Sept. 5, 1961 — J. J. FORST ET AL — 2,998,639

METHOD OF MAKING HEAT EXCHANGERS

Filed March 3, 1959 — 2 Sheets-Sheet 1

FIG. 1

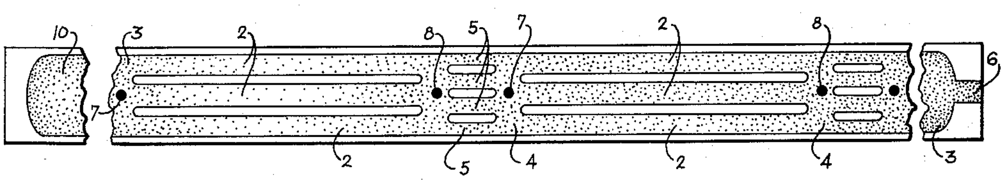


FIG. 2

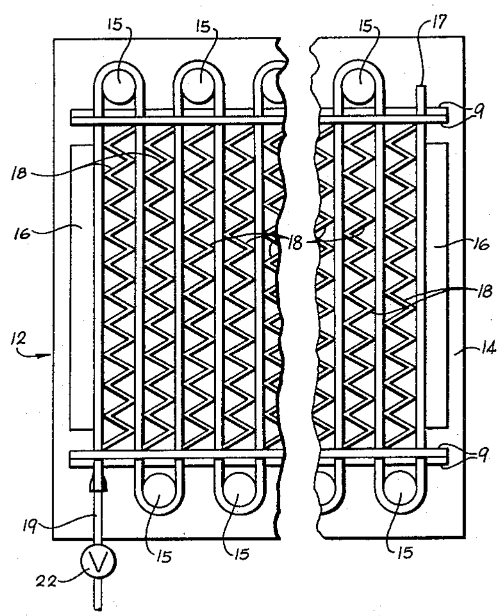


FIG. 3

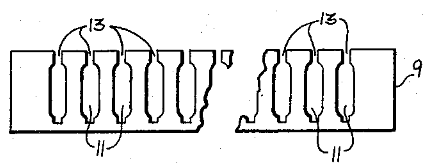


FIG. 4

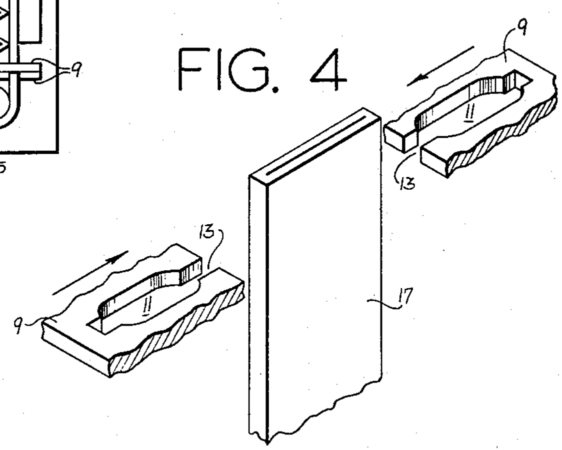
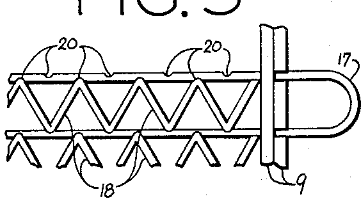


