

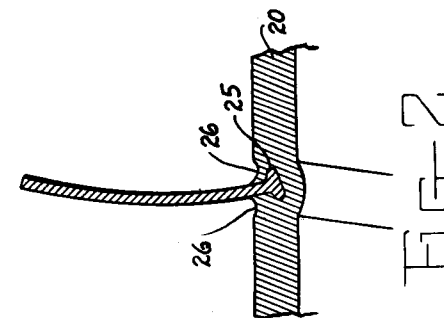
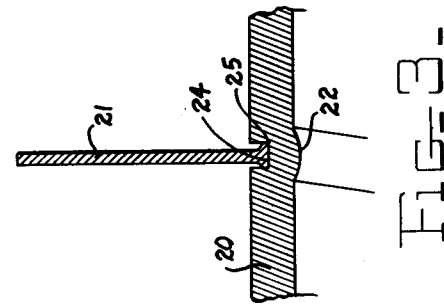
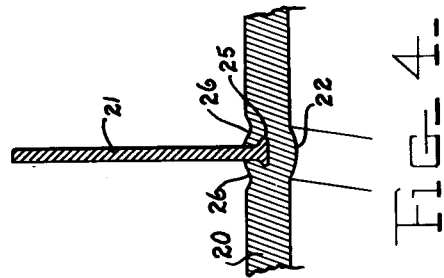
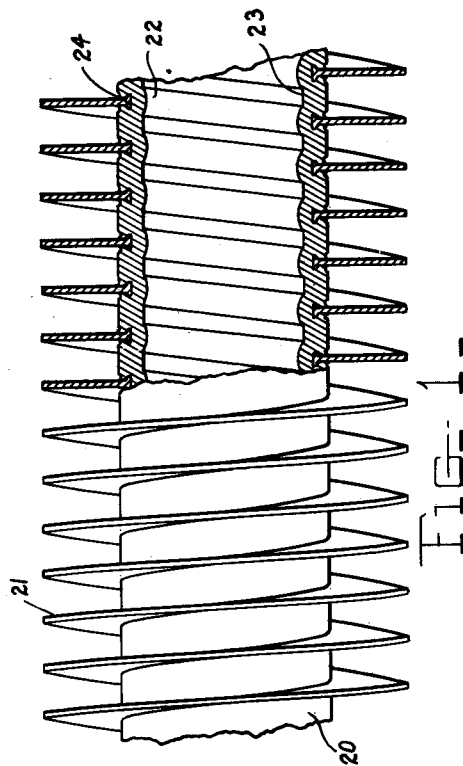
June 20, 1933.

A. J. BERG
HEAT EXCHANGER METHOD

1,914,477

Filed Dec. 2, 1929

2 Sheets-Sheet 1



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June 20, 1933.

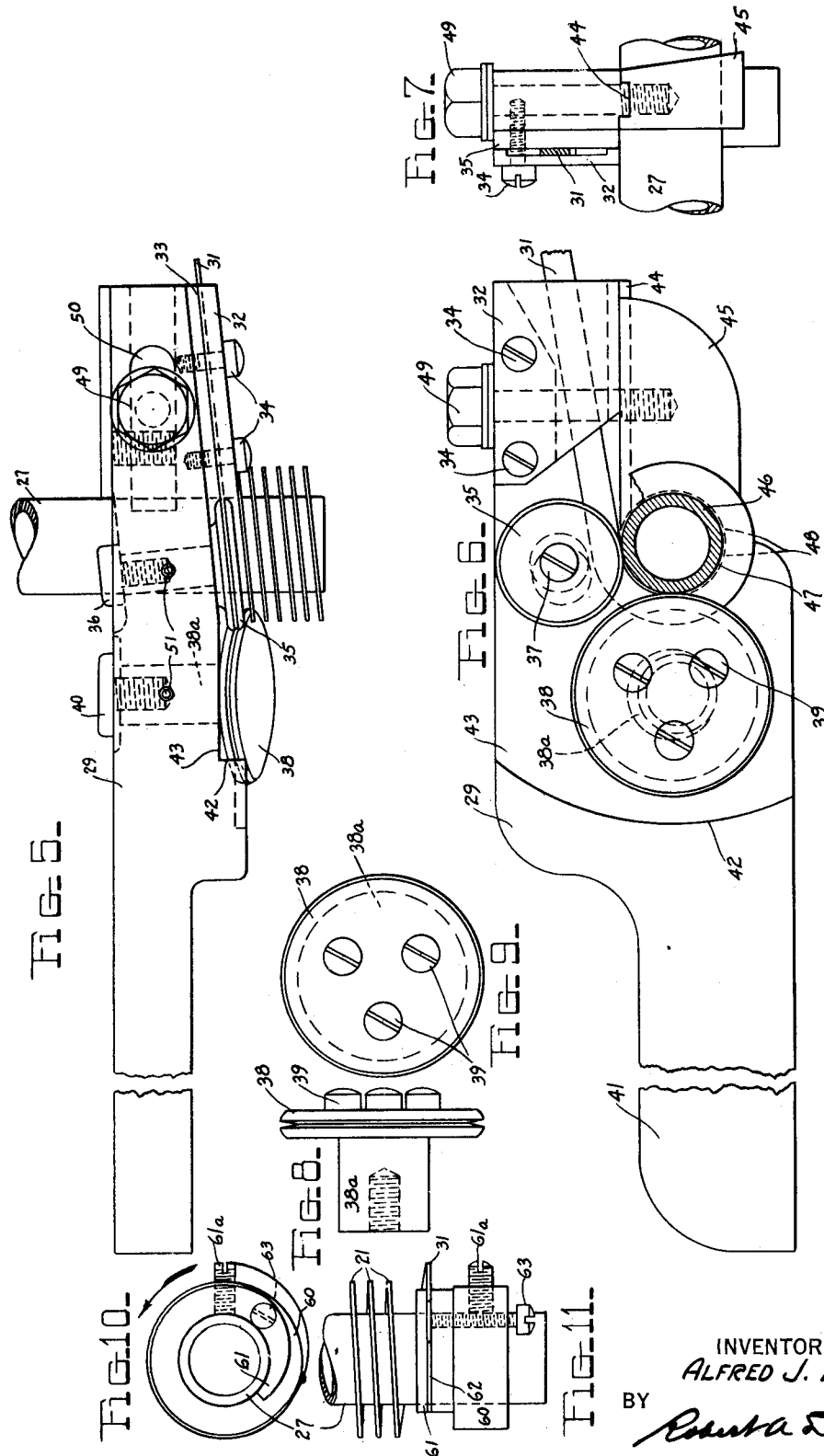
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1,914,477

