

Sept. 23, 1969

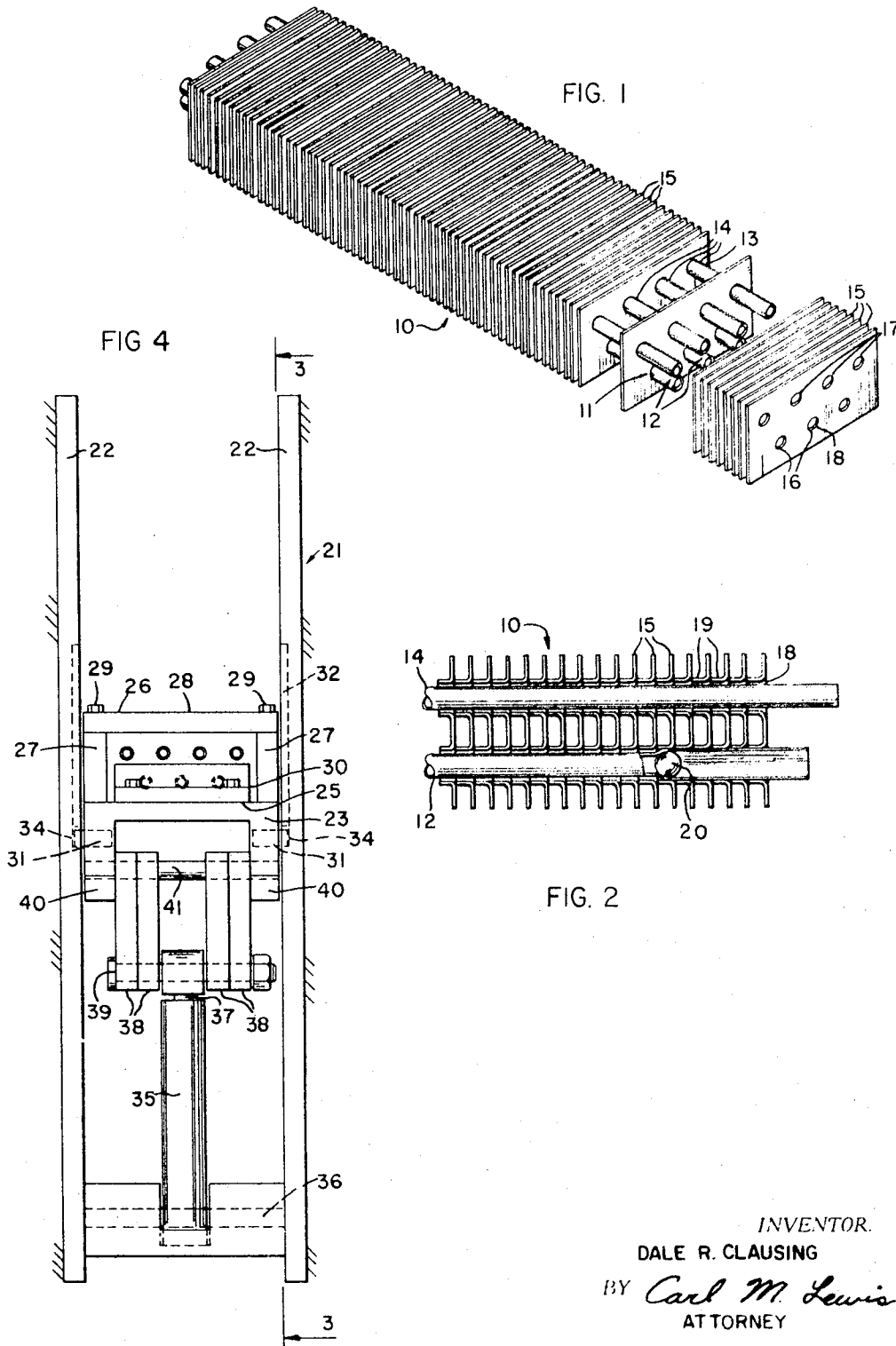
D. R. CLAUSING

3,468,009

METHOD FOR CONSTRUCTING A FIN-AND-TUBE HEAT
EXCHANGER HAVING A BEND FORMED THEREIN

Filed May 29, 1967

