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(54) **FOLDED TUBE MULTIPLE BANK HEAT EXCHANGE UNIT**

(71) Applicant: **CARRIER CORPORATION**, Farmington, CT (US)

(72) Inventor: **Michael F. Taras**, Fayetteville, NY (US)

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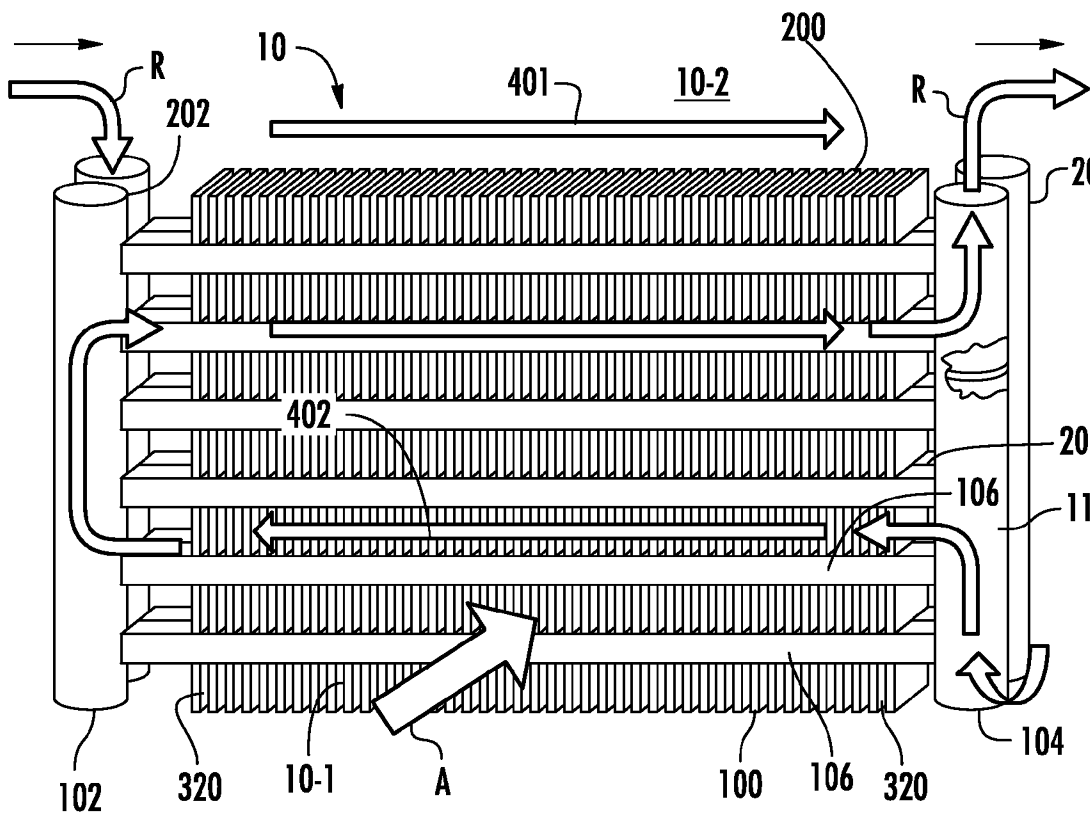
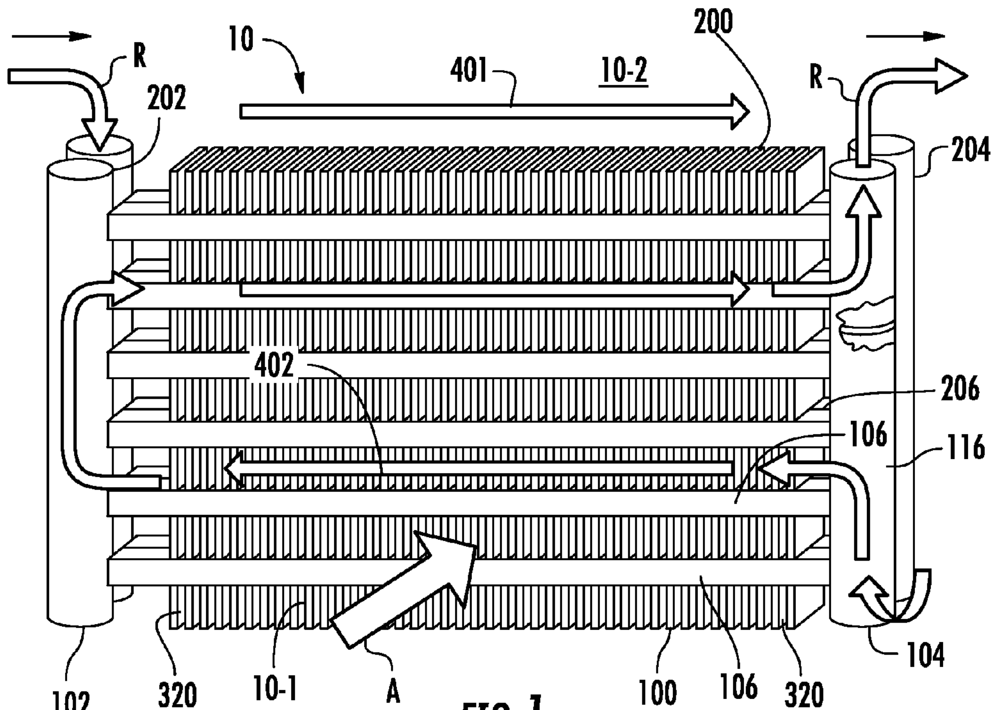
CPC ***F28F 1/12*** (2013.01); ***F28F 9/02*** (2013.01)

(57) **ABSTRACT**

A multiple bank, flattened tube heat exchange unit includes a first tube bank including a flattened first tube segment extending longitudinally between a first manifold and a second manifold; and a second tube bank including a flattened second tube segment extending longitudinally between the first manifold and the second manifold, the second tube bank disposed behind the first tube bank; wherein an outer surface of the first tube segment and an outer surface of the second tube segment are formed from a single sheet of material.





R
10
401
10-2
200
R
202
204
402
206
106
116
102
320
10-1
A
100
106
320
104

FIG. 1

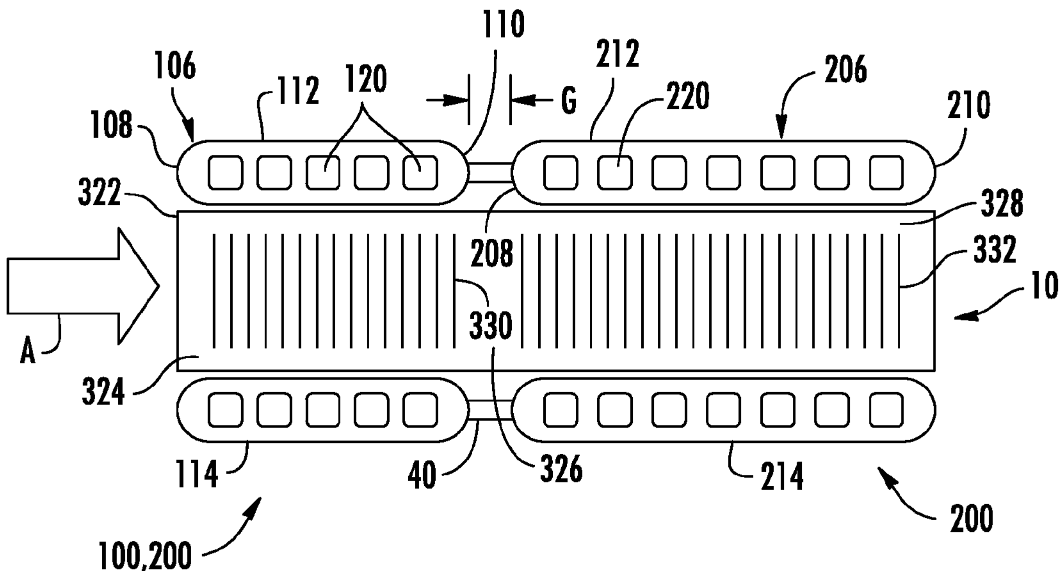

110
106
112
120
G
212
220
206
210
108
322
328
208
332
10
330
A
324
114
40
326
214
200
100,200

FIG. 2

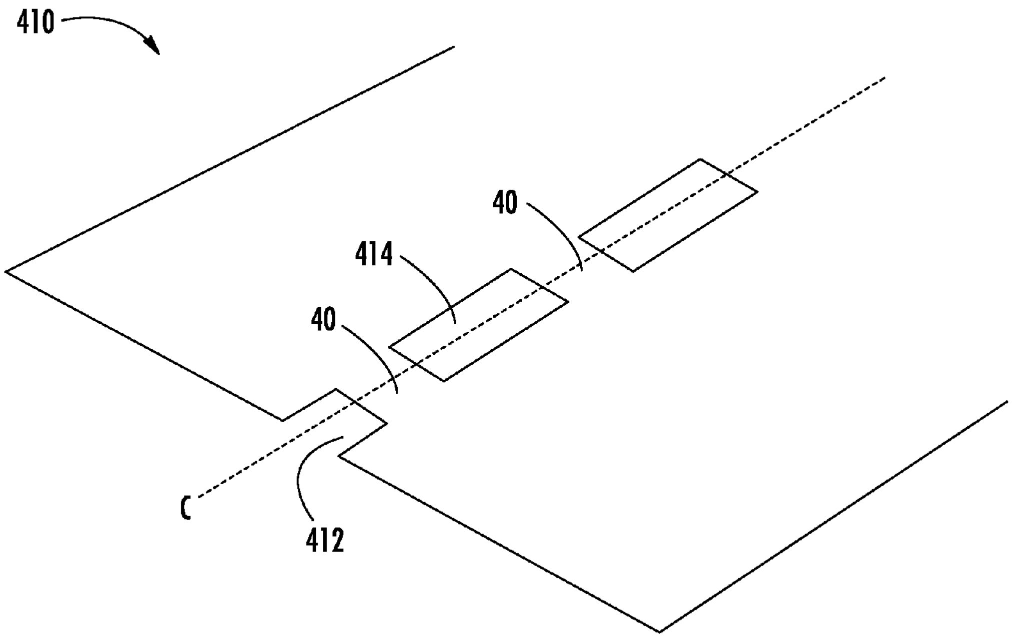


FIG. 3

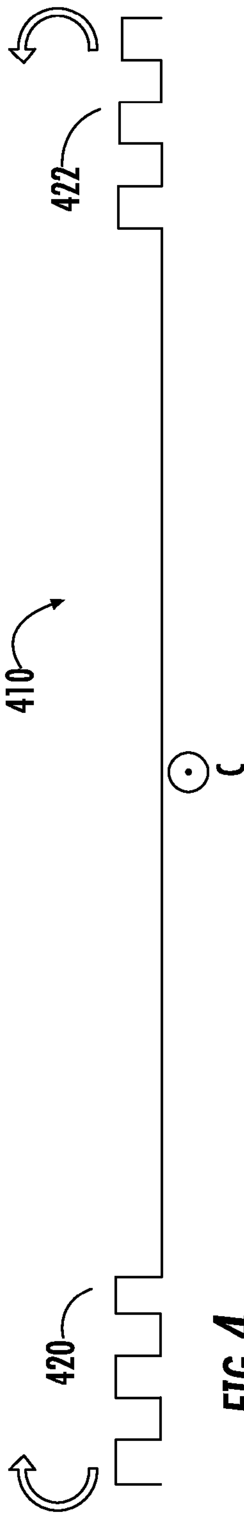


FIG. 4

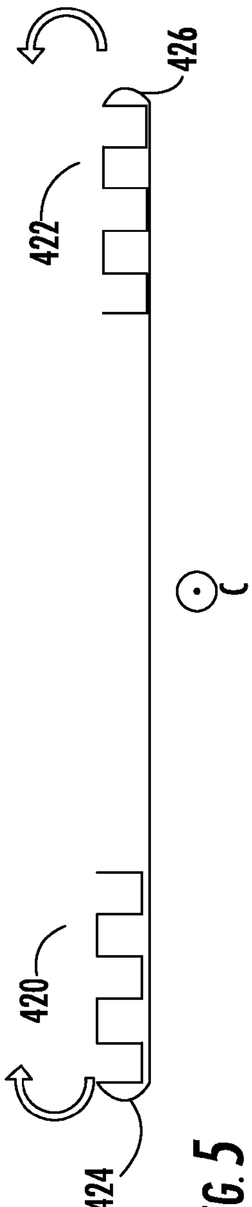


FIG. 5

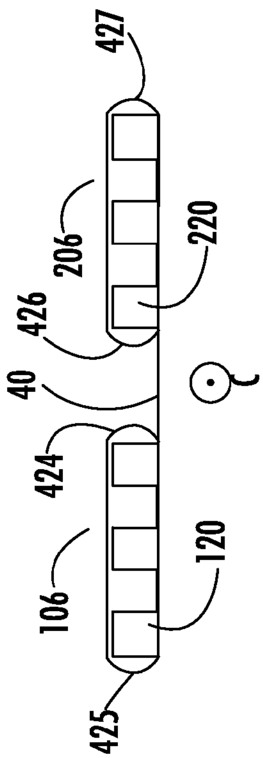


FIG. 6

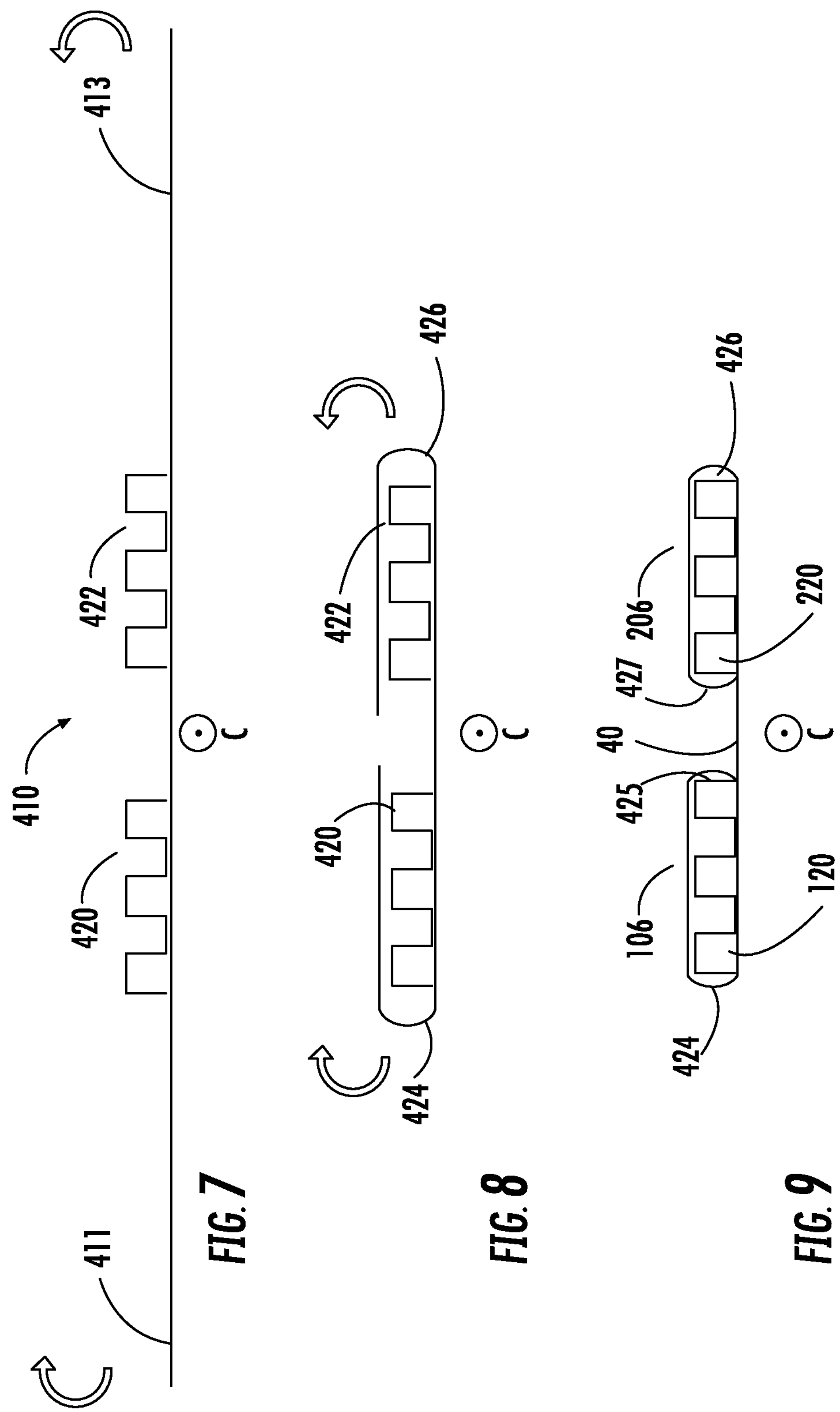


FIG. 7

FIG. 8

FIG. 9

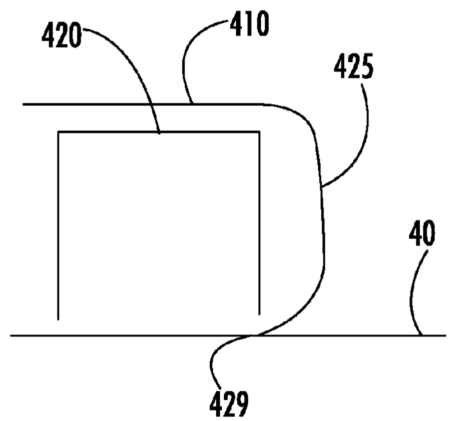


FIG. 10

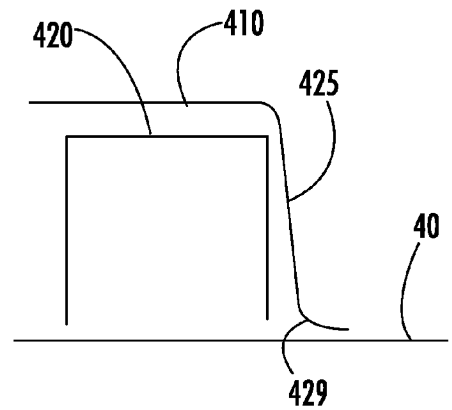


FIG. 11

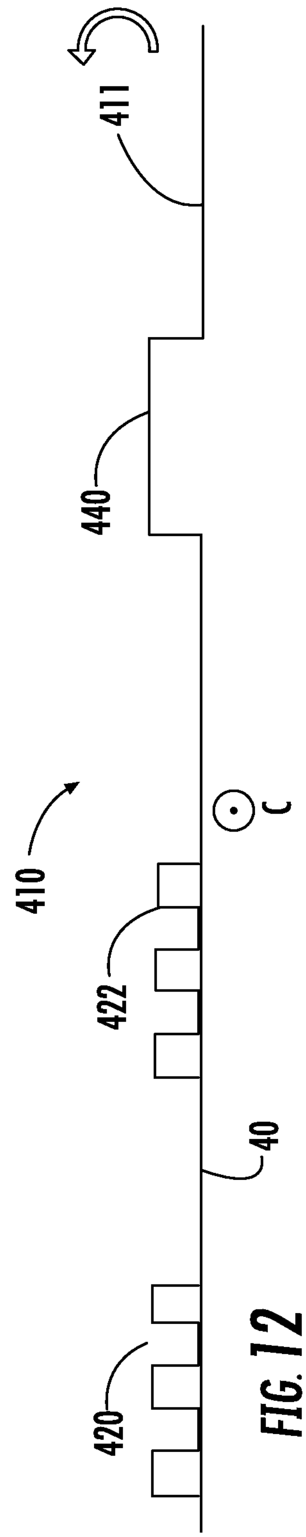


FIG. 12

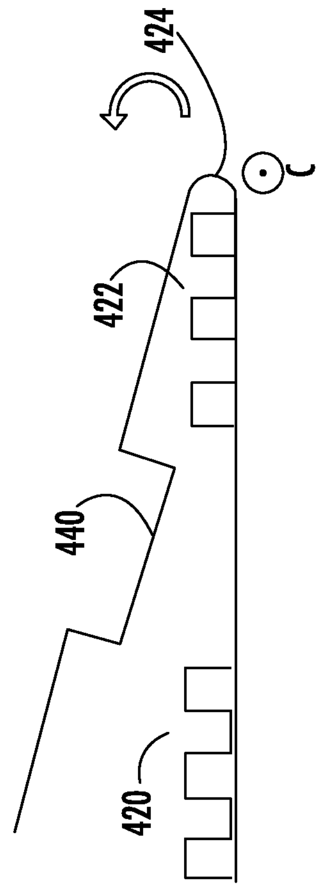


FIG. 13

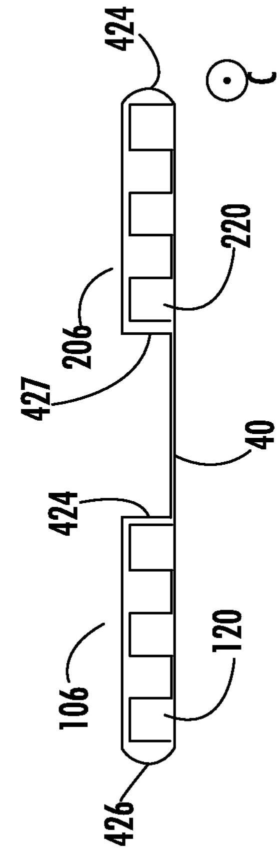


FIG. 14

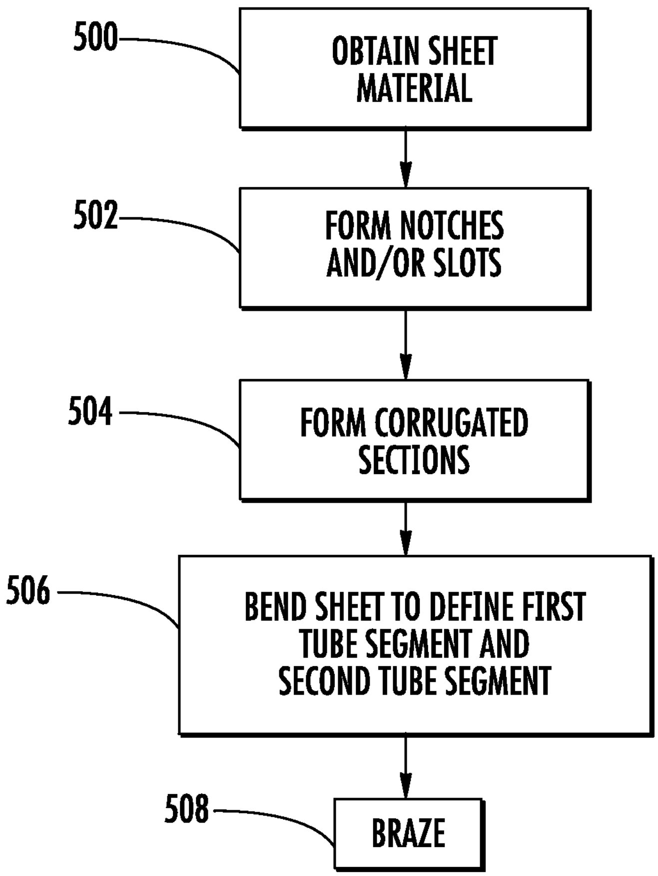

500
OBTAIN SHEET MATERIAL
502
FORM NOTCHES AND/OR SLOTS
504
FORM CORRUGATED SECTIONS
506
BEND SHEET TO DEFINE FIRST TUBE SEGMENT AND SECOND TUBE SEGMENT
508
BRAZE

FIG. 15

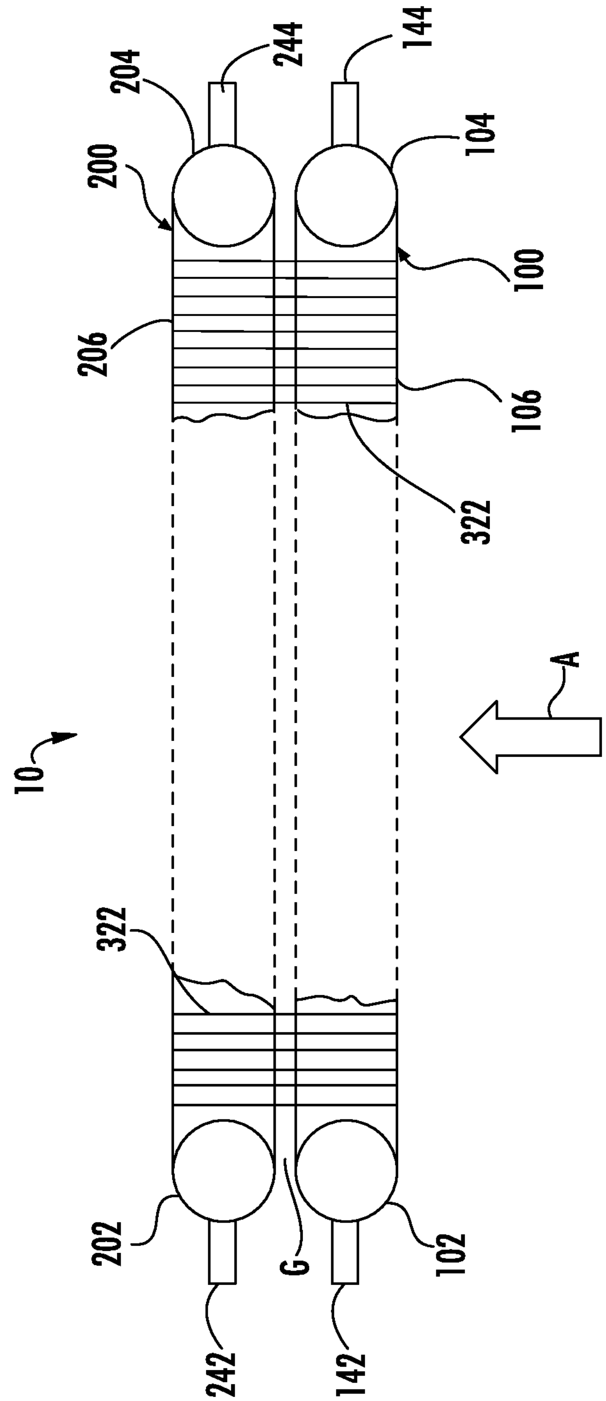


FIG. 16

FOLDED TUBE MULTIPLE BANK HEAT EXCHANGE UNIT

