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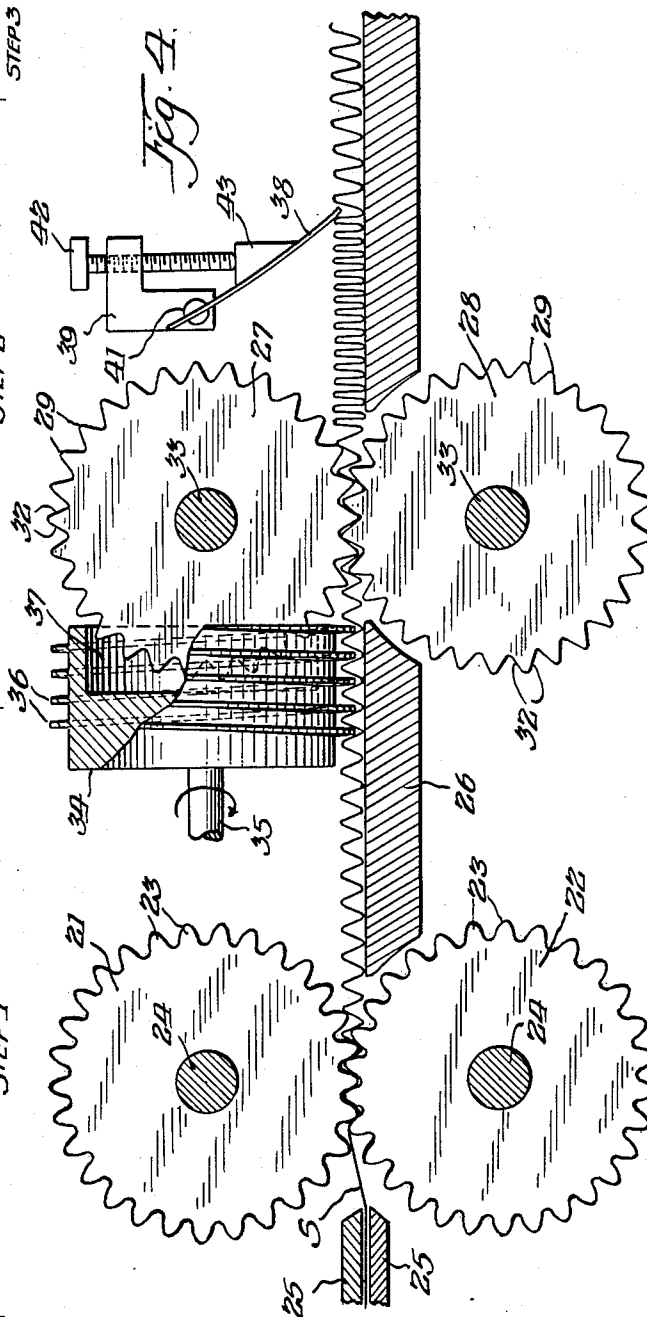
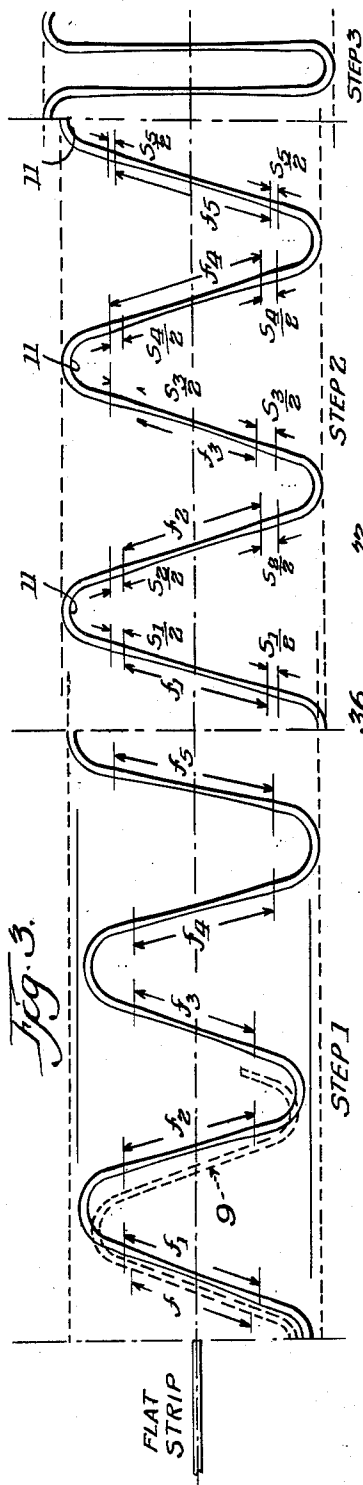
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3,191,418