HEAT EXCHANGER METHOD

Filed Dec. 2, 1929

2 Sheets-Sheet 2



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ALFRED J. BERG, OF PORTSMOUTH, NEW HAMPSHIRE

HEAT EXCHANGER METHOD

Application filed December 2, 1929. Serial No. 411,198.

(GRANTED UNDER THE ACT OF MARCH 3, 1883, AS AMENDED APRIL 30, 1928; 370 O. G. 757)

My present invention relates to an improved heat exchanger method and more especially, to such heat exchangers for example as tubes having heat transferring fins or vanes thereon.

In my co-pending application, Serial Number 407,087, of which this is a continuation in part, there is disclosed a form of heat exchanger tube provided with fins or vanes, and an apparatus for placing the fins about the exterior surface of the tube. In the disclosure of this application, a helical groove is rolled about the exterior surface of the tube, which simultaneously forms an internal rib by the metal of the tube displaced by the rolling of said groove. A thin ribbon-like strip of metal is then wound about the tube with one edge extending into said rolled groove with said edge upset against the bottom and sides of said groove. The metal of the tube is then displaced, for example by swaging, against the sides of the edge of said strip embedded in said pre-formed groove.

In my co-pending application, Serial Number 249,405, of which this is also a continuation in part, I directly embed an edge of the fin-forming strip helically into the outer surface of the tube by the pressure of coiling the strip about the tube whose inner surface or bore remains normally smooth.

An object of my present invention is to provide a method of and apparatus for applying the fin strip to the tube and which fin will be of greater strength, stability and heat exchanging efficiency than that of my last stated application and be more economically produced than the tubes of my first stated application.

My method contemplates and includes the steps of mounting the tube in a screw cutting lathe, unsupported by mandrel or otherwise on the interior surface of the tube adapted to be ribbed, securing an end of a strip, adapted to form a fin, to the tube, relatively rotating the tube and said strip, embedding an edge of said strip into the outer surface of the tube, forming a rib upon the interior of the tube simultaneously with the embedding of said fin and preferably by the metal of the tube displaced thereby; and more spe-

cifically contemplates and includes in and as a part of said embedding step said strip shall be and remain under substantial longitudinal stress, and that said embedding be accomplished by inward pressure applied upon said strip, and that said pressure may be applied to the outer edge of said strip by rollers which have but a relatively small portion of their surfaces in progressive contact with said strip, and that said rolling pressure also coils the strip helically about the tube simultaneously with said embedding; and that the point at which said pressure or rolling pressure is applied and said tube shall be relatively longitudinally movable; that the heat of said rolling pressure be substantially kept from said strip to obviate the removal of the rolled temper or hardness of said strip, preferably by the major surfaces of said roller or rollers and of said strip being in contact with the air which absorbs and carries off said heat; and that the inward pressure upon said strip shall camber said strip longitudinally and preferably progressively and that the extent of said camber be definitely controlled; and

