole 24 of plate 220 and the second outlet hole 28' of plate 222, the holes 24 and 28' being aligned with one another.

It can be seen from Figure 16 that the upper surface 31 of boss 30 of plate 220 is in sealed engagement with a portion of the bottom surface 16' surrounding the first inlet hole 22' of plate 222. Although not shown in Figure 16, the other boss 32 of plate 220 is similarly sealed to the bottom surface 16' surrounding the first outlet hole 24' of plate 222.

Figure 17 illustrates a pair of plates 230 according to a third preferred embodiment of the invention. Plates 230 are identical to each other and substantially identical to plates 220, 222 with the exception that the first inlet and outlet openings 22, 24 are located on the same side of the plate 230, as are the second inlet and outlet openings 26, 28. This arrangement of the openings permits a stack to be formed from only one type of plate 230, eliminating the need for an identical mirror image plate as in the first and second preferred embodiments. It will be appreciated that a transverse cross section through a stack of plates 230, in a plane corresponding to that of Figure 16, would have substantially the same appearance as Figure 16.

Figures 18 and 19 illustrate a pair of plates 234, 236 according to a fourth preferred embodiment of the present invention. Plates 234, 236 are mirror images of one another and like elements of plates 234, 236 are identified by

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like reference numerals, with the elements of plates 236 being primed.

Furthermore, most of the elements of plates 234, 236 correspond to elements of plate 10 described above, and are therefore the same reference numerals are used to describe these elements. For convenience, only plate 234 is
5 described in detail below. Unless otherwise noted, the description of plate 234 also applies to plate 236.

Plate 234 comprises a plate bottom 12 having a top surface 14, a bottom surface 16 and a peripheral edge 18 which is joined to a continuous plate wall 20. Plate 234 is provided with two pairs of holes for passage of fluids, namely
10 first inlet and outlet holes 22, 24 and second inlet and outlet holes 26, 28. The respective inlet and outlet holes of each pair are located at diagonally opposed corners of the plate 234. As in the second preferred embodiment, the second inlet and outlet holes 26, 28 are formed in the upper surfaces 31, 33 of bosses 30, 32, respectively. Further discussion of these openings is therefore
15 unnecessary.

On the other hand, the first inlet and outlet openings 22, 24 are located in respective depressions 238, 240 formed in the plate bottom 12. (These depressions 238, 240 also referred to herein as "depressed bosses") comprise flat surfaces 242, 244 surrounding the respective openings 22, 24, as well as
20 diagonally extending shoulders 246, 248 through which the flat surfaces 242, 244 are joined to the remainder of plate bottom 12. As shown in Figure 19, three planes are defined by the openings and the plate bottom of plate 234, namely a lower plane P_1 in which the first inlet and outlet openings 22, 24 and surfaces 242, 244 are provided, an intermediate plane P_2 occupied by plate
25 bottom 12, and a raised plane P_3 in which the second inlet and outlet openings 26, 28 are provided.

The flat surfaces 242, 244 of depressions 238, 240 are preferably of the same shape and size as the upper surfaces 31, 33 of bosses 30, 32. As shown in the

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transverse cross section of Figure 19, these areas are in engagement with each other in the assembled plate stack 232.

As shown in Figure 19, the plate stack 232 comprises a plurality of plates 234, 236 arranged in alternating layers, the plates 234, 236 being oriented as in the exploded view of Figure 18. The plate walls 20, 20' of plates 234, 236 are nested with one another, thereby forming a seal around their outer peripheries. A plurality of alternating fluid flow passages 250, 252 are formed between the plate bottoms. Fluid flow passages 250 are formed in alternating layers of plate stack 232 between the bottom surface 16 of a plate 234 and a top surface 14' of an adjacent (underlying) plate 236. The flow passages 250 are in communication with the second inlet hole 26 of plate 234 and the first inlet hole 22' of adjacent plate 236, the holes 26, 22' being aligned with one another. Although not shown in Figure 19, flow passages 250 are also in communication with the diagonally opposed second outlet hole 28 of plate 234 and the first outlet hole 24' of plate 236.

Similarly, fluid flow passages 252 are formed in alternating layers of plate stack 232 between the bottom surface 16' of a plate 236 and the top surface 14 of an adjacent (underlying) plate 234. Fluid flow passages 252 are in flow communication with the first inlet hole 22 of plate 234 and the second inlet hole 26' of plate 236, and also with the first outlet hole 24 of plate 234 and the second outlet hole 28' of plate 236.

As mentioned above, the upper surfaces 31, 33 of bosses 30, 32 are in sealed engagement with the flat bottom surfaces 242, 244 of depressed areas 238, 240, thereby sealing fluid flow passages 250, 252 from one another and preventing mixing of the heat exchange fluids.

One advantage of the preferred embodiment shown in Figures 18 and 19 is that additional strengthening is provided in the corners of the plate stack 232 by tripling of the plate walls 20, 20' in areas 256 and 258.

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Figure 20 illustrates a pair of identical heat exchange plates 254 which are identical to each other and are substantially identical in all respects to plates 234, 236 described above, with the exception that the first inlet and outlet openings 22, 24 are located on the same side of the plate 254, as are the
5 second inlet and outlet openings 26, 28. This permits the formation of a plate stack from a single type of plate 254. It will be appreciated that a transverse cross section through a stack of plates 254, in a plane corresponding to that of Figure 19, would have substantially the same appearance as Figure 19.

Figure 21 illustrates a heat exchange plate 260 which is similar to that
10 described with reference to Figures 18 and 19. Similar elements of plate 260 are therefore identified by similar reference numerals. Plate 260 comprises a plate bottom 12 having a top surface 14, a bottom surface 16 (not shown) and a peripheral edge 18 which is joined to a continuous plate wall 20. Plate 260 is provided with two pairs of holes for passage of fluids, namely first inlet and
15 outlet holes 22, 24 and second inlet and outlet holes 26, 28. The first inlet and outlet holes 22, 24 are located in depressions 238, 240 formed in the plate bottom 12 at diagonally opposed corners of the plate 260. The second inlet and outlet holes 26, 28 are located along opposite sides of the plate 260 and are formed in the upper surfaces of elongate, raised bosses 262, 264 which are
20 joined to the plate wall 20 along a first portion of their peripheral edges and which extend from one of the depressions 238, 240 to a point adjacent the opposite end of the plate 260. Furthermore, the second inlet and outlet holes 26, 28 are divided into segments by a plurality of webs 266. Lastly, the plate bottom 12 is provided with a central raised boss 268 in which a central aperture
25 270 is formed. This would permit a plate stack including plates 260 to be bolted together through the central aperture, thereby eliminating the need for a baseplate, and may preferably also provide an additional fluid flow passageway through the plate stack. It will be appreciated that a plate stack including plate 260 would also require a second type of plate having diagonally opposed
30 raised corner bosses corresponding to depressions 238, 240 and having

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elongate depressions formed along opposite edges of the plate corresponding to raised bosses 262, 264.

Although the invention has been described in relation to certain preferred embodiments, it is not limited thereto. Rather, the invention includes all
5 embodiments which may fall within the scope of the following claims.

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What is claimed is:

1. A heat exchanger comprising a plurality of plates arranged in a stack, with fluid flow passages being provided between adjacent plates in the stack, each of the plates comprising:
 - 5 (a) a plate bottom having a top surface and a bottom surface, the top surface facing upwardly and the bottom surface facing downwardly, the plate bottom having a peripheral edge;
 - (b) a continuous plate wall extending upwardly and outwardly from the peripheral edge of the plate bottom;
 - 10 (c) a first inlet hole and a first outlet hole provided through the plate bottom, the first inlet and outlet holes being spaced from one another and spaced from the peripheral edge of the plate bottom;
 - (d) a second inlet hole and a second outlet hole provided through the plate bottom, the second inlet and outlet holes being spaced from one another,
 - 15 spaced from the first inlet and outlet holes, and spaced from the peripheral edge of the plate bottom, wherein the second inlet and outlet holes are spaced upwardly relative to the first inlet and outlet holes; and
 - (e) a pair of bosses in which the second inlet and outlet holes are provided, wherein each said boss has a surface surrounding one of the second
 - 20 inlet and outlet holes, and wherein each said surface has a peripheral edge which, for a first part of its length, is joined directly to the plate wall;
- wherein the plates in said stack are in nested, sealed engagement with one another, with the plate bottoms of adjacent plates being spaced from one another to form said fluid flow passages, with the first inlet and outlet holes in
- 25 each plate being aligned with the second inlet and outlet holes, respectively, of an adjacent plate, and with said surfaces of the bosses in each plate sealingly engaging the plate bottom of an adjacent plate;
- wherein the joining of the peripheral edges of the bosses directly to the plate wall prevents fluid from flowing between the peripheral edge of each boss
- 30 and the plate wall.

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2. The heat exchanger of claim 1, wherein the plate bottom of each plate is rectangular and has four corners, and wherein the plate wall has four sides which intersect at the corners.
- 5 3. The heat exchanger of claim 1, wherein the plate bottom of each plate is square and has four corners, and wherein the plate wall has four sides of equal length which intersect at the corners, and wherein the first inlet and outlet of each plate is displaced by 90 degrees relative to the first inlet and outlet of an adjacent plate.
- 10 4. The heat exchanger of claim 2 or 3, wherein each of the holes is located proximate one of the corners.
5. The heat exchanger of claim 4, wherein the first portion of the peripheral
15 edge of each of the bosses is joined to two sides of the plate wall, and wherein the peripheral edge of each of the bosses has a second portion which is joined to the plate bottom through a shoulder.
6. The heat exchanger of claim 4, wherein the first inlet and outlet holes of
20 each plate are diagonally opposed to one another and wherein the second inlet and outlet holes of each plate are diagonally opposed to one another.
7. The heat exchanger of claim 4, wherein the first inlet and outlet holes of each plate are located along the same side of the plate and wherein the second
25 inlet and outlet holes of the plate are located along the same side of the plate.
8. The heat exchanger of claim 1, wherein said bosses in which the second inlet and outlet holes are provided comprise raised bosses, wherein said surfaces of the bosses comprise upper surfaces which engage the bottom
30 surface of an adjacent plate, and wherein the upper surfaces of the bosses are substantially flat and coplanar with one another.