METHOD AND APPARATUS FORMING SERPENTINE FINS

Filed Jan. 6, 1961

3 Sheets-Sheet 2



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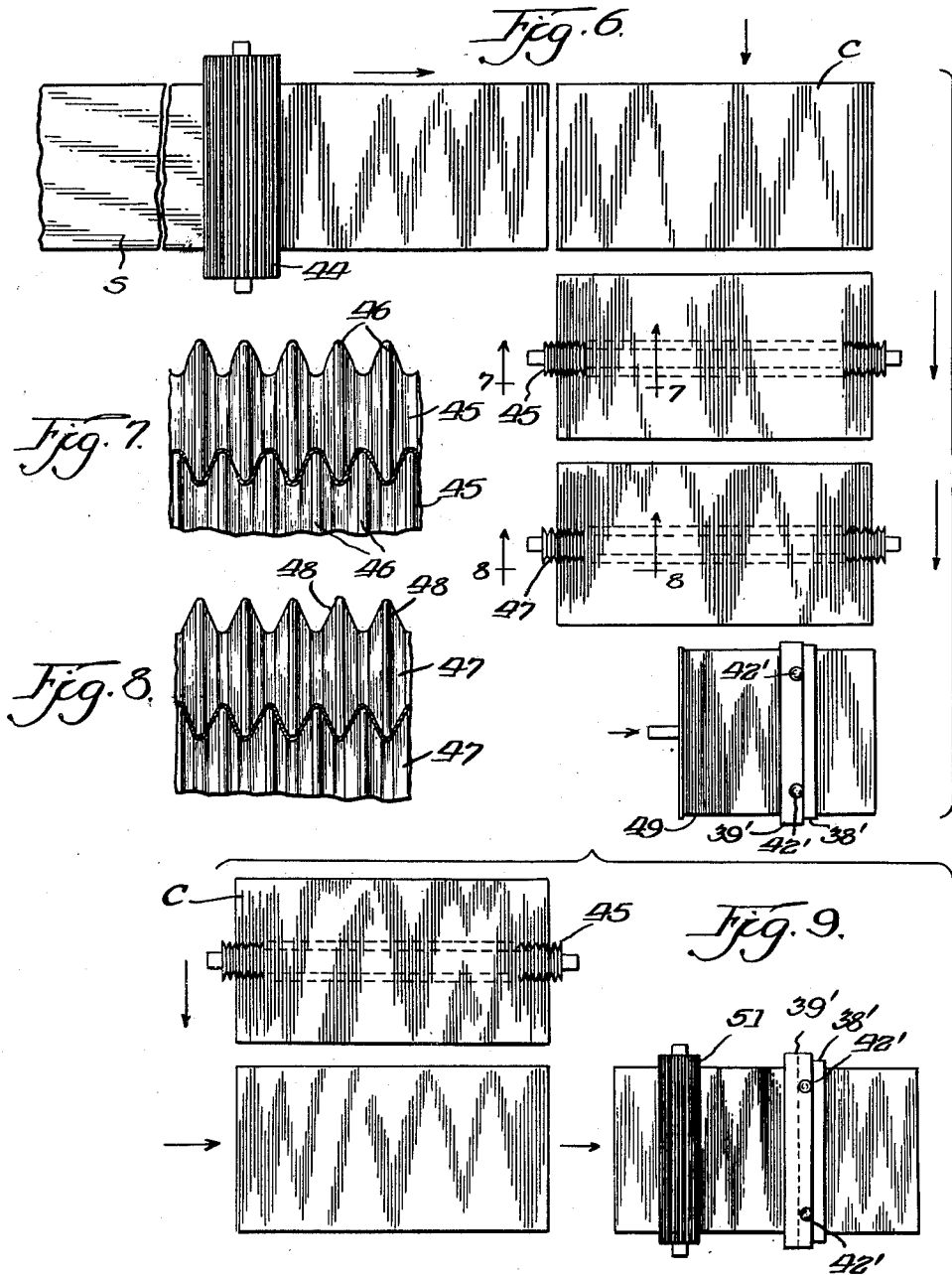
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METHOD AND APPARATUS FORMING SERPENTINE FINS

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16 Claims. (Cl. 72-187)

The invention relates generally to heat exchange structures and more particularly to a heat exchange structure of the serpentine fin type.

Heat exchange structures of the type here involved utilize primarily heat exchanger fluid conducting elements, as for example, a plurality of laterally spaced tubes through which a liquid may pass, the tubes being arranged in generally parallel relation with intermediate secondary heat transfer fin structures disposed therebetween, the fin structures being formed from strips of metal which are shaped in a serpentine or corrugated fashion to provide a plurality of fin elements. The serpentine structures are secured to the tubes at the connecting portions between the respective fin elements to provide a durable and efficient heat transfer connection therebetween. An example of the general type of fin structure involved is illustrated in Patent No. 2,329,789, issued to H. E. Schank, et al., on September 21, 1943. Such patent also illustrates a fin structure wherein the surface of the fin may be suitably contoured, and discloses an apparatus for making elements of the type therein described.

As brought out in my prior Patent No. 2,914,842, dated December 1, 1959, the advantages of tapered fin structures in heat transfer devices has been well known for many years, but the advantages thereof have been substantially incapable of utilization in current type of heat exchange structures wherein extremely thin fin material on the order of five-thousandths of an inch or less is utilized, due to the necessity of employing heavier material capable of providing adequate rigidity in the finished structure and also, in the case of serpentine fin structures, the inability to efficiently produce tapered fin elements thereon. Consequently in such fin structures the thickness of the material employed therein has been determined by the fabrication requirements, the thickness being so selected that it is structurally adequate to efficiently conduct heat from the tubes to which the structure is connected to the effective area of the fin element. Obviously, if the thickness of the fin is not great enough, the central portion of the fin will not receive and dissipate its full share of heat as the material is incapable, due to its insufficient thickness, to carry the heat to such central portion. On the other hand, if the thickness of the material is adequate for such purpose and is uniform in thickness throughout the area of the fin, the excess material represents a waste both in the ratio of surface area to weight as well as a waste in the cost of the additional material employed.

The present invention therefore has among its objects the production of a secondary surface fin structure of the serpentine type which is so designed that the heat transfer fins are of generally tapered cross section, the thickest portion of the fin being disposed adjacent the primary heat exchanger surfaces such as the fluid tubes, such thickness tapering toward the longitudinal central portion of the fin, thus providing a more efficient fin design with a reduction in the amount of material required and thus a corresponding reduction in fabrication cost for a given capacity heat exchange structure. This saving is quite substantial, depending upon the particular heat exchanger structure involved, and may run, for example, to fifteen percent and more.

Another object of the invention is the development of a novel method of producing a heat transfer structure of the type described, whereby strip material having a

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relatively uniform thickness may be suitably formed to provide a serpentine structure having fin surfaces of tapering cross section, the serpentine folds or corrugations being accurately dimensioned and sized to enable their securement in effective heat transfer relation with the cooperable fluid tubes or the like.

A further object of the invention is the production of a novel apparatus for making fin structures of the type involved.