6 Sheets-Sheet 1



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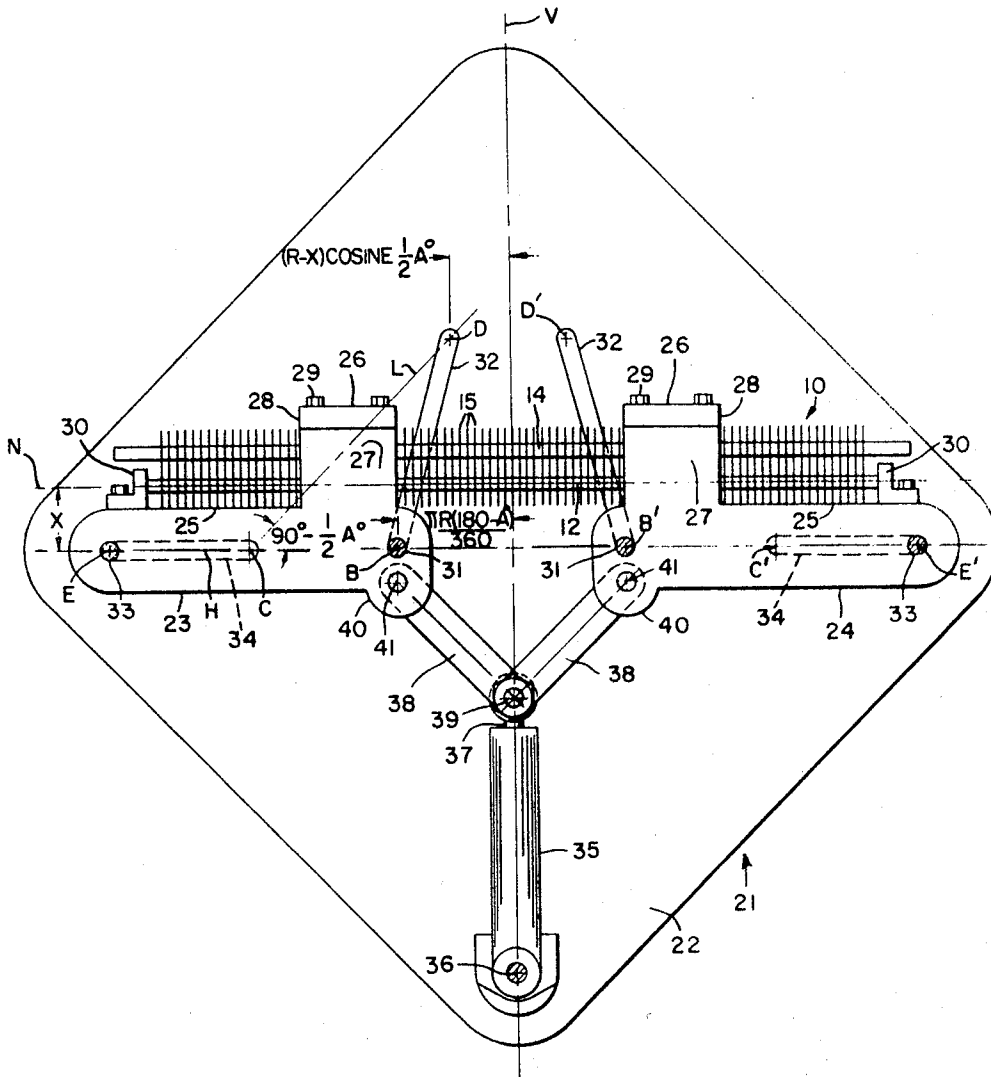
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FIG. 3