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9. The heat exchanger of claim 1, wherein said bosses in which the second inlet and outlet holes are provided comprise depressed bosses, wherein said surfaces of the bosses comprise lower surfaces which engage the top surface of an adjacent plate, and wherein the lower surfaces of the bosses are
5 substantially flat and coplanar with one another.

10. The heat exchanger of claim 1, wherein the first inlet and outlet holes are substantially coplanar with one another.

10 11. The heat exchanger of claim 1, wherein the second inlet and outlet holes are substantially coplanar with one another.

12. The heat exchanger of claim 1, wherein the first inlet and outlet holes are both located in a first plane, the second inlet and outlet holes are both
15 located in a second plane, and wherein the second plane is spaced upwardly relative to the first plane.

13. The heat exchanger of claim 12, wherein the first inlet and outlet holes are coplanar with the plate bottom.

20

14. The heat exchanger of claim 12, wherein the plate bottom is located in an intermediate plane which is between the first and second planes.

15. The heat exchanger of claim 14, wherein the bosses in which the
25 second inlet and outlet holes are provided comprise raised bosses, and wherein each of the plates further comprises:

(f) a pair of depressed bosses having lower surfaces in which the first inlet and outlet holes are provided, wherein the lower surface of each said depressed boss surrounds one of the first inlet and outlet holes and wherein
30 each of the depressed bosses has a peripheral edge which, for a first part of its length, is joined directly to the plate wall.

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16. The heat exchanger of claim 1, wherein each of the plates further comprises:

a pair of ribs, each of the ribs comprising a first end, a second end and an intermediate portion extending between the ends, the intermediate portion
5 comprising a rib side wall and a rib upper surface;

each of the ribs extending along the plate wall, the first end being joined to one of the bosses, the intermediate portion located between the plate wall and one of the first inlet and outlet holes, the intermediate portion extending from a side of said hole which is proximal to the first end of the rib to a side of
10 the said hole which is distal to the first end of the rib, the second end of the rib being located at the distal side of the hole and being joined to the plate bottom;

wherein the upper surface of each rib engages a bottom surface of one of the bosses of an overlying plate.

15 17. The heat exchanger of claim 16, wherein the rib side wall of each rib extends upwardly from the plate bottom to the rib upper surface, and wherein the rib upper surface is joined to the plate wall.

18. The heat exchanger plate of claim 16, wherein the rib upper surface is
20 spaced upwardly relative to the first inlet and outlet holes and relative to the second inlet and outlet holes.

19. The heat exchanger of claim 16, wherein each of the ribs forms a flow distribution channel which is in flow communication with one of the fluid flow
25 passages at the ends of the rib and which is sealed along the intermediate portion of the rib.

20. The heat exchanger of claim 19, wherein each of the flow distribution channels is defined by the sidewall and upper wall of one of the ribs of a first
30 plate and by the plate wall and an upper surface of one of the bosses of an underlying plate.

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21. The heat exchanger of claim 20, wherein the flow distribution channel formed by each of said ribs is in fluid flow communication with a fluid flow passage between the plate in which said rib is formed and an immediately underlying one of said plates.
- 5
22. The heat exchanger of claim 16, wherein at least some of the fluid flow passages are provided with turbulence-enhancing elements selected from the group comprising corrugated fins, turbulizers and turbulence-enhancing protrusions formed in the plate bottoms.
- 10
23. A heat exchanger plate, comprising:
- (a) a plate bottom having a top surface and a bottom surface, the top surface facing upwardly and the bottom surface facing downwardly, the plate bottom having a peripheral edge;
 - 15 (b) a continuous plate wall extending upwardly and outwardly from the peripheral edge of the plate bottom;
 - (c) a first pair of holes provided through the plate bottom, the first pair of holes being spaced from one another and from the peripheral edge of the plate bottom;
 - 20 (d) a second pair of holes provided through the plate bottom, the second pair of holes being spaced from one another, spaced from the first pair of holes, and spaced from the peripheral edge of the plate bottom, wherein the second pair of holes are spaced upwardly relative to the first pair of holes; and
 - (e) a pair of bosses in which the second pair of holes are provided,
 - 25 wherein each said boss has a surface surrounding one of the second pair of holes, wherein each said surface has a peripheral edge which, for a first part of its length, is joined directly to the plate wall.
24. The heat exchanger plate of claim 23, wherein the plate bottom is
- 30 rectangular and has four corners, and wherein the plate wall has four sides which intersect at the corners.

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25. The heat exchanger plate of claim 23, wherein the plate bottom is square and has four corners, and wherein the plate wall has four sides of equal length which intersect at the corners.
- 5 26. The heat exchanger plate of claim 24 or 25, wherein each of the holes is located proximate to one of the corners.
27. The heat exchanger plate of claim 26, wherein the first portion of the peripheral edge of each of the bosses is joined to two sides of the plate wall,
10 and wherein the peripheral edge of each of the bosses has a second portion which is joined to the plate bottom through a shoulder.
28. The heat exchanger plate of claim 26, wherein the first pair of holes are diagonally opposed to one another and wherein the second pair of holes are
15 diagonally opposed to one another.
29. The heat exchanger plate of claim 26, wherein the first pair of holes are located along the same side of the plate and wherein the second pair of holes are located along the same side of the plate.
20
30. The heat exchanger plate of claim 23, wherein said bosses in which the second pair of holes are provided comprise raised bosses, wherein said surfaces of the bosses comprise upper surfaces which are spaced above the plate bottom, and wherein the upper surfaces of the bosses are substantially
25 flat and coplanar with one another.
31. The heat exchanger plate of claim 23, wherein said bosses in which the second pair of holes are provided comprise depressed bosses, wherein said surfaces of the bosses comprise lower surfaces which are spaced below the
30 plate bottom, and wherein the lower surfaces of the bosses are substantially flat and coplanar with one another.

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32. The heat exchanger plate of claim 23, wherein the first pair of holes are substantially coplanar with one another.

33. The heat exchanger plate of claim 23, wherein the second pair of holes
5 are substantially coplanar with one another.

34. The heat exchanger plate of claim 23, wherein the first pair of holes is located in a first plane, the second pair of holes is located in a second plane, and wherein the second plane is spaced upwardly relative to the first plane.

10

35. The heat exchanger plate of claim 34, wherein the first inlet and outlet holes are coplanar with the plate bottom.

36. The heat exchanger plate of claim 34, wherein the plate bottom is
15 located in an intermediate plane which is between the first and second planes.

37. The heat exchanger plate of claim 23, further comprising:
a pair of ribs, each of the ribs comprising a first end, a second end and
an intermediate portion extending between the ends, the intermediate portion
20 comprising a rib side wall and a rib upper surface;
each of the ribs extending along the plate wall, the first end being joined
to one of the bosses, the intermediate portion located between the plate wall
and one of the first pair of holes, the intermediate portion extending from a side
of said hole which is proximal to the first end of the rib to a side of the hole
25 which is distal to the first end of the rib, the second end of the rib being located
at the distal side of said hole and being joined to the plate bottom.

38. The heat exchanger plate of claim 37, wherein the rib side wall of each
rib extends upwardly from the plate bottom to the rib upper surface, and
30 wherein the rib upper surface is joined to the plate wall.

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39. The heat exchanger plate of claim 37, wherein the rib upper surface is spaced upwardly relative to the first pair of holes and the second pair of holes.

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FIG.1. (PRIOR ART)