Many other objects and advantages of the present invention will be obvious to those skilled in the art from the disclosure herein given.

In the drawings, wherein like reference characters indicate like or corresponding parts:

FIG. 1 is a partial view of a radiator core of the type to which the present invention is applicable;

FIG. 2 is a sectional view similar to FIG. 1 of a portion of two fluid-conducting tubes and associated fin structures embodying the invention;

FIG. 3 is a diagrammatic figure illustrating the steps of forming a fin strip in accordance with the present invention;

FIG. 4 is a semi-diagrammatic sectional view of an apparatus for forming fin structures in accordance with the present invention;

FIG. 5 is an enlarged figure of a portion of the forming rolls disclosed in FIG. 4, illustrating the shape of the forming teeth thereof;

FIG. 6 is a diagrammatic figure of a modified form of apparatus for producing fins embodying the present invention;

FIG. 7 is a partial sectional view taken approximately on the line 7-7 of FIG. 6;

FIG. 8 is a partial sectional view taken approximately on the line 8-8 of FIG. 6; and,

FIG. 9 is a diagrammatic figure similar to FIG. 6 illustrating a portion of a modified form of apparatus for producing fins constructed in accordance with the present invention.

Heat exchangers of the type to which the present invention is applicable, as illustrated in FIG. 1, may comprise upper and lower header members indicated respectively by the numerals 1 and 2 having respective tube sheets 3 and 4 which are suitably formed as indicated at 5, as for example, to provide punched openings in which are received respective fluid-conducting tubes 6, the headers also being connected at their respective ends by suitable side plates or frame members 7, only one of which is illustrated in FIG. 1. Extending between each adjacent pair of tubes 6, and at the respective sides of the core, between the associated side frame member 7 and adjacent tube 6 are respective fin structures indicated generally by the numeral 8.

Each of the structures 8 comprises a strip of material which is formed into a corrugated or serpentine shape to provide a plurality of secondary surface fin elements 9 which are connected along their lateral edges to the respective tube elements or side frame members with each fin element being connected at one of its edges to a corresponding edge of an adjacent fin element at the same side thereof and at its opposite edge to the corresponding edge of the adjacent fin element at the other side thereof, with the connecting portions 11, so formed, providing a means of securement to the associated fluid-conducting tube.

In practice, all, or certain of the elements to be assembled in the final core structure are suitably tinned whereby the assembly may be suitably fluxed and heated, causing the solder or other bonding material to become molten and upon cooling, effect a suitable bond between the elements of the structure. In the case of the fin structures 9 and tubes 6, the bond will normally provide a fillet 12

of bonding material adjacent each fin element providing an efficient heat transfer bond, as well as a strong and durable structural connection between the fin structure and the associated tube.

In the manufacture of serpentine fin structures such as that described, relatively thin sheet metal is employed therein which may range from approximately five-thousandths of an inch to less than three-thousandths, the tube stock normally being considerably heavier than that of the fin material. The number of fins per inch in the serpentine structure may vary, depending upon the degree of expansion or contraction of the corrugations of the fin structure during manufacture, FIG. 1 illustrating relatively closely spaced fin elements having substantially parallel walls whereas the structure of FIG. 2 illustrates the corrugations spread apart to position the fin elements at angles with respect to one another. Thus the number of fins per inch in the finished structure may be readily controlled by varying the degree of compression or compaction of the serpentine structure.

To achieve high efficiency in the final assembly, it is necessary to have a suitable bond between the connecting portions of the fin structure and the associated fluid-conducting tubes, to thereby insure full heat transfer from the tube side walls to the secondary heat exchanger surface comprising the respective fin elements, and if the bond were not suitable, a loss in efficiency would occur as well as a possible structural weakness. It will be appreciated that one of the factors pertaining to the heat transfer efficiency of the connection between the secondary surface and the wall of the heat exchanger tube is the uniformity of the serpentine fin structure as it is desirable to have all of the connecting portions of the corrugated structure in firm contact with the side wall of the fluid-conducting tube so that maximum heat transfer efficiency will exist in the ultimate bonded assembly. If the fin elements and thus the corrugations of the serpentine structure vary in transverse width, as viewed in FIG. 2, those of shorter width cannot be in as firm engagement or possibly even in contact with the tube as compared with those having a greater width, and uniformity of connection between the respective fin elements and the tubes cannot be achieved, thereby correspondingly reducing the efficiency of the exchanger.

Referring to FIG. 2, wherein the fin structure is constructed in accordance with the present invention, it will be noted that the central portion 13 of each fin element 9 has minimum thickness with the thickness increasing from such central portion outwardly toward the connecting portions 11, so that each fin element has its greatest thickness adjacent its connection to the associated tube, and tapers toward the center of the fin element providing an efficient tapered fin. The tapering of the fin in this manner results in considerable saving in material which may be readily demonstrated by considering a typical example involving actual proportions of the fin structure. Thus, assuming that the portions 11 and adjacent portions of the fin structure have an approximate thickness of .00275, and the minimum thickness of the fin element at the central portion 13 is approximately .002, approximately 15% in material can be saved over a fin structure having a substantially uniform thickness of .00275, keeping in mind that if uniform material is employed, it will be necessary to employ a thickness which is equivalent to the maximum thickness required in the fin element at its connection to the primary heat exchanger tube. As the saving in material is achieved without any reduction in the heat exchange efficiency in the finished fin structure, the ratio of surface area to exchanger weight is increased and the heat exchange efficiency per unit of weight is likewise increased. It will also be noted that at least theoretically, the fin surface is increased as a result of the tapering surfaces which would also tend to increase efficiency.

While it is comparatively easy to manufacture serpentine fin structures having fin elements of relatively uniform thickness and at the same time provide a satisfactory de-

gree of uniformity in the dimensions of the corrugations of the fin structure, the fabrication of a tapered fin structure such as illustrated in FIG. 2, which will normally be fabricated from commercial strip stock of commercially uniform thickness, presents additional problems in the manufacture as the production of the tapering cross-sections will necessitate a working or coining of the material of the strip with an elongation in the width of the corrugations.

