Oct. 3, 1933. A. J. BERG 1,928,639

METHOD OF MAKING HEAT EXCHANGERS

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Fig. 1,

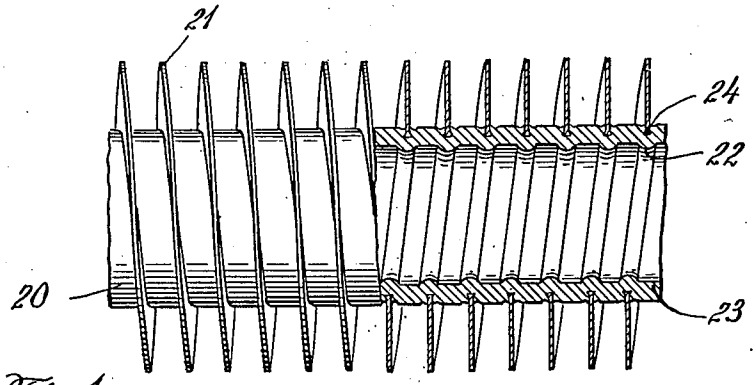


Fig. 1a,

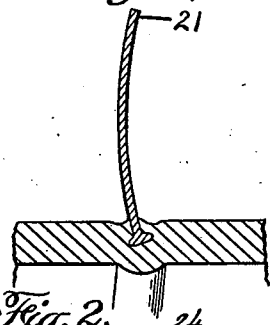


Fig. 2,

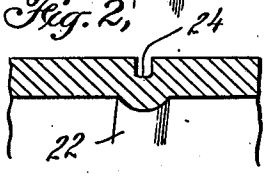


Fig. 3,

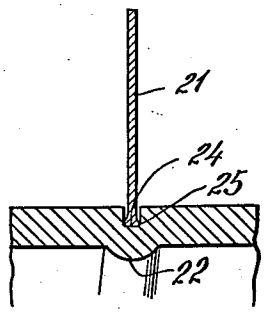


Fig. 4,

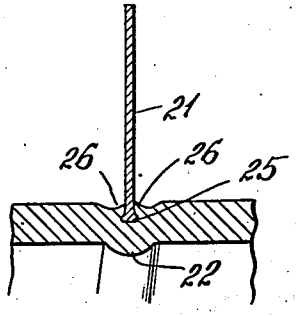


Fig. 3a,

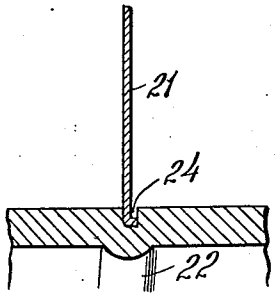
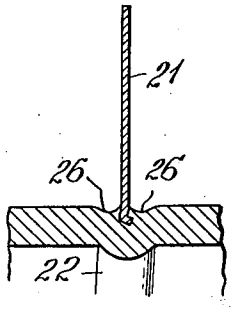


