



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.02.2021 Bulletin 2021/07

(51) Int Cl.:
F28D 9/00 (2006.01) **F28F 3/12 (2006.01)**
F28F 9/02 (2006.01) **F28F 9/00 (2006.01)**

(21) Application number: **20188782.5**

(22) Date of filing: **30.07.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **BARRIGA, Jorge**
Morris Plains, NJ 07950 (US)
• **ARELLANO, Ahuizotl**
Morris Plains, NJ 07950 (US)
• **CAMPAS, Maximilano**
Morris Plains, NJ 07950 (US)

(30) Priority: **14.08.2019 US 201916540761**

(74) Representative: **Haseltine Lake Kempner LLP**
138 Cheapside
London EC2V 6BJ (GB)

(71) Applicant: **Honeywell International Inc.**
Morris Plains, NJ 07950 (US)

(54) **HEAT EXCHANGER**

(57) In some examples, a plate fin heat exchanger including a cold passage defined by a cold frame; a hot passage defined by a hot frame; a tube sheet between the cold passage and the hot passage; a top side plate; and a bottom side plate, wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger, wherein at least a portion of the first bar is configured to be removed from the cold frame, wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, wherein at least a portion of the third bar is configured to be removed from the hot frame, and wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

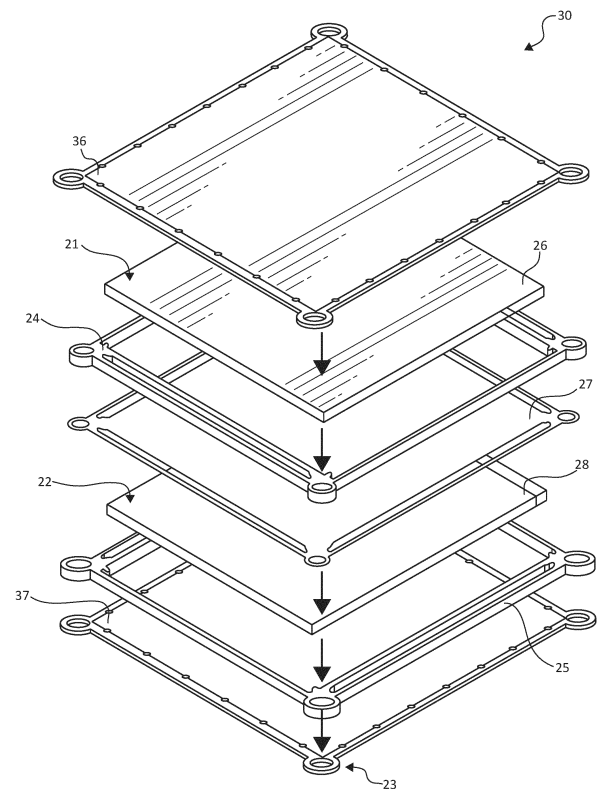


FIG. 2

Description

TECHNICAL FIELD

[0001] The present disclosure relates to heat exchangers.

BACKGROUND

[0002] An environmental control system (ECS), such as an aircraft ECS, may include one or more heat exchangers. Such heat exchangers may be of the fluid-to-fluid type, either gas or liquid, and may include a core assembly including alternating rows of heat transfer fins and plates. The rows are interposed to create multiple hot and cold side passageways extending through the core assembly. The passageways may create a counter-flow, parallel flow, or cross-flow heat exchange relationship between fluids flowing through the passageways. During operation, heat is exchanged between the fluids flowing through the core assembly. Because an aircraft ECS often operates at, and generates within itself, relatively extreme temperature and pressure conditions, the heat exchanger may be subjected to the adverse effects of temperatures as well as the forces generated by operation of the aircraft.

SUMMARY

[0003] In some examples, the disclosure relates to a plate fin heat exchanger, and a method of making a plate fin heat exchanger. The plate fin heat exchanger may include a heat exchanger core defining hot and cold passages, e.g., alternating between hot and cold passage in a stacked configuration. The stacked hot and cold passages of the core may be separated by tube sheets. The respective hot passage and cold passage may have frames defining the lateral sides of the passages. One or more corners of the heat exchanger core defined by the frames may be shaped corners, e.g., corners defining respective non-square shapes. In some examples, one or more portions of the hot frame and/or cold frames may be configured to be removed from the assembly (e.g., after brazing of the components of the heat exchanger core). In some examples, the hot frame and cold frames may include portions that, when assembled, define flow manifolds into and/or out of the hot and cold passages, respectively.

[0004] In one aspect, the disclosure relates to a plate fin heat exchanger. The heat exchanger assembly comprises a cold passage defined by a cold frame; a hot passage defined by a hot frame; a tube sheet between the cold passage and the hot passage; a top side plate; and a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger, wherein at least a portion

of the first bar is configured to be removed from the cold frame, wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, wherein at least a portion of the third bar is configured to be removed from the hot frame, and wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

[0005] In another aspect, the disclosure relates to a method for making a plate fin heat exchanger. The method comprises assembling a cold frame, a hot frame, a tube sheet, a top sheet, and a bottom sheet in a stacked configuration; attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration, wherein, in the stacked configuration, the cold frame defines a cold passage, the hot frame defines a hot passage, wherein, in the stacked configuration, the tube sheet is between the hot frame and the cold frame, wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger, wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, and wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape; and removing at least a portion of the first bar from the cold frame and at least a portion of the third bar from the hot frame.

[0006] In another aspect, the disclosure relates to a plate fin heat exchanger comprising a cold passage defined by a cold frame; a hot passage defined by a hot frame; a tube sheet between the cold passage and the hot passage; a top side plate; and a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first pair of bars defining the cold passage, a second pair of bars defining cold flow manifolds, and a third pairs of bars defining hot flow manifolds, wherein the hot frame includes a fourth pair of bars defining the hot passage, a fifth pair of bars defining the hot flow manifolds, and a sixth pairs of bars defining the cold flow manifolds, and wherein a corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

[0007] In another aspect, the disclosure relates to a method for making a plate fin heat exchanger. The method comprises: assembling a cold frame, a hot frame, a tube sheet, a top sheet, and a bottom sheet in a stacked configuration; attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration, wherein, in the stacked configuration, the cold frame defines a cold passage, the hot frame defines a hot passage, the tube sheet is between the hot frame and the cold frame, and the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first pair of bars defining the cold passage, a second pair of bars defining cold flow manifolds, and a third pairs of bars defining hot flow

manifolds, wherein the hot frame includes a fourth pair of bars defining the hot passage, a fifth pair of bars defining the hot flow manifolds, and a sixth pairs of bars defining the cold flow manifolds, and wherein a corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

[0008] This summary is intended to provide an overview of the subject matter described in this disclosure. It is not intended to provide an exclusive or exhaustive explanation of the systems, devices, and methods described in detail within the accompanying drawings and description below. Further details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the statements provided below.

BRIEF DESCRIPTION OF THE FIGURES

[0009]

FIG. 1 is a conceptual diagram illustrating an example plate fin heat exchanger core.

FIG. 2 is a conceptual diagram illustrating an exploded view of an example plate fin heat exchanger core. FIG. 3 is a conceptual diagram illustrating an example frame in accordance with some examples of the disclosure.

FIG. 4 is a conceptual diagram illustrating an example tube plate in accordance with some examples of the disclosure.

FIGS. 5 and 6 are conceptual diagrams illustrating an example heat exchanger during an example assembly process.

FIG. 7 is a conceptual diagram illustrating a magnified view of a corner of the heat exchanger shown in FIG. 6, with support and side bars removed.

FIGS. 8A and 8B are conceptual diagram illustrating an example cold frame before and after, respectively, portions of the frame are removed.

FIGS. 9A and 9B are conceptual diagram illustrating an example hot frame before and after, respectively, portions of the frame are removed.

FIG. 10 is a flow diagram illustrating an example technique for assembling a heat exchanger.

FIGS. 11 and 12 are conceptual diagrams illustrating example cold and hot frames with pans attached at the corners.

FIGS. 13A and 13B are conceptual diagrams illustrating example cold and hot frames in accordance with some examples of the disclosure.

FIGS. 14A and 14B are conceptual diagrams illustrating example cold and hot frames in accordance with some examples of the disclosure.

FIGS. 15 and 16 are conceptual diagrams illustrating various example shaped corners in accordance with some examples of the disclosure.

FIGS. 17A-17C are conceptual diagrams illustrating

various magnified views of an example heat exchanger having an outer shell attached to the heat exchanger core at a shaped corner.

FIGS. 18A-18H are conceptual diagrams illustrating various views of an example heat exchanger with shaped corners.

FIGS. 19A-19D are conceptual diagrams illustrating various components of an example heat exchanger.

FIGS. 20A-20E are conceptual diagrams illustrating another example heat exchanger core in accordance with the disclosure.

DETAILED DESCRIPTION

[0010] In some examples, the disclosure describes plate fin heat exchangers and techniques for making such heat exchangers. Plate fin heat exchanger may be employed in a variety of applications, such as, but not limited to, in an ECS of an aircraft.

[0011] In some examples, a plate fin heat exchanger may be manufactured by stacking the heat exchanger core components, e.g., cold and hot passage frames, fins, tube sheets, top and bottom side plates, in a tooling fixture. The core component stack inserted in the tooling fixture may start with a bottom side plate as the base, then a tube sheet may be added, followed by the addition of a hot frame and fins of a "hot" passage (e.g., a passageway in which relatively hot fluid may flow during operation of the heat exchanger), followed by the addition of another tube sheet on the hot frame and fins, and then followed by the addition a cold frame and fins of a "cold" passage (e.g., a passageway in which relatively cold fluid may flow during operation of the heat exchanger). The process of forming alternating layers of hot passage components and cold passage components separated by tube sheets may be repeated until the desired number of hot and cold passages are achieved. Atop side plate similar or identical to the bottom side plate may then be added on the top of the stack in the fixture.

[0012] The stack of core components may then be heated in a brazing furnace to achieve the brazing of the core components to each other. Once the core component stack is completed and brazed, inlet and outlet heat exchanger pans, which form part of the outer shell of the heat exchanger, may be welded to the core components.

[0013] In some examples, the corners of the core components may have linear, square corners (defining a 90 degree angle at the corners). FIG. 21 is a conceptual diagram illustrating a simplified plan view of an example heat exchanger core 132 having four linear, square corners (e.g., corners 130a and 130b). However, the linear, square corners may not provide one or more of the advantages and/or benefits associated with the other examples described in this disclosure.

[0014] In accordance with some examples of the disclosure, a plate fin heat exchanger core may have one or more shaped corners. As used herein, a shaped corner may refer to a corner having a shape other than that of

the square corners shown in FIG. 21, e.g., sharp corners, which may be defined by planar surfaces intersecting orthogonal to each other. For example, a shaped corner may have a curvilinear, (e.g., partial or full circle or oval), square, triangular, and/or rectangular projection at the corner of the heat exchanger core. In some examples, a shaped corner has one or more projections in the corner of the heat exchanger core. As will be described further below, FIGS. 15 and 16 illustrate examples of shaped corners in accordance with the disclosure. While the examples described herein primarily related to heat exchanger cores with square or rectangular shapes having any variety of shaped corners, other examples are contemplated. There are multiple cold-hot flow paths that may describe a given heat exchanger and the shaped corners may apply to all types of heat exchangers, as well as locations for the shaped features (e.g., middle, one side, and the like).

[0015] The shaped corner(s) of the heat exchanger core may be defined at least in part by the frames of the hot and cold passages. In some examples, each corner of the heat exchanger core may be a shaped corner (e.g., all four corners of a square shaped heat exchanger), while in other examples some but not all of the corners may be shaped with the other corners by square corners. In some examples, the shaped corners may extend substantially the entire height (measured in the stacking direction of the hot and cold frames) of the heat exchanger core (e.g., where each hot passage frame and cold passage frame in the stack has a shape at the corresponding corner) while in other examples, the shape corner may only extend a portion of the height (e.g., with some cold frames and/or hot frames having a shape at the corresponding corner while other cold frames and/or hot frames in the stack having square corners at the same corner). A shaped corner may have any suitable shape that does not constitute a linear, 90 degree angle corner such as that shown in FIG. 21. In some examples, the shaped corner may be a curvilinear or triangular corner although other examples are contemplated. FIGS. 15 and 16 are conceptual diagrams illustrating various example shaped corners.

[0016] In some examples, one or more portions of the hot frame and/or cold frames of a heat exchanger core with one or more shaped corners may be configured to be removed from the assembly (e.g., after brazing of the components of the heat exchanger core). For examples, as described further below, a hot frame and/or cold frame may initially include one or more support bars and/or side bars in addition to one or more main bars. In some examples, once the heat exchanger core components have been brazed together, the support bar(s) and/or side bar(s) may be removed from the hot and cold frames, e.g., to open up the hot and cold flow paths, respectively. The support bar(s) and/or side bar(s) may assist in keeping all passages aligned and supported at all sides while the whole stack of core components are compressed and brazed. This may prevent distortion and fins collapsing

while also aiding in reducing the gaps between respective layers of the core, e.g., since more pressure can be applied with the support bar(s) and/or side bar(s) present. Additionally, the support bar(s) and/or side bar(s) may provide extra material to form any shape for corners or in-between separators for more than two flow paths.

[0017] In some examples, the hot frame and cold frames of a heat exchanger core with one or more shaped corners may include portions that, when assembled, define flow manifolds into and/or out of the hot and cold passages, respectively.

[0018] The shaped corners of a heat exchanger may provide one or more benefits, including any combination of the benefits described herein. For example, the shaped corner(s) may be function as a supporting and/or mounting area for bracket, tubes, pins, or any holding mechanisms. In some examples, the shaped corner(s) may be used as an additional fluid flow circuit for the heat exchanger. The shaped corner(s) may have a shape/form that may serve as a guide to assemble pans, ducts and frames, and the like for a heat exchanger assembly. The shaped corners may serve to install (e.g., attach or otherwise position) the core inside a three-dimensional (3D) printed or otherwise preformed shell. The shaped corners may be extended and oriented from frame to give the desired direction of fluid flow either or both when the fluid enters or exits the heat exchanger core. The shaped corners may absorb core size variation for assembly component attachment. The shaped corners may provide a relatively smooth flow transition in the heat exchanger to prevent pressure losses. The shaped corners may function as a stiffener element for heat exchanger strength purposes. The shaped corners may be used as a mounting machined surface for bolts, inserts, tubes, hoses and the like. The shaped corners can be machined as guides for heat exchanger assembly. The shaped corners can be used as identification and/or traceability elements in the heat exchanger. The shaped corners may be used as a pivoting element for thermal growth. The shaped corners may be used as hoisting element for packaging/installation purposes. The shaped corners can be used as a structural pillar to support relatively heavy loads. The shaped corners can be used for ducting/tubing purposes, e.g., to replace external components.

[0019] FIG. 1 is a conceptual diagram illustrating an example plate fin heat exchanger core 20. Heat exchanger core 20 may include first or hot passages 21 (only a single hot passage is labelled) extending substantially perpendicular to second or cold passages 22 (only a single cold passage is labelled). Hot passage 21 is separated from cold passage 22 by tube sheet 27. Hot frame 24 may define (e.g., frame) hot passage 21 by defining opposing lateral sides of hot passage 21. Hot fins 26 may be positioned between hot frames 24. Similarly, cold frame 25 may define (e.g., frame) cold passage 22 by defining opposing lateral sides of cold passage 22. Cold fins 28 may be positioned between cold frames 25. Cor-

ner 23 of the core 20 defines a shaped, curvilinear (e.g., defining a full circle) corner 23 rather than a linear, square corner having a 90 degree angle such as those corners of heat exchanger 132 shown in FIG. 21.