Assuming that the thickness of the stock initially being formed was of exact uniformity of thickness, and the forming elements of the apparatus were perfectly uniform, the degree of elongation could be satisfactorily controlled to produce a suitably uniform serpentine strip which could be efficiently bonded to the fluid-conducting tubes of the heat exchanger structure. However, as commercial stock normally has a tolerance of 10% in thickness and will also vary in the degree of temper of the metal of the strip, either or both may produce a variation in the forming action so that non-uniform elongations may be effected in the fin elements, creating a serious problem with respect to uniformity of corrugations in the completed fin structure.

Referring to FIG. 3, a portion of a serpentine structure of relatively uniform thickness and of relative uniformity in the effective width of the fin element is illustrated in dotted lines, it being noted that such fin elements are of lesser width than the tapered fin structures illustrated in solid lines with the solid serpentine fin structure being illustrated in step 1 as having corrugations which vary in width appearing as a variation in the vertical dimension as viewed in FIG. 3.

It might be mentioned that while the respective corrugations of the structure illustrated in step 1 disclose adjacent corrugation of varying widths, in actual practice the variations may occur with less frequency so that, in many cases, a series of corrugations of one size may be followed by a series of shorter, or longer corrugations, as the case may be, rather than a variation between successive corrugations, although of course such a possibility is not precluded.

The present invention contemplates the utilization of a novel method for fabricating serpentine fin structures employing tapered fin elements whereby satisfactory uniformity of the width of the fin elements and corrugations of the structure may be achieved and maintained.

The method of the invention contemplates the use of strip metal of a thickness having the usual 10% tolerance variation, which strip material is first suitably formed to provide an initial corrugating of the strips and either thereafter or simultaneously therewith, working or coining the material of the respective fin elements to achieve the desired tapering of the thickness of such elements. Such working of the metal in effect increases the transverse width (or height, as viewed in FIG. 3), of the respective fin elements, the width of the fin elements varying with the thickness of the stock and variations in the temper of the metal. Thus, corrugations formed from the portion of the material of maximum thickness will normally be of greater width than corrugations formed from portions of the material having minimum thickness, and likewise portions of less temper will produce fin elements of maximum widths while those portions of maximum temper will produce fin elements of minimum widths. Obviously, the various combinations of temper and thickness are capable of producing wide variations in the final width of the corrugations of the fin structure.

To insure accurate uniformity of the corrugations and thus the width of the respective fin elements, the present method contemplates the initial coining of the fin structure to provide a tapered cross-section in the individual fin elements, such coining or forming operations being designed to only partially elongate the fin width so that the corrugations, whether relatively wide or narrow, have an overall width less than that desired in the ultimate fin

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structure, and subsequently forming or sizing the corrugations to the exact width desired, this being accomplished by what may be essentially termed a stretching operation to bring each corrugation, irrespective of its initial degree of elongation, to an exact size. This second step in the method is diagrammatically illustrated in FIG. 3 and designated step 2. For the purpose of comparison, it is assumed that the corrugations of step 2 illustrate, in finished form, the corresponding corrugations illustrated in step 1 of FIG. 3 so that a comparison between the operations of the first step and the effect of thickness and temper on the fin width may be compared with the operations of the second step and with the effect of the latter operations on the respective corrugations illustrated in the first step.

It might be mentioned that in comparing the proportions of the various corrugations, it should be kept in mind that the structure of the drawings is merely illustrative, it being substantially impossible to show the thickness of the fin structures and the width of the fin elements in proper proportion, as the width of the fin elements may, for example, normally vary from approximately one-fourth of an inch to three-fourths of an inch or more, with the thickness of the fin element being in the neighborhood, for example, of .00275", the widths of each fin element would have to be somewhere between three and four hundred times the maximum thickness of the fin structure. Likewise, the variations in fin width illustrated are considerably exaggerated to that which would normally be encountered in actual practice. The proportions of the fin structures illustrated in FIG. 3 are thus relative, for illustrative purposes, and do not represent true scale dimensions.

Thus, assuming that corrugations of uniform wall thickness were formed which would take the relative proportions illustrated in dotted lines under step 1 of FIG. 3, it may be considered that the material designated f on the dotted structure would be expanded to the dimension f_1 , representing an increase in the width of the fin structure. Assuming that the dimension f_1 represents the normal elongation that would take place if the stock from which the corrugations was made was of relatively uniform thickness, it may be considered that the portion of the stock forming the second corrugation is somewhat thinner or harder as to temper than that of the fin element having the dimension f_1 , so that the corresponding dimension f_2 is smaller than f_1 , and similarly the dimension f_3 is less than f_2 . The material forming the next corrugation, however, may be assumed to be of greater thickness initially, or of less temper, resulting in an increase in the overall width so that the corresponding portions f_4 and f_5 are accordingly increased in length.

Following the forming operations of step 1, the connecting portions 11 of the structure may then be outwardly tensioned, stretching the respective fin elements therebetween to bring all of the fin elements and corrugations into a condition of substantially uniform width, step 2 illustrating the configuration of the fin structure following the completion of the stretching operation, in which case it will be noted that all of the corrugations are now of uniform size.

It will be appreciated that as the operations of step 1 resulted in a diminishing of the thickness of the central portion of each fin element, such decrease in thickness will, in effect, provide a point of weakened resistance to stretch so that upon the performance of step 2, the stretching of the corrugated structure will take place substantially entirely at the central portion of the fin element as distinguished from the longitudinal edge portions thereof. Thus, the operation of step 1 provides not only the initial forming desired but results in the provision of a means for effecting localization of the stretching action of step 2 upon the fin elements.

