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METHOD OF PRODUCING FINNED TUBING

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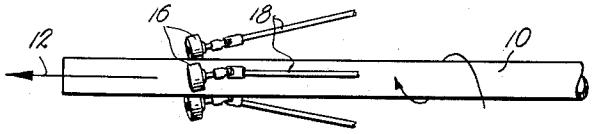


Fig. 1.

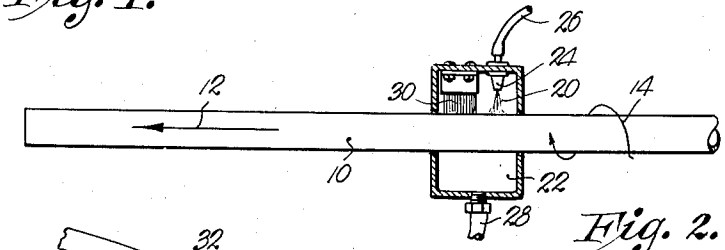


Fig. 2.

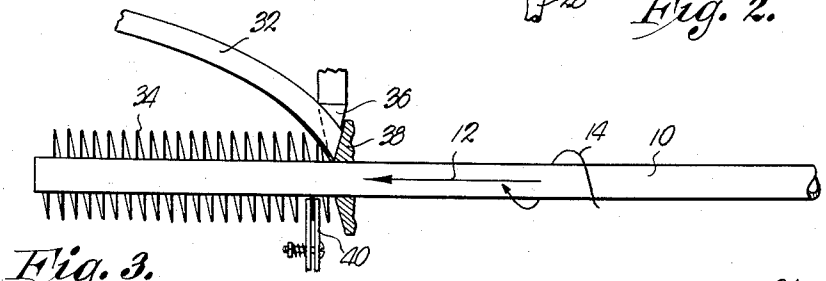


Fig. 3.

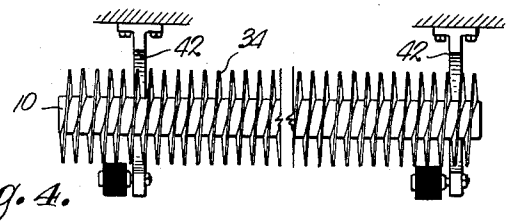


Fig. 4.

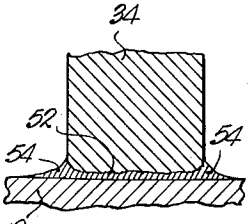


Fig. 7.

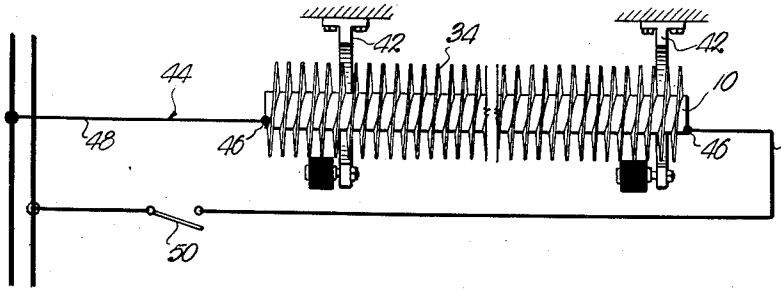


Fig. 5.

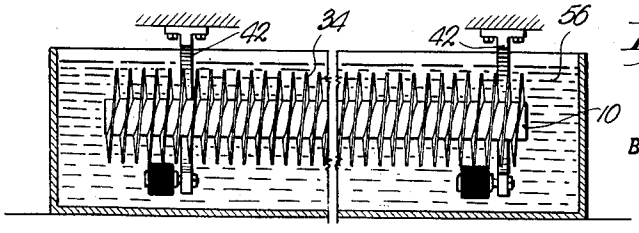


Fig. 6.

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METHOD OF PRODUCING FINNED TUBING

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Application January 18, 1954, Serial No. 404,512

4 Claims. (Cl. 29—496)

This invention relates to improvements in heat exchangers and particularly to equipment of that type which contemplates the utilization of finned tubing, the primary object being to provide a new and improved method of producing a finned tube permitting utilization of dissimilar metals of high heat conductivity and presenting an excellent juncture between the fin and the tube upon which it is mounted that will not break down under influence of fluids of relatively high temperature to be directed through the tube.

It is the most important object of the present invention to provide a method of producing finned tubing employing a metal-joining process that produces a brazing alloy between one edge of the fin and the tube upon which it is spirally wound or otherwise placed, which alloy not only adheres to the base metals which it interconnects, but combines with the proximal surfaces of the tube and fin so as to create a strong and sound union of high heat conductivity between the two parts of the finished article.

Another important object of this invention is to provide a method of securing a spiral, plate or other type of fin to a tube utilizing a metallic element such as cadmium that is initially placed on the tube and subsequently fused in the presence of a reagent so as to produce a brazing alloy or filler metal which not only flows into the butt joint between the fin and the tube by capillary action, but builds up reinforcing fillets between the fin and the tube serving the additional function of increased heat dissipation.