Fig. 4a,

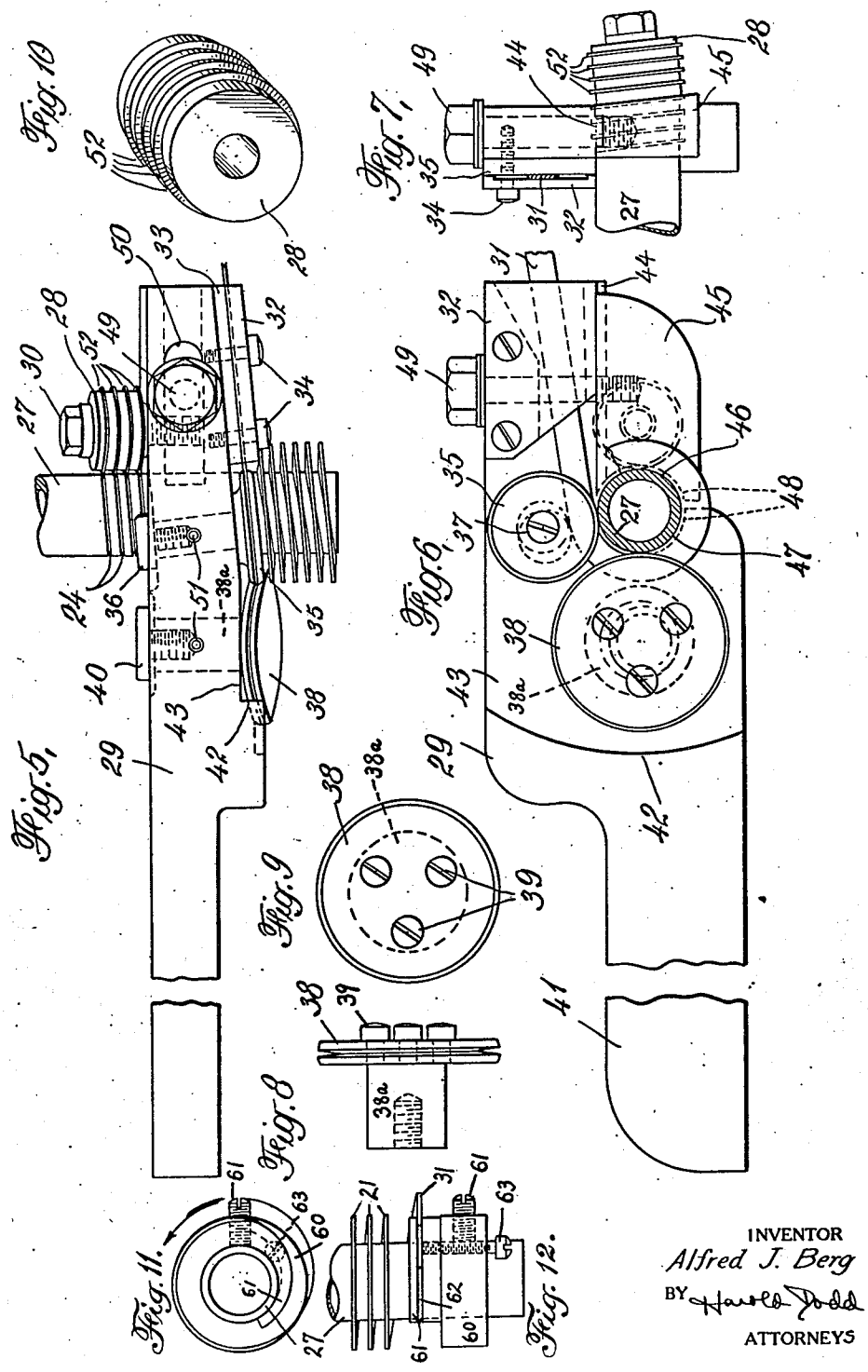


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Oct. 3, 1933. A. J. BERG 1,928,639

METHOD OF MAKING HEAT EXCHANGERS

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UNITED STATES PATENT OFFICE

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METHOD OF MAKING HEAT EXCHANGERS

Alfred J. Berg, Portsmouth, N. H.

Application November 14, 1929
Serial No. 407,087

9 Claims. (Cl. 29—157.3)

(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 such heat exchangers for example as tubes having heat transferring fins or vanes thereon.

In Patent No. 1,668,534 granted to me on May 1, 1928, there is disclosed a form of heat exchanger tube provided with such fins or vanes, and an apparatus for placing the fins upon the exterior surface of the tube. According to the disclosure of this prior patent, a helical groove is formed about the exterior surface of the tube, and a thin ribbon-like strip of metal is wound edgewise into this groove, the edge of the strip which is within the groove being upset against the sides of the groove. In addition the metal of the tube is displaced, for example, by crimping against the sides of the fin.

By providing the tube with fins in this manner the product is strong mechanically, the fins and the tube are in excellent heat conduction relation with one another, and the product can be made commercially on a large scale and at moderate cost. The apparatus disclosed in my prior patent forms the groove in the tube by means of a cutting tool and the fin is applied in such manner that the inside wall of the tube is left in its original smooth condition.