Further contemplates and includes more securely fastening the embedded edge of said strip to the tube, and simultaneously increasing the thermal contact therebetween, by knurling or swaging metal of the tube against one or both sides of the strip, and that said embedding of the strip may upset, distort or thicken the embedded edge of said strip; and

Further contemplates the shortening of the tube substantially proportionate to the metal of the tube displaced into the internal rib by said embedding of said strip whereby the thermal efficiency and strength of the tube are each substantially increased which also reduces the production cost by enabling tubes of a thinner wall to be employed; and

Further contemplates and includes the employment of a very thin strip coiled about and embedded into the tube, while subjected to substantial longitudinal stress and/or camber, whereby said strip will be of equal or greater strength and resistance to displacement or distortion to or than a thicker strip

and enable the employment of more coils of said strip per unit of length of the tube and increase the heat exchange efficiency of the element thus formed; and

5 Further contemplates increasing the density of the metal of the tube in the region of the exterior fin and internal rib to thereby increase their heat exchange efficiency.

I have found that a film of the through
10 flowing fluid forms upon the smooth interior surface of the heat interchange member or tube which film offers substantial resistance to heat interchange therethrough.

The object of this invention is to provide
15 heat exchange method and apparatus for facilitating and increasing the efficiency of heat exchange and the more expeditious and less expensive production thereof.

To attain these and other objects, and in
20 accordance with the general features of this unitary and related invention, my improved method further contemplates, in heat exchange through a medium, the breaking up of the heat interchange resisting film of the
25 heat medium which forms upon the juxtaposed surface of the exchange medium, and that such breaking up be attained most economically and efficiently by causing an abnormal turbulence and flow of such film and its
30 juxtaposed heat medium so that said film and its juxtaposed heat medium substantially commingle; and further contemplates that in said flow said film and its juxtaposed heat medium will be maintained in thermal contact with the exchange medium to a substantially greater than normal extent and area, for instance by the substantially angular or
35 spiral direction of said flow relative to the exchange medium; and in its apparatus aspect more specifically contemplates the breaking up of said film be attained by projecting portions of said exchange medium formed by the attachment of a heat exchanger rib or ribs
40 to the outer or opposite surface of said exchange medium.

To demonstrate the practical utility of my
said method a related, improved and novel apparatus embodying my invention is provided which may be used advantageously and
50 economically in practicing said improved method as a unitary invention. Said apparatus also serves as an example, to those skilled in the art, of the facility with which, after becoming familiar with my invention, the many forms and kinds of existing apparatus, with or without substantial modification, may be employed in the efficient practice of my said method.

Said provided apparatus contemplates and
60 includes a heat exchange member, preferably a tube, whose bore or upon whose inner surface, the heat medium is adapted to flow past angular or spirally disposed projecting portions of said member or tube, which projecting
75 portions are preferably continuous and

extend substantially into said flowing medium. Said projections break up the heat interchange resisting film of the heat medium which otherwise forms upon the adjacent
70 surface of the exchange member or tube, and causes said film and its juxtaposed heat medium to become turbulent, substantially commingle and flow to a substantially greater than normal extent in thermal contact with the exchanger member or tube with said flow
75 tending in the direction of the angular or spiral disposition of said projecting portion or portions, which is or are longer than the normal extent or length of the exchanger member or tube as well as said flow being in
80 thermal contact with the area of said portion or portions which is much greater than the area of the portion of the surface of said member or tube displaced by said portion or portions; and further contemplates that
85 the efficiency of the exchange member or tube be increased by the usual exterior fin or fins and that said fin or fins be so applied to the outer surface of the member or tube in such manner as to produce the projecting portion
90 or portions; and to apply said fin or fins to said member or tube by displacing metal of one, or the outer, surface of said member or tube inwardly to form a groove in said surface and a projection on the opposite surface, said groove and projection being preferably simultaneously formed; the insertion of an edge of said fin or fins into said groove, and the lateral displacement of metal of said member or tube against said fin or fins.

My present method and apparatus dispenses with each of the following essentials of my foregoing applications: the rolling or pre-forming of the helical groove; a mandrel for mounting each tube between lathe centers; a different mandrel for each different diameter and length of tube required to be made; snugly fitting each tube to its mandrel before it is placed in the lathe; and the removal of each tube from its mandrel after being finished. Because of the relative thinness and softness of said tube, the tightness with which said tube must fit its mandrel, and the care required to prevent distortion
115 when fitting or removing the mandrel, such eliminations result in a substantial saving in production costs. They also result in an additional characteristic of the product which produces an increased thermal efficiency and
120 rigidity of said tube.