FIG. 5



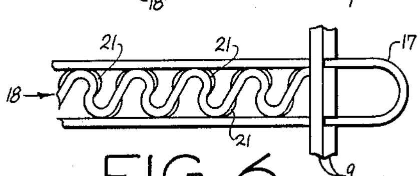


FIG. 6

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FIG. 7

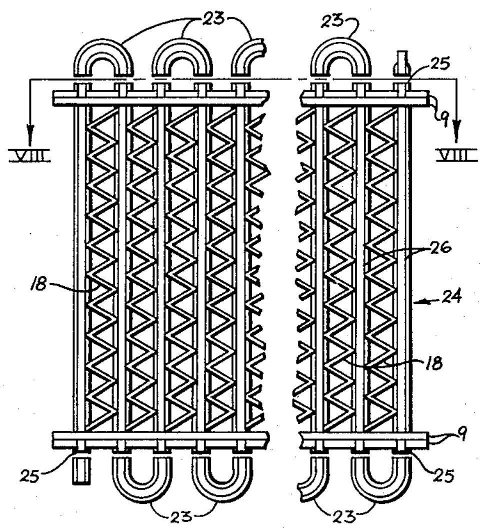


FIG. 8

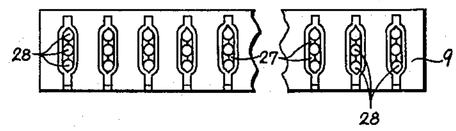


FIG. 9

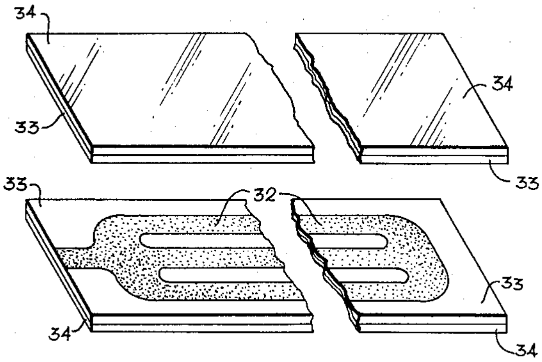
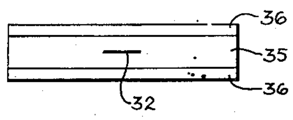


FIG. 10



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1

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METHOD OF MAKING HEAT EXCHANGERS

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11 Claims. (Cl. 29—157.3)

This invention relates generally to heat exchangers and more particularly to a method of making heat exchangers for automobile radiators and the like.

Heretofore the making of such articles has been time consuming and expensive and involves the assembly of a great number of separate tubes together with heat dissipating fin stock inserted between adjacent tubes. The assembly was then suitably joined together with the ends of the tube inserted in suitable headers. Although various attempts have been made to simplify fabrication of such structures, these attempts have served only to accentuate the various complex problems involved in the construction of these structures.

The general object of this invention is to provide an improved process for simplifying the making of tubular heat exchanger cores for automobile heaters, radiator cores and the like.

Another object is to provide a method for fabricating a multi-tube heat exchanger core from a single substantially flat tube.

Another object is to provide an economical method adapted for rapid mass production of heat exchanger cores complete with alternate layers of fin stock and tube stock.

A further object of this invention is to simplify the heretofore complex operations presently employed in the fabrication of heat exchangers for radiators and the like.

Other objects and advantages will become apparent from the description of a specific embodiment of the invention which follows.

According to this invention the entire radiator core section can be made in an economical and simple manner from a continuous length of thin metal tube stock, such as aluminum, copper and the like, containing embryonic or collapsed passageways. This tube stock is folded or bent back and forth in a serpentine or zig-zag fashion within a suitable strip handling and forming apparatus with a connecting, or supporting, webbing mounted transverse the tube stock across the terminals of the straight portions between the formed return bends. The tube stock of the assembly is then subjected to internal pressure to develop the desired tube form and to establish intimate contact of the tube stock with the webbing. The assembly is then sheared to remove the interconnecting bent portions. The supporting or connecting webbing can be formed from any sheet metal which may be similar or different from that employed in the tube stock in which suitable shaped openings are formed for insertion of the desired tube form. The openings are shaped to the general configuration of the desired distended tubes, and to encompass and intimately contact the subsequently distended tubular walls as well as the web of the sheet.

If desired, secondary heat dissipating fins may be inserted between adjacent portions of the bent tube stock and fastened thereto simultaneously with the expansion of the tube stock. Various types of secondary heat dissipating heat stock may be employed, such as a plurality of the above mentioned connecting webbing spaced across the straight portions between the return bends, or, preferably, a closely corrugated or pleated fin strip inserted between adjacent portions of the tube stock. These strips of corrugated fin stock may be stacked up or inserted so as to have parts fitting between adjacent sections of the bent tube stock.

2

The tube stock may contain a single continuous passage or preferably a number of parallel passages from end to end of the strip for continuous and interrupted flow of fluid. Alternately, these passages may take any shape through the length of the strip, for example, they may be present as a plurality of interconnected passages in parallel alignment, or they may extend longitudinally in serpentine fashion through the tube stock. Although the portions between the return bends need not be parallel to each other, the tube stock preferably takes the form of a plurality of substantially straight parallel hollow portions with hollow 180° bent-end portions connecting the adjacent straight portions. To faciltate an even admission and maintenance of a fluid pressure throughout the entire length of the tube stock, particularly around the bent portions, the tube passageway in the tube stock is subdivided into a greater number of smaller passages at the portions disposed at the bends.

