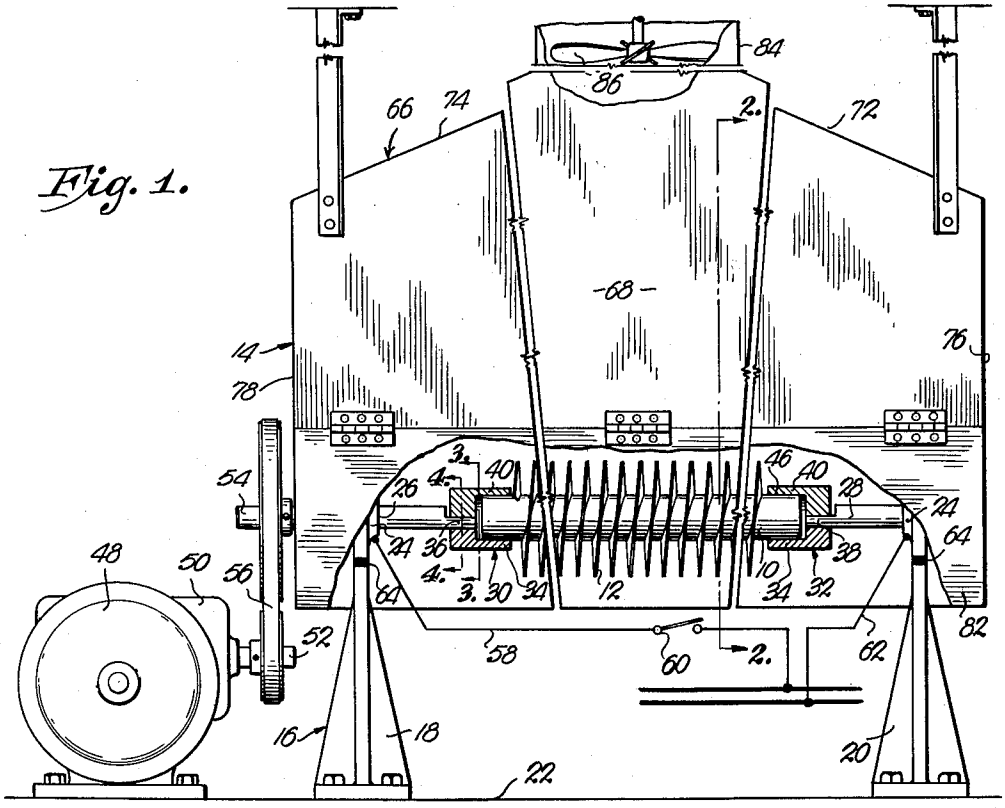
Oct. 30, 1962 R. A. ELLIOTT 3,060,556

METHOD AND APPARATUS FOR PRODUCING FINNED TUBING

Filed Feb. 24, 1958

Fig. 1.



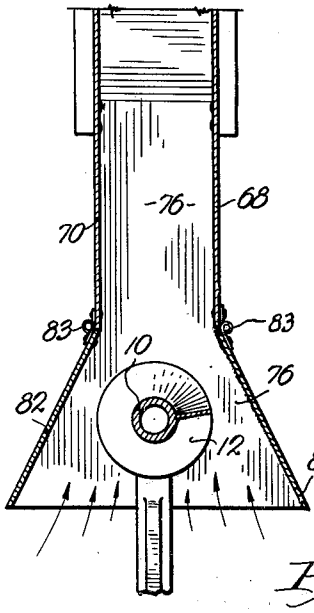


Fig. 2.

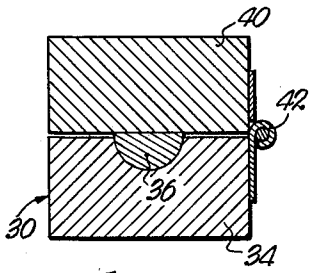


Fig. 3.

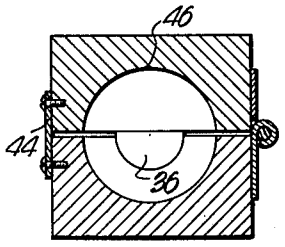


Fig. 4.