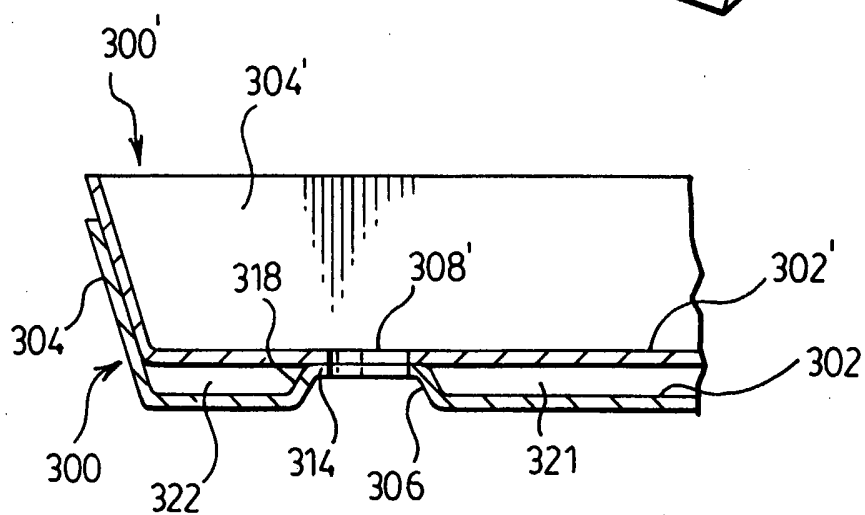
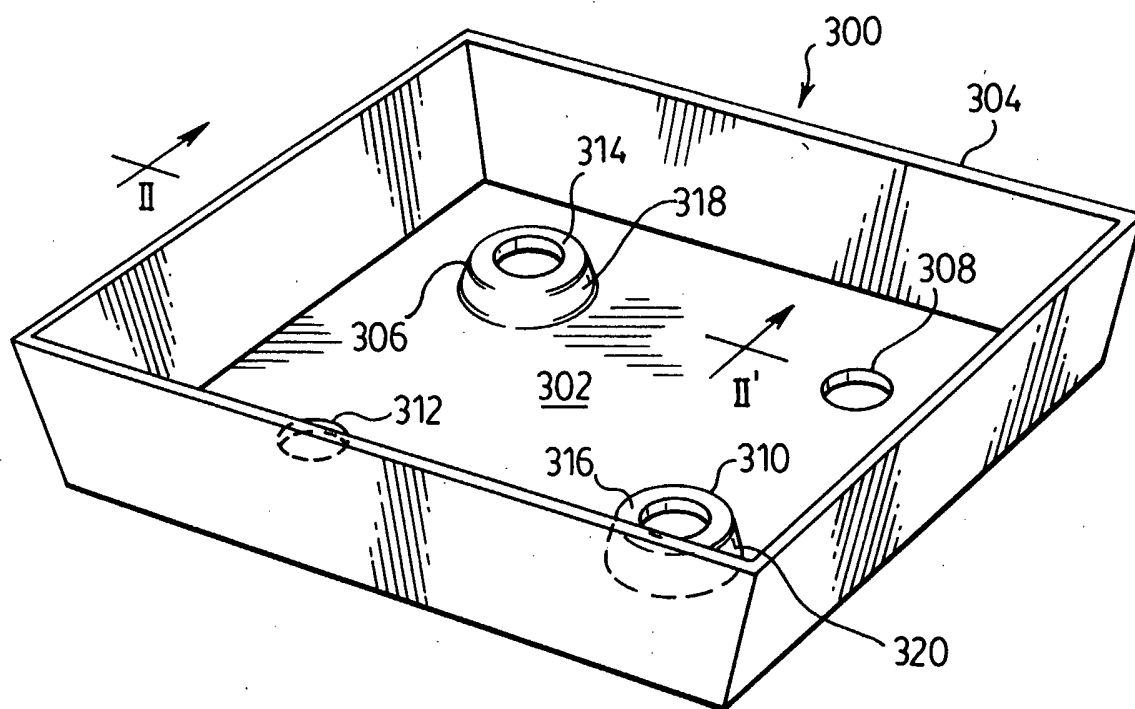
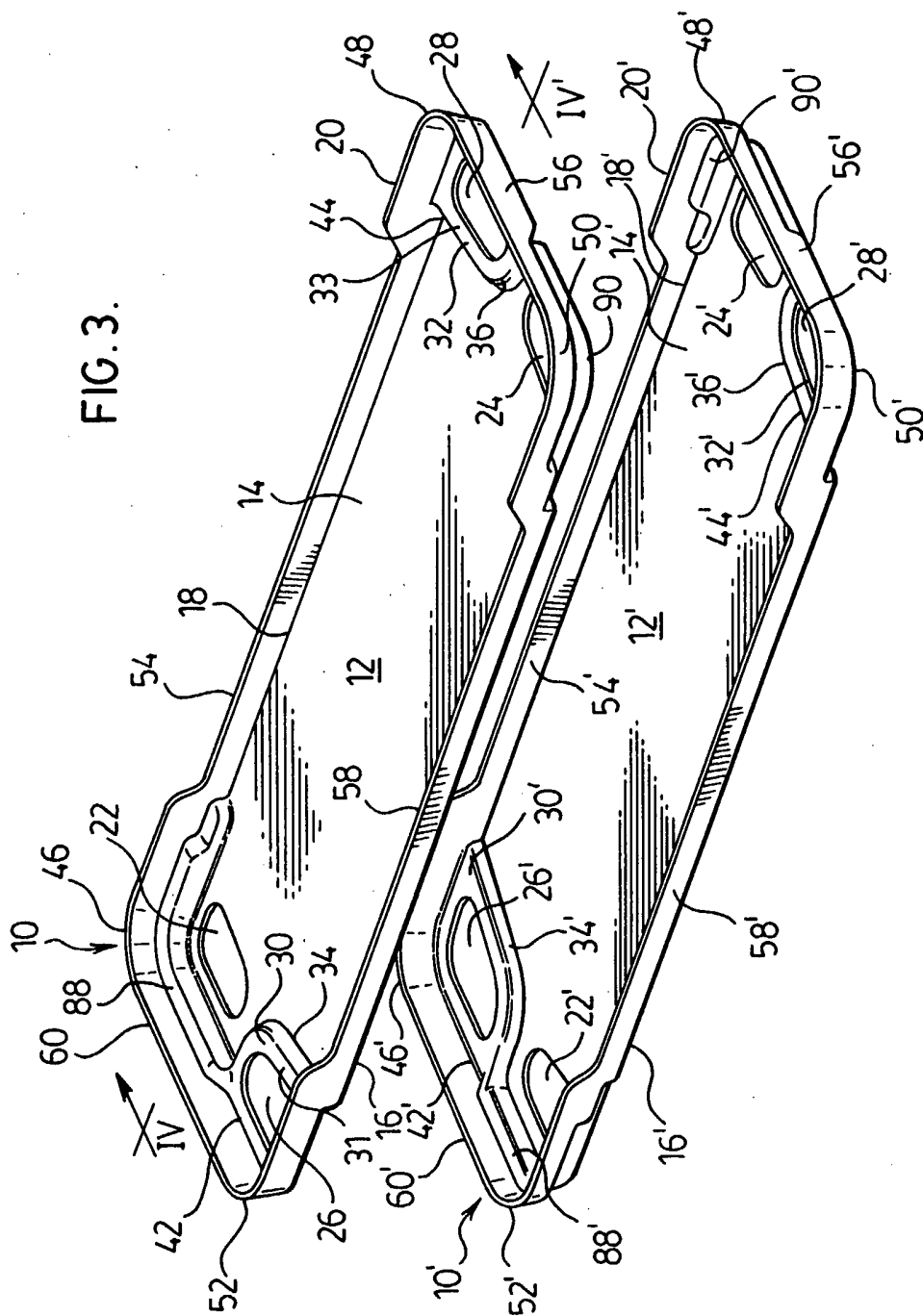


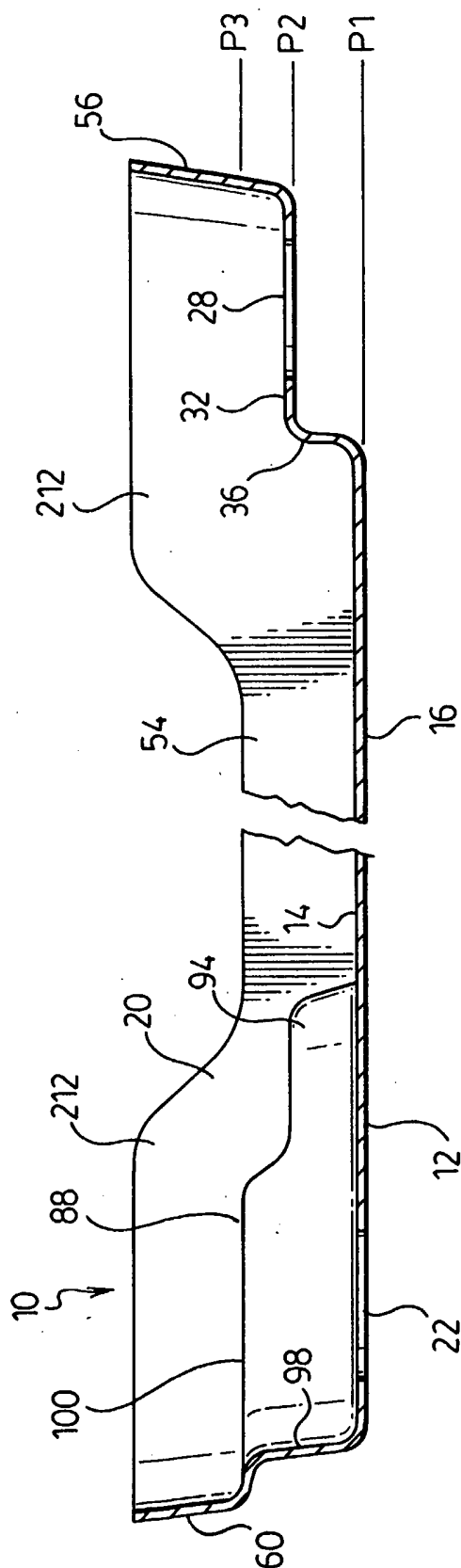
FIG.2. (PRIOR ART)

FIG. 3.



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FIG. 4.