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to heat exchangers and, more particularly, to a folded tube multiple bank heat exchange unit.

[0002] Heat exchangers have long been used as evaporators and condensers in heating, ventilation, air conditioning and refrigeration (HVACR) applications. Historically, these heat exchangers have been round tube and plate fin (RTPF) heat exchangers. However, all aluminum flattened tube serpentine fin heat exchangers are finding increasingly wider use in industry, including the HVACR industry, due to their compactness, thermal-hydraulic performance, structural rigidity, lower weight and reduced refrigerant charge, in comparison to conventional RTPF heat exchangers. Flattened tubes commonly used in HVACR applications typically have an interior subdivided into a plurality of parallel flow channels. Such flattened tubes are commonly referred to in the art as multichannel tubes, mini-channel tubes or micro-channel tubes. Flattened tube serpentine fin heat exchangers may include a single tube bank of flattened tubes and two or multiple tube banks of flattened tubes.

[0003] Existing manufacturing techniques for flattened tubes involve an extrusion process. The extrusion process is costly and often requires specialty manufacturing equipment, often complicating the supply chain. Furthermore, the extrusion process is limited to certain class of aluminum alloys, due to manufacturing limitations and production cost, often detrimentally affecting corrosion durability of the flattened tube and the entire heat exchanger. There also exist techniques for forming a folded, single bank flattened tube from sheet material.

SUMMARY OF THE INVENTION

[0004] In an aspect, a multiple bank, flattened tube heat exchange unit includes a first tube bank including a flattened first tube segment extending longitudinally between a first manifold and a second manifold; and a second tube bank including a flattened second tube segment extending longitudinally between the first manifold and the second manifold, the second tube bank disposed behind the first tube bank; wherein an outer surface of the first tube segment and an outer surface of the second tube segment are formed from a single sheet of material.

[0005] In another aspect, a method of forming a multiple bank, flattened tube heat exchange unit includes obtaining a single sheet of material, the single sheet of material having a longitudinal axis; bending a first portion of the single sheet of material towards the longitudinal axis to define an outer surface of a first tube segment; and bending a second portion of the single sheet of material towards the longitudinal axis to define an outer surface of a second tube segment.

[0006] In another aspect, a method of forming a multiple bank, flattened tube heat exchange unit includes obtaining a single sheet of material, the single sheet of material having a longitudinal axis; and bending a first portion of the single sheet of material towards the longitudinal axis to define an outer surface of a first tube segment and define an outer surface of a second tube segment.

[0007] Other aspects, features, and techniques of embodiments of the invention will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For further understanding of the disclosure, reference will be made to the following detailed description which is to be read in connection with the accompanying drawing, where:

[0009] FIG. **1** is a diagrammatic illustration of an exemplary embodiment of a multiple tube bank, flattened tube finned heat exchange unit;

[0010] FIG. **2** is a side elevation view, partly in section, illustrating an exemplary embodiment of a fin and a set of integral flattened tube segments of the heat exchange unit of FIG. **1**;

[0011] FIG. **3** depicts a sheet of material for forming a first tube segment and a second tube segment in an exemplary embodiment;

[0012] FIGS. **4-6** depict forming a first tube segment and a second tube segment in an exemplary embodiment;

[0013] FIGS. **7-9** depict forming a first tube segment and a second tube segment in an exemplary embodiment;

[0014] FIGS. **10-11** depict an orientation of an edge of sheet material in exemplary embodiments;

[0015] FIGS. **12-14** depict forming a first tube segment and a second tube segment in an exemplary embodiment;

[0016] FIG. **15** is a flowchart of a process of forming a first tube segment and a second tube segment in an exemplary embodiment; and

[0017] FIG. **16** is a top down view of a heat exchange unit in an exemplary embodiment.

DETAILED DESCRIPTION

[0018] An exemplary embodiment of a multiple bank flattened tube finned heat exchange unit in accordance with the disclosure, generally designated **10**, is depicted in perspective illustration in FIG. **1**. As depicted therein, the multiple bank flattened tube finned heat exchange unit **10** includes a first tube bank **100** and a second tube bank **200** that is disposed behind the first tube bank **100**, that is downstream with respect to air flow, A, through the heat exchanger. The first tube bank **100** may also be referred to herein as the front heat exchanger slab **100** and the second tube bank **200** may also be referred to herein as the rear heat exchanger slab **200**.

[0019] The first tube bank **100** includes a first manifold **102**, a second manifold **104** spaced apart from the first manifold **102**, and a plurality of heat exchange tube segments **106**, including at least a first and a second tube segment, extending longitudinally in spaced parallel relationship between and connecting the first manifold **102** and the second manifold **104** in fluid communication. The second tube bank **200** includes a first manifold **202**, a second manifold **204** spaced apart from the first manifold **202**, and a plurality of heat exchange tube segments **206**, including at least a first and a second tube segment, extending longitudinally in spaced parallel relationship between and connecting the first manifold **202** and the second manifold **204** in fluid communication. Each set of manifolds **102**, **202** and **104**, **204** disposed at either side of the dual bank heat exchanger **10** may comprise separate paired manifolds, may comprise separate chambers within an integral one-piece folded manifold assembly or may comprise separate chambers within an integral fabricated (e.g. extruded, drawn, rolled and welded) manifold assembly. Each tube bank **100**, **200** may further include "dummy" tubes (not shown) extending between its first and second manifolds typically at the top of the tube bank and at the bottom of the tube bank. These "dummy" tubes do not convey refrigerant flow, but add structural support to the tube bank and protect the uppermost and lowermost fins.

[0020] Referring now to FIG. **2**, each of the heat exchange tube segments **106**, **206** comprises a flattened heat exchange tube having a leading edge **108**, **208**, a trailing edge **110**, **210**, an upper surface **112**, **212**, and a lower surface **114**, **214**. The leading edge **108**, **208** of each heat exchange tube segment **106**, **206** is upstream of its respective trailing edge **110**, **210** with respect to airflow through the heat exchange unit **10**. In the embodiment depicted in FIG. **2**, the respective leading and trailing portions of the flattened tube segments **106**, **206** are rounded thereby providing blunt leading edges **108**, **208** and trailing edges **110**, **210**. However, it is to be understood that the respective leading and trailing portions of the flattened tube segments **106**, **206** may be formed in other configurations.

[0021] The interior flow passage of each of the heat exchange tube segments **106**, **206** of the first and second tube banks **100**, **200**, respectively, may be divided by interior walls into a plurality of discrete flow channels **120**, **220** that extend longitudinally the length of the tube segment from an inlet end of the tube segment to an outlet end of the tube segment and establish fluid communication between the respective headers of the first and the second tube banks **100**, **200**. In the embodiment of the multi-channel heat exchange tube segments **106**, **206** depicted in FIG. **2**, the heat exchange tube segments **206** of the second tube bank **200** have a greater width than the heat exchange tube segments **106** of the first tube bank **100**. Also, the interior flow passages of the wider heat exchange tube segments **206** may be divided into a greater number of discrete flow channels **220** than the number of discrete flow channels **120** into which the interior flow passages of the heat exchange tube segments **106** are divided. The flow channels **120**, **220** may have a circular cross-section, a rectangular cross-section or other non-circular cross-section.

[0022] The second tube bank **200**, i.e. the rear heat exchanger slab, is disposed behind the first tube bank **100**, i.e. the front heat exchanger slab, with respect to the airflow direction, with each heat exchange tube segment **106** directly aligned with a respective heat exchange tube segment **206** and with the leading edges **208** of the heat exchange tube segments **206** of the second tube bank **200** spaced from the trailing edges **110** of the heat exchange tube segments of the first tube bank **100** by a desired spacing, G.

[0023] In the embodiment depicted in FIG. **2**, an elongated web **40** or a plurality of spaced web members **40** span the desired spacing, G, along at least of portion of the length of each aligned set of heat exchange tube segments **106**, **206**. For a further description of a dual bank, flattened tube finned heat exchanger unit wherein the heat exchange tubes **106** of the first tube bank **100** and the heat exchange tubes **206** of the second tube bank **200** are connected by an elongated web or a plurality of web members, reference is made to U.S. provisional application Ser. No. 61/593,979, filed Feb. 2, 2012, the entire disclosure of which is hereby incorporated herein by reference.

[0024] Referring still to FIGS. **1** and **2**, the flattened tube finned heat exchange unit **10** disclosed herein further includes a plurality of folded fins **320**. Each folded fin **320** is formed of a single continuous strip of fin material tightly folded in a ribbon-like serpentine fashion thereby providing a plurality of closely spaced fins **322** that extend generally orthogonal to the flattened heat exchange tube segments **106**, **206**. Typically, the fin density of the closely spaced fins **322** of each continuous folded fin **320** may be about 16 to 25 fins per inch, but higher or lower fin densities may also be used. Heat exchange between the refrigerant flow, R, and air flow, A, occurs through the outside surfaces **112**, **114** and **212**, **214**, respectively, of the heat exchange tube segments **106**, **206**, collectively forming the primary heat exchange surface, and also through the heat exchange surface of the fins **322** of the folded fin **320**, which forms the secondary heat exchange surface.

[0025] In the depicted embodiment, the depth of each of the ribbon-like folded fin **320** extends at least from the leading edge **108** of the first tube bank **100** to the trailing edge of **210** of the second bank **200**, and may overhang the leading edge **108** of the first tube bank **100** or/and trailing edge **210** of the second tube bank **200** as desired. Thus, when a folded fin **320** is installed between a set of adjacent multiple tube, flattened heat exchange tube assemblies in the array of tube assemblies of the assembled heat exchange unit **10**, a first section **324** of each fin **322** is disposed within the first tube bank **100**, a second section **326** of each fin **322** spans the spacing, G, between the trailing edge **110** of the first tube bank **100** and the leading edge **208** of the second tube bank **200**, and a third section **328** of each fin **322** is disposed within the second tube bank **200**. In an embodiment, each fin **322** of the folded fin **320** may be provided with louvers **330**, **332** formed in the first and third sections, respectively, of each fin **322**.

[0026] The multiple bank, flattened tube heat exchange unit **10** disclosed herein is depicted in a cross-counterflow arrangement wherein refrigerant (labeled "R") from a refrigerant circuit (not shown) of a refrigerant vapor compression system (not shown) passes through the manifolds and heat exchange tube segments of the tube banks **100**, **200**, in a manner to be described in further detail hereinafter, in heat exchange relationship with a cooling media, most commonly ambient air, flowing through the airside of the heat exchanger **10** in the direction indicated by the arrow labeled "A" that passes over the outside surfaces of the heat exchange tube segments **106**, **206** and the surfaces of the folded fins **320**. The air flow first passes transversely across the upper and lower horizontal surfaces **112**, **114** of the heat exchange tube segments **106** of the first tube bank, and then passes transversely across the upper and lower horizontal surfaces **212**, **214** of the heat exchange tube segments **206** of the second tube bank **200**. The refrigerant passes in cross-counterflow arrangement to the airflow, in that the refrigerant flow passes first through the second tube bank **200** and then through the first tube bank **100**. The multiple tube bank, flattened tube finned heat exchange unit **10** having a cross-counterflow circuit arrangement yields superior heat exchange performance, as compared to the crossflow or cross-parallel flow circuit arrangements, as well as allows for flexibility to manage the refrigerant side pressure drop via implementation of tubes of various widths within the first tube bank **100** and the second tube bank **200**.

[0027] A method of manufacturing heat exchange tube segments **106**, **206** and at least one web **40** is described with reference to FIGS. **3-6**. The manufacturing method includes folding a sheet of stock material to define tube segments **106**, 206 and at least one web 40. FIG. 3 depicts a sheet 410 of stock material such as a metal (e.g., aluminum). Sheet 410 may be clad on both sides with a brazing alloy. The sheet 410 is stamped or punched to define a notch 412 along a lateral edge of the sheet 410. A notch 412 may be formed at each distal end, or lateral edge, of sheet 410. Notches 412 define how deep first tube segment 106 and second tube segment 206 can be inserted into manifolds 102, 104, 202 and 204. Slots 414 are also stamped or punched from sheet 410. Slots 414 promote water drainage (e.g., condensate drainage) and prevent thermal cross-conduction between first tube segments 106 and second tube segments 206. Slots 414 are formed in the interior of sheet 410, intermediate the distal ends of sheet 410. Notches 412 and slots 414 are formed along a central, longitudinal axis of sheet 410. The remaining material along longitudinal axis, C, are webs 40, that join the first tube segment 106 and second tube segment 206. It is understood that axis C need not be centrally located on sheet 410, in embodiments where tube segment 106 and tube segment 206 have different widths.

[0028] The first tube segment 106 and second tube segment 206 are formed, in an exemplary embodiment, as shown in FIGS. 4-6. Referring the FIG. 4, a first corrugated section 420 is formed along a first longitudinal edge of sheet 410. The first corrugated section 420 may be stamped, punched, or otherwise formed in sheet 410. First corrugated section 420 includes a series of peaks and troughs that eventually define flow channels 120 of first tube segment 106. The peaks and troughs are shown as square in FIG. 4, but it is understood that other cross-sections may be used in first corrugated section 420. A second corrugated section 422 is formed along a second longitudinal edge of sheet 410. The second corrugated section 422 may be stamped, punched, or otherwise formed in sheet 410. Second corrugated section 422 includes a series of peaks and troughs that eventually define flow channels 220 of second tube segment 206. The peaks and troughs are shown as square in FIG. 4, but it is understood that other cross-sections may be used in second corrugated section 422.

[0029] As shown in FIGS. 4 and 5, first corrugated section 420 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C, to form a first bend 424 of first section 420. Similarly, second corrugated section 422 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C to form a first bend 426 of second section 422. As shown in FIGS. 5 and 6, again the first corrugated section 420 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C, to form a second bend 425 of first section 420. Similarly, second corrugated section 422 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C, to form a second bend 427 of second section 422. The two bending steps form first tube segment 106 and second tube segment 206. The corrugated sections 420 and 422 define the flow channels 120 and 220, respectively, in first tube segment 106 and second tube segment 206. First bend 424 of first section 420 corresponds to trailing edge 110 of first tube segment 106. Second bend 425 of first section 420 corresponds to leading edge 108 of first tube segment 106. First bend 426 of second section 422 corresponds to leading edge 208 of second tube segment 206. Second bend 427 of second section 422 corresponds to trailing edge 210 of second tube segment 206. In FIGS. 4-6, the outer surface of the first tube segment 106, flow channels 120, the outer surface of the second tube segment 206, flow channels 220 and the at least one web 40 are formed from a single sheet 410.

[0030] The formed first tube segment 106 and second tube segment 206 are joined by at least one web 40. The first tube segment 106 and second tube segment 206 may then be brazed using known techniques, such as controlled atmosphere brazing. The brazing process seals the corrugated sections 420 and 422 to the adjacent sheet material to seal first tube segment 106 and second tube segment 206. In an alternative embodiment, a plurality of first tube segments 106 and second tube segments 206 are assembled to manifolds 102, 104, 202 and 204, along with folded fins 320. The entire assembly may then be brazed using known techniques, such as controlled atmosphere brazing.

[0031] An alternative method of manufacturing heat exchange tube segments 106, 206 and web 40 is described with reference to FIGS. 7-9. The manufacturing method includes folding the sheet 410 of stock material to define tube segments 106, 206 and at least one web 40. Prior to folding, as described above with reference to FIG. 3, one or more notches 412 and/or one or more slots 414 may be formed in sheet 410.

[0032] The first tube segment 106 and second tube segment 206 are formed as shown in FIGS. 7-9. Referring the FIG. 7, a first corrugated section 420 is formed along a first longitudinal axis of sheet 410, at an interior of sheet 410, proximate to a central axis, C. The first corrugated section 420 may be formed by a separate sheet of material placed on top of sheet 410. First corrugated section 420 includes a series of peaks and troughs that eventually define flow channels 120 of first tube segment 106. The peaks and troughs are shown as square in FIG. 7, but it is understood that other cross-sections may be used in first corrugated section 420. A second corrugated section 422 is formed along a second longitudinal axis of sheet 410, at an interior of sheet 410, proximate to a central axis, C, and on an opposite side of axis C as first corrugated section 420. The second corrugated section 422 may be formed by a separate sheet of material placed on top of sheet 410. Second corrugated section 422 includes a series of peaks and troughs that eventually define flow channels 220 of second tube segment 206. The peaks and troughs are shown as square in FIG. 7, but it is understood that other cross-sections may be used in second corrugated section 422.

[0033] As shown in FIGS. 7 and 8, a first section 411 of sheet 410 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C to form a first bend 424 of first section 411. Similarly, second section 413 is bent about 180 degrees along a longitudinal axis parallel to axis C, inwards towards axis C to form a first bend 426 of second section 413. As shown in FIGS. 8 and 9, the first section 411 is bent along a longitudinal axis parallel to axis C, downwards towards axis C, to form a second bend 425 of first section 411. Similarly, second section 413 is bent along a longitudinal axis parallel to axis C, downwards towards axis C, to form a second bend 427 of second section 413. The two bending steps form first tube segment 106 and second tube segment 206. The corrugated sections 420 and 422 define the flow channels 120 and 220, respectively, in first tube segment 106 and second tube segment 206. First bend 424 of first section 411 corresponds to leading edge 108 of first tube segment 106. Second bend 425 of first section 420 corresponds to trailing edge 110 of first tube segment 106. First bend 426 of second section 413 corresponds to trailing edge 210 of second tube segment 206. Second bend 427 of second section 413 corresponds to leading edge 208 of second tube segment 206.

[0034] The outer surface of the first tube segment **106**, the outer surface of the second tube segment **206**, and the at least one web **40** are formed from a single sheet of stock material **410**.

[0035] The formed first tube segment **106** and second tube segment **206** are joined by at least one web **40**. The first tube segment **106** and second tube segment **206** may then be brazed using known techniques, such as controlled atmosphere brazing. The brazing process seals the corrugated sections **420** and **422** to the adjacent sheet material to seal first tube segment **106** and second tube segment **206**. In an alternative embodiment, a plurality of first tube segments **106** and second tube segments **206** are assembled to manifolds **102**, **104**, **202** and **204**, along with folded fins **320**. The entire assembly may then be brazed using known techniques, such as controlled atmosphere brazing.

[0036] The folding directions of sheet **410** in FIGS. **4-9** are exemplary, and a number of differing folding orientations may be used in forming first tube segment **106** and second tube segment **206**. For example, FIG. **10** is an enlarged view of second bend **425** from FIG. **9**. As shown in FIG. **10**, an edge **429** of sheet **410** defines the end of bend **425**. Edge **429** may be bent inwardly towards the interior of tube segment **106**. As shown in FIG. **11**, edge **429** may be bent outwardly towards the web **40**. This is just one example of alternative bend directions that may be used over several sections of first tube segment **106** and second tube segment **206**. Further, localized features, such as nesting pockets, overlaps, and ribs can be incorporated into the design to promote brazing, structural strength, etc.

[0037] An alternative method of manufacturing heat exchange tube segments **106**, **206** and web **40** is described with reference to FIGS. **12-14**. The manufacturing method includes folding the sheet **410** of stock material to define tube segments **106**, **206** and at least one web **40**. Prior to folding, as described above with reference to FIG. **3**, one or more notches **412** and/or one or more slots **414** may be formed in sheet **410** between locations of first corrugated section **420** and second corrugated section **422**.

[0038] The first tube segment **106** and second tube segment **206** are formed as shown in FIGS. **12-14**. Referring the FIG. **12**, a first corrugated section **420** is formed along a first longitudinal axis of sheet **410**. The first corrugated section **420** may be formed by stamping sheet **410** or may be a separate sheet of material placed on top of sheet **410**. First corrugated section **420** includes a series of peaks and troughs that eventually define flow channels **120** of first tube segment **106**. The peaks and troughs are shown as square in FIG. **12**, but it is understood that other cross-sections may be used in first corrugated section **420**.

[0039] A second corrugated section **422** is formed along a second longitudinal axis of sheet **41**, on the same side of axis C as first corrugated section **420**. The second corrugated section **422** may be formed by stamping sheet **410** or may be separate sheet of material placed on top of sheet **410**. Second corrugated section **422** includes a series of peaks and troughs that eventually define flow channels **220** of second tube segment **206**. The peaks and troughs are shown as square in FIG. **12**, but it is understood that other cross-sections may be used in second corrugated section **422**.

[0040] Also formed in sheet **410** is a rib **440**, which may be formed by stamping sheet **410**. Rib **440** is generally rectangular and is formed along a longitudinal axis parallel to longitudinal axis, C. Rib **440** has a width substantially corresponding to web **40**. One or more notches **412** and one or more slots **414** may be formed in rib **440**, to correspond notches and/or slots formed in web **40** between first corrugated section **420** and second corrugated section **422**.

[0041] As shown in FIGS. **12** and **13**, a first section **411** of sheet **410**, including rib **440**, is bent about **180** degrees along a longitudinal axis parallel to axis C, inwards towards axis C to form a first bend **424** of first section **411**. This places rib **440** juxtaposed web **40** between first corrugated section **420** and second corrugated section **422**. As shown in FIGS. **13** and **14**, an edge of first section **411** is bent along a longitudinal axis parallel to axis C, towards axis C, to form a second bend **426** of first section **411**. The bending steps form first tube segment **106** and second tube segment **206**. The corrugated sections **420** and **422** define the flow channels **120** and **220**, respectively, in first tube segment **106** and second tube segment **206**. First bend **424** of first section **411** corresponds to trailing edge **210** of second tube segment **206**. Second bend **426** of first section **411** corresponds to leading edge **108** of first tube segment **106**. A first interior wall **425** of rib **440** corresponds to trailing edge **110** of first tube segment **106**. A second interior wall **427** of rib **440** corresponds to leading edge **208** of second tube segment **206**.

[0042] The outer surface of the first tube segment **106**, the outer surface of the second tube segment **206**, and the at least one web **40** are formed from a single sheet of stock material **410**.

[0043] The formed first tube segment **106** and second tube segment **206** are joined by at least one web **40**. The first tube segment **106** and second tube segment **206** may then be brazed using known techniques, such as controlled atmosphere brazing. The brazing process seals the corrugated sections **420** and **422** to the adjacent sheet material to seal first tube segment **106** and second tube segment **206**. In an alternative embodiment, a plurality of first tube segments **106** and second tube segments **206** are assembled to manifolds **102**, **104**, **202** and **204**, along with folded fins **320**. The entire assembly may then be brazed using known techniques, such as controlled atmosphere brazing.

[0044] FIG. **15** is a flowchart of a process of forming a first tube segment and second tube segment in an exemplary embodiment. The process begins at **500** where sheet **410** is obtained. Sheet **410** may be a metal (e.g. aluminum) and may be clad on both sides with a brazing alloy. At **502**, notches **412** may be formed at each end of sheet **410**, about a longitudinal axis. Slots **414** may also be formed at **502** along the longitudinal axis.

[0045] At **504**, the corrugated sections **420** and **422** are formed on sheet **410**. This may entail stamping or punching the corrugated sections into sheet **410**. Alternatively, as shown in FIGS. **7-9**, this may entail using a second sheet of material having the corrugations formed therein. At **506**, the outer sections of the sheet material are bent inwards towards the longitudinal axis to form the first tube segment **106** and second tube segment **206**. At **508**, brazing is performed. This may entail brazing just the first tube segment **106** and second tube segment **206**. Alternatively, a plurality of first tube segments **106** and second tube segments **206** are assembled to manifolds **102**, **104**, **202** and **204**, along with folded fins **320**, and then brazing is performed.

[0046] Forming the tube segments **106**, **206** and web **40** by folding sheet **410** eliminates the need for an extrusion process, allowing tube fabrication at the heat exchanger manufacturer site, reducing logistics complexity, improving reliability and providing noticeable cost savings. Additionally, the material system limitations imposed by the extrusion process can be avoided and heat exchanger corrosion durability significantly improved.

[0047] It is understood that various tube folding patterns can be employed and will not deviate from the scope and spirit of the invention. Furthermore, at least one of the tube segments **106**, **206** may not have internal ports and may carry a separate fluid. In the latter case, the manifolds in the first tube bank **100** and in the second tube bank **200** are separated, while the tube banks have independent inlet pipes and outlet pipes. This is shown in FIG. **16**, which is a top down view of heat exchange unit **10**, where manifolds **102**, **104** of first tube bank **100** are not in fluid communication with manifolds **202**, **204** of tube bank **200**. First tube bank **100** and second tube bank **200** have independent inlet pipes **142**, **242** and outlet pipes **144**, **244**, respectively.

[0048] While the present invention has been particularly shown and described with reference to the exemplary embodiments as illustrated in the drawing, it will be recognized by those skilled in the art that various modifications may be made without departing from the spirit and scope of the invention. Therefore, it is intended that the present disclosure not be limited to the particular embodiment(s) disclosed as, but that the disclosure will include all embodiments falling within the scope of the appended claims.

We claim:

1. A multiple bank, flattened tube heat exchange unit comprising:

a first tube bank including a flattened first tube segment extending longitudinally between a first manifold and a second manifold; and

a second tube bank including a flattened second tube segment extending longitudinally between the first manifold and the second manifold, the second tube bank disposed behind the first tube bank;

wherein an outer surface of the first tube segment and an outer surface of the second tube segment are formed from a single sheet of material.

2. The multiple bank, flattened tube heat exchange unit of claim **1** further comprising:

at least one web joining the first tube segment and the second tube segment.

3. The multiple bank, flattened tube heat exchange unit of claim **2** wherein:

the outer surface of the first tube segment, the outer surface of the second tube segment and the at least one web are formed from the single sheet of material.

4. The multiple bank, flattened tube heat exchange unit of claim **1** further comprising:

a first corrugated section positioned inside the first tube segment, the first corrugated section defining plurality of discrete flow channels in the first tube segment.

5. The multiple bank, flattened tube heat exchange unit of claim **4** wherein:

the first corrugated section and the outer surface of the first tube segment are formed from the single sheet of material.

6. The multiple bank, flattened tube heat exchange unit of claim **5** further comprising:

a second corrugated section positioned inside the second tube segment, the second corrugated section defining plurality of discrete flow channels in the second tube segment.

7. The multiple bank, flattened tube heat exchange unit of claim **6** wherein:

the second corrugated section and the outer surface of the second tube segment are formed from the single sheet of material.

8. The multiple bank, flattened tube heat exchange unit of claim **6** wherein:

the second corrugated section is formed from a second sheet of material.

9. The multiple bank, flattened tube heat exchange unit of claim **4** wherein:

the first corrugated section is formed from a second sheet of material.

10. The multiple bank, flattened tube heat exchange unit of claim **1** further comprising:

a notch formed in the single sheet of material, the notch positioned between the first tube segment and the second tube segment, the notch positioned proximate to a distal end of the first tube segment and the second tube segment.

11. The multiple bank, flattened tube heat exchange unit of claim **1** further comprising:

at least one slot formed in the single sheet of material, the slot positioned between the first tube segment and the second tube segment, the slot positioned intermediate distal ends of the first tube segment and the second tube segment.

12. A method of forming a multiple bank, flattened tube heat exchange unit, the method comprising:

obtaining a single sheet of material, the single sheet of material having a longitudinal axis;

bending a first portion of the single sheet of material towards the longitudinal axis to define an outer surface of a first tube segment; and

bending a second portion of the single sheet of material towards the longitudinal axis to define an outer surface of a second tube segment.

13. The method of claim **12** further comprising:

defining a first corrugated section, the first corrugated section defining plurality of discrete flow channels in the first tube segment.

14. The method of claim **13** wherein:

the first corrugated section includes forming the first corrugated section in the first portion of the single sheet of material.

15. The method of claim **14** further comprising:

defining a second corrugated section, the second corrugated section defining plurality of discrete flow channels in the second tube segment.

16. The method of claim **15** wherein:

the second corrugated section includes forming the second corrugated section in the second portion of the single sheet of material.

17. The method of claim **15** wherein:

the second corrugated section includes forming the second corrugated section in a second sheet of material.

18. The method of claim **13** wherein:

the first corrugated section includes forming the first corrugated section in a second sheet of material.

19. The method of claim **12** further comprising:

forming a notch in the sheet of material, the notch positioned along the longitudinal axis at a distal end of the sheet of material.

20. The method of claim **12** further comprising:
forming at least one slot in the sheet of material, the slot positioned along the longitudinal axis intermediate distal ends of the sheet of material.

21. The method of claim **12** further comprising:
brazing the first tube segment and the second tube segment.

22. The method of claim **12** further comprising:
assembling the first tube segment and the second tube segment with a first manifold and a second manifold; and
brazing the assembled first tube segment, the second tube segment, the first manifold and the second manifold.

23. The method of claim **12** wherein:
the single sheet of material is cladded with a brazing material.

24. A method of forming a multiple bank, flattened tube heat exchange unit, the method comprising:
obtaining a single sheet of material, the single sheet of material having a longitudinal axis;
bending the first portion of the single sheet of material towards the longitudinal axis to define an outer surface of a first tube segment and define an outer surface of a second tube segment.

25. The method of claim **24** further comprising:
forming a first corrugated section and a second corrugated section in the sheet of material prior to bending.

26. The method of claim **25** further comprising:
forming a rib in a first portion prior to the bending.

27. The method of claim **26** wherein:
upon the bending, the rib is positioned between the first corrugated section and the second corrugated section.

28. The method of claim **26** further comprising:
forming a notch in the single sheet of material, the notch located to be positioned between the first tube segment and the second tube segment, the notch positioned proximate to a distal end of the first tube segment and the second tube segment; and
forming a notch in the rib, wherein upon bending the notch in the rib is aligned with the notch in the single sheet of material.

29. The method of claim **26** further comprising:
forming at least one slot in the single sheet of material, the slot located to be positioned between the first tube segment and the second tube segment, the slot positioned intermediate distal ends of the first tube segment and the second tube segment; and
forming at least one slot in the rib, wherein upon bending the at least one slot in the rib is aligned with the at least one slot in the single sheet of material.

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