It may generally be assumed that the stretching action will take place relatively uniformly with respect to the

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previously worked areas of step 1 so that the elongation resulting from the operations of step 2 may generally be considered as being equally divided at both sides of the central portion of each fin element. This is graphically represented in FIG. 3, the term s_1, s_2 , etc., designating the amount of stretch which results in the final sizing operation of step 2, which amount is illustrated as being equally divided at each end of the corresponding elongation f_1, f_2 , etc.

Step 3 merely comprises the compacting or gathering of the corrugations formed in steps 1 and 2, to suitably dispose the respective fin portions in the desired relationship, that illustrated in step 3 of FIG. 3 being with the planes of the respective fin elements extending generally parallel to one another and thus more or less corresponding to the fin structures of FIG. 1.

FIGS. 4 through 9 illustrate several forms of suitable apparatus for producing fin structures in accordance with the invention, FIGS. 4 and 5 illustrating the use of intermeshing gear-type teeth for effecting the operation of steps 1 and 2 of the method illustrated in FIG. 3, whereas FIGS. 6, 7 and 8 illustrate one form of apparatus utilizing forming rollers acting in a longitudinal direction relative to the respective corrugations of the fin structure while the apparatus of FIG. 9 embodies a combination of those illustrated in FIGS. 4 through 8.

Referring to FIGS. 4 and 5, reference numerals 21 and 22 indicate generally a pair of forming rolls provided with cooperable meshing teeth 23 thereon, the rolls being carried by respective shafts 24 which may be operatively connected to a suitable source of power. The strip S of flat stock may be fed from suitable guide means or members 25 between the meshing teeth 23 of the rolls 21 and 22, and is thereby formed into a series of corrugations with the corrugated strip riding over a suitable bed member 26 and fed between a pair of rolls 27 and 28, each of which is provided with a plurality of teeth 29, with the teeth on the respective gears being disposed in meshing relationship as illustrated.

Referring to FIG. 5, it will be noted that the configuration of the teeth 23 are such that the curved flanks 31 of each tooth are designed and proportioned to squeeze and coin the intermediate portion of each corrugation formed by the intermeshing teeth as the strip passes therethrough, thereby effecting the operations illustrated in step 1 of FIG. 3, comprising the initial forming of the corrugations of the structure and, in this case, simultaneously forming the tapering of the respective fin elements.

The teeth 29 on the rolls 27 and 28 are generally similar to the teeth 23 with the exception that the teeth 29 may have substantially straight or flat flanks 32 with the axes of the supporting shafts 33 for the respective rolls 27 and 28 being so spaced that the tips or apexes of the respective teeth 29 will determine the ultimate width of the respective fin elements. It will be apparent that the action of the respective pairs of forming and sizing rolls may be varied by increasing or decreasing the distance between the shafts supporting the rolls. Thus, by moving the shafts 24 closer together, an increased coining action will result with a diminished thickness of the fin element at the central portion thereof or an increase in the thickness of such portion by effecting a separation of the shafts 24. In like manner, the final width of the corrugations of fin elements may be varied by a corresponding variation in the distance between the shafts 33 of the rolls 27 and 28, and a separation of the shafts resulting in the decrease in the final width of the fin structure or the movement of the shafts towards one another resulting in an increase in the width of the resulting fin structure.

Generally it is desirable to position the rolls 21 and 22 as near as possible to the rolls 27 and 28, and the rolls preferably are so connected to the source of power that the respective pairs of rolls will be operated in synchronism. Thus, as one corrugation leaves the rolls 21 and 22, a corrugation will enter the rolls 27 and 28, whereby

the number of corrugations between the two rolls will be constant. Even with such precaution, there is a possibility that due to factors beyond control, a tooth on one of the rolls 27 or 28 may pick up two corrugations instead of one resulting in damage to the fin structure. To prevent such possibility, suitable synchronizing means may be provided as, for example, a cylindrical member 34 carried by a shaft 35, and rotatable therewith, the shaft being suitably connected to the power source whereby the cylinder 34 may be rotated in synchronism with the respective pairs of forming and sizing rolls.

As clearly illustrated in FIG. 4, the member 34 may be provided with suitably shaped teeth 36 thereon adapted to mesh with the corrugations, the member 34 preferably being recessed at the end opposite the shaft 35 as indicated at 37 to accommodate and adjacent portion of the sizing roll 27, operative to position the teeth 36 as close as possible to the corrugations being picked up by the teeth 29 of the respective rolls. The speed of the member 34 is coordinated to the speed of the respective rolls so that the helical thread on the member 34 will advance the corrugations at the same rate as they are passed through the meshing teeth of the rolls 27 and 28, thereby preventing any possibility of a bunching up of the corrugations at the inlet side of the rolls. It will be appreciated that in the construction illustrated in FIG. 4, the respective rolls 21 and 22, and 27 and 28 are designed to operate on relatively narrow strip material so that the roll 27 may be inserted in the member 34 as illustrated. Obviously if the forming rolls are materially wider, it would be necessary to employ other means to take the place of the member 34.

The speeds of the shafts 24, 33 and 35 will, of course, depend upon the relative sizes of the respective rolls and of the member 34, as well as the pitch of the teeth 36 on the latter, such teeth, in most cases, probably being multiple teeth to reduce the speed that would otherwise be required on the part of the member 34 to advance the corrugations in synchronism with the teeth 29 on the rolls 27 and 28. Likewise, it would appear quite possible that it may be desirable to construct the rolls 21 and 22 of a lesser diameter than that of the rolls 27 and 28, and the rolls illustrated in FIG. 5 are designed on a relatively smaller diameter than the rolls 21 and 22 of FIG. 4.