Said eliminations were contributed to by my discovery that the curling and knurling of the fin 21 about the tube could be done without requiring that the tube, even when
125 of thin and soft metal, be supported by any mandrel or otherwise than by the wall of the tube, and that the tool for curling and knurling the ribbon about the tube acted, in a substantial sense, as a steady rest for the tube at
130

the point of the application of the stresses requisite therefor.

In its apparatus aspect an object of my present invention is to provide a heat exchanger tube in which the interior wall of the tube is provided with spaced rib-like, preferably spiral projections which serve to produce turbulence in the stream of fluid flowing through the tube, thus agitating the stream and preventing the formation of a core of fluid at the center of the tube which is shielded from the desired heat transferring action by the outer layers of fluid adjacent the tube walls. Said agitation, in the instance of spiral ribs on the interior, tends to produce turbulence in and a spiral motion of the stream or layer of fluid while flowing through the tube or over the heat surface of the exchange member.

My invention will be further understood in its several aspects by referring to the accompanying drawings which show by way of example one form of the improved heat exchanger tube of my present invention, and also one form of apparatus by which the improved tubing may be manufactured. In these drawings, in which like characters of reference indicate the same parts:

Figure 1 is a view partly in side elevation and partly in section of a fragment of my improved heat exchanger tube;

Figures 2, 3 and 4 are enlarged sectional views of a small portion of tubing adjacent a single fin and illustrate the various steps of the application of the fin ribbon to the tube, Figure 2 showing the cambered fin, while Figures 3 and 4 show the fin uncambered;

Figures 5, 6 and 7 are respectively a plan, side elevation and an end view of an apparatus for applying the metal ribbon to the tubing;

Figures 8 and 9 are respectively a side and an end view of the knurling or crimping wheel;

Figure 10 is an end view of the means for starting the winding of the external fin upon the tube; and

Figure 11 is a top plan view of the structure shown in Figure 11.

Referring now to the accompanying drawings and in particular to Figures 1 to 4 inclusive, my improved heat exchanger element comprises a metal tube 20 on the outside surface of which there is wound a continuous metal ribbon 21. The ribbon 21 is edgewise wound with its inner edge embedded in the surface of the tube in a manner to be presently described. On the interior the tube is provided with a helical rib-like projection 22 which is integral with the wall 23 of the tube.

In making my improved heat exchanger element as a tube, the tube is suitably mounted to be revolved in a screw cutting lathe with the interior of the tube, to be formed

with internal ribs, unsupported by any mandrel.

Referring to Figure 6, the fin strip 31 is led between the tension plates 32—33 and into the grooves in the roller 35. The outer half of roller 38 is removed by its screws 39 and the end of strip 31 is secured to tube 27 as will hereinafter be described. Screws 34 are set to clamp strips 31 between plates 32—33 so that strip 31 will be placed in substantial longitudinal stress between tube 27 and plates 32—33. Tube 27 is then rotated through a part of a revolution to bring the point of securing of strip 31 to tube 27 below the half of wheel 38 which is attached to its hub 38a. During this partial rotation the clamping force on strip 31 by plates 32—33 sufficiently resists the longitudinal movement of strip 31 to cause the edge of said strip adjacent tube 27 to be embedded into the outer surface of tube 27. The outer half of roller 31 is then mounted upon its inner half and secured thereto with the screws 39. Tube 27 may then be further rotated until the fin strip 31 is coiled about, embedded into, and secured to the tube 27 to the extent desired to complete the tube.

The metal fin-forming strip 31 is adapted to be moved in a direction approximately parallel to the tool body, and is guided in a vertical plane by passing between flat metal tension plates 32 and 33 attached to the tool body, and exerting the desired clamping tension upon strip 31, by screws 34. Plate 32 is countersunk as indicated by the dotted lines in Figure 6 to accommodate part of the thickness of the strip.

Reference numeral 35 designates a lead wheel preferably consisting of two metal discs spaced apart approximately the thickness of the ribbon or strip. These discs constituting the lead wheel are free to rotate upon a bearing passing transversely through the tool body to which it is attached by means of a thrust member 36 and a screw 37. As shown in Figure 5 this bearing is not normal to the length of tool body 29, but is placed at an angle thereto for reasons which will presently appear.

The knurling or crimping wheel 38 shown in detail in Figures 8 and 9 is made up of two rotating discs adjustably secured together by means of screws 39, one of these discs having a preferably integral bearing member 38a held within the tool body by thrust screw 40. The axis of rotation of the crimp wheel 38 is inclined from the vertical causing the wheel to tilt upwardly as best shown in Figure 5. As shown in Figure 8, the discs forming the crimp wheel 38 are spaced apart slightly at their peripheries forming a tapered slot to accommodate the fin after it is placed upon the tube 27, the depth of the slot being sufficient to allow the smooth or fine toothed periphery of each half of the wheel 38 to en-

gage the surface of the tube and knurl or crimp metal of the tube against each side of fin 31.

