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PEORIA, IL 61629-6490 (US)(21) Appl. No.: **11/642,147**(22) Filed: **Dec. 20, 2006****Related U.S. Application Data**(60) Provisional application No. 60/753,812, filed on Dec.
23, 2005.(57) **ABSTRACT**

A heat exchanger is provided. The heat exchanger includes a stack assembly with a plurality of plates and a plurality of frames arranged in an alternating stacked relationship with the plates along a predetermined direction. Each of the plates has a plurality of first openings and each of the frames has a plurality of second openings. A plurality of first and second fluid channels extends through the stack assembly along the predetermined direction and through the plurality of first and second openings. A first fluid flow path includes a first inlet channel in fluid communication with the plurality of first fluid channels, and a first outlet channel in fluid communication with the plurality of second fluid channels. A second fluid flow path is in thermal contact with the first fluid flow path and fluidically isolated from the first fluid flow path.

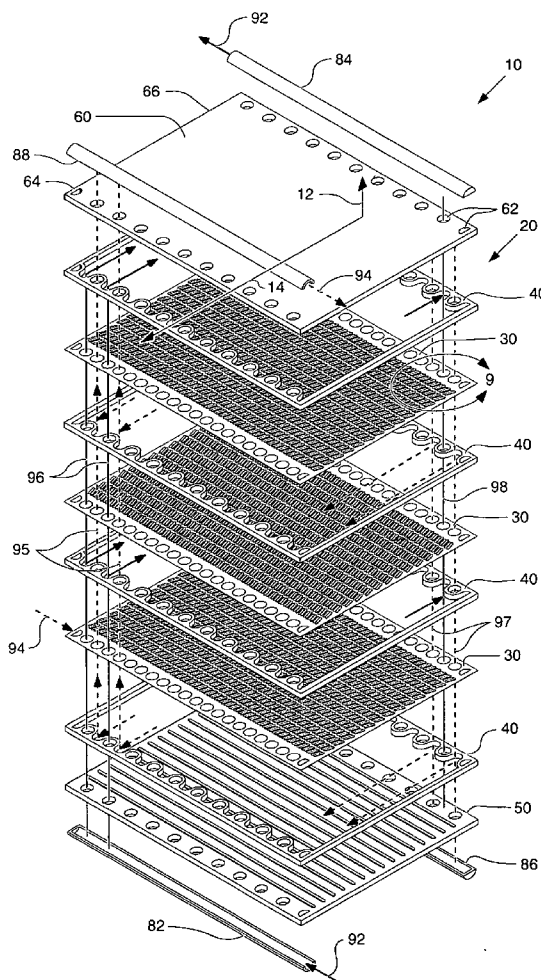


Fig. 1.

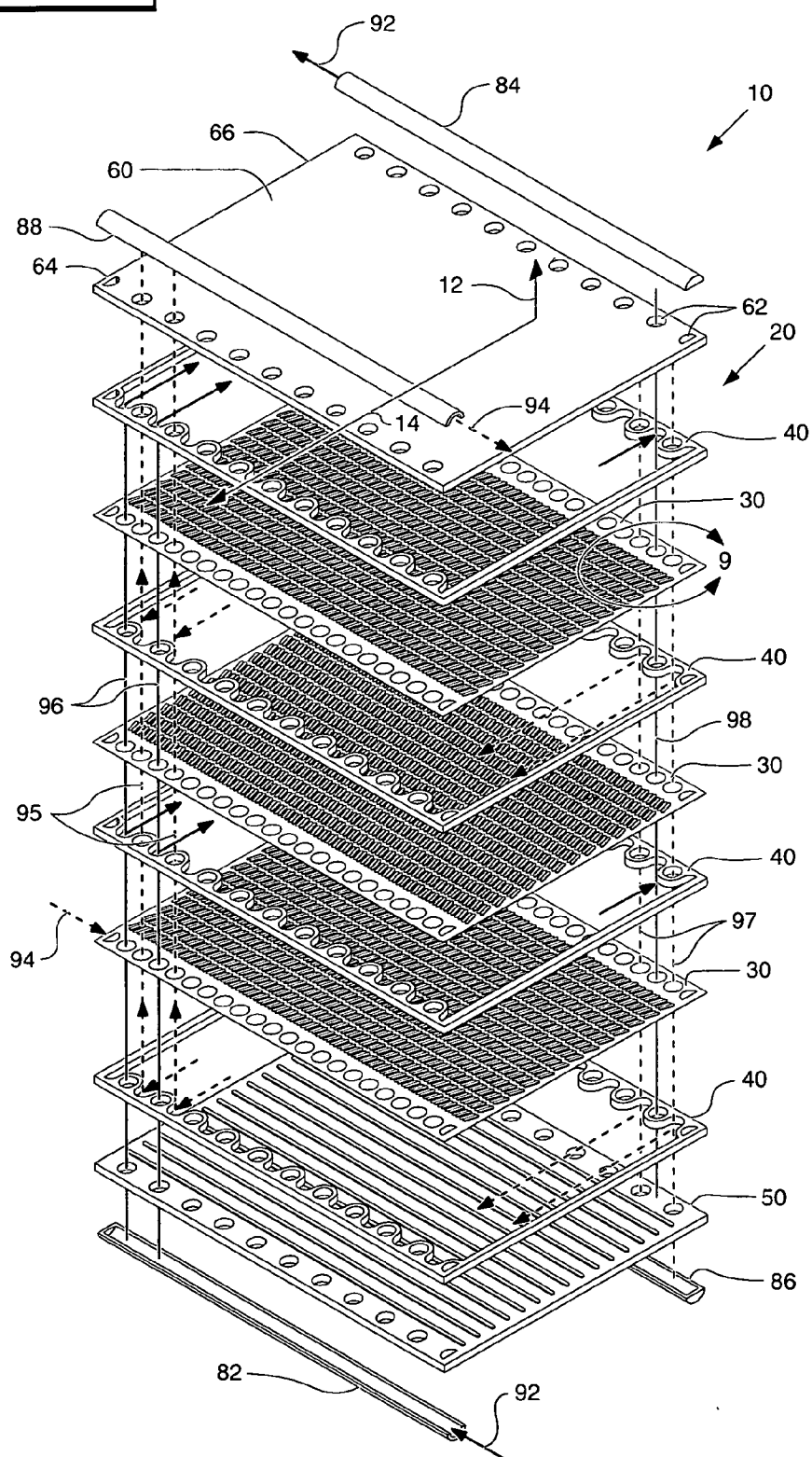


FIG. 2.

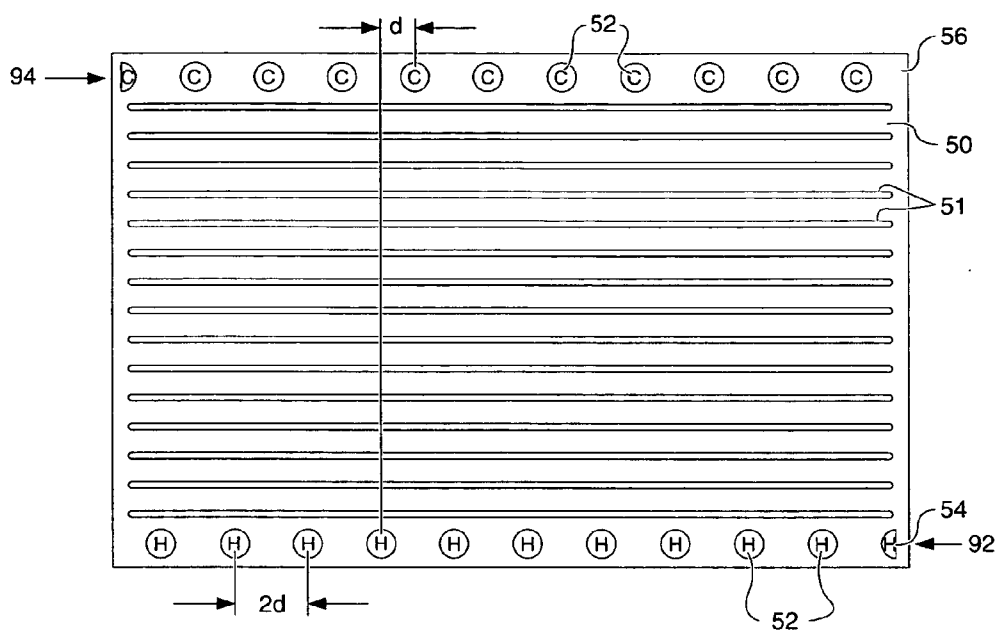


FIG. 3.

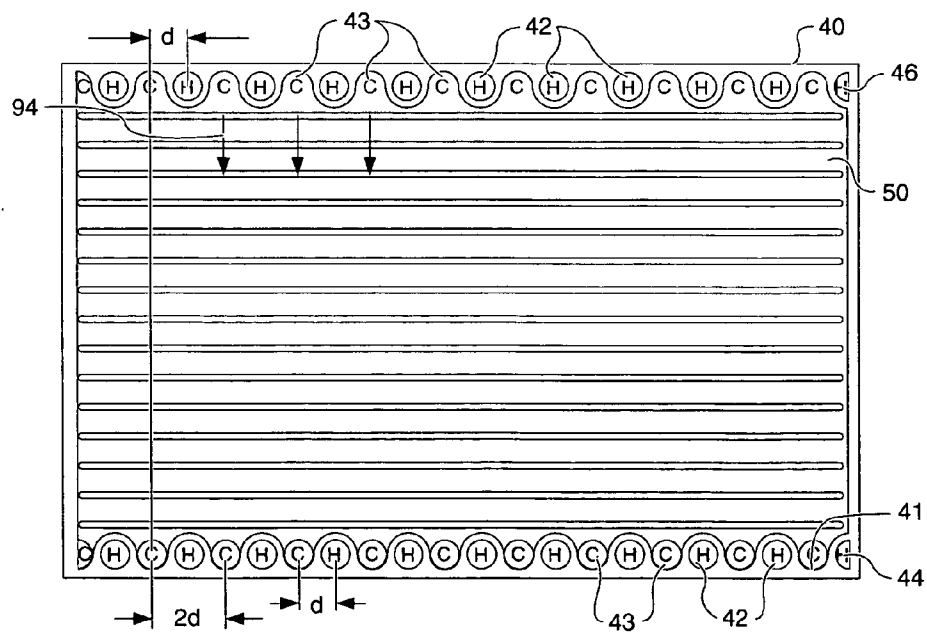


FIG. 4.

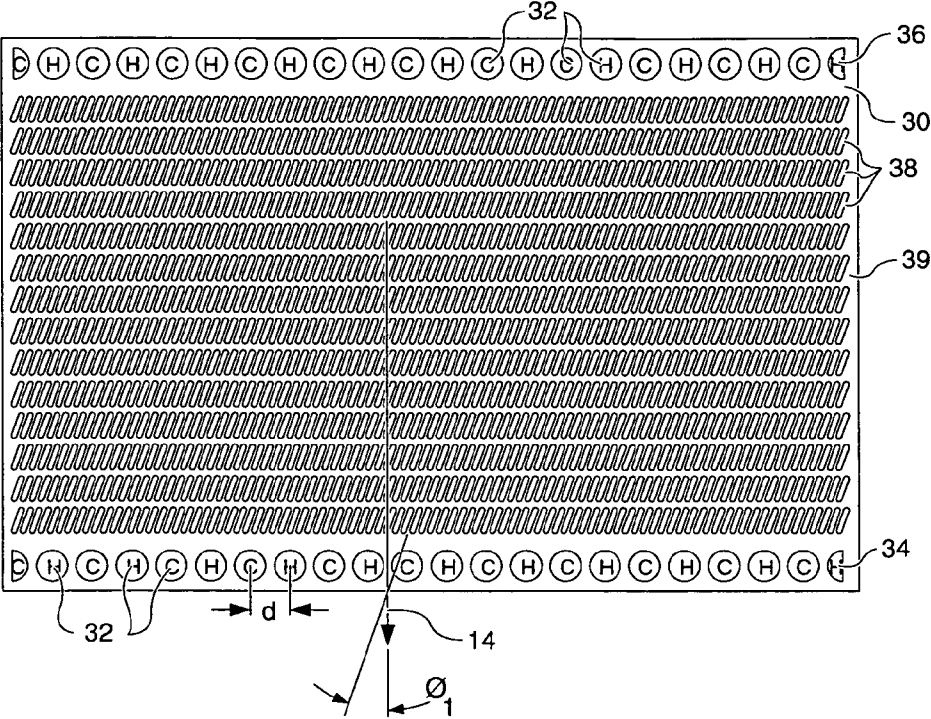


FIG. 5.

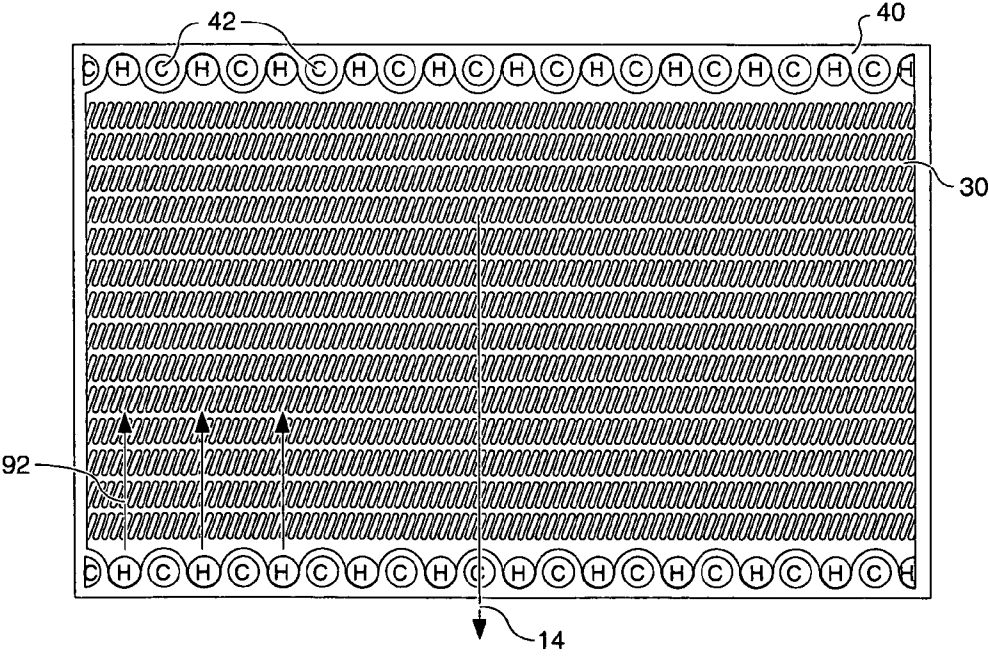


FIG. 6.

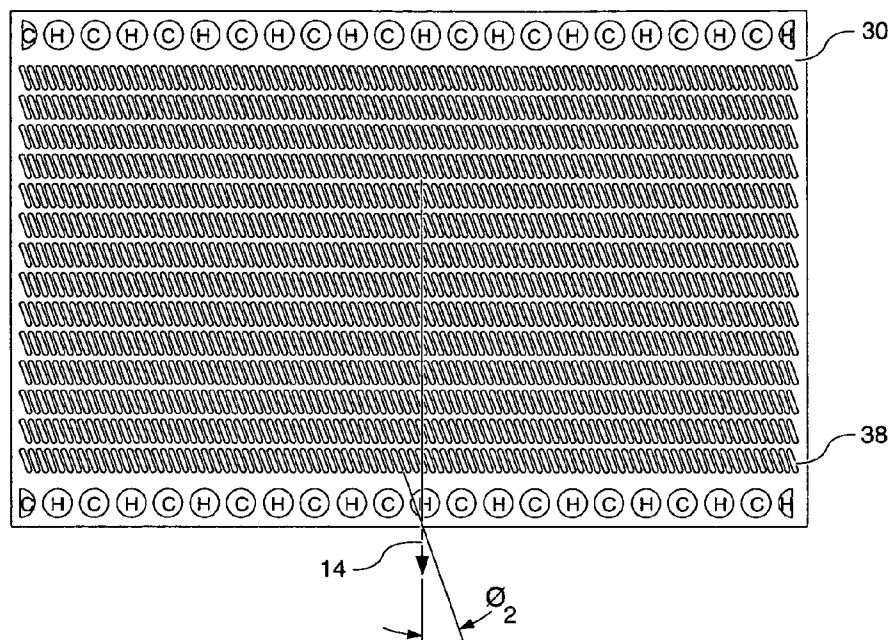


FIG. 7.

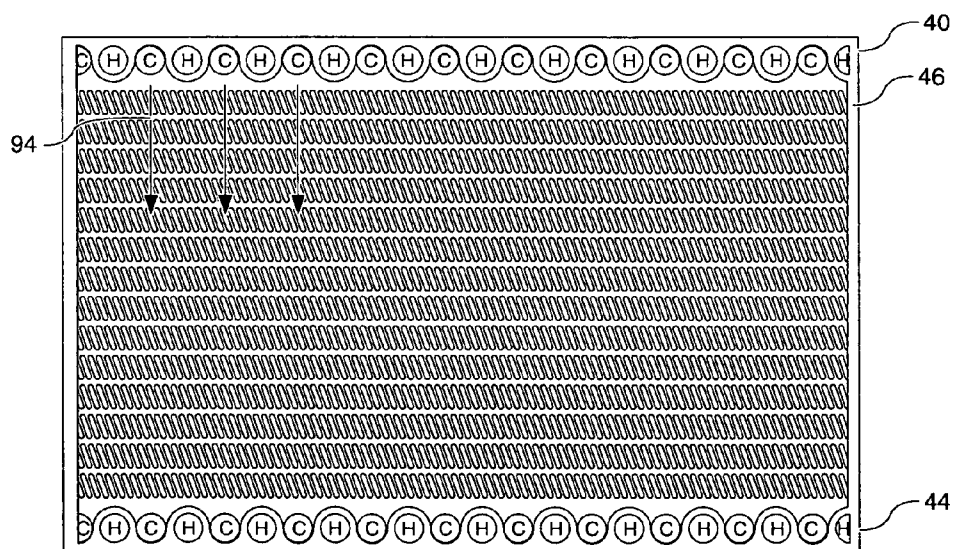


FIG. 8.

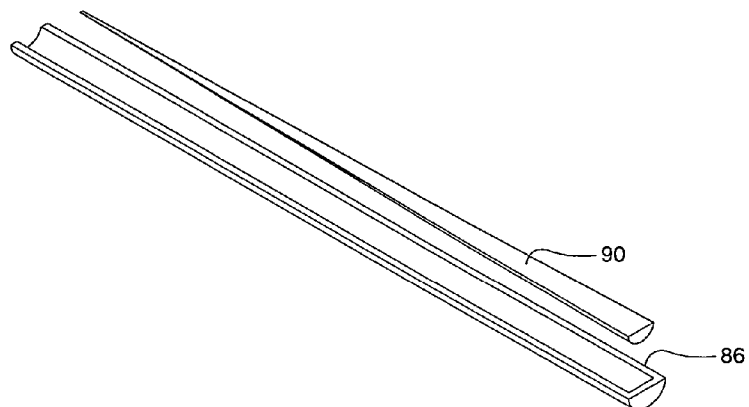


FIG. 9.

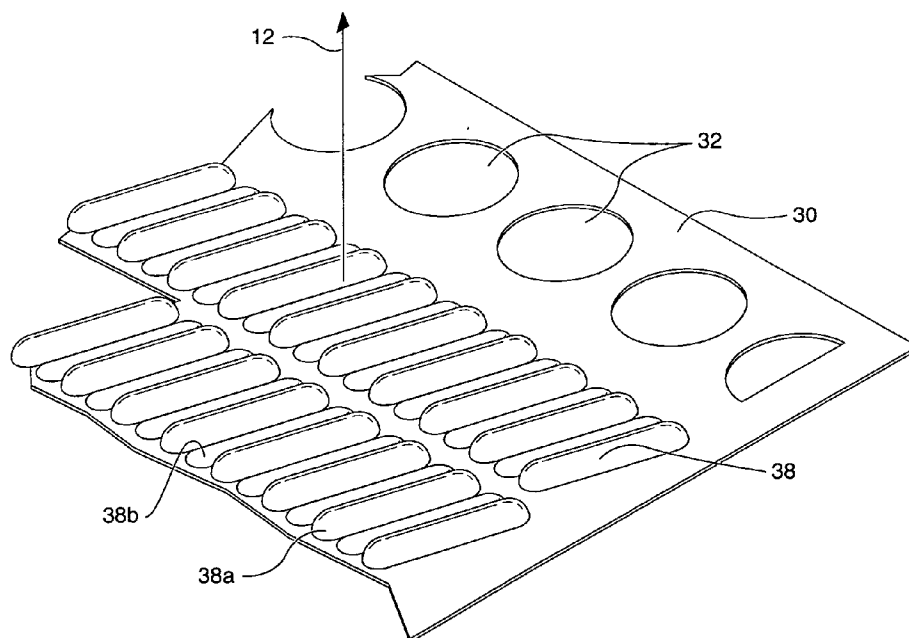


FIG. 10.

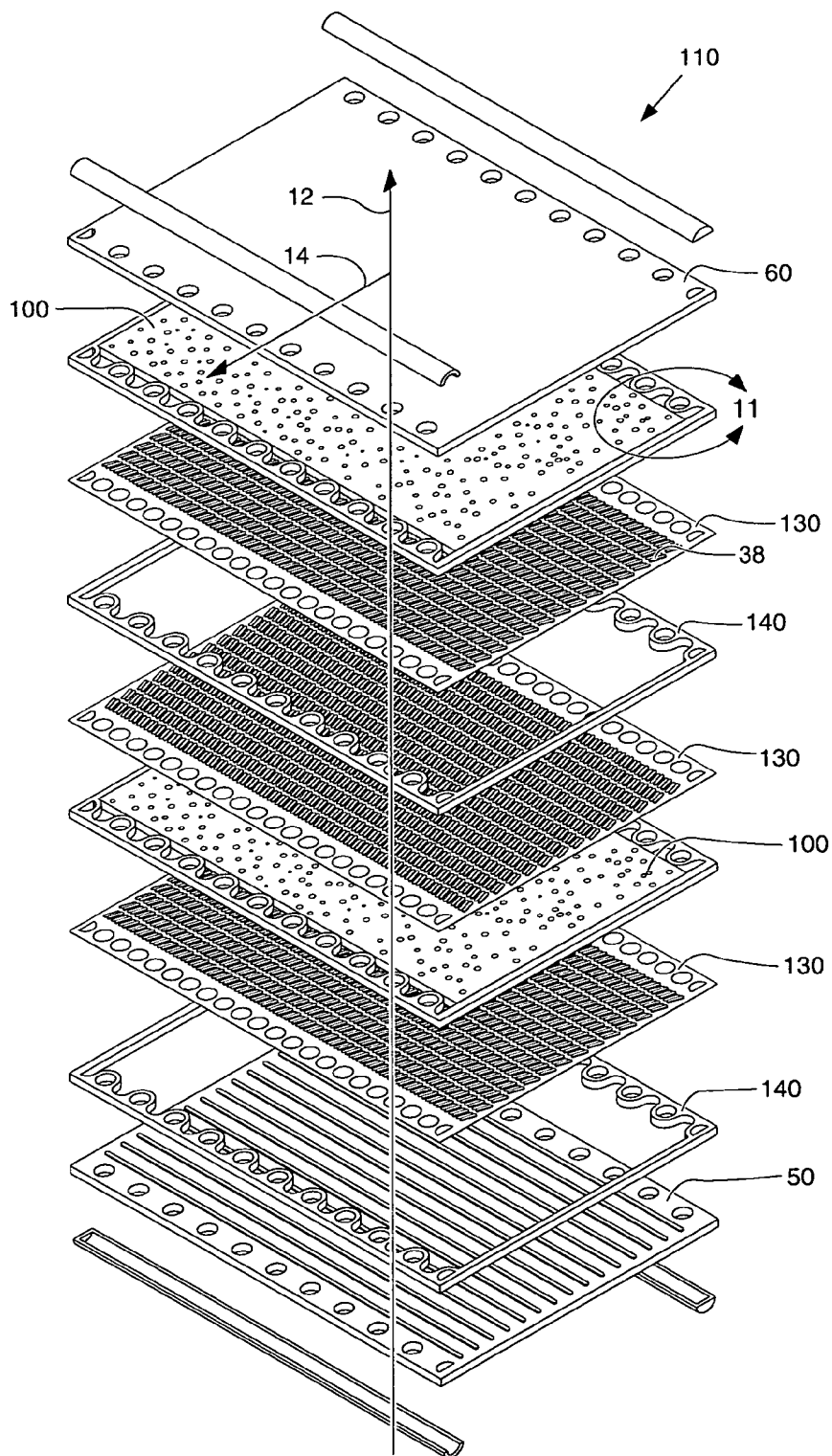


FIG. 11.

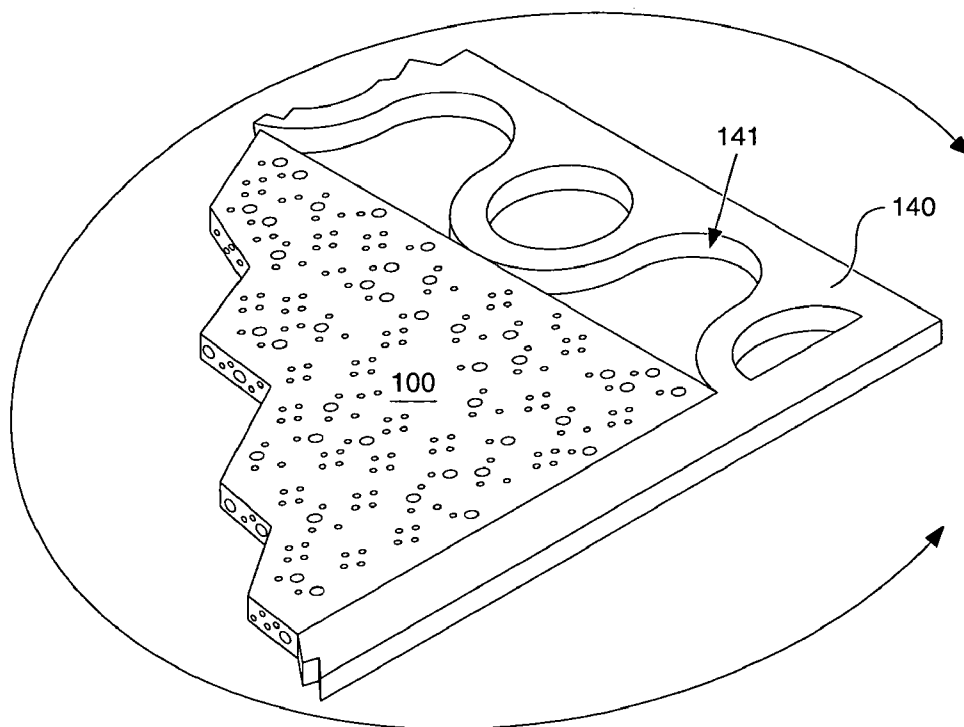


FIG. 12.

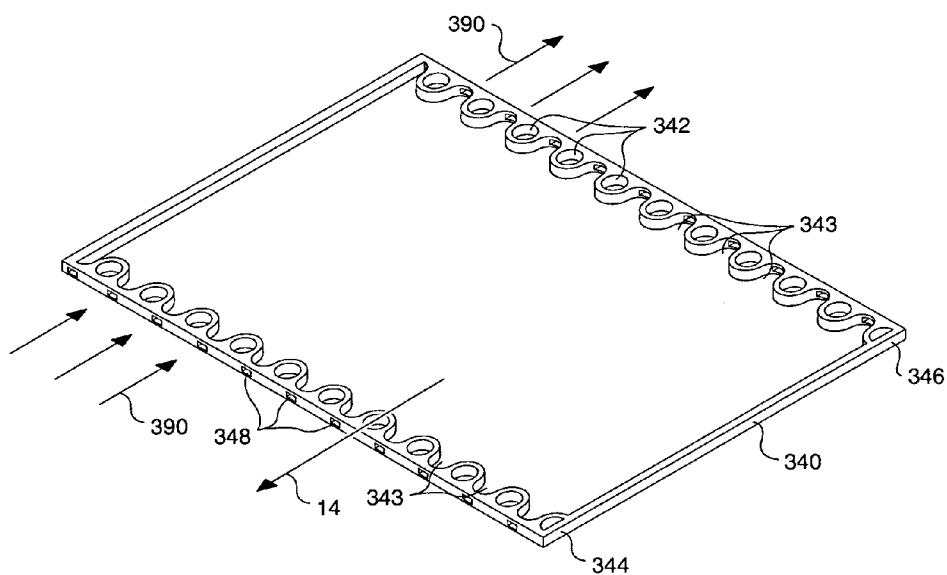
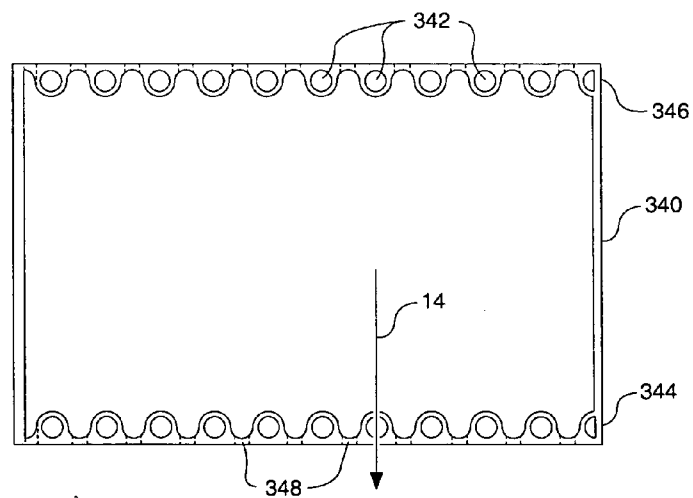


FIG. 13.



HEAT EXCHANGER

CLAIM FOR PRIORITY

[0001] The present application claims priority from U.S. Provisional Application Ser. No. **60/753,812**, filed Dec. 23, 2005, which is fully incorporated herein.

TECHNICAL FIELD

[0002] The present disclosure is directed to a heat exchanger, and more particularly to a stacked plate heat exchanger and method of assembly thereof.

BACKGROUND

[0003] Plate-type heat exchangers are used for certain industrial applications in place of fin and tube or shell and tube type heat exchangers because they are less expensive and easier to make than most forms of heat exchangers. In one form of such plate-type heat exchangers, a plurality of primary surface plates are brazed together in a unitary structure with spacer frames located between adjacent plates and traversing a course adjacent to the plate peripheries. Flow of the two fluids involved in heat exchange is through alternate layers defined by the brazed plates. The space between the plates may be occupied by protuberances or fins formed in the plates to increase turbulence or heat exchange in the fluid flow. All of the fluid flowing in a given defined space is in contact with the plates to enhance heat transfer.

[0004] In order to handle larger heat loads, existing plate-type heat exchangers may be scaled up in size by adding more layers or using denser configurations of layers. However, one problem that arises with some designs is that the pressure loss across the heat exchanger increases. One technique used to decrease the pressure loss is to transversely supply each layer from a single conduit. The conduit is sized to minimize any pressure drops. An example of such a heat exchanger is disclosed in U.S. Pat. No. 5,911,273 to Brenner et al. ("the '273 patent"). The '273 patent discloses a heat exchanger having a stacked plate construction made of four distinct parts: a cover, a flow duct plate, a connection cover plate, and a connection plate. These parts are alternated and rotated in a stack assembly. A first fluid flows into the heat exchanger through a connection opening, into a single connection conduit, then transversely through fluidically parallel layers. A second fluid has a similar flow pattern, with the heat exchange occurring across the parallel layers of the stack assembly.

[0005] While the configuration of the '273 patent attempts to decrease pressure losses, it results in an increased manifold volume or supply conduit volume to heat exchanger volume ratio. As the size or the number of layers in the heat exchanger increases, the size of the manifold volume increases as well. For applications requiring a compact construction, this may prove to be unacceptable. In addition, there may be non-uniform heat exchange such that layers farthest from the supply conduit inlets may receive less flow than layers closest to the supply conduit inlets.

[0006] The present disclosure is directed to overcoming one or more of the problems set forth above.

SUMMARY OF THE INVENTION

[0007] In one aspect, the present disclosure is directed to a heat exchanger. The heat exchanger includes a stack

assembly with a plurality of plates and a plurality of frames arranged in an alternating stacked relationship with the plates along a predetermined direction. Each of the plates has a plurality of first openings and each of the frames has a plurality of second openings. A plurality of first and second fluid channels extends through the stack assembly along the predetermined direction and through the plurality of first and second openings. A first fluid flow path includes a first inlet channel in fluid communication with the plurality of first fluid channels and a first outlet channel in fluid communication with the plurality of second fluid channels. A second fluid flow path is in thermal contact with the first fluid flow path and fluidically isolated from the first fluid flow path.

[0008] In another aspect, the present disclosure is directed to a method of making a heat exchanger including the steps of providing a plurality of plates having a plurality of first openings and providing a plurality of frames having a plurality of second openings. The method also includes the steps of alternately stacking the plates with the frames along a stack direction and aligning the plurality of first openings with the plurality of second openings to define a first and second plurality of fluid channels extending through the plates and the frames along the stack direction. The method also includes the steps of coupling a first manifold to each of the first plurality of fluid channels along the stack direction and coupling a second manifold to each of the second plurality of fluid channels along the stack direction. The method also includes the step of sealingly interconnecting the stacked plates and frames to each other.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is an exploded perspective view of one exemplary embodiment of a heat exchanger.

[0010] FIG. 2 is a plan view of a cover for the heat exchanger of FIG. 1.

[0011] FIG. 3 is a plan view of a frame layered on the cover of FIG. 2.

[0012] FIG. 4 is a plan view of a plate of the heat exchanger of FIG. 1.

[0013] FIG. 5 is a plan view of a frame, which is rotated 180 degrees about a stack direction from the frame of FIG. 3, layered on the plate of FIG. 4.

[0014] FIG. 6 is a plan view of a plate that is rotated 180 degrees about a transverse direction from the plate of FIG. 4.

[0015] FIG. 7 is a plan view of a frame layered on the plate of FIG. 6.

[0016] FIG. 8 is a perspective view of a tapered insert that may be placed in the manifolds or fluid channels of FIG. 1.

[0017] FIG. 9 is a detail view of the plate of FIG. 1.

[0018] FIG. 10 is an exploded perspective view of another exemplary embodiment of the heat exchanger, shown with foam inserts.

[0019] FIG. 11 is a detail view of the inserts of FIG. 10.

[0020] FIG. 12 is a perspective view of a frame that may be used with another exemplary embodiment of a heat exchanger.

[0021] FIG. 13 is a plan view of the frame of FIG. 12.

DETAILED DESCRIPTION

[0022] Reference will now be made in detail to the drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[0023] FIG. 1 shows a heat exchanger 10. Heat exchanger 10 includes a stack assembly 20 made up of alternating layers of plates 30 and frames 40, a bottom cover 50, a top cover 60, and manifolds 82, 84, 86, and 88. Heat exchanger 10 is shown assembled along a stack direction 12 that is oriented vertically, but this is only for purposes of illustration.

[0024] Stack assembly 20 is made up of layers of plates 30 and frames 40. As seen in FIG. 1, plates 30 are flat plates formed of a thin sheet of material such as stainless steel, aluminum, brass, copper, bronze, or any other material with desired heat transfer characteristics. In addition, while plates 30 are depicted as rectangular, other shapes may also be used. In one exemplary embodiment plates 30 have dimensions of 279 mm long by 179 mm wide by 0.1 mm thick, although plates 30 of other sizes may also be used. Plates 30 may be formed by methods known in the art, such as stamping, laser beam cutting, water torch cutting, eroding, etc.

[0025] As seen in FIG. 4, a first and second row 34, 36 of openings 32 are positioned along parallel edges of plate 30. Openings 32 in each of first and second row 34, 36 are spaced a distance of "d" apart. In one exemplary embodiment, openings 32 are symmetrically aligned on opposite edges of plate 30, although other configurations may also be used.

[0026] In addition, as seen in FIGS. 1, 4, and 9, plates 30 are integrally formed with a plurality of turbulators 38 arranged in an array 39. As seen in FIG. 9, plates 30 may be formed such that adjacent turbulators 38 have opposite configurations with respect to stack direction 12. One turbulator 38a may project out of plate 30 along stack direction 12, while an adjacent turbulator 38b may project into plate 30 along stack direction 12. In one exemplary embodiment, turbulators 38 have a height of 1 mm, or one half the thickness of frames 40. As seen in FIG. 4, the turbulators 38 may be oriented at an angle of "θ1" to a transverse direction 14, which is approximately twenty degrees in one exemplary embodiment.

[0027] As seen in FIGS. 5 and 7, frames 40 are sized to have similar outer dimensions to that of plates 30, and may also be made of similar materials. Frames 40 also may have a thickness of approximately twice the height of turbulator 38, which in one exemplary embodiment is 2 mm, although other thicknesses may be used. As seen in FIG. 3, frames 40 also have a first and second row 44, 46 of alternating openings 42 and voids 43 that are positioned along parallel edges. Openings 42 in each of first and second row 44, 46 are spaced a distance of "2d" apart, and are enclosed within the interior periphery 41 of frame 40. Voids 43 are also formed in the interior periphery 41 of frame 40 and are

spaced a distance of "2d" apart, such that each opening 42 is spaced a distance of "d" from an adjacent void 43. This spacing between voids 43 and openings 42 is maintained for both first row 44 and second row 46. In addition, the openings 42 and voids 43 in first and second row 44, 46 may be symmetrically aligned along parallel edges of frame 40, such that the openings 42 and voids 43 in the first row 44 are mirror images of the openings 42 and voids 43 in the second row 46. Openings 42 and voids 43 are sized to match the openings 32 in plates 30, although they may be slightly increased or decreased to facilitate alignment and sealing.

[0028] As seen in FIG. 1, stack assembly 20 begins with a frame 40. A first plate 30 is aligned on the frame 40. A second frame 40, which is rotated 180 degrees about the stack direction 12 from the first frame 40, is placed on the plate 30. A second plate 30, rotated 180 degrees about a transverse direction 14, is placed onto the frame 40. As seen in FIG. 6, the turbulators 38 of the second plate 30 are symmetrically disposed about the transverse direction 14, such that "θ2" is equal to the "θ1" shown in FIG. 1. The stack continues in this fashion, alternating frames 40 and plates 30, with successive frames 40 and plates 30 rotated 180 degrees about a transverse direction 14 from the preceding one.

[0029] Stack assembly 20 is placed onto a bottom cover 50. As seen in FIG. 2, bottom cover 50 has a first and second row 54, 56 of openings 52 positioned along parallel edges. Openings in first and second row 52 are positioned a distance of "2d" apart. In addition, a series of ridges 51 may extend across an inner surface of bottom cover 50. Depending on the orientation, these ridges 51 may serve to direct the flow of fluid across the cover, turbulate the water, and/or increase heat exchange. The openings 52 in first and second row 54, 56 of bottom cover 50 are laterally offset a distance of "d", such that the first and second rows 54, 56 of openings 52 are not symmetric along the length of the cover. Bottom cover 50 may be sized with substantially the same outer dimensions as frame 40 or plate 30.

[0030] As seen in FIG. 1, a top cover 60 is placed at the top of the stack assembly 20. Top cover 60 has a first and second row 64, 66 of openings 62 positioned on parallel edges. In one exemplary embodiment, top cover 60 is identical to bottom cover 50. However, in assembling top cover 60 to stack assembly 20, top cover 60 is rotated 180 degrees about a transverse direction 14 with respect to bottom cover 50. Other aspects of top cover 60 are similar to bottom cover 50, shown in FIGS. 1 and 2 and described above.

[0031] As the heat exchanger 10 is stacked, the alignment of openings 32, 42, 52 and voids 43 in the plates 30, frames 40, and covers 50, 60 define a plurality of fluid channels 95, 96, 97, 98 that extend through the stack assembly 20 along the stack direction 10. Fluid channels 95, 96 are defined in the first row 34, 44, 54, 64 of plates 30, frames 40, and covers 50, 60, while fluid channels 97, 98 are defined in the second row 36, 46, 56, 66 of plates 30, frames 40, and covers 50, 60. In one exemplary embodiment, fluid channels 95, 96 alternate openings 32, 42, 52, 62 and voids 43 throughout first row 34, 44, 54, 64, so that each fluid channel 95 is adjacent a fluid channel 96. Similarly, fluid channels 97, 98 alternate openings 32, 42, 52, 62 and voids 43 throughout second row 36, 46, 56, 66, so that each fluid channel 97 is adjacent a fluid channel 98.

[0032] As seen in FIG. 1, each of manifolds **82**, **84**, **86**, and **88** is positioned over the first and second row of openings **54**, **56**, **64**, **66** of top and bottom covers **60**, **50**. Manifolds **82**, **84**, **86**, and **88** each serve as fluid conduits. Manifolds **82** and **84** function as an inlet and outlet, respectively, for a first fluid, such as hot engine oil. Manifolds **86** and **88** function as an inlet and outlet, respectively, for a second fluid, such as coolant.

[0033] As seen in FIG. 8, tapered inserts **90** may be placed in manifolds **82**, **84**, **86**, and **88**. In one exemplary embodiment of the present invention, inserts **90** are placed in the first and second fluid outlet manifolds **84** and **88**. These inserts serve to equalize the pressure drop across the heat exchanger so that there is a substantially equal flow and heat exchange between fluids across the length and height of the heat exchanger **10**. Alternately, inserts **90** may be placed in the fluid channels **95**, **96**, **97**, **98** extending along the stack direction **12**, designated as “h” and “c” in first and second row **34**, **36** in FIG. 4. The inserts **90** may be integrally formed with manifolds **82**, **84**, **86**, and **88**, or sealed to the manifolds **82**, **84**, **86**, and **88** in a separate step. Inserts **90** may be made from stainless steel, aluminum, brass, copper, bronze, or other material with desired heat transfer characteristics.

[0034] FIGS. 10-11 illustrate another exemplary embodiment of the present invention. Foam inserts **100** are placed within the interior periphery **141** of frames **140**. Foam inserts **100** may be made from a porous metal or carbon as described in U.S. Pat. Nos. 3,616,841 and 3,946,039 to Walz, U.S. Pat. App. No. 2004/0226702 to Toonen, or U.S. Pat. No. 6,673,328 to Klett. Inserts **100** have large surface area per unit volumes (approximately 1600 square feet/cubic foot).

[0035] These inserts may be placed in the interior periphery **141** of every frame **140**, or only used with alternate frames **140**, as is shown in FIG. 10. As is shown in FIG. 10, plates **130** are formed with only a single surface of turbulators **38**. Other aspects of heat exchanger **110** are similar to the heat exchanger **10** shown in FIG. 1 and described above.

[0036] In another exemplary embodiment, a gas to fluid heat exchanger (not shown) may be constructed by substituting layers of frames **340**, as shown in FIGS. 12 and 13, with every other frame **40**, **140** in heat exchangers **10**, **110** as shown in FIGS. 1 and 10. Similar to frames **40** and **140**, frame **340** has a first and second row **344**, **346** of alternating openings **342** and voids **343** that are positioned along parallel edges. A plurality of transverse openings **348** extend through the voids **343** in both the first and second row **344**, **346**. These transverse openings **348** permit a transverse flow **390** along the transverse direction **14** to flow past the turbulators **38** and through the frame **340**, providing heat transfer to alternate plates **30**, **130**. These transverse openings **348** open the heat exchanger to ambient air, allowing for an air-to-fluid heat exchanger. Such a heat exchanger could also eliminate one set of manifolds.

[0037] Heat exchangers **10**, **110** may be formed using a brazing operation. Before assembly, a flux is applied to the peripheries of each of manifolds **82**, **84**, **86**, **88**; covers **50**, **60**, frames **40**, and plates **30**. Thin sheets of solder may be placed between each layer to ensure a solder seal extending around the entire periphery. After assembly, the heat exchanger **10**, **110** may be clamped together and heated to

form a sealed unit. Alternately, the heat exchanger **10**, **110** may be formed from any other technique known in the art, such as welding.

INDUSTRIAL APPLICABILITY

[0038] In operation, a first and a second fluid flow path **92**, **94** are defined through the heat exchanger **10**, **110**. A first fluid, such as heated engine oil, follows first fluid flow path **92** and enters through manifold **82**. From manifold **82**, the first fluid next flows into the fluid channels **96** extending through the stack assembly **20** defined by the first row **54** of openings **52** in the bottom cover **50** (as seen in FIG. 2, designated by “h”). From the flow channels, the first fluid flows through voids **43** in the first row **44** of alternate frames **40**, **140** flowing across the turbulators **38** of primary surface sheets or plates **30**, **130**. The flow path **92** continues into voids **43** in the second row **46** of alternate frames **40**, **140** and back through fluid channels **98** extending through the stack assembly **20** (“designated by “h” in the second row **36** in FIG. 4). Flow path **92** continues from the fluid channels **98** in the second row to manifold **84**, where it exits after being cooled by the heat exchange with the second fluid.

[0039] Similarly, a second fluid, such as coolant, follows second fluid flow path **94** and enters through manifold **86**. From manifold **86**, the second fluid next flows into fluid channels **97** extending through the stack assembly **20** defined by the second row **56** of openings **52** in the bottom cover **50** (as seen in FIG. 2, designated by “c”). From the fluid channels **97**, the second fluid flows through voids **43** in the second row **46** of alternate frames **40**, **140** flowing across the turbulators **38** of primary surface sheets or plates **30**. The flow path **94** continues into voids **43** in the first row **46** of alternate frames **40**, **140** and back through fluid channels **95** extending through the stack assembly **20** (“designated by “c” in the first row **36** in FIG. 4). Flow path **94** continues from the fluid channels **95** in the second row to manifold **88**, where it exits after being heated by the heat exchange with the first fluid. Alternately, the first and second fluid flow paths **92**, **94** may be reversed. In addition, the first and second fluid inlets may feed into the upper manifolds **88**, **84** instead of the lower manifolds **82**, **86**, or any other combination. Fluid flow path **92** is fluidically isolated from fluid flow path **94**.

[0040] Foam inserts **100** or turbulators **38** may also be used to increase the heat exchange that occurs across primary surface sheet or plate **30**, **130**. Additional heat exchange may also occur in alternating channels in each of the first and second rows (as seen in FIG. 2, adjacent “h” and “c”).

[0041] It will be apparent to those having ordinary skill in the art that various modifications and variations can be made to the disclosed heat exchanger without departing from the scope of the invention. Other embodiments of the invention will be apparent to those having ordinary skill in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the invention being indicated by the following claims and their equivalents.

What is claimed is:

1. A heat exchanger comprising:
 - a stack assembly including:
 - a plurality of plates, each of the plates having a plurality of first openings;
 - a plurality of frames arranged in an alternating stacked relationship with the plates along a predetermined direction, each of the frames having a plurality of second openings; and
 - wherein a plurality of first and second fluid channels extend through the stack assembly along the predetermined direction and through the plurality of first and second openings;
 - a first fluid flow path including:
 - a first inlet channel in fluid communication with the plurality of first fluid channels; and
 - a first outlet channel in fluid communication with the plurality of second fluid channels; and
 - a second fluid flow path in thermal contact with the first fluid flow path and fluidically isolated from the first fluid flow path.
2. The heat exchanger of claim 1, wherein a plurality of third and fourth fluid channels are defined along the predetermined direction through the plurality of first and second openings; and
 - the second fluid flow path includes a second inlet channel in fluid communication with the plurality of third fluid channels and a second outlet channel in fluid communication with the plurality of fourth fluid channels.
3. The heat exchanger of claim 1, wherein the first inlet channel is configured to provide substantially equal fluid flow to each of the first plurality of fluid channels.
4. The heat exchanger of claim 3, further comprising a tapered insert in the first inlet channel.
5. The heat exchanger of claim 1, wherein the second fluid flow path is substantially perpendicular to the predetermined direction.
6. The heat exchanger of claim 1, wherein each of the plurality of plates has a first array of turbulators on a first surface.
7. The heat exchanger of claim 6, wherein each of the plurality of plates has a second array of turbulators on a second surface.
8. The heat exchanger of claim 1, wherein the plurality of first openings are aligned in a first and a second row, the first and second rows are positioned along parallel edges of each of the plates, and each of the first openings in the first row and each of the first openings in the second row are positioned a predetermined distance apart.
9. The heat exchanger of claim 8, wherein the plurality of second openings are aligned in a third and a fourth row, the third and fourth rows are positioned along parallel edges of each of the frames, and each of the second openings in the third rows and each of the second openings in the fourth rows are positioned twice the predetermined distance apart.
10. The heat exchanger of claim 1, wherein the stack assembly includes a plurality of foam layers arranged in an alternating stacked relationship with the plates and frames along the predetermined direction.

11. The heat exchanger of claim 10, wherein the plurality of foam layers are aluminum or carbon foam.

12. The heat exchanger of claim 1 further comprising a top and a bottom cover positioned on opposite sides of the stack assembly along the predetermined direction, the top and bottom cover having a plurality of third openings, and

wherein the first and second plurality of fluid channels extend through the top and bottom cover through the plurality of third openings.

13. The heat exchanger of claim 12, wherein the top and bottom cover are substantially identical.

14. A method of making a heat exchanger comprising:

providing a plurality of plates, each of the plates having a plurality of first openings;

providing a plurality of frames, each of the frames having a plurality of second openings;

alternately stacking the plates with the frames along a stack direction;

aligning the plurality of first openings with the plurality of second openings to define a first and second plurality of fluid channels extending through the plates and the frames along the stack direction;

coupling a first manifold to each of the first plurality of fluid channels along the stack direction;

coupling a second manifold to each of the second plurality of fluid channels along the stack direction; and

sealingly interconnecting the stacked plates and frames to each other.

15. The method of claim 14, further comprising rotating alternate frames 180 degrees about the stack direction.

16. The method of claim 15, further comprising tapering the first manifold to provide substantially equal flows to each of the first plurality of fluid channels.

17. The method of claim 14, wherein each of the plurality of plates has a first array of turbulators on a first surface and a second array of turbulators on a second surface opposite the first surface, and

further comprising rotating alternate plates about a second direction perpendicular to the stack direction.

18. The method of claim 14, further comprising:

providing a plurality of foam layers; and

stacking the foam layers with the plates and frames along a stack direction.

19. The method of claim 14, further comprising:

providing at least one cover having a plurality of third openings; and

aligning the plurality of third openings with the first and second plurality of fluid channels extending through the plates and the frames along the stack direction.