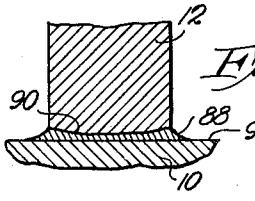


Fig. 5.

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METHOD AND APPARATUS FOR PRODUCING FINNED TUBING

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4 Claims. (Cl. 29—157.3)

This invention relates to thermal exchange equipment and particularly to an improved method of producing finned tubing, as well as novel apparatus for expeditiously carrying out the defined process.

Various types of heat exchange equipment have heretofore been utilized, and it has been a conventional practice to attach fins of high thermal conductivity to the outermost surface of the fluid conducting tube portion of the exchanger so as to increase the maximum heat transfer characteristics of the system. Heat conductivity from the fluid within the tube to the surrounding atmosphere is best attained if the fin itself is joined to the tube in such manner as to substantially eliminate all interference with conduction of heat through the fins. Most of the problems have arisen in this field in the attempts of manufacturers to produce maximum efficiency by utilization of materials which are in greatest demand by the public because the materials have known resistance to corrosion and possess high heat transfer characteristics. The problem has been further enhanced by virtue of the necessity of using metals and processes which do not materially increase the cost of production of the system.

The heat exchange industry has proposed many methods of securing fins of high thermal conductivity to metal tubes, but many of the problems arising in the joining process have not been satisfactorily solved. For example, it has been known for a long time that many metals can be used satisfactorily in the production of finned tubing and in particular those having high heat conductivity while being substantially resistant to corrosion. Metals having the above mentioned physical properties include copper, admiralty, carbon and stainless steel, and aluminum, but the most universally accepted materials are copper tubes having aluminum fins affixed thereto. Therefore, since competition requires that the cost of manufacture be kept to a minimum, for the present at least, it is encumbent upon manufacturers of finned tubing to use copper in the production of heat exchange tubing and aluminum as the most widely utilized fin material because of its cheapness, lightweight characteristics and ability to transfer heat efficiently and quickly.

The aluminum fin is most generally applied to the tube by winding an elongated strip of the metal around the tube in a spiral or helical configuration and thereupon brazing the surface of the fin adjacent the tube to the outermost surface of the latter. Such brazing operations have been carried out in various ways but one of the most successful has been to wind the fin material around the tube subsequent to placement of a nonferrous metal compound on the outermost surface of the tube and thereupon to heat the finned tubing to a sufficient temperature to melt the brazing compound and thereby form a molten bonding substance capable of flowing into the butt joint between the proximal edge surface of the fin and the outermost surface of the tube to present a sound interconnection between the fin and the tube upon cooling of the components. Such brazing of the aluminum fin to the copper tube has not met with complete success in past methods, however, because of the fact that during heating

of the finned tubing to effect brazing of the components together, the difference in the coefficients of expansion of the fin and the tube caused the fin to expand to a greater extent than the tube and thus pull away and leave a relatively wide space between the fin and the tube. Manifestly, movement of the fin away from the outermost surface of the tube destroys the tight engagement of the fin with the tube and prevents the molten material from flowing into the joint between the fin and the tube by capillary action, which results when a tight butt joint is presented between the components to be joined.

It is, therefore, the most important object of this invention to provide a method of brazing a fin to a tube of a dissimilar metal wherein the fin is prevented from expanding away from the tube during heating of the components, so that a tight butt joint is maintained between the inner edge surface of the fin and the outermost surface of the tube throughout the brazing process.

Also an important object of the present invention is to provide a method of producing finned tubing wherein the latter is rotated on its longitudinal axis throughout the brazing process to thereby assure that the quantity of brazing substance attaching the fin to the tube is substantially uniform around the circumference of the tube after cooling of the components.

A further important object relates to a method of producing finned tubing wherein expansion of the fin away from the tube during brazing thereof is prevented by removing thermal energy from the fin at a sufficient rate to preclude substantial movement of the inner edge surface of the fin away from the outermost surface of the tube.