The tool body 29 is preferably a wrought steel member formed at one end with a shank 41 to fit a standard tool post, and tapered in thickness at the other end so that the side thereof extending beyond the region of wheel 38 forms an angle coinciding with that defined by the space between the lead wheel discs, which in turn is determined by the horizontal progression or pitch of the fin along the surface of the tube 27.

The tool body 29 is cut away as indicated at 42, Figure 5, to form a flat surface 43 which is inclined slightly to the vertical so as to form a bearing surface for the crimp wheel 38. Under the forward end of the tool a tongue and groove joint 44 aligns the adjustable steady-rest member 45 in a vertical plane. This member 45 and its coating portion of the tool body 29 are provided with outlet portions 46 and 47 respectively corresponding to the curvature of and adapted to engage and support as a steady-rest the tube 27 at the point of progressive application thereto of the stresses requisite to the formation of the fin strip 31 about the tube and embedding therein of an edge of the strip as well as the formation of the internal rib or ribs 22 by the displacement of said strip.

The embedding of the edge of the strip 31 into the metal of the tube will cause the embedding edge of strip 31 to be deformed, upset or thickened, which will increase the securement of the strip to the tube and tend to make something of a dovetailed joint between the strip and tube. The thickness and/or hardness of the metal of strip 31 and of the wall of the tube, together with the setting of the rollers 35 and 38 and the pressure-resisting longitudinal movement of strip 31, are the factors determining the extent to which the strip 31 is embedded into the tube as well as of the extent of projections 22 within the bore of the tube. For example, with a copper tube it is easier to produce a deep internal rib, than with a steel tube. However, even a relatively shallow internal rib produces a remarkable degree of turbulence in the column of liquid flowing through the tube.

Fluid flowing through the bore of a tube normally flows therethrough in a uniform column whose outer film is in thermal contact with the tube, and its inner portions interchange their heat with the tube through said outer film due to its temperature being thus changed. The resistance to heat exchange of said film is substantial and varies with the kind of fluid. With gases said resistance is very high. Said film remains relatively fixed to the juxtaposed surface of the heat exchange member except at higher velocities at which such film moves substan-

tially slower than the inner hotter portions of the fluid, and to the extent of such movement of said film the heat interchange efficiency is increased to some extent.

However, with my invention, the internal integral rib 22 formed on, and projecting substantially inward from, the bore of tube 27 creates substantial turbulence in the fluid flowing past such rib or ribs, breaks up said film and mixes it with the inner hotter portions of the fluid and forces hotter inner portions into direct thermal contact with said rib or ribs and the other portions of the bore of tube 27. Such action is repeated due to the force of such turbulency and the encountering of succeeding ribs 22, or succeeding portions of said rib 22. The angular or spiral disposition of said rib or ribs 22 tends to impart progressive angularity to said turbulence. Said turbulence and its angularity each substantially increases the heat exchanging efficiency of my said tube in all its said uses, and especially so in hot gas and refrigeration uses in which it is also extensively employed.

Rigid connection is made between the tool body 29 and the steady-rest member 45 by means of a clamping screw 49 passing through a slot 50 in the outer end of the tool body 29. The tool body is provided with oil holes as indicated at 51 for lubricating the bearing surfaces of the lead and crimp rolls 37 and 38 respectively.

A sleeve 60, Figures 10 and 11, having a longitudinal opening therethrough, adapted to fit the diameter of tube 27, is placed upon the end of said tube to be finned and is secured in place thereon by a radially disposed, in the instance shown, screw 61. The preferred place of securement of sleeve 60 to tube 27 is near the tail-stock of the lathe in which tube 27 is mounted for the performance of the ribbing and finning operation on said tube. Said sleeve 60 is provided with a relatively short groove 62 opening into the surface of sleeve 60 away from the tail-stock, and adapted to receive the leading end of the fin-ribbon 31. Said end of ribbon 31 is secured in said groove 62 by a longitudinally disposed screw 63, which therefore secures said end of ribbon 31 as it is being coiled about tube 27.

The manner of operation of my device is as follows:

The tool is rigidly fastened in the tool post of a standard lathe equipped with thread cutting gear. The tube or cylinder 27 to be finned and having sleeve 60 secured thereto is mounted in the lathe, without a mandrel or other support for its interior that is to be ribbed, and said tube rotated in the usual manner.

The lathe spindle is then rotated, preferably by hand, a portion of a turn with the outer half of wheel 38 removed as aforesaid, whereupon said half of wheel 38 is mounted

in place and the tube rotated in the lathe, during which the tube and the wound end of strip 31 are relatively rotated and the tool and the tube are relatively longitudinally moved.