Upon assembly, uniting material, such as solder, brazing alloy and the like, is interposed between the tube stock, fin stock and connecting webbing by coating or in the form of an insert, or both. If solder or a brazing alloy is employed, the inflating structure is heated at a temperature at which the solder or a brazing alloy melts to join the assembly together.

Any suitable apparatus may be employed for forming the zig-zag or serpentine folds of the tube stock. After bending of the tube stock and assembly of the components as discussed above, the tube stock is inflated and the resultant assembly in the apparatus is heated to accomplish the desired union of the various components. The apparatus may be adapted to permit shearing of the return bends from the resultant core while retained in the apparatus, or the joined assembled structure may be removed from the core whereafter the removal of the return bends may then be accomplished by shearing and the like.

The resultant core is comparable in configuration to heretofore conventional types of radiators or heater core sections, and thus, is interchangable therewith necessitating substantially no designed changes for replacement therefor. By this invention a properly dimensioned heat exchanger radiator core can be made having a plurality of tubes in parallel relationship to each other with intervening fin stock between adjacent tubes. It will be appreciated that by this invention the steps of tube shaping and fastening of the connecting webbing and/or fins are done in a single operation.

The invention will be better understood from a detailed description and drawings in which:

FIGURE 1 is a plan view of an embodiment of this invention illustrating one pattern of stop-weld that may be employed in fabricating tube stock for pressure welding this embodiment;

FIGURE 2 is a plan view illustrating an apparatus that may be employed in the bending of the tube stock of FIGURE 1 in zig-zag fashion and with connecting webbing and secondary heat dissipating fin stock assembled therein;

FIGURE 3 is a plan view illustrating one embodiment of connecting webbing that may be employed in this invention;

FIGURE 4 is a perspective view illustrating one method of assembling the connecting webbing of FIGURE 3 to tubular stock;

FIGURE 5 is a plan view illustrating one form of intimate contact established between the inflated tube stock and fin stock of FIGURE 2;

FIGURE 6 is a plan view illustrating another form of intimate contact established between the inflated tube stock and fin stock of FIGURE 2;

FIGURE 7 is a plan view of a heat exchanger removed from the confining and forming structure of FIGURE 2 subsequent to the shearing of the return bends formed in zig-zag folding the tube stock;

FIGURE 8 is a view taken along line VIII—VIII of FIGURE 7;

FIGURE 9 is a perspective view of another embodiment of this invention illustrating a method of fabricating clad tube stock; and

FIGURE 10 is an end view of the welded embodiment of FIGURE 9 with a coating or brazing alloy provided thereon.

Referring to the drawings, FIGURE 1 shows a sheet of metal **1**, such as aluminum or aluminum alloys, copper or copper base alloys, or ferrous alloys and more specifically an alloy having the following composition, 93% copper, 2.33% iron, balance zinc having applied to its clean surface a pattern of weld inhibiting material defining the desired pattern of passages in the tube stock. A portion of the weld inhibiting material in the instant example defines the tubular passageways **2** to be obtained in the straight portion in a subsequent zig-zag folding of the tube stock into a serpentine configuration. These portions merge at their ends into sections **3** and **4** which subsequently form a single relatively large hollow in the final structure. Section **4** extending from the desired straight portions of the serpentine folded tube stock defines the hollow desired in the return bends. Section **4** is further subdivided into a plurality of smaller size passages **5** to prevent obstruction to fluid pressure during the folding of the tube stock and a subsequent inflation operation. One end of sheet **1** is provided with a strip of weld inhibiting material **6** extending from the pattern of weld inhibiting material described to the edge of the sheet **1**. This pattern of weld inhibiting material will ultimately form the passageways of the inflated stock.