Other important objects of the present invention relate to the provision of a method of affixing a fin to a metal tube wherein resistance brazing is utilized to secure the fin to the tube and thereby permit the fin to be maintained at a sufficiently low temperature to preclude expansion of the same away from the tube and to assure that a sound joint is formed between proximal surfaces of the fin and the tube; to the provision of a method as described wherein air at substantially room temperature is pulled over the finned tubing during heating and rotation thereof in sufficient volume to prevent expansion of the fin away from the tube at any time during the heating and rotating process; to the provision of novel apparatus for carrying out the instant method and including an open bottom hood disposed over structure for supporting, rotating and heating the finned tubing to braze the fin to the outermost surface of the tube, to the end that air pulled into the hood and thereby passed over the finned tubing maintains the fin at a sufficiently low temperature to prevent expansion of the same away from the tube; to the provision of a method and apparatus which is particularly adapted for resistance brazing so that the overall cost of the operation as well as the equipment necessary to carry out the same is maintained at an absolute minimum; and to other important objects and details of construction which will become obvious as the following specification progresses.

Reference may be had to the accompanying drawing for a better understanding of the method of the instant invention, as well as the novel apparatus thereof, wherein:

FIGURE 1 is a fragmentary, side elevational view of apparatus especially adapted for carrying out the method of the present invention with certain parts thereof being broken away and in cross-section to reveal details of construction;

FIG. 2 is a fragmentary, enlarged, vertical, cross-sectional view taken substantially on the line 2—2 of FIG. 1 and looking in the direction of the arrows;

FIGS. 3 and 4 are enlarged, vertical, cross-sectional views taken substantially on lines 3—3 and 4—4 respectively of FIG. 1; and

FIG. 5 is an enlarged, fragmentary, microscopic view showing the fin connected to the tube by a metallic joint.

Briefly, the present invention contemplates initially placing a coating of a liquid on a copper tube and which includes a fluxing material adapted for removing interfering oxides and films from the components to be joined, as well as a nonferrous metal and/or a metal compound capable of effectively joining an aluminum fin to the tube. Subsequently, an elongated strip of aluminum is spirally wound around the copper tube in a manner to present a helical fin with the innermost edge surface of the fin in tight abutting relationship to the outermost surface of the tube. The finned tubing is next subjected to a suitable brazing process capable of heating the same to a temperature above the melting point of the brazing compound and below the melting temperatures of the fin and the tube to thereby form a molten bonding material which is capable of flowing into the butt joint between the fin and the tube by capillary action and presenting a sound metallic union between the fin and the tube upon cooling of the components. The finned tubing is continuously rotated on its longitudinal axis during the heating operation to prevent running of the substance when the latter is in a molten state and to cause the same to form fillets along opposed sides of the fin adjacent the edge thereof in engagement with the tube. Furthermore, air at room temperature is drawn over the finned tubing during heating and rotation thereof to maintain the fin at a sufficiently low temperature to prevent expansion of the same away from the outermost surface of the tube and which would tend to prevent firm attachment of the fin to the fluid conducting tube.

The method of producing a finned tube in accordance with the present invention includes a brazing step and therefore, as hereinafter used, the term "brazing" shall be understood to mean a metal joining process for producing fusion of certain of the components by heating the entire assembly to temperatures within the range of approximately 750° F. to 850° F. and by utilization of a nonferrous, brazing alloy or filler metal having a melting point well below that of the metals to be joined and somewhat below the temperature range set forth above.

Inasmuch as the present process cannot involve a melting of the base metal parts, as is the case in a true welding process, it is necessary that the fin be placed over the tube with the proximal surfaces thereof in close abutting relationship so that the molten brazing or filler metal may move between the proximal portions of the fin and the tube by capillary attraction. Furthermore, since it is not feasible or economically practical to provide a lap joint or other type of strong interengagement between the fin and the tube, and inasmuch as a butt joint which must be employed in the present method is not of itself sound, it is necessary to reinforce the juncture between the fin and the tube by effecting the production of fillets from the intermediate brazing alloy and lying against opposed faces of the fin adjacent the tube.