Step 3 of the method illustrated in FIG. 3 is performed in the apparatus illustrated in FIG. 4 by a gathering or retarding plate 38 which is illustrated as being supported by a bracket 39, the member 38 being pivotally supported on suitable bearing members or pins 41 and adapted to be adjustably positioned by means of one or more adjusting screws 42, carried by the bracket 39 and bearing on suitable blocks or abutments 43 on the plate 38. The plate 38 is adapted to bear on the top portions of the corrugations discharged from the rolls 27 and 28, retarding the advance of the corrugations and thereby, in effect, gathering the same until the corrugations so gathered have sufficient stiffness to push by the lower edge of the plate 38. As the stock from which the structures are formed is relatively springy having some inherent resiliency, upon release of such corrugations with the plate 38, they will tend to at least partially expand as illustrated in FIG. 4, the amount of such expansion of course depending upon the degree of gathering effected by the plate 38.

FIG. 6 illustrates diagrammatically an apparatus for producing fin structures embodying the invention wherein the coining and sizing operations are performed in a longitudinal direction with respect to the corrugations rather than transverse thereto as in the construction illustrated in FIG. 4, and the apparatus of FIG. 6 is primarily designed for use in connection with the forming of corrugated fin structure, having tapered fin elements, wherein the depth of the fin elements, from front to rear as the same may be assembled in the manner illustrated in FIGS. 1 and 2, is considerably greater whereby the fin

structure has a substantially greater depth than a fin structure of the type illustrated in FIGS. 1 and 2 or adapted to be produced by the apparatus of FIG. 4.

Referring to FIG. 6, the strip S of stock is fed between a pair of rolls 44 which generally correspond to the rolls 27 and 28, having intermeshing teeth thereon which are provided with relatively flat flanks so that the roll performs primarily only a corrugating function and not a coining function comparable to the rolls 21 and 22. Following the discharge of the strip from the rolls 44, the strip of corrugations may be cut to size and thus severed from the original strip following which the severed corrugated structure is advanced transversely to its original direction through the rolls 44, the corrugated sheet C then passing through a pair of forming rolls 45, each having a series of disc-like members 46 with the members of the respective rolls being intermeshed, as clearly illustrated in FIG. 7. In some cases it may be desirable to cut the stock to length prior to its entry into the rolls 44. The cross-sectional shape of the teeth 46 is generally comparable to that of the teeth 23 of the forming rolls 21 and 22, the corresponding surfaces of the discs 46 having convex annular flank surfaces corresponding to the flanks 31 of the teeth 23 so that as the corrugated strip passes between the rolls, the central portions of the respective fin elements will be coined or worked to reduce the thickness at such central portions and produce a tapered fin structure generally corresponding to that discharged from the rolls 21 and 22 of FIG. 4. After such forming operation, the corrugated strip may be passed through sizing rolls 47 which, as illustrated in FIG. 8, likewise comprise a series of annular disc-like members 48 having a transverse cross-sectional shape generally corresponding to the teeth 29 of the rolls 27 and 28 so that the outer periphery of the intermeshing discs 47 will determine the final overall width of the completed fin structures. Following discharge of the formed and sized corrugated strip from the rolls 47, the strip may be subjected to a gathering action as indicated at 49 to adjust the spacing of the fin elements thereof.

FIG. 9 illustrates a modified form of apparatus and generally would utilize the same general construction as that illustrated in FIG. 6 up to and including the forming rolls 45 of such construction. However, after the corrugated strip is passed through the rolls 45, as illustrated in FIG. 9, it is then moved transversely to its direction through the rolls 45 and is passed through a pair of rolls 51, generally conforming to the sizing rolls 27 and 28, to similarly size the respective corrugations, following which the corrugations may be engaged with a gathering plate 38' carried by a bracket 39' and having suitable adjusting screws 42'.

It will be appreciated that while the apparatus of FIG. 6 could theoretically embody suitably shaped forming rolls in lieu of the rolls 44, whereby the corrugations could be initially formed in the flat strip by suitable rolls acting in the same direction on the strip as the rolls 45 and 47, due to the considerable length of material which would normally be required to fabricate a corrugated strip of a length corresponding, for example, to that utilized in an average automobile radiator structure, the width of the initial stock would have to be considerably in excess to that normally available at the present time. Longitudinal rolling of the corrugations would thus be of practical value only in cases involving fin structures comprising a relatively few number of corrugations, in which case, the overall width of the original stock forming the same would be sufficiently small to enable use of standard widths of the strip stock.

It will be appreciated that in either of the operations, the size of the rolls may be varied and that the respective speeds of the rolls will be accordingly determined to synchronize the respective operations.

While I have illustrated the invention in connection with plain, uncontoured fin elements, obviously, if desired,

the respective fin elements could be suitably contoured, as for example, similar to that illustrated in the Schank patent or could be provided with a series of transverse slits therein, to form, in effect, strip fins. Where intermeshing forming rolls similar to the rolls 27 and 28 are employed, such rolls may also include the contours for forming the desired protuberances or slits in the fin structure. Likewise, in the construction illustrated in FIG. 9, the forming or slitting operations could be performed by the roll 51.

It might be mentioned with respect to FIGS. 7 and 8 that the discs 46 and 47 would be so shaped and dimensioned as to provide clearance between the crown or tips of the respective teeth on one gear and the valley of the teeth on the other gear, similar to that illustrated in FIG. 5, which clearances have not been shown in FIGS. 7 and 8 in view of the relatively small scale of these figures. It will also be apparent that adjustment of the distance between the axes of the rolls 45, and between the rolls 47 will result in the same end results with respect to the proportions of the final fin structure as adjustment of the rolls 21-22 and 27-28.

It will be appreciated that if strip or sheet metal stock were available having exceptionally uniform quality as to thickness, temper, etc., it might be possible to utilize a single pair of forming rolls which would satisfactorily size the fin structure and render further sizing unnecessary, in which case the sizing rolls could be omitted. However, in view of the usual commercial tolerances existing in metal stock of the type involved, as well as variations in temper, it is believed that it would be desirable in substantially all cases to provide a sizing step and means for performing the same, thereby insuring satisfactory uniformity in the completed structure under all conditions which would normally be experienced.