An object of my present invention is to provide a method of applying the fin ribbon to the tubing in such a manner that the tube and the fin will be of greater strength and stability and that rib-like formations will be formed on the interior walls of the tube during the application of the fin ribbon to the tube.

I have found that a film of the through 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 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 accordance with the general features of this unitary and related invention, my improved method contemplates, in heat exchange through a medium, the breaking up of the heat interchange resisting film of the 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 juxtaposed heat medium so that said film and its juxtaposed heat medium substantially commingle; and further contemplates that in such 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 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 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 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 includes a heat exchange member, preferably a tube, whose bore or upon whose inner surface, the heat medium is adapted to flow over projecting portions of said member or tube which may be angularly or spirally disposed and which projecting 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 surface of the exchange member or tube, and cause 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 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 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 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 tubes in such manner as to produce the projecting portion 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 the necessity of each of the following: 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 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 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 of thin and soft metal, be supported by any mandrel or otherwise than by the wall of the tube, when the tool for inserting and knurling the edge of the ribbon into the tube acts, in a substantial sense, as a steady-rest for the tube progressively at the point of the application of the stresses requisite for such insertion and knurling.

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 increase the normal heat exchange area of the tube as well as 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 best surface of the exchange member. The tube is shortened, stiffened and its thermal efficiency increased by the rolling of the metal from its normal length into said interior rib-like formations.

A further object of my invention is to increase the normal density of the tube in an area surrounding said tube, and preferably adjacent the internal rib and external fin of said tube, and to thereby increase the heat conducting capacity of said tube. I preferably have said internal rib and external fins project from points juxtaposed to or within said area of increased heat conductive capacity.

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 1*a*, 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;

Figures 3*a* and 4*a* are views similar to Figures 3 and 4 respectively showing a modification.

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 a perspective view of the roll for rolling the groove into the surface of the tube;

Figure 11 is an end view of the means for starting the winding of the external fin upon the tube; and

Figure 12 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, a helical groove 24 is first formed in the exterior surface of the tube by displacing the metal of the tube in such a way as to simultaneously form the rib-like projection 22, which is also of helical shape and follows on the inside of the tube the course of the groove 24. Groove 24 is preferably formed by a rolling operation, in order that no metal of the tube may be severed from the tube-wall in the formation of groove 24 as well as that the metal adjacent the surfaces of groove 24 may by said rolling be increased in density and thereby attain increased thermal conductive capacity throughout the area of said increased density, all as will be described further on.

After the formation of groove 24 the metal ribbon 21, which may be slightly thinner than the width of groove 24, is wound edgewise in the groove in such manner that the inner edge of the ribbon is upset or expanded as shown at 25 against one or both side walls of the groove. The winding action insures that the base of the fin ribbon 21 is in contact with the bottom of the groove, and the upsetting of the base of the fin insures that these surfaces remain in efficient thermal contact.

After upsetting the base of the metal fin within the groove 24, the metal of the tube itself is displaced, as indicated at 26, against both sides of the fin just above the upset portion 25. Said displacement also increases the density of the metal forming the wall of the tube throughout substantially the displaced areas. Said increased density accelerates the thermal conductive capacity throughout the area of said increased density. This displacement can most easily be accomplished by a knurling operation accomplished by the knurled periphery of wheels 38 and firmly secured in embedded relation to the wall of the tube 20.

While Figures 1 to 4 inclusive indicate that the upset portion 25 is substantially symmetrical to the center line of the fin, the symmetry of

the fin base depends upon the setting of the winding apparatus, and a non-symmetrical base portion 25 produces as good a joint as the perfectly symmetrical base illustrated.

In Figures 5 to 10 there is illustrated one form of apparatus by which my improved heat exchanger tubing may be made. This apparatus is constructed in the form of a tool which is adapted to be secured in the tool post of a standard lathe having a thread cutting gear. The groove 24 may be formed in the tubing 27 (Figure 5) by means of a quadruple roll 28 which is rotatably mounted upon the tool body 29 by means of a bolt 30. The operation of this roll will be described in detail later.