It may be assumed in further description of the present process that the metal tube is of copper having a melting point of approximately 1080° C. and that the fin is composed of aluminum having a melting point approximating 660° C. In order that the inner edge of the aluminum fin may be firmly brazed to the proximal surface of the copper tube, it is desirable to produce an alloy system and therefore, to employ an alloy which will fuse at a temperature substantially below the melting temperatures of the fin and the tube and, additionally, capable of not only adhering to the two base metals, copper and aluminum, but also of creating a metallic union by reacting with the fin to produce a permanent bond between the fin and the bonding alloy and also with the outermost surface of the tube. It is for this reason that it is advantageous to incorporate a nonferrous metal and/or a metal compound into the fluxing material, such compound being capable of forming a brazing alloy which, upon cooling, firmly joins the fin to the tube. As hereinabove set forth, the metal or metal compound which is initially placed on the tube in conjunction with the fluxing material melts at a lower temperature than the similar or dissimilar metals to be joined.

It has heretofore been demonstrated that compounds such as zinc and cadmium or other similar nonferrous metals are especially adaptable for brazing of aluminum fins to copper tubes beacuse these compounds, for the most part, have melting points slightly below the range set forth above and further, the free metal produced during the heating step forms a brazing alloy which results in an excellent metallurgical bond between the fin and the tube upon cooling of the components. It is manifest that many metals and metal compounds of the desired chemical and physical characteristics can be employed in the present process, the metal chlorides being particularly useful, for the reason that aluminum will react with the chloride radical and be driven off as a gas, leaving the metal molecule to unite with the nonferrous metal initially placed on the tube and thereby firmly unite the tube and the proximal edge of the fin.

The chemical fluxing material which may be employed to remove and inhibit interfering films and oxides on the surfaces of the tube and the fin should be chosen to assure a sound interconnection between the fin and the tube, and for the purposes of illustration only, it is pointed out that if the fin employed is made of aluminum and the tube of copper, fluxing material including the following constituents performs the required functions of removing the interfering impurities and producing a suitable brazing alloy between the fin and the tube:

	Percent by weight
Zinc Oxide	10 to 20
Zinc Chloride	50 to 70
Ammonium Chloride	2 to 5
Sodium Fluoride	1 to 3
Water	15 to 20

The above formula may be varied by the use of cadmium compounds as specified above and also by the inclusion of other substances such as surface active agents, as desired, and it is to be understood that the exact quantities of each of the components in the formula will vary with the particular circumstances encountered. It is pointed out that a stronger bond between the fin and the tube is obtained if the amount of alloying material available during the brazing step of the process is increased by incorporating suitable amounts of additional nonferrous filler metal into the flux in powdered form prior to application of the flux to the tube or by initially plating a nonferrous metal on the outermost surface of the tube before placement of the flux and the fin on the same. This additional nonferrous metal material preferably is cadmium, but may be zinc or other metals or metal compounds having similar properties.

The means for heating the finned tube such as by torch, induction, furnace brazing or internally heating the tube, may be chosen to suit the desires of the manufacturer, but the method of the instant invention is particularly adapted for permitting utilization of resistance brazing wherein resistance to the passage of low voltage and high amperage furnishes the necessary heat. It is manifest, however, that other similar methods may be employed to heat the tube and the fin thereon to fuse the nonferrous compound and thereby, join the fin to the tube upon cooling of the components, but a process employing electrothermal agitation of the molecular structure in order to produce the necessary heat is preferable.

In order to carry out the concepts of the present invention, an elongated metal tube having relatively high thermal conductivity characteristics and particularly one

formed of copper, and designated by the numeral 10, is advanced or fed along a rectilinear, horizontal path of travel and simultaneously rotated on its longitudinal axis by suitable motivating apparatus in a manner so that tube 10 is rotated and advanced through a spray chamber into which flux material containing a nonferrous metal compound is sprayed onto tube 10 by nozzle structure communicating with a suitable source of supply. It is preferable that excess flux material be removed from the outermost surface of the tube and therefore, brush structure is employed to assure that a relatively thin but uniform coating of the flux material remains on the tube as the same emerges from the spray chamber.

After the flux is brushed evenly onto tube 10 and while the latter is still moving forwardly and rotating, an elongated, flexible, aluminum strip 12 is directed to tube 10 and wound thereon in the form of a helix through utilization of suitable forming rolls and the like before passing to ironing plates for smoothing out any crinkles formed in fin 12 during winding of the same around tube 10.