The portion of sheet **1** to which strips **2** of weld inhibiting material have been applied form the straight portions of a subsequently bent serpentine tube stock. These portions extend generally between points **7** and **8** at which points connecting webbing **9** is mounted in a subsequent operation. Although in the instant embodiment the pattern or strips of weld inhibiting material **2** have been longitudinally duplicated twice, it will be understood that the portion of strips **2** between their respective points **7** and **8**, together with strips of weld inhibiting material **5**, may be repeated as often as required depending on the amount of pleats desired in tube stock after folding of it into the serpentine configuration. As shown in FIGURE 1, the pattern of passages described may terminate at its ends into communicating relationship with areas of weld inhibiting material **3** and **10**, respectively. In addition, to facilitate the inflation of the tube stock, the area **3** may also be extended to the edge of sheet **1** by a strip of weld inhibiting material **6**. It is to be understood as noted above, that if the tube stock is fabricated by pressure welding a plurality of superimposed strips of metal having a weld inhibiting material interposed therebetween, the pattern applied may be varied as desired according to the demands of the application intended for the final structure obtained by this invention. For example, strips **2** of weld inhibiting material may be either a single or plurality of strips extending in sinuous form longitudinally on sheet **1**, or the configuration of weld inhibiting material may take the from of interconnected passageways and be fabricated in accordance with the method fully disclosed in a patent to Grenell, U.S. No. 2,690,002 granted on September 28, 1954.

A surface of a second sheet is superimposed on the surface of sheet **1**, to which the weld inhibiting material has been applied. The two sheets are then tacked together as by spot-welding, or any appropriate manner, as by heli-arc welding the edges of the sheet, to prevent relative slippage of adjacent surfaces of the superimposed sheets during a subsequent welding operation. Any suitable weld inhibiting material may be employed to prevent welding of the coating surfaces during the welding operation. An example of such weld inhibiting material is graphite in water glass.

The assembled structure is then heated to welding temperatures, for the specific composition set forth above, to 925° F. for about 20 minutes as per the teachings of the aforementioned patent, and then passed through mill rolls wherein the sheets are joined or welded together at the adjacent surfaces not separated by weld inhibiting material. During rolling, the assembled structure is reduced in thickness and elongated in the direction of rolling. The welded structure may then be further cold rolled to the final gauge desired and further annealed to remove the cold working to increase the ductility of the metal for inflation. The resultant welded structure forms the tube stock for fabrication of the radiator core in accordance with this invention.

It is to be understood that the invention is not limited to tube stock fabricated by the process specifically described above. This invention is equally applicable to tube stock fabricated in other manner, for example, the tube stock may be formed from a metal strip by folding it along the longitudinal center which brings the lateral edges adjacent each other where they are fastened together by any well known process, such as by welding, brazing and the like. Also, the folded strip may be further spot-welded or seam welded in portions intermediate the lateral edges of the folded strip to define a pattern of passageways desired in a subsequent inflated article.

From a separate sheet of metal similar or different from that employed for the tube stock, a supporting and connecting webbing **9** is formed by providing therein a plurality of suitably shaped openings **11** for mounting upon the serpentine form of the tube stock. These openings are shaped so as to encompass and intimate contact subsequently distended tubular walls preferably at points indicated by numerals **7** and **8**, as well as the web at the referred-to points. Generally two such webs or combs are utilized at each terminal portion **7** and **8** of the spaced portion, between the return bends, of a zig-zag folded tube stock. This will be better explained by reference to FIGURE 1 by considering the central portion of the drawing. With reference thereto, the webbing **9** will be mounted on and across the spaced pleats at the terminals of the tube defined by stop-weld tube at each pair of adjacent points **7** and **8** separated by strips **5**.

The connecting webbing **9** is then mounted in spaced relationship by any appropriate manner, such as a slot, in a forming jig **12** with the openings **13** of the web extending upwardly. The tube stock is then threaded through the forming jig **12**, with the pleats inserted into the openings **11** of webbing **9**, in zig-zag fashion to a serpentine configuration. The jig has a base plate **14** having a plurality of upwardly extending pegs **15** arranged in staggered parallel relationship across which the tube stock is threaded in the aforesaid serpentine manner. A pair of restraining plates **16** are also fastened upwardly from the base plate **14** to engage the outermost pleats of the bent tube stock in order to restrain and limit the displacement of the outermost pleats during expansion. It is to be understood that although, with respect to FIGURE 2, the pleats are shown to be straight and in parallel relationship to each other, additional pegs may be employed to corrugate the pleats of the serpentine tube stock **17** if desired.

After threading the tube stock **17** in the forming jig **12**, a second connecting and supporting webbing **9** is mounted upon tube stock **17** adjacent each web **9** in which the tube stock **17** was previously inserted. FIGURE 4 depicts broadly a method of mounting a pair of webbing **9** on a pleat, of tube stock **17**, which may be assumed to be the outermost pleat. A pair of webbing **9** in spaced and parallel relationship to each other with the portion **13** of openings **11** facing each other, are moved toward each other to engage the tube stock 17 into openings 11 to the portion 13. After mounting, the webbings 9 are preferably moved into adjacent and contiguous relationship to each other.

Although not required, in the preferred form of this invention a plurality of corrugated secondary heat dissipating fins 18 are inserted between adjacent straight portions, or pleats, of the serpentine tube stock 17. This tube stock may be a relatively thin sheet metal of substantially the same width as the tube stock and of the same or different alloy from which the tube stock was fabricated. The tube stock may be formed by bending strips of metal into a serpentine form followed by insertion between adjacent straight sections of the tube stock 17. It is to be understood that if desired, the fin stock may be perforated in the pleat or appropriately shaped, in the pleat, by stamping in the straight portions to provide additional deflecting means for passage of air through the radiator core.

After the assembly of various components in forming jig 12, a suitable pressure is injected by means of nozzle 19 into the tube stock 17 of sufficient magnitude to permanently distend the area within the tube stock defined by the weld inhibiting material into intimate contact with the fin stock 18 and with the walls of the distended passages fitting snugly in openings 11 of webbing 9. The resultant cross-sectional area of the distended tube stock will depend not only upon the magnitude of the applied fluid pressure but also upon the pattern of weld inhibiting material employed and upon the strength of the fin stock. For example, if the fin stock is of sufficient strength to resist deformation by the applied fluid pressure, the crest of the fins will cause indentations 20 in the wall of the distended tubes. However, where the fin stock is deformed in that it does not possess sufficient strength to resist deformation by the applied fluid pressure, the fins assume an arcuate shape at the portion in contact with the distended area and assume a bowed or bent configuration 21 at the straight portions of the fin stock. These two configurations of fin stock are illustrated in FIGURES 5 and 6.

After inflation of the assembled tube stock, fins and connecting webbing, the resultant structure may be appropriately coated with a solder or a brazing alloy of any suitable type, such as copper, silver, or nickel-chrominum alloy. However, the solder or brazing alloy is preferably applied to the exterior surface of the tube stock, and/or the fin stock and webbing at any time prior to threading in forming jig 12. The assembled components inflated into intimate contact with each other are placed in any appropriate heating furnace and heated to soften the solder. The furnace temperature is high enough to melt the uniting material, solder or brazing alloy, on the outside of the components to which it was applied, causing it to flow and braze or unite the fins and connecting webbing to the tube stock. The united assembly is then removed from the furnace and allowed to cool.

Although the applied fluid pressure, for distending the tube stock, may be removed prior to uniting the various components by heating, the fluid pressure is preferably sealed within the tube stock by means of valve 22 during the uniting operation. The fluid pressure may then be relieved after the united unit is cooled. It is also to be understood that the assembled unit may be heated to the temperature necessary to melt the uniting material simultaneously with the inflation of the tube stock. It will be apparent that the uniting material in addition to its forms as solder or brazing alloy may take the form of appropriately placed inserts between the various components where they contact each other.

Subsequent to the distending and uniting operation, the inflated structure with the fluid pressure relieved therein is subjected to a shearing operation to remove the return bends 23 of the inflated tube stock 24 as indicated in FIGURE 7. The shearing operation may be accomplished either while the inflated structure is still mounted in forming jig 12 or after its removal therefrom. The return bends 23 of the inflated structure may be sheared even with the connecting webbing 9, but are preferably sheared with a small portion 25, about 0.010 inch, of the parallel sections 26 extending beyond the connecting webbing 9. The resultant structure, comparable to the cores of conventional type radiators, has an opening 27 defined by the portion of weld inhibiting material 3 and subdivided into a plurality of smaller passages 28 defined by the area 2 of weld inhibiting material.

After the shearing operation, appropriate header connections may be built at the top and bottom of the resultant radiator core about connecting webbing 9.

It is to be understood that when the tube stock is formed by welding strips of metal, containing weld inhibiting material together, various combinations of metals may be employed depending on the application desired for the resultant fabricated core structure of this invention. For example, the weld inhibiting material 32 may be interposed between two adjacent sheets of like material 33, such as 72S aluminum, which after superimposition upon each other are clad by an additional pair of sheets 34, such as 2S and 3S aluminum. After assembly of the various components they are appropriately tacked, as by spot-welding, heated to welding temperatures and welded according to the procedure defined above with respect to FIGURE 1. The resultant tube stock 35 may then be coated with an appropriate brazing alloy 36 and then bent into a serpentine configuration, as described above, assembled with the various components and distended according to the procedure described with respect to FIGURES 1 to 8.

