May 28, 1968 G. A. ANDERSON ETAL 3,384,947

METHOD OF FABRICATING HEAT EXCHANGE DEVICES

Filed June 7, 1965 4 Sheets-Sheet 1

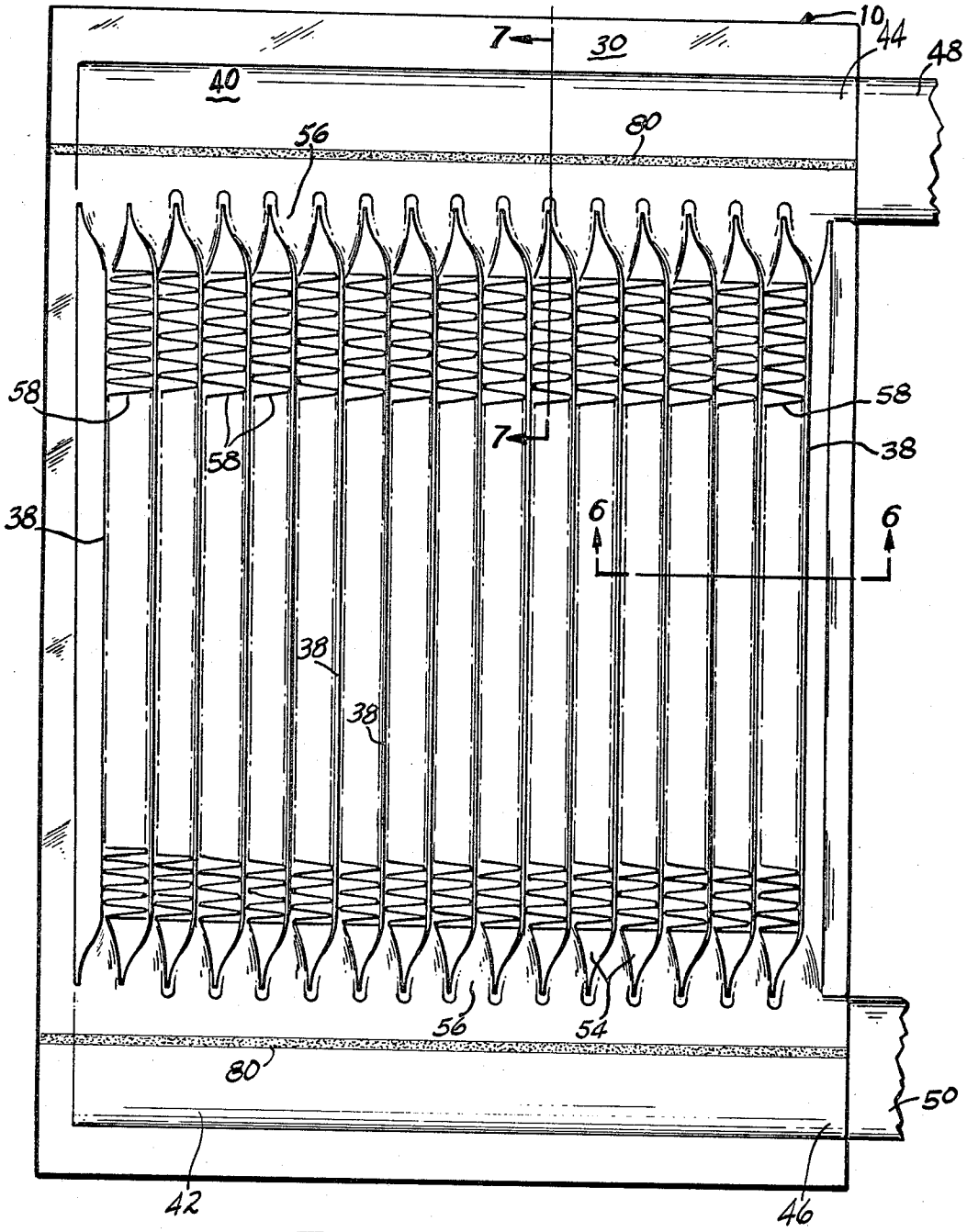

FIG - 1

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METHOD OF FABRICATING HEAT EXCHANGE DEVICES

Filed June 7, 1965 4 Sheets-Sheet 2

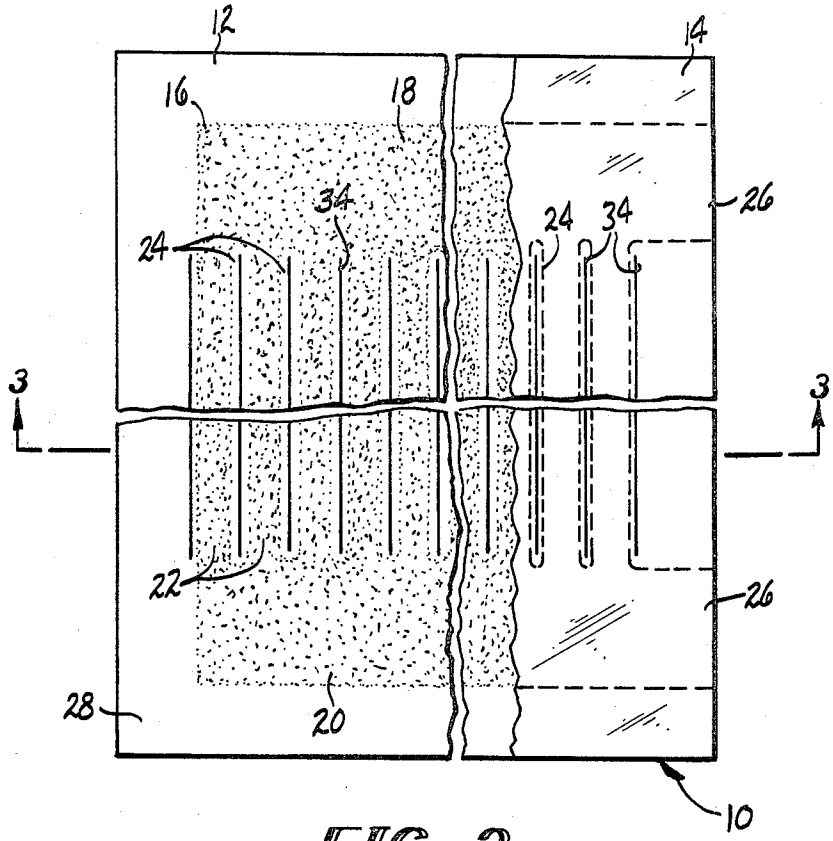

FIG - 2

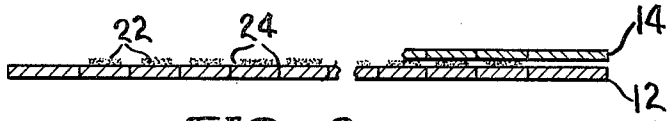

FIG - 3

FIG - 4

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METHOD OF FABRICATING HEAT EXCHANGE DEVICES

Filed June 7, 1965 4 Sheets-Sheet 3

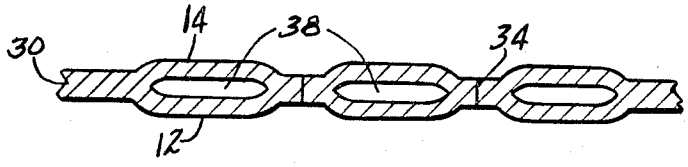

FIG - 5

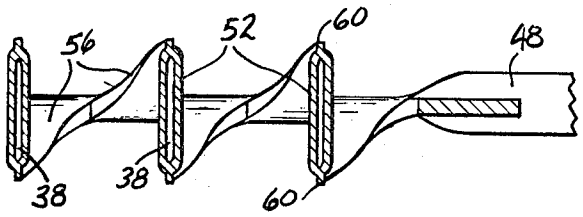

FIG - 6

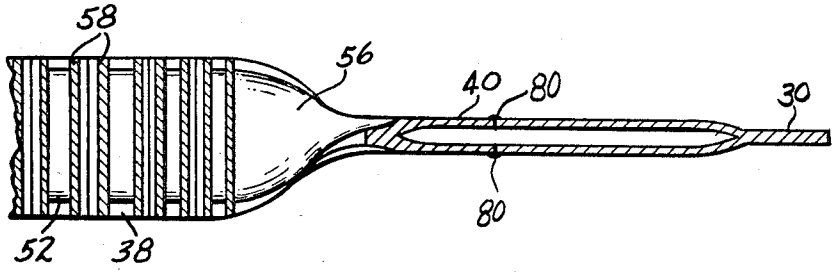

FIG - 7

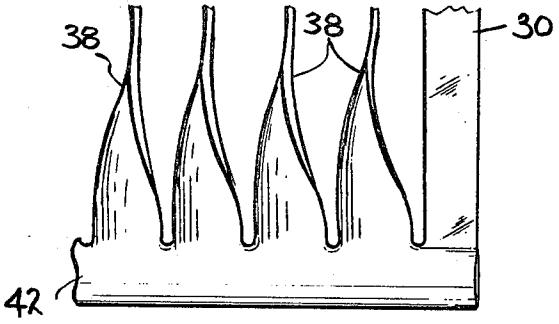

FIG -11

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METHOD OF FABRICATING HEAT EXCHANGE DEVICES

Filed June 7, 1965 4 Sheets-Sheet 4

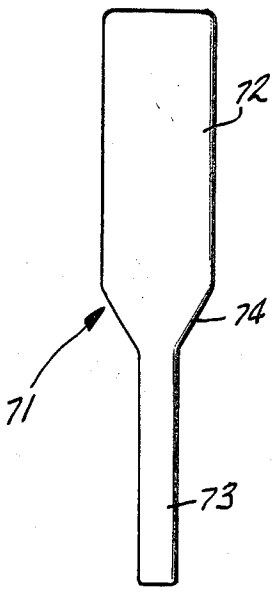

FIG-9

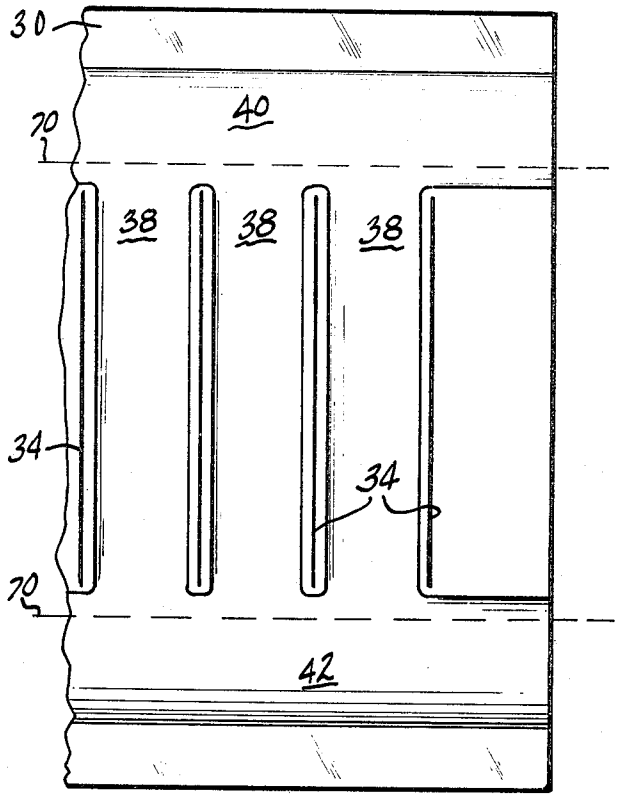

FIG-8

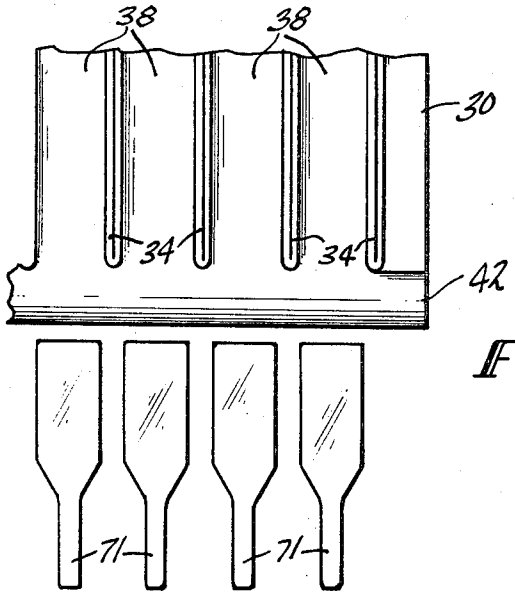

FIG-10

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METHOD OF FABRICATING HEAT EXCHANGE DEVICES

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Filed June 7, 1965, Ser. No. 461,993
6 Claims. (Cl. 29—157.3)

ABSTRACT OF THE DISCLOSURE