The next step in affixing fin 12 to tube 10 consists of utilization of brazing apparatus forming the subject matter of the instant invention and broadly designated by the numeral 14. Apparatus 14 includes a conventional resistance brazing machine 16 comprising a pair of spaced, substantially upright supports 18 and 20 secured to a horizontal base 22, each of the supports 18 and 20 being provided with a bearing 24 on the uppermost end thereof disposed to receive horizontal shafts 26 and 28 in a manner so that the aluminum axes of shafts 26 and 28 are in exact alignment.

Clamping blocks 30 and 32 are secured to proximal ends of shafts 26 and 28 respectively and each of the blocks 30 and 32 includes a lower, semi-cubical section 34 rigidly secured to semi-cylindrical segments 36 and 38 integral with shafts 26 and 28 respectively. An upper section 40 mounted on each of the sections 34 in symmetrical, overlying relationship thereto is swingable with respect to the latter by virtue of hinge means 42 interconnecting sections 34 and 40 at one side thereof. Latch means 44 is provided on the faces of sections 34 and 40 in direct opposition to hinge 42 for releasably holding the same together. As clearly indicated in FIG. 4, socket 46 may consist of opposed, aligned, semi-cylindrical portions in each of the sections 34 and 40, but it is manifest that the only consideration is that the longitudinal axes of sockets 46 be in exact alignment with the axes of rotation of shafts 26 and 28. Means is provided for driving one of the shafts such as 26 at a constant speed and therefore, there is provided a prime mover 48 operably coupled with a gear reducer 50 disposed with the output shaft 52 thereof in horizontal alignment with the outermost end 54 of shaft 26. Belt and pulley means 56 suitably interconnects shafts 52 and 26 so that shaft 26 is driven at a constant speed upon energization of prime mover 48.

A conductor line 58, connected to bearing 24 of support 18, coupled with a suitable source of power and having a switch 60 therein conducts current to bearing 24 of support 18 while another similar conductor line 62 interconnecting bearing 24 of support 20 with a suitable source of power serves to complete the circuit in a manner to be hereinafter described. Additionally, there may be provided means in the circuit for regulating the current as well as a timer capable of controlling switch 60 so that the brazing operation will be stopped at the end of a prescribed period. Bearings 24 are insulated from supports 18 and 20 respectively by virtue of insulating material 64 and, inasmuch as the belt interconnecting shafts 26 and 52 is also formed of non-conducting material, it can be appreciated that shafts 26 and 28 and their respective bearings 24 are suitably insulated from the ground.

Support 20 preferably is constructed so that it is adjustable with respect to base 22 so that a tube 10 of any desired length may be inserted in the machine.

Hood structure generally enumerated 66 is positioned over supports 18 and 20 of machine 16 as well as tube 10 clamped within blocks 30 and 32, and preferably comprises a polygonal, box-like member including a pair of opposed, substantially trapezoidal walls 68 and 70 joined by upper, angularly disposed cross walls 72 and 74, upright end walls 76 and 78, as well as substantially rectangular, outwardly flared, lower walls 80 and 82 connected to the lowermost edges of respective walls 68 and 70. It can be seen that the lowermost portions of end walls 76 and 78 have a substantially trapezoidal segment which serves to maintain walls 80 and 82 in an outwardly flared position.

As indicated in FIG. 1 of the drawing, hood 66 is positioned over machine 16 with shafts 26 and 28 and respective bearings 24 disposed within the portion of hood 66 presented by outwardly flared walls 80 and 82 and, in order to expedite placement of tube 10 within machine 16 and subsequent removal of the same therefrom, lower walls 80 and 82 are preferably hingedly mounted on the lowermost edge of side wall 68 by suitable hinge means 83 so that lower walls 80 and 82 may be swung upwardly to clear tube 10.

A stack 84 is connected to the uppermost part of hood 66 and communicates with the same, and fan means 86 is positioned within stack 84 and is driven by suitable mechanism in a direction to pull air into hood 66 from the surrounding atmosphere through the open bottom thereof.

The amount of heat produced by a given brazing current for a unit of time is determined by the electrical resistance of tube 10 and fin 12, but in any event, the heating and subsequent cooling of the components should be rapid and uniform to prevent annealing of the copper from which tube 10 is formed. It can be appreciated that the high amperage current passed through tube 10 creates a uniform temperature because of the uniform electrical resistance of the same.

In carrying out the invention an electrical current of sufficient intensity to properly unite fin 12 to tube 10 is employed and, as an example, it is pointed out that when fin 12 is applied to a twelve foot length of tube 10, an electrical current should be supplied of sufficient intensity to provide a heating temperature of approximately 800° F. Under such conditions, the fusing operation is completed in from eighteen to twenty-five seconds, with these experimental figures being predicated upon a copper tube having a 5/8 inch outside diameter and wherein the thickness of the wall thereof is 0.025 inch.

Ten aluminum fins 12 per inch were applied to the tube and the width of the strip from which the fins 12 were made was $1\frac{3}{32}$ inch, discrepancies from theoretic values being accounted for in radiation loss and resistance within secondary leads. In the event the method is utilized in the production of tubes of higher resistance, such as steel, a higher voltage usually must be employed to attain the desired amperage. Furthermore, tubes of larger diameters and heavier walls require either additional amperage or a longer period of time. It should be kept in mind, however, that the time interval of the brazing operation should be kept at a minimum for best results.

The zinc chloride in the fluxing material initially applied to tube 10 combines with a portion of the aluminum which has been fused by the heating process and the result is formation of pure zinc metal by driving off of aluminum chloride which is formed. The same result is obtained if a cadmium compound is included in the fluxing material and a brazing alloy composed of a zinc cadmium complex is formed during the heating operation. It is believed that the zinc cadmium alloy not only combines with the fused surface of fin 12 but also strongly adheres to the outermost surface of tube 10. In this connection it is pointed out that the brazing alloy

produced in the resistance process flows into the relatively tight butt joint between fin 12 and tube 10 as shown in FIG. 5 to thereby present, upon cooling of the components, a tight metallurgical bond between fin 12 and tube 10. There is also sufficient abundance of brazing alloy present to coat the tube and to produce fillets 88 on opposite sides of fin 12, as shown in FIG. 5.

It is seen that the zinc chloride forming a part of the fluxing material is converted to zinc metal and aluminum chloride. The brazing temperature of approximately 800° F. is well above the sublimation point of the aluminum chloride and the latter escapes in the form of a gas as it is formed, leaving the pure zinc metal which forms a part of the bonding alloy. The same is equally true if other metal compounds, such as cadmium, are incorporated into the fluxing material. The ammonium chloride in the flux also decomposes and the small amount of residual deposit is composed mostly of oxides of a non-corrosive nature.

The step of rotating the tube 10 while fin 12 is being brazed thereto is extremely important for the reason that if sufficient fluxing material is applied to the tube to give a tight metallurgical bond between fin 12 and tube 10, there is a tendency for the fused brazing alloy and flux to run toward the lowermost side of tube 10 unless the same is rotated at a speed sufficient to maintain the fused alloy at the base of fin 12 proximal to tube 10. By such rotation there is assurance of a uniform joint between fin 12 and tube 10 around the entire circumference of the tube. Also, the appearance of the finished tube is improved because the brazing alloy is retained at the base of fin 12 and does not mar the surfaces thereof by running toward the outer portions of the fin 12.

It is of further importance in this respect that since a uniform distribution of the brazing alloy is maintained around the entire circumference of the tube, the amount of fluxing material initially applied to the tube may be substantially reduced below what would be necessary if the fin 12 were brazed to the tube 10 while the same was maintained in one position, for the reason than an allowance would otherwise have to be made for the fused alloy which gravitated toward the lower portion of the tube.

It can be appreciated that aluminum fin 12 and copper tube 10 have different coefficients of expansion, and that fin 12 will expand to a greater degree than tube 10. Heating tube 10 and fin 12 wound therearound to a temperature of approximately 800° F. causes fin 12 to expand to a greater degree than tube 10 and thus, causes the inner edge surface 90 of fin 12 to move away from the outer surface 92 of tube 10 and destroys the tight butt joint of fin 12 against tube 10. The result of the movement of fin 12 away from the outermost surface of tube 10 is to prevent flow of molten substance into the joint between the same by capillary attraction, as discussed above. Thus, a sound interconnection is not formed between fin 12 and tube 10 and the thermal efficiency of the fined tubing is materially decreased.

However, by pulling air at a substantially lower temperature over tube 10 and fin 12 during heating and rotation of the same, sufficient thermal energy is removed from fin 12 to prevent expansion of the same away from tube 10 while not in any manner interfering with bonding of fin 12 to tube 10. It has been determined that air at room temperature gives the best results and it can be appreciated that one skilled in this art can readily determine the speed at which fan means 86 must be rotated in order to pull sufficient volumes of air at room temperature over tube 10 and fin 12 during heating and rotation thereof to prevent movement of edge 90 of fin 12 away from outer surface 92 of tube 10.

After the finned tube has been suitably brazed, the same is removed from machine 16 and immersed in a suitable washing flux to loosen any residue adhering to the outermost surface of fin 12 or tube 10 and which might have deleterious effects upon the finished product by its corrosive action. Following such soaking step, the loosened residue is flushed away or subjected to an agitated rinse and the finned tube is thereupon ready for subsequent use in heat exchange apparatus, as may be desired.

Finned tubes made according to the invention hereinabove set forth are especially well adapted for receiving high temperature fluids without any deleterious effect upon the joint that interconnects the tube 10 and the fin 12.

The method above described is not necessarily limited to spiral fins, since plate or disc fins may be utilized if desired. Good results are also attained when following the method of the present invention in attaching aluminum fins to aluminum, carbon steel and stainless steel tubing as well as to tubes of this character which have a nonferrous metal plated over the outermost surface thereof, an example being a copper plated carbon steel tube. It is to be understood that wherever used hereinabove, aluminum and copper shall be understood to include the family of aluminum alloys and the family of copper alloys respectively.

The temperature range above set forth contemplates an approximate upper limit which will vary according to many factors, chief of which is the time during which the materials are held at brazing temperature, but must be sufficiently low to prevent annealing. The lower limit should be above soft soldering temperatures for best results.

Having thus described the invention what is claimed as new and desired to be secured by Letters Patent is:

1. The method of affixing a fin to a metal tube comprising the steps of placing a nonferrous metal compound on the tube; applying the fin to the tube with the inner edge surface thereof in close abutting relationship to the outermost surface of the tube to produce a relatively tight butt joint between the fin and the tube; heating the finned tubing to a predetermined temperature above the melting point of said compound and below the melting temperature of the fin and the tube whereby a molten bonding substance is formed capable of flowing into said butt joint between the inner edge surface of the fin and the outermost surface of the tube by capillary action; and simultaneously with said heating, continuously passing a fluid over said finned tubing at a temperature and in sufficient volume to prevent substantial expansion of the fin during the bonding operation to thereby maintain said inner edge surface of the fin in tight abutting relationship to said outermost surface of the tube whereby, upon cooling of the components, a sound interconnection of high heat conductivity is formed between the fin and the tube.

2. The method as set forth in claim 1 wherein said finned tubing is rotated on its longitudinal axis throughout heating of the same to said predetermined temperature to prevent running of the substance when the latter is in a molten state and to cause the same to form fillets along opposed sides of the fin adjacent said edge thereof.

3. The method as set forth in claim 1 wherein said fluid is air at room temperature and pulled over said finned tubing from the surrounding atmosphere in sufficient volume to preclude material expansion of the fin during heating thereof.

4. The method of affixing an aluminum fin to a copper tube comprising the steps of placing a nonferrous metal compound on the tube in conjunction with a fluxing material adapted to remove interfering films and oxides on said fin and the tube, said compound containing a metal radical selected from the group consisting of cadmium and zinc; applying the fin to the tube with the inner edge surface thereof in close abutting relationship to the outermost surface of the tube to produce a relatively tight butt joint between the fin and the tube; heating the finned

tubing to a predetermined temperature above the melting point of said compound and below the melting temperature of the fin and the tube whereby a molten bonding substance is formed capable of flowing into said butt joint between the inner edge surface of the fin and the outermost surface of the tube by capillary action; and simultaneously with said heating, continuously passing a fluid over said finned tubing at a temperature and in sufficient volume to prevent substantial expansion of the fin during the bonding operation to thereby maintain said inner edge surface of the fin in tight abutting relationship to said outermost surface of the tube whereby, upon cooling of the components, a sound interconection of high heat conductivity is formed between the fin and the tube.

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