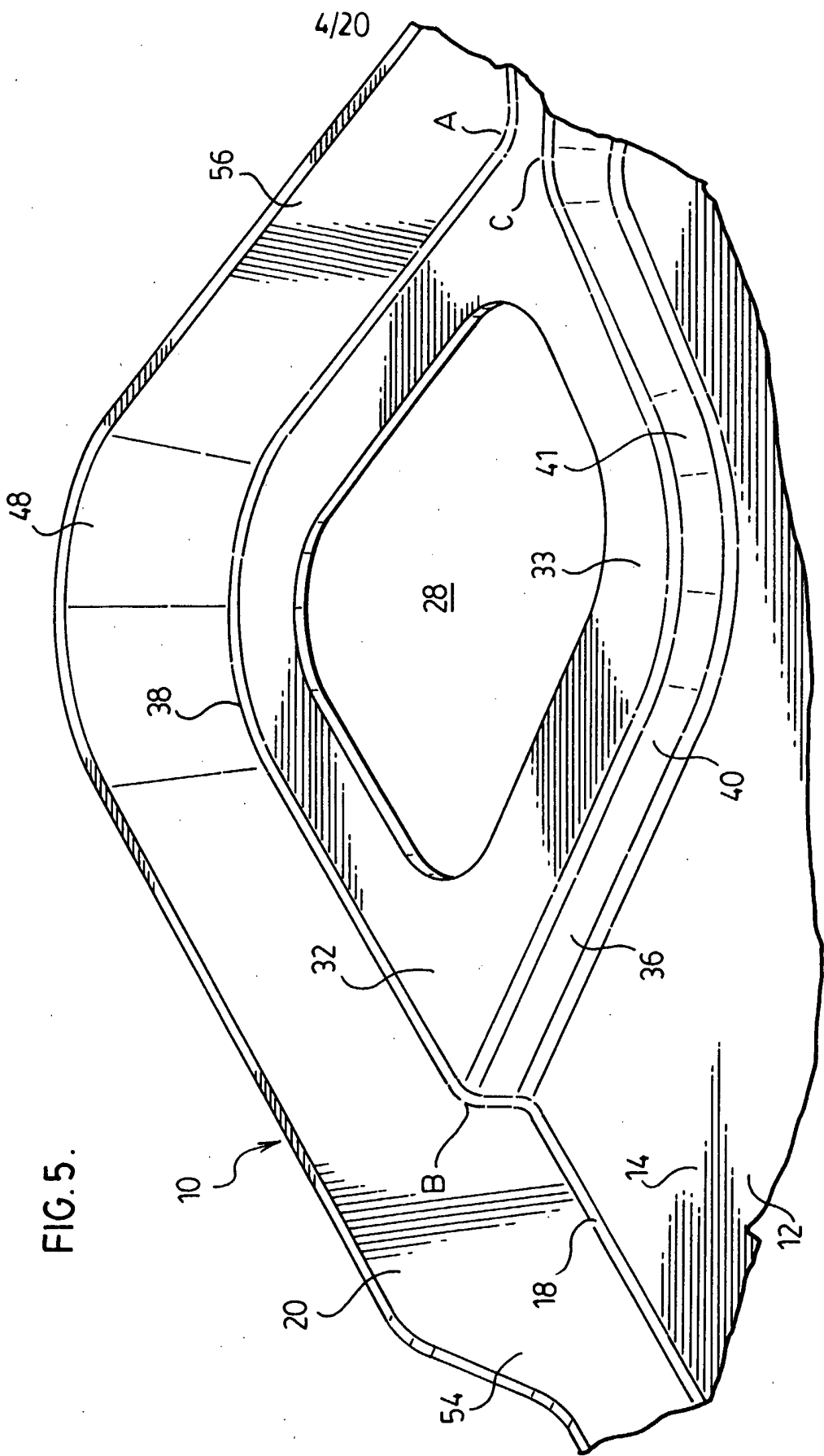
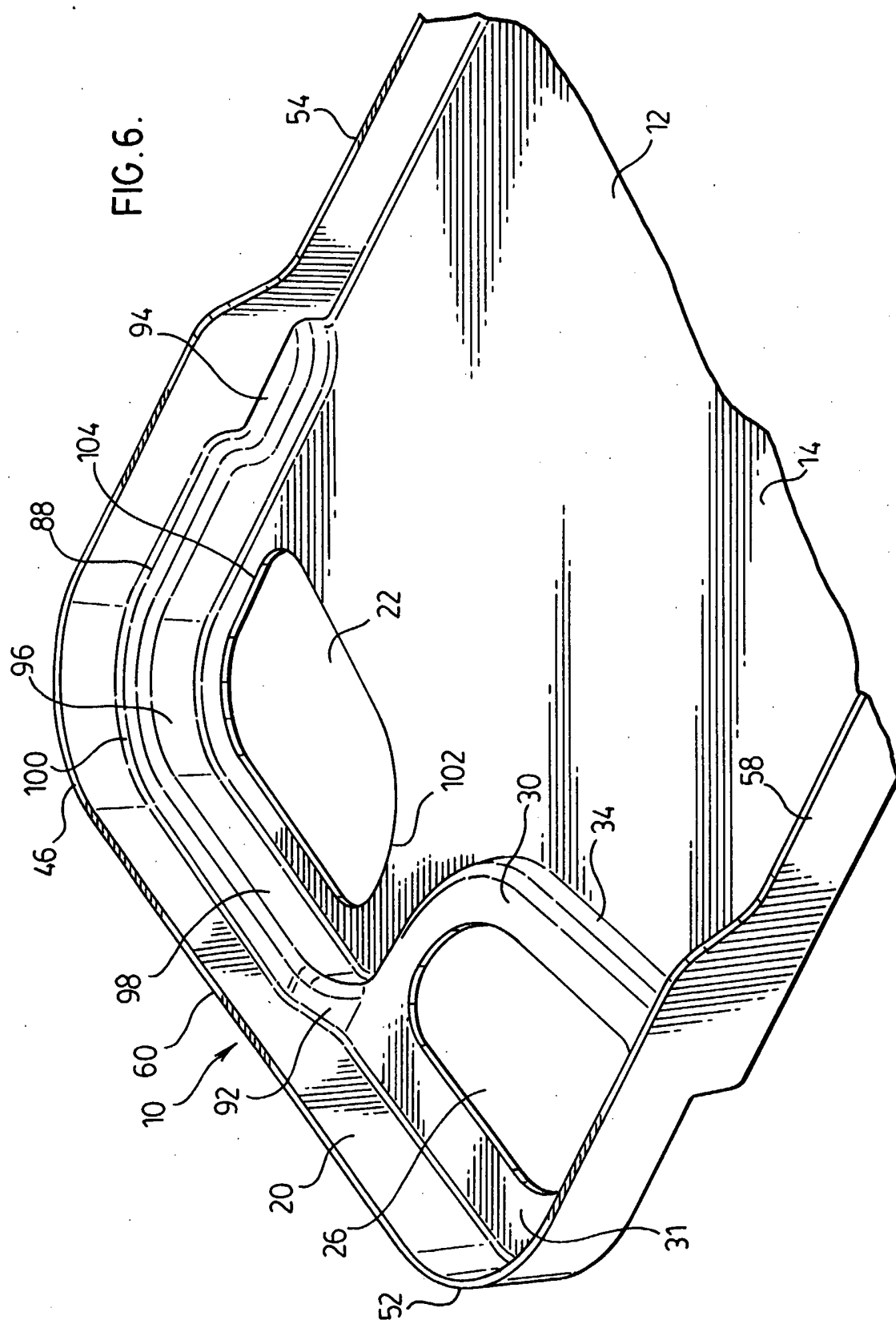
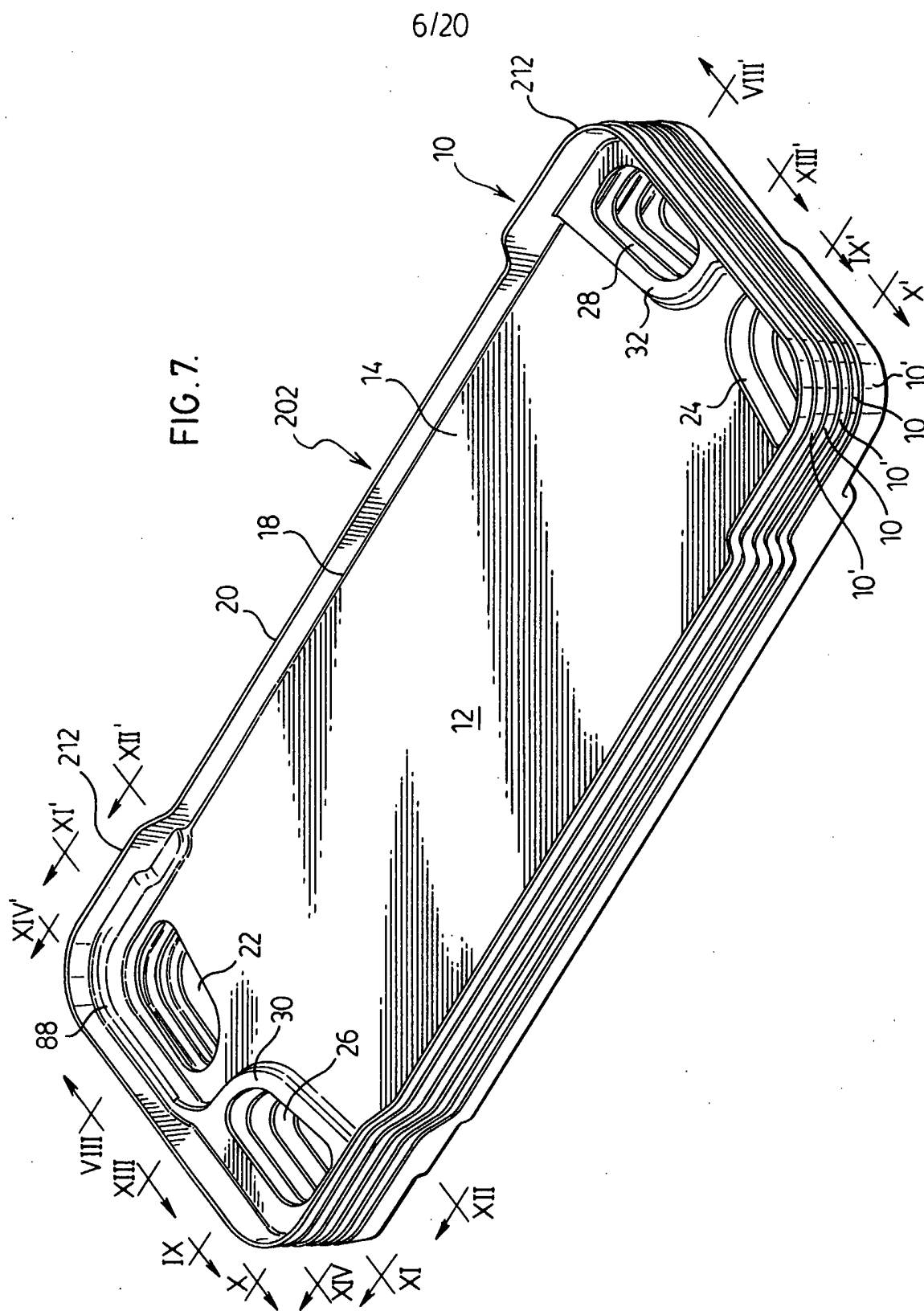


FIG. 5.