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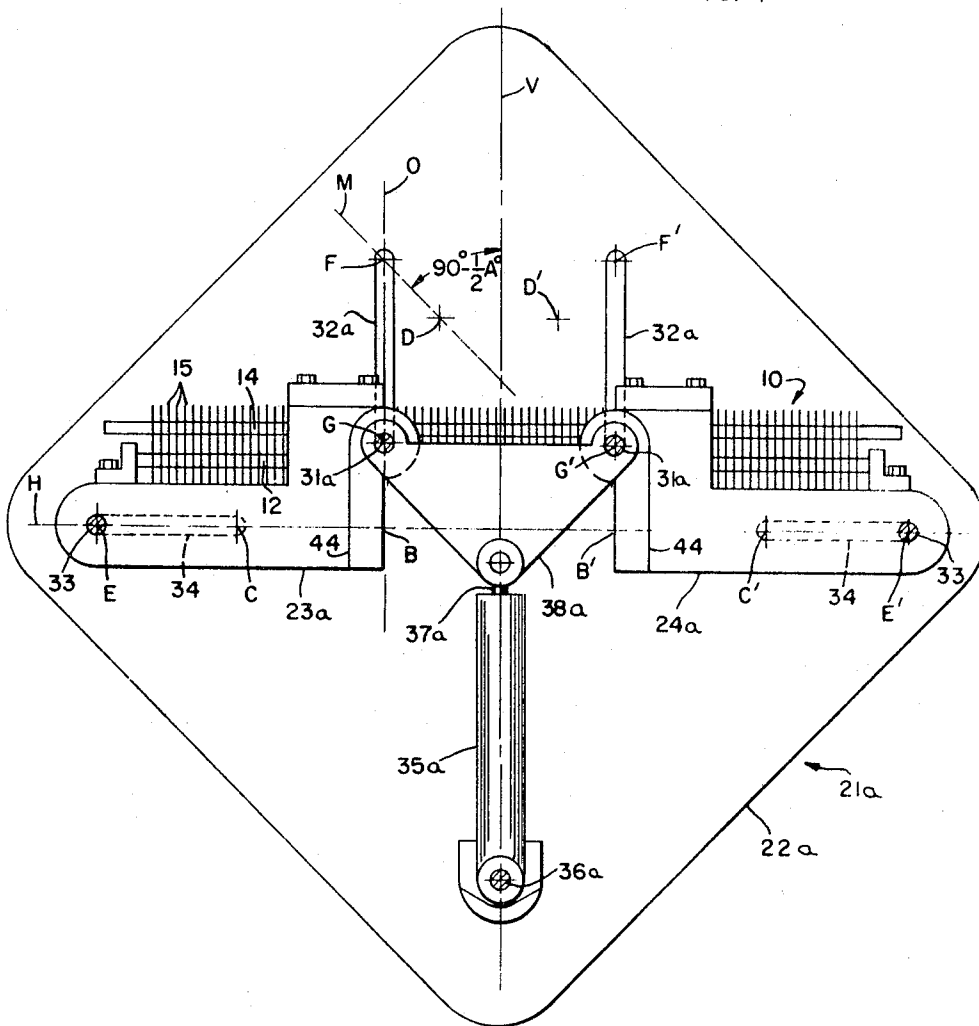
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FIG. 7



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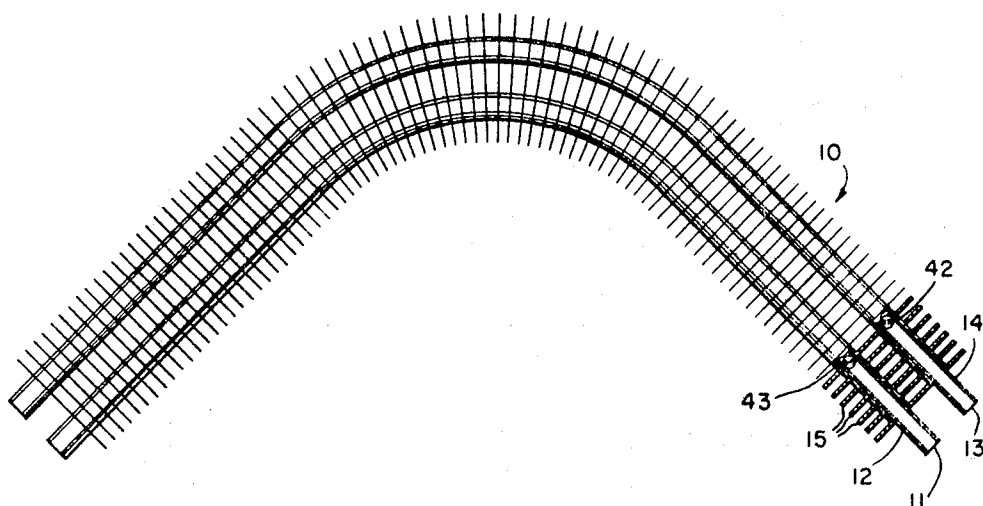


FIG. 10

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METHOD FOR CONSTRUCTING A FIN-AND-TUBE HEAT EXCHANGER HAVING A BEND FORMED THEREIN

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U.S. Cl. 29—157.3

10 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for constructing a fin-and-tube heat exchanger having a bend formed therein by bending the heat exchanger with apparatus which does not support or contact the heat exchanger fins at the situs of the bend, and a method for constructing a multirow fin-and-tube heat exchanger having a bend formed therein to facilitate the bending operation by initially expanding the tubes of only one row to fix the spacial relation of the fins during the bending step and allowing the tubes of the other rows to move freely relative to the fins during the bending operation, to thereby eliminate adverse distortion of the fins especially in the bend area.