Likewise, it will be apparent that the method of the present invention is not limited to rolling operations but could be satisfactorily accomplished by stamping operations with dies which would be correspondingly shaped to coin the fin elements in a manner comparable to that herein illustrated, and the sizing means could likewise be performed as a stamping operation. It will be apparent that stamping operations of this character could be performed either as a single operation on the entire fin structure, assuming that the physical dimensions of the structure were such as to accommodate an operation of such type, or the forming could be done in successive stamping operations, each of which forms a single corrugation in a manner similar to some equipment which has heretofore been used in fabricating serpentine-type fin structures.

It will be apparent from the above disclosure that I have provided a novel fin structure of the serpentine type having improved efficiency characteristics on the basis of the amount of material employed, providing a desirable tapered fin construction, together with a novel method by means of which such a fin may be fabricated to close tolerances to provide a suitably uniform structure, with a considerable saving in cost due to the reduction in material, without in any way sacrificing the efficiency of the structure. Likewise, I have provided novel apparatus for carrying out the method.

Having thus described my invention, it will be obvious to those skilled in the art from the above disclosure that various immaterial modifications may be made in the same without departing from the spirit of my invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. The method of forming a serpentine fin structure for a heat exchange structure, said fin structure comprising a plurality of fin elements adapted to be connected along their lateral edges to respective tube elements of the heat exchange structure with each fin element being connected at one of its edges to a corresponding edge of an adja-

cent fin element at one side thereof and at its opposite edge to the corresponding edge of the adjacent fin element at the other side thereof, providing a generally corrugated or serpentine shaped structure, the connecting portions between adjacent fin elements providing means by which the fin element may be connected to associated tube elements of the heat exchange structure, said method comprising the steps of forming a strip of metal into a generally corrugated shape, simultaneously reducing and tapering the thickness of the strip by squeezing and coining at intermediate portions of the fin elements, whereby the latter generally taper in thickness from their lateral edges toward the central portion thereof, and stretching the fin element at said intermediate portions of reduced thickness as may be necessary to provide said fin structure with fin elements of uniform width, gathering the corrugations to bring the latter into closer proximity than desired in the finished structure, and releasing the corrugations to permit expansion thereof to the desired spacing.

2. The method of forming a serpentine fin structure for a heat exchange structure, said fin structure comprising a plurality of fin elements adapted to be connected along their lateral edges to respective tube elements of the heat exchange structure with each fin element being connected at one of its edges to a corresponding edge of an adjacent fin element at one side thereof and at its opposite edge to the corresponding edge of the adjacent fin element at the other side thereof, providing a generally corrugated or serpentine shaped structure, the connecting portions between adjacent fin elements providing means by which the fin element may be connected to associated tube elements of the heat exchange structure, said method comprising the steps of forming a strip of metal into a generally corrugated shape, reducing and tapering the thickness of the strip by squeezing and coining at intermediate portions of the fin elements, whereby the latter generally taper in thickness from their lateral edges toward the central portion thereof, gathering the corrugations to bring the latter into closer proximity than desired in the finished structure, and releasing the corrugations to permit expansion thereof to the desired opening.

3. The method of forming a serpentine fin structure for a heat exchange structure, said fin structure comprising a plurality of fin elements adapted to be connected along their lateral edges to respective tube elements of the heat exchange structure with each fin element being connected at one of its edges to a corresponding edge of an adjacent fin element at one side thereof and at its opposite edge to the corresponding edge of the adjacent fin element at the other side thereof, providing a generally corrugated or serpentine shaped structure, the connecting portions between adjacent fin elements providing means by which the fin element may be connected to associated tube elements of the heat exchange structure, said method comprising the steps of forming a strip of metal into a generally corrugated shape, reducing and tapering the thickness of the strip by squeezing and coining at intermediate portions of the fin elements, whereby the latter generally taper in thickness from their lateral edges toward the central portion thereof and stretching the fin element at said intermediate portions of reduced thickness as may be necessary to provide said fin structure with fin elements of uniform width.

4. An apparatus for forming a serpentine fin structure for a heat exchange structure having a plurality of fin elements adapted to be connected along their lateral edges to respective tube elements of the heat exchange structure with each fin element being connected at one of its edges to a corresponding edge of an adjacent fin element at one side thereof and at its opposite edge to the corresponding edge of the adjacent fin element at the other side thereof, providing a generally corrugated or serpentine-shaped structure from a strip of metal, the connecting portions between adjacent fin elements pro-

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viding means by which the fin element may be connected to associated tube elements of the heat exchange structure, comprising means including intermeshing gear-like teeth for forming the strip into a corrugated structure and for reducing the thickness of the strip at the intermediate portions of said fin elements, said intermeshing gear-like teeth complementally formed for squeezing and coining the intermediate portions of the fin elements, means for sizing the width of said fin elements, and means for gather the corrugations, said last mentioned means including a corrugation release element which will permit the corrugations to partially expand.

5. An apparatus as defined in claim 4, wherein said means for forming the strip into a corrugated structure and for reducing the thickness of the strip at the intermediate portions of said fin elements comprises a pair of cooperable rolls rotatable on parallel axes and having intermeshing corrugation-forming teeth thereon, said rolls including the aforesaid intermeshing gear-like teeth comprising cooperable flank portions engageable with the central portions of the fin elements to apply pressure by squeezing and coining to reduce the thickness of the central portion of the fin elements, and said means for sizing comprising a pair of cooperable rolls having intermeshing teeth thereon with the apexes of intermeshing teeth on one roll being spaced from the apexes of the intermeshing teeth on the other roll a distance to stretch the fin elements to a predetermined substantially uniform size.

6. An apparatus as defined in claim 4, wherein said means for reducing the thickness of the strip at the intermediate portions of said fin elements comprises a pair of cooperable rolls comprising a series of axially spaced disc-like members thereon, each having a generally tooth-shaped peripheral cross-section with the discs on one roll intermeshing with the disc-like members on the other and adapted to receive a corrugated strip therebetween, said disc-like members including cooperable portions thereon engageable with the respective fin elements of the corrugated structure to apply pressure thereto for reducing the thickness thereof.