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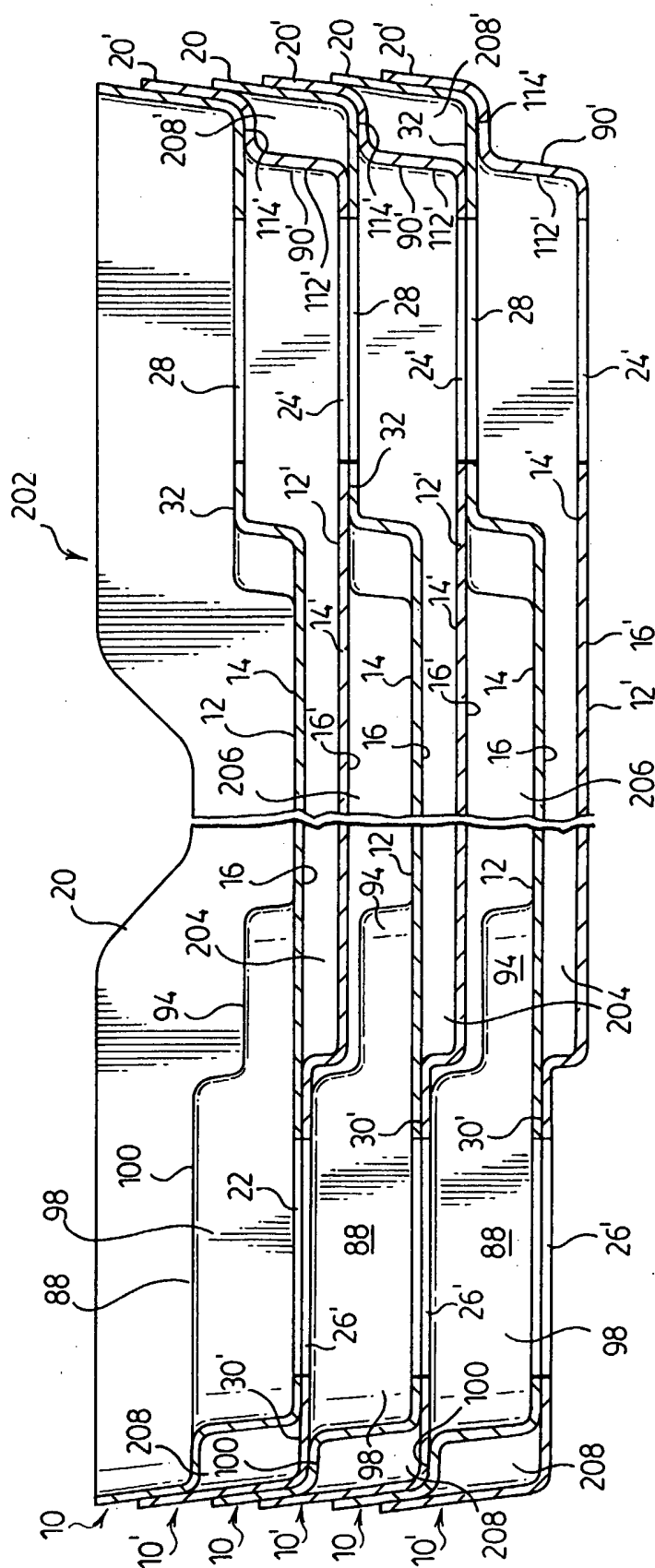


FIG. 8.

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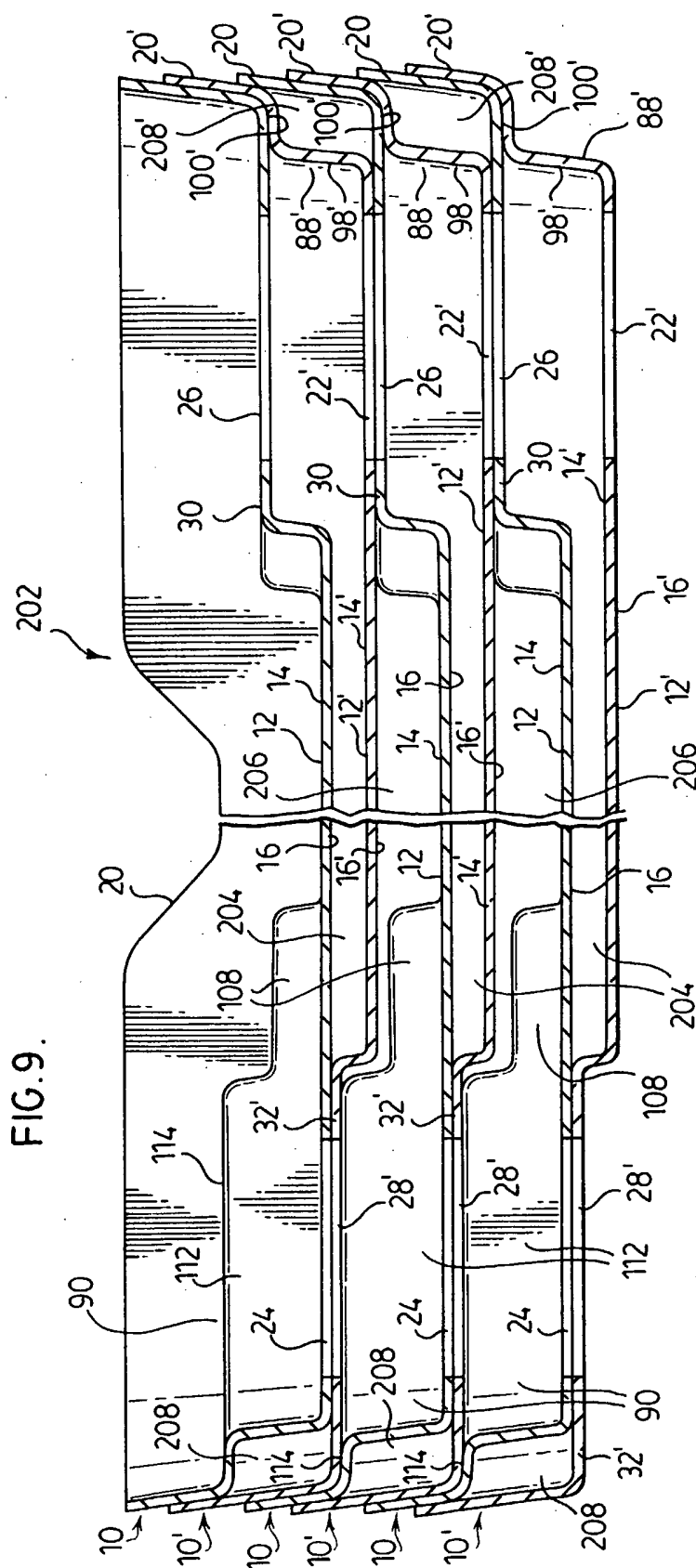
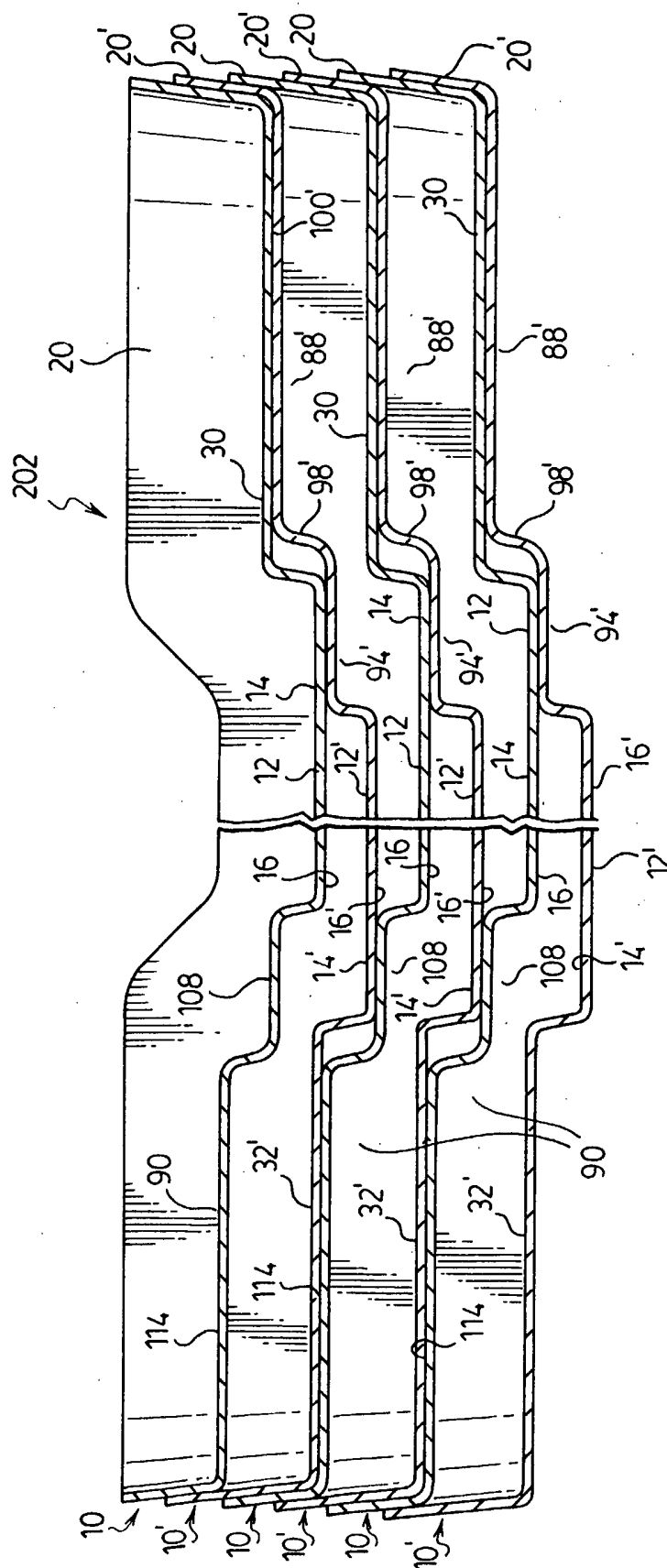
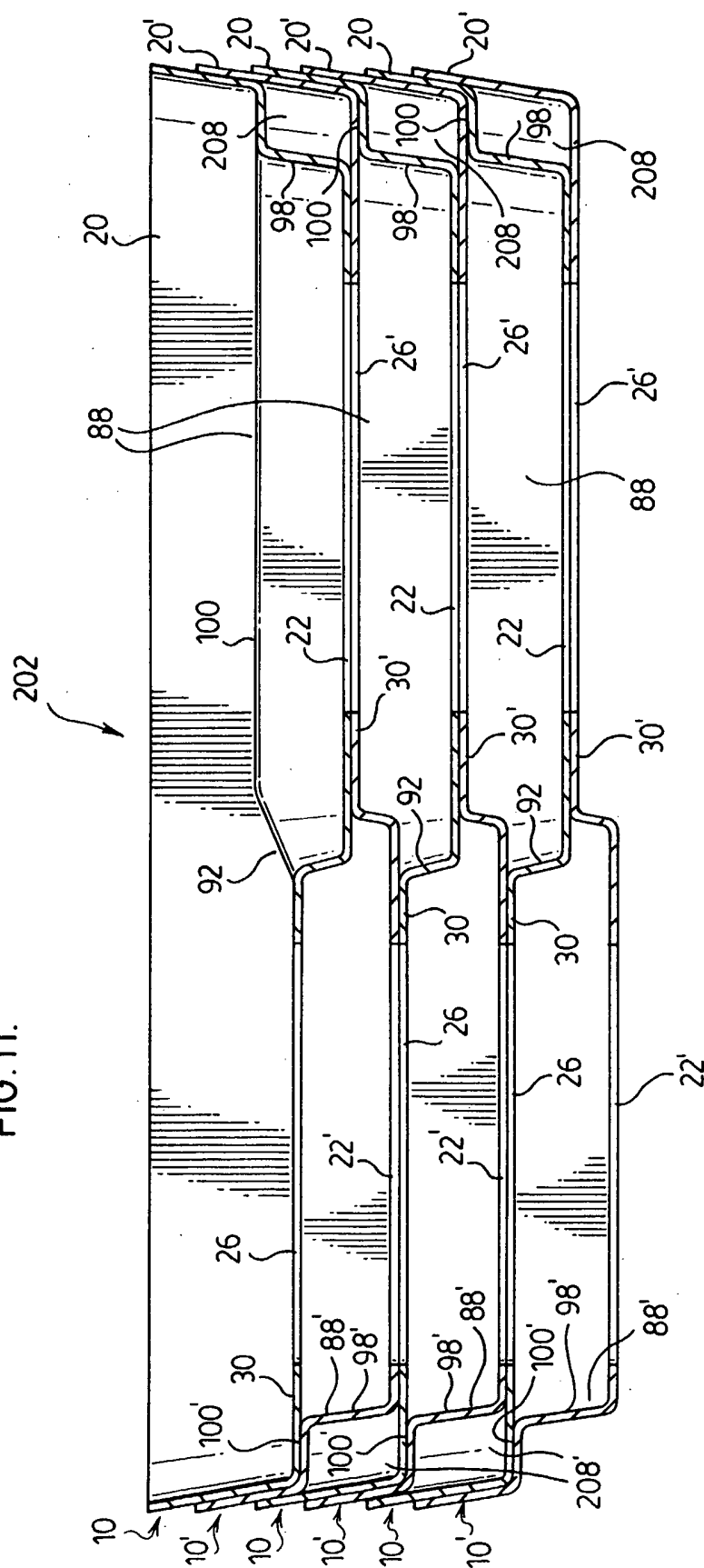