A method of fabricating heat exchangers in which a plurality of tubes and headers at each end thereof are formed in a sheet. The sheet is then slit between the tubes and the headers are severed to yield access to said tubes. Then tools are inserted into the tubes to affect rotation of the tubes out of the plane of the sheet. The original headers are then resealed, or preformed headers can be provided instead.

This invention relates generally to the fabrication of heat exchange devices and more particularly to the fabrication of single piece sheet metal heat exchange structures having multiple parallel tubes.

A commonly used and efficient type of heat exchange unit for air-conditioning evaporators and condensers, internal combustion engine cooling radiators, and the like is formed from a plurality of superimposed sheets of metal having internally disposed between the sheets a number of conduits generally in a parallel spaced arrangement extending from a first or intake header to a second or outlet header. One or more of such units may be employed; the conduits or tubes serve to carry a heat exchange medium such as water or other coolant in conductive relationship with another medium such as air or other gas passing between the tubes. This type of construction is typical of automobile radiators where, for example, the heated water issues from the cooling block of the engine with the aid of a pump, first enters one of the two headers, and then passes through a great number of thin-walled, relatively flat, closely spaced tubes between which cooling air is blown and which extend usually vertically from one to the other of the headers. Condensers are also frequently of this same type of construction.

According to one known method of manufacture as illustrated in U.S. Patent 2,690,002, this type of heat exchange unit may be readily manufactured to provide a great multiplicity of tubes in a sheet of metal. This method involves the application of a suitable predetermined pattern of weld inhibiting material between component sheets, pressure welding all adjoining areas except those separated by the weld inhibiting material, thereby forming a unified composite panel, and inflating along the unwelded areas to erect the tubes integral with the resultant tubed panel. Full advantage heretofore has not been taken of this method inasmuch as the tubes formed are of rather flat or oval shape with the major dimensions lying within or parallel to the panel in which the tubes are formed. In many applications it is desirable that the tubes extend not only longitudinally but also extend perpendicularly out of the panel to a considerable extent so as to place the tubes in spaced parallel relationship rather than in the same plane. This design adapts the units to fabrication as single pieces of large size, a lesser number of which may then be put together for installations where the external medium passes through perforations in the panel transversely to it rather than passing parallel to the panel along its surfaces.

In accordance with the concepts of this invention, a

sheet metal panel is formed according to the procedure of the above-mentioned U.S. Patent No. 2,690,002, to form the desired tubular passageway system in its embryonic form. This panel is then slit along a plurality of parallel spaced apart lines extending between two oppositely disposed headers to define the interconnecting tubes. The tube portions lying between adjacent slits are then rotated out of the normal plane of the panel in a novel manner so as to dispose the tube portions in substantially perpendicular relationship to the plane of the panel.

The rotation of these tube portions is most expeditiously done by inserting into one or both ends of each of the tubes an appropriately shaped tool which may then be rotated the desired amount. As will become evident, this method achieves the desired positioning of the tubes by internal rotation and yields ancillary advantages to be described shortly.

In order to improve the heat transfer characteristics of the device, secondary heat dissipating fin material may be inserted between the parallel opposing surfaces or walls of adjacent tubes and secured in place as by brazing or soldering. This construction, while extremely simple to fabricate and assemble, presents a practical and highly efficient heat exchanger adapted to provide a maximum amount of external heat exchange medium flow between the tubes with a miniumu amount of impediment thereto.