7. An apparatus as defined in claim 6, wherein said means for forming the strip into a generally corrugated structure comprises a pair of rolls, the aforesaid intermeshing gear-like teeth formed thereon, and said means for sizing comprises a pair of cooperable rolls including a series of axially spaced disc-like members thereon, each having a generally tooth-shaped peripheral cross-section, with the disc-like members on one roll intermeshing with the disc-like members on the other roll with the peripheral edges of said intersecting disc-like members on one roll being spaced from the apexes of intermeshing disc-like members on the other roll a distance to stretch the fin elements to a predetermined substantially uniform size.

8. An apparatus as defined in claim 6, wherein said means for sizing comprises a pair of cooperable rolls having intermeshing teeth thereon with the apexes of intermeshing teeth on the other roll a distance to stretch the fin elements to a predetermined substantially uniform size.

9. In an apparatus for forming a serpentine fin structure comprising a plurality of fin elements providing heat transfer fins from a strip of heat transfer material of generally tapered cross-section, the combination of means for forming the strip into a corrugated structure and for reducing the thickness of the material at the intermediate portions of said fin elements, the aforesaid means for forming the strip into a corrugated structure and for reducing the thickness of the material at the intermediate portions of said fin elements comprising a pair of cooperable rolls rotatable on parallel axes and having intermeshing corrugation-forming teeth thereon, the teeth of said rolls having cooperable flank portions engageable with the central portions of the fin elements to apply

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pressure thereon to reduce the thickness thereof, so that the central portions taper from the thickness of the material at the intermediate portions of said fin elements to the longitudinal axis of the serpentine fin structure.

10. In an apparatus for forming a serpentine fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal, the combination of means for forming the strip into a corrugated structure and for reducing the thickness of the material at the intermediate portions of said fin elements, the aforesaid means for forming the strip into a corrugated structure and for reducing the thickness of the material at the intermediate portions of said fin elements comprising a pair of cooperable rolls having a series of axially spaced disc-like members thereon, each having a generally tooth-shaped peripheral cross-section with the discs on one roll intermeshing with the disc-like members on the other and adapted to receive a corrugated strip therebetween, and said disc-like members having cooperable portions thereon engageable with the central portions of the respective fin elements of the corrugated structure to apply pressure thereto for reducing the thickness thereof, so that the central portions taper from the thickness of the material at the intermediate portions of said fin elements to the longitudinal axis of the serpentine fin structure.

11. In an apparatus for forming a secondary surface serpentine and controlled fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, the combination of means including intermeshing teeth for forming the strip of metal into a generally serpentine and contoured fin structure, and means for simultaneously reducing the thickness of the strip at intermediate portions of the fin elements so that the fin elements taper in thickness from their lateral edges toward the central portion thereof.

12. In an apparatus for forming a secondary surface serpentine and contoured fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, the combination of means for forming the strip of metal into a generally serpentine and contoured fin structure, means for simultaneously reducing the thickness of the strip at intermediate portions of the fin elements so that the fin elements taper in thickness from their lateral edges toward the central portion thereof, and means for stretching the fin element at said intermediate portions of reduced thickness as may be necessary to provide said fin structure with fin elements of uniform width.

13. In an apparatus for forming a secondary surface serpentine fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, the combination of means for forming the strip into a corrugated structure and for reducing the thickness of the strip at the intermediate portions of said fin elements, said means for forming comprising intermeshing corrugation-forming teeth means complementally formed and operably mounted and including cooperable flank portions engageable with the central portion of the fin elements to apply pressure thereon to reduce the thickness thereof and for stretching the fin elements to a predetermined substantially

uniform size, whereby a serpentine fin structure is formed with the fin elements thereof including heat transfer fins of generally tapered cross-section toward the longitudinal axis of the serpentine fin structure.

14. As an article of manufacture, a mating roll for use in pairs in an apparatus for forming a secondary surface serpentine fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, said roll adapted for rotation in pairs on parallel axes, said roll including corrugation-forming teeth thereon complementally formed to the teeth of the other roll when used in pairs, the teeth of said roll having cooperable flank means engageable with the central portion of the fin elements when the rolls are used in pairs to apply pressure thereon to reduce the thickness thereof, whereby a serpentine fin structure is formed with the fin elements thereof including heat transfer fins of generally tapered cross-section and a predetermined substantially uniform size.

15. As an article of manufacture, a mating roll for use in pairs in an apparatus for forming a secondary surface serpentine fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, said roll adapted for rotation in pairs on parallel axes, said roll including corrugation-forming teeth thereon complementally formed to the teeth of the other roll when used in pairs, the teeth of said roll including cooperable curved flank means for squeezing and coining the intermediate portion of each corrugation of the serpentine fin structure formed by the intermeshing corrugation-forming teeth when the rolls are used in pairs as the strip passes there-through, whereby the corrugations of the serpentine fin structure and tapering of the respective fin elements are simultaneously formed.

16. As an article of manufacture, a mating roll for use in pairs in an apparatus for forming a secondary surface serpentine fin structure comprising a plurality of fin elements providing heat transfer fins of generally tapered cross-section from a strip of metal of substantially uniform quality as to thickness and temper, the thickest portion adapted for disposing adjacent a primary heat exchange surface, said thickness tapering toward the longitudinal central portion of the fin, said roll adapted for rotation in pairs on parallel axes, said roll including corrugation-forming teeth thereon complementally formed to the teeth of the other roll when used in pairs, the teeth of said roll including cooperable substantially flat flank means with the axes of the shafts for the mating rolls, when the rolls are used in pairs, adapted for operably mounting for varying the spacing of the apexes of the corrugation-forming teeth of the rolls when used in pairs, whereby the apexes of the respective corrugation-forming teeth determine the ultimate width of the respective fin elements.

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