FIG. 10.



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FIG. 11.



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FIG. 12.

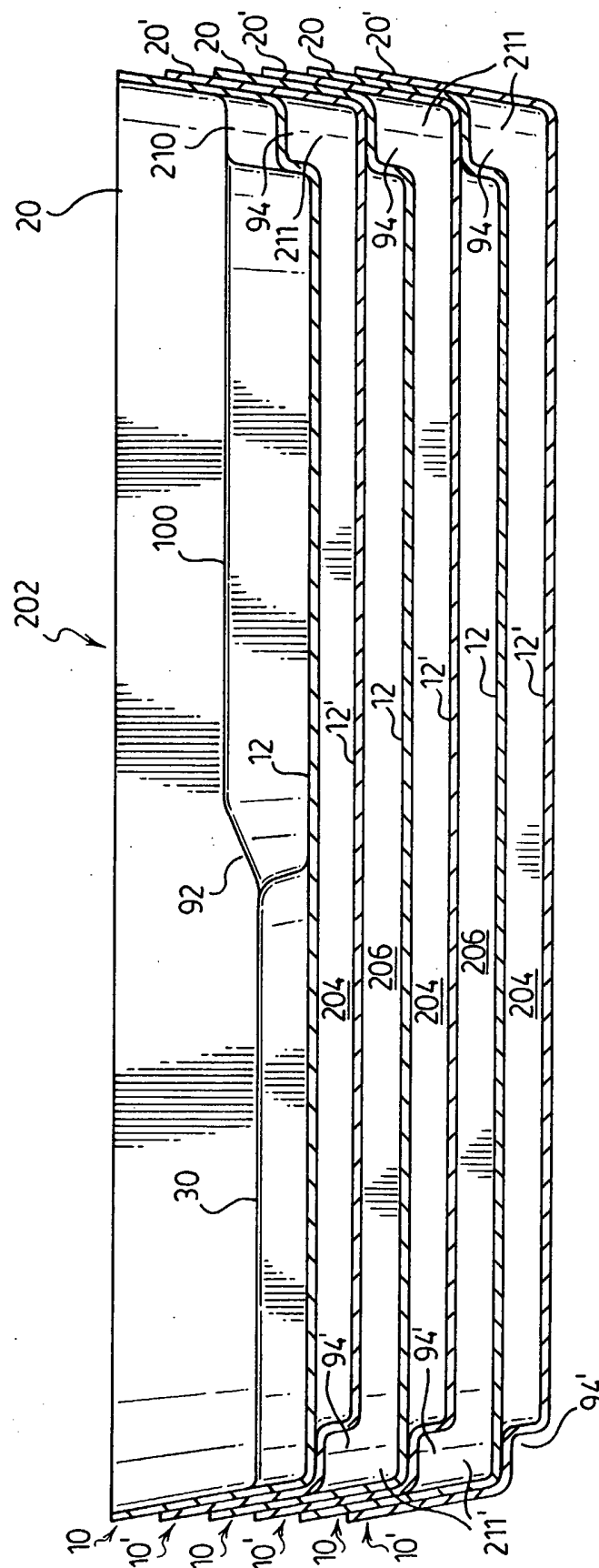


FIG. 13.

