US 20040003916A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2004/0003916 A1

Nash et al. (43) Pub. Date: Jan. 8, 2004

(54) UNIT CELL U-PLATE-FIN CROSSFLOW HEAT EXCHANGER

(75) Inventors: **James Stephen Nash**, North Hampton, NH (US); **Alexander Haplau-Colan**, Hampton, NH (US); **Frederick Wells Hodous**, Sanford, ME (US)

Correspondence Address:
**MICHAEL BEST & FRIEDRICH LLP**
**3773 CORPORATE PARKWAY**
**SUITE 360**
**CENTER VALLEY, PA 18034-8217 (US)**

(73) Assignee: **Ingersoll-Rand Energy Systems, Inc.**, Portmouth, NH

(21) Appl. No.: **10/190,046**

(22) Filed: **Jul. 3, 2002**

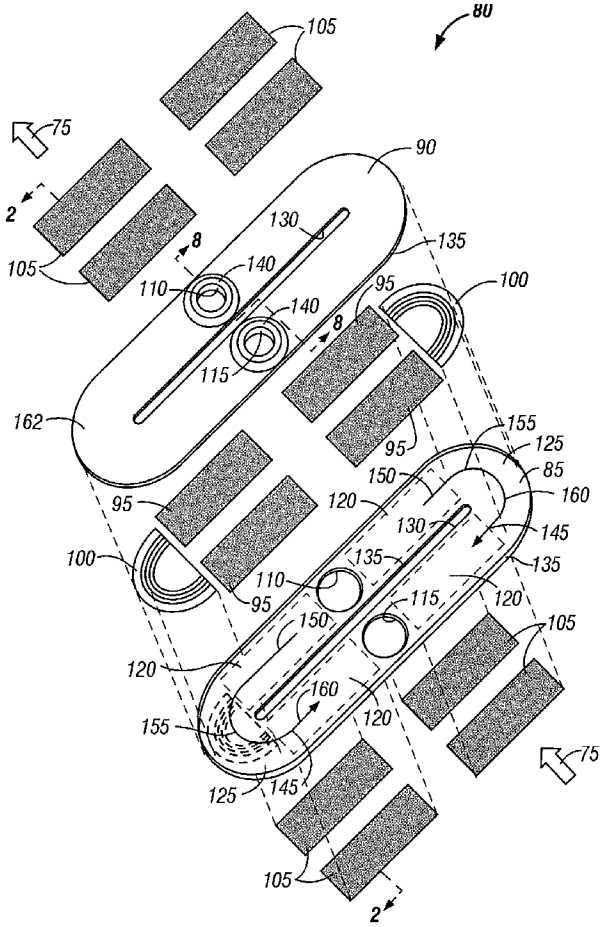
**Publication Classification**

(51) **Int. Cl.**[7] ..... **F28D 1/02**; F28D 7/06

(52) **U.S. Cl.** ..... **165/153**; 165/176

(57) **ABSTRACT**

The invention recites a heat exchanger for the exchange of heat between an internal fluid and an external fluid comprising at least two heat exchange cells. Each heat exchange cell includes a first plate having an outer surface, raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture. Each cell further includes a second plate including raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture. The inlet aperture of the first plate is aligned with the inlet aperture of the second plate to define a cell inlet and the outlet aperture of the first plate is aligned with the outlet aperture of the second plate to define a cell outlet. The heat exchange area of the first plate is aligned with the heat exchange area of the second plate to define an internal U-shaped flow path and the raised peripheral edges of the first plate connect to the raised peripheral edges of the second plate to substantially enclosing the U-shaped flow path between the first and second plate. An internal finned member is disposed within the internal U-shaped flow path and is attached to one of the first and second plates and an external finned member is connected to the outer surface of the first plate.



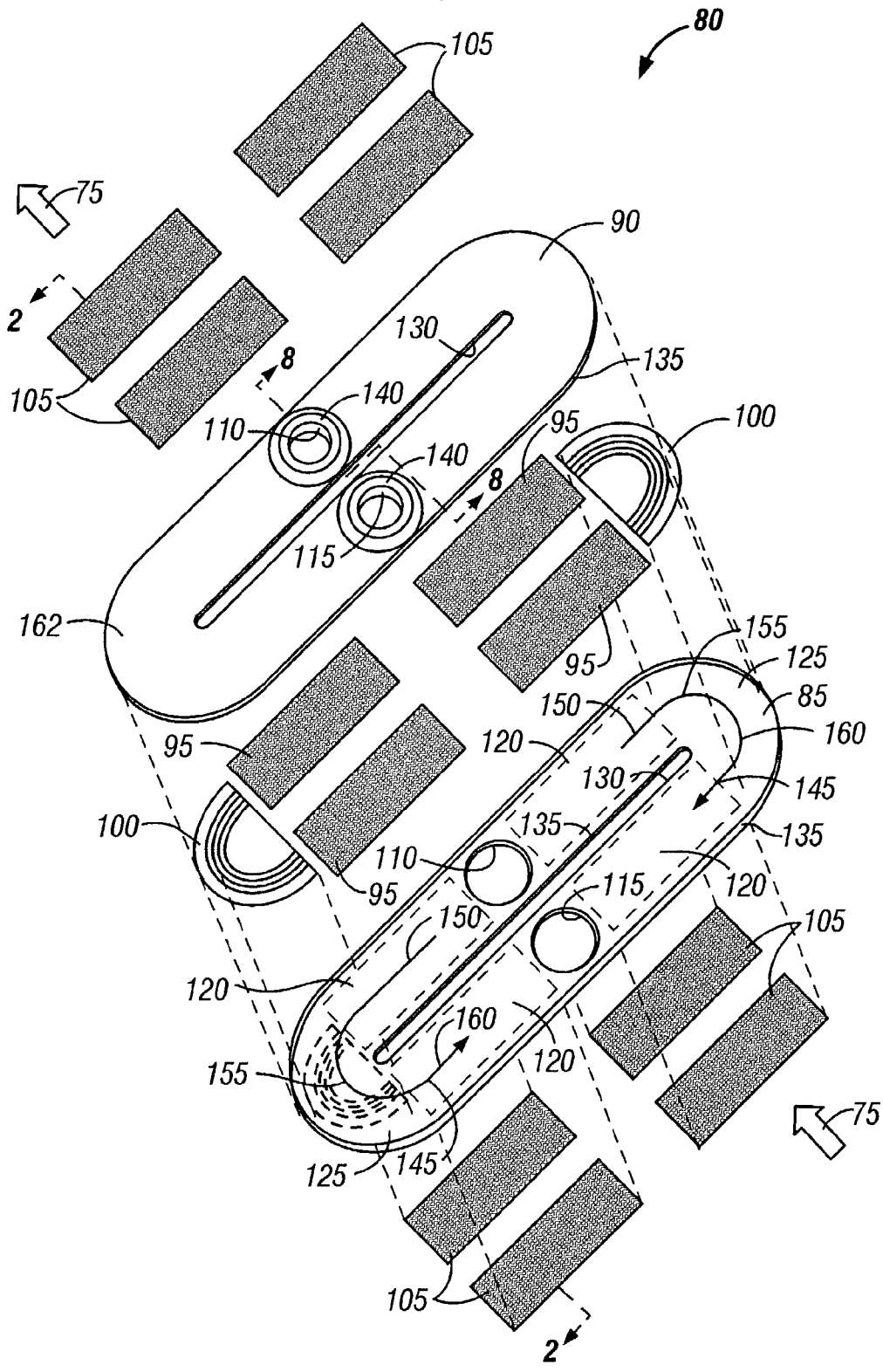
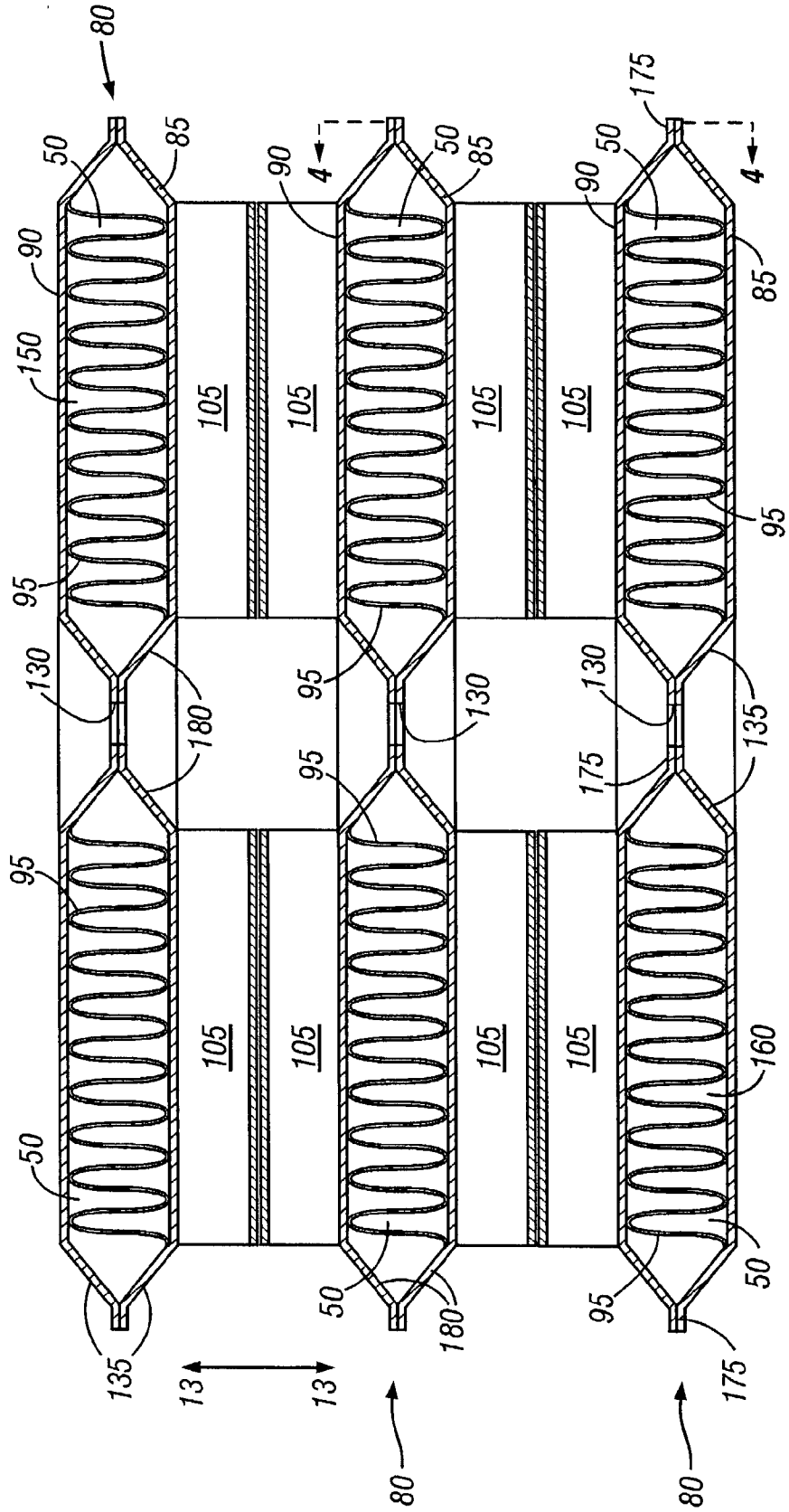

80
105
75
90
2
130
135
8
140
105
110
140
95
100
8
115
162
155
95
125
150
85
95
120
160
130
145
100
135
135
110
120
95
115
150
105
120
160
120
155
75
125
145
105
2

FIG. 1


80
50
85
90
4
175
150
105
95
130
180
135
160
13
FIG. 2

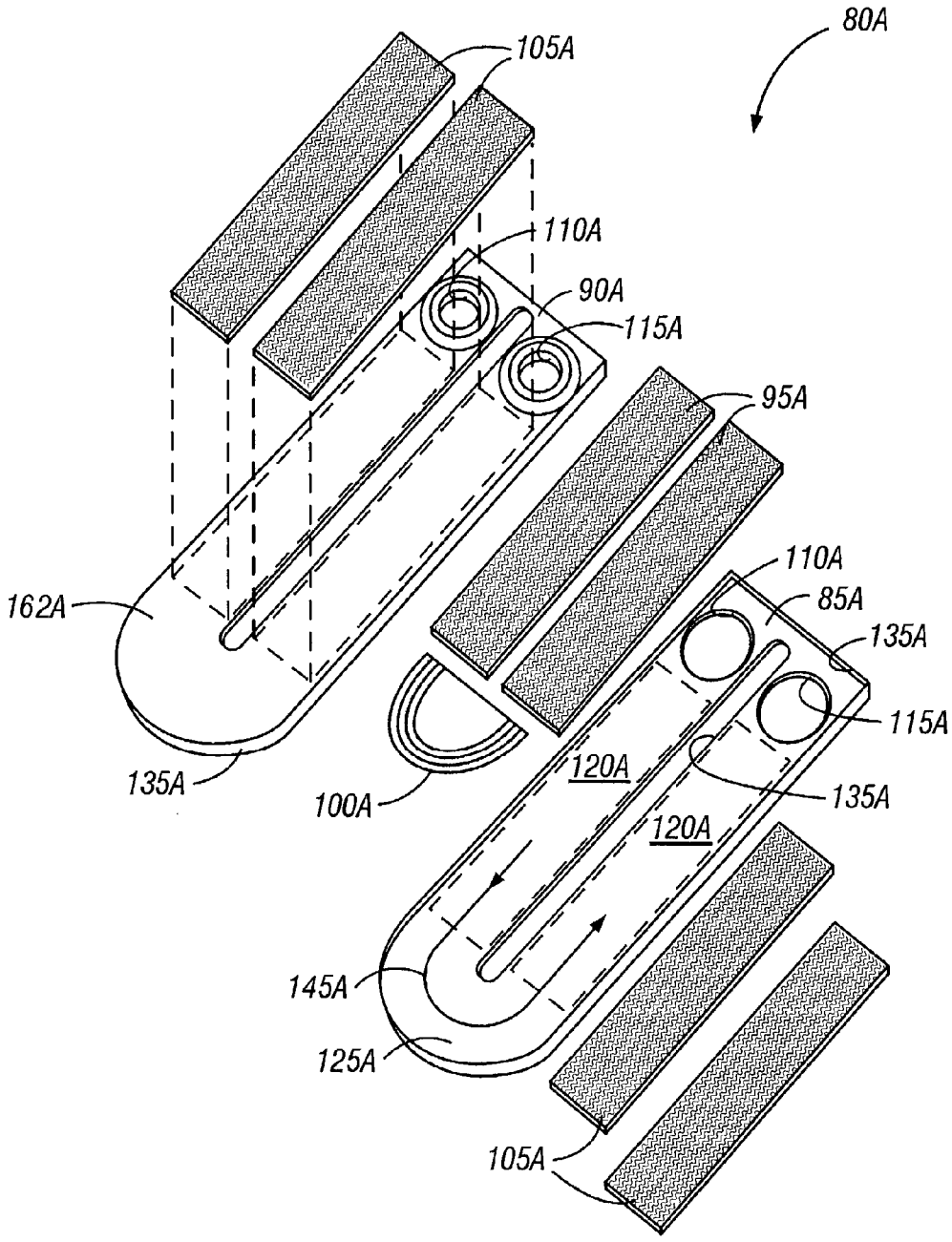

80A
105A
110A
90A
115A
95A
110A
85A
135A
115A
162A
135A
100A
120A
135A
120A
145A
125A
105A

FIG. 3

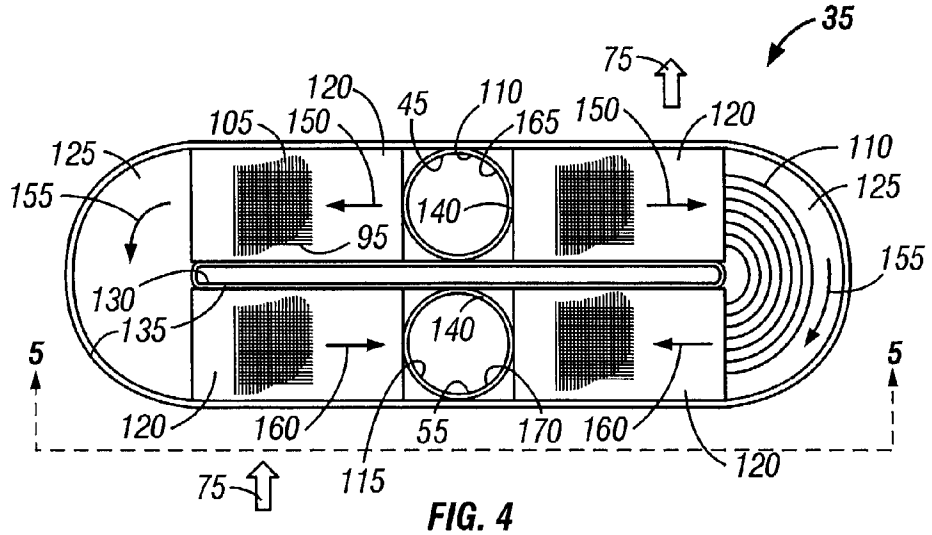

35
75
120
45
110
105
150
165
150
120
125
110
155
140
125
95
155
130
140
135
5
5
120
160
55
170
160
120
75
115

FIG. 4

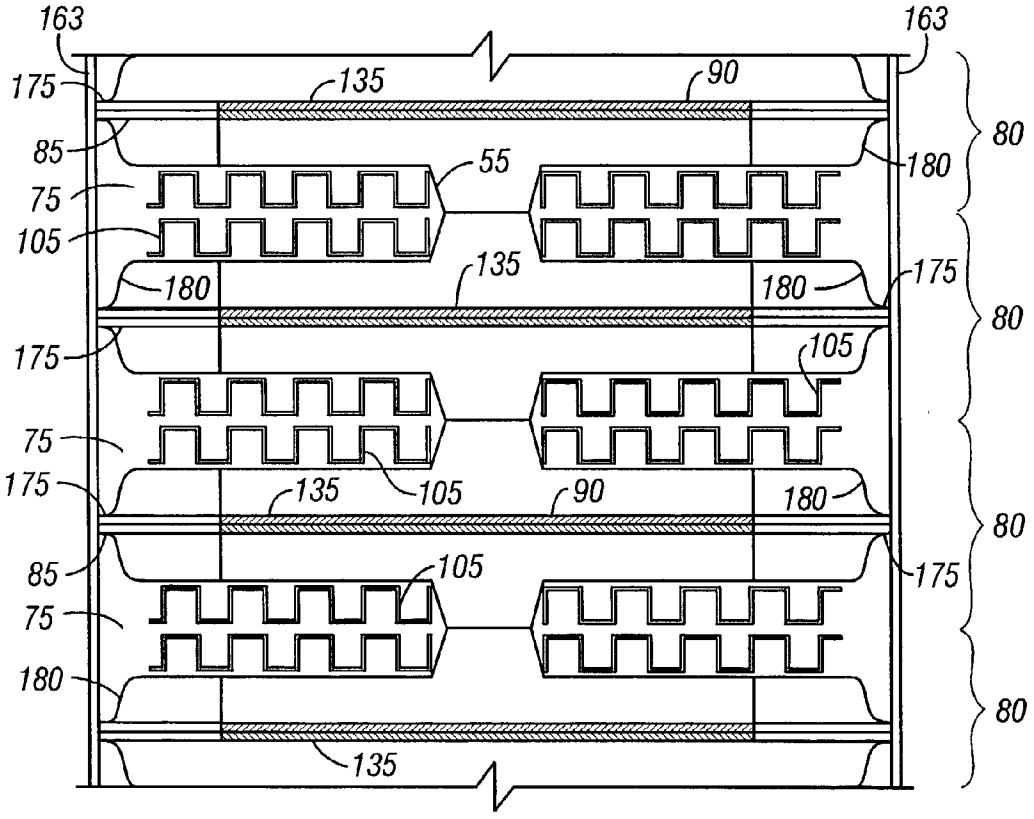

163
163
175
135
90
80
85
55
180
75
105
135
180
180
175
80
175
105
75
175
135
105
90
180
80
85
105
175
75
180
80
135

FIG. 5

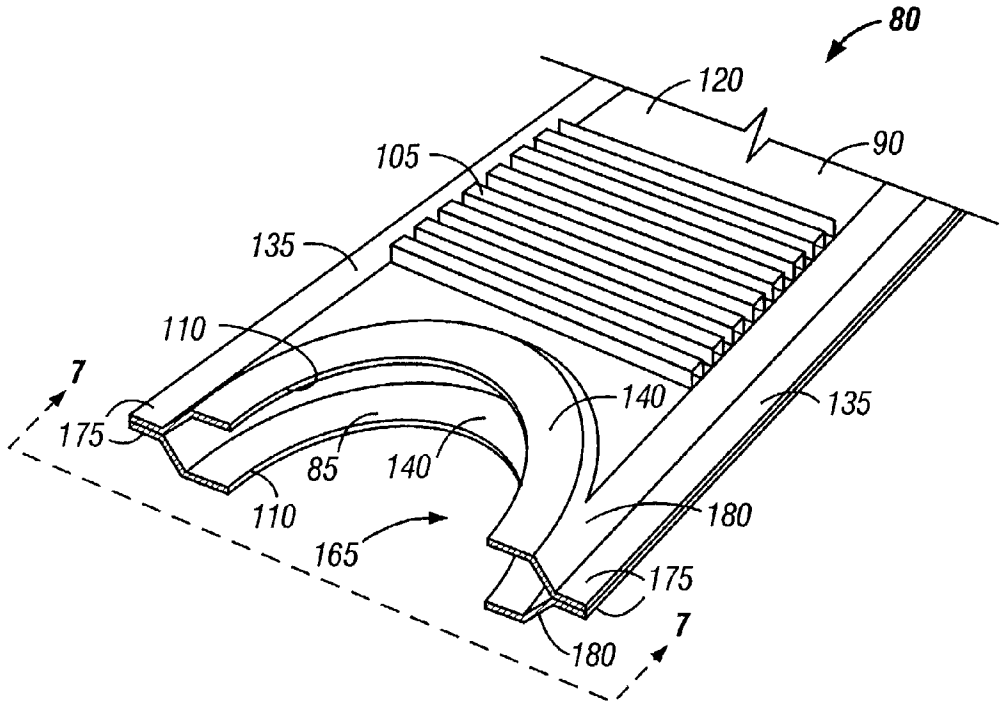

80
120
90
105
135
110
7
175
85
140
140
135
110
180
165
175
180
7

FIG. 6

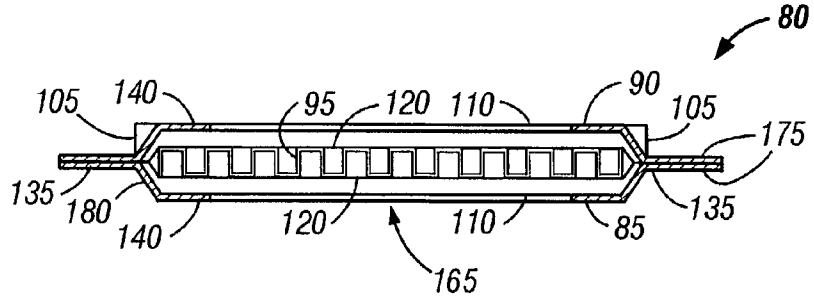

80
105
140
95
120
110
90
105
175
135
180
140
120
110
85
135
165

FIG. 7

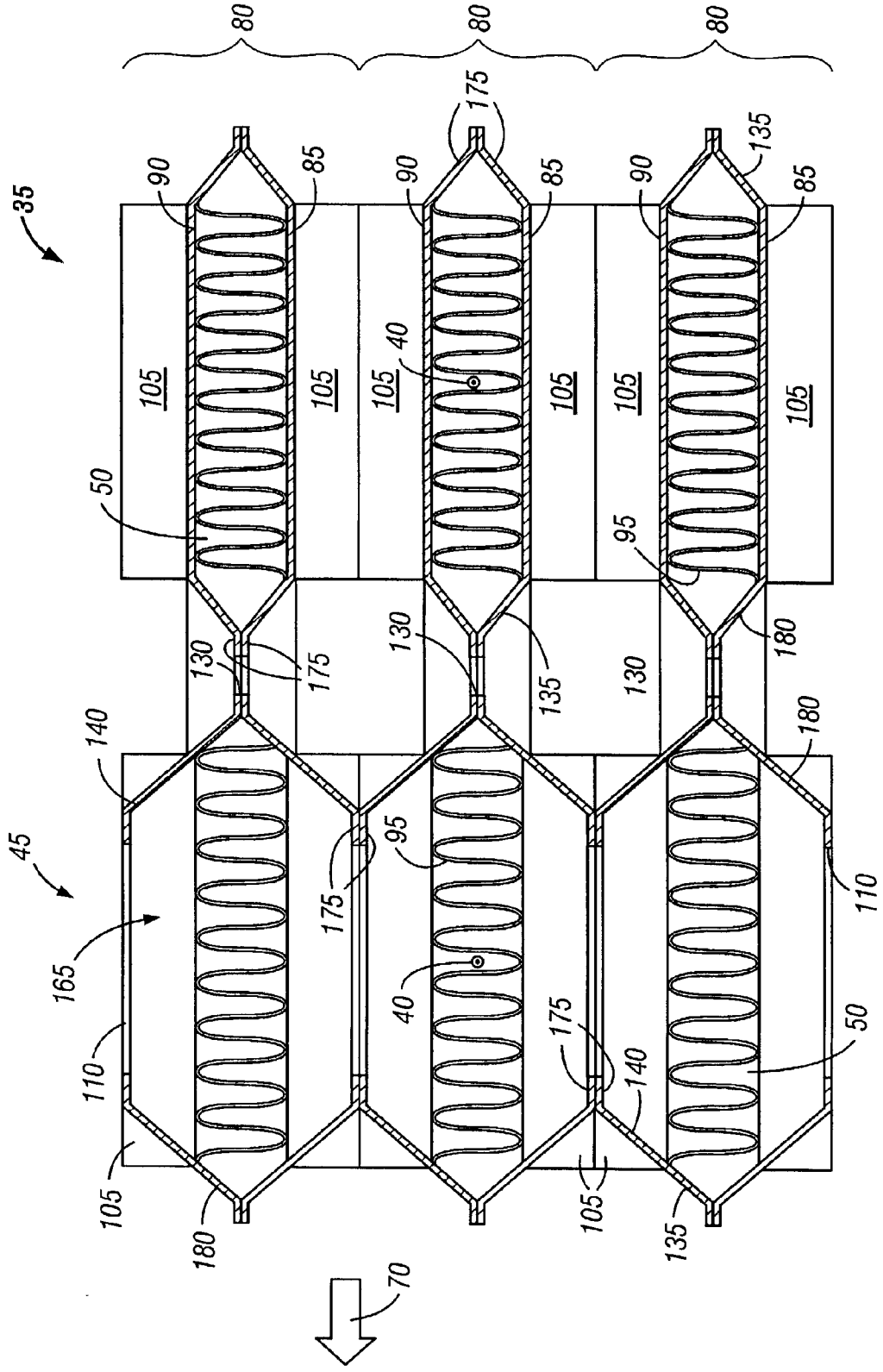

80
80
80
175
35
90
85
90
85
90
135
85
105
105
105
105
105
105
40
50
95
130
130
135
130
180
175
140
180
45
95
175
165
40
110
175
140
50
110
105
105
105
135
180
70

FIG. 8

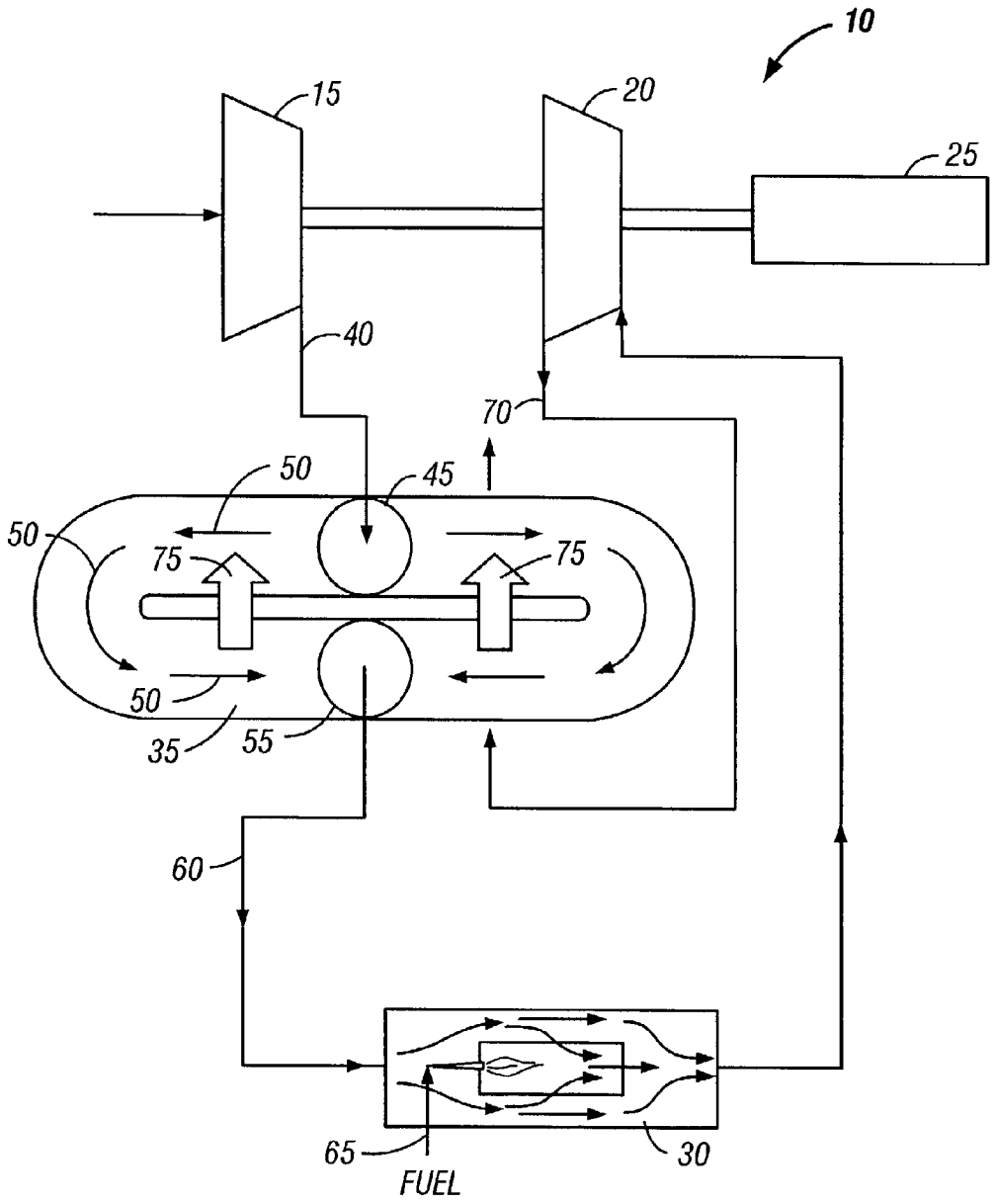



FIG. 9

# UNIT CELL U-PLATE-FIN CROSSFLOW HEAT EXCHANGER

## BACKGROUND AND SUMMARY OF THE INVENTION

[0001] The present invention relates to combustion turbine engines, and particularly to recuperated microturbine engines. More particularly, the present invention relates to recuperated microturbine engines employing plate-fin recuperators.

[0002] Recuperators are heat exchangers used to transfer heat from a hot fluid to a cold fluid. In the case of microturbine engines, the hot fluid is generally turbine exhaust gas while the cold fluid is generally compressed air exiting a compressor. The recuperator preheats the compressed air prior to combustion to improve the overall efficiency of the engine.

[0003] To maximize the efficiency of the engine, it is desirable to use the most effective recuperator possible. To that end, counterflow plate-fin type recuperators are often employed. However, counterflow plate-fin recuperators require inlet manifolds and outlet manifolds spaced apart from one another, increasing the complexity of the heat exchanger. In addition, the spaced apart manifolds reduce the amount of area that can be used for efficient heat exchange.

[0004] Crossflow heat exchangers are known to be less effective than counterflow heat exchangers. To improve crossflow heat exchanger effectiveness, one of the flows can make two or more passes across the other flow. One way to produce a multi-pass crossflow heat exchanger is to provide a U-shaped path for one of the flows. Tube-type heat exchangers that employ U-shaped tubes are known.

[0005] Thus, according to the present invention a heat exchanger for the exchange of heat between an internal fluid and an external fluid comprises at least two heat exchange cells. Each heat exchange cell includes a first plate having an outer surface, raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture. Each cell further includes a second plate including raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture. The inlet aperture of the first plate is aligned with the inlet aperture of the second plate to define a cell inlet and the outlet aperture of the first plate is aligned with the outlet aperture of the second plate to define a cell outlet. The heat exchange area of the first plate is aligned with the heat exchange area of the second plate to define an internal U-shaped flow path and the raised peripheral edges of the first plate connect to the raised peripheral edges of the second plate to substantially enclosing the U-shaped flow path between the first and second plate. An internal finned member is disposed within the internal U-shaped flow path and is attached to one of the first and second plates and an external finned member is connected to the outer surface of the first plate.

[0006] In preferred embodiments, the heat exchange cells include multiple finned members disposed within the U-shaped flow path to enhance the heat transfer efficiency.

[0007] In another preferred embodiment, the cell inlets align with one another and define an inlet manifold and the cell outlets align with one another to define an outlet manifold. The heat exchanger inlet manifold and outlet manifolds align with one another relative to the external fluid flow to maximize useable heat exchange space for a fixed volume. In addition, two separate and distinct U-shaped flow paths are provided to improve the heat exchanger effectiveness.

[0008] In still other preferred embodiments, the heat exchange cells include a slot disposed between the parallel flow regions of the U-shaped flow path. The slot separates the hottest portions of the heat exchanger area from the coolest portions.

[0009] Additional features and advantages will become apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments exemplifying the best mode of carrying out the invention as presently perceived.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The detailed description particularly refers to the accompanying figures in which:

[0011] **FIG. 1** is an exploded view of a heat exchange cell of a recuperator in accordance with the present invention;

[0012] **FIG. 2** is a cross sectional view taken along line **2-2** in **FIG. 1**, and illustrating several heat exchange cells;

[0013] **FIG. 3** is an exploded view of another embodiment of the heat exchange cell;

[0014] **FIG. 4** is a partially broken away top view of the recuperator of **FIG. 1**;

[0015] **FIG. 5** is a partial front view of the recuperator of **FIG. 4**, taken along line **5-5** in **FIG. 4**;

[0016] **FIG. 6** is a partial perspective view of a cell inlet of the heat exchange cell of **FIG. 1**;

[0017] **FIG. 7** is a cross sectional view taken along line **7-7** in **FIG. 6**;

[0018] **FIG. 8** is a cross sectional view taken along line **8-8** of **FIG. 1** and illustrating several heat exchange cells;

[0019] **FIG. 9** is a schematic representation of a recuperated microturbine engine in accordance with the present invention.

## DETAILED DESCRIPTION OF THE DRAWINGS

[0020] A recuperated microturbine engine **10** in accordance with the present invention is illustrated schematically in **FIG. 9**. The engine **10** includes a compressor **15**, a turbine **20**, a generator **25**, a combustor **30**, and a recuperator **35**. The turbine **20** includes a rotary element (not shown) that rotates in response to a flow of products of combustion. The turbine rotary element is coupled to a compressor rotary element (not shown) and to a generator rotary element (also not shown) or other driven device. The turbine rotation rotates the compressor rotary element to produce a supply of compressed gas **40**, typically air, and further rotates the generator rotary element to produce a current of electricity. There are many different arrangements of microturbine engines **10** including engines that employ two turbines, or engines that drive devices other than generators **25**. The present invention functions with any arrangement that uses

a turbine **20** and a flow of compressed gas **40**. Therefore, the invention should not be limited to the arrangement of **FIG. 9**.

[**0021**] In a recuperated microturbine engine **10**, the supply of compressed air **40** flows to a recuperator **35** or heat exchanger where it is preheated. The air enters the recuperator **35** through an inlet manifold **45**, flows along an internal flow path **50**, and exits the recuperator at an outlet manifold **55**. The preheated air **60** flows to the combustor **30** where it is combined with a fuel flow **65** and combusted to generate a flow of products of combustion. The products of combustion flow through the turbine **20** imparting rotational energy to the turbine rotary element, which in turn rotates the compressor rotary element to produce the flow of compressed air **40** and rotates the generator rotary element to generate electricity. The products of combustion leave the turbine **20** as a flow of exhaust gas **70**. The exhaust gas **70**, which is still quite hot, is directed through the recuperator **35** in an external flow path direction **75**, allowing heat transfer to the relatively cool compressed air stream **40** flowing along the internal flow path **50**. The exhaust gas **70** exits the recuperator **35** and is vented to the atmosphere or further processed as desired. The use of a recuperator **35** in the standard Brayton cycle allows for increased thermal efficiency, with the effectiveness of the recuperator **35** directly effecting the thermal efficiency of the cycle.

[**0022**] Referring to **FIGS. 1 and 2**, one construction of a heat exchange cell **80** includes a lower plate **85**, an upper plate **90**, a plurality of inner fin members **95**, two turning region fin members **100**, and a plurality of outer fin members **105**. The lower plate **85** defines an inlet aperture **110**, an outlet aperture **115**, heat exchange areas **120**, two turning regions **125**, and a slot **130**. The peripheral edges **135** surrounding the outside of the plates **85**, **90** and defining the slots **130** are raised toward the interior of the heat exchange cell **80**, as is best shown in **FIG. 2**. Interior edges **140** surround the inlet aperture **110** and the outlet aperture **115** and are raised away from the interior of the heat exchange cell **80**. The peripheral edges **135** and interior edges **140** will be discussed in greater detail below.

[**0023**] To assemble the heat exchange cell **80** of **FIG. 1**, inner fin members **95** first attach to the lower or upper plate **85**, **90** in the heat exchange area **120**. The inner fin members **95**, which are generally corrugated pieces of metal, define internal flow channels that guide the flow from the inlet aperture **110** to one of the turning regions **125**. Turning region fin members **100** attach to the lower or upper plates **85**, **90** at either end to turn the fluid and redirect it toward the outlet aperture **115**. Additional inner fin members **95** attach to the lower or upper plate **85**, **90** and receive the flow from the turning regions **125**. The inner fin members **95** guide the flow to the outlet aperture **115**. Thus, the arrangement illustrated in **FIG. 1** provides two separate and distinct U-shaped flow paths **145** within the heat exchange cell **80**. Each U-shaped flow path **145** includes an outbound flow leg **150**, a flow reversing leg **155**, and an inbound flow leg **160**. The second U-shaped flow path **145** is positioned so that the flow follows a path that is a substantial mirror image of the path followed by the flow within the first U-shaped flow path **145**.

[**0024**] The upper plate **90**, which is substantially identical to the lower plate **85**, is inverted and positioned relative to the lower plate **85** so that the inlet apertures **110**, outlet apertures **115**, and slots **130** align with one another. The peripheral edges **135** of the upper plate **90** contact the peripheral edges **135** of the lower plate **85**, thereby sandwiching the inner fin members **95** between the plates **85**, **90**. The peripheral edges **135** are connected to one another utilizing a suitable attachment method (e.g., welding, soldering, brazing, bolting, etc.) to seal all but the inlet apertures **110** and the outlet apertures **115**. The aligned inlet apertures **110** define a cell inlet **165** where fluid flow enters the two U-shaped flow paths **145** and the aligned outlet apertures **115** define a cell outlet **170** where fluid flows out of the two U-shaped flow paths **145**. The cell inlet defines an axis **11-11** that extends through the centers of the inlet apertures **110** from the lower plate **85** to the upper plate **90**. The cell outlet defines an axis **12-12** that extends through the centers of the outlet apertures **115** from the lower plate **85** to the upper plate **90**. The cell inlet and outlet axes are substantially parallel to each other and together define a plane that is substantially perpendicular to the flow channels defined by the inner fin member **95**.

[**0025**] The aligned slots **130** separate the outbound flow legs **150** and the inbound flow legs **160** of the U-shaped flow paths **145**. The exhaust gas **70** flowing through the recuperator **35** along exhaust gas flow direction **75** is at its hottest temperature when adjacent the inbound flow leg **160** and at its coolest temperature when adjacent to the outbound flow leg **150**. In response to these temperature differences and the thermal gradients created thereby, the heat exchange area **120** supporting the inbound flow leg **160** of the U-shaped flow paths **145** will have a tendency to thermally expand to a greater extent than the heat exchange area **120** supporting the outbound flow leg **150** of the U-shaped flow path **145**. This differential thermal expansion can result in large thermal stress levels and structural failure if left unchecked. The slot **130** separates the outbound flow legs **150** from the inbound flow legs **160** and allows the legs **150**, **160** to substantially independently expand, thereby reducing the thermal stress within the heat exchange cells **80**.

[**0026**] Outer fin members **105** attach to the outer surface **162** of the heat exchange cell **80** to define external flow channels that guide the flow of exhaust gas **70** around the outside of the heat exchange cell **80** and define the flow path **75**. The outer fin members **105** are generally corrugated metal pieces like the inner fin members **95**, however the outer fin member corrugations are turned approximately ninety degrees with respect to the corrugations of the inner fin members **95**. Thus, the outbound flow leg **150** and inbound flow leg **160** of the U-shaped flow paths **145** and the external flow path direction **75** are arranged in a generally crossflow orientation. While the construction of **FIG. 1** shows outer fin members **105** on both the top and bottom outer surfaces **162** of the heat exchange cell **80**, other constructions may use outer fin members **105** on only one of the top and bottom surface **162**.

[**0027**] Slot **130** is open to the exhaust gas flow and permits, the exhaust gas to travel vertically and into flow paths between different adjacent heat exchange cells **80**. This vertical flow is minimal due to the substantially even distribution of exhaust gas **70** and the substantially equal exhaust gas pressures between adjacent heat exchange cells **80**. To prevent leakage out of the top and bottom of the slot **130**, a housing or duct **163** (shown partially in **FIG. 5**)

surrounds the stack of heat exchange cells **80**. The duct **163** guides the flow of exhaust gas **70** into the recuperator **35** and simultaneously prevents leakage through the top and bottom of the stacked heat exchange cells **80**. The duct **163** also prevents exhaust gas from escaping from the recuperator **35** before it flows across the entire U-shaped flow path **145** of the recuperator **35**.

[**0028**] **FIG. 2** better illustrates the peripheral edges **135** and the inner fin members **95** of several heat exchange cells **80**. **FIG. 2** is a cross sectional view of **FIG. 1** taken along line **2-2** with three heat exchange cells **80** stacked on top of one another along a stackwise direction **13-13**. It should be understood that **FIG. 2** shows only three heat exchange cells **80** for clarity, and that many heat exchange cells **80** would be stacked on top of one another to complete a recuperator **35**. The inner fin members **95** illustrated in **FIG. 2** have a substantially sinusoidal cross-section. **FIG. 7** illustrates an inner fin member **95** having a square wave cross-section, rather than the sinusoidal section shown in **FIG. 2**. Fin members **95, 100, 105** with many other cross sections will also function with the invention (e.g., triangle-wave pattern, D-shape, W-shape, etc.). In fact, the present invention will function with any shape fin members **95, 100, 105** because the shape is likely to only influence the overall effectiveness of the recuperator.

[**0029**] The peripheral edges **135** of the upper plate **90** contact those of the lower plate **85** to facilitate connection of the plates **85, 90** and to substantially enclose the U-shaped flow path **145**. The peripheral edges **135** include an attachment portion **175** and an angled portion **180**. The angled portion **180** extends from the heat exchange area **120** to the attachment portion **175**, which is generally parallel to the heat exchange area **120** of the plate **85, 90**. The attachment portions **175** of the upper plate **90** and lower plate **85** contact one another and provide a convenient attachment location around the periphery of the heat exchange cell **80** and around the inside border of the slot **130**. Once sealed, the cell inlet **165** and the cell outlet **170** become the only entry and exit points to the U-shaped flow path **145**. The actual shape of the peripheral edges **135** is not critical to the function of the invention. Therefore, other shapes (e.g., Z-shaped, L-shaped, S-shaped, etc.) are contemplated and will function with the invention so long as they provide a convenient means of spacing the upper plate **90** heat exchange area **120** from the lower plate **85** heat exchange area **120** while attaching the plates **85, 90** to one another. For example, **FIG. 5** illustrates a construction of a recuperator **35** in which S-shaped peripheral edges **135** are employed.

[**0030**] Turning to **FIG. 3**, an alternative construction of a U-shaped heat exchange cell **80**A in accordance with the present invention is shown, wherein similar components are labeled with similar reference numerals and the extension "A". The heat exchange cell **80**A includes an upper plate **90**A, a lower plate **85**A, two inner fin members **95**A, a turning fin member **100**A and four outer fin members **105**A. The upper plate **90**A and lower plate **85**A are substantially similar to the upper plate **90** and lower plate **85** of **FIG. 2** with the exception of the inlet and outlet aperture **110**A, **115**A locations. Instead of positioning the apertures **110**A, **115**A away from the ends of the plates **85**A, **90**A to provide two distinct U-shaped paths **145**A, the present construction positions the inlet and outlet apertures **110**A, **115**A near one of the ends. The present construction thus provides a single U-shaped flow path **145**A. Each plate **85**A, **90**A includes a heat exchange area **120**A, a turning region **125**A, peripheral edges **135**A and apertures **110**A, **115**A having interior edges **140**A. The peripheral edges **135**A of the upper plate **90**A attach to the peripheral edges **135**A of the lower plate **85**A as described with respect to previous constructions to define a U-shaped flow path **145**A extending from the inlet aperture **110**A to the outlet aperture **115**A. The inner fin members **95**A and the turning fin member **100**A are sandwiched between the plates **85**A, **90**A and guide the flow along the U-shaped path **145**A while improving the effectiveness of the heat exchange cell **80**A. The outer fin members **105**A attach to the outer surface **162**A of the heat exchange cell **80**A to guide the flow of exhaust gas **70** across the U-shaped flow path **145**A and improve the effectiveness of the heat exchange cell **80**A.

[**0031**] **FIG. 4** is a top view of a recuperator **35** in accordance with the present invention, better illustrating the fin member **95, 105** orientations. The inner fin members **95** positioned within the individual heat exchange cells **80** extend generally from left to right to define the internal flow paths **50**. The outer fin members **105** positioned on the outer surfaces **162** of the individual heat exchange cells **80** extend generally from front to back and define the direction of flow of exhaust gas **75**. Thus, the heat exchanger of **FIG. 4** includes four distinct crossflow heat exchange areas **120**. The slot **130** separates the heat exchange areas **120** supporting the outbound flow leg **150** from the areas supporting the inbound flow leg **160** and the inlet manifold **45** and outlet manifold **55** separate the heat exchange areas **120** of the two U-shaped flow paths **145** from one another.

[**0032**] The turning regions **125** also perform some heat transfer and add to the overall effectiveness of the recuperator **35**. In fact, as the compressed air makes the turn in the turning regions **125**, it is closer to the more effective counterflow heat exchanger model.

[**0033**] **FIG. 4** also illustrates the alignment of the inlet and outlet manifolds **45, 55** relative to the direction of flow of exhaust gas **75**. By aligning the inlet and outlet manifolds **45, 55** the effective heat exchange area for a fixed length recuperator **35** is maximized, thereby improving the overall effectiveness of the recuperator **35**. The inlet and outlet manifold **45, 55** can be located at one end of the recuperator **35**A as illustrated in **FIG. 3** to maximize the useable length of a single flow U-shaped recuperator **35**A. However, the multiple path recuperator **35** is preferred, as it allows for reduced flow velocities within the U-shaped flow paths **145**, thereby improving the heat exchanger performance and reducing the pressure drop of the gas flowing through the internal flow path **50** (defined by the outbound flow leg **150**, flow reversing leg **155**, and the inbound flow leg **160**).

[**0034**] Turning to **FIGS. 6 and 7**, a perspective and end view of a cell inlet **165** in accordance with the present invention better illustrate the peripheral edges **135** and the aperture interior edges **140**. The heat exchange area **120** of the plates **85, 90** supports the outer fin members **105** as shown in **FIG. 6**. The peripheral edges **135** extend from the heat exchange area **120** toward the interior of the heat exchange cell **80**. The interior edges **140**, on the other hand, extend from the heat exchange area **120** of the plate **85, 90** away from the interior of the heat exchange cell **80**. This arrangement allows each heat exchange cell **80** to sandwich

an inner fin member **95** between the heat exchange areas **120** of the upper plate **90** and lower plate **85** as shown in **FIG. 7**. In addition, the raised interior edges **140** provide for sufficient space between adjacent heat exchange cells **80** to accommodate one or more outer fin members **105** as shown in **FIG. 6**.

[**0035**] **FIG. 8** illustrates the interior edges **140** of adjacent cell inlets **165** attached to one another in a manner similar to that described above with regard to the peripheral edges **135**. The interior edges **140** contact one another, thereby providing sufficient space between the adjacent heat exchange cells **80** for the outer fin members **105**. Like the peripheral edges **135**, any suitable attachment method can be used, however welding is preferred. In other constructions (not shown), support members located away from the inlet and outlet manifolds **45**, **55** provide additional support to the adjacent heat exchange cells **80**. The support members attach to adjacent heat exchange cells **80** to maintain the desired gap between adjacent heat exchange cells **80**, while still allowing free expansion and contraction in response to temperature changes.

[**0036**] It should be noted that the figures contained herein are meant to further clarify the reader's understanding of the invention. To that end, many features are exaggerated or shown out of scale for the sake of clarity. For example, the plates **85**, **90** are shown as having a substantial thickness when compared to the fin members **95**, **105**. In practice, the plates **85**, **90** as well as the fin members **95**, **105** would be as thin as practicable to facilitate more rapid heating and improved heat transfer. Therefore, the drawings should not be interpreted as limiting the scope of the invention in any way.

[**0037**] Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of the invention as described and defined in the following claims.

What is claimed is:

**1**. A heat exchanger comprising at least two heat exchange cells for the exchange of heat between an internal fluid and an external fluid, each heat exchange cell comprising:

a first plate having an outer surface, raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture;

a second plate including raised peripheral edges, an inlet aperture, an outlet aperture, and a heat exchange area extending between the inlet aperture and the outlet aperture, the inlet aperture of the first plate aligned with the inlet aperture of the second plate to define a cell inlet, the outlet aperture of the first plate aligned with the outlet aperture of the second plate to define a cell outlet, the heat exchange area of the first plate aligned with the heat exchange area of the second plate to define an internal U-shaped flow path, and the raised peripheral edges of the first plate connected to the raised peripheral edges of the second plate to substantially enclose the U-shaped flow path between the first and second plates;

an internal finned member disposed within the internal U-shaped flow path, and attached to one of the first and second plates, the internal finned member defining flow channels; and

an external finned member connected to the outer surface of the first plate.

**2**. The heat exchanger of claim 1, wherein the heat exchange cells are stacked on top of one another and the external finned member is disposed between adjacent heat exchange cells, the external finned member defining flow channels oriented substantially perpendicular to the flow channels of the internal finned member.

**3**. The heat exchanger of claim 1, wherein each cell inlet defines an inlet axis and each cell outlet defines an outlet axis, the inlet and outlet axes defining a plane substantially perpendicular to the internal flow channels.

**4**. The heat exchanger of claim 1, wherein each of the heat exchange cells includes a turning region receiving a flow of the internal fluid from the internal finned member and redirecting the flow in substantially the opposite direction to the cell outlet.

**5**. The heat exchanger of claim 1, wherein the first and second plates further define a slot within each plate, the slots having raised peripheral edges connected to one another to at least partially enclose the U-shaped flow path.

**6**. The heat exchanger of claim 1, wherein the heat exchange area of the first plate and the heat exchange area of the second plate align with one another to define two U-shaped flow paths providing two distinct flow paths that substantially mirror one another.

**7**. The heat exchanger of claim 6, wherein the cell inlet and the cell outlet are disposed between the two U-shaped flow paths.

**8**. A heat exchanger for the exchange of heat between an internal fluid and an external fluid, the heat exchanger comprising:

a plurality of heat exchange cells stacked in a stackwise direction, each cell including first and second plates, each plate having peripheral edges raised in a first direction, an inlet aperture having internal edges raised in a second direction substantially opposite the first direction, an outlet aperture having internal edges raised in the second direction, and a heat exchange area extending between the inlet aperture and the outlet aperture, the second plate being inverted with respect to the first plate such that the inlet aperture of the first plate aligns with the inlet aperture of the second plate to define a cell inlet, the outlet aperture of the first plate aligns with the outlet aperture of the second plate to define a cell outlet, the heat exchange area of the first plate aligns with the heat exchange area of the second plate to define an internal U-shaped flow path, and the peripheral edges of the first plate connect to the peripheral edges of the second plate to substantially enclose the U-shaped flow path;

wherein the inlet internal edges of adjacent heat exchange cells align with and are connected to one another to define an inlet manifold and the outlet internal edges of adjacent heat exchange cells align with and are connected to one another to define an outlet manifold.

**9**. The heat exchanger of claim 8, wherein the U-shaped flow path further includes a turning region, a first flow leg extending in a first flow direction from the cell inlet to the

turning region, and a second flow leg extending in a second flow direction from the turning region to the cell outlet, the second flow direction substantially opposite the first flow direction.

**10**. The heat exchanger of claim 9, further comprising a first internal finned member disposed within the first flow leg, a second internal finned member disposed within the second flow leg, and a turning finned member disposed within the turning region.

**11**. The heat exchanger of claim 8, wherein the heat exchange cells include a top surface and a bottom surface and wherein a first external finned member is connected to one of the top surface and bottom surface.

**12**. The heat exchanger of claim 11, wherein each cell inlet defines an inlet axis extending from the first plate to the second plate and each cell outlet defines an outlet axis extending from the first plate to the second plate, the inlet and outlet axes defining a plane substantially parallel to the external flow channels.

**13**. The heat exchanger of claim 8, wherein the first and second plates further define a slot within each plate, the slots having raised peripheral edges connected to one another to at least partially enclose the U-shaped flow path.

**14**. The heat exchanger of claim 8, wherein the internal U-shaped flow path within each heat exchange cell is a first internal U-shaped flow path, and wherein the first plate and the second plate further define a second internal U-shaped flow path that is a substantial mirror image of the first U-shaped flow path.

**15**. A recuperated combustion turbine engine comprising:

a compressor operable to produce a flow of compressed gas;

a combustor receiving the flow of compressed gas and combusting it with a flow of fuel to produce a flow of products of combustion;

a turbine receiving the flow of products of combustion and discharging an exhaust gas, the turbine operable under the influence of the flow of products of combustion therethrough; and

a plate-fin heat exchanger having a plurality of heat exchange cells stacked in a stackwise direction, each heat exchange cell including first and second plates having raised peripheral edges connected to one another to define an inner U-shaped flow path, a cell inlet, and a cell outlet, each heat exchange cell including a finned member connected to one of the first and second plates and disposed within the inner U-shaped flow path to define internal flow channels;

wherein the flow of exhaust gas passes through the heat exchanger along a first flow path between adjacent heat exchange cells and the flow of compressed gas passes through the heat exchanger along the U-shaped flow path within the heat exchange cells.

**16**. The engine of claim 15, wherein each U-shaped flow path further includes a turning region, a first flow leg extending in a first flow direction from the cell inlet to the turning region, and a second flow leg extending in a second flow direction substantially opposite the first flow direction from the turning region to the cell outlet.

**17**. The engine of claim 16, wherein the finned member is a first finned member disposed within the first flow leg, each heat exchange cell further including a second internal finned member disposed within the second flow leg, and a turning finned member disposed within the turning region.

**18**. The engine of claim 15, wherein the heat exchange cells include a top surface and a bottom surface and wherein a first external finned member is connected to one of the top surface and bottom surface to define external flow channels substantially perpendicular to the internal flow channels.

**19**. The engine of claim 15, wherein the cell inlets of adjacent heat exchange cells are aligned and attached to one another to define an inlet manifold and cell outlets of adjacent heat exchange cells are aligned and attached to one another to define an outlet manifold.

**20**. The engine of claim 15, wherein each cell inlet defines an inlet axis and each cell outlet defines an outlet axis, the inlet and outlet axes defining a plane substantially perpendicular to the internal flow channels.

**21**. The engine of claim 15, wherein the first and second plates further define a slot within each plate, the slots having raised peripheral edges connected to one another to at least partially enclose the U-shaped flow path.

**22**. The engine of claim 15, wherein the U-shaped flow path within each heat exchange cell is a first U-shaped flow path, and wherein the first plate and the second plate define a second U-shaped flow path that is a substantial mirror image of the first U-shaped flow path.

* * * * *