March 9, 1965 T. F. PAULS 3,172,194

METAL FABRICATION

Filed Aug. 29, 1962 3 Sheets-Sheet 1

FIG - 1

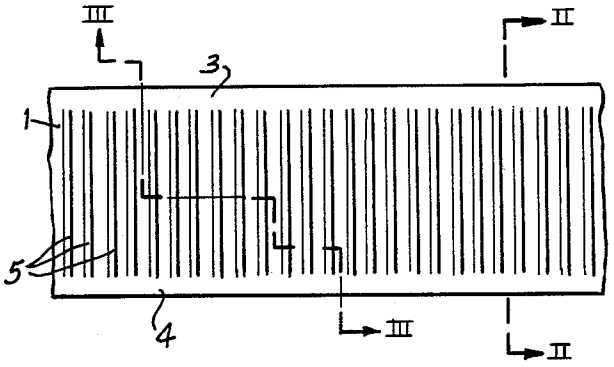



FIG - 2

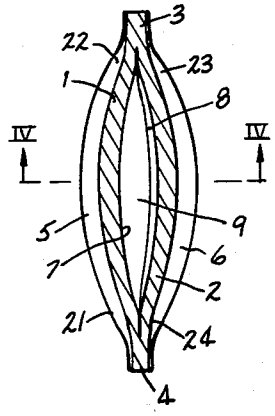
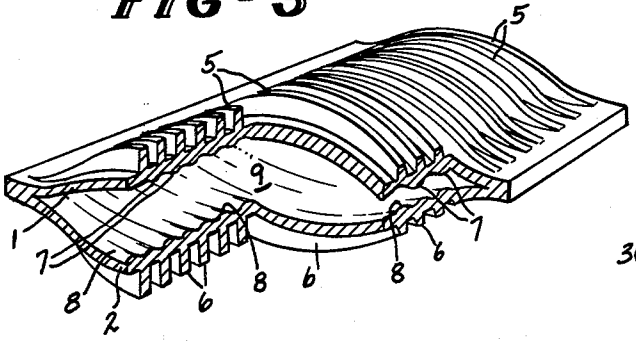



FIG - 3



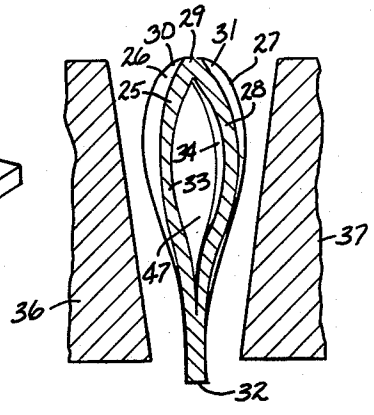
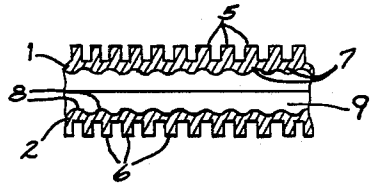




FIG - 8

FIG - 4




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METAL FABRICATION

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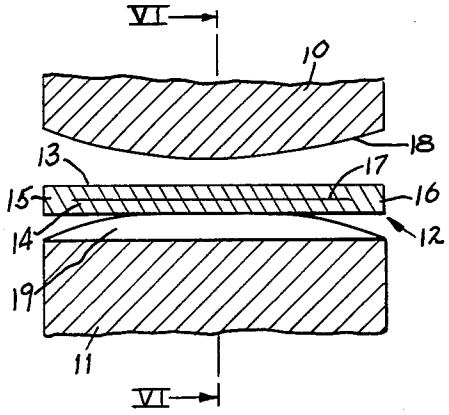



FIG - 5

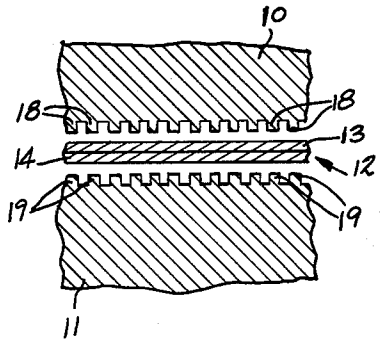



FIG - 6

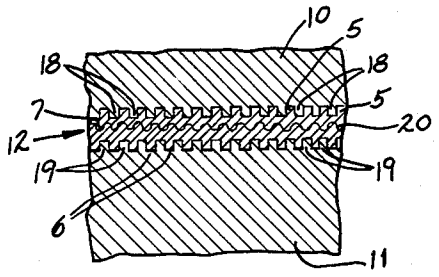



FIG - 7

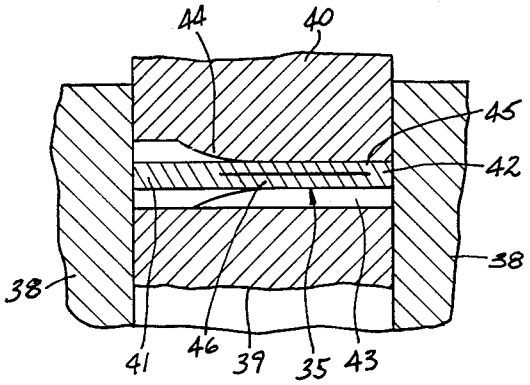



FIG - 9

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METAL FABRICATION

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FIG - 10

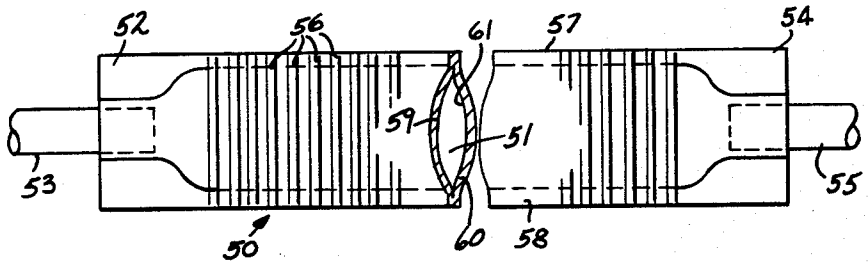
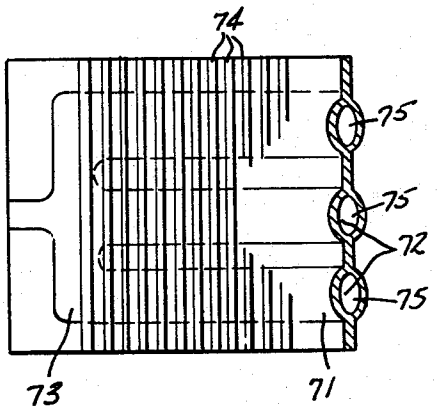



FIG - 11



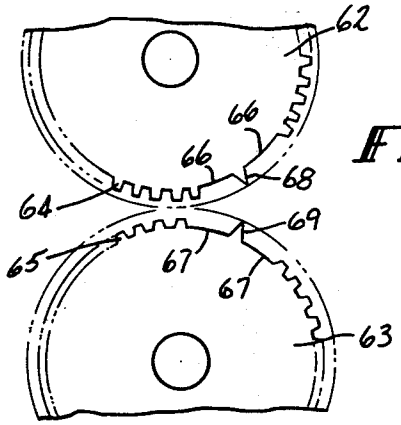




FIG 12

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United States Patent Office 3,172,194 Patented Mar. 9, 1965



3,172,194

# METAL FABRICATION

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Filed Aug. 29, 1962, Ser. No. 220,195
6 Claims. (Cl. 29—157.3)

This application is a continuation-in-part of co-pending application, Serial No. 556,225, filed December 29, 1955.

This invention relates to a heat transfer device and more particularly to a heat exchanger tube having integral fins.

It is desirable that heat exchange tubing for boilers, refrigerators, condensers and the like be provided with external fins. Such heat transfer fins are usually brazed or soldered on the tubing except where the tube structure is very heavy and permits the fins to be cast, extruded, or rolled. However, especially where the tubing is of the flat or oblong sheet metal type, thin walled tubing and the fins are usually brazed or soldered together. This is not only expensive and time consuming, but frequently fails to result in a rigid and efficient joint. Generally, a brazed or soldered joint is of reduced heat exchange efficiency for lack of unimpeded heat transfer through the joint. Another heretofore known method of forming fins is a helical rolling method which, however, has the disadvantage of requiring a fully formed round tube blank together with an internal mandrel and which has the further disadvantage of requiring a considerably thick tube wall and complicated apparatus and controls for the proper extension of integral fins. This prior method is not readily adapted to formation of fins in conjunction with relatively thin sheet metal walls.

One object of this invention is to provide a simple low-cost but improved design of finned heat exchanger tube. Another object is to provide a thin-walled, relatively flat, sheet metal tube having a plurality of integral fins on the external and internal surfaces of the tube for improved heat transfer efficiency. Another object is to provide an improved method for making a tubular form of heat exchanger unit having extended heat transfer surfaces and of improved heat transfer efficiency. A further object is to provide a method adapted to high speed mass production of finned tubing from sheet metal.

Other objects and advantages will become more apparent from the following description and drawings in which:

FIGURE 1 is a plan elevational view of a typical portion of one embodiment of this invention;

FIGURE 2 is a cross-sectional view taken along lines II—II of FIGURE 1;

FIGURE 3 is a perspective view of the embodiment of FIGURE 1 with portions broken away and shown in section on lines III—III of FIGURE 1;

FIGURE 4 is a cross-sectional view taken along lines IV—IV of FIGURE 2;

FIGURE 5 is a fragmentary view in cross-section showing a flat uninflated tube sheet between grooved die platens suitable for manufacturing the embodiment of FIGURES 1 to 4;

FIGURE 6 is a fragmentary cross-sectional view taken along lines VI—VI of FIGURE 5;

FIGURE 7 is a fragmentary cross-sectional view illustrating a further stage in the use of the device shown in FIGURES 5 and 6;

FIGURE 8 is a cross-sectional view of another embodiment of this invention shown in conjunction with the apparatus used in its manufacture;

FIGURE 9 is a fragmentary view in cross-section showing a flat uninflated tube strip in a die arrangement suitable for manufacturing the embodiment of FIGURE 8;

FIGURE 10 is a fragmentary view showing one form of a heat exchanger using the features of this invention;



FIGURE 11 is a fragmentary view showing another form of a heat exchanger incorporating this invention; and

FIGURE 12 is a semi-diagrammatic representation of portions of swaging rolls capable of forming the fin structure shown in the embodiments of FIGURES 10 and 11.

In the aforesaid co-pending application, Serial No. 556,225, there is shown a novel method of fabricating a new type of finned tubing characterized by a relatively thin-walled structure compared to the extension of the formed fins. This type of structure is particularly adaptable to the manufacture of integrally finned tubing from a flat, collapsed but inflatable tube blank. The invention in this co-pending application contemplates the provision on the external surface of an elongated tubular walled sheet metal blank of transversely and longitudinally extending fins together with thin intervening wall portions. In accordance with the invention of this co-pending application an elongated tube blank is provided having double walls the opposed interior surfaces of which are contiguous but separable forming predetermined areas therebetween corresponding to a desired passageway system. These types of structures are exemplified by those obtained in accordance with the well-known method of U.S. Patent No. 2,690,002, granted September 28, 1954 to L. H. Grenell. In one embodiment of this invention the walls of this type of structure are formed by pressure welding component sheets together in preselected areas between them while simultaneously forging opposed tube walls to swage fins from the material of the walls. Adherence is prevented by coating these preselected areas with stop-weld material which separates the component sheets during the deformation operation while the fins are being forged or swaged from the sheet material of the walls which are preferably of sheet metal.

In a preferred embodiment of the invention of this co-pending application, the fins are preferably formed in a direction transverse the elongation of the sheet unit.

In accordance with this invention, it has been discovered that a finned tubing of greater efficiency and extended surface can be obtained by forging the tube blank to upset or swage fins thereon with the fins on one of the external surfaces, of the blank, being in alternate offset relationship with the fins formed on the other external surface of the tube blank. In addition, the forging is done under sufficient pressure to induce internal metal flow within the tube blank which deforms or corrugates the interface between component sheets to form projections on the adjacent internal face between the component sheets disposed in intermeshed relationship with each other. The foregoing is accomplished by a device having opposed teeth or pressure points with the pressure points of one side being staggered with respect to the pressure points on the other side. Upon distention and separation of the intermeshed internal projections the spaced-apart tube walls are provided with inwardly extending fin projections which additionally increase the heat transfer area of the tube blank and further provide means for inducing turbulence in the fluid flowing within the tubular structure.

More specifically with reference to the drawings, a specific illustrative embodiment of this invention is shown in FIGURES 1, 2, 3, and 4 which consists of a first said wall 1, the opposite side wall 2 both of which are integrated or preferably joined together by pressure welding at the lateral edges 3 and 4 so as to form at these lateral edges a unitary structure completely sealed together and requiring no extraneous brazing or welding materials. Side wall 1 bears a series of external fins 5, while side wall 2 bears a second series of external fins 6. The fins are integral with the tube walls, however, each of the fins 5 in the first series is in offset relationship with corresponding fins 6 of the second

series. In addition, side wall 1 is also provided with a series of internal fins 7 projecting inwardly within the tube structure. Also the side wall 2 bears a similar series of fins 8 projecting inwardly of the tube structure in opposed direction to the fins 7 on side wall 1. In the specific embodiment illustrated, fins 7 and 8 form in effect transverse crimps or ruffles functioning as transverse fin projections with the fin projections 7 of side wall 1 being in offset relationship with corresponding fin projections 8 of side wall 2, with each series of fin projections forming a corrugated-like surface on the corresponding finned walls carrying them. Further, the internal fin projections 7 on side wall 1 are also in offset relationship with the external fin projections 5 of this side wall. In like manner, the internal fin projections 8 on side wall 2 are in offset relationship with the external fin projections 6 on this side wall.

As will be appreciated this construction greatly extends the heat transfer area of the tubular structure to provide improved heat exchange. The single fluid passageway 9 may be generated by bulging of the finned walls 1 and 2 in any suitable manner but preferably by inflation, and, as also illustrated, is of lenticular shape. As will be obvious the shape of this passageway can be of various configurations from extremes of an ovoid shape to a rather flat oblong or nearly rectangular shape.

The fins of the embodiment of FIGURES 1 to 4 can be formed with apparatus such as illustrated in FIGURES 5 to 7 where 10 is a working end of an upper forging die and 11 is the working end of a lower forging die adapted for reciprocating cooperating relationship by means well known in the art. These forging dies are illustrated as operating on a special flat laminated stock generally indicated at 12 having opposed component layers 13 and 14 joined at their lateral edges 15 and 16 but maintained in separation at 17 in any suitable manner while in contiguity. For example, at 17 there may be provided a thin layer of any suitable weld or adherence preventing material.

Die block 10 is provided with a series of grooves between protruding lands 18. In similar manner, die block 11 has a grooved working face provided with a series of spaced lands 19 for cooperating coaction with lands 18 of die block 10. However, the lands 18 of die block 10 are in offset relationship with lands 19 of die block 11 as a result of which, during forging, the opposed series of lands exert coextending areas of pressure to upset and deform the surface of the metal into external fin projections and concurrently induce sufficient flow of metal within the laminated stock 16 to deform the interface or line of separation 12 between component layers 13 and 14 to form the desired internal fin projections on the adjacent face of the component layers. As a result of this forging operation the laminated stock is swaged to produce the external fin projections 5 and 6 disposed in offset relationship to each other and the internal fin projections 7 and 8 in offset and intermeshed relationship with one another with their interface defined by the corrugated line of separation 20.

In addition, in the specific embodiment shown, each of lands or teeth 18 and 19 are shaped by lengthwise tapering to be of greatest protrusion which is to say greatest approach, adjacent their mid-section with respect to the corresponding opposing lands. Such a die face arrangement works the greatest deformation of component sheets 13 and 14 adjacent the longitudinal mid-plane structure 12 to provide there the greatest extension of the fins 5 and 6. Upon engagement of forging dies 10 and 11 into the laminated stock or blank 12 with the desired pressure or impact, the resultant uneven deformation of the blank also shapes the integral fins 5 and 6 to be tapered down in the ends 21, 22, 23, and 24 as shown in FIGURES 1 to 4. The resultant blank, now not only internally laminated but also externally and internally finned, may be, with or without annealing, suitably distended or bulged by injection of an inflation fluid pressure along the interface or unwelded area 20 and erection of the side walls 1 and 2 and generation of the internal passageway 9. It is noted that the forged blank may be distended by inflation either freely or between sizing dies to give a desired longitudinal uniformity during the distention.



The embodiment of the tube structure of this invention, shown in FIGURE 8, is characterized by a streamline or tear drop cross-sectional configuration. In this embodiment, the finished tube consists of side wall 25 which bears a series of external fins 26 in offset relationship to a similar series of external fin projections 27 extending from the opposite side wall 28. These external fin projections of this embodiment are of greatest outward extension adjacent the leading lateral edge 29 which in conjunction with the leading edge 30 of external fins 25 and the leading edge 31 forms a generally rounded streamline leading fin section. Adjacent the trailing lateral edge 32 of the tube, the fins 25 and 28 are tapered down to merge gradually into the opposing side walls 25 and 28, which as in the previous embodiment are integrated at both lateral edges 29 and 32. In addition, this embodiment is also formed with internal fin projections 33 extending internally from the inner surface of said wall 25 with internal side projections 34 extending internally from inner surface of side wall 28 with each of the internal fin projections 33 being in offset relationship with corresponding fin projections 34 of side wall 28. In addition, the internal fin projections 33 on side wall 25 are in offset relationship with the external fin projections 26 on this wall.

This embodiment of FIGURE 8 can advantageously be formed from an internally laminated blank 35 in the apparatus shown in FIGURE 9, after the structure is inflated to the final finished form shown in FIGURE 8 between the spaced sizing platens 36 and 37, the working faces of which are closely spaced adjacent the trailing end 32 and more remotely spaced adjacent the leading edge 29. In the fabrication of this embodiment, the internally laminated blank 35, preferably in completely annealed condition, is placed in the die cavity of the block 38 (FIGURE 9) where it is supported on the grooved working face of the lower movable forging ram 39, also nested in the cavity of the block 38. Upper forging ram or die 40 is movable into the cavity of block 38 and is adapted, together with the lower ram 39, to subject the laminated blank 35 to a forging or swaging action. As will be noted, in the apparatus of FIGURE 9, the lateral edges of the blank are confined, thus edge 41, which will form trailing edge 32 of the finished tube, and also edge 42 of blank 39, which will form the leading edge 29 of the finished tube, are confined in the cavity of die block 38. Working faces of the forging rams 39 and 40 are provided with a series of spaced teeth or lands 43 and 44, respectively, with the lands 43 in one series being in offset relationship with the lands 44 of the other series in a manner similar to that of the preceding embodiment. As will be noted, forging lands 43 and 44 are tapered back as to approach edge 41, of the laminated blank 35, and to accomplish less finning and forging of the laminated blank 35. Although specific configuration of forging lands has been shown, it is to be understood that the forging lands 43 and 44 may extend uniformly all the way across the working face of the forging rams 39 and 40, respectively, to provide fins substantially completely across the tube structure, as, for example, shown in FIGURES 10 and 11.

Upon completion of the forging operation the swaged blank 35, now provided with a series of internal and external fins on both sides of component sheets 45 and 46, is then placed between suitably separated platens 36 and 37 (FIGURE 8) and subjected to internal inflation pres-

sure so as to produce the space of the finished tube shown in FIGURE 8 having fluid passageway 47.

In any event, by the production of the foregoing and other embodiments, there is provided a flat, two-walled blank in any suitable manner. Such blank may be formed by rolling or drawing a relatively thin-walled tube shut. Also the blank may be formed by extrusion after which the extruded blank may be flattened either by rolling or passage through a sizing or drawing die. If naturally occuring oxide within the interior of such a blank is insufficient for purposes of preventing welding, a coating of stop-weld material may be applied to the interior of the blank so as to prevent the undesired welding or sticking between the opposing inner walls of the blank during the rolling, drawing, or subsequent forging operation described herein. However, as indicated above, a preferred mode of providing the blank is by the method described in the aforesaid U.S. Letters Patent No. 2,690,002 which method comprises superimposing two metal sheets together having between them an intervening layer of stop-weld material extending in a pattern corresponding to a desired fluid passageway system, followed by pressure welding the sheets together in their adjacent areas not separated by the stop-weld material in any appropriate manner. This type of blank is then suitable and ready for forging or swaging thereof to form the desired finned structure.

FIGURE 10 illustrates another embodiment of this invention wherein a strap type of heat exchanger **50** is made in accordance with this invention. The unit is provided with a single heat exchanger fluid passageway **51**, one end of which at **52** is constricted so as to enable an inlet connection to be made with ordinary tubing **53**. In the other end **54**, the unit is similarly constructed for connection with outlet tube **55**. Between these ends there is provided on the exterior surface of the unit **50** a series of transverse integral fin structures such as **56** extending all the way across the unit **50** including lateral edges **57** and **58**. As with the preceding embodiments, the fin structures projecting from one external surface of the unit **50** are in offset relationship with the fins projecting from the opposite surface of this unit. Also, in accordance with this invention, the unit is provided with internal fins on each of the inner surfaces of tube walls **59** and **60**, as for example, the fin projection **61** on the inner surface of tube side wall **60**. In manner similar to that of the preceding embodiments, the internal fin projections, such as **61**, are in offset relationship to the external fin projections provided on the common tube side wall.

To produce the external and internal fins of the foregoing embodiment, they may be formed by means of swaging rolls **62** and **63** of FIGURE 12 instead of the reciprocating forging dies described hereinbefore. Rolls **62** and **63**, the latter of which may be flanged on both the ends have a peripheral construction suitable for manufacturing the fin structure and strip of FIGURE 10. It is to be understood that the roll periphery may be of grooved or toothed form identical or similar to the working fabrication shown in FIGURES 5 and 9. Each roll is provided with protruding forging teeth or lands such as **64** of roll **62** and teeth **65** of roll **63**. These teeth are designed so that the teeth **64** of roll **62** are in offset relationship with the teeth **65** of roll **63** at the roll bite at which the roll spacing is adapted to accomplish the desired swaging for flow of metal needed to make the fins. The rolls **62** and **63** may each be free over a portion of their peripheries such as shown at **66** and **67**, respectively, so that these recessed portions of the periphery may render the ends **52** and **54** of the unit of FIGURE 10 free from fins. In these recessed portions of the rolls **62** and **63** there is provided a pair of registerable pinch-off sharp protrusions such as **68** and **69**, respectively. When these come together in the substantial contact and registry desired, measured portions of the strip are cut apart from each other.

In similar manner to the foregoing embodiments, FIGURE 11 illustrates a further modification of this invention depicting the provision of fins on a tube sheet **70** containing internally therein a system of interconnected fluid passageways **71** comprising, as for example, fluid passageways **72** interconnected together by a cross header **73**. This embodiment may be provided by any of the foregoing methods with external fin projections on each of the external surfaces of unit **70**, as for example, the fin projections **74** illustrated in FIGURE 11, with the transversely extending fins on one external surface disposed in offset relationship with transverse fin projections extending on the opposite surface of the unit **70**. In addition, the unit **70** is also provided with transverse internal fin projections **75** on the inner walls of each of the tube side walls, such as fins **75**, in the offset relationship with each other hereinbefore described.

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

What is claimed is:

1. In a method of making seamless finned tubing the steps comprising forming a blank by superimposing into substantial contiguity a pair of component metal sheets, interposing a thin layer of stop-weld material interfacially separable except at laterally spaced portions, joining said sheets at said lateral spaced portions, applying spaced points of forging pressure concurrently to each of the opposite faces of said blank with the points of said pressure applied on one of said faces being disposed in offset relationship to the points of pressure applied to the other of said faces, said application of pressure being sufficient to forge on each of said faces intermediate each of said points externally extending projections with said pressure inducing sufficient internal flow of metal in said blank to deform the interface of said sheets to form offset internal projections on the adjacent faces of said sheets in intermeshed relationship with each other with the internal projection on one of said sheets being in offset relationship with the external projection on said one sheet and said external projections on one of said faces being in offset relationship with the external projections on the other of said faces, said superimposition being maintained by joinder of said sheets at said lateral spaced portions.

2. The method of claim 1 wherein the step of joining comprises pressure welding said sheets at said lateral spaced points simultaneously with the application of said forging pressure.

3. The method of making seamless, finned heat exchanger tubing comprising forming a substantially flat tube sheet blank having a pair of opposed component sheet metal portions superposed in substantial contiguity with an interposing thin pattern of stop-weld material and integral with each other along their lateral edges, forging adjacent portions of said blank between a pair of opposed pressure means with each of said means comprised of spaced pressure points with the pressure points of one of said means being in offset relationship with the pressure points of the other of said means, said forging swaging said blanks at each of said portions intermediate each of said points adjacent thereto into external projections extending in alternate directions out of each of the opposite faces of said blank with the external projection at one of said portions extending in an opposite direction and in offset relationship to the external projection at an adjacent portion and said forging inducing sufficient internal metal flow in said blank to deform the interface of said sheet metal portions to form offset internal pro-

jections on the adjacent faces of said sheet metal portions in intermeshed relationship with each other with the internal projections on one of said sheet metal portions being in offset relationship with the external projections on said one sheet, and thereafter separating said sheet metal portions intermediate said lateral edges to final finish tube form having a fluid passageway corresponding to said pattern.

4. A method of making a finned hollow sheet structure from a plurality of superimposed welded metal sheets adapted to provide within the confines of said sheet structure a desired system of fluid passages adapted to contain a fluid under pressure, comprising forging said sheet structure from opposite sides thereof, concurrently to swage externally extending fins on one side offset from externally extending fins on the opposite side and to induce sufficient internal flow of metal in said blank to deform the interface of adjacent sheets to form internally extending projections on the adjacent faces of said sheets in intermeshed and offset relationship with each other with the internal projections on one of said sheets being in offset relationship with the external projections on said one sheet and with the external projections on one of said sides being in offset relationship with the external projections on the other of said sides.

5. A method of making a finned hollow sheet structure comprising forming an assembly of superposed metal component sheets having stop-weld material interposed between adjacent sheets in a pattern corresponding to a desired fluid passageway system adapted to contain a fluid under pressure, rolling said assembly under sufficient reduction to pressure weld said sheets in their adjacent areas not separated by said material and simultaneously forging said assembly from opposite sides thereof, concurrently sufficiently to swage externally extending fins on one side offset from externally extending fins on the opposite side and to induce sufficient internal flow of metal in said assembly to deform the interface of adjacent sheets and to form internally extending projections on the adjacent faces of said sheets in intermeshed relationship with each other with the internal projections on one of said sheets being in offset relationship with the external projections on said one sheet and with the external projections on one of said sides being in offset relationship with the external projections on the other of said sides, and thereafter distending the unwelded portions between said sheets defined by said material to form said passageway system.

6. A method of making a finned hollow tube sheet structure comprising interposing between superposed metal sheets a pattern of stop-weld material corresponding to a desired fluid passageway system, forming a blank by pressure welding said sheets together in their areas not separated by said stop-weld material, forging the exterior surfaces of said blank by applying spaced coextending parallel areas of forging pressure to each of said surfaces concurrently, with the areas of said pressure applied to one of said surfaces being disposed in offset relationship to the areas of pressure applied to the other of said surfaces, said application of pressure being sufficient to forge on each of said surfaces intermediate each of said areas externally extending projections coextending with each other with said pressure inducing sufficient internal flow of metal in said blank to deform the interface of said sheets to form offset internal projections on the adjacent faces of said sheets in intermeshed relationship with each other with the internal projections on one of said sheets coextending with and being in offset relationship with the external projections on said one sheet and said external projections on one of said surfaces being in offset relationship with the external projections on the other of said surfaces, and distending the unwelded blank between said sheets defined by said material into said fluid passageway system.

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