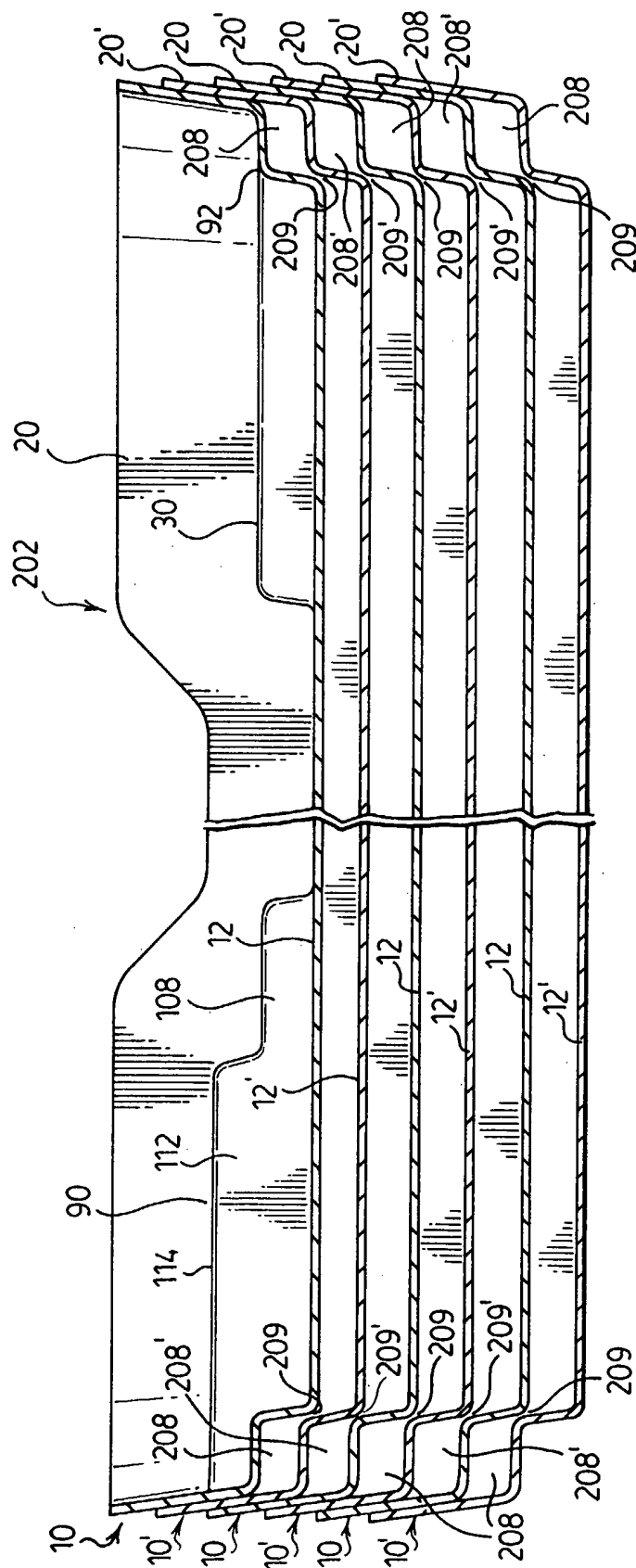
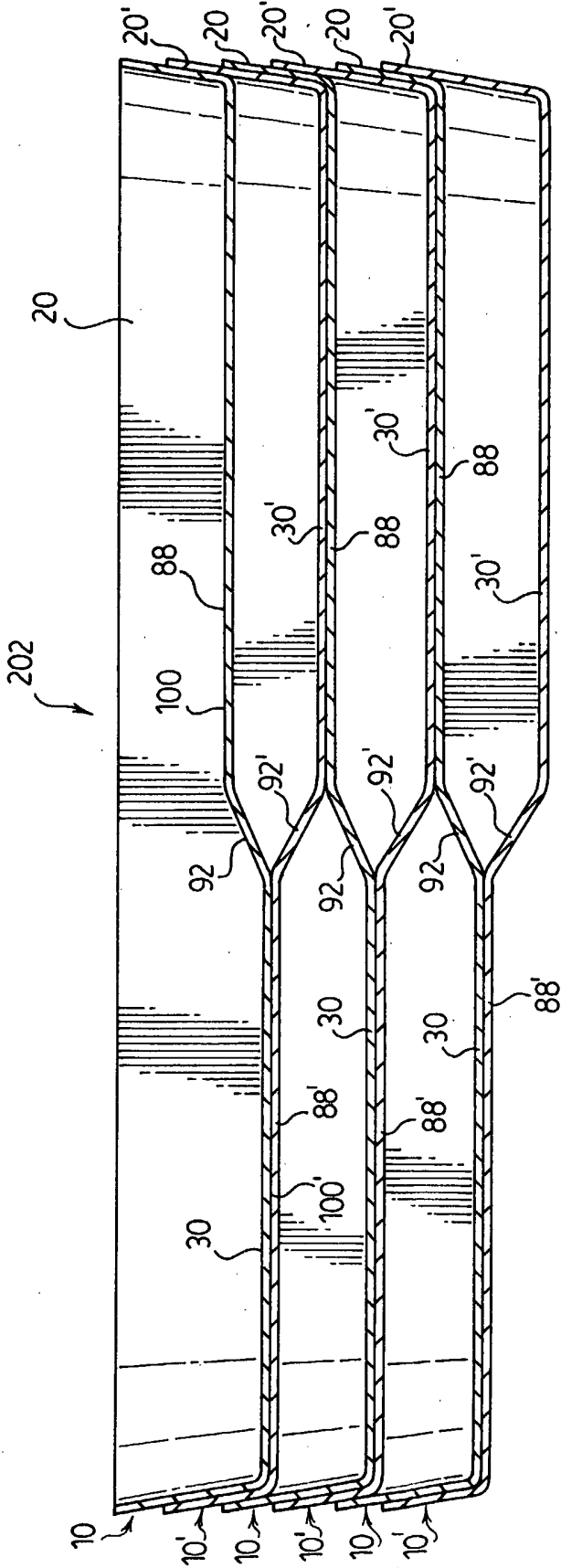
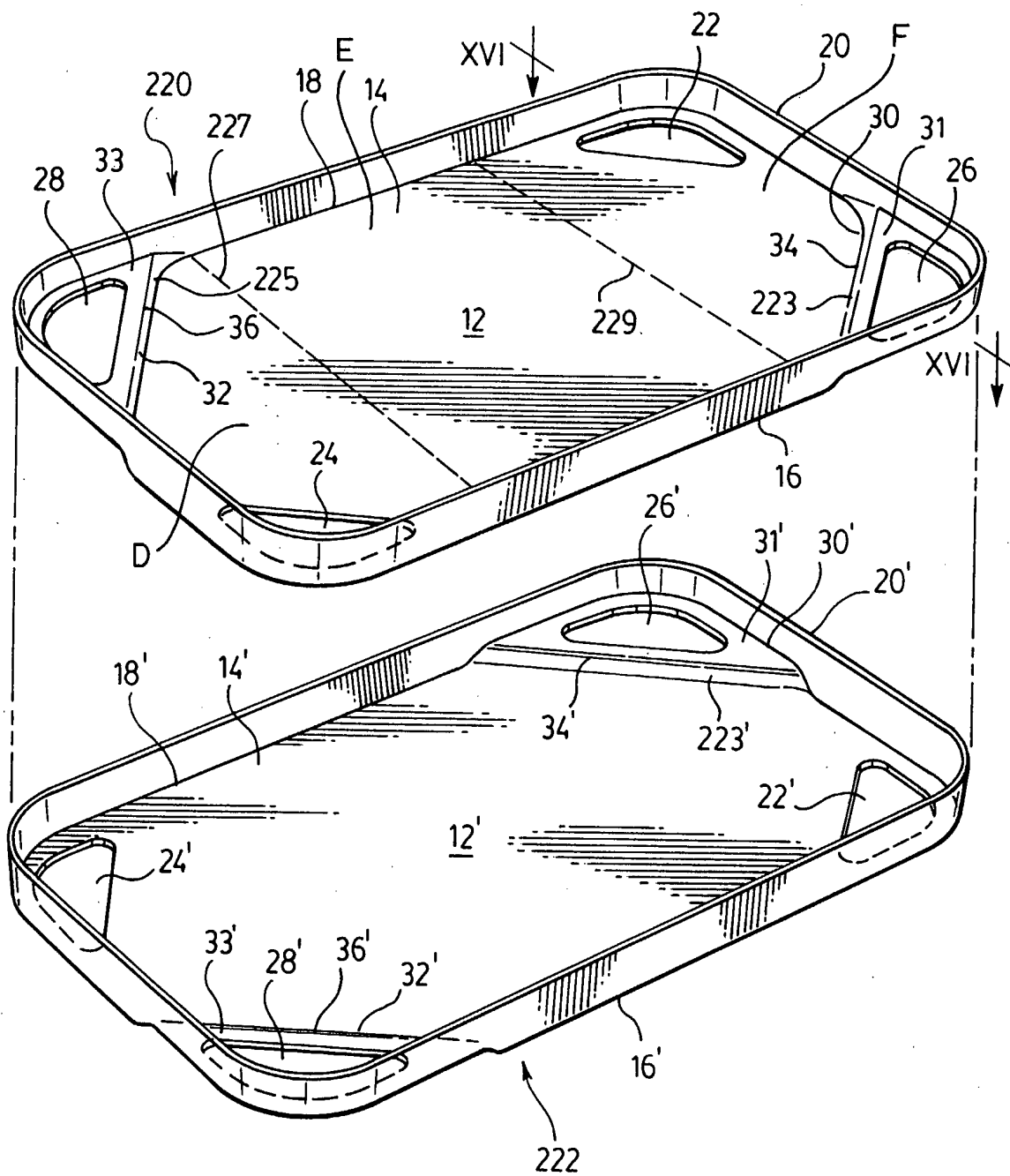


FIG. 14.