BACKGROUND OF THE INVENTION

This invention relates to the art of fin-and-tube heat exchangers and particularly to those heat exchangers comprising a stack of generally planar parallel fins having a plurality of tubes extending normally therethrough. Such tubes may be disposed in a coplanar arrangement as in a one-row heat exchanger coil. Or, they may be arranged in two or more planes as in a two or more row coil. Often a two row coil is preferred over a one row coil for the reason that it requires less face area for the equivalent heat transfer surface.

In modern air conditioning applications it may be desirable to bend a fin-and-tube heat exchanger coil so that the coil lies generally along two or more intersecting planes. For example, it may be desirable to arrange a refrigerant condenser coil so that it forms two or more sides of a rectangular condensing unit. Conventionally one-row coils of this type have been bent with tangent type coil bending machines. A tangent type bender fixedly clamps one leg or end of the coil while a bending platen journaled at a fixed center is pivoted to warp the other leg of the coil over a curved forming die located at the bight of the bend. A bend of final curvature progresses from one end toward the other end of the area to be bent.

I have found that in heat exchanger coils having relatively thin fins or thick tubes and especially in those coils having multiple rows, excessive pressures are imposed upon the fins by conventional tangent bending methods which adversely deform the fins. Such pressures may originate from the relative sliding movement between the pivoted platen and the coil fins and from the localized pressures exerted by the fin forming die on the fins as the coil is form wrapped over the die. In a two or more row coil, these pressures are increased because the neutral axis of the bend cannot coincide with both rows of tubes simultaneously and the tubes of one row tend to slide relative to the fins. This relative tube-to-fin motion produces forces which increase the above mentioned bending pressures.

SUMMARY OF THE INVENTION

It is thus an object of my invention to provide a method and apparatus to mitigate these pressures which tend to

adversely deform the fins of a fin-and-tube heat exchanger coil when being provided with a discrete bend.

It is also an object to provide a method and apparatus for constructing a multiple row fin-and-tube heat exchange coil with a discrete bend.

Another object is to provide a method and apparatus for bending a fin-and-tube heat exchange coil which does not require the application of external pressure on the fins in the bend area.

It is a further object of the invention to provide a fin-and-tube heat exchange coil bending apparatus having a pair of platens fixedly secured to the fins of the coil and operated to bend the coil by pivoting one platen relative to the other about a moving center or axis.

This invention includes a method of constructing a fin-and-tube heat exchange coil having a depth of at least two rows of tubes and bent to a predetermined angle comprising the steps of: providing a first plurality of generally straight first tubes; providing a second plurality of generally straight second tubes; providing a plurality of generally planar fins each having a first row of spaced first apertures adapted to receive and embrace a first row of tubes and a second row of spaced second apertures spaced from said first row of apertures adapted to receive and embrace a second row of tubes; arranging said fins in generally parallel superposed relation and positioning said first tubes within said first apertures and said second tubes within said second aperture thereby forming a fin-and-tube heat exchange coil having spaced first and second rows of tubes respectively whereby the tubes of said first row lie within a first plane and the tubes of said second row lie within a second plane parallel to and spaced a predetermined distance from said first plane; said tubes extending from one end to the other end of said heat exchange coil; fixedly securing a first platen to the fins on a first portion of said coil adjacent said one end thereof; fixedly securing a second platen to the fins on a second portion of said coil adjacent said other end thereof, said second portion being spaced from said first portion thereby defining a third portion interposed between said first and second portions; bending said third portion of said heat exchange coil to said predetermined angle by rotating said second platen relative to said first platen about an instant center and simultaneously moving said instant center along a predetermined path relative to said first platen in a manner to avoid excessive pressures on said fins and fin distortion normally attendant therewith; and removing the resulting bent fin-and-tube heat exchange coil from said platens.

This invention further involves the apparatus for forming an arcuate bend of a predetermined angle in a fin-and-tube heat exchange coil, said coil including a longitudinally extending tube with a plurality of fins disposed longitudinally therealong, said coil having a first section, a second section spaced longitudinally from said first section, and a third section longitudinally intermediate said first and second sections, said apparatus comprising: a first platen fixedly connected to the fins of said first section; a second platen fixedly connected to the fins of said second section; means for pivoting said second platen relative to said first platen through the supplement of said predetermined angle about a central axis and simultaneously moving said axis through a curvilinear path whereby said third section is bent to said predetermined angle without the necessity of applying external pressure to the fins on said third section.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete disclosure of the invention will be revealed as this specification proceeds to describe the invention in detail with reference to the accompanying draw-

ings wherein like elements have been identified by like numerals throughout and in which:

FIGURE 1 illustrates the step of arranging the fins on the tubes to form a two row heat exchange coil;

FIGURE 2 is an enlarged sectional view of a fragment of the coil of FIGURE 1 and illustrates the subsequent step of expanding the tubes of only one row prior to the step of bending the coil;

FIGURE 3 is a section taken at line 3—3 of FIGURE 4 through a fin-and-tube heat exchanger coil bending machine incorporating aspects of the instant invention and showing the heat exchanger coil of FIGURE 2 mounted therein ready for bending;

FIGURE 4 is a side elevation of the coil bending machine shown in FIGURE 3;

FIGURE 5 is a view similar to FIGURE 3 after the coil bending machine thereof has been moved through the bending step;

FIGURE 6 is a diagrammatic showing of the relative movement of the two platens of the coil bending machine shown in FIGURES 3-5 as the machine performs the step of bending the heat exchange coil of FIGURE 2 and particularly showing the locus of instant centers of relative motion between the platens of the machine;

FIGURE 7 is a view similar to FIGURE 3 showing a modified form of the coil bending machine of FIGURE 3;

FIGURE 8 is a view similar to FIGURE 5 showing the modified coil bending machine after the bending step;

FIGURE 9 is a view similar to FIGURE 6 illustrating the relative platen movement for the modified coil bending machine of FIGURES 7 and 8; and

FIGURE 10 illustrates the step of expanding the tubes of all rows of the coil subsequent to the coil bending step.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now with reference to the embodiment of the invention disclosed in FIGURES 1-6 and 10, there is shown a fin-and-tube heat exchange coil 10 having a first row 11 of coplanar parallel laterally spaced tubes 12; a second row 13 of coplanar parallel laterally spaced tubes 14; and a plurality of generally planar rectangular relatively thin heat conductive fins 15 each having a first row 16 and a second row 17 of apertures 18 therein to receive respectively the tubes 12 and 14 of first and second tube rows 11 and 13. The fins 15 are stacked on the tubes in parallel generally spaced relationship. This stacking step is illustrated in FIGURE 1. It will be appreciated that in the alternative the tubes 12 and 14 may be inserted into the apertures 18 of the stacked fins 15. For purposes of this invention as defined and claimed, the one manner of arranging the tubes with respect to the fins is considered the full equivalent of the other. It will also be appreciated, as more fully illustrated in FIGURE 2, that the collar 19 at each aperture 18 is preferably in contact with an adjacent fin whereby the fins become substantially equally spaced prior to bending of the coil. Subsequent to arranging the fins 15 with respect to the tubes 12 and 14, the tubes 12 of row 11 are expanded within the apertures 18 of row 16 to secure a mechanical bond between the fins 15 and the tubes 12 of the first row of tubes. This is accomplished by passing a bullet 20 (FIGURE 2) of larger size through the tubes 12 by any of several methods known to the art of heat exchange coil construction. The expander bullet diameter will be different for different size tubes and is best determined by experiment on the basis of best results. The tubes 14 of row 13 are not expanded at this time so as to permit tubes 13 to slide relative to fins 15 during a subsequent bending step as more fully described hereinafter. The heat exchanger coil assembly 10 is then clamped into the coil bending machine 21 of FIGURES 3-5 or the modified coil bending machine 21a of FIGURES 7, 8 and 9.

Now referring specifically to FIGURES 3, 4 and 5,

it will be seen that coil bending machine 21 has two stationary guide plate members 22 fixed in parallel spaced relation. Interposed between guide members 22 are first elongated platen 23 and second elongated platen 24 each having a primary pressure bearing planar surface 25 for supporting a first face of the heat exchanger coil 10. Platens 23 and 24 are so arranged that surfaces 25 are initially coplanar and normal to guide members 22 as shown in FIGURES 3 and 4. Heat exchanger coil 10, following the aforementioned tube expanding step shown in FIGURE 2, is laid upon and clamped to surfaces 25 via a clamp means 26 on each platen. Each clamp means may include a pair of legs 27 extending upwardly from surface 25 at the margins thereof and a clamp plate 28 extending between the free ends of legs 27 for the purpose of applying pressure on the other or second face of coil 10 via bolts 29. Each platen further includes an angle member 30 which presents a secondary pressure bearing surface at the ends of the tubes 12. Members 30 may be integral with or merely attached to the platens as desired.

The platens 23 and 24 each have at their adjacent ends a pair of laterally projecting pins 31 which are slidably received in vertically extending guide slots 32 in guide members 22. The platens 23 and 24 each further have at their remote ends a pair of laterally projecting pins 33 which are slidably received in horizontally extending guide slots 34 in guide members 22. Thus platens 23 and 24 may be rotatably guided by pins 31 and 33 and slots 32 and 34 from the position shown in FIGURE 3 to the position shown in FIGURE 5. To bring about this movement there may be provided a hydraulic power cylinder 35 anchored to guide members 22 by pin 36. The piston rod 37 of the hydraulic cylinder 35 may be pivotally connected to links 38 as by bolt 39 which links are in turn connected to adjacent ends of platens 23 and 24 at ears 40 as by pins 41. It will thus be appreciated that extension of the power cylinder piston rod 37 causes the platens to move from the position shown in FIGURE 3 to their position shown in FIGURE 5, thereby bending the heat exchanger coil 10 as shown in FIGURE 5. It should be noted that it is not necessary that the platens 23 and 24 contact the fins at any point along the bend of the coil 10 and that there is no substantial movement of the platens relative to the coil fins clamped therein.

The heat exchange coil bending machine 21 shown is constructed to provide coil 10 with up to a 90° bend having a neutral axis palne N coinciding with the longitudinal axes of tubes 12. Thus, as the coil is bent, those portions of coil 10 above plane N are expected to undergo expansion while those portions of the coil 10 below plane N are expected to undergo compression. The substantially no expansion or compression of the coil takes place at the intersection with plane N. Thus there is little distortion of collars 19 at tubes 12 during the bending step as these collars lie on the neutral axis N.

The location of pins 31 and 33 and slots 32 and 34 may be determined as follows.

(1) Locate a horizontal axis H parallel to and X distance below neutral axis N (FIGURE 3) and locate central vertical axis V normal to axis H. The value of X may be selected as desired.

(2) Locate point B for pin 31 (FIGURE 3) at the inner end of platen 23 on horizontal axis H a distance

$$\frac{\pi R(180^\circ - A^\circ)}{360^\circ}$$

to the left of vertical axis V where R is the desired coil bend radius to the neutral axis N and A° is the desired coil bend included angle in degrees (see FIGURE 5) and π equals 3.1416. For purposes of this example A° is selected as 90°.

(3) Select a point C (FIGURE 3) on horizontal axis H to the left of point B.

(4) Project from point C a line L upward and toward

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vertical axis V at an angle to horizontal axis H equal to $90^\circ - \frac{1}{2}A^\circ$.

(5) Locate point D on line L to the left of vertical axis V a distance equal to $(R-X) \cos \frac{1}{2}A^\circ$.

(6) Locate point E to the left of vertical axis V on horizontal axis H so that the distance between points D and C equals the distance between points B and E.

(7) Locate points B', C', D' and E' on the right side of vertical axis V in similar manner as points B, C, D, and E. Points B, B', C, C', D, D', E and E' are points in fixed relation to guide members 22.

Pins 31 and 33 are located on platen 23 at points B and E respectively when the platen is in the position shown in FIGURE 3. Pins 31 and 33 are located on platen 24 at points B' and E' respectively when the platen is in the position shown in FIGURE 3.

The straight vertical diverging slots or grooves 32 are formed in each of guide members 22 connecting between B and D, and B' and D' for guiding pins 31. Thus, during the coil bending step, pins 31 on platen 23 move from points B to points D and pins 31 on platen 24 move from points B' to points D'.

The straight horizontal slots or grooves 34 are formed in each of guide members 22 connecting between C and E, and C' and E' for guiding pins 33. Thus, during the coil bending step, pins 33 on platen 23 move from points E to points C and pins 33 on platen 24 move from points E' to points C'.

After the platens have been rotated from the position shown in FIGURE 3 to the position shown in FIGURE 5, the clamp plates 28 are removed and the bent coil 10 can be removed from machine 21. The hydraulic power cylinder 35 may then be contracted to return the platens to their position of FIGURE 3 for receiving another coil 10. The machine 21 may be designed for a slight over bend to compensate for the slight spring back that is often encountered in bending.

FIGURE 6 illustrates the movement of platen 24 relative to platen 23 during the bending step. Platen 24 rotates $180^\circ - A^\circ$ relative to platen 23 about an instant center moving relative to platen 23 along a locus or path P. Path P is substantially an arc of $90^\circ - \frac{1}{2}A^\circ$ having a radius substantially equal to

$$\frac{\pi R(180^\circ - A^\circ)}{360^\circ}$$

and a center at S. During the rotation of the platens, the radius R of the coil bend from the central axis of curvature T to the neutral axis N is gradually reduced and the bend is effected simultaneously over the entire bend area as shown in FIGURE 6.

After the bent coil 10 has been removed from the coil bending machine 21 the tubes 14 of the outside row 13 are expanded such as by passing an expander bullet 42 therethrough as illustrated in FIGURE 10 to secure an efficient heat conductive mechanical connection especially in the bend area between the tubes 14 and fins 15. The tubes 12 of row 11 are further expanded at this time with an expander bullet 43 also to secure an efficient heat conductive mechanical connection especially in the bend area between the tubes 12 and fins 15. Bullet 43 is several thousandths of an inch larger in diameter than first expander bullet 20. The ends of tubes 12 and 14 may then be appropriately connected to provide the desired heat exchanger coil circuits.

Referring again to machine 21 it will be appreciated that the platen guide pins 31 and 33 may be transposed with guide slots 32 and 34. However, in such case, the slots formed on the platen members would be curvilinear and thus more difficult to construct than the straight grooves 32 and 34 of FIGURES 3-5.

The heat exchanger coil bending machine of FIGURES 3-5 may be simplified by substituting for the plural links 38 thereof a single link 38a for connecting the inner ends

of the platens by pins 31a of the coil bending machine 21a shown in FIGURES 7, 8 and 9. Platens 23a and 24a may be recessed at 44 to accommodate link 38a. The pins 31a are located on platens 23a and 24a (FIGURE 7) at points G and G' respectively for vertical movement in slots or grooves 32a on each of guide members 22a which slots extend in parallel relation to vertical axis V from points G to points F and from points G' to points F'. Points F, F', G and G' may be located in the following manner:

(1) Construct a line M (FIGURE 7) passing through point D downwardly toward vertical axis V at an angle thereto equal to $90^\circ - \frac{1}{2}A^\circ$. Construct a vertical line O passing through point B.

(2) Locate point F at the intersection of lines M and O.

(3) Locate point G above horizontal axis H on line O so that the distance between points E and G is equal to the distance between points C and F. Groove or slot 32a extends along a straight line connecting F and G.

(4) Locate from points B', C' and E' points G' and F' and a second groove 32a on the other side of vertical axis V between points G' and F' in a similar manner.

Link 38a is connected to a piston rod 37a of hydraulic cylinder 35a anchored by pin 36a to guide members 22a for driving movement of the platens 23a and 24a.

Except for the structural differences just described and their associated functions, the operation of the coil bending machine 21a is substantially the same as coil bending machine 21. During the heat exchange coil bending step the machine elements of the modified form of the invention move from a position shown in FIGURE 7 to a position shown in FIGURE 8. During the bending step platen 24a rotates $180^\circ - A^\circ$ relative to platen 23a about an instant center moving relative to platen 23a along a locus or path Q. Path Q is substantially an arc of $90^\circ - \frac{1}{2}A^\circ$ having a radius equal to

$$\frac{\pi R(180^\circ - A^\circ)}{360^\circ}$$

and a center S coinciding with pin 31a of platen 23a as shown in FIGURE 9. During the rotation of the platens, the radius R of the coil bend from the central axis of curvature T to the neutral axis N is gradually reduced and the bend is effected simultaneously over the entire bend area. Path Q coincides with path P described in connection with the coil bending machine of FIGURES 3-6.

After a coil is bent in bending machine 21a, it is removed and the tubes of the coil are expanded in the same manner as described in connection with coil bending machine 21 following completion of the bend. As with coil bending machine 21, the platen guide pins 31a and 33 may be transposed with guide slots 32a and 34. Again, however, in such case, the slots formed on the platen members would be curvilinear and thus more difficult to construct than the straight grooves 32a and 34 of FIGURES 7 and 8.

Having now described in detail preferred exemplary embodiments of my invention, I contemplate that many changes may be made without departing from the scope or spirit thereof and I desire to be limited only by the following claims.

I claim:

1. A method of constructing a fin-and-tube heat exchange coil having a depth of at least two rows of tubes and bent to a predetermined angle comprising the steps of: providing a first plurality of generally straight first tubes; providing a second plurality of generally straight second tubes; providing a plurality of generally planar fins each having a first row of spaced first apertures adapted to receive and embrace a first row of tubes and a second row of spaced second apertures spaced from said first row of apertures adapted to receive and embrace a second row of tubes; arranging said fins in generally

parallel superposed relation and positioning said first tubes within said first apertures and said second tubes within said second apertures thereby forming a fin-and-tube heat exchange coil having spaced first and second rows of tubes respectively whereby the tubes of said first row lie in a first plane and the tubes of said second row lie in a second plane parallel to and spaced a predetermined distance from said first plane; said tubes extending from one end to the other end of said heat exchange coil; fixedly securing a first platen to the fins on a first portion of said coil adjacent said one end thereof; fixedly securing a second platen to the fins on a second portion of said coil adjacent said other end thereof; said second portion being spaced from said first portion thereby defining a third portion interposed between said first and second portions; bending said third portion of said heat exchange coil to said predetermined angle by rotating said second platen relative to said first platen about an instant center and simultaneously moving said instant center along a predetermined path relative to said first platen in a manner to avoid excessive pressures on said fins and fin distortion normally attendant therewith; and moving the resulting bent fin-and-tube heat exchange coil from said platens.

2. The method as defined by claim 1 wherein said predetermined path simulates an arc of a circle.

3. The method as defined by claim 2 wherein said arc encompasses an angle equal to substantially one-half the supplement of said predetermined angle.

4. The method as defined by claim 3 wherein said arc has a radius equal to substantially

$$\frac{\pi R(180^\circ - A^\circ)}{360^\circ}$$

wherein R is the radius of curvature at the neutral axis of the bend and A° is the predetermined angle in degrees.

5. The method as defined by claim 1 including the step of applying compressive pressure to the ends of said first tubes during the bending step to further hold the ends of said tubes in fixed relation with respect to the adjacent platen and maintaining the neutral axis of the bend coincident with said first plane.

6. The method as defined by claim 1 including the steps of sliding the end portions of said second tubes relative to the fins adjacent said end portions during the bending step and maintaining the neutral axis of the bend radially inward of said second plane.

7. The method as defined by claim 6 including the steps of expanding said first tubes prior to said bending step and expanding said second tubes subsequent to said bending step.

8. The method as defined by claim 7 further including the step of reexpanding said first tubes subsequent to said bending step.

9. A method of constructing a fin-and-tube heat exchange coil having a depth of at least two rows of tubes and bent to a predetermined angle comprising the steps of: providing a first plurality of generally straight first tubes; providing a second plurality of generally straight second tubes; providing a plurality of generally planar fins each having a first row of spaced first apertures adapted to receive and embrace a first row of tubes and a second row of spaced second apertures spaced from said first row of apertures adapted to receive and embrace a second row of tubes; arranging said fins in generally parallel superposed relation and positioning said first

tubes within said first apertures and said second tubes within said second apertures thereby forming a fin-and-tube heat exchange coil having spaced first and second rows of tubes respectively whereby the tubes of said first row lie in a first plane and the tubes of said second row lie in a second plane parallel to and spaced a predetermined distance from said first plane; said tubes extending from one end to the other end of said heat exchange coil; fixedly securing a first platen to the fins on a first portion of said coil adjacent said one end thereof; fixedly securing a second platen to the fins on a second portion of said coil adjacent said other end thereof, said second portion being spaced from said first portion thereby defining a third portion interposed between said first and second portions; bending said third portion of said heat exchange coil to said predetermined angle and simultaneously maintaining the neutral axis of said bend coincident with said first plane; and removing the resulting bent fin-and-tube heat exchange coil from said platens.

10. A method of constructing a fin-and-tube heat exchange coil having a depth of at least two rows of tubes and bent to a predetermined angle comprising the steps of: providing a first plurality of generally straight first tubes; providing a second plurality of generally straight second tubes; providing a plurality of generally planar fins each having a first row of spaced first apertures adapted to receive and embrace a first row of tubes and a second row of spaced second apertures spaced from said first row of apertures adapted to receive and embrace a second row of tubes; arranging said fins in generally parallel superposed relation and positioning said first tubes within said first apertures and said second tubes within said second apertures thereby forming a fin-and-tube heat exchange coil having spaced first and second rows of tubes respectively whereby the tubes of said first row lie in a first plane and the tubes of said second row lie in a second plane parallel to and spaced a predetermined distance from said first plane; said tubes extending from one end to the other end of said heat exchange coil; fixedly securing a first platen to the fins on a first portion of said coil adjacent said one end thereof; fixedly securing a second platen to the fins on a second portion of said coil adjacent said other end thereof, said second portion being spaced from said first portion thereby defining a third portion interposed between said first and second portions; bending said third portion by gradually reducing the radius of curvature of the entire area of said third portion; and removing the resulting bent fin-and-tube heat exchange coil from said platens.

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