[0020] Core components 20 includes a plurality of tube sheets 27 (only an individual tube sheet is labelled in FIG. 1 for clarity) which separate alternating hot passages 21 and cold passages 22 of heat exchanger core 20. Each respective cold passage 22 of core 20 includes cold frame 25 and cold fins 28 (only individual cold frame 25 and cold fin 28 are labeled for clarity). Each hot passage 21 of core 20 includes hot frame 24 and hot fins 26 (only individual hot frame 24 and hot fin 26 are labeled for clarity).

[0021] FIG. 2 is a conceptual diagram illustrating an exploded perspective view of a heat exchanger core 30 according to an exemplary embodiment. Although FIG. 2 shows only one hot passage and one cold passage for purposes of illustration, it will be understood by those skilled in the art that multiple hot passages, heat exchanger core 30 can include multiple cold passages, multiple hot frames, and multiple cold frames in other examples.

[0022] Heat exchanger core 30 may be similar to heat exchanger core 20 in FIG. 1. Accordingly, reference numbers in FIG. 2 correspond to like reference numbers in FIG. 1. However, heat exchanger core 30 may be representative of heat exchanger core 20 prior to removal of a portion of each of hot frame 24 and cold frame 25, as described below. Put another way, an example heat exchanger core, such as heat exchanger core 20 in FIG. 1, may be derived from heat exchanger core 30 shown in FIG. 2 by removing portions of hot frame 24 and cold frame 25 in the manner described herein.

[0023] The heat exchanger core 30 may generally be constructed in a stacked, plate fin design. Top side plate 36 may be on one side of the core 30 and bottom side plate 37 may be on an opposite side of the core 30. Reference to "top," "bottom," and "sides" is for ease of description only and is not intended to limit the orientation of heat exchanger core 30 in operation. Between top and bottom plates 36, 37, hot passage 21 may run generally perpendicular to second or cold passage 22. Tube sheet 27 is interposed between hot and cold passages 21, 22. The outer perimeter configuration of tube sheet 27 may match a combined perimeter configuration of both hot and cold frames 24, 25 described below.

[0024] In some examples, hot frame 24 may frame or at least partially surround the perimeter of hot passages 21. Hot fins 26 are located between hot frame 24 on the lateral sides and top side plate 36 and tube sheet 27 on top and bottom, respectively. Cold frame 25, similar in design and construction to the hot frame 24, may frame or at least partially surround the perimeter of cold passages 22. Cold fins 28 are located between cold frame 25 on the lateral sides and tube sheet 27 and bottom plate 37 on top and bottom. Corner 38 of the core 30 may extend from a corner of top plate 36, through the frames

24, 25, and to a corner of bottom plate 37. Corner 23 may correspond to a corner of core 20, such as, corner 23 in FIG. 1.

[0025] When heat exchanger core 30 shown in FIG. 2 is assembled, the "bottom" layer of core 30 may form cold fluid passage 22 bounded by tube sheet 27 on "top," bottom plate 37 on "bottom" and cold frame 25 on the "sides." As will be described in further detail below, in some examples, at least a portion of two bars on opposing sides of cold frame 25 may be removed to form openings that allow for fluid flow across cold passage 22. Cold fins 28 are located within cold passage 22 between cold frame 25, and may define the spacing between tube sheet 27 and bottom plate 37.

[0026] Similarly, the adjacent layer directly on "top" of this "bottom" layer of core 30 may form hot fluid passage 21 bounded by top plate 36 on "top," tube sheet 27 on "bottom" and hot frame 24 on the "sides." As will be described in further detail below, in some examples, at least a portion of two bars on opposing sides of hot frame 24 may be removed to form openings that allow for fluid flow across hot passage 21. Hot fins 26 are located within hot passage 21 between hot frame 24, and may define the spacing between tube sheet 27 and top plate 36. As shown, heat exchanger core 30 includes multiple layers which define alternating cold and hot passages 22, 21.

[0027] During operation, a relatively cold fluid (e.g., cold air) may flow into heat exchanger core 30 via a cold intake manifold, through cold passage 22 and out via a cold outlet manifold. Likewise, a relatively hot fluid (e.g., hot air) may flow into heat exchanger core 30 via a hot intake manifold, through hot passage 21 and out via a hot outlet manifold. In this manner, heat from the hot fluid within hot passage 21 is transferred to the cold fluid within the adjacent cold passage 22. Hot fins 26 and cold fins 28 form a secondary surface for heat transfer during operation to remove heat from the fluid within the hot passage 21.

[0028] The tube sheets, enclosure bars, and fins of heat exchangers described herein may be formed of any suitable material. For example, the top plate, bottom plate, tube sheets, frames, and/or fins may be aluminum, copper, iron, stainless steel, nickel based alloy (e.g., Inconel), titanium components, or any combination thereof, although other materials are contemplated. In some examples, all the components of a heat exchangers may be made from the same material. For example, an aluminum heat exchanger may have parts such as the tube sheets, enclosure bars, and fins made from aluminum (e.g., along with the outer shell). Likewise, a stainless steel heat exchanger may have parts such as the tube sheets, enclosure bars, and fins made from stainless steel (e.g., along with the outer shell). The frames, including frames with one or more shaped corners, may be produced via extrusion, machining, and/or additive manufacturing. A braze material for joining the parts may be selected based on the composition of the parts being joined.

[0029] The hot and cold fluid passageways (e.g., passages 21 and 22) are shown as extending approximately ninety degrees (90°) to each other, forming a cross-flow condition between fluids flowing through core components 16. However, in other examples, the fluid passageways may extend approximately parallel to each other, creating a parallel-flow condition between the fluids. Alternatively, the fluid passageways may extend in opposite directions to each other, creating a counter-flow condition between the fluids.

[0030] FIG. 3 is a top plan view of a frame 40 according to an example of the present disclosure. Frame 40 may be used, for example as one or both of the hot and cold frames 24, 25 in FIGS. 1 and 2.

[0031] Frame 40 may include, at a perimeter thereof, a pair of main bars 41a, 41b which are on a pair opposite sides of the perimeter of frame 40. One or both of main bars 41a, 41b may be configured to permanently remain as part of frame 40 and, thus, not removable from frame 40. Frame 40 also includes a pair of support bars 42a, 42b that are respectively paired with the main bars 41a, 41b. So paired, support bars 42a, 42b may extend generally parallel to the main bars 41a, 41b. Support bars 42a, 42b may also be spaced apart from the main bars 41a, 41b where support bars 42a, 42b can be disposed outside of main bars 41a, 41b. In other words, support bars 42a, 42b are further from a center area of the frame 40 than main bars 41a, 41b.

[0032] With the support bars 42a, 42b spaced apart from the main bars 41a, 41b, a pair of slots 44a, 44b are formed between the support bars 42a, 42b and the main bars 41a, 41b, respectively. In some examples, slots 44a, 44b can provide for air passage. In some examples, slots 44a, 44b may define manifolds defining the flow in and out of either the hot passages or cold passages 21, 22 of core 30, e.g., during operation of the heat exchanger.

[0033] In some examples, frame 40 may further include a pair of side bars 43a, 43b disposed on another pair of opposite sides of the perimeter of frame 40. In other words, side bars 43a, 43b form one pair of opposite sides of the frame perimeter, and the main bars/support bars 41a, 41b/42a, 42b form another pair of opposite sides of the frame perimeter.

[0034] In some examples, all or a portion of support bars 42a, 42b may be configured to be removed from frame 40. Likewise all or a portion of side bars 43a, 43b may be configured to be removed from frame 40. FIGS. 8A-9B illustrate an example in which support bars 42a, 42b and side bars 43a, 43b (shown in FIGS. 8A and 9A) are removed (shown in FIGS. 8B and 9B). In some examples, support bars 42a, 42b and/or side bars 43a, 43b may include one or more grooves 45a-45g that may be used to guide a cut through support bars 42a, 42b and/or side bars 43a, 43b to remove portions of support bars 42a, 42b and/or side bars 43a, 43b from frame 40, e.g., during the assembly of heat exchanger core 30 in the manner described below. Accordingly, one or more of support bars 42a, 42b and/or one or more of side bars

43a, b may be configured to be removable from the frame 40.

[0035] Frame 40 includes corners 38a-38d at the intersection of main bars 41a, 41b and side bars 43a, 43b. Following the removal of side bars 43a, 43b (e.g., as shown in FIGS. 8B and 9B), corners 38a-38d may be located at the ends of main bars 41a, 41b. Corners 38 may be disposed to correspond in location and configuration to the corners 23, 38 depicted in FIGS. 1 and 2.

[0036] Rather being a square corner, corners 38a-38d each constitute shaped corners. In the case of FIG. 3, corners 38a-38d have a curvilinear shape defining a central aperture. Corners 38a-38d each have substantially the same shape. In other examples, corners 38a-38d may each have the same or different shape relative to each other. In some examples, one or more of corners 38a-38d may be shaped corner and one or more of corners 38a-38d may be linear, square corners (such as that shown in FIG. 21).

[0037] FIG. 4 is a conceptual diagram illustrating a top plan view of a side plate 50. Side plate 50 may be used, for example, as either one or both of top plate 36 or bottom plate 37 of heat exchanger core 20 shown in FIG. 2.

[0038] Side plate 50 may include a side or perimeter edge 51. Corners 54a-54d along perimeter 51 may correspond in location and configuration of corners 38a-38d in FIG. 3. In such a manner, corners 54a-54d may align with corners 38a-38d when heat exchanger core 30 in FIG. 2 is assembled with hot frames 24 and cold frames 25 stacked on each other between top plate 36 and bottom plate 37.

[0039] Side plate 50 may further include cut line 53 that extends along all or a portion of perimeter edge 51. Cut line 53 may correspond to the location of one or more of the grooves 45a-45h in the frame 40 in FIG. 3. Along all or a portion of cut line 53 may be one or more holes 52 that are disposed on the cut line 53. Accordingly, the one or more holes 52 may correspond to the location of one or more of the grooves 45a-45h in the frame 40 in FIG. 4. As described below, holes 52 may be used to evacuate air during brazing and/or heat treatment of the core. Cut line 53 may be used to guide cutting of the side plate 50 after brazing.

[0040] FIG. 5 is a conceptual diagram illustrating a perspective view of heat exchanger core 60 before machining/cutting according to an example of the present disclosure. In this example depiction, core 60 includes a top plate 61, holes 61a, cut line 61b, corner 62, and alternating hot frames 63 and cold frames 64. All of these features can be similar to that depicted in FIGS. 2-4.

[0041] In the configuration shown in FIG. 5, core 60 may undergo brazing. During brazing, air within core 60 may be evacuated through slots 44a, 44b (FIG. 3) in the frames 63, 64 and out of core 60 via holes 61a.

[0042] FIG. 6 is a conceptual diagram illustrating a perspective view of heat exchanger core 60 after brazing and subsequent machining/cutting. In this example depiction, plate 61 has been cut all along the cut line 61b

and also through all of the holes 61a, as well throughout grooves 45a-45h. Thus, a portion of the plate 61 has been removed and discarded. Any suitable machining or cutting technique may be employed.

[0043] FIG. 7 is a conceptual diagram illustrating a magnified, perspective view of an example heat exchanger core 70. A side bar and a support bar have been cut away from cold frame 74 to define openings to cold passage 72. Cold passage 72 is open to air entering or existing passage 72 because of the side bar removal. However, main bar 74a remains as part of the cold frame 74 for structural support.

[0044] Likewise, a side bar has been cut away from a hot frame 75 to define hot passage 71. Hot passage 71 is open to air entering or existing the passage 71 because of the side bar removal. However, main bar 75a remains as part of hot frame 75 for structural support. In some examples, corner 78 extends from a top plate 76 and through cold and hot frames 74, 75.

[0045] FIG. 8A is a conceptual diagram illustrating frame 40 prior to all or a portion of side bars 43a, 43b and support bars 42a, 42b being cut from frame 40 to define cold passage 22 (FIG. 2) of a heat exchanger core. FIG. 8B is a conceptual diagram illustrating cold frame 74, e.g., as shown in FIG. 7. Cold frame 74 in FIG. 8B is produced by removal of all or a portion of side bars 43a, 43b and support bars 42a, 42b of frame 40 shown in FIG. 8A.

[0046] Similarly, FIG. 9A is a conceptual diagram illustrating frame 40 prior to all or a portion of side bars 43a, 43b and support bars 42a, 42b being cut from frame 40 to define hot passage 21 (FIG. 2) of a heat exchanger core. FIG. 9B is a conceptual diagram illustrating hot frame 75, e.g., as shown in FIG. 7. Hot frame 75 in FIG. 9B is produced by removal of all or a portion of side bars 43a, 43b and support bars 42a, 42b of frame 40 shown in FIG. 9A.

[0047] FIG. 10 is a flow diagram illustrating an example technique for assembling a heat exchanger core such as, e.g., heat exchanger core 70. As shown in FIG. 10, the components of the heat exchanger components may be stacked on each other, e.g., in the arrangement shown in the exploded view of FIG. 2 (80). For example, cold frame 25 and cold fins 28 may be placed on bottom plate 37 with cold fins 28 within cold frame 25. Cold frame 25 and cold fins 28 correspond to a cold passage layer in the final heat exchanger core. Tube sheet 27 may be placed on cold frame 25 followed by hot frame 24 and hot fins 26 being placed on tube sheet 27. Hot frame 24 and hot fins 26 correspond to a hot passage layer in the final heat exchanger core. Alternating cold and hot passage layers may be formed using this process until the desired amount of layers are present. Top plate 36 may then be placed on top of the stack.

[0048] The stack of component may then be brazed to attach the components to each other (82). Any suitable brazing technique may be used. During brazing, one or more slots, such as, slots 44a, 44b, in the hot and cold

frames may allow for the evacuation of air in the core. Holes in top and bottom plates 37, 36 may assist in that evacuation. A braze material may be located at interfaces between adjacent components during and/or after the heat exchanger core components are stacked. For example, a braze material may be located on the "top" and "bottom" of hot frame 24 at the interface between hot frame 24 and the adjacent top plate and tube sheet. During brazing, the braze material may melt and join hot frame 24 to the adjacent top plate and tube sheet.

[0049] Once the stack of components are brazed, then a portion of side bars 43a, 43b and support bars 42a, 42b of cold frames 25 and hot frames 24 may be removed to define fluid flow passages of the heat exchanger core, e.g., via machining, e.g., as shown in FIGS. 8A-9B. A portion of top plate and bottom plate 37, 36 may also be removed, e.g., via machining, as described above. Any suitable removal process may be used including, e.g., a machining process and not limited to saw blade, water jet, end milling, grinding, CNC, or the like. Heat exchanger core 70 may remain once the removal process is complete.

[0050] As described herein, in some examples, one or more corners of a heat exchanger core may constitute shaped corners. The one or more shaped corners may be provided for a desired functionality. FIGS. 11 and 12 are conceptual diagrams illustrating cold frame 74 and hot frame 75, respectively, with curvilinear corners (such as corner 78) on all four corners. As shown, pans (or ducts) 87a, 87b may be welded or otherwise attached to corners 78 of cold frame 74. During operation, pan 87a may define an outlet flow manifold from cold passage 72 and pan 87b may define an inlet flow manifold into cold passage 72. Similarly, pans (or ducts) 86a, 86b may be welded or otherwise attached to corners 78 of hot frame 75. During operation, pan 86b may define an outlet flow manifold from hot passage 71 and pan 86a may define an inlet flow manifold into hot passage 71.