Having thus generally described the invention, it becomes a principal object thereof to provide a method of producing an efficient heat exchange device adapted for transfer of heat between an internal and external heat exchange medium.

Another object of this present invention is to provide a method of producing a heat exchange device having a plurality of parallel heat transfer tubes interconnected between a pair of headers for maximum flow of an internal heat transfer medium.

Still another object of the present invention is to provide a method of producing a heat transfer device having a plurality of heat transfer tubes interconnected between a pair of headers, the tubes being elongate in cross-section with the cross-sectional major dimension of the tube being disposed at substantially right angles to the normal plane of the panel from which the device is fabricated.

Still another object of the present invention is to provide a method of producing a heat exchange device having a plurality of heat transfer tubes interconnected between a pair of oppositely disposed headers which are bent or twisted out of the normal plane of the panel from which the device is fabricated so as to provide slots or apertures through which an external heat transfer medium may flow unimpeded over the external surfaces of the heat transfer tubes.

It is still a further object of the present invention to provide a method of producing a heat exchange device having a plurality of heat transfer tubes interconnected between a pair of headers and having the major cross-sectional dimension disposed at substantially right angles to the normal plane of the panel from which the device is fabricated to provide elongate apertures in which secondary heat dissipating fin stock material is inserted in heat transfer relationship with the outer walls of the tubes to achieve maximum efficiency of heat exchange between the internal and external heat transfer mediums.

Still another object of the present invention is to provide a method of producing a device of the above character in a minimum number of steps of simplified nature.

Further objects and advantages of the present invention will become apparent from the following detailed description when considered in conjunction with the accompanying drawings, in which:

FIGURE 1 is a view of one embodiment of the completed heat exchange device of this invention;

FIGURE 2 is a composite view illustrating a number of steps involved in the fabrication of the device of FIGURE 1;

FIGURE 3 is a sectional view taken on line 3—3 of FIGURE 2;

FIGURE 4 is a view similar to FIGURE 3 illustrating the device in an intermediate stage of fabrication;

FIGURE 5 is a fragmentary view similar to FIGURE 4, but on an enlarged scale, illustrating a further stage in the fabrication of the device;

FIGURE 6 is a fragmentary sectional view on an enlarged scale taken on line 6—6 of FIGURE 1;

FIGURE 7 is a fragmentary sectional view on an enlarged scale taken on line 7—7 of FIGURE 1;

FIGURE 8 is a partial view of the panel of FIGURE 2 after inflation of the tubes;

FIGURE 9 is a plan view of a suitable tool contemplated in this invention;

FIGURE 10 is a partial view of the panel of FIGURE 8 illustrating a number of tools about to be inserted; and

FIGURE 11 is a partial view of the panel of FIGURE 8 illustrating the tubes in their position after rotation thereof.

Referring now to the drawings and particularly to FIGURE 1, there is seen an illustrative embodiment of this invention which is a heat exchange device generally indicated by the reference numeral **10**. The initial stage of fabrication of this device is substantially as set forth in great detail in the above-mentioned U.S. Patent 2,690,-002, and is generally illustrated, in conjunction with other steps in the formation of the heat exchange device **10**, in FIGURES 2, 3 and 4.

Referring now to FIGURE 2 it will be seen that the heat exchange device **10** is initially formed from a plurality of superposed flat metal sheets **12** and **14**. Sheet **12** has applied thereto a pattern of weld-inhibiting material **16** which is a foreshortened version of the desired pattern of tubular passageways in the finished article. This pattern consists of a pair of parallel bands **18** and **20** which are spaced apart adjacent a pair of opposite edges of the stack of sheets formed by the individual sheets **12** and **14**. Interconnecting the two bands **18** and **20** are a plurality of bands **22** of weld-inhibiting material which cover the extent of sheet **12** intermediate bands **18** and **20** except for elongated parallel islands **24** which are free of weld-inhibiting material, and which also extend between the aforementioned bands **18** and **20**. It will become apparent that the bands **18** and **20** of weld-inhibiting material correspond to the headers in the finished article and that the bands **22** correspond to the plurality of interconnecting tubes. In order to provide ingress and egress apertures for a heat transfer medium, one or both of the bands **18** and **20** may be extended to an edge of sheet **12**, as indicated at **26**. It will also be seen that a marginal portion of sheet **12** along opposite sides transverse to the aforementioned opposite sides has been left free of weld-inhibiting material **16** forming a peripheral marginal area **28** with the exception of the two strips **26** extending to one of the transverse edges for the ultimate provision of openings adapted for connection to an external source of heat transfer medium.

