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(54) **Plate heat exchanger with tension ties**

(57) A plate heat exchanger (100) includes a stack of main plates (110) having ridges and troughs to direct first and second flows of fluids through cavities between the main plates (110) to exchange heat between the fluids while maintaining the first and second flows of fluids separate from each other. The plate heat exchanger (100)

includes a first end plate (120) stacked at one end of the stack of main plates (110) and a second end plate (130) stacked at an opposite end of the main plates (110). Tension ties (140) mechanically connect to each of the first and second end plates (120, 130) through the stack of main plates (110).

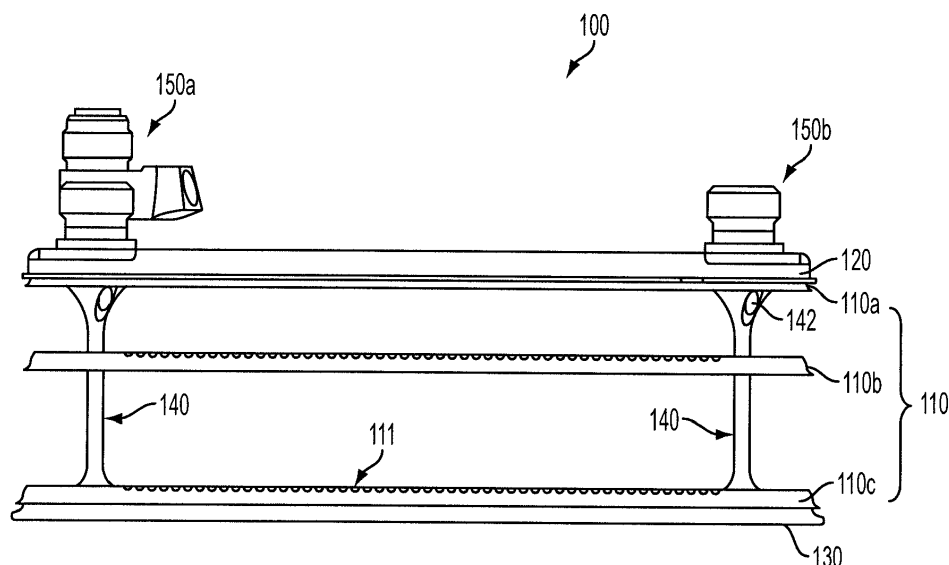


FIG. 1

Description

BACKGROUND OF THE INVENTION

[0001] Embodiments of the invention relate to a plate heat exchanger, and in particular to a heat exchanger having tension ties as ports.

[0002] Plate heat exchangers are widely used in the commercial industry as a means of exchanging energy between two liquids. The construction consists of a series of main plates having ribbed patterns on their surfaces and stacked one on top of the other. This arrangement forms channels between the plates through which the two liquids pass. As the two liquids enter their respective inlet ports they are independently directed to flow into alternating fin channels which permits heat to transfer from one liquid to the other. In order to maintain separation of the two liquids within the ports, the main plates incorporate local depressions in the port areas which alternately block off the flow passage from the port to the fin channels. In this way each port is hydraulically connected to every other fin channel. Each plate is coated with a braze filler metal. The entire heat exchanger assembly is placed in a furnace where the filler metal is melted creating a metallurgical bond between the plates and forming a fluid seal.

[0003] Plate heat exchangers are subjected to stresses from internal fluid pressures. Stress resides in the main plates as the fluid pressure tries to separate each plate. The top plate and bottom plate provide some additional support and stiffness to resist the internal pressure. The load emanating from the fluid pressure in the vicinity of the ports is commonly called a plug load. The area immediately surrounding the port areas is inherently subjected to high stresses due to the reduction of material to form the port holes which must exist to allow fluid flow. However the rectangular shape of the heat exchanger does not function as an efficient pressure vessel. Material may be added to the top and bottom plates to increase strength, but adding the material also increases a weight of the plate heat exchanger.

[0004] The position tolerance of the ports is subject to the ability to maintain a repeatable and consistent stack height of the main plates. Small variations in the material thickness of the main plates (in the order of micrometers) will multiply by the number of main plates. An 80 plate heat exchanger, for example can differ in stack height from unit to unit by 2.03 millimeters (mm) if each main plate had a variation of just 0.00254 mm. When considering the additional tolerance associated with other components of the heat exchanger, the resultant position tolerance of the ports can be 2.54 mm, for example. This large variation from unit to unit is unacceptable for installations where precision is critical, such as in aerospace applications.

BRIEF DESCRIPTION OF THE INVENTION

[0005] Embodiments of the present invention include a plate heat exchanger which includes a stack of main plates having ridges and troughs to direct first and second flows of fluids through cavities between the main plates to exchange heat between the fluids while maintaining the first and second flows of fluids separate from each other. The plate heat exchanger includes a first end plate stacked at one end of the stack of main plates and a second end plate stacked at an opposite end of the main plates. One or more tension ties mechanically connect to each of the first and second end plates through the stack of main plates.

[0006] Embodiments of the invention further include a plate heat exchanger which includes a stack of main plates having ridges and troughs to direct first and second flows of fluids through cavities between the main plates to exchange heat between the fluids while maintaining the first and second flows of fluids separate from each other. The plate heat exchanger includes a first end plate stacked at one end of the stack of main plates and a second end plate stacked at an opposite end of the main plates. The plate heat exchanger includes a tension tie mechanically connected to the first end plate and the second end plate to resist a pressure exerted against at least one of the first and second end plates, the tension tie including a fluid fitting mount to receive a fluid fitting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a lengthwise side view of a heat exchanger according to one embodiment of the invention;

FIG. 2 illustrates a widthwise side view of a heat exchanger according to one embodiment of the invention;

FIG. 3 is a cut-away view of a portion of a tension tie according to one embodiment of the invention;

FIG. 4 is a tension tie according to one embodiment of the invention;

FIG. 5 is a tension tie according to another embodiment;

FIG. 6 is a tension tie according to another embodiment; and

FIG. 7 is a tension tie according to another embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0008] Conventional plate heat exchangers are subject to stresses, particularly around port openings in the end plates. Embodiments of the invention relate to a plate heat exchanger having ports that are tension ties to provide support at the ends of the plate heat exchanger.

[0009] FIG. 1 illustrates a plate heat exchanger 100 according to one embodiment. The plate heat exchanger 100 includes main plates 110 having ridged regions 111. The ridged regions 111 may have a herringbone or chevron pattern to increase a surface area of the main plate 110 contacted by the fluid and to generate turbulence in the fluid. In FIG. 1, only three main plates 110a, 110b and 110c are illustrated for purposes of description. However, in a complete plate heat exchanger 100, the main plates 110 are stacked on top of each other between the bottom end plate 130 and the top end plate 120. Openings are formed in the main plates 110 at locations on the main plates 110 corresponding to the ports 150a and 150b. The main plates 110 are provided, alternatingly, with protrusions or recesses surrounding the openings to alternate a fluid that enters a cavity between the main plates. For example, a first fluid may enter first, third and fifth cavities between the main plates, and a second fluid may enter second, fourth and sixth cavities. The fluids are maintained separate and exchange heat as they flow through the cavities.

[0010] The plate heat exchanger 100 includes a first end plate 120, also referred to herein as a top end plate 120 for purposes of description. The plate heat exchanger 100 also includes a second end plate 130, also referred to herein as a bottom end plate 130 for purposes of description. The top end plate 120 and bottom end plate 130 are positioned at opposite sides of the plurality of main plates 110. It is understood that although the terms "top" and "bottom" may be used for purposes of description, embodiments of the invention encompass a plate heat exchanger 110 having the first and second end plates 120 and 130 arranged with any spatial alignment relative to an earth plane. While FIG. 1 illustrates only one top end plate 120 and only one bottom end plate 130, embodiments of the invention encompass plate heat exchangers having seal plates and end plates instead of one integrated end plate at each end of the heat exchanger.

[0011] The illustrated top end plate 120 includes openings to receive the fluid fittings 150a and 150b, as well as two additional fluid fittings not shown in FIG. 1. While particular shapes are used in FIG. 1 to represent the main plates 110, end plates 120 and 130 and fittings 150a and 150b, it is understood that these and other elements may have any desired shape. For example, the main plates 110 may have substantially rectangular, square, oval or any polygonal shape.

[0012] In embodiments of the present invention, tension ties 140 are mechanically connected to each of the top plate 120 and the bottom plate 130. The fittings 150a and 150b are set directly into the tension ties 140 rather than the top plate 120, such that vibration or movement of the top plate 120 does not substantially affect the stability of the fittings 150a and 150b. As the fluid pressure exerts force against the top and bottom end plates 120 and 130, the tension ties 140 resist the load and keep the top and bottom plates 120 and 130 together

[0013] While FIG. 1 illustrates a side lengthwise view of the plate heat exchanger 100 having some main plates 110 omitted for clarity in description, FIG. 2 illustrates a side width-wise cut-out view of the plate heat exchanger 100. The heat exchanger 100 includes the top end plate 120, bottom end plate 130 and main plates 110. In FIG. 2, stacked main plates 110a and 110d are illustrated as being stacked adjacent to the top end plate 120, stacked main plates 110c and 110e are illustrated as being stacked adjacent to the bottom end plate 130 and main plate 110b is illustrated as being located along center columns 141a and 141b of tension ties 140a and 140b, respectively. It is understood that the main plates 110a-110e are merely representative examples of main plates 110 that are stacked to span the entire distance between the top end plate 120 and the bottom end plate 130. The main plates 110 include openings 112, represented by the opening 112b in main plate 110b, to permit and direct fluid flow between the plates 110.

[0014] The bottom end plate 130 includes fasteners 131a and 131b. Each tension tie 140a and 140b includes first connectors 144a and 144b, which may also be referred to as bottom connectors 144a and 144b, to connect to the fasteners 131a and 131b. The tension ties 140a and 140b also include second connectors 143a and 143b, which may also be referred to as top connectors 143a and 143b, and center columns 141a and 141b that connect the bottom connectors 144a and 144b with the top connectors 143a and 143b. The tension ties 140a and 140b include openings 142a and 142b that permit fluid flow into and out from the stack of main plates 110.

[0015] The top connectors 143a and 143b are configured to receive the fluid fittings 150a and 150c, such that an outer circumferential surface 151a and 151c of the fluid fittings 150a and 150c contacts an inner circumferential surface 145a and 145b of the tension ties 140a and 140b. The fluid fittings 150a and 150c also include conduits 152a and 152c to permit fluid flow from outside the fluid fittings 150a and 150c into and out from the stack of main plates 110.

[0016] In operation, the bottom connectors 144a and 144b of the tension ties 140a and 140b are connected to the fasteners 131a and 131b to mechanically connect the tension ties 140a and 140b to the bottom plate 130. The connection of the bottom connectors 144a and 144b to the fasteners 131a and 131b may be a screw or other fastening mechanism, or may be merely a fitting of a slot onto a protrusion, which may then be brazed or welded

to form a permanent connection. Main plates 110, including the illustrated example main plates 110a-110e, are stacked between the bottom plate 130 and the top plate 120. The top plate 120 is stacked on the top-most main plate 110a. The fluid fittings 150a and 150c are inserted into the top connectors 143a and 143b of the tension ties 140a and 140b. The connections between the tension ties 140a and 140b and the bottom plate 130, between the bottom plate 130 and the bottom-most main plate 110c, between each of the main plates 110, between the top-most main plate 110a and the top end plate 120, between the tension ties 140a and 140b and the top end plate 120, and between the tension ties 140a and 140b and the fluid fittings 150a and 150c may be connected by brazing or by any other welding method or adhesive method.

[0017] When fluid F is input into the fluid fitting 150a, the fluid flows through the channel 152a, out of the openings 142a of the tension tie 140a into the stack of main plates 110. Openings 112 in the main plates 110 permit the fluid F to flow into some cavities between main plates 110 while fluid flow is restricted from other openings 112 to prevent fluid flow to some cavities between main plates 110. Another fluid fitting (not shown) also allows fluid flow in to the stack of main plates 110. The fluid flows may be allowed into alternating cavities between main plates to facilitate heat transfer between the fluids. The tension tie 140b includes openings 142b to permit the fluid F to flow out from the stack of main plates 110 into the channel 152c and out from the fluid fitting 150c.

[0018] During operation, the fluids in the stack of main plates 110 generates pressure outward against the bottom end plate 130 and the top end plate 120. The tension ties 140a and 140b resist the pressure and maintain the top and bottom end plates 120 and 130 in position. The tension ties 140a and 140b are connected directly to the fluid fittings 150a and 150c, stabilizing the fluid fittings 150a and 150c.

[0019] In one embodiment, the center columns 141a and 141b of the tension ties 140a and 140b are solid, or include no passageway to permit the flow of fluid through the column 141a and 141b. Instead, the center columns 141a and 141b have an outer diameter less than an inner diameter of openings 112 in the main plates 110, allowing fluid to flow through the openings 112. In such an embodiment, an outer diameter of the center columns 141a and 141b may be less than an outer diameter of the top connectors 143a and 143b. In alternative embodiments, the center columns 141a and 141b may have passageways to permit fluid flow through the center columns 141a and 141b and openings to permit the fluid to flow from the center columns 141a and 141b into either the openings 112 or directly into cavities between the main plates.

[0020] FIG. 3 illustrates a connection between a tension tie 140 and the fluid fitting 150 and top end plate 120. In embodiments of the invention, the fluid fitting 150 may include an outside surface 151 having a smaller outer diameter at a braze region 163, a larger outer diameter

at a pilot region 164, and a recess 153, also referred to as a braze ring 153, located between the pilot region 164 and the braze region 163. The outer diameter surface 151 of the fitting 150 is configured to fit within the inside diameter surface 145 of the tension tie 140. During brazing, the braze extends through the braze gap in the braze region 163 to maintain a strong connection between the fluid fitting 150 and the tension tie 140.

[0021] The top connector 143 of the top end plate 120 may have an inside surface 121 having a larger inner diameter at a braze region 161, a smaller inner diameter at a pilot region 162, and a recess 147, also referred to as a braze ring 147, located between the pilot region 162 and the braze region 161. The outer diameter surface 146 of the tension tie 140 is configured to fit within the inside diameter surface 121 of the top end plate 120. During brazing, the braze extends through the braze gap in the braze region 161 to maintain a strong connection between the tension tie 140 and the top end plate 120.

[0022] FIG. 3 also illustrates main plates 110a and 110d on which the top end plate 120 is stacked. In addition, FIG. 3 illustrates the opening 142 and center column 141 of the tension tie 140. In the embodiment illustrated in FIG. 3, the braze rings 153 and 147 are controlled spaces where braze material is stored precisely. During brazing, the braze material flows through the braze regions 161 and 163 having predetermined widths to maintain braze strength. In some embodiments, the outer surface 151 of the fluid fitting 150, the inner surface 145 of the tension tie 140, the outer surface 146 of the tension tie 140 and the inner surface 121 of the top end plate 120 are all parallel to each other, both in the braze region 161 and in the pilot region 164.

[0023] FIGS. 4 to 7 illustrate tension ties according to some embodiments. As illustrated in FIG. 4, in one embodiment, the tension tie 440 includes a top connector 443, a bottom connector 444 and a center column 441 between the top connector 443 and bottom connector 444. The center column 441 includes openings 445 along the length of the center column 441. The openings 445 may be small holes, for example. Fluid enters the top connector 443 and the center column 441 and exits from the holes 445 in the center column 441 into a stack of main plates of a plate heat exchanger. In the embodiment of FIG. 4, the top connector 443 has an outer diameter that is larger than an outer diameter of the center column 441. In one embodiment, the top connector 443 does not include openings to permit fluid flow into an opening formed in stacked main plates. Instead, all of the fluid that flows into or out from the tension tie 440 flows through the holes 445 and the center column 441. In another embodiment, openings may also be provided in the top connector 443. The center column 441 may have an outer diameter less than an inner diameter of a channel formed by openings in a stack of main plates, permitting fluid to flow to and from the holes 445 in the center column 441 and the channel formed by the openings in the stack of main plates.

[0024] As illustrated in FIG. 5, in one embodiment, the tension tie 540 includes a top connector 543, a bottom connector 544 and a center column 545 between the top connector 543 and bottom connector 544. The center column 541 includes openings 545 along the length of the center column 541. The openings 545 may be vertical slots, for example. Fluid enters the top connector 543 and the center column 541 and exits from the vertical slots 545 in the center column 541 into a stack of main plates of a plate heat exchanger. In the embodiment of FIG. 5, the top connector 543 has an outer diameter that is larger than an outer diameter of the center column 541. In one embodiment, the top connector 543 does not include openings to permit fluid flow into an opening formed in stacked main plates. Instead, all of the fluid that flows into or out from the tension tie 540 flows through the vertical slots 545 and the center column 541. In another embodiment, openings may also be provided in the top connector 543. The center column 541 may have an outer diameter less than an inner diameter of a channel formed by openings in a stack of main plates, permitting fluid to flow to and from the vertical slots 545 in the center column 541 and the channel formed by the openings in the stack of main plates.

[0025] As illustrated in FIG. 6, in one embodiment, the tension tie 640 includes a top connector 643, a bottom connector 644 and a center column 641 between the top connector 643 and bottom connector 644. The center column 641 includes openings 645 along the length of the center column 641. The openings 645 may be fluted slots, for example. Fluid enters the top connector 643 and the center column 641 and exits from the fluted slots 645 in the center column 641 into a stack of main plates of a plate heat exchanger. In the embodiment of FIG. 6, the top connector 643 has an outer diameter that is larger than an outer diameter of the center column 641. In one embodiment, the top connector 643 does not include openings to permit fluid flow into an opening formed in stacked main plates. Instead, all of the fluid that flows into or out from the tension tie 640 flows through the fluted slots 645 and the center column 641. In another embodiment, openings may also be provided in the top connector. The center column 641 may have an outer diameter less than an inner diameter of a channel formed by openings in a stack of main plates, permitting fluid to flow to and from the holes 645 in the center column 641 and the channel formed by the openings in the stack of main plates.

[0026] As illustrated in FIG. 7, in one embodiment, the tension tie 740 includes a top connector 743, a bottom connector 744 and a center column 741 between the top connector 743 and bottom connector 744. The center column 741 may be a cylinder that includes openings 745 along the length of the center column 741. The openings 745 may be small holes aligned to fin passages, or cavities between main plates, for example. Fluid enters the top connector 743 and the center column 741 and exits from the small holes 745 in the center column 741

into a stack of main plates of a plate heat exchanger. In one embodiment, an outer diameter of the center column 741 is substantially the same as an inner diameter of a channel formed by openings in a stack of main plates. In other words, the center column 741 may have an outer diameter such that the center column 741 fits snugly in the channel formed by the openings. In such an embodiment, fluid may not be permitted to flow through the channel formed by the openings in the stack of main plates outside the center column 741. In other words, in one embodiment, substantially all of the fluid that flows in cavities between main plates in the stack of main plates flows directly out from or into the holes 745 and the center column 741. In one embodiment, the outer diameter of the center column 741 is bonded to an inner diameter of the openings in the main plates defining the channel by welding or brazing, thereby preventing fluid flow through the channel, other than through the center column 741.

[0027] In embodiments of the present invention, tension ties are provided between a top end plate and bottom end plate of a plate heat exchanger. The tension ties include fluid fitting mount portions to receive fluid fittings. The tension ties include openings to permit fluid from the fluid fittings to flow into a main plate stack and out from the main plate stack. The tension ties strengthen the plate heat exchanger while reducing the need to form the top and bottom end plates with extra material, thereby reducing a weight of the plate heat exchanger. In addition, since the fluid fittings are positioned inside the tension ties, the fluid fittings may be precisely located, even if the top end plate is subject to movement. In addition, the thicknesses of braze material in critical locations is controlled to maintain a high and consistent braze strength.

[0028] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A plate heat exchanger (100), comprising:

a stack of main plates (110) having ridges and troughs to direct first and second flows of fluids through cavities between the main plates (110) to exchange heat between the fluids while maintaining the first and second flows of fluids sep-

- arate from each other;
a first end plate (120) stacked at one end of the stack of main plates (110);
a second end plate (130) stacked at an opposite end of the main plates (110); and
tension ties (140; 440; 540; 640; 740) mechanically connected to each of the first and second end plates (120, 130) through the stack of main plates (110).
2. The plate heat exchanger of claim 1, wherein the tension ties (140; 440; 540; 640; 740) extend through openings (112) in the main plates (100), the openings (112) in the main plates (100) being in fluid communication with the cavities between the main plates (100), and
a first tension tie (140a) among the tension ties includes an opening (142a) configured to permit a flow of fluid from the first tension tie (140a) into a channel formed by the openings (112) in the main plates (100).
 3. The plate heat exchanger of claim 2, wherein the first tension tie includes a first end connector (143a) configured to connect to the first end plate (120), a second end connector (144a) configured to connect to the second end plate (130) and a center column (141a) extending between the first end connector (143a) and the second end connector (144a), the center column (141a) having an outer diameter less than an inner diameter of the channel formed by the openings (112) in the main plates (110).
 4. The plate heat exchanger of claim 1, wherein the tension ties extend through openings in the stack of main plates (100), the openings in the stack of main plates (100) forming a first channel from the first end plate (120) to the second end plate (130),
a first tension tie (740) among the tension ties extending through the first channel, the first tension tie (740) being a hollow tension tie having an outer diameter that is substantially the same as an inner diameter of the first channel, the first tension tie including openings (745) configured to permit a flow of fluid between the hollow tension tie (740) and the cavities between the main plates (110).
 5. The plate heat exchanger of claim 1, wherein a first tension tie among the tension ties has a first end connector (443; 543; 643) configured to connect to the first end plate (120), a second end connector (444; 544; 644) configured to connect to the second end plate (130) and a center column (441; 541; 641) extending between the first end connector (443; 543; 643) and the second end connector (444; 544; 644), the center column (441; 541; 641) having a width less than a width of the first end connector (143), and the center column (141) includes at least one opening (445) to permit fluid to flow between the stack of main plates (110) and a channel through the first end connector (143).
 6. The plate heat exchanger of claim 5, wherein the at least one opening (565; 645) extends a length of the center column (541; 641).
 7. The plate heat exchanger of claim 5 or 6, wherein the at least one opening is a fluted opening (645) extending a length of the center column (641).
 8. The plate heat exchanger of any preceding claim, wherein the tension ties (140; 440; 540; 640; 740) include bottom connectors (144; 444; 544; 644; 744) to mechanically fix the tension ties (140; 440; 540; 640; 740) to the second end plate (130).
 9. The plate heat exchanger of claim 8, wherein the tension ties (140; 440; 540; 640; 740) are configured to resist a pressure exerted in opposing directions against the first and second end plates (120, 130), respectively.
 10. The plate heat exchanger of any preceding claim, further comprising:
fluid fittings (150),
wherein the tension ties (140; 440; 540; 640; 740) include receptacles to receive the fluid fittings (150) and openings to permit fluid to flow between the fluid fittings (150) and the stack of main plates (100).
 11. The plate heat exchanger of claim 10, wherein each of the tension ties includes a first connection end including the receptacle, the first connection end configured connect to one of the fluid fittings (150) along an inner diameter surface (145) and to connect to the first end plate (120) along an outer diameter surface (146) opposite the inner diameter surface (145).
 12. The plate heat exchanger of any preceding claim, further comprising:
fluid fittings (150),
wherein the tension ties (140; 440; 540; 640; 740) include receptacles configured to mechanically connect the tension ties (140; 440; 540; 640; 740) to the fluid fittings (150),
a first fluid fitting (150) among the fluid fittings includes a recess (153) around an outer diameter circumference of the first fluid fitting adjacent to an inner diameter surface (145) of a first tension tie (140) among the tension ties, and
the outer diameter surface (151) of the first fluid fitting (150) has a larger diameter on one side

of the recess (153) and a smaller diameter on an opposite side of the recess (153).

13. The plate heat exchanger of any preceding claim, wherein the tension ties include top connectors (143) configured to mechanically connect the tension ties to the first end plate (120) and a recess (147) around an outer diameter circumference of the top connector (143) adjacent to an inner diameter surface (121) of the first end plate (120), and the inner diameter surface (121) of the first end plate (120) has a larger diameter on one side of the recess (147) and a smaller diameter on an opposite side of the recess (147).

14. A plate heat exchanger (100) comprising:

a stack of main plates (110) having ridges and troughs to direct first and second flows of fluids through cavities between the main plates (110) to exchange heat between the fluids while maintaining the first and second flows of fluids separate from each other;
a first end plate (120) stacked at one end of the stack of main plates (110);
a second end plate (130) stacked at an opposite end of the main plates (110); and
a tension tie (140; 440; 540; 640; 740) mechanically connected to the first end plate (120) and the second end plate (130) to resist a pressure exerted against at least one of the first and second end plates (120, 130), the tension tie (140; 440; 540; 640; 740) including a fluid fitting mount to receive a fluid fitting (150).

15. The plate heat exchanger of claim 14, wherein the fluid fitting mount includes a recess having an inner diameter configured to receive a fluid fitting (150) of a substantially same outer diameter, the inner diameter (145) of the recess being opposite an outer diameter (146) of the tension tie (140), the outer diameter (146) of the tension tie (140) configured to connect to an inner diameter (121) of an opening in the first end plate (120).

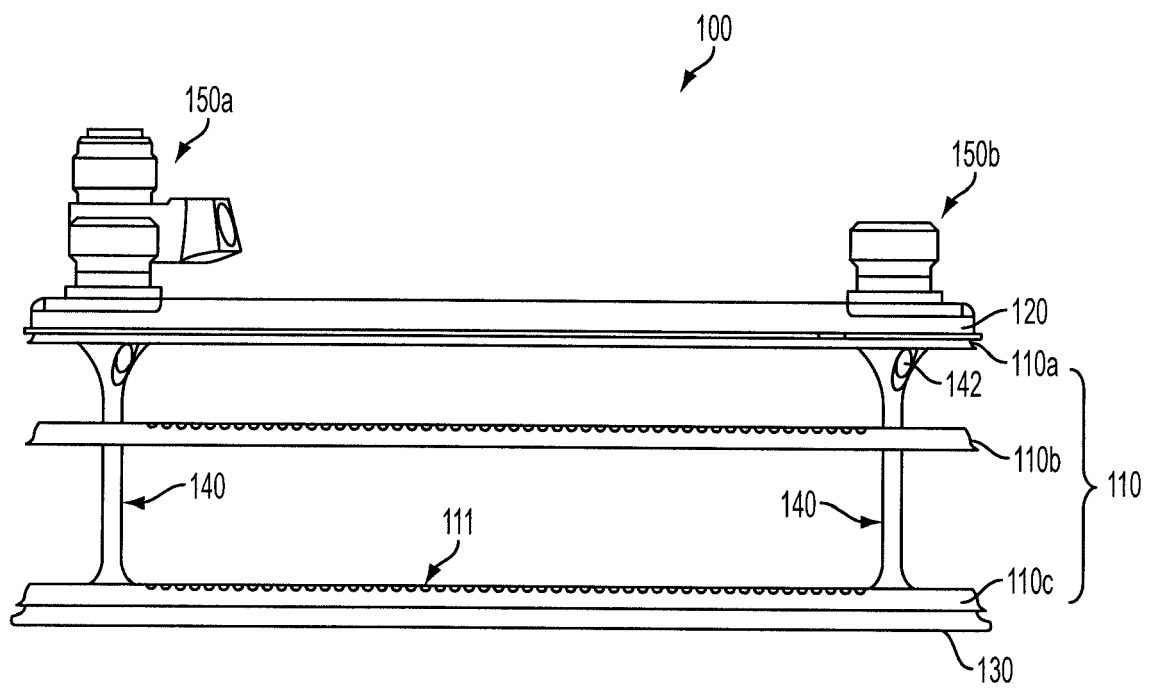


FIG. 1

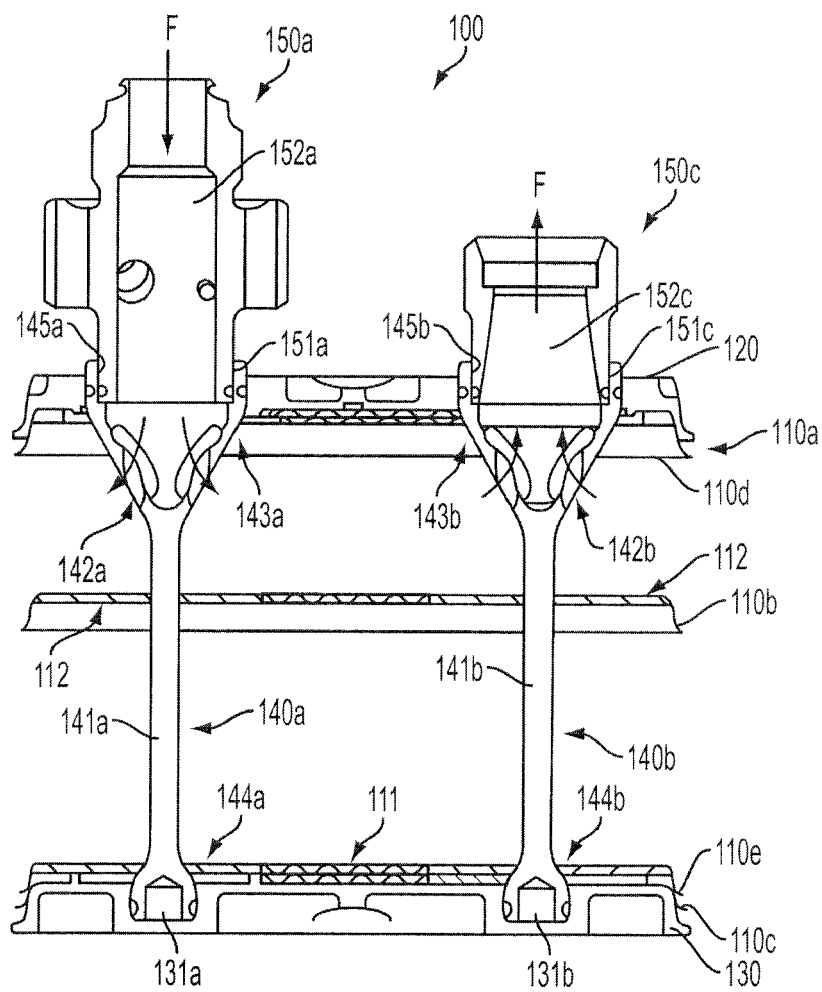


FIG. 2

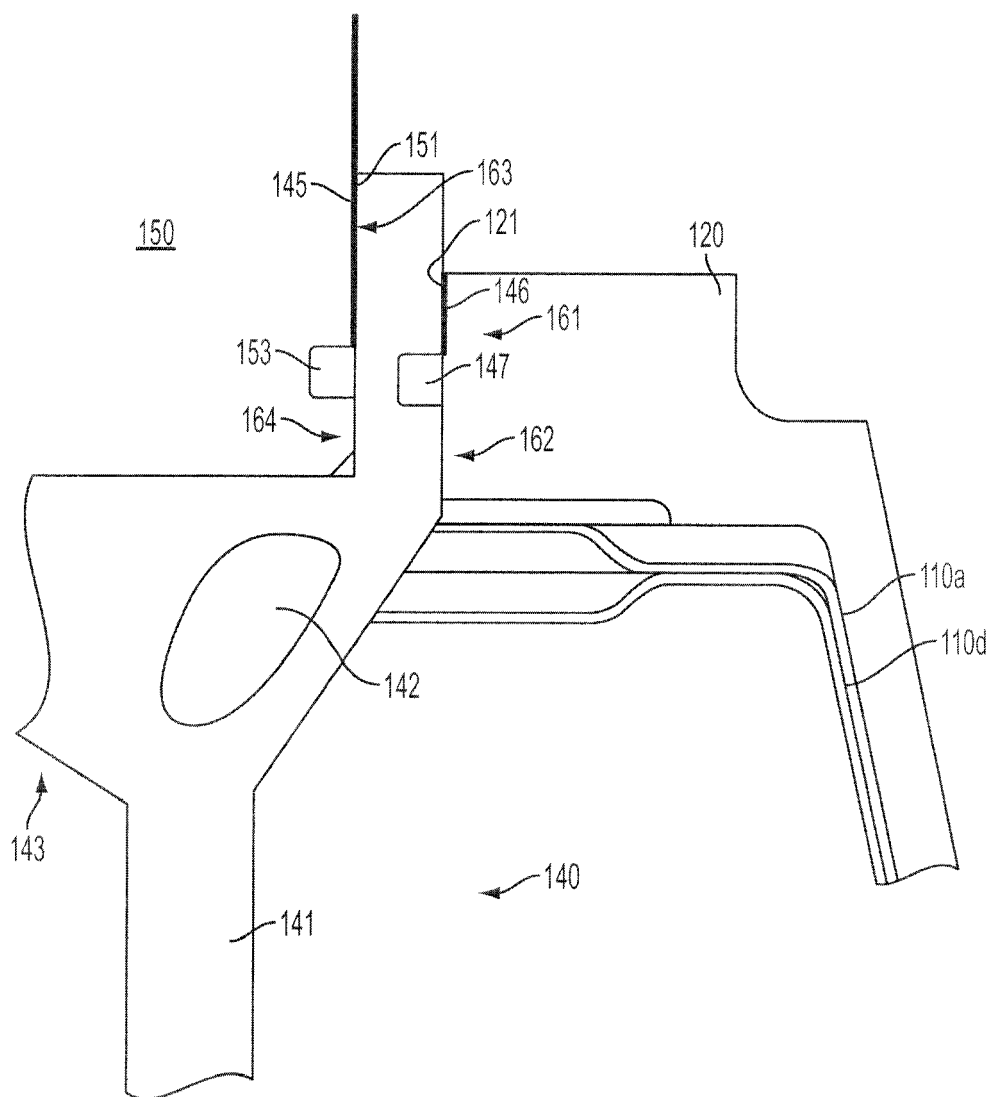


FIG. 3

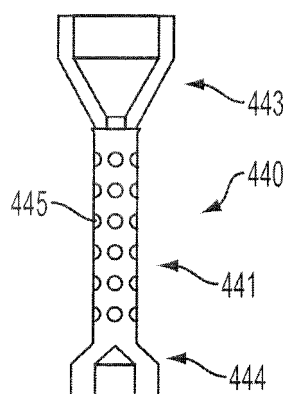


FIG. 4

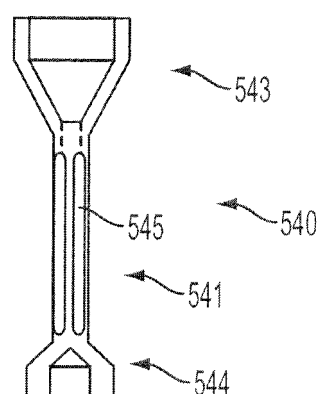


FIG. 5

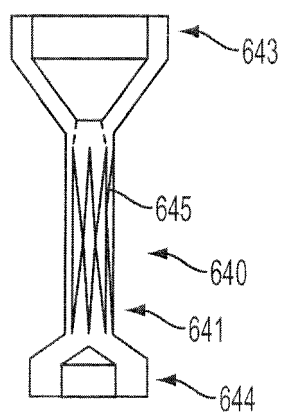


FIG. 6

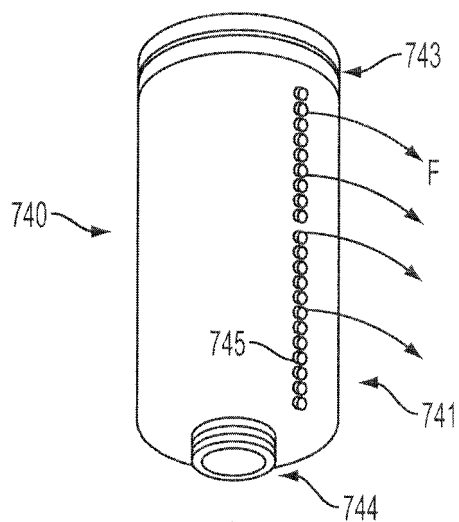


FIG. 7