The metal fin-forming strip 31 is free to move 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 engage 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 coacting 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 the tube 27 substantially at the point of the progressive application thereto of the stresses requisite to the formation of grooves 24, internal rib 22 and the application of the fin 31.

These co-acting portions 46 and 47 are square threaded as indicated by the dotted line 48 in Figure 6, and said threads are substantially the same pitch as groove 24 so as to clear any burr that may be raised in forming the groove, as will be explained later. In addition to serving as a support for the tube 27, the steady-rest member 45 provides an inclined bearing surface and support for the groove roll 28 as best shown in Figure 7.

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 11 and 12, 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 to tube 27 and compels the rotation in unison therewith of 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. After the lathe is started, the groove roll 28 is moved against the rest member 45 and its adjustment along tongue and grooved joint 44 until portions 46 and 47 engage the outer surface of tube 27, where member 45 is clamped by screw 49 to the tool body 29. Upon further rotation of tube 27, the projections 52 are each progressively pressed into the surface of the tube a sufficient distance to form the grooves 24 of the required depth.

The groove roll 28 is provided with four similar ribs 52, but the inclination of the axis of the roll to the axis of the tube 27 causes the formation of groove 24 to take place in successive stages. The projections 52 are of such shape as to form a groove of the contour desired, and this may be varied to a certain extent depending on the materials which are used for the tube and the fin. The size of the rib 22 formed on the inside of the tube depends on the depth of groove and the character of the metal 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 an 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 substantially 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.

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 11 and 12). 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 into groove 24, 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.

With the grooving roll 28 arranged to form a groove 24 as shown in Figure 2, and the lead wheel 35 arranged so that its fin-receiving groove is in alignment with the helical groove formed by the grooving roll, 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 into the prepared groove.

These actions of the lead wheel 35 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 insertion into the groove 24 prepared in the tube. 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 forced into the groove in the tube.

The operation is best illustrated in Figures 3 and 4, the strip 31 being inserted into the groove in 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, thus forming efficient thermal contact with the side 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 dove-tailed 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 29 into intimate contact with the imbedded sides of fin 31. This joint obviates any possibility of the tube releasing 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.

By regulating the angular position of the lead wheel 35 with respect to the groove 24 in the tube 27, the manner in which the inner edge of the strip or fin engages the side walls of the groove may be controlled. If the lead wheel is accurately in alignment with the groove in the tube as indicated in Figure 5, the upsetting of the edge of the fin will be substantially symmetrical as shown in Figures 3 and 4, but if the lead wheel is inclined slightly with respect to the groove, it will cause the thickening of the tube to be thrown off center, and a joint somewhat as shown in Figures 4*a* and 4*b* will be formed.

In this latter operation the inner edge of the fin is turned slightly upon itself as shown in Figure 4*a* and this is because, as the fin strip 31 enters the groove, the inner edge of the strip engages one of the side walls of the groove and is thereby turned to one side.

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 1*a*, 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 and groove 24. 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 groove 24 against the adjacent walls of the fin as shown in Figures 4 and 4*b*. 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.

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 an exceptionally high quality of very durable and efficient 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 grooves 24. Moreover, by rolling the grooves 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, the preferred method of forming the grooves disclosed in my previous patent above referred to.

Hence, when the grooves 24 are of moderate depth, which is the preferable arrangement, the strength of the tube with the fin-strip swaged in said grooves, 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 grooving roll, hardens 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 the rolled grooves 24 and internal ribs 22 results in a shortening of the finished tube proportionate to the amount of metal comprising said ribs. This increases the rigidity of the finished tube and also the grooves 24 and ribs 22 add to the internal and external heat-exchanging areas of the tube when formed.

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

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of permanently attaching a metal ribbon to a metal tube which includes the following substantially simultaneously executed steps or progressively rolling metal of the tube inwardly in a definite path to form on said tube an external groove and a coincident internal rib while the bore of said tube is unsupported in said path; progressively coiling about the tube and pressing into said groove a portion of the metal ribbon which is to form the fin; progressively compressing metal of the tube adjacent the groove into gripping engagement with the metal ribbon to firmly secure the ribbon in place; and progressively supporting the tube adjacent said path against lateral deflection by, and substantially at the place where, the stresses occasioned by said steps are applied to the tube.