Reference may be had to the accompanying drawing for a full understanding of the method of the present invention, wherein:

Figure 1 is a schematic view illustrating one way in which a metallic tube to be finned may be advanced and rotated on its longitudinal axis.

Fig. 2 is a schematic view illustrating one way of applying a fluxing material to the plated tube as it is advanced and rotated.

Fig. 3 is a schematic view illustrating the way in which a metallic strip is wound upon the tube in the form of a spiral as the tube is advanced and rotated.

Fig. 4 is a schematic view illustrating a manner of supporting the tube with the fin thereon preparatory to a brazing step forming a part of the method.

Fig. 5 is a schematic view illustrating one way of heating the tube and the fin by resistance means to a brazing temperature.

Fig. 6 is a schematic view illustrating the step of washing or soaking the finished article to remove residue; and

Fig. 7 is an enlarged, fragmentary, microscopic view showing the fin connected to the tube by a metallic union.

It has long been recognized in the field of heat-exchange structures utilizing finned tubing that maximum efficiency, so far as heat conductivity is concerned, can best be attained if the fin itself is joined to the tube in such manner as to eliminate all interference with conduction of heat. Many problems have arisen however, in attempting to produce maximum efficiency primarily because of the fact that the trade has become accustomed to certain metals having known resistances to corrosion and possessing high heat transfer characteristics. The problem has been further enhanced by virtue of the necessity of using metals and processes which do not unduly increase the cost of production.

With this in mind the industry has resorted to many methods of joining the fin to the tube, but in no case have all of the problems been satisfactorily met. For example, it has long been known that many metals could be used in the production of finned tubing. However, so far as the tube itself is concerned, copper has been so universally accepted as a proper metal because of its high heat transfer characteristics and because of its resistance to corroson that it is most difficult to teach the industry that other metals would be equally satisfactory. Furthermore, competition requires that the cost of manufacture be kept at a minimum and those who have attempted to solve the problems by resorting to other metals have been faced with many other difficulties.

Accordingly, for the present at least, it is incumbent upon manufacturers of finned tubing to use copper or steel tubing and a satisfactory fin such as aluminum which is also advantageous because of its cheapness, lightweight characteristics and ability to transfer heat efficiently and quickly.

As will hereinafter appear, therefore, the method contemplated by the present invention represents a decided improvement over the many procedures heretofore suggested for joining an aluminum fin to the copper, copper alloy or steel tube.

As will hereinafter appear, the method of making a finned tube contemplated by the present invention, includes a brazing step and, therefore, as herein used, the term "brazing" shall be understood to mean a metal-joining process for producing coalescence by heating at temperatures approximately from 750° F. to 850° F. through use of a nonferrous, brazing alloy or filler metal having a melting point well below that of the metals to be joined.

By virtue of the fact, therefore, that the process cannot involve a melting of the base metal parts as is the case in a true welding process, it becomes necessary to first provide a closely fitted joint to enable movement of the molten brazing or filler metal between the proximal surfaces of the base metals by capillary attraction. Furthermore, since it is not feasible to provide a lap joint or other type of strong interengagement between the fin and the tube, and since a butt joint which must be employed in the method is not of itself sound, it is necessary to reinforce the juncture by effecting the production of fillets from the intermediate brazing alloy.

In order to present a closely fitted butt joint between the tube and the fin, it is to be preferred that tube **10** be advanced in one direction as indicated by arrow **12** in Fig. 1, and simultaneously rotated on its longitudinal axis as shown by arrow **14**. Any suitable instrumentality may be utilized for effecting such movement and, therefore, there has been shown a plurality of angled friction rollers **16** in Fig. 1 of the drawings, engaging the tube **10** and driven by an operable connection with corresponding shafts **18**.

As the tube **10** is advanced and rotated, a fluxing material **20** is applied thereto in any suitable manner such as by the means illustrated in Fig. 2 of the drawings. Tube **10** is advanced through a spraying chamber **22** into which the fluxing material **20** is sprayed by means of a nozzle **24** communicating with a source of the material **20** (not shown) by means of a conduit **26**. Excess fluxing material **20** is removed from the chamber **22** by drain conduit **28**. A relatively thin, but uniform, coating of the material **20** should be applied to the

tube **10** and, therefore, it is desirable to utilize a brush **30** disposed in wiping engagement with the tube **10** in the chamber **22** directly following the spray of flux material **20**.

After the flux **20** is brushed evenly on the tube **10**, and while the latter is still moving forwardly and rotating, an elongated, flexible, metallic strip **32** is directed to the tube **10** and wound thereon in the form of a spiral **34** through utilization of forming rolls **36** and **38**, the fin **34** passing between ironing plates **40** after being acted upon by the rolls **36** and **38**.

Succeeding steps in the making of the finned tube include the metal-joining process above referred to and it is, therefore, pointed out that a nonferrous, metallic substance is first placed on the metal tube **10**. It may be assumed in further description of the method that tube **10** is made from copper having a melting point of approximately 1083° C. and that the fin **34** is composed of aluminum having a melting point of 660° C. In order to braze the inner edge of fin **34** which is in abutting relationship to the tube **10**, to the surfaces of the latter, it is necessary to produce an alloy system and, therefore, to employ a fusible alloy of metals capable of not only adhering to the two base metals, copper and aluminum, but of creating a metallic union by partial fusing of the metal surfaces to be interconnected.