[0051] In some examples, after the covers are removed pans, flanges, or any next lever component may be welded. The curvilinear corners may provide extra faying surface to eliminate alignments/sizes variance from both heat exchanger core and pans. The curvilinear corners may also aid to keep the resulting heat from welding away from fins that can potentially burned away reducing heat transfer performance

[0052] In some examples, flow circuits may be defined by the combination of apertures 89 in curvilinear corners 78 of hot frame 75 and cold frame 74. For example, the flow circuits may be used for extra heat circuits (reflow) or fresh flow to either heat or cold electronics, chilled water, oil, fuel, air, and the like.

[0053] Curvilinear corners are just one example of a shaped corner that may be employed in some examples of the disclosure. FIGS. 15 and 16 are conceptual diagrams illustrating various example shaped corners that may be employed, e.g., as part of frame 40. The shapes can be utilized as holding features for sensing and con-

trol, act as brackets, extra circuits, and/or mounting surface for assembly.

[0054] FIGS. 13A and 14A are conceptual diagrams illustrating two example designs for cold frames 74 that have shaped corners, such as, corner 78. FIGS. 13B and 14B are conceptual diagrams illustrating two example designs for hot frames 74 that have shaped corners, such as, corner 78, and which correspond to the designs of cold frames 74 in FIGS. 13A and 14A, respectively.

[0055] FIGS. 17A-17C are conceptual diagrams illustrating various views of a corner portion of an example heat exchanger 90. For example, FIG. 17A illustrates a top view of shaped corner 78 of cold frame 74 and hot frame 75, e.g., of heat exchanger core 70. Shaped corner 78 is designed to mate with a corresponding mating feature formed in outer shell 91. For example, as shown in FIG. 17A, shaper corner 78 may define two non-linear protrusions that are configured to mate (e.g., fit within in a friction fit or a looser fit) with grooves in outer shell 91 of substantially the same size and shape.

[0056] Outer shell 91 is configured to surround the heat exchanger core and defines a cold flow manifold 92 (e.g., inlet manifold or outlet manifold) into cold passage 72 and a hot flow manifold 93 (e.g., inlet manifold or outlet manifold) into hot passage 71. In some examples, outer shell 91 may be fabricated separate from heat exchanger core 70, e.g., using additive manufacturing (3-dimensional printing) techniques. Outer shell 91 may be subsequently attached to heat exchanger core 70, e.g., by mating outer shell 91 with shaped corner 78. In some examples, a glue or other adhesive may be applied to further join outer shell 91 to shaped corner 78, e.g., in apertures in outer shell 91 distributed between top and bottom plate 36, 37 of core 70. FIG. 17B illustrates a front view of outer shell 92 at corner 78 including apertures 94 that may be filled with an adhesive to join corner 78 to outer shell 92. FIG. 17C illustrates an additional, or alternative mounting option, where a threaded stud is used to join corner 78 to outer shell 92. In other examples, a rivet, a pin, a bolt, or other mechanical fastener may be used to keep the side plate and heat exchanger core sealed.

[0057] As described above, in some examples, one or more portions of a hot frame and a cold frame of a heat exchange core may also define flow manifolds into and/or out of the hot passage(s) and cold passage(s) of a heat exchange core. Like the example heat exchangers described above in which portions of the hot frame and cold frames are removable, e.g., after brazing, such example heat exchanger may have corners that constitute shaped corners.

[0058] FIGS. 18A-18H are conceptual diagrams illustrating various views of example heat exchanger 100 in an assembled configuration. FIG. 18G is a conceptual diagram illustrating a cross-section along line B-B shown in FIG. 18F. FIG. 18H is a conceptual diagram illustrating a cross-section along line A-A shown in FIG. 18F.

[0059] Heat exchanger 100 includes a top plate 136, outer shell 192, cold flow inlet 102, cold flow outlet 104,

hot flow inlet 108, and hot flow outlet 106. Heat exchanger 100 may function similar to that of, e.g., heat exchanger 20 in that heat exchanger 100 includes at least one cold passage 122 defined in part by a cold frame 125 (e.g., where cold fins are located in the cold passage between the cold frame) and at least one hot passage 121 defined in part by a hot frame 124 (e.g., where hot fins are located in the hot passage between the hot frame). A relatively cold fluid is directed into cold flow inlet 102 of heat exchanger 100 where it flows through the various cold passages (e.g., cold passage 122 in FIG. 18G) of the heat exchanger core and exits out of cold flow outlet 104. Likewise, a relatively hot fluid is directed into hot flow inlet 108 of heat exchanger 100 where it flows through the various hot passages (e.g., hot passage 121 in FIG. 18G) of the heat exchanger core and exits out of hot flow outlet 106. In this manner, heat may be transferred from the relatively hot fluid to the relatively cold fluid by the heat exchanger.

[0060] FIGS. 19A-19D are conceptual diagrams of various components that may be assembled and attached (e.g., via brazing) to form heat exchanger 100. FIGS. 19A illustrates an example top plate 136. FIG. 19B illustrates an example tube sheet 127. FIG. 19C illustrates an example cold frame 125. FIG. 19D illustrates an example hot frame 124. For ease of illustration, only a single hot frame 124, cold frame 125, and tube sheet 127 are shown in detail. However, it is understood that heat exchanger 100 may include a plurality of each component depending on the number of individual hot and cold passages desired for heat exchanger 100, e.g., with the respective passages formed by alternating between hot and cold frames being separated by a tube sheet.

[0061] Hot frame 124 and cold frame 125 each include main bars 141a, 141b which define the edges or sides of hot passage 121 and cold passage 122, respectively, between adjacent tube sheets 127. Additionally, each of tube sheet 127, hot frame 124 and cold frame 125 include manifold bars 143a-143d. Tube sheet 127, hot frame 124, and cold frame 125 are configured such that when tube sheet 127, hot frame 124, and cold frame 125 are stacked on each other, manifold bars 143a-143d align with each other. When combined and attached (e.g., via brazing), manifold bars 143a-143d define a portion of outer shell 192 that defines the inlet and outlet flow manifolds for the hot and cold passages of heat exchanger 100.

[0062] For example, when stacked and brazed, manifold bars 143a of hot frame 124, cold frame 125, and tube sheet 127 may combine to define the flow manifold for cold inlet flow 102. Likewise, when stacked and brazed, manifold bars 143b of hot frame 124, cold frame 125, and tube sheet 127 may combine to define the flow manifold for cold outlet flow 104. Likewise, when stacked and brazed (e.g., as described in FIG. 10), manifold bars 143c of hot frame 124, cold frame 125, and tube sheet 127 may combine to define the flow manifold for hot inlet flow 108. Likewise, when stacked and brazed, manifold

bars 143d of hot frame 124, cold frame 125, and tube sheet 127 may combine to define the flow manifold for hot outlet flow 106.

[0063] As shown, heat exchanger 100 includes shaped corners 138a-138f. Shaped corners 138a-138f may be defined at least in part by the cold frames (e.g., cold frame 125) and/or the hot frames (e.g., hot frame 124) of heat exchanger 100. For example, corners 138a and 138b are each a curvilinear shaped corner. As shown, curvilinear shaped corners 138a, 138b may be configured to mate with mounting bar 151 by sliding mounting bar 151 into the apertures of curvilinear shaped corners 138a, 138b, e.g., to attach heat exchanger 100 to mounting bar 151. Corners 138a and 138b may each be defined by one of the hot or cold frames 124, 125 (e.g., only one hot frame 124 includes the curvilinear shape corner) or by more than one of the hot and/or cold frames 124, 125 of heat exchanger 100 (e.g., both hot frame 124 and cold frame 125 define corner 138a).

[0064] As another example, corners 138c and 138d are each shaped to receive a complementary section, e.g., via fasteners, that serves to attach mounting bar 153 to the respective corners. In this manner, heat exchanger 100 may be mounted to mounting bar 153 via corners 138c, 138d as shown, e.g., in FIG. 18C.

[0065] As another example, corners 138c and 138d may be shaped to receive a complementary section, e.g., via fasteners, that serves to attach tubing/hoses 153 to the respective corners. In this manner, heat exchanger 100 may be mounted to tubing/hoses 153 via corners 138c, 138d.

[0066] As another example, corners 138e may partially protrude from core body in a particular area to create a pad where a threaded hole can be machined for multiple applications (e.g., temperature sensing, mounting cables, tubes, brackets, or the like).

[0067] As another example, corners 138e may be shaped to form a rectangular protrusion from the middle of the core that is later machined to create an access port to a specific passage that could serve as a mean to attach features like temperature sensors for in-core temperature measurements in commercial applications of IoT (internet of things), instrumentation for cores testing, and/or the like.

[0068] As another example, corner 138f is a grooved configuration where T-Shape head bolts can slide in and be used for mounting purposes or any prior defined alternatives. As another example, corners 138f may be shaped to form a T-slot along the length of the core stack that could serve as a mean to attach other details thru bolts or any other holding device at unit level of the heat exchanger such as brackets, mounts, ducts, or to mount the heat exchanger itself.

[0069] FIGS. 20A-20E are conceptual diagrams illustrating another example heat exchanger core with corners shaped to form mounting points (FIG. 20E), one in each corner, that serve as a mean to mount the unit pans through a set of brackets that are part of the pans them-

selves (FIG. 20D). The figures show an example of how shaped corners may be used, with a complete heat exchanger unit (pans included) with shaped corners described above ready to be mounted on a refrigeration system.

[0070] As described herein, example heat exchangers of the disclosure may include one or more shaped corners, e.g., at the intersection of respective ends hot and cold frames. In some examples, the shaped corner(s) may provide one or more advantages. For example, such a design concept may enable multiple corner shapes or other configurations that may be used to improve manufacturing for assembly interfaces and may provide new design alternatives for heat exchangers assemblies. For example, the shaped corners may be utilized as an installation reference or guide for welding or machining next assembly components such as ducts, pans, frames, brackets, mounts, and the like. In some examples, shaped corners may be designed to provide integral mounting points within the heat exchanger core, and also to provide extra stiffness if desired. In some examples, shaped corners may help to prevent dimensional variations due to brazing and heat treatment processes, thereby aiding the manufacturing process. In some examples, the shaped corners may reduce heat exchanger core stacking complexity and cycle time by providing stacking reference points along with the box-bar frame design. In some examples, the shaped corners may simplify heat exchanger core fit up for next assembly process when machining is desired. In some examples, along with box-bar frames concept, shape corners may prevent passages collapsing during brazing, welding and heat treating.

[0071] In some examples, shaped corners may be also contribute to the function of the heat exchanger function. For example, the shaped corners may be used to embed additional flow circuits for any fluid, e.g., at the corners of the heat exchanger. As another example, the shaped corners may provide additional heat exchanger core stiffness. In some examples, the shaped corners may substantially eliminate the deformation of core heat exchanger, e.g., caused from welding process may be associated with butterpass designs (e.g., a process including adding material by welding/melting base material at each corner and adding filler material (e.g., a welding rod) where the resulting corner is not smooth or does not provide a desirable mounting surface for next assembly). In some examples, the shaped corners may improve overall heat exchanger assembly cycle time.

[0072] Various examples have been described. These and other examples are within the scope of the following claims and clauses.

[0073] Clause 1. A plate fin heat exchanger comprising: a cold passage defined by a cold frame; a hot passage defined by a hot frame; a tube sheet between the cold passage and the hot passage; a top side plate; and a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame

includes a first bar and a second bar attached at a corner of the heat exchanger, wherein at least a portion of the first bar is configured to be removed from the cold frame, wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, wherein at least a portion of the third bar is configured to be removed from the hot frame, and wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

[0074] Clause 2. The heat exchanger of clause 1, wherein the corner of the heat exchanger has a curvilinear shape.

[0075] Clause 3. The heat exchanger of any one of clauses 1 or 2, further comprising a pan attached to the corner of the heat exchanger, wherein the pan defines a flow manifold fluidically coupled to one of the hot passage or the cold passage.

[0076] Clause 4. The heat exchanger of any one of clauses 1-4, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate.

[0077] Clause 5. The heat exchanger of any one of clauses 1-4, wherein the corner of the heat exchanger defines a mount for the heat exchanger.

[0078] Clause 6. The heat exchanger of any one of clauses 1-5, further comprising an outer shell configured to define a first flow manifold into the hot passage and a second flow manifold into the cold passage, and wherein the outer shell is configured to mate with the corner to attach the outer shell to the corner.

[0079] Clause 7. The heat exchanger of any one of clauses 1-6, wherein the hot frame and cold frame are attached to each other via one or more braze joints.

[0080] Clause 8. The heat exchanger of any one of clauses 1-7, further comprising: hot fins between the hot frame in the hot passage; and cold fins between the cold frame in the cold passage.

[0081] Clause 9. A method for making a plate fin heat exchanger, the method comprising: assembling a cold frame, a hot frame, a tube sheet, a top sheet, and a bottom sheet in a stacked configuration; attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration, wherein, in the stacked configuration, the cold frame defines a cold passage, the hot frame defines a hot passage, wherein, in the stacked configuration, the tube sheet is between the hot frame and the cold frame, wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger, wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, and wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape; and removing at least a portion of the first bar from the cold frame and at least a portion of the third bar from the hot frame.

[0082] Clause 10. The method of clause 9, wherein attaching the cold frame, the hot frame, the tube sheet,

the top sheet, and the bottom sheet to each other in the stacked configuration comprises brazing the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration.

5 **[0083]** Clause 11. The method of any one of clauses 9 or 10, wherein the corner of the heat exchanger has a curvilinear shape.

10 **[0084]** Clause 12. The method of any one of clauses 9-11, further comprising attaching a pan to the corner of the heat exchanger, wherein the pan defines a flow manifold fluidically coupled to one of the hot passage or the cold passage.

15 **[0085]** Clause 13. The method of any one of clauses 9-12, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate.

[0086] Clause 14. The method of any one of clauses 9-13, further comprising mounting the heat exchanger to another member via the corner.

20 **[0087]** Clause 15. The method of any one of clauses 9-14, further comprising mating an outer shell to the corner to attach the outer shell to the corner, wherein the outer shell is configured to define a first flow manifold into the hot passage and a second flow manifold into the cold passage.

25 **[0088]** Clause 16. The method of any one of clauses 9-15, further comprising placing hot fins between the hot frame in the hot passage, and placing cold fins between the cold frame in the cold passage.

30 **[0089]** Clause 17. A plate fin heat exchanger comprising: a cold passage defined by a cold frame; a hot passage defined by a hot frame; a tube sheet between the cold passage and the hot passage; a top side plate; and a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first pair of bars defining the cold passage, a second pair of bars defining cold flow manifolds, and a third pairs of bars defining hot flow manifolds, wherein the hot frame includes a fourth pair of bars defining the hot passage, a fifth pair of bars defining the hot flow manifolds, and a sixth pairs of bars defining the cold flow manifolds, and wherein a corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

35 **[0090]** Clause 18. The heat exchanger of clause 17, wherein the corner of the heat exchanger has a curvilinear shape.

40 **[0091]** Clause 19. The heat exchanger of any one of clauses 17 or 18, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate.

45 **[0092]** Clause 20. The heat exchanger of any one of clauses 17-19, wherein the corner of the heat exchanger defines a mount for the heat exchanger.

50 **[0093]** Clause 21. The heat exchanger of any one of clauses 17-20, wherein the hot frame and cold frames are attached to each other via one or more braze joints.

[0094] Clause 22. A method for making a plate fin heat exchanger, the method comprising: assembling a cold frame, a hot frame, a tube sheet, a top sheet, and a bottom sheet in a stacked configuration; attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration, wherein, in the stacked configuration, the cold frame defines a cold passage, the hot frame defines a hot passage, the tube sheet is between the hot frame and the cold frame, and the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first pair of bars defining the cold passage, a second pair of bars defining cold flow manifolds, and a third pairs of bars defining hot flow manifolds, wherein the hot frame includes a fourth pair of bars defining the hot passage, a fifth pair of bars defining the hot flow manifolds, and a sixth pairs of bars defining the cold flow manifolds, and wherein a corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape.