Although the invention has been described with reference to specific embodiments, materials and details, various modifications and changes will be apparent to one skilled in the art and are contemplated to be embraced within the invention.

What is claimed is:

1. A method for manufacturing a heat exchanger core which comprises providing a single length of elongated flat tube sheet containing an internally extending collapsed area of separation, bending said tube sheet in zig-zag fashion to form a plurality of spaced portions interconnected by bent-end portions, inserting secondary fin stock between the spaced tube portions of said tube stock, expanding said tube sheet to distend said tube sheet along said area of separation to effect intimate contact of said tube sheet with said fin stock, joining said tube sheet to said fin stock, and removing said bent-end portions.

2. The method of claim 1 wherein said spaced portions are substantially straight and in parallel relationship to each other.

3. A method of manufacturing a heat exchanger core comprising providing a single length of elongated flat tube sheet containing an internally extending and inflatable collapsed area of separation, bending said tube back and forth in zig-zag fashion to form a plurality of spaced portions interconnected by bent-end portions, providing an opening in a metal web-like member wherein a first portion of said opening has a configuration and size desired for the tube at the terminal of said spaced portions and a second portion of said opening communicating with first said portion corresponding to the shape and size of said tube sheet, placing said tube sheet in said web-like member at said terminals, expanding said tube sheet to distend it along said area of separation to effect intimate contact of said tube sheet with said web-like member, and removing said bent-end portions.

4. The method of claim 3 wherein said spaced portions are substantially straight and in parallel relationship to each other.

5. The method of claim 4 wherein said tube sheet is joined to said member prior to removal of said bent-end portions.

6. A method of manufacturing a heat exchanger core comprising providing a single length of elongated flat tube sheet containing an internally extending and inflatable collapsed area of separation, bending said tube back and forth in zig-zag fashion to form a plurality of spaced portions interconnected by bent-end portions, providing openings in a metal web-like member wherein a first portion of said opening has a configuration and size desired for the tube at the terminal of said spaced portions and a second portion communicating with first said portion corresponding to the shape and size of said tube sheet, placing said tube sheet in said web-like member at said terminals, inserting secondary fin stock between the spaced portions of said tube sheet, expanding said sheet to distend it along said area of separation to effect intimate contact of said tube sheet with said fin stock and said member, and removing said bent-end portions.

7. The method of claim 6 wherein said spaced portions are substantially straight and in parallel relationship to each other.

8. A method of manufacturing a heat exchanger core comprising providing a single length of elongated flat tube sheet containing an internally extending and inflatable collapsed area of separation, bending said tube back and forth in zig-zag fashion to form a plurality of spaced portions interconnected by bent-end portions, providing an opening in metal web-like member wherein a first portion of said opening has a configuration and size desired for the tube at the terminal of said spaced portions and a second portion communicating with first said portion corresponding to the shape and size of said tube sheet, placing said tube sheet in said web-like member at said terminals, inserting secondary fin stock between the spaced portions of said tube sheet, expanding said sheet to distend it along said area of separation to effect intimate contact of said tube sheet with said fin stock and said member, joining said tube sheet to said members and said fin stock, and removing said bent-end portions.

9. The method of claim 8 wherein said spaced portions are substantially straight and in parallel relationship to each other.

10. A method of manufacturing a heat exchanger core comprising providing a single length of elongated flat tube sheet containing an internally extending and inflatable collapsed area of separation, bending said tube back and forth in zig-zag fashion to form a plurality of spaced portions interconnected by bent-end portions, providing openings in metal web-like members wherein portions of said openings have a configuration and size desired for the tube at the terminal of said spaced portions and portions communicating with first said portions corresponding to the shape and size of said tube sheet, placing said tube sheet in said web-like members at said terminals, inserting secondary fin stock between the spaced portions of said tube sheet, interposing uniting material between said tube sheet and said fin stock and members, expanding said tube sheet to distend it along said area of separation to effect intimate contact of said tube sheet with said members and said fin stock, and removing said bent-end portions.

11. The method of claim 10 wherein said spaced portions are substantially straight and in parallel relationship to each other.

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