Referring to Figure 6, the metal ribbon 31 may be led from a suitable carrier such as a spool or the like (not shown) and passed loosely between the guide plates 32 and 33, and into groove 62 of sleeve 60, where its leading end is secured by screw 63 (Figures 10 and 11). This secures the leading end of fin-ribbon 31 to tube 27 mounted to be rotated by the lathe so that its rotation, with the longitudinal motion of tool body 29 by the usual screw-cutting means of the lathe, brings said ribbon with its adjacent edge juxtaposed to the outer surface of tube 27; plate 32 having been clamped, by screws 34, with ribbon 31 against plate 33 so that substantial longitudinal tension is placed upon ribbon 31 to resist to a substantial extent the movement of ribbon 31 between plates 32, 33, and the strip 31 having been duly entered into the peripheral grooves of lead wheel 35 and knurling wheel 38, and with the tube 27 rotating in the proper direction, the operation of the apparatus may proceed.

The lead wheel 35 is arranged so that its fin-receiving groove will be in alignment with the helical fin to be coiled about the tube. The lead wheel 35 serves two purposes. First, it bends the strip or ribbon 31 to the contour of the tube 27, and secondly, it forces the inner edge of the ribbon 31 to be embedded into the tube 27 in cooperation with the resistance placed upon strip by plates 32 and 33.

These actions of the lead wheel 35 and plates 32 and 33 are carried out simultaneously as illustrated in Figure 6. In fact, it may be said, that the bending operation of the strip occurs simultaneously with its embedding into the metal of tube 27. The bending of the strip in the helical or so called spiral form causes the inner edge of the strip to thicken appreciably, which thickening takes place during the time the edge is being embedded into the tube.

The operation is best illustrated in Figures 3 and 4, the strip 31 being embedded into the tube 27, and as it is coiled spirally by rollers 37 and 38 as its inner edge is forced, upset and thickened against the bottom of the groove in tube 27, formed therein by said embedding, thus forming efficient thermal contact with the walls of the groove.

The upsetting of the inner edge of the strip 31 forms an exceedingly tight joint between the tube and the fin. The union provided is in the form of a dovetailed joint, as may be seen in Figure 4, by knurling or swaging wheel 38 displacing the metal of tube 27 adjacent each side of slot 24 into intimate contact with the embedded sides of fin 31. This joint obviates any possibility of the tube re-

leasing the fin, and permits heat to pass from the tube to the fin, or vice versa, with substantially greater rapidity and efficiency due to the greater density of the metal of tube and fin in the region of said joint, than was possible before my invention.

The screws 39 may be, and preferably are, adjusted to exert such force inwardly upon strip 31 as to cause it to be cambered or curved longitudinally, as shown in Figure 2, which, with the substantial longitudinal tension placed on strip 31, as the strip is being coiled spirally about the tube, and substantially simultaneously swaged into groove 24, causes the fin-strip 31 to retain said camber and longitudinal tension as fixed to the tube and to be of substantially greater mechanical strength and rigidity, as well as enables said strip to be made of much thinner metal and efficiently increase the number of fins per given length, than was possible before my invention. This also substantially decreases the production cost and increases the thermal efficiency of the tube, and produces a finned tube of substantially greater strength and stability of its fins which substantially resist stresses which would otherwise distort their symmetry and impair their efficiency.

The action of the crimping wheel 38 follows the operation of the lead wheel 35. The crimping wheel 38 straddles the fin and its peripheral edges exert a knurling or swaging pressure against the metal of the tube lying adjacent to the sides of the fin. The pressure of the crimping wheel 38 is adjusted so that sufficient metal is depressed along with the fin-receiving groove of the tube to seal the outer side walls of the tube against the adjacent walls of the fin as shown in Figures 2 and 4. The action of the crimping roll 38 may be such as to roll the metal of the tube evenly against the walls of the fin, or it may be such as to perform a knurling of the tube metal, in which case the metal of the tube is unevenly displaced against the sides of the fin, and in either case the tube may be of uniform exterior or provided with curved recesses 27a on opposite sides of each fin 21.

The rib-like formation 22 of my improved heat exchanger tube serves to break up the uniform flow of the fluid through the interior of the tube and cause all particles of the fluid flowing therethrough to be brought into contact with the interior walls of the tube, and thus all of the fluid in the tube is uniformly heated or cooled as the case may be.

The method and apparatus of the present invention provides a simple and cheap way of making heat exchanger tubing having fins on the outside and agitating formations on the interior, inasmuch as the ribs 22 are produced simultaneously with the formation of the fins about the tube and their embedding into the tube. Moreover, by the formation of ribs 22 by the embedding of the outer fins

21 into the tube, in accordance with my present invention, no metal is removed from the walls of the tubes, as is the case when the grooves are cut, and no grooves are required to be pre-formed for the fins in the tube, and the tubes are not required to be mounted upon and removed from any mandrel in the production of heat exchanger elements according to my present invention.

When the grooves formed in the tube 27 by said embedding of strip 31 therein are of moderate depth, which is the preferable arrangement, with the fin-strip swaged in said grooves, the strength of the tube, as well as its heat exchanger efficiency is substantially increased. In addition, when copper or brass tubing is used, the cold working of the metal of the tube which is effected by the action of the embedding of strip 31 therein, hardens or increases the density of the metal to a certain extent, and makes the tube more rigid. This is of advantage when the tubing is used in certain forms of heat exchangers where it is desirable to eliminate vibration as much as possible, besides production cost may be efficiently lowered by employing tubes of thinner metal, yet having greater strength when produced in accordance with my invention.

The formation of helical grooves in the outer surface of the tube and internal rib 22 upon the inner surface of the tube simultaneously with and as a result of the embedding into the tube of an edge of the thin strip 31, results in a shortening of the finished tube proportionate to the amount of metal comprising said rib. This increases the rigidity of the finished tube, while the embedded fin and fin 21 and internal rib 22 substantially increase the internal and external heat exchanging areas of the tube when formed.

The heat occasioned by the edgewise coiling of the fin-strip 31 about the tube 27, and the embedding of an edge of such strip into the metal of the tube, as well as the swaging of metal of the tube against the sides of said strip, is quite substantial. Such heat ordinarily would tend to draw the production temper or hardness of strip 31 and tube 27 and render them softer and more subject to distortion from handling and ordinary usage. This difficulty is substantially eliminated by accomplishing each of said steps or operations by a rolling pressure which, in the instance shown in Figures 5 and 6, requires but a relatively small portion of the surfaces of the rollers 35 and 38 to be in progressive contact with the metal being worked upon and the remainder of such surfaces are in contact with and dissipate their acquired heat to, the atmosphere.

This application is a continuation in part of my co-pending applications, Serial Number 249,404, for apparatus for securing metal

finns to tubes or cylinders, and Serial Number 251,589 for heat exchanger elements.

The invention herein described may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon or therefor.

Having now so fully described my invention that others skilled in the art may therefrom make and use the same, what I claim and desire to secure by Letters Patent is:

1. The method of forming a heat radiator element comprising the steps of placing a fin-strip in contact with the outer surface of the element, progressively inwardly crushing a portion of the fin-strip into the metal of the element, and by said crushing inwardly displacing metal of the element thereby raising a rib on the surface of the element opposite that into which the portion of the fin-strip is crushed.

2. The method of forming a heat radiator element comprising the steps of placing a fin-strip in contact with the outer surface of the element, crushing a portion of the fin-strip into the metal of the element by pressure inwardly applied progressively along the outer edge of the fin-strip, and by said applied pressure inwardly displacing metal of the element thereby progressively raising a rib on the surface of the element opposite that into which the portion of the fin-strip is crushed.

3. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, upsetting the edge of the strip against the walls of the groove, and raising a rib on the surface of the element opposite that into which the fin-strip is crushed.

4. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, upsetting the edge of the strip within the groove, and raising a rib on the surface of the element opposite that into which the fin-strip is crushed.

5. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, raising a rib on the surface of the element opposite that into which the fin-strip is crushed, and crimping the edges of the groove against the sides of the strip.

6. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, raising a rib on the surface of the element opposite that into which the fin-strip is crushed, upsetting the edge of the fin-strip within the groove and crimping the edges of the groove against the sides of the strip.

7. The method of forming a heat radiator element which includes the edge of a fin-strip

into the metal of the element to form a groove, upsetting the edge of the fin-strip against the walls of the groove, simultaneously with said crushing raising a rib on the surface of the element opposite that into which the fin-strip is crushed, and crimping the edges of the groove against the sides of the strip.

8. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, upsetting the metal of the edge of the fin-strip against the bottom and sides of the groove, and simultaneously raising a rib on the surface of the element opposite that into which the fin-strip is crushed.

9. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, upsetting the metal of the edge of the fin-strip against the bottom and sides of the groove, simultaneously raising a rib on the surface of the element opposite that into which the fin-strip is crushed, and crimping the metal of the edges of the groove against the sides of the strip.

10. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, raising a rib in the region of the edge of said fin-strip and on the surface of the element opposite that into which the fin-strip is crushed, and crimping the metal of the edges of the groove into the metal of the fin-strip.

11. The method of forming a heat radiator element which includes crushing the edge of a fin-strip into the metal of the element to form a groove, raising a rib in the region of the edge of said fin-strip and on the surface of the element opposite that into which the fin-strip is crushed, and crimping the metal of the edges of the groove into the metal of the fin-strip while maintaining the fin-strip at the bottom of the groove.

12. The method of forming a heat radiator tube which includes crushing the edge of a fin-strip into the metal of the tube and raising a rib on the inner surface of the tube by bending the fin-strip about the tube, and moving metal of the tube against the fin-strip while the fin-strip is being maintained in the metal of the tube.

13. The method of forming a heat radiator tube which includes the steps of associating a tube and fin-strip, relatively rotating said tube and a portion of said strip and embedding a portion of the fin-strip into the metal of the tube, and substantially simultaneously with said embedding raising a rib on the inner surface of the tube.

14. The method of forming a heat radiator tube which includes the steps of associating a tube and fin-strip, relatively rotating said tube and strip, simultaneously with said rotation embedding an edge of said strip into

metal of the tube, and raising a rib on the inner surface of the tube and upsetting the embedded edge of said strip against metal of the tube.

15. The method of forming a heat radiator tube which includes the steps of associating a tube and a fin-strip, relatively rotating said tube and a portion of said strip, applying pressure to one portion of said strip to embed another portion of said strip into metal of the tube, and raising a rib on the inner surface of the tube by the metal of the tube displaced by the embedding of said strip.

16. The method of forming a heat exchanger metallic element which includes the steps of placing a fin-strip under longitudinal stress and in contact with an adjacent surface of the element, moving said stressed element toward and crushing a portion of said strip into said surface of the element, and by said crushing movement raising a rib on the surface of the element opposite that into which the fin strip is crushed.

17. The method of forming a heat exchanger element which includes the steps of placing a fin-strip under longitudinal stress, crushing one edge of said strip into metal of the element by pressure upon another edge of said strip, and simultaneously with said crushing raising a rib on the surface of the element opposite that into which the fin strip is crushed.

18. The method of forming a heat exchanger metallic element which includes the steps of associating a fin-strip with said element, placing progressive portions of the fin-strip under longitudinal stress and juxtaposed to a surface of the element, moving said strip toward and crushing a part of the stressed portion progressively into the juxtaposed surface thereby inwardly displacing metal of the element; and substantially simultaneously with said crushing raising, by the inward displacement of metal of the element by said crushing, a rib on the surface of the element opposite that into which the fin-strip is crushed.

19. The method of forming a heat exchanger element which includes the steps of placing a fin-strip under longitudinal stress, and substantially simultaneously accomplishing the following steps: crushing one edge of said strip into metal of the element; upsetting said crushed edge beneath the surface of said element; and raising a rib on the surface of the element opposite that into which the fin-strip is crushed.

20. The method of forming a heat exchanger element which includes the steps of associating a tube and a fin-strip with an edge of said strip adjacent the tube, placing the fin-strip under longitudinal stress, relatively rotating said tube and a portion of said strip, simultaneously with said rotation performing the steps of crushing one

edge of said strip into metal of the element by pressure upon another edge of said strip, in the region of said crushing raising a rib on the surface of the element opposite that
5 into which the fin-strip is crushed, and upsetting said crushed edge of said strip beneath the surface of said element.

21. The method of forming a heat exchanger element which includes the steps
10 of associating a tube and a fin-strip with an edge of said strip adjacent the tube, placing the fin-strip under longitudinal stress, relatively rotating said tube and a portion of said strip, simultaneously with said rotation performing the steps of crushing one
15 edge of said strip into metal of the element by pressure upon another edge of said strip, in the region of said crushing raising a rib on the surface of the element opposite that
20 into which the fin-strip is crushed, upsetting said crushed edge of said strip beneath the surface of said element, and moving metal of the element into further contact with said strip.

22. The method of forming a heat exchanger element which includes longitudinally cambering a fin-strip, crushing an
25 edge of said strip into metal of the element, and raising a rib on the surface of the element opposite that into which the fin-strip is crushed.
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23. The method of forming a heat exchanger metallic element which includes the steps of placing a portion of a relatively
35 long fin-strip juxtaposed to an outer surface of the element, longitudinally cambering progressive portions of the fin-strip, progressively moving the body of the fin-strip toward and inwardly crushing a cambered
40 portion of said strip into metal of the element; progressively inwardly displacing metal of the element, by said crushing, thereby raising a rib on the surface of the element opposite that into which the fin-strip is crushed, and maintaining the camber
45 of the fin-strip.

24. The method of forming a heat exchanger element which includes the steps of placing a fin-strip under longitudinal stress,
50 cambering a portion of the stressed strip, crushing an edge of said cambered stressed strip into metal of the element, and raising a rib on the surface of the element opposite that into which the fin-strip is crushed.

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