[0095] Clause 23. The method of clause 22, wherein the corner of the heat exchanger has a curvilinear shape.

[0096] Clause 24. The method of any one of clauses 22 or 23, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate.

[0097] Clause 25. The method of any one of clauses 22-24, wherein the corner of the heat exchanger defines a mount for the heat exchanger.

[0098] Clause 26. The method of any one of clauses 22-25, wherein the hot frame and cold frames are attached to each other via one or more braze joints.

Claims

1. A plate fin heat exchanger comprising:

a cold passage defined by a cold frame;
a hot passage defined by a hot frame;
a tube sheet between the cold passage and the hot passage;
a top side plate; and
a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger, wherein at least a portion of the first bar is configured to be removed from the cold frame,
wherein the hot frame includes a third bar and a fourth bar attached at the corner of the heat exchanger, wherein at least a portion of the third bar is configured to be removed from the hot frame, and
wherein the corner of the heat exchanger de-

fined by at least one of the hot frame or the cold frame has a non-square shape.

2. The heat exchanger of claim 1, wherein the corner of the heat exchanger has a curvilinear shape.

3. The heat exchanger of any one of claims 1 or 2, further comprising a pan attached to the corner of the heat exchanger, wherein the pan defines a flow manifold fluidically coupled to one of the hot passage or the cold passage.

4. The heat exchanger of any one of claims 1-3, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate.

5. The heat exchanger of any one of claims 1-4, wherein the corner of the heat exchanger defines a mount for the heat exchanger.

6. The heat exchanger of any one of claims 1-5, further comprising an outer shell configured to define a first flow manifold into the hot passage and a second flow manifold into the cold passage, and wherein the outer shell is configured to mate with the corner to attach the outer shell to the corner.

7. The heat exchanger of any one of claims 1-6, wherein the hot frame and cold frame are attached to each other via one or more braze joints.

8. The heat exchanger of any one of claims 1-7 further comprising:

hot fins between the hot frame in the hot passage; and
cold fins between the cold frame in the cold passage.

9. A method for making a plate fin heat exchanger, the method comprising:

assembling a cold frame, a hot frame, a tube sheet, a top sheet, and a bottom sheet in a stacked configuration;
attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration, wherein, in the stacked configuration, the cold frame defines a cold passage, the hot frame defines a hot passage, wherein, in the stacked configuration, the tube sheet is between the hot frame and the cold frame,
wherein the cold frame includes a first bar and a second bar attached at a corner of the heat exchanger,
wherein the hot frame includes a third bar and

a fourth bar attached at the corner of the heat exchanger, and
 wherein the corner of the heat exchanger defined by at least one of the hot frame or the cold frame has a non-square shape; and
 removing at least a portion of the first bar from the cold frame and at least a portion of the third bar from the hot frame.

has a non-square shape.

- 5
- 10
10. The method of claim 9, wherein attaching the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration comprises brazing the cold frame, the hot frame, the tube sheet, the top sheet, and the bottom sheet to each other in the stacked configuration. 10 15
11. The method of any one of claim 9 or 10, wherein the corner of the heat exchanger has a curvilinear shape. 20
12. The method of any one of claims 9-11, further comprising attaching a pan to the corner of the heat exchanger, wherein the pan defines a flow manifold fluidically coupled to one of the hot passage or the cold passage. 25
13. The method of any one of claims 9-12, wherein the corner of the heat exchanger defines an internal passage extending from the top side plate to the bottom side plate. 30
14. The method of any one of claims 9-13, further comprising mating an outer shell to the corner to attach the outer shell to the corner, wherein the outer shell is configured to define a first flow manifold into the hot passage and a second flow manifold into the cold passage. 35
15. A plate fin heat exchanger comprising: 40
 - a cold passage defined by a cold frame;
 - a hot passage defined by a hot frame;
 - a tube sheet between the cold passage and the hot passage;
 - a top side plate; and 45
 - a bottom side plate, wherein the cold passage, the tube sheet, and the hot passage are between the top side plate and the bottom side plate, wherein the cold frame includes a first pair of bars defining the cold passage, a second pair of bars defining cold flow manifolds, and a third pairs of bars defining hot flow manifolds, wherein the hot frame includes a fourth pair of bars defining the hot passage, a fifth pair of bars defining the hot flow manifolds, and a sixth pairs of bars defining the cold flow manifolds, and wherein a corner of the heat exchanger defined by at least one of the hot frame or the cold frame 50 55