The stack of component sheets **12** and **14** with weld-inhibiting material **16** sandwiched therebetween is then temporarily secured together as by clamps, spot welding or the like to prevent relative movement between the sheets **12** and **14**. The assembly thus formed is then heated to a required temperature and fed through a pair of pressure rolls which exert sufficient pressure on the stack to firmly weld the sheets **12** and **14** together into a single integrated sheet in the areas not coated with the weld-inhibiting material **16**. Simultaneously with the bonding operation, the sheets **12** and **14** undergo a substantial reduction in thickness as well as an elongation in the direction of rolling. If so desired, a cold rolling operation may follow the hot rolling operation; in any event, the aforeshortened pattern of weld-inhibiting material is stretched to a length corresponding to the desired pattern of tubular passageways in the finished article. FIGURE 4 illustrates in cross-section the unified sheet **30** with the unwelded portions **32** at this stage of the fabrication.

Referring again to FIGURE 2, it will be seen that a plurality of slits **34** are formed in the islands **24** free of weld-inhibiting material, the slits extending almost the full length of these islands. The slits **34** may be formed during any desirable stage of the fabrication process, either in the individual sheets **12** and **14**, or after the sandwich of sheets **12** and **14** and weld-inhibiting material **16** has been formed and temporarily secured together or still alternatively after the aforementioned rolling steps. Preferably the last-mentioned alternative would be selected so as to eliminate both the problem of proper alignment of individual sheets **12** and **14** with slits already formed therein, and the problem of rewelding of adjacent slit edges during the rolling steps if no weld-inhibiting material is inserted between these edges. However, it is apparent that the article is readily adaptable to any of a number of arrangements of the aforementioned steps to achieve the heat exchange device in its embryonic form as illustrated in cross-section in FIGURE 4.

Subsequent to the pressure welding stage in the fabrication process, the unwelded areas **26** which extend to the transverse edge of the unified sheet **30** are mechanically pried open and a suitable nozzle is inserted therein and connected to an external source of pressure fluid. The pressure fluid is pumped into the unwelded portions defined by the weld-inhibiting material **16** to expand the sheets **12** and **14** over these portions and thereby create the desired systems of internal fluid passageways. The expansion may be carried out in a variety of manners but is preferably performed with the composite sheet **30** inserted between suitable dies or platens, either flat or shaped, so as to limit the extent to which the passageway walls can expand outwardly, thus creating a tubular passageway of generally rectangular configuration in cross-section as seen in FIGURE 5. The heat exchange device now consists essentially of the flat unified sheet **30** with an expanded pattern of tubular passageways **38** corresponding to the original pattern of weld-inhibiting material **16**, with the bands **18** and **20** forming the headers **40** and **42**.

Referring again to FIGURE 1, the heat exchange device **10** comprises the integrated sheet **30**, for example of generally rectangular configuration, having the parallel spaced-apart internally disposed headers **40** and **42** and the elongate tubular passageways **38**. The headers **40** and **42** terminate adjacent an edge of sheet **30** in inlet and outlet openings **44** and **46** respectively to which conduits **48** and **50** respectively are connected for communication of the heat exchange device with a source of internal heat transfer medium.

It will be seen from FIGURE 1 and in greater detail in FIGURE 6 that the tubular passageways **38** have been twisted out of the normal plane of sheet **30** so as to dispose the major cross-sectional dimension of tubes **38** at approximately right angles to the normal plane of sheet **30**. The disposition of tubes **38** is of an extent covering substantially all of the length of the slits **34** previously formed in the unified sheet **30**, and is accomplished by a unique method to be described shortly. Thus, in the finished product, the individual tubes **38** are disposed with opposed parallel outer wall surfaces **52** in spaced-apart relationship, providing relatively wide and elongate slots or apertures **54** through which an external heat transfer medium can flow substantially unimpeded. Communication between the headers **40** and **42** and interconnecting tubes **38** is maintained through the interior of the tubes **38** which traverses the transition portions **56** of tubes **38**

which lie between the point of connection between the headers 40 and 42 and the remainder of the tubes 38 which are disposed in the aforementioned perpendicular relationship. Of course, it is desirable to maintain these transition portions 56 as short as possible within the limits of the bending characteristic of the metal in order to provide the maximum length of apertures 54 for unimpeded flow of air and, as will be seen in more detail hereinbelow, to provide the maximum amount of space for secondary heat dissipating fins.

When the tubular passageways have been completed and the interconnecting tubes 38 bent to the desired relationship secondary heat dissipating fins 58 formed of closely corrugated or pleated fin stock may be inserted and positioned within the elongate spaces or apertures between the opposing faces 52 and tubes 38, and suitably secured therein by conventional means, such as solder, brazing and the like interposed between the panel and the fin stock. It will be noted from FIGURE 6 that when the tubes 38 are bent, the welded portions of sheets 12 and 14 formerly defined by the islands 24 free of weld-inhibiting material now constitute oppositely directed flanges 60, thereby leaving the opposing faces 52 of tubes 38 smooth and free of any projecting obstructions. Consequently, it is a relatively simple matter to slip the strips of fin stock 58 into place between adjacent tubes for subsequent unification therewith as explained above. The position of the fin stock 58 is illustrated in the view of FIGURE 1 and in the cross-sectional view of FIGURE 7.

Considering now the precise method by which the tubes may be rotated, reference is had to FIGURES 8–11 of the drawings. While rotation of the tubes according to the instant invention may take place while the tubes are uninflated, partially inflated, or wholly inflated, the latter is preferred. Accordingly, while the discussion which follows is directed to rotation of the fully inflated tubes, such discussion is merely exemplary and the modifications required for rotation of partially inflated or uninflated tubes will be readily apparent to those skilled in the art.

Thus, as is shown in FIGURE 8, the tubes 38 may have been inflated and the slitting operation performed to yield the slits 34. The inflated headers 40 and 42 may then be severed along their full longitudinal extent, for example as along the dotted lines 70 of FIGURE 8, in order to achieve access to the interior of each of the tubes 38. A suitable tool may then be inserted into one or both ends of each of the tubes 38. Such a tool may of course take a variety of forms; however, the tool must fit firmly against the interior surface of the flanges 60 so that rotation is accomplished with a minimum of distortion to the tube. One suitable tool is illustrated in FIGURE 9. As can there be seen, tool 71 comprises a blade portion 72 joined to a shank portion 73 connected by a transitional portion 74. It will be evident that the shank portion 73 may be of any desired cross-sectional configuration, for example of a configuration to be grasped by a mechanical turning means. The blade portion 72 may similarly be of any desired cross-section, but it is desirable that it be of a configuration matching the interior configuration of the tubes 38. When so designed, force upon the tube 38 during the rotating operation would then be substantially equal around the periphery of the tube.

As can be seen in FIGURE 10, a plurality of tools such as 71 may be inserted directly into the tubes 38. By severing the headers 40 and 42, easy access is had to the tubes 38 and the tools 71 may thus be inserted at one or both ends of the tubes 38. The panel may then be suitably restrained, as by clamping it in a suitable support. When all of the tools 71 are in place, they may be rotated, either manually or by a suitable mechanism which grasps the shank portions 73 of each of the tools 71 to rotate them either singly and independently, or simultaneously.

It will be evident that such rotation of the tools 71 causes the tubes 38 to be rotated into the desired position relative to the remainder of the panel, as can be best seen in FIGURE 11. The tools 71 may then be removed and the portions of headers 40 and 42 which were severed may then be replaced and suitably joined, as by welding as shown in 80 in FIGURES 1 and 7. Alternatively, a preformed header may be employed instead of the portions which were removed. Such a preformed header may, for example, be open at two or more sides to allow for connection of a plurality of panels to a single header.

The primary advantage of the method indicated herein is that the tubes may be rotated the desired amount while assuring that the transitional portions of the tubes near the headers remain open. Were it not for the presence of the tools 71 within such transitional areas, as if the tubes were rotated by a mechanism on the outside, the interior of the tube would become deformed and possibly completely closed, and would have to be subsequently reopened.

Additionally, the instant method assures that the length of the transitional portion of the tube is kept to a minimum. An ancillary advantage of the method here disclosed is that while the headers 40 and 42 are open the interiors of tubes 38 are exposed for easy cleaning, as to remove excess weld-inhibiting material.

Various modifications of the above-described method of rotating the tubes are well adapted to the practice of this invention. For example, the tool illustrated in FIGURE 9 is of a rigid construction and upon withdrawal after rotation, force must be exerted upon the tool to extract the blade portion from the transitional portion of the tube. This is not an undesirable feature for such action further opens the tube in the transitional area. However, it is possible to instead provide the tool with movable portions on the blade which expand after introduction into the tube to fill the interior configuration and contract to their initial position for ease of removal. Such a tool could be introduced into the tube in a loose manner such that on expansion it would locate itself in the center of the tube.

With either the rigid or expandable tool, the blade portion could be lengthened to the entire length of the tube, thus allowing for rotation of the tubes from only one end. Also, by provision of appropriate means in the rotating mechanism, the tools may be made to vibrate during the turning operation, thereby working the metal of the tubes while rotating. Additionally, if it is desired, localized heating or annealing of the material of the tubes may be readily accomplished from the outside during the turning operation.

It will be apparent from the foregoing description and accompanying drawings that there has been provided a method for producing a heat exchanger which is believed to provide a solution to the foregoing problems and achieve the aforementioned objects. It is to be understood that the invention is not limited to the illustrations described and shown herein which are deemed to be merely illustrative of the best modes of carrying out the invention, and which are susceptible of modification of form, size, arrangement of parts, and detail of operation, but rather is intended to encompass all such modifications as are within the spirit and scope of the invention as set forth in the appended claims.

What we claim and desire to secure by Letters Patent is:

1. A method of producing a heat exchange device from a composite sheet formed of two superposed planar sheets having a pattern of weld-inhibiting material interposed between said sheets, said pattern including a pair of first bands in parallel spaced-apart relationship located adjacent opposite edges of said composite sheet with at least one of said first bands extending to a transverse edge of said sheet, and a plurality of second bands in closely spaced-apart relationship lying parallel to said transverse edge and joined at opposite ends with said first bands, said first bands and second bands thereby defining islands free of said weld-inhibiting material, said method comprising the steps of

(A) slitting said composite sheet in said weld-inhibiting material free islands over a major portion of the length thereof to provide a plurality of individual strips of said composite sheet,

(B) forming a system of hollow tubes in said composite sheet corresponding to said pattern of weld-inhibiting material by applying thereto a fluid under pressure to expand the areas of said composite sheet covered with said weld-inhibiting material, said system of hollow tubes comprising

(1) a pair of first tubes corresponding to said pair of first bands, and

(2) a plurality of second tubes corresponding to said plurality of second bands

(C) severing at least a portion of each of said first tubes to yield access to the ends of said second tubes,

(D) inserting into the ends of each of said second tubes a tool having an exterior configuration substantially matching the interior configuration of the said second tube in which it is inserted,

(E) rotating each said tool to displace the elongate portion of said second tubes out of the normal plane of said composite sheet, thereby forming elongate apertures between adjacent confronting surfaces of said second tubes, and

(F) closing each of said first tubes to form a conduit in communication with a header at each end of said tubes.

2. A method as set forth in claim 1 further including the steps of inserting secondary heat exchange fin stock into said apertures between said confronting surfaces and securing said fin stock to said surfaces.

3. A process according to claim 1 in which said closing step F is carried out by welding.

4. A process according to claim 1 in which the header in step F is one of said first bands.

5. A process according to claim 1 in which the header in step F is a preformed header.

6. A process according to claim 3 in which a plurality of tools are inserted into the ends of said second tubes simultaneously and are thereafter simultaneously rotated.

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