The substance that is initially placed on the tube **10** must, therefore, be of easier fusion than the two similar or dissimilar metals to be joined.

It has been found that, through use of cadmium melting at approximately 320.9° C., an excellent juncture is produced when the brazing step is carried out in accordance with the principles of the present invention.

The cadium may be applied to the tube **10** in any suitable manner, it being understood that a relatively thin film or layer of brazing metal should be employed because of its relatively low strength so as to effect capillary movement into the closely fitted butt joint and to avoid excessive costs of manufacture.

It has been found that coverage of the tube **10** with the cadmium by electrodeposition produces a satisfactorily thin, adherent coating without adversely effecting the form and details of the original surface of the copper tube **10**. While other metallic platings for the tube **10** may be employed less expensively, the cadmium may be deposited in a thin coating and, therefore, be no more expensive than other materials. The layer of cadmium deposited upon the tube **10** should not be less than 0.0001 inch, but is preferably from approximately 0.0002 inch to 0.0005 inch.

The chemical flux **20** employed first to remove interfering films and oxides should be chosen to assure a sound brazed joint and it has been found that if the same includes zinc chloride, proper reaction will take place during the heating step with the aluminum, as well as with the copper of fin **34** and tube **10** respectively, to create a suitable filler metal or alloy to carry out the objects of the present invention. If the fin **34** is made of aluminum, as herein contemplated, the fluxing material **20** should also include sodium fluoride and extensive experimentation has proved further that the inclusion of zinc oxide in the fluxing material **20**, produces an extremely sound joint of high heat conductivity.

One specific example of a suitable fluxing material **20** may be made in accordance with the following formula:

	Percent by weight
Zinc oxide	16
Zinc chloride	61½
Ammonium chloride	3
Sodium fluoride	2
Water	17½

The above formula may be varied by the inclusion of wetting agents as desired and it is manifest that the amount of zinc oxide may be reduced, but should not exceed the 16% above set forth. The amount of ammonium chloride used in the formula may vary from 2 to 4% and the sodium fluoride used may vary from 1 to 2%.

The means of heating the electrolytically plated finned tube such as by torch, induction, or furnace brazing, may be chosen to suit the desires of the manufacturer, but the method of the present invention is particularly adapted for permitting utilization of resistance brazing wherein resistance to the passage of low voltage and high currents furnishes the necessary heat.

Accordingly, the finned tube is placed on a suitable holder **42** as illustrated in Figs. 4 and 5 of the drawing and coupled with a brazing circuit broadly designated by the numeral **44**.

The necessary equipment for carrying out the heating step is not fully illustrated in the drawing but must include a high secondary current brazing transformer, electrodes **46** contacting the tube **10**, conductors **48** connecting the electrodes **46** with the transformer, means for regulating the brazing current, a contactor **50** for interrupting the power to the transformer, and a timer capable of properly controlling the action of the contactor **50**.

Manifestly, the amount of heat produced by a given brazing current for a unit of time is determined by the electrical resistance of the tube **10** and the fin **34**, but in any event, the heating and subsequent cooling step should be rapid and uniform to prevent annealing of the copper from which the tube **10** is made. The high amperage current passed through the tube **10**, creates a uniform temperature because of the uniform electrical resistance of the tube **10**.

It has been found that a secondary current of 47 volts and 2,850 amperes will properly unite fin **34** with a tube **10** that is 24 feet in length in approximately 20 seconds. When the fin is applied to a 12 foot tube, 35 volts and 2600 amperes will produce a heating temperature of approximately 800° F. and complete the fusing operations in approximately 23 seconds. These experimental figures are predicated upon a copper tube having a ⅝ inch outside diameter wherein the thickness of the wall thereof is .025 inch.

Ten aluminum fins **34** per inch were applied to the tube and the width of the strip **32** from which the fins **34** were made, was $1\frac{3}{32}$ inch. Discrepancies from theoretical values are accounted for in radiation loss and resistance within secondary leads. In the event the method is employed in connection with tubes of higher resistance such as steel, a higher voltage must be used to attain sufficient amperage. Tubes of larger diameters and heavier walls require either additional amperage or a longer period of time. It must be kept in mind however, that the time interval should be kept at a minimum for best results.

It is appreciated that the relatively high brazing current is necessary in order to produce a temperature of approximately 750 to 850° F. because of the low electrical resistance of both the copper and the aluminum and, therefore, care must be exercised in reducing the time interval to a minimum so as to prevent annealing of the copper and so as to produce a surface alloy.

The zinc chloride forming a part of the fluxing material **20** to defend the metals from oxidation, combines with the aluminum forming the fin **34** because of surface fusing of the fin **34** at the innermost edge thereof, producing a pure zinc metal. The zinc thereupon combines with the fused cadmium plated on the tube **10** to form a zinc-cadmium alloy which not only adheres to the tube **10** and to the proximal edge of the fin **34**, but combines with the aluminum and the copper. In this connection, it is to be pointed out that a surface fusