



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
25.07.2007 Bulletin 2007/30

(51) Int Cl.:
F28D 9/00 (2006.01) F28F 3/00 (2006.01)
F28F 3/04 (2006.01)

(21) Application number: **06256427.3**

(22) Date of filing: **18.12.2006**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

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(30) Priority: **20.01.2006 US 336374**

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(54) **Double-wall, vented heat exchanger**

(57) A plate heat exchanger (10) includes a plurality of plate pairs (26,28) for providing a flow path for two fluids (F1,F2). The plate heat exchanger (10) has an inlet (18,22) and an outlet (20,24) for each of the two fluids (F1,F2), wherein facing surfaces of two adjacent plate pairs of the plurality of plate pairs (26,28) defines a flow path for a first fluid (F1). The opposite surface of one of the two adjacent plate pairs and a facing surface of an-

other adjacent plate pair from the plurality of plate pairs (26,28) provides a flow path for a second fluid (F2). The first fluid (F1) and the second fluid (F2) flowing along their respective flow paths are maintained in thermal communication with each other. A predetermined vent path (54) is formed in at least one of the facing surfaces of each plate pair capable of venting each fluid exterior of the heat exchanger (10).

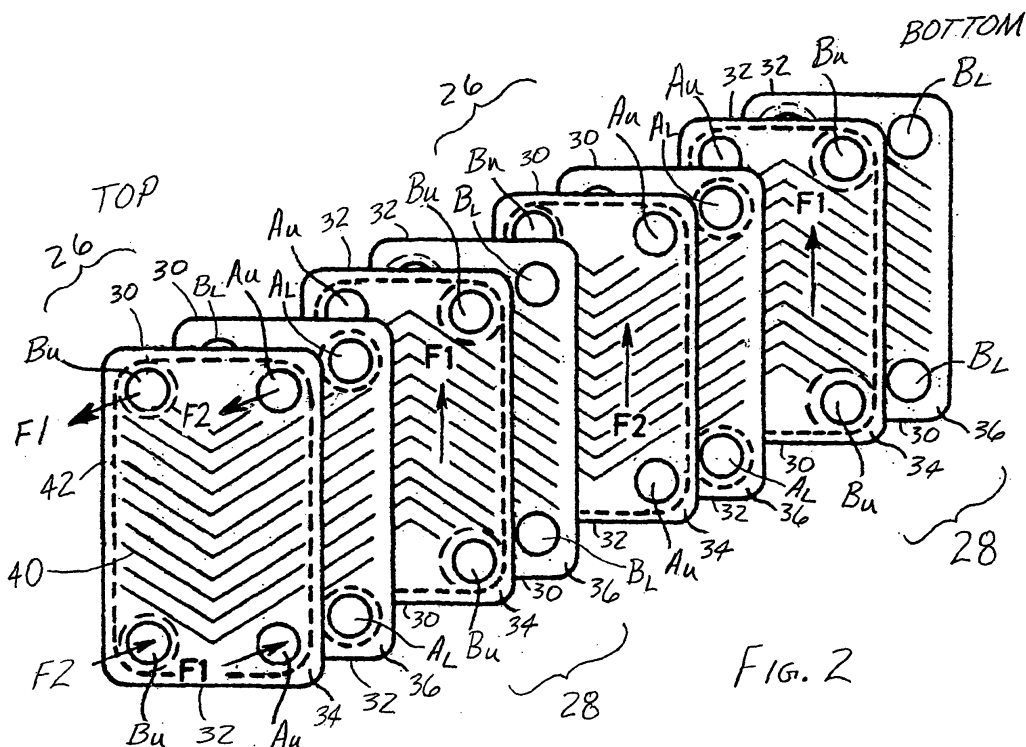


FIG. 2

Description

FIELD OF THE INVENTION

[0001] The present invention is directed to a plate heat exchanger, and more specifically to a plate heat exchanger having double-wall, vented construction for venting a fluid resulting from leakage occurring within the plate heat exchanger along a predetermined leak path to a predetermined region along the exterior of the plate heat exchanger.

BACKGROUND OF THE INVENTION

[0002] Heat exchangers are traditionally used to heat or cool potable or process critical fluids using non-potable fluids while providing a physical, mechanical boundary to prevent contact between the respective fluid streams. Heat exchangers, as with all mechanical devices, have their respective, unique finite operating timeframes at the end of which the devices fail for one or more reasons. A typical failure mode for heat exchangers is a boundary breach that either allows one or both fluids: 1) to escape to the outside environment or atmosphere (external leak) or 2) to mix with one another without escaping to the outside environment (internal leak). With heat exchangers used in potable, sanitary, or critical fluid applications, an internal leak that allows the two fluids to mix can have catastrophic results, such as illness or poisoning in the case of potable and sanitary applications, or chemical fire or explosion in the case of critical fluid process applications. Internal leaks are generally not noticed immediately, whereas external leaks are usually visually evident.

[0003] To avoid this possible situation of having an unseen (internal) leak, it is desirable to provide a fully vented, double-wall boundary that exhausts the leaking fluid to the outside environment or atmosphere in lieu of having the respective fluids mix inside the heat exchanger while the heat exchanger continues to operate. The manufacturing processes required to manufacture heat exchangers having double-wall construction are more intensive, thus double-wall heat exchangers are generally more expensive than conventional, single-wall heat exchangers. As a result, in unregulated competitive markets, many single-wall heat exchangers are used in applications that truly require fully vented, double-wall construction to provide an adequate level of safety. In an effort to increase the general public safety, various agencies and governmental bodies have implemented construction codes that require the use of a "double-wall" heat exchanger or "double-wall, vented" heat exchanger for potable fluid applications.

[0004] For example, UNDERWRITERS LABORATORIES INC. ® or UL®, both registered trademarks of Underwriters Laboratories, Inc. of Chicago, Illinois, has established certification requirements to include double-wall vented construction for all refrigerant to potable wa-

ter heat exchangers. Examples include water coolers/fountains and refrigerant desuperheaters. Also, IAPMO®, a registered trademark of the International Association of Plumbing and Mechanical Officials of Ontario, Canada has established plumbing code certification requirements to include double-wall heat exchangers for potable water heating, or at minimum, double separation or two heat exchangers. Examples of double separation heat exchangers include domestic hydronic or steam boilers used to heat domestic hot water. In addition, various U.S. states and municipalities and other countries require double-wall or double separation of the respective fluids when used in potable water applications.

[0005] A double-wall heat exchanger is one in which the heat transfer surface separating the two fluids is comprised of two separate surface layers, rather than one. Thus, if the first surface layer fails to provide a fluid tight barrier, the second layer should remain intact, causing an amount of fluid that is in contact with the failed surface layer to flow between the surface layers, preferably to a location where the leaking fluid can be detected externally of the heat exchanger so that the heat exchanger can be removed from service. The double-wall construction is intended to be a safety feature to prevent cross-contamination of the fluids.

[0006] A further definition of this leak detection process is a "leak path" between the two surface layers. This leak path is either due to an inherent spacing between the metal-to-metal surfaces of the two layers, or an intentionally formed spacing between the two layers, or sufficient porosity between the two layers. In any event, the fluid from the failed surface layer will follow the "leak path" to an external location for detection of the leaking fluid.

[0007] The first commercially available double-wall heat exchangers to incorporate these operational features were tubular designs. For example, U.S. Patent No. 4,210,199 issued to Doucette et al. is directed to double-wall tubes utilizing two tubes, one tube disposed inside the other tube. The diameter of the outer tube is intermittently reduced, or swaged upon the inner tube, thereby creating the double-wall construction, the contact between the walls being provided for heat transfer and a vent path between the fluids. Other similar tubular designs have also been used. These methods yield a product that has a relatively accurately controlled vent-path and contact area dimensions.

[0008] When the above-mentioned double-wall tube is inserted into a heat exchanger, a "double tube sheet" method is used, in which an outer tube and an inner tube is each inserted through adjacent tube sheets. A tube sheet is a typical component of tubular heat exchangers through which the tubes are inserted and subsequently sealed by means of mechanical rolling, hydraulic expansion, or welding/brazing. This method provides a double seal between the inner and outer tubes and a leak path for the tube joints, resulting in a fully-vented double-wall heat exchanger. These tubular designs suffer from at least two main drawbacks: 1) high fabrication cost, and

2) large physical size relative to conventional, single-wall designs.

[0009] Double-wall plate-type heat exchangers are a later development. The double-wall plate-type heat exchanger is fabricated by simultaneously forming two thin-wall strips of material in the same tool, such that both strips are formed together, substantially identically, resulting in a pair of heat exchanger plates that serve as a double layer. The double-layer plate pairs or sets are then stacked to form fluid flow passages between the plate pairs and are separated from each other plate pair via elastomer gaskets disposed along the periphery of the plate pairs. The entire assembly is then compressed and held together via long, threaded bolts that are positioned along the heat exchanger periphery.

[0010] A primary limitation of this construction is that the contact area between the two formed plates and the flow area in the vent path (i.e., leak path) are difficult to control because the tensile properties of the plates of the respective plate pairs cause a "spring back" effect that occurs after the forming process. This spring back effect prevents the strips from completely nesting together, or forming a substantially conformal contact therebetween. The vent path flow area can be extremely small when the vent path is adjacent to locations that have contact between the substantially conformal adjacent plates, such that elevated levels of fluid pressure can be required to force a flow of a leaking fluid through the vent path flow area. These locations of conformal surface contact between the adjacent plates typically have a relatively high heat transfer coefficient. Other locations between the adjacent plates that are not in conformal surface contact typically have a lower heat transfer coefficient because of the additional thermal resistance caused by the spacing between the plate surfaces. The leak path flow area adjacent to these locations are typically relatively large and thereby offer a relatively lower flow resistance for the leaking fluid. If the designed vent path gap is increased to minimize the amount of fluid pressure necessary to force fluid flow between the plates, then the coefficient of heat transfer for the double-wall plate is significantly decreased. This decrease in heat transfer coefficient is due to the increased thermal resistance associated with the increased spacing between the plates, the relationship between decreased heat transfer coefficient and increased spacing between the plates being a substantially linear relationship. The reduction of fluid leakage pressure versus the reduced heat transfer coefficient resulting from increased plate spacing is a primary dilemma of plate heat exchangers in double-wall applications.

[0011] An additionally important consideration in the design of double-wall plate heat exchangers involves the regions surrounding the port areas where the two fluids are separated by a port seal. To fully meet the intent of the aforementioned building codes requiring double-wall construction, the port areas must be fully-vented to the outside environment via a double-port-seal system. In

gasketed-type plate heat exchangers, various gasketing methods are used to create double port seal structures that allow a leak to be revealed externally to the heat exchanger if the first port seal fails. U.S. Patent No. 4,976,313 issued to Dahlgren provides an example of this technology. However, gasketed-type plate heat exchanger designs suffer from three primary drawbacks: 1) high fabrication cost, 2) gasket life that is shorter than that of all-metal construction types, and 3) lower pressure-bearing capabilities than the tubular-type exchangers.

[0012] Brazed-plate heat exchangers are the latest entry into the double-wall heat exchanger market. Brazed-plate type heat exchangers are similar in construction to the gasketed-type plate heat exchangers in that they are constructed using plates fabricated by simultaneously forming two thin-wall strips of material in the same tool, such that both are formed together, substantially identically, as a double layer. These double-plate pairs or sets are then stacked to form the fluid passages. However, instead of utilizing gaskets and long bolted fasteners to provide the sealing mechanism, brazed-plate heat exchangers utilize thin sheets of braze material such that the plate pairs braze together in a brazing furnace or other heating device. U.S. Patent No. 5,291,945 issued to Blomgren et al. is directed to a double-wall brazed plate heat exchanger.

[0013] A critically important manufacturing concern in the manufacture of double-wall, brazed-plate heat exchangers is in preventing the braze material from flowing into the vent path between adjacent plates via capillary action and thereby blocking the flow path for the leaking fluid to escape the heat exchanger. The aforementioned U.S. Patent No. 5,291,945 addresses this problem at the periphery of the plate pairs only. The solution offered by the heat exchanger construction of this patent is to provide a sufficiently large spacing between the peripheral edges of the double plate pairs such that both capillary and gravity forces prevent the braze metal from wicking to the small interspace gaps between the respective double plate sets, with the heat exchanger plates being brazed in a particular orientation to take advantage of the gravity forces.

[0014] Another drawback of the heat exchanger construction of U.S. Patent No. 5,291,945 is its lack of pressure-bearing capability. This lack of pressure-bearing capability is a result of the peripheries of the respective double plate pairs not being brazed, such that the only use of braze material to hold the plate pairs together is limited to the port areas. To increase the pressure-bearing capability of the unit such that it can withstand the requirements of relatively low-pressure systems, a mechanical reinforcement system consisting of a threaded rod, two washers, and two nuts is added to each port structure.

[0015] In summary, U.S. Patent No. 5,291,945 design has several drawbacks including:

- i) port holes not having vented, double-seals needed to meet building code requirements;
- ii) port areas requiring structural re-enforcement;
- iii) braze material foil not being stamped at the same time as the plates;
- iv) lacking provisions to prevent or encourage braze material wicking into the vent path;
- v) lacking a predetermined location for the external leak to occur; and
- vi) low design working pressure.

[0016] Others, such as SWEP International AB, of Sweden and WTT (Wilchwitz Thermo-Technik) of Germany, also manufacture double-wall, vented brazed-plate heat exchangers. They each separate the double-plate pairs after the forming process and apply to a portion of the periphery of the plate surfaces a coating, such as an oxide, that repels the capillary flow of the braze material, and then rebuild the double-plate pairs prior to assembling the heat exchanger for brazing. This step prevents the entire periphery of the plates from being filled with braze material, which would completely close the leak path from venting to the environment, and provides an amount of structural reinforcement to the heat exchanger.

[0017] However, all of the known double-wall brazed-plate heat exchanger constructions have a common drawback in that no construction has provided a double seal around the ports or a separate vent path around the ports. An inherent assumption behind all known constructions of brazed-plate heat exchangers is that if a port joint fails (e.g., braze material etches away) the vent area opens up and allows the leak to be vented between the plates. This assumed venting of a leak in the port area cannot be guaranteed, and thus presents a major obstacle in meeting the intent of the building and plumbing codes and requirements that require double-wall separation.

[0018] In summary, brazed-plate heat exchangers have the inadequacies of: a high vent path pressure drop, no specific vent path for plate leaks to vent to the external environment, and no double seal and vent path around the ports. Further, since the vent path is not sufficiently channeled, leak detection can be elusive. Coupled with the state of the art construction methods, low heat transfer efficiency is a problem, as well as low working pressure containment, due to the design. Thus, brazed-plate heat exchangers, when constructed in double-wall configurations, need specific features and attributes to meet safety requirements and a significant improvement over the state of the art.

SUMMARY OF THE INVENTION

[0019] The present invention relates to a plate heat exchanger including a plurality of nested pairs of plates, each plate of the plurality of pairs of plates having opposed surfaces and perimeter flanges and having sub-

stantially similar surface profiles. Each plate pair forms a substantially conformal fit between contacting surfaces when pressed together, opposed surfaces of each plate pair providing a portion of at least one flow path for each of at least two fluids. Facing surfaces and perimeter flanges of adjacent plate pairs of the plurality of plate pairs provide a flow path boundary for two fluids of the at least two fluids. Opposed surfaces of at least one plate pair of each pair of adjacent plate pairs provides a flow path boundary for two fluids of the at least two fluids. The at least one plate pair has a high thermal conductivity and provides a portion of the flow path boundary for two fluids of the at least two fluids, thereby providing thermal communication between the two fluids on the opposed surfaces of the plate. An inlet and outlet for each fluid of the at least two fluids is provided, the inlet and outlet for each fluid being in fluid communication with each flow path for said fluid. A predetermined vent path is formed in at least one of the facing surfaces of each plate pair capable of venting each fluid exterior of the perimeter flanges.

[0020] The present invention further relates to a method for making plates for a plate heat exchanger, the steps include providing a plurality of nested pairs of plates, each plate of the plurality of pairs of plates having opposed surfaces and perimeter flanges and having substantially similar surface profiles. Each plate pair forms a substantially conformal fit between contacting surfaces when pressed together, opposed surfaces of each plate pair providing a portion of at least one flow path for each of at least two fluids. Facing surfaces and perimeter flanges of adjacent plate pairs of the plurality of plate pairs provide a flow path boundary for two fluids of the at least two fluids. Opposed surfaces of at least one plate pair of each pair of adjacent plate pairs provide a flow path boundary for two fluids of the at least two fluids, the at least one plate pair having a high thermal conductivity and providing a portion of the flow path boundary for two fluids of the at least two fluids, thereby providing thermal communication between the two fluids on the opposed surfaces of the plate. Each plate of plurality of plates includes the step of forming a plurality of apertures in the plate, at least two of the apertures having an embossed region surrounding the apertures, each embossed region defining a path for venting fluids of the at least two fluids leaking between nested plate pairs along aligned apertures of the plurality of apertures. The method further includes the step of forming at least one primary vent path in the plate, the at least one primary vent path in fluid communication with the at least two embossed regions for venting the at least two fluids exterior of the perimeter flanges. The method further includes the step of selectively applying a surface treatment to at least one surface and perimeter flanges of at least one plate, the at least one surface corresponding to a contacting surface of a plate pair.

[0021] The present invention still further relates to a plurality of nested pairs of plates, each plate of the plurality of pairs of plates having opposed surfaces and pe-

rimeter flanges and having substantially similar surface profiles. Each plate pair forms a substantially conformal fit between contacting surfaces when pressed together, opposed surfaces of each plate pair providing a portion of at least one flow path for each of at least two fluids. Facing surfaces and perimeter flanges of adjacent plate pairs of the plurality of plate pairs provide a flow path boundary for two fluids of the at least two fluids. Opposed surfaces of at least one plate pair of each pair of adjacent plate pairs provide a flow path boundary for two fluids of the at least two fluids. The at least one plate pair has a high thermal conductivity and provides a portion of the flow path boundary for two fluids of the at least two fluids, thereby providing thermal communication between the two fluids on the opposed surfaces of the plate. An inlet and outlet for each fluid of the at least two fluids is provided, the inlet and outlet for each fluid being in fluid communication with each flow path for said fluid. A predetermined vent path is formed in at least one of the facing surfaces of each plate pair capable of venting each fluid exterior of the perimeter flanges.

[0022] An advantage of the present invention is a predetermined flow path between each plate pair for permitting the flow of leaking fluid to the outside environment.

[0023] A further advantage of the present invention is that the flow of leaking fluid to the outside environment occurs at a predetermined location or locations.

[0024] A further advantage of the present invention is that a vent path is formed around each port to ensure a fluid leakage around the port seal flows to the outside environment.

[0025] An advantage of the present invention is that there is a double seal around each port.

[0026] A still further advantage of the present invention is that the vent path does not coincide with nodal connections between contacting surfaces of adjacent plate pairs.

[0027] A yet further advantage of the present invention is that the vent path can be configured to reduce the level of fluid pressure required for a leaking fluid to flow to the outside environment within a predetermined time duration.

[0028] A further advantage of the present invention is that it can truly meet the intent of double-wall building codes.

[0029] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Fig. 1 is a perspective view of a plate heat exchanger of the present invention;

[0031] Fig. 2 is a schematic exploded plan view of a plate arrangement of a plate heat exchanger of the present invention;

[0032] Fig. 3 is a plan view of one plate of a plate pair of the plate heat exchanger of the present invention;

[0033] Fig. 4 is a plan view of the other plate of the plate pair of the plate heat exchanger of the present invention;

[0034] Fig. 5 is a cross-section of a portion of a port of two adjacent, nested plate pairs of the plate heat exchanger of the present invention;

[0035] Fig. 6 is a plan view of a plate subjected to a surface treatment of the plate heat exchanger of the present invention;

[0036] Fig. 7 is a perspective view of secondary embossments formed in the plates of the plate heat exchanger of the present invention; and

[0037] Fig. 8 is a plan view of stacked plate pairs of the plate heat exchanger of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0038] The present invention is directed to a double-wall plate heat exchanger 10 depicted in Figs. 1-8. Such a heat exchanger is similar in principle of operation to a single-wall heat exchanger construction set forth in U.S. Patent No. 5,462,113 issued on October 31, 1995 and U.S. Patent Application No. 10/643,689 titled PLATE HEAT EXCHANGER WITH ENHANCED SURFACE FEATURES, filed on August 19, 2003, both incorporated herein by reference in their entirety. The heat exchanger 10 includes a plurality of formed plates 12 comprising a high thermal conductively material such as copper disposed between a top plate 14 and a bottom plate 16 providing separated flow passages for a first fluid F1 and a second fluid F2 while simultaneously providing thermal communication between the first fluid F1 and the second fluid F2. To assist with orienting the plates 12 of heat exchanger 10, Figures 1 and 2 include labeling of TOP and BOTTOM, Figure 2 lacking the top and bottom plates 14, 16. It is to be understood that the heat exchanger may be placed in a variety of physical orientations, including vertical, horizontal and any position therebetween. While atypical, the first and second fluids F1, F2 may have the same composition. Typically, a diametrically opposed inlet port 18 and an outlet port 20 are formed in the top plate 14 permitting the first fluid F1 to access the plates 12, and similarly, a diametrically opposed inlet port 22 and an outlet port 24 are formed in the top plate 14 permitting the second fluid F2 to also access the plates 12. Alternately, it may be advantageous to reverse the orientation of one of the pair of inlet/outlet ports so that the first pair and second pair of fluid inlets/outlets are located on opposite ends of the heat exchanger 10.

[0039] Referring to Figures 1 and 2, the formed plates 12 include alternately arranged plate pairs 26, 28. Each plate pair 26, 28 includes similarly arranged plates 34, 36 that are nested together, each plate 34, 36 having opposed ends 30, 32. That is, the heat transfer surfaces of plates 34, 36 are substantially similar, so that when

plates 34, 36 are pressed together, the surfaces nest together to form a substantially conformal contact therebetween, which provides a high heat transfer coefficient through the combined thickness of the plates. Typically, the only difference between the plate pair 26 and the plate pair 28 is that the ends 30, 32 are reversed, or stated alternatively, that plate pair 26 is rotated 180 degrees about an axis 38 (see Figure 1), which is perpendicular to the surface of top plate 14. Each plate 34 includes a plurality of apertures A_U , B_U , which align with respective inlet/outlet ports when the plates 34 are installed in the heat exchanger 10. Similarly, each plate 36 includes a plurality of apertures A_L , B_L , which align with respective inlet/outlet ports when the plates 36 are installed in the heat exchanger 10. Depicted in an arrangement that includes inlet/outlet ports 18, 20, 22, 24, it being understood that additional inlet/outlet ports can be included, such as when three or more heat exchange fluids are utilized. Formed in the surface of plate 34, 36 are a plurality of V-ridges 40, also referred to as corrugations, typically arranged in a herringbone configuration to provide a tortuous flow passage of changing direction and cross-section when arranged in adjacent plate pairs 26, 28 as discussed in above-mentioned U.S. Patent No. 5,462,113 and U.S. Patent Application No. 10/643,689 to effect thermal communication between fluids F1, F2. The plates 34, 36 extend outwardly to a flange 42 formed at the plate-edges, which defines the periphery of the plates 34, 36. The flanges 42 of the stacked plates 34, 36 physically touch one another and form a barrier to fluid flow to form heat exchanger 10.

[0040] The plate heat exchanger 10 of the present invention is preferably of a brazed construction, although in one embodiment, only the ports and not the entire heat exchanger surfaces require an operation or special rings to provide a fluid tight seal along the ports. Although not shown in Figure 2, preferably, at least one foil plate comprised of a brazeable material is inserted between adjacent plate pairs 26, 28. Once the foil plates are inserted and the plates sufficiently pressed together, the heat exchanger 10 is heated to a predetermined temperature below the melting point of plates 34, 36, but above the melting point of the inserted foil plates for sufficient duration to melt the foil plates. Due to capillary action, the molten metal, preferably copper, is drawn to regions between adjacent plate pairs 26, 28 that are in contact with each other, such as the nodes 44 (see Figure 8), which are the intersections of the apexes of the oppositely oriented V-ridges 40 of the plate pairs 26, 28, and the peripheral flanges 42. The foil plates, typically comprised of copper, form metallic bonds along these regions or nodes which are fluid tight (i.e., along the peripheral flanges), and provide greatly increased structural support, normally expressed in terms of burst pressure, which can approach 3,000 psi and sufficient to withstand pressures from the fluids F1, F2 and meet safety code requirements.

[0041] However, during the brazing process, not only will the molten braze material flow between the contact

surfaces of adjacent plate pairs 26, 28, but other contacting surfaces as well. In other words, surfaces in conformal contact between plates 34, 36 of plate pairs 26, 28, including the peripheral flanges 42, can also be brazed together, unless a surface treatment is applied to at least one plate surface. For example, referring to Figure 6, for plate 34, 36, the entire heat transfer surface 46 is typically treated except for regions 52 surrounding the port apertures (A_U , B_U , A_L , B_L), as well as region(s) 48 along peripheral flange 42. By not brazing the contacting heat transfer surface 46, in case of a breach in one of the plates of plate pairs 26, 28, fluid can flow through the breach and between the conformal contact surfaces to a vent path 54 (Figure 3) that permits the flow of the leaking fluid to the outside environment as an alert to replace the heat exchanger. The port regions 52 (Figure 6) are masked to prevent the application of surface treatment material around the port apertures (A_U , B_U , A_L , B_L) because it is desirable that a double seal is formed along the peripheries of the port apertures.

[0042] It is noteworthy that except for region(s) 48, the surface treatment is not applied to flange 42, which permits a brazed joint to be formed on the vast majority of the contacting flange 42 surface. The reason for masking region(s) 48 is not only to provide a leak path along the flange 42 to ensure leaking fluid can escape to the outside environment, but to provide a focused leak path by blocking all other access along the peripheral flange. Preferably, a focused inspection area, such as an embossed area 50 is formed within the non-treated region 50 to pinpoint to an outside observer the expected location of any external fluid leakage. As shown in Figure 6, a pair of opposed regions and corresponding embossed regions 50 are provided on opposite portions of the flanges 42. The embossed regions 50 are also shown in an assembled heat exchanger 10 in Figure 7. Alternately, instead of embossing the regions 50, other indicia to indicate the location of fluid leakage that does not mar the flange surface 42, such as marking, can also be employed. Failing to provide such a focused leak path makes leak detection more difficult, since fluid leakage could otherwise occur along any portion or portions along the periphery of flange 42, or spread out the possible leakage region over an extended area of the flange.

[0043] The novel predetermined vent path of the present invention will now be discussed. For ease of understanding, Figures 3 and 4 together represent the plate pair 28 with plate 34 (Figure 3) stacked on top of plate 36 (Figure 4) when end 32 is oriented as an upper end as shown in Figure 2. However, when end 30 is oriented as an upper end as shown in Figure 2, Figures 3 and 4 represent the other plate pair 26 with plate 34 (Figure 3) stacked on top of plate 36 (Figure 4). As further shown in Figure 3, a vent path 54 is formed in plate 34 and preferably runs in a straight line from end 30 to end 32 to provide a predetermined path for fluid leaking between the conformal contact surfaces of plates 34, 36 to flow toward the outside environment. It is to be understood

that a vent path 54 could be alternately or additionally be formed in plate 36 or that multiple vent paths 54 could be formed in each plate 34, 36. However, each vent path 54 provides a narrow region having a reduced coefficient of heat transfer through the plate pair thickness, so that a single vent path may be preferable. It is also possible that the vent path 54 does not continue in a straight path from end 30 to end 32, nor is it necessary that the vent path even provide a contiguous path from end 30 to end 32 as one or more "branches" extending to one or more of the opposed ends of the plates 34, 36 that are transverse to ends 30, 32. Those skilled in the art can appreciate that increasing the number of vent paths 54 may decrease the amount of fluid pressure required to flow the leaking fluid and the length between the nearest vent path from possible leak locations, but increases the amount of area having a reduced heat transfer coefficient, so that an optimum arrangement can be achieved. The only limitation to the possible routing of the vent path 54 is that the vent path not intersect with any of the nodes 44 (Figure 8). The profile of vent path 54 defined by a cross section that is perpendicular to the vent path can resemble an angled rooftop, curved or any other closed geometric profile so long as leaking fluid can flow along the vent path 54 with sufficiently reduced resistance as compared to other regions of the conformal contact surfaces between the plate pair 26, 28 to flow toward and ultimately past the peripheral flanges 42 to the outside environment.

[0044] It is to be understood that in addition to the profile(s) and path(s) of vent path 54, the sizing of the vent path can also be another factor to consider. For example, some safety regulations; such those promulgated by UNDERWRITERS LABORATORIES INC. ® or UL®, both registered trademarks of Underwriters Laboratories, Inc. of Chicago, Illinois, or IAPMO®, a registered trademark of the International Association of Plumbing and Mechanical Officials of Ontario, Canada, specify that a leak must be visually evident within a predetermined time duration, such as 30 minutes, while operating the heat exchanger at a predetermined fluid pressure, such as 12 psi. Combinations of size, vent path routing and vent path profiles can be provided to permit these regulations to be met. That is, these parameters can also be configured with respect to each other so that higher fluid pressures are required so that heat transfer efficiency can be improved for example, resulting in alternate constructions in which fluid pressures up to about 400 psi or more to about 1 psi, including increments of 1 psi levels within this range.

[0045] It is to be understood that in the case multiple vent paths 54 are formed in the plates 34, 36, corresponding regions 48 for surface treatment and embossed regions 50 or other visually evident indicia can also be added to the plate flanges 42.

[0046] In addition to providing a predetermined vent path 54, the heat exchanger 10 of the present invention includes fluid ports having a double seal that provide enhanced protection against inadvertent mixing of fluids F1,

F2. Moreover, a vent path surrounds each fluid port aperture to vent fluid leaking along any portion of any port that breaches the double seal in the heat exchanger to the outside environment. The term port is intended to refer to the aligned openings of the assembled plates, while the term aperture is intended to refer to the openings in an individual plate, although the terms openings, apertures and ports may be used interchangeably. For ease of understanding and for orienting the plates, Figures 3 and 4 together represent the plate pair 28 with plate 34 (Figure 3) stacked on top of plate 36 (Figure 4) when end 32 is oriented as an upper end as shown in Figure 2. However, when end 30 is oriented as an upper end as shown in Figure 2, Figures 3 and 4 represent the plate pair 26 with plate 34 (Figure 3) stacked on top of plate 36 (Figure 4).

[0047] Preferably, there are two substantially identical pairs of apertures A_U , B_U formed in plate 34. Preferably, there are two substantially identical pairs of apertures A_L , B_L formed in plate 36. The subscript "U" indicates that the associated apertures (A_U , B_U) correspond to apertures formed in the upper plate in the plate pair 26, 28. Similarly, the subscript "L" indicates that the associated apertures (A_L , B_L) correspond to the lower plate in the plate pair 26, 28. Preferably, aperture A_U has the largest diameter of the apertures A_U , B_U , A_L , B_L and does not contain a peripheral embossment, while aperture B_U preferably has the smallest diameter of the apertures, but includes a peripheral embossment region 56. Preferably, aperture A_L has a diameter that is greater than the diameter of aperture B_U but less than the diameter of aperture B_L , and additionally includes a peripheral embossment region 58. Aperture B_L has a diameter that is greater than the diameter of A_L but less than the diameter of A_U and does not include a peripheral embossment. In other words, in a preferable construction, the diameters are sized accordingly: $A_U > B_L > A_L > B_U$.

[0048] In keeping with the above convention, plate pair 28 is formed when, for example, aperture B_U of plate 34 is stacked on top of and nested with aperture B_L , which stack-up is expressed as $B_U - B_L$. Similarly, when plate pair 28 is stacked upon nested plate pair 26, the stacking arrangement from the top plate of plate pair 28 to the bottom plate of plate pair 26 as shown in Figure 5, which is taken along line 5-5 from Figure 8 and is expressed as $B_U - B_L - A_U - A_L$. After assembly and the brazing operation is completed, Figure 5 shows a partial cross section of a fluid port of an adjacent set of plate pairs 26, 28 as evidenced by a port centerline 66. A sealed region 60 provides a double seal to prevent a fluid flowing through a port from flowing between any of the plates of adjacent plate pairs 26, 28. The first or primary port seal is formed between plate 34 of plate pair 28 and plate 36 of plate pair 26. However, assuming sufficient braze material is etched away so that the fluid can pass between plate 34 of plate pair 28 and plate 36 of plate pair 26, the secondary seal is actually two separate seals. The first of the two secondary seals is disposed between plate 34

and plate 36 of the plate pair 28, which prevents fluid from flowing into a peripheral vent path 62 formed from embossed region 56 of plate 34. The second of the two secondary seals is disposed between plate 36 of plate pair 28 and plate 36 of plate pair 26, which prevents fluid from flowing into a peripheral vent path 64 formed from embossed region 58 of plate 36.

[0049] It is to be understood that while molten braze material flows into and forms the double seal for the ports, braze material does not flow into the vent paths 62, 64 because the embossed regions 56, 58 are configured so that there are insufficient capillary forces at the junctions within region 60 between embossed regions 56, 58 that contact opposite sides of adjacent plate 36 of plate pair 28. It is noteworthy that the diameter A_U is sufficiently large so that plate 34 of plate pair 26 does not extend into the junction between embossed region 58 and plate 36 of plate pair 28, which increases the angular spacing between the embossed region 58 and plate 36 of plate pair 28 and provides for a more efficient secondary port seal.

[0050] However, in the case that both primary and secondary seals surrounding a port are breached or etched away, vent paths 62, 64 ensure that the leaking fluid has a predetermined path to flow to the outside environment. Referring back to Figures 3-5, a leaking fluid that reaches vent path 62 then flows through a vent path 68 formed in plate 34 that bridges vent path 62 and vent path 54. Similarly, a leaking fluid that reaches vent path 64 then flows through a vent path 70 formed in plate 36 that bridges vent path 64 and vent path 54. As previously discussed, vent paths 68, 70 can extend outwardly from the respective vent path 62, 64 in any direction, and include more than one path and be formed in either or both conformal surfaces of plates 34, 36, so long as the vent paths do not coincide with nodes 44 nodal connections.

[0051] It is to be understood that the surface treatment which prevents the formation of brazed joints can exhibit favorable thermal conductance properties such that the overall thermal conductance through the double-wall plate pairs 26, 28 is measurably enhanced. For example, a surface treatment using a special formulation of oxides can produce a thermal conductance that is approximately 250 times higher than of air and approximately one half of the thermal conductance of an example plate material, stainless steel. Testing has revealed that this surface treatment material reduced the spacing between contacting heat transfer surfaces of plate pairs, which spacing being primarily due to spring back of the plates, thereby enhancing the overall thermal conductance through the plate pairs.

[0052] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the in-

vention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A plate heat exchanger comprising:

a plurality of nested pairs of plates, each plate of the plurality of pairs of plates having opposed surfaces and perimeter flanges and having substantially similar surface profiles, each plate pair forming a substantially conformal fit between contacting surfaces when pressed together, opposed surfaces of each plate pair providing a portion of at least one flow path for each of at least two fluids, wherein facing surfaces and perimeter flanges of adjacent plate pairs of the plurality of plate pairs provide a flow path boundary for two fluids of the at least two fluids, and wherein opposed surfaces of at least one plate pair of each pair of adjacent plate pairs provide a flow path boundary for two fluids of the at least two fluids, the at least one plate pair having a high thermal conductivity and providing a portion of the flow path boundary for two fluids of the at least two fluids, thereby providing thermal communication between the two fluids on the opposed surfaces of the plate;
an inlet and outlet for each fluid of the at least two fluids, the inlet and outlet for each fluid being in fluid communication with each flow path for said fluid; and
wherein a predetermined vent path is formed in at least one of the facing surfaces of each plate pair capable of venting each fluid exterior of the perimeter flanges.

2. The plate heat exchanger of claim 1 wherein an internal leakage of fluid between adjacent plate pairs or between adjacent plates of adjacent plate pairs flows along a vent path and is visually evident exterior of the perimeter flanges when the heat exchanger is pressurized to less than about 400 psi for a predetermined time duration.

3. The plate heat exchanger of claim 2 wherein the heat exchanger is pressurized to less than about 50 psi.

4. The plate heat exchanger of claim 3 wherein the heat exchanger is pressurized to about 1 psi.

5. The plate heat exchanger of claim 1 wherein at least a portion of one of the contacting surfaces of each

plate pair includes a surface treatment.

6. The plate heat exchanger of claim 1 wherein the vent path does not coincide with nodal points of contact between opposed surfaces of adjacent plate pairs.
7. The plate heat exchanger of claim 6 wherein the vent path extends in a substantially linear path toward a perimeter flange.
8. The plate heat exchanger of claim 6 wherein the linear path extends in a curved path toward a perimeter flange.
9. The plate heat exchanger of claim 6 wherein the vent path includes a plurality of paths toward a perimeter flange.
10. The plate heat exchanger of claim 1 wherein each adjacent pair of plate pairs includes a plurality of ports for providing a flow channel for at least one fluid through the adjacent pair of plate pairs, each port of the plurality of ports having a double seal.
11. The plate heat exchanger of claim 10 wherein each port has at least two surrounding embossed regions formed in the outermost opposed plates of the adjacent plate pair in fluid communication with the vent path.
12. The plate heat exchanger of claim 1 wherein the plate heat exchanger is of brazed construction comprising the insertion of at least one foil plate between the adjacent plate pairs of the plurality of plate pairs, the at least one foil plate becoming molten and flowing between adjacent plates of the plurality of plates to form brazed nodal contacts between facing surfaces of the adjacent plate pairs of the plurality of plate pairs when the plate heat exchanger is heated to a predetermined temperature below the melting point of the adjacent plate pairs of the plurality of plates, but above the melting temperature of the at least one foil plate.
13. The plate heat exchanger of claim 12 wherein predetermined regions of plate surfaces are selectively treated to prevent brazed contacts in the predetermined regions.
14. The plate heat exchanger of claim 13 wherein at least one portion of at least one surface of at least one perimeter flange of the contacting surfaces between the plate pairs are selectively treated to prevent the formation of brazed contacts.
15. The plate heat exchanger of claim 14 wherein a focused inspection area substantially coincides with the at least one treated portion.

16. The plate heat exchanger of claim 15 wherein the focused inspection area is an embossed region formed in the at least one perimeter flange.

- 5 17. A method making plates for a plate heat exchanger, the steps comprising:

providing a plurality of nested pairs of plates, each plate of the plurality of pairs of plates having opposed surfaces and perimeter flanges and having substantially similar surface profiles, each plate pair forming a substantially conformal fit between contacting surfaces when pressed together, opposed surfaces of each plate pair providing a portion of at least one flow path for each of at least two fluids, wherein facing surfaces and perimeter flanges of adjacent plate pairs of the plurality of plate pairs provide a flow path boundary for two fluids of the at least two fluids, and wherein opposed surfaces of at least one plate pair of each pair of adjacent plate pairs provide a flow path boundary for two fluids of the at least two fluids, the at least one plate pair having a high thermal conductivity and providing a portion of the flow path boundary for two fluids of the at least two fluids, thereby providing thermal communication between the two fluids on the opposed surfaces of the plate; each plate of plurality of plates including the step of:

forming a plurality of apertures in the plate, at least two of the apertures having an embossed region surrounding the apertures, each embossed region defining a path for venting fluids of the at least two fluids leaking between nested plate pairs along aligned apertures of the plurality of apertures;

forming at least one primary vent path in the plate, the at least one primary vent path in fluid communication with the at least two embossed regions for venting the at least two fluids exterior of the perimeter flanges; and

selectively applying a surface treatment to at least one surface and perimeter flanges of at least one plate, the at least one surface corresponding to a contacting surface of a plate pair.

18. The method of claim 17 wherein the at least one primary vent path does not coincide with nodal connections defined between facing surfaces of adjacent plate pairs of the plurality of plate pairs.

19. The plate heat exchanger of claim 1 wherein each adjacent pair of plate pairs includes a plurality of ports for providing a flow channel for at least one

fluid through the adjacent pair of plate pairs, each port of the plurality of ports having a double seal, each port having at least two surrounding embossed regions formed in the outermost opposed plates of the adjacent plate pair to vent two fluids of the at least two fluids leaking along a port between the plates of each adjacent plate pair to the vent path.

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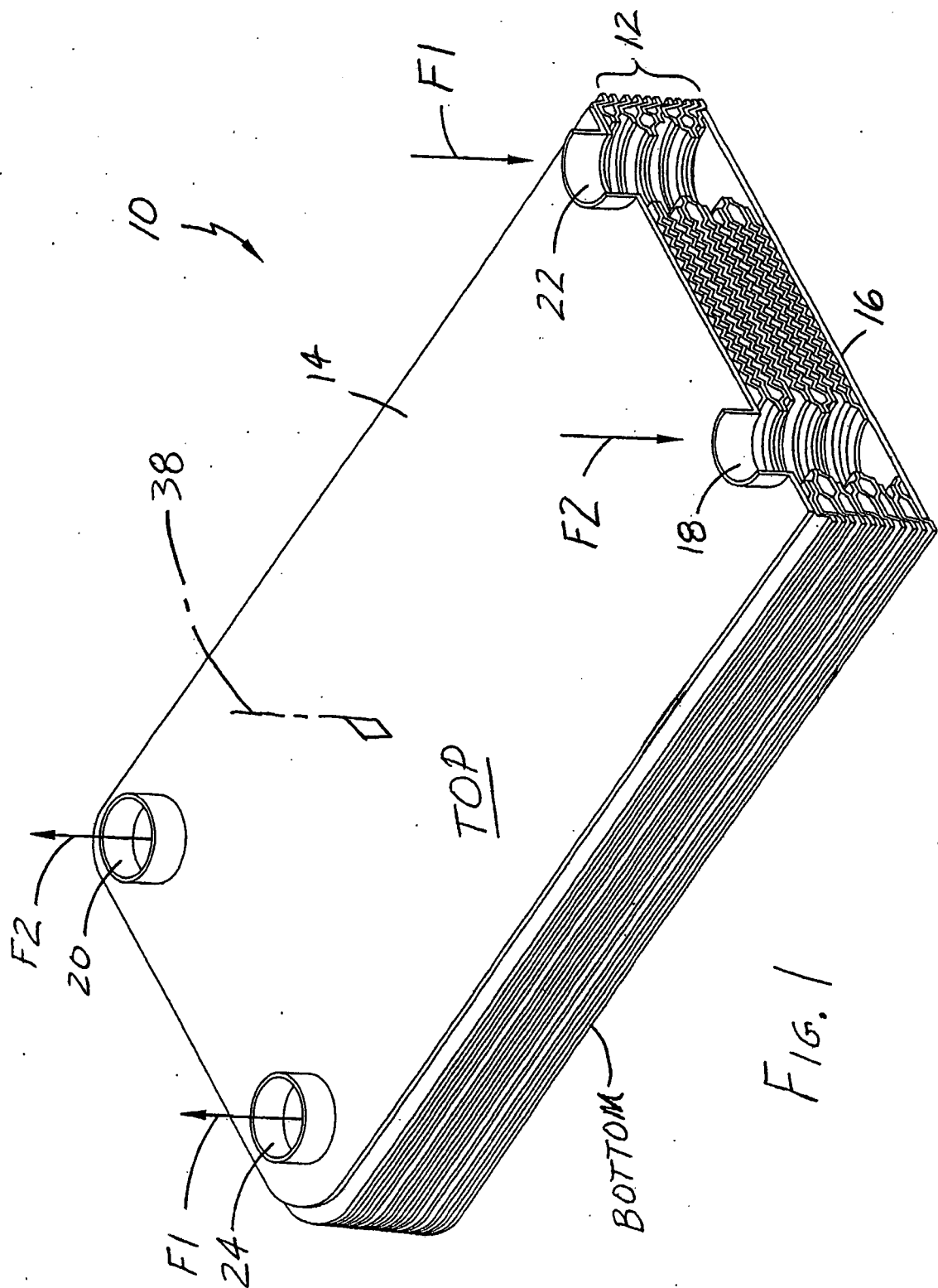
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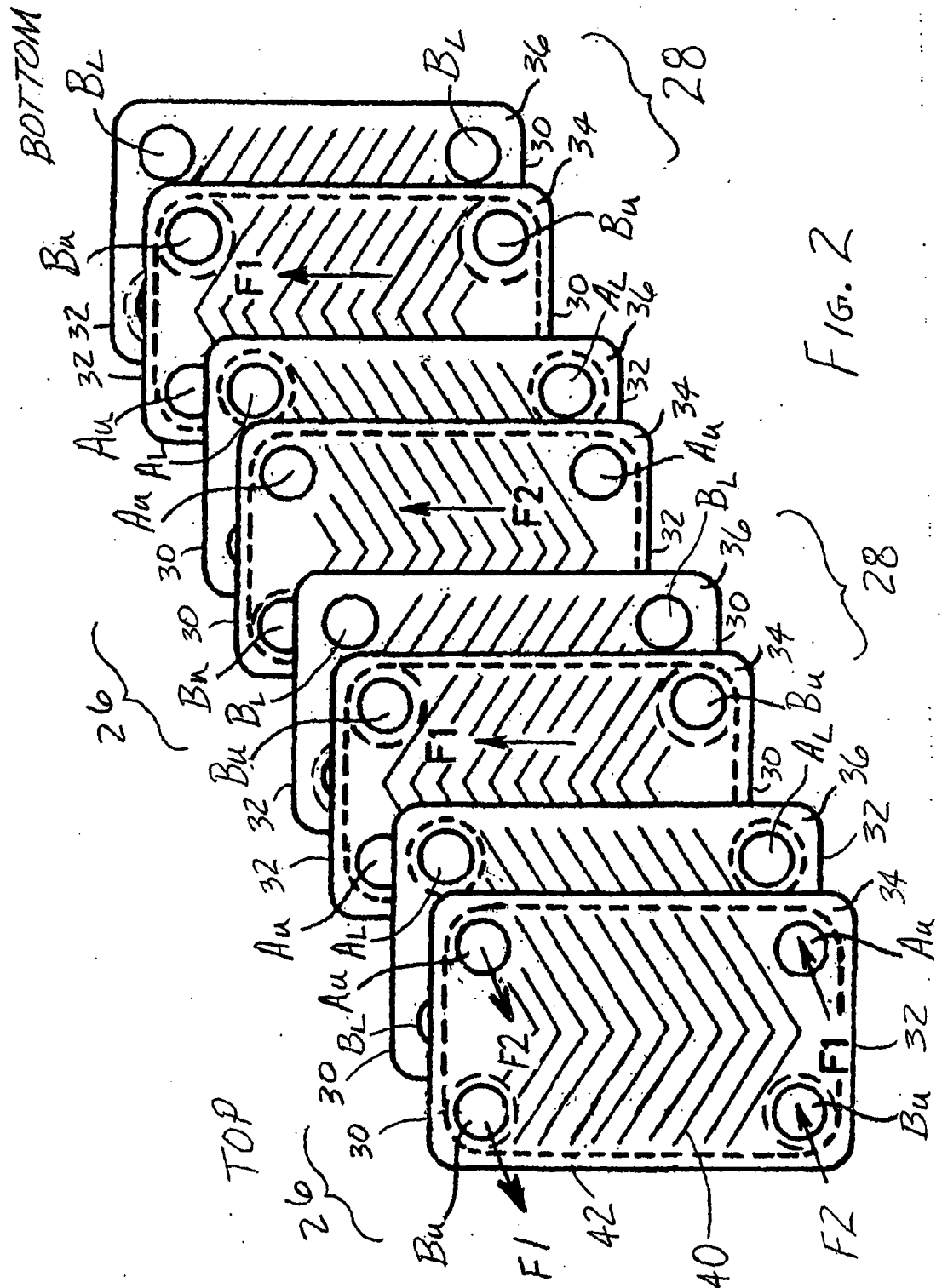
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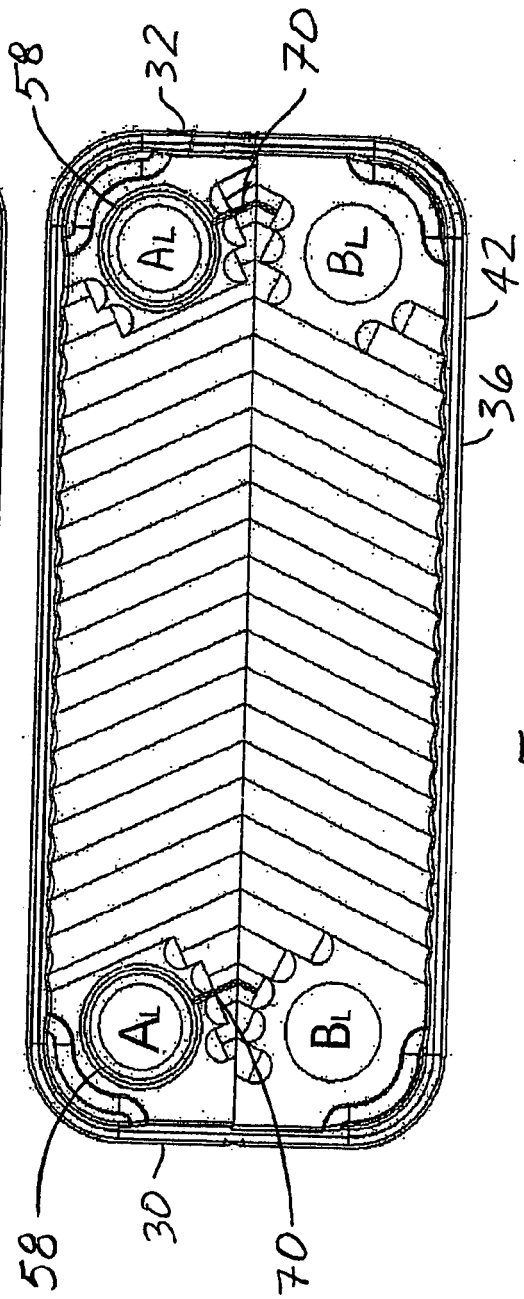
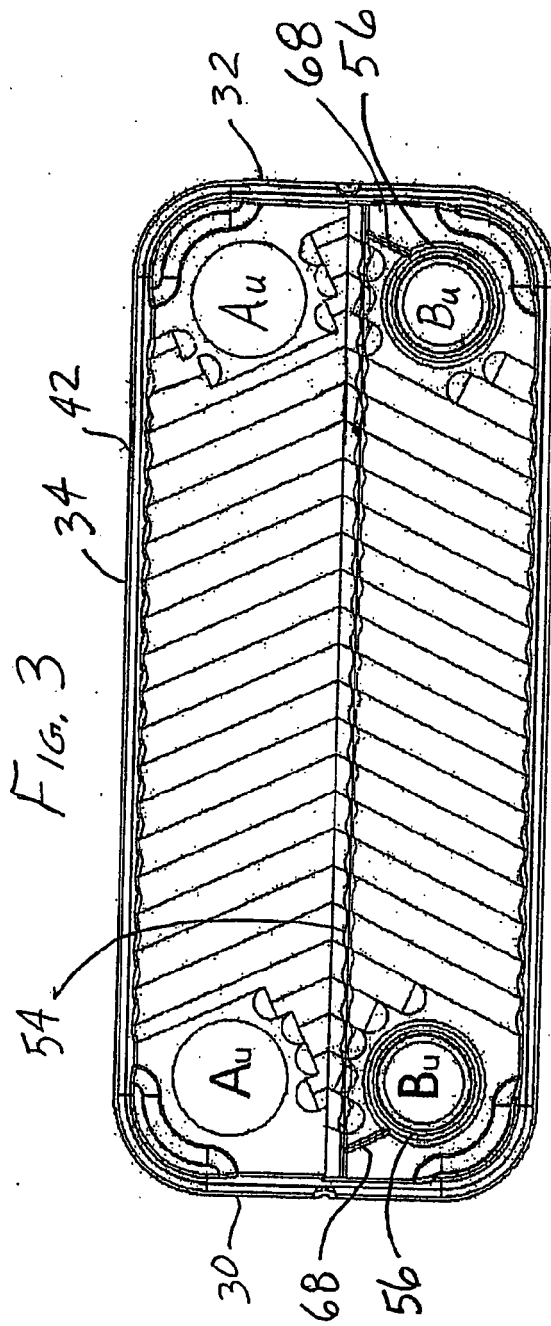
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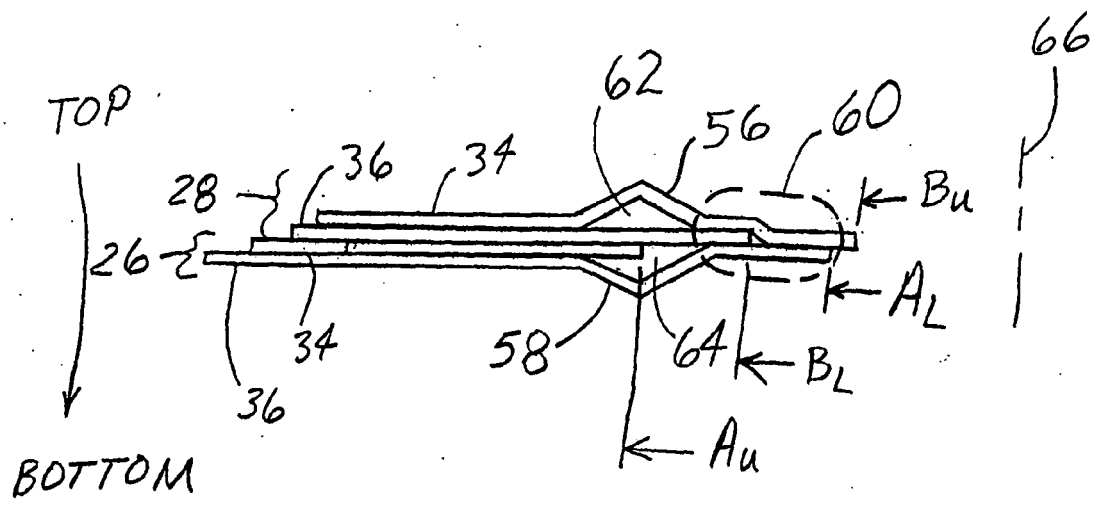


FIG. 5

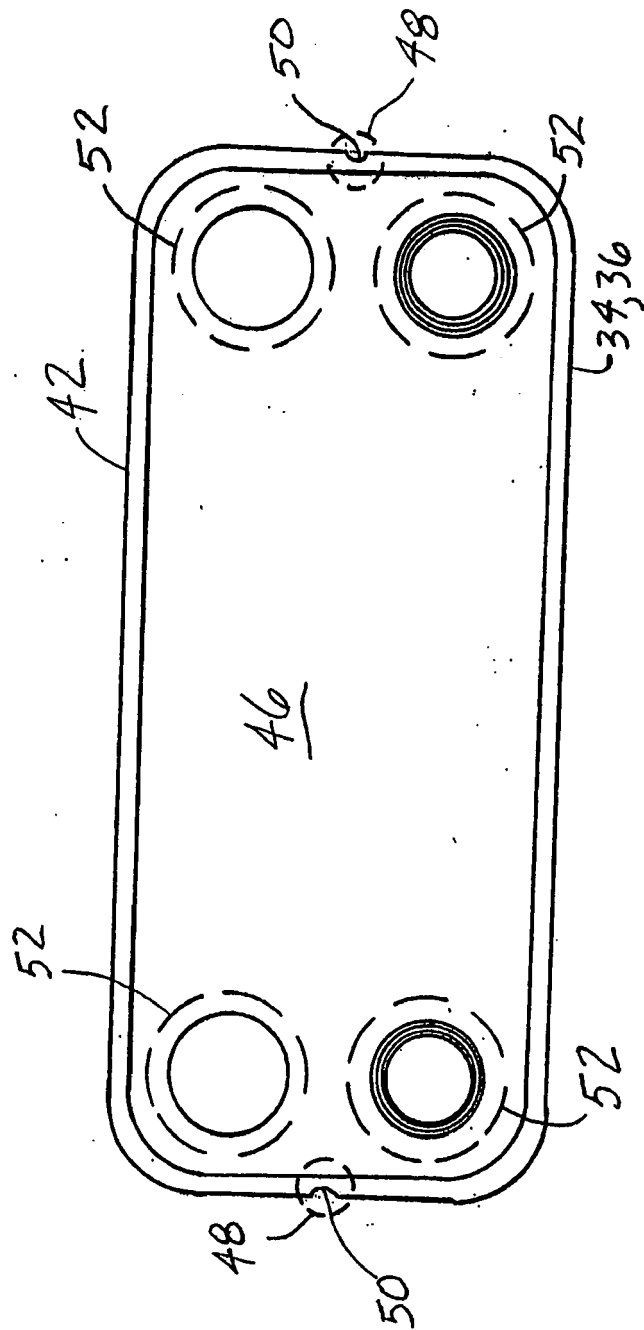


FIG. 6

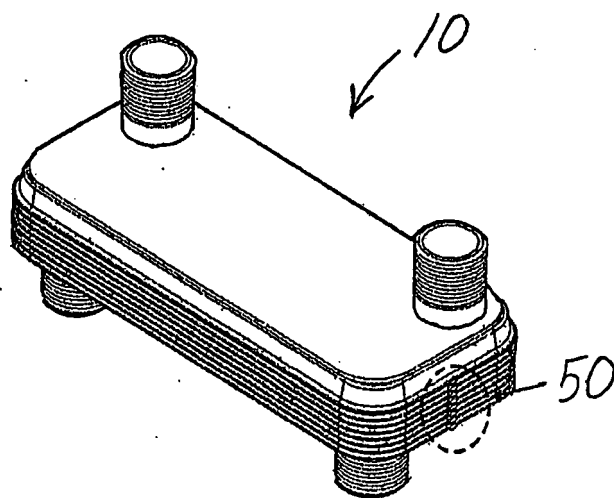


FIG. 7

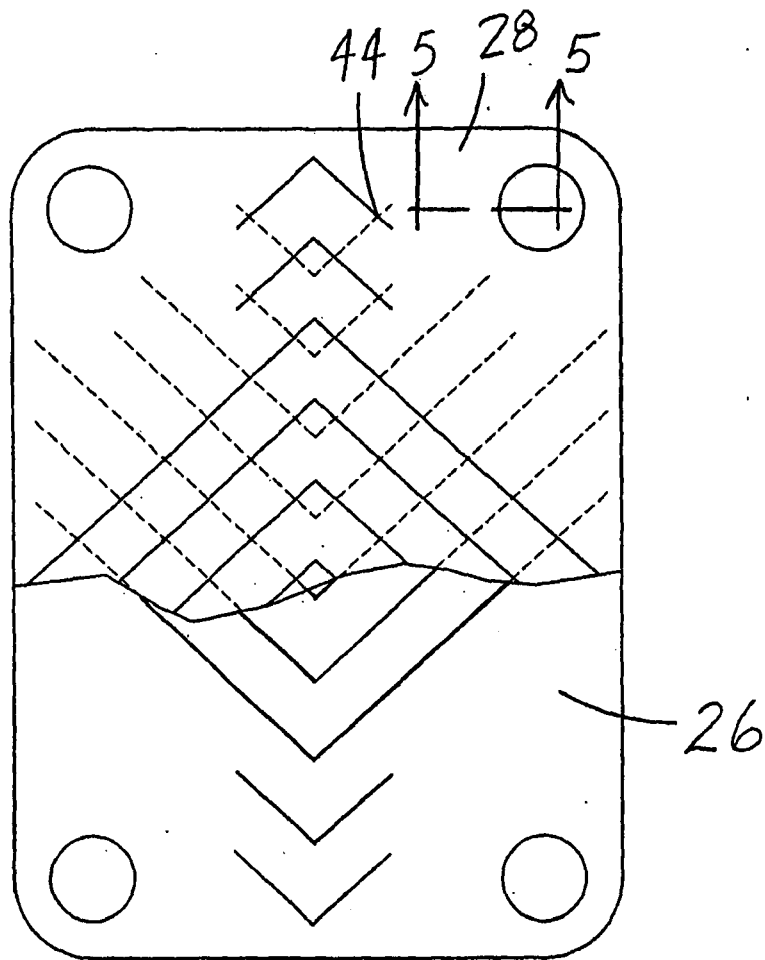


FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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