2. The method of making finned metal tubing which comprises the steps of progressively displacing metal of the tube inwardly to form a helical groove on the outside of the tube and a helical rib following said groove on the inside of the tube; simultaneously with said displacing step, subjecting to substantial longitudinal tension a flat metallic ribbon while progressively winding said ribbon tightly about the tube with an edge in said groove; simultaneously with the preceding steps, placing metal of the tube tightly against a side of, and substantially throughout the length of, the ribbon in said groove thereby securing the ribbon under tension to the tube; and simultaneously with said preceding steps progressively supporting the tube externally against lateral deflection substantially at the place where the stresses occasioned by the preceding steps are applied to the tube.

3. The method of producing a heat exchanger metallic member, comprising the steps of simultaneously forming a groove in one surface of said member and raising a substantial projection upon the opposite surface of said member registering with said groove; simultaneously with and following the commencement of said groove forming step associating progressive portions of the fin strip and the metallic member unsupported on its opposite surface in the path of said projection and forming the fin strip into said groove; simultaneously with and following the commencement of the next preceding step progressively extending metal of the member adjacent said groove into binding engagement with the sides of the portion of said fin strip in proximity to said groove; and simultaneously with said steps progressively supporting the member by external contact against lateral deflection substantially at the place where the stresses occasioned by said steps are applied to the member.

4. The method of producing finned metallic tubing which comprises the following substantially simultaneously executed steps of progressively displacing metal of said tube from the outer surface thereof inwardly in a path to form a helical groove in the outer surface and a helical registering rib on the inside of said tube; supporting the tube with its bore unsupported within its length to be grooved; associating progressive portions of a metallic ribbon and said tube while curling said ribbon edgewise into said groove and about said tube to form a helical fin projecting from said groove and rib; subjecting the ribbon material being coiled to a substantial longitudinal tension; progressively displacing metal of said tube against a portion of said formed fin to secure the tensioned fin to the tube; and revolubly and longitudinally movably holding the tube against lateral deflection by engagement with its outer surface adjacent the place where the stresses occasioned by said steps are applied to the tube and in advance of the curling step, whereby the tube is prevented from lateral deflection at said place by said stresses and tension.

5. The method of applying a metal ribbon to a metallic element which includes the steps of subjecting progressive portions of the ribbon to a pressure which longitudinally cambers the portion of the ribbon subjected thereto, and progressively securing to the element portions of the ribbon while the same are subjected to said pressure.

6. The method of applying a metal ribbon to a metallic element which includes the steps of subjecting the outer edge of the ribbon to pressure resisted by the inner edge of the ribbon being against the element and said pressure being to the extent required to longitudinally camber the ribbon, and securing the inner edge of the ribbon

to the element while subjected to said pressure.

7. The method of applying a metal ribbon to a metallic element which includes the steps of limiting the lateral movement of a longitudinal central portion of the ribbon, subjecting the outer edge of said limited portion of the ribbon to an inward pressure while its inner edge is against the element and longitudinally cambering the subjected portion of the ribbon, and securing to the element the subjected portion of the ribbon while the same is subjected to said pressure.

8. The method of applying a metal ribbon to a metallic element which includes the steps of, progressively longitudinally subjecting the outer edge of the ribbon to pressure resisted by an inner portion of the ribbon being against the element, and said pressure being to the extent required to longitudinally camber the ribbon, and progressively thermally connecting and securing to the element said inner portion while the same is subjected to said resisted pressure.

9. The method of applying a thin metal ribbon to a metallic element which comprises the steps of forming a groove in a surface of the element, securing an end of the ribbon to the element and in said groove, applying at a point upon the outer edge of the ribbon an inward pressure upon and longitudinally cambering the ribbon, simultaneously with said cambering step coiling the ribbon about the element with its inner edge in said groove, and simultaneously with and following the commencement of said coiling step securing progressive portions of the ribbon in thermal contact with walls of the groove while such ribbon portions are subjected to said pressure.

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