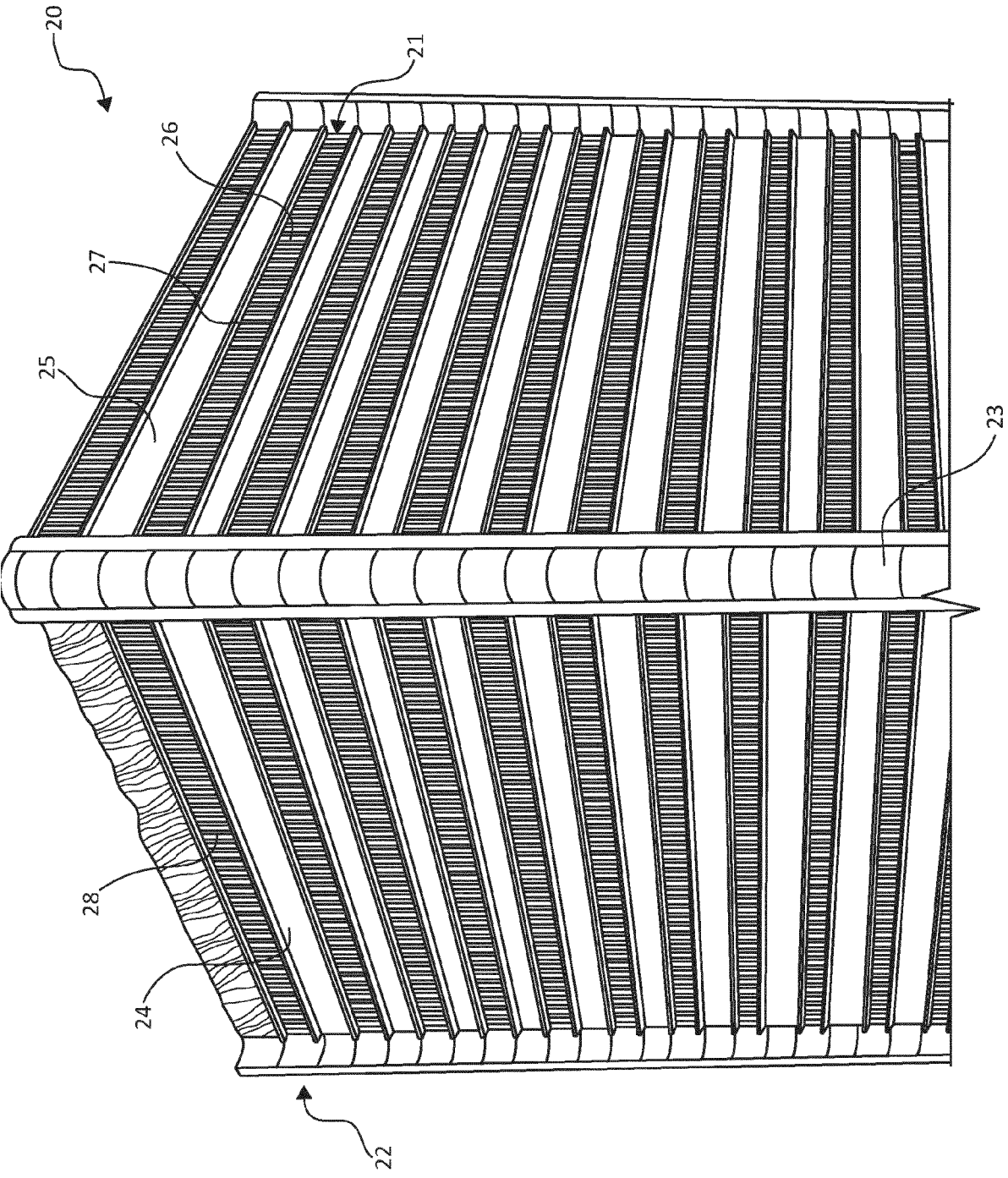


FIG. 1

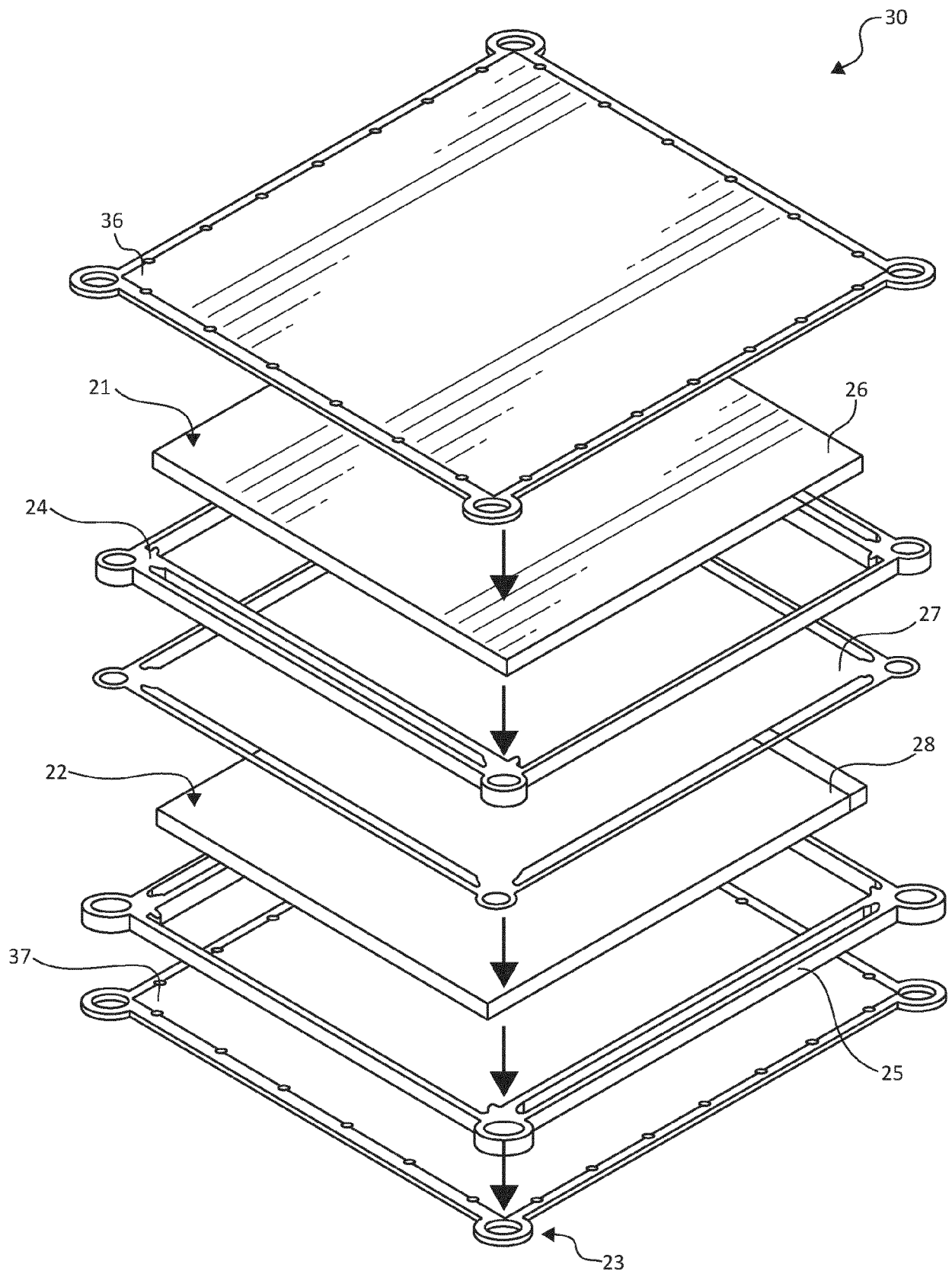


FIG. 2

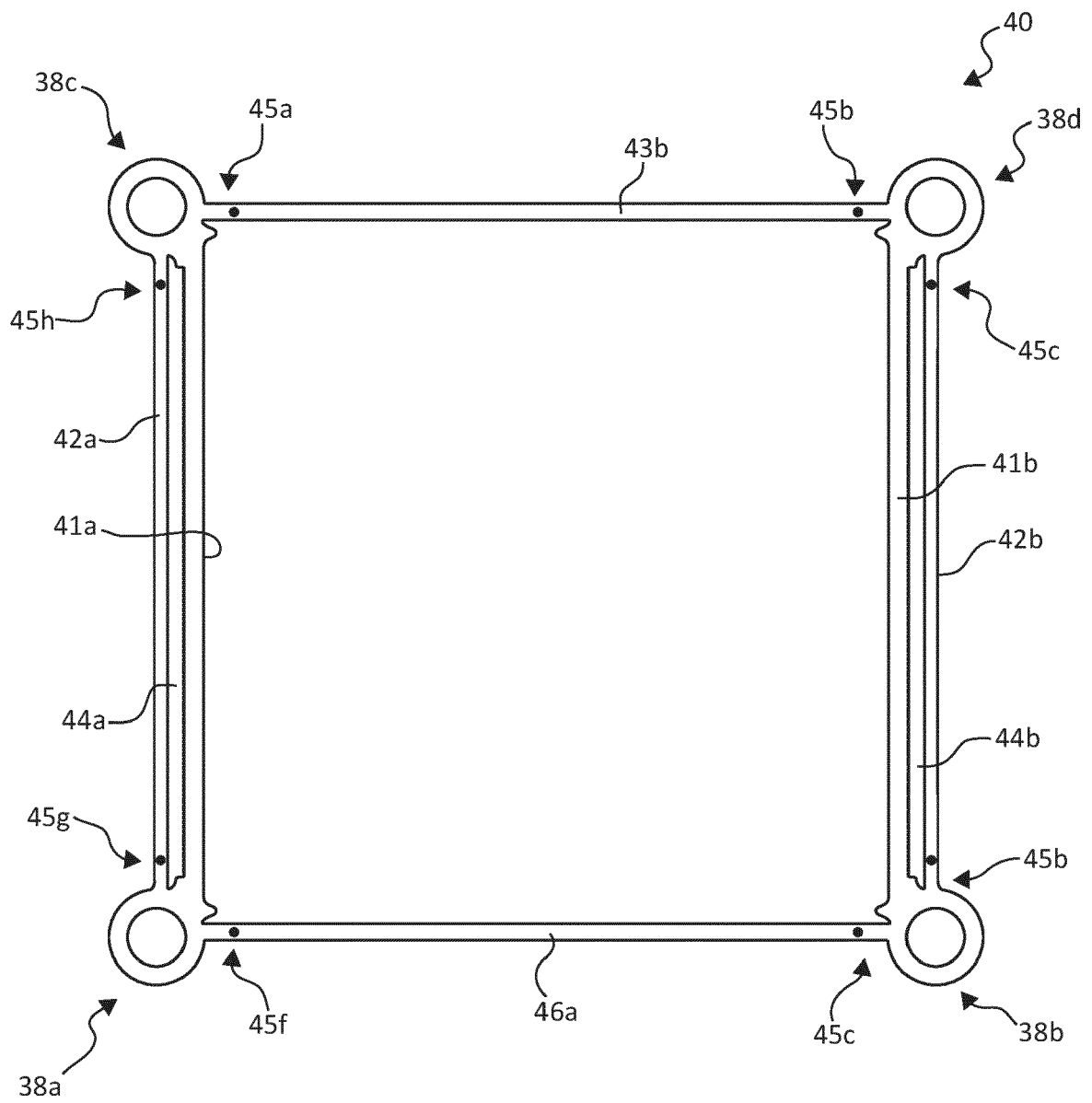


FIG. 3

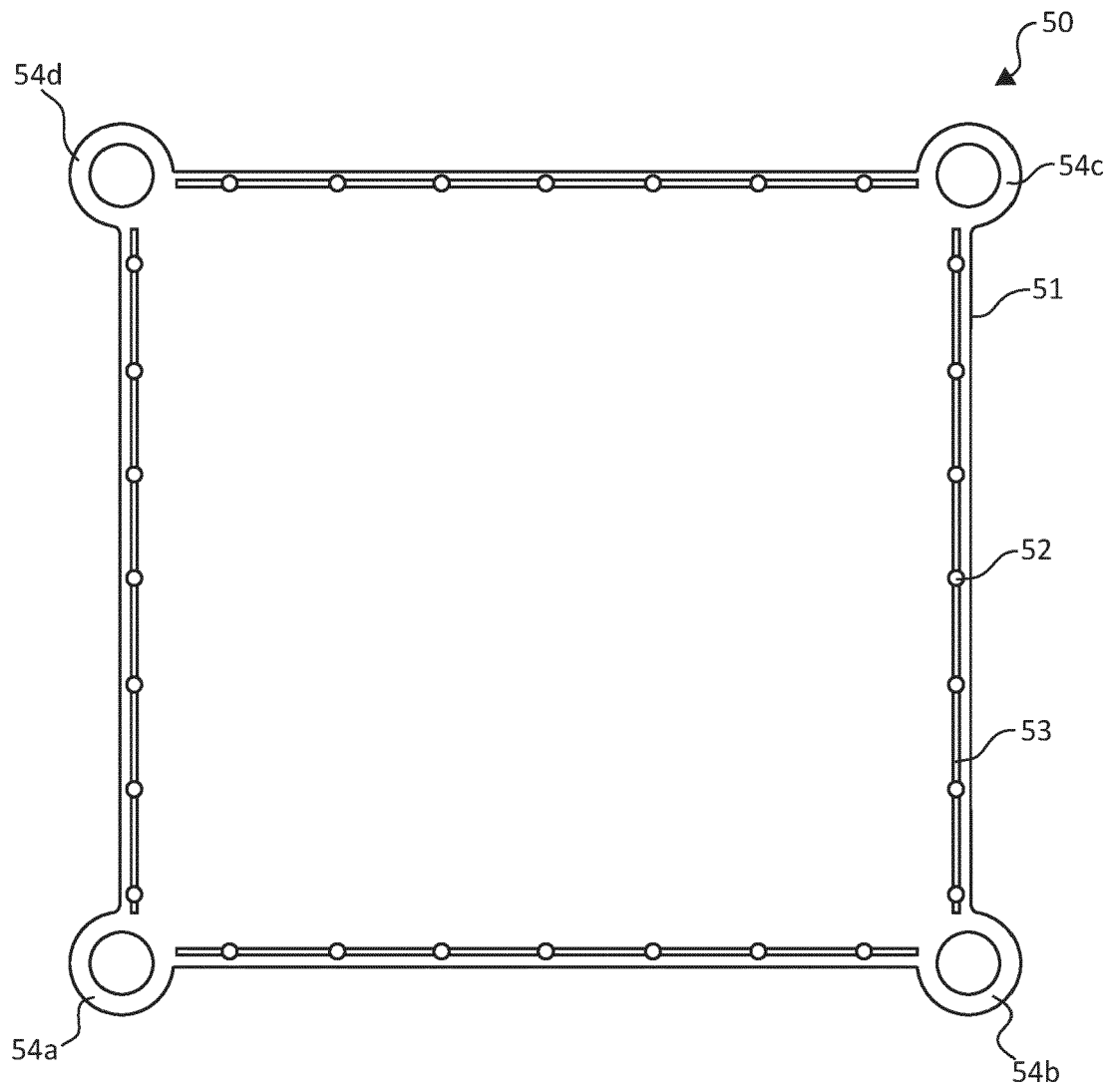


FIG. 4

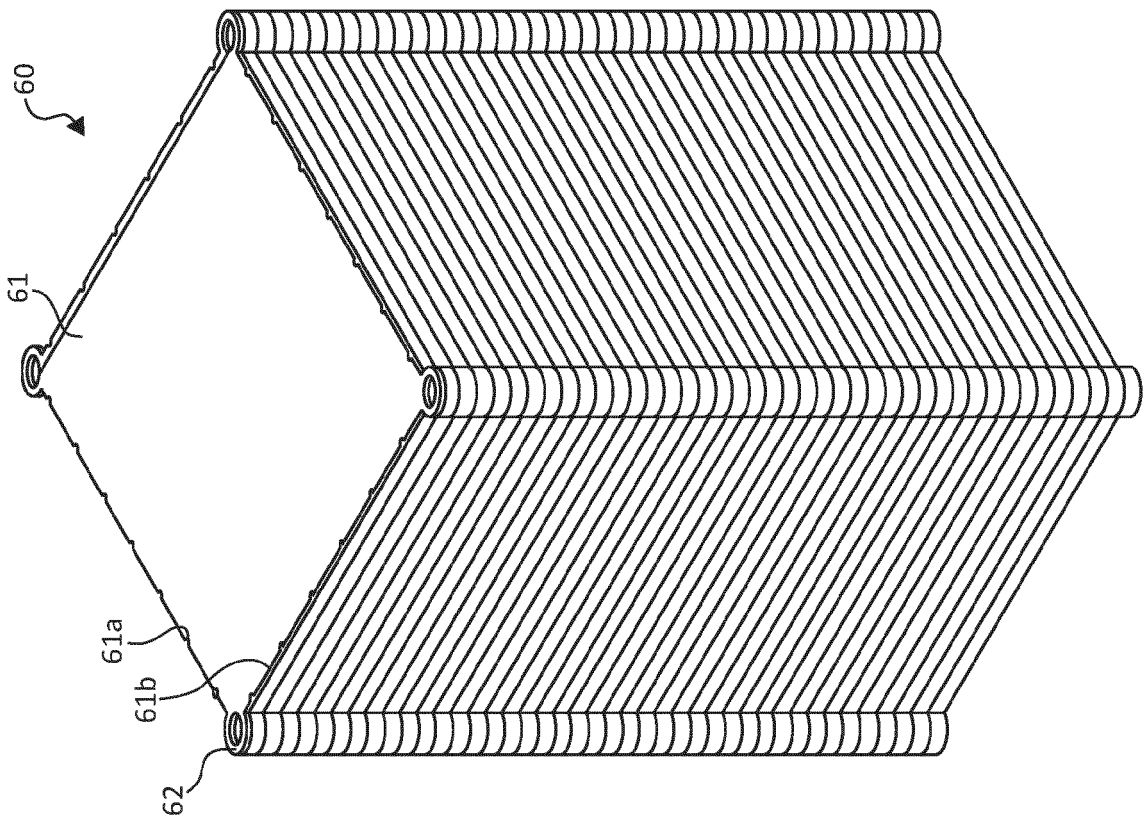


FIG. 6

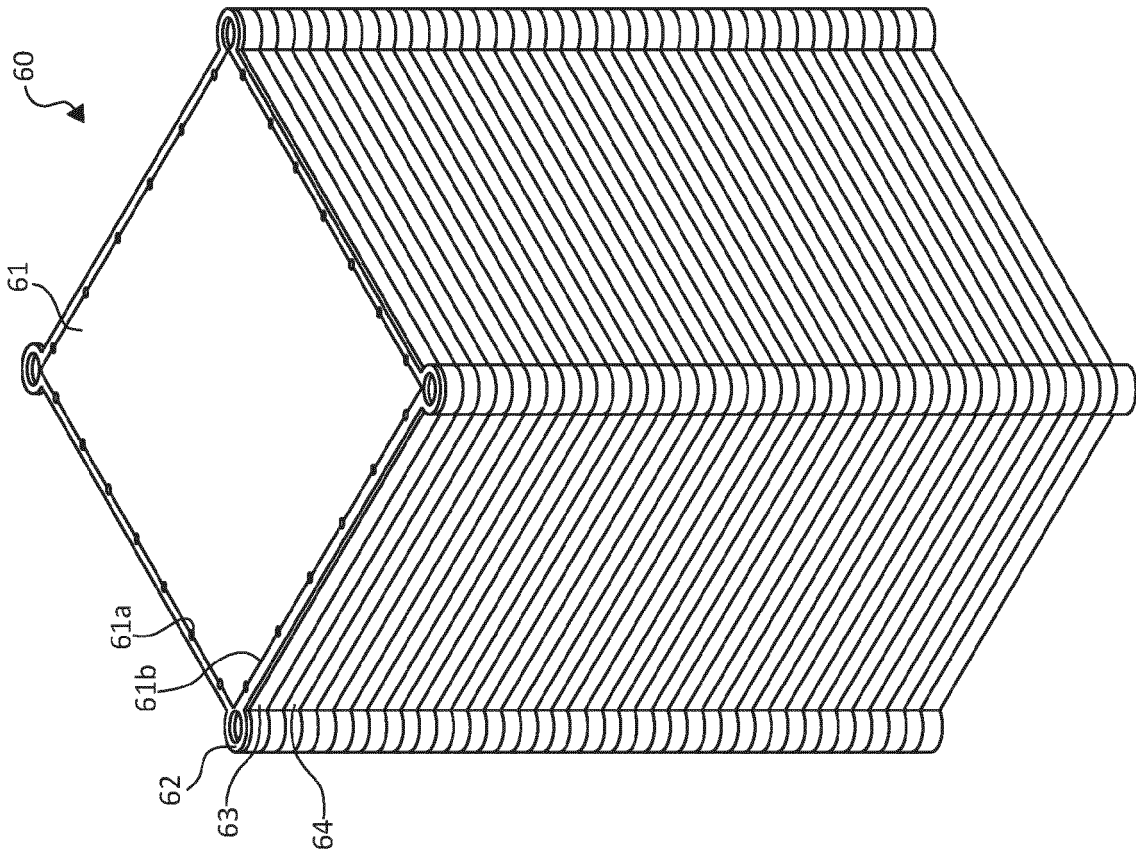


FIG. 5

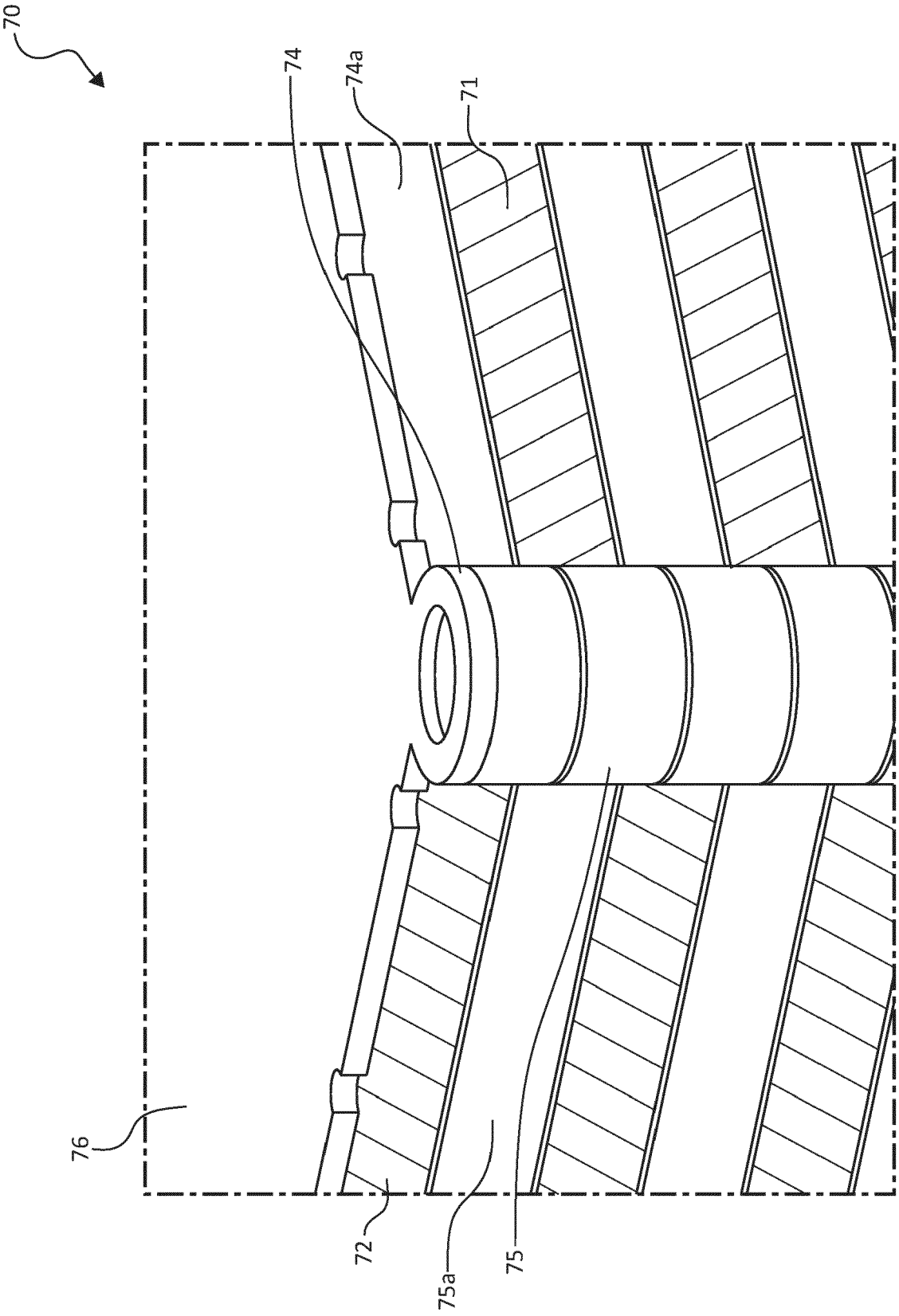


FIG. 7

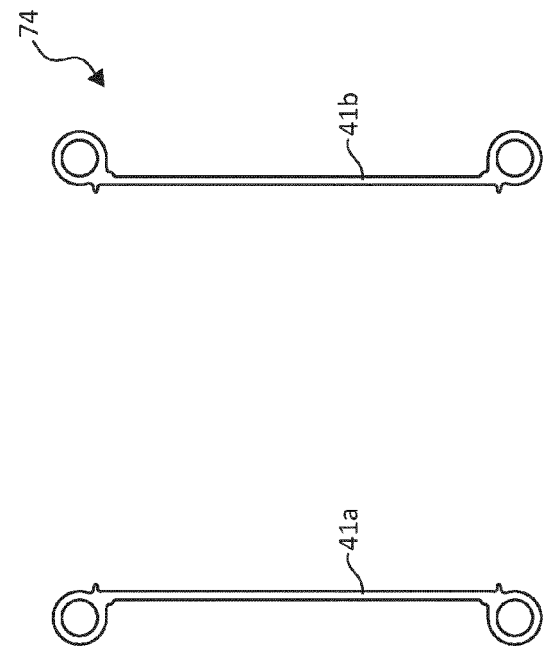


FIG. 8B

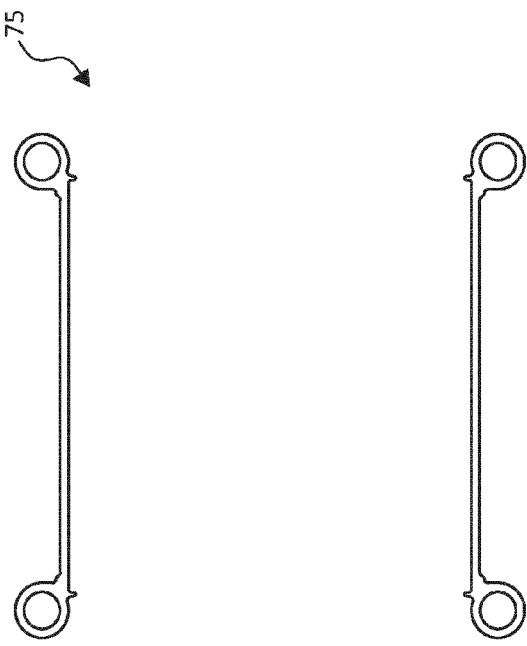


FIG. 9B

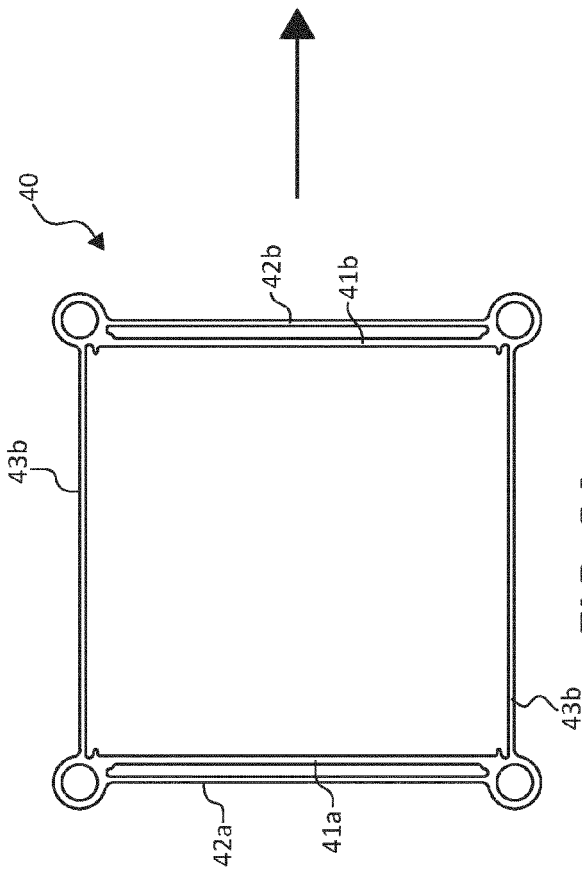


FIG. 8A

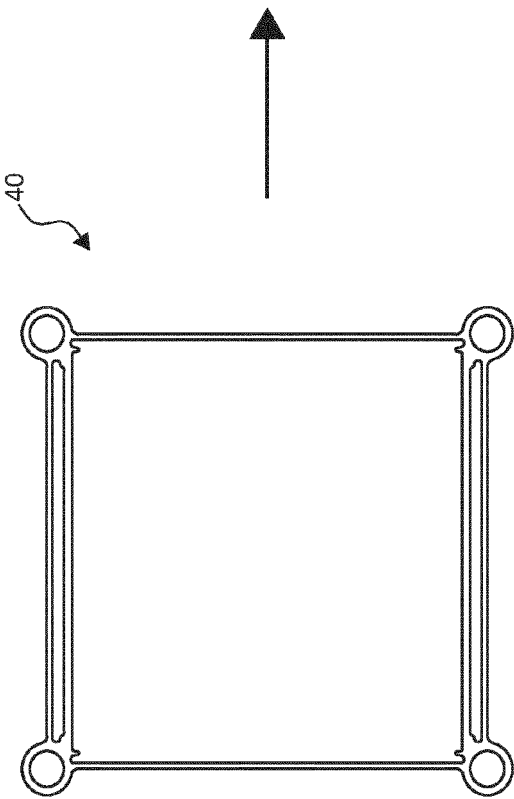


FIG. 9A

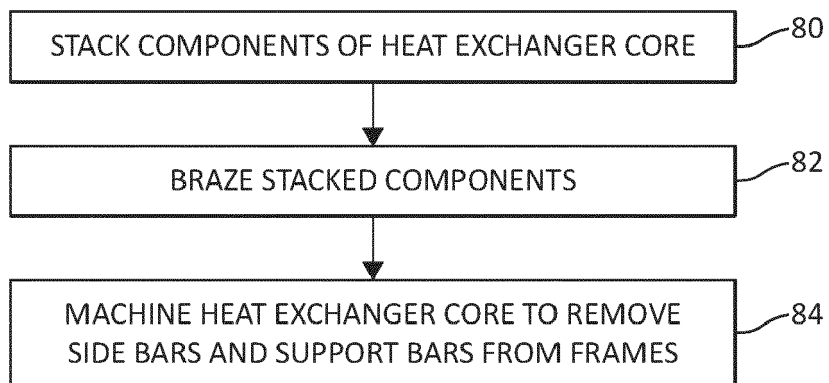


FIG. 10

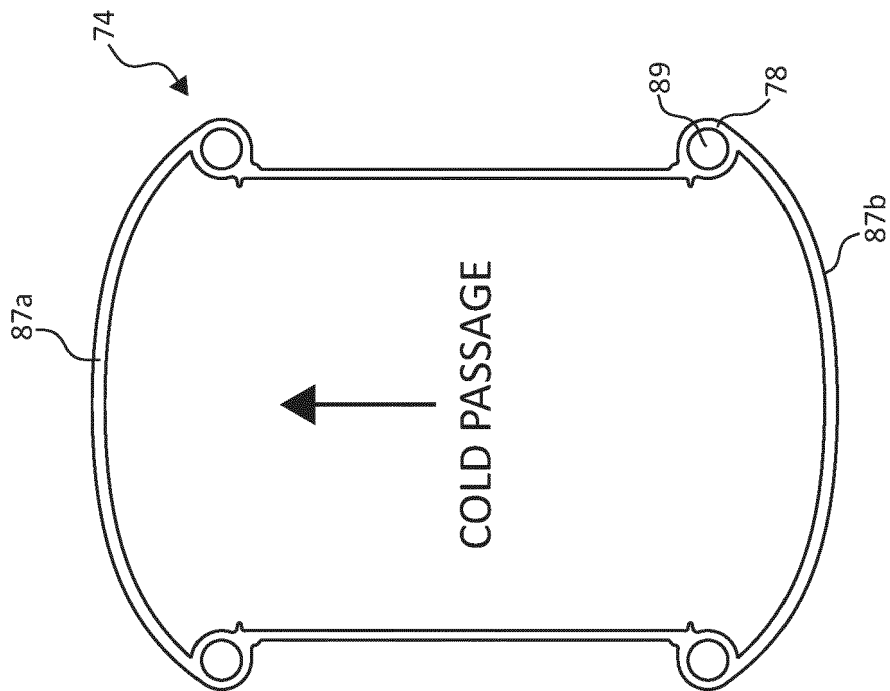


FIG. 11

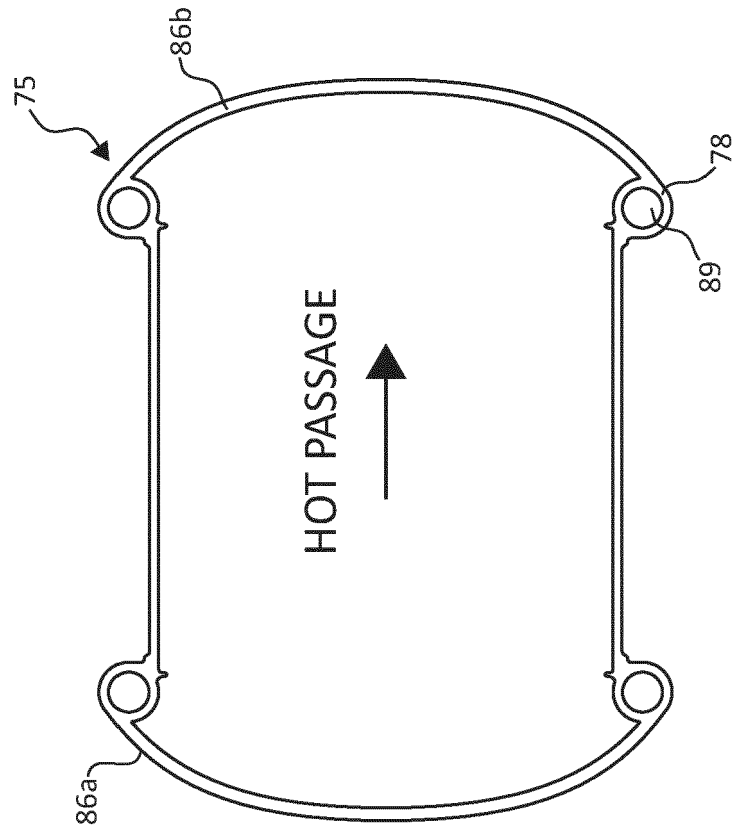


FIG. 12

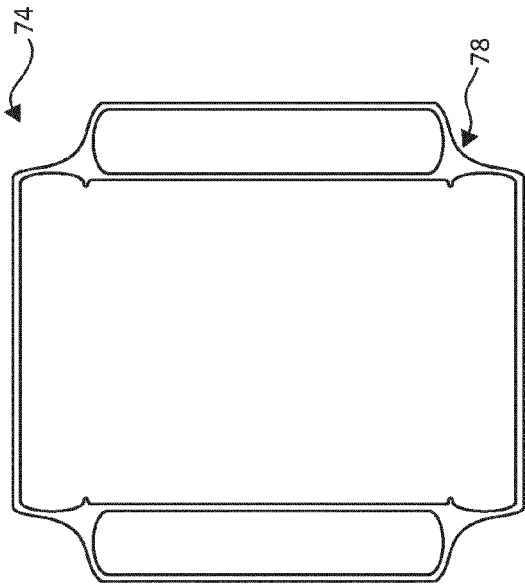


FIG. 14A

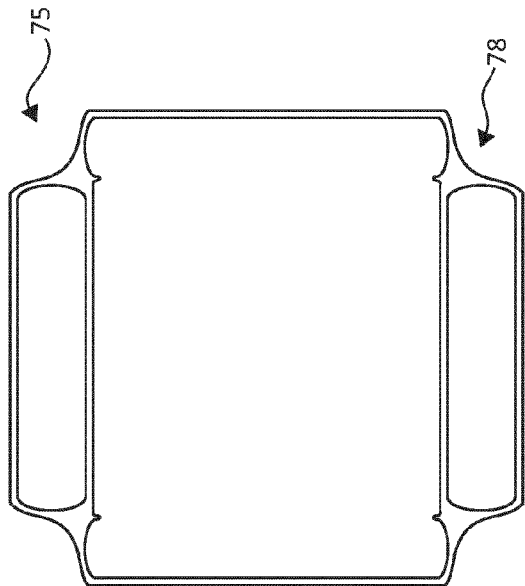


FIG. 14B

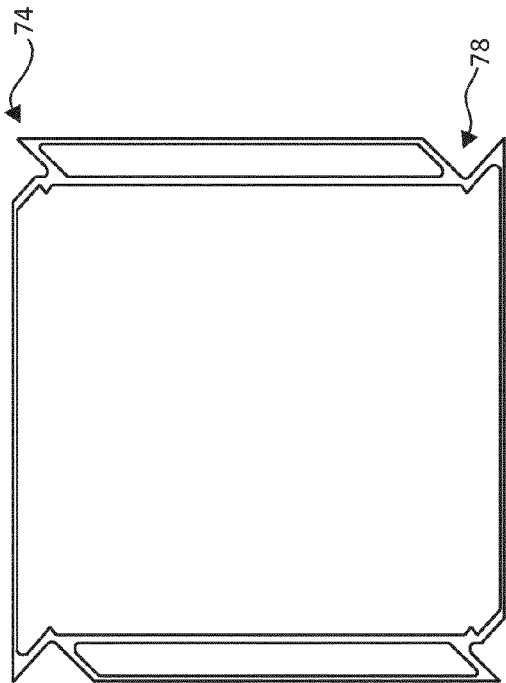


FIG. 13A

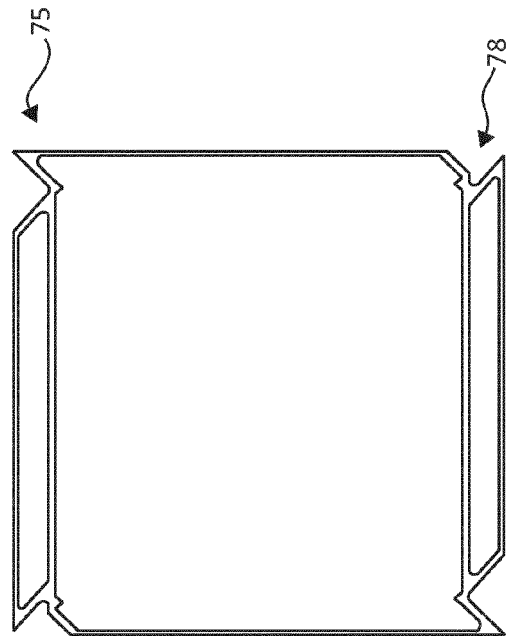


FIG. 13B

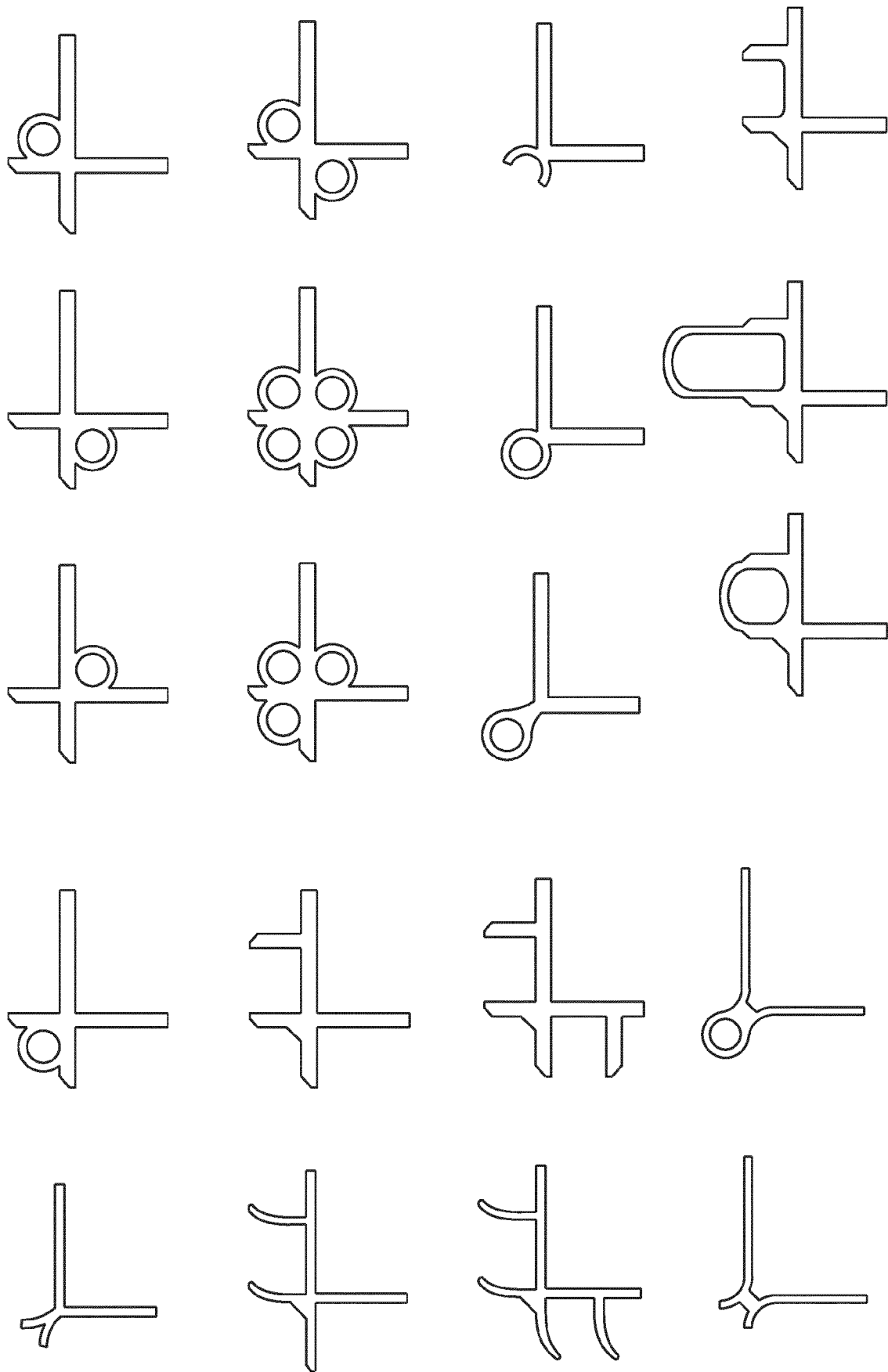


FIG. 15

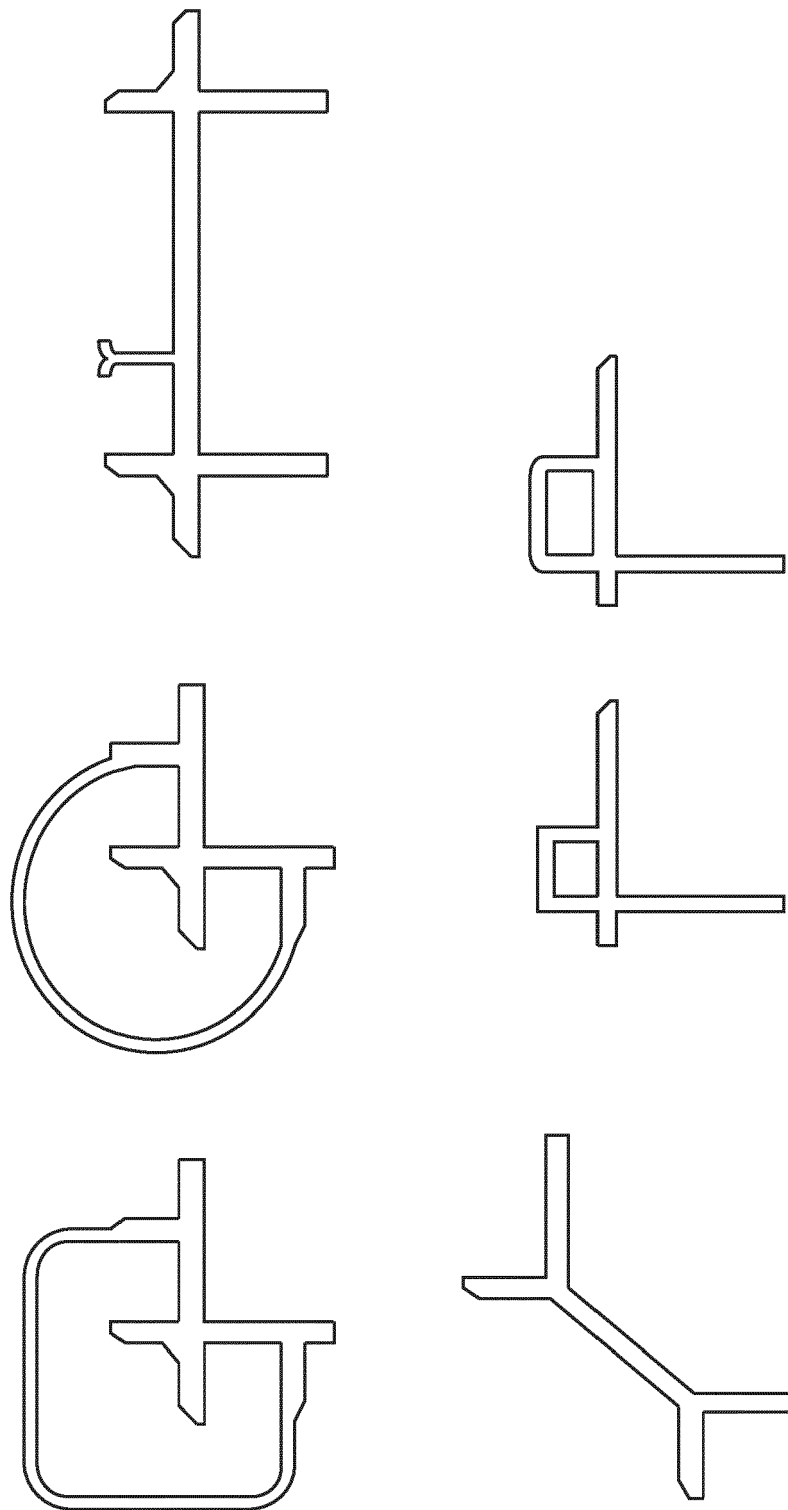


FIG. 16

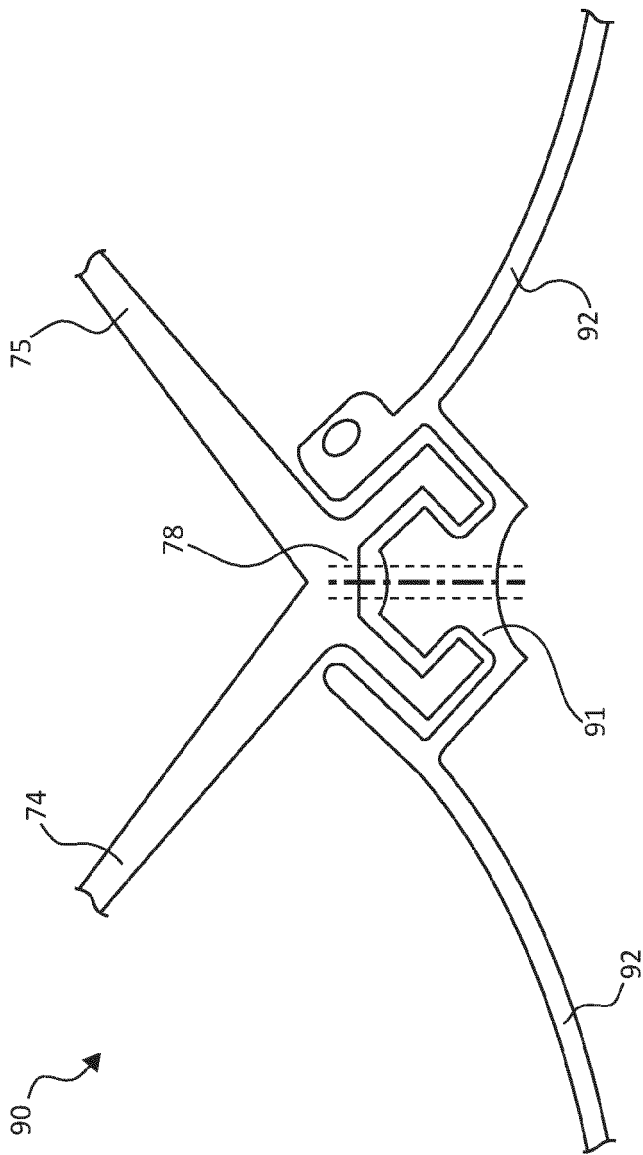


FIG. 17A

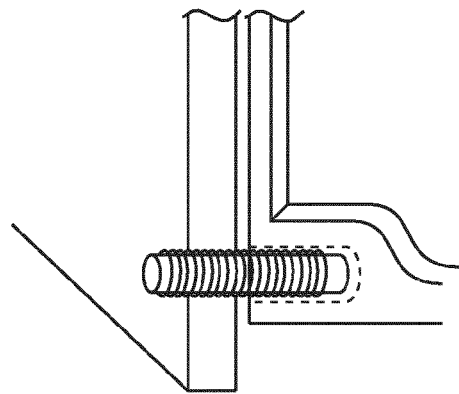


FIG. 17C

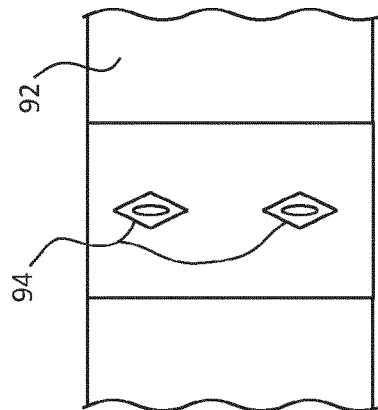


FIG. 17B

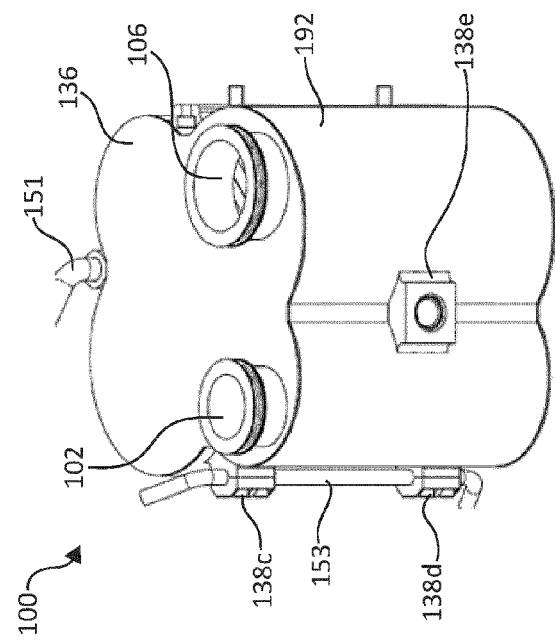


FIG. 18A

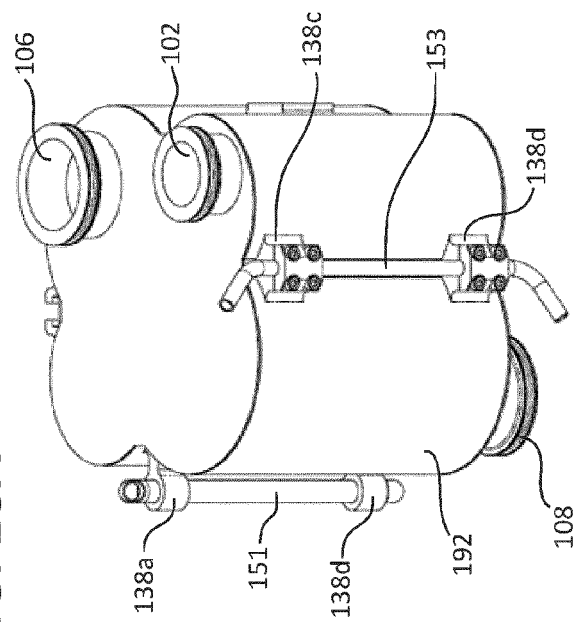


FIG. 18C

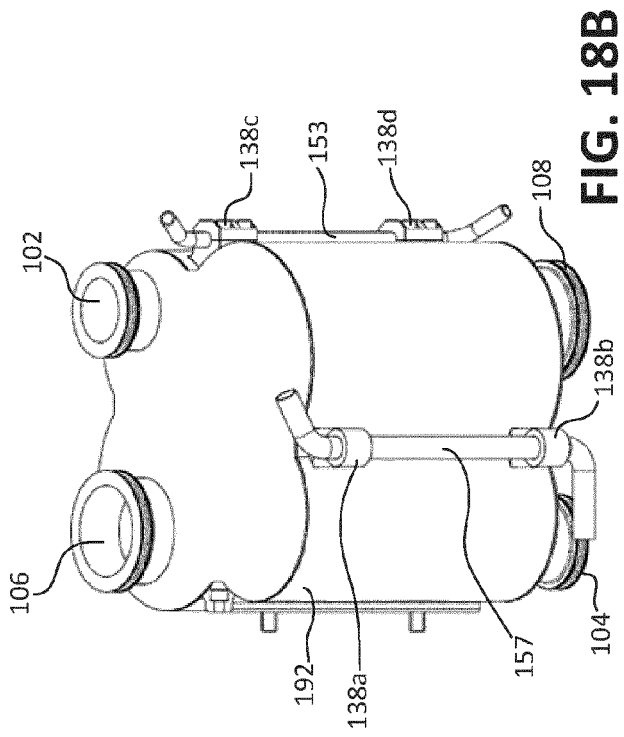


FIG. 18B

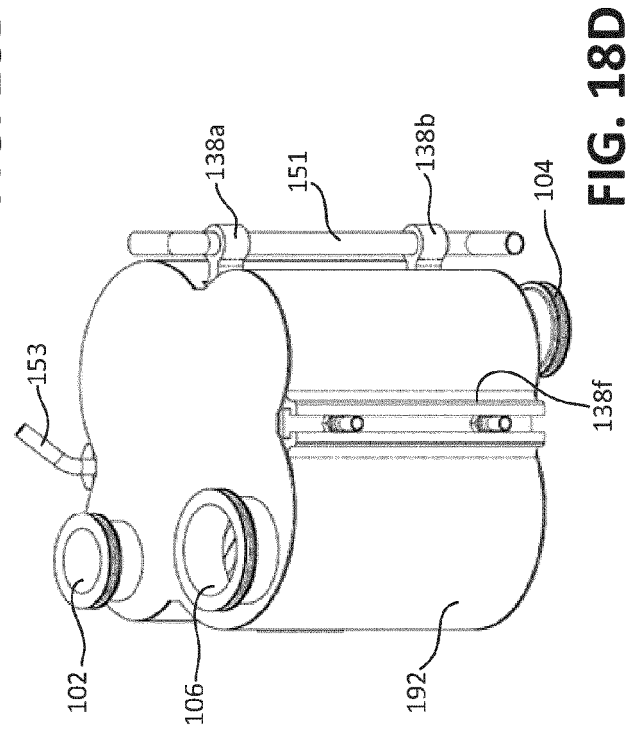
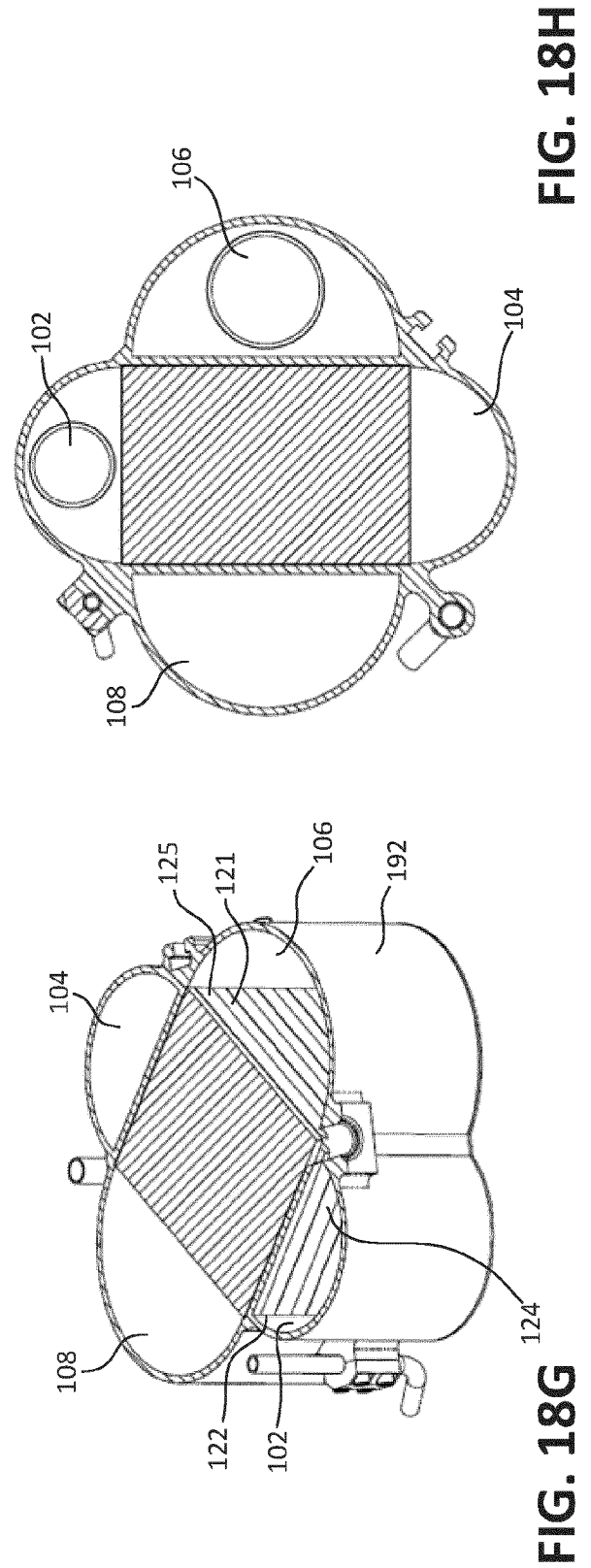
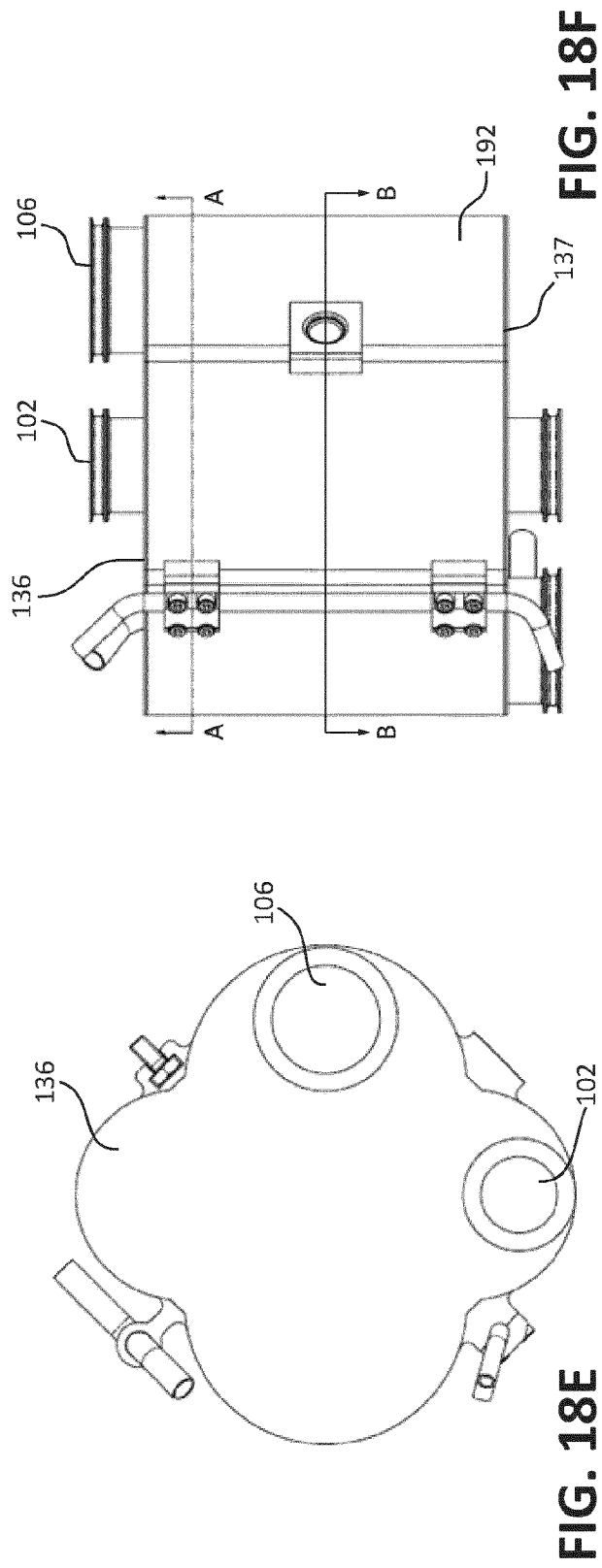


FIG. 18D



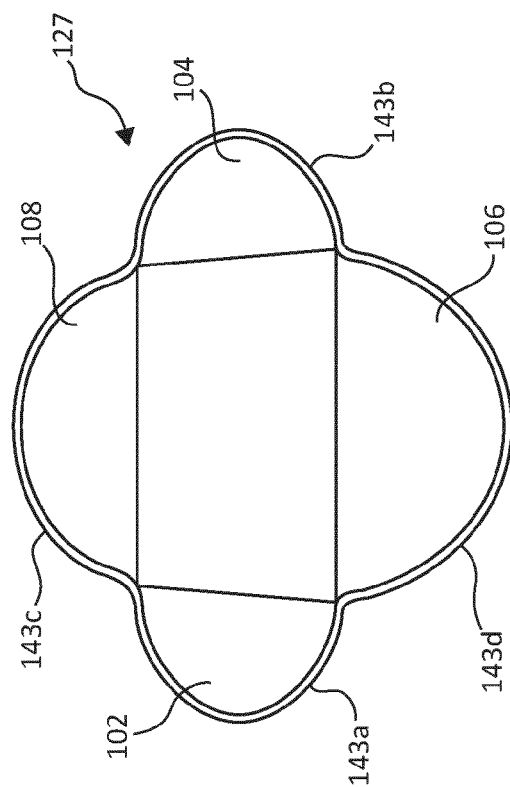


FIG. 19B

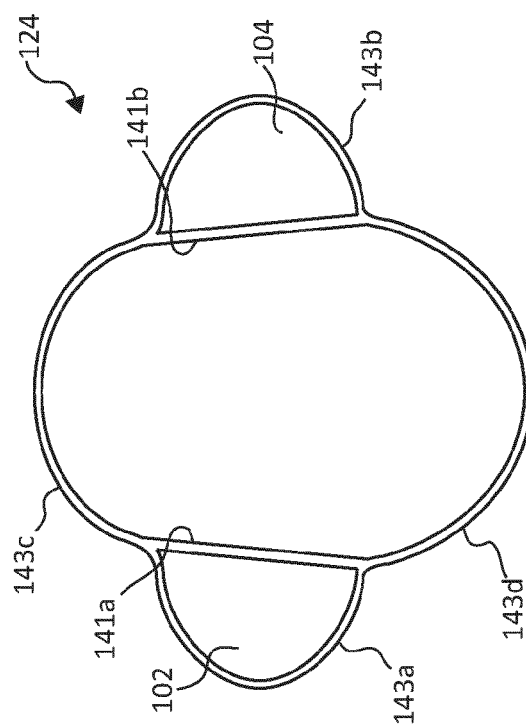


FIG. 19D

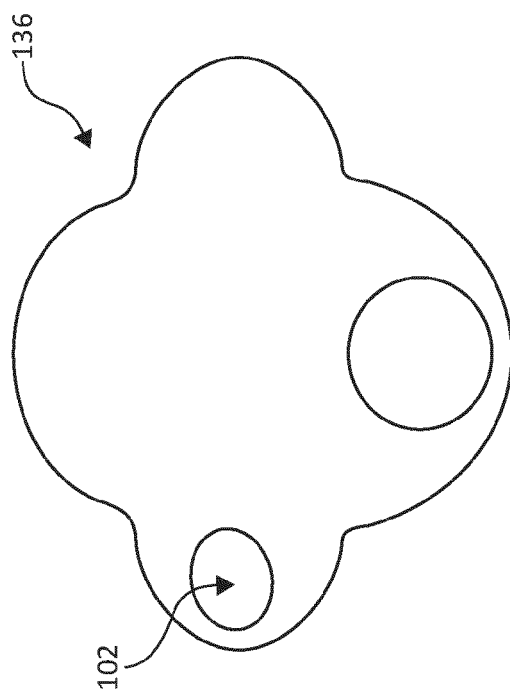


FIG. 19A

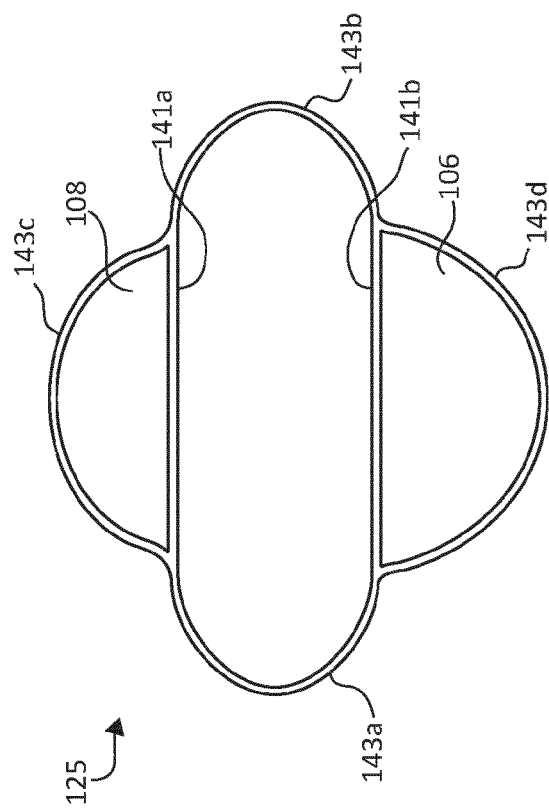


FIG. 19C

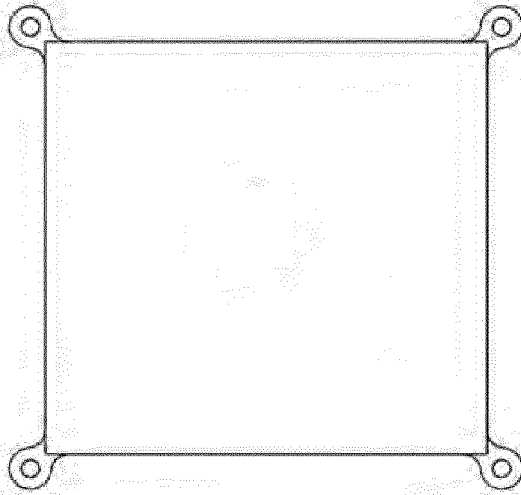


FIG. 20E

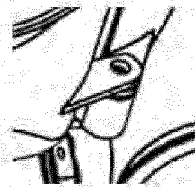


FIG. 20D

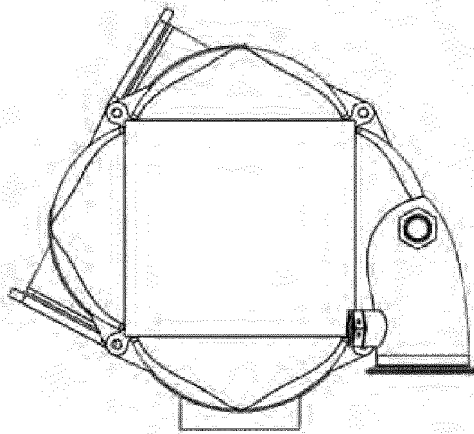


FIG. 20C

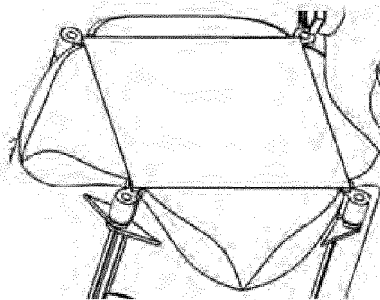


FIG. 20B

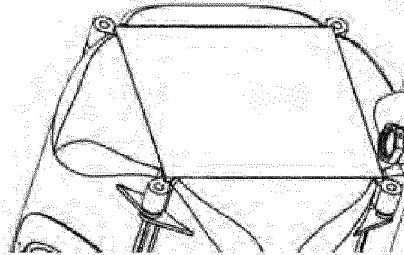


FIG. 20A

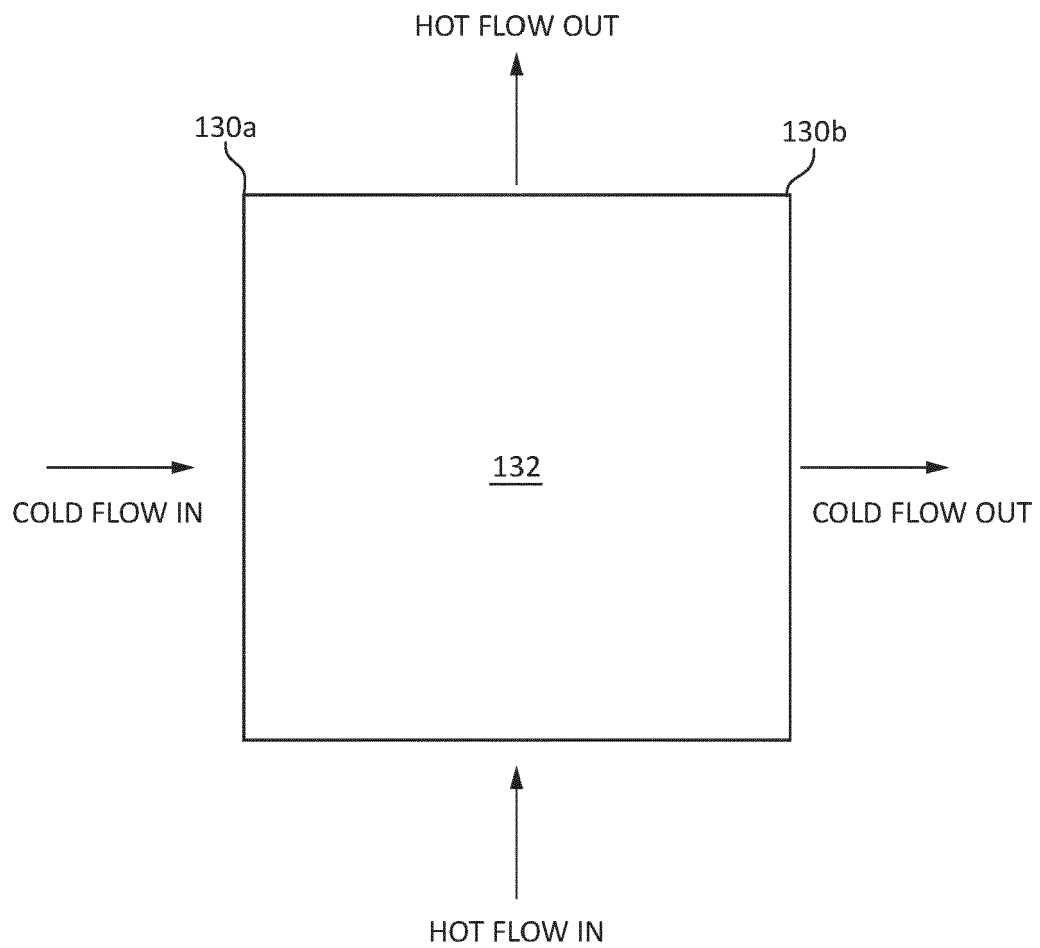


FIG. 21