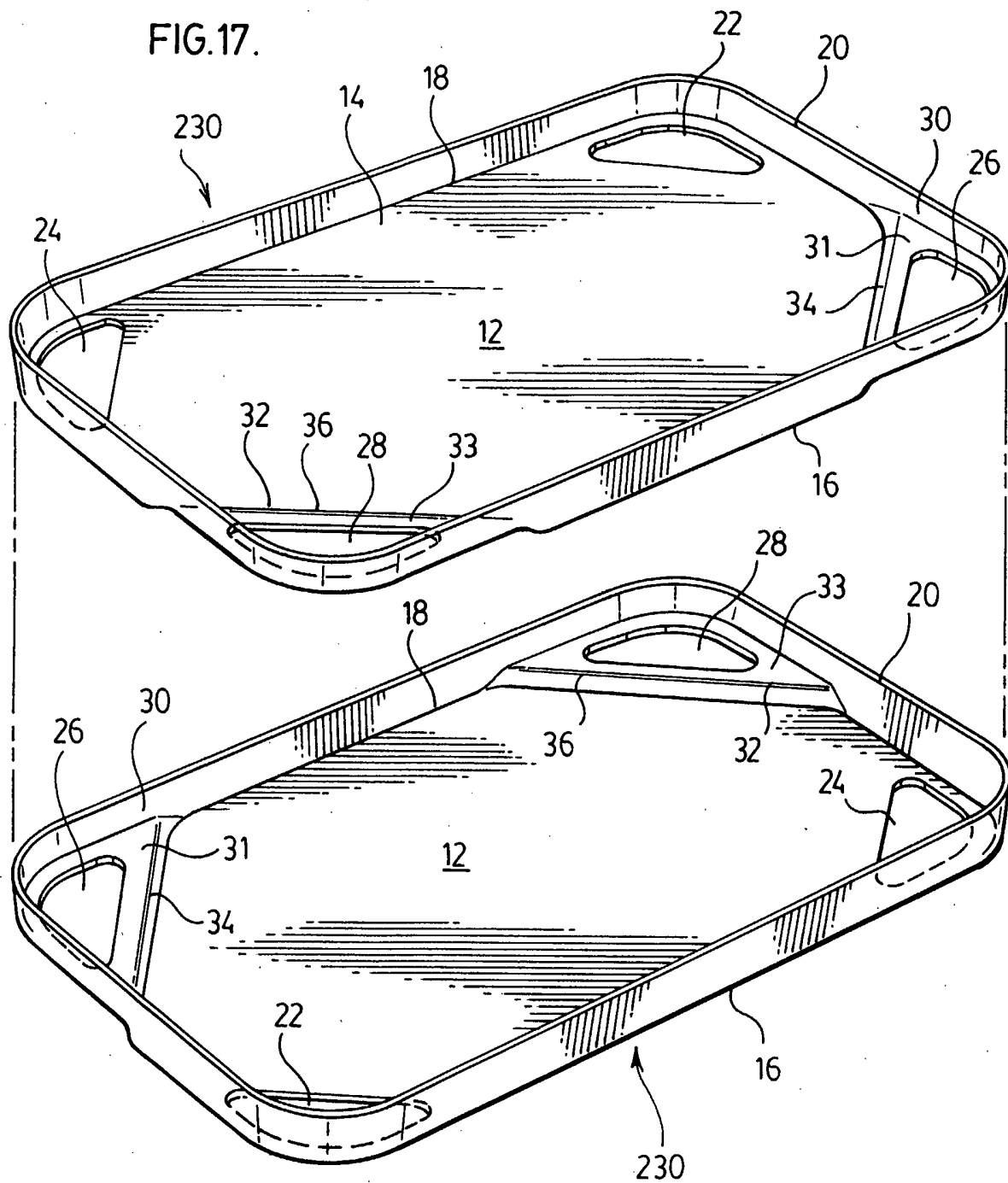
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FIG.15.

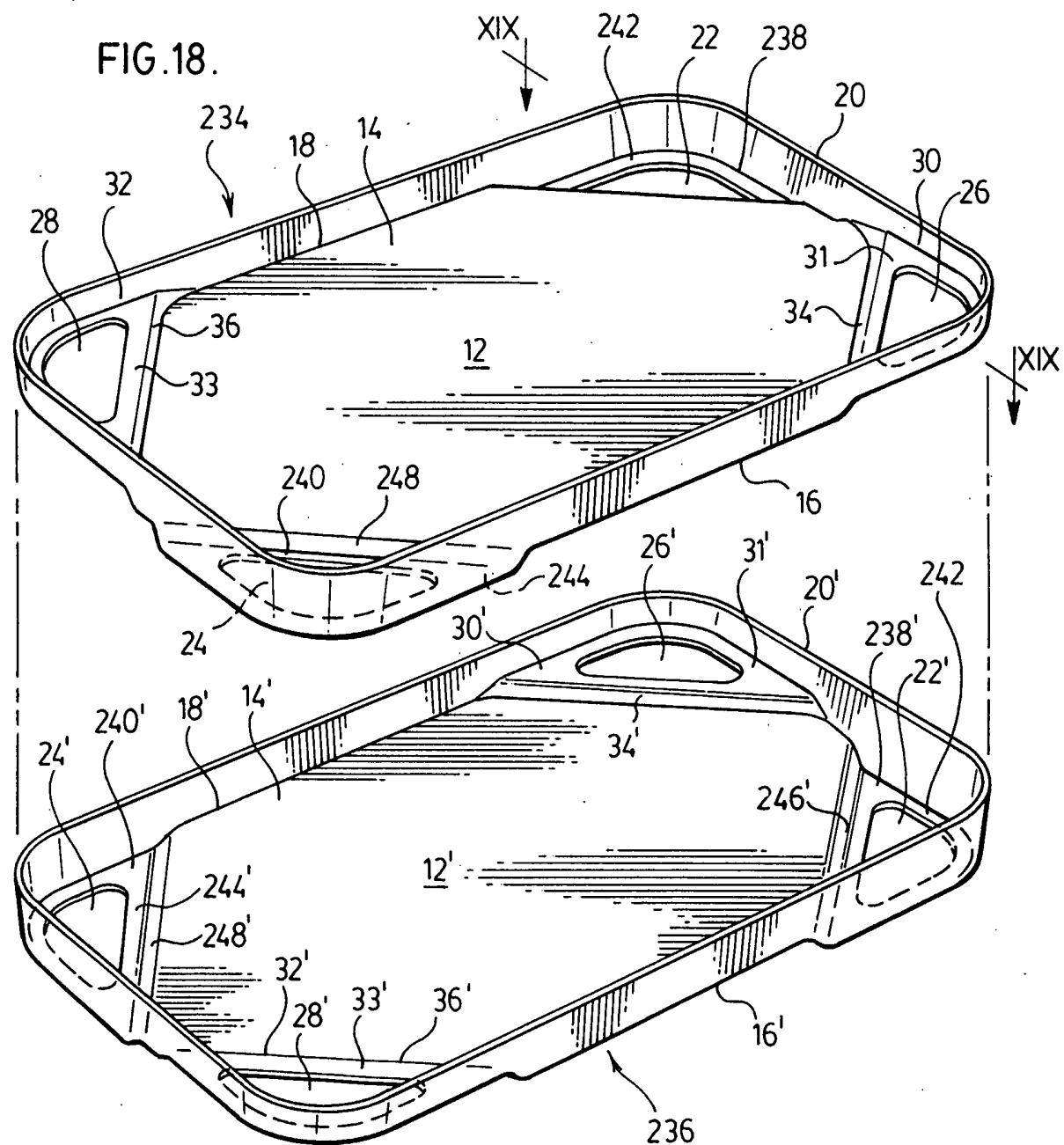


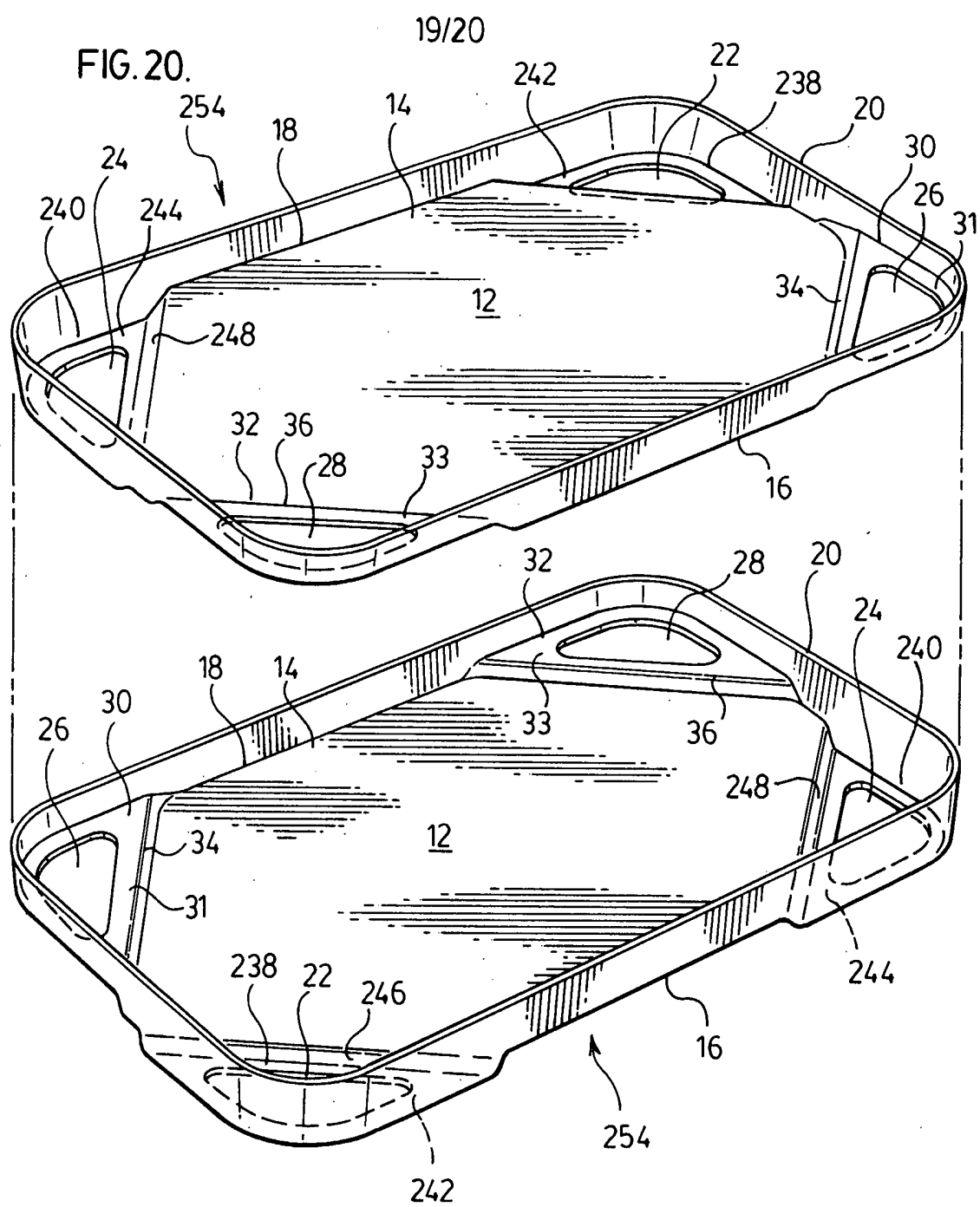
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FIG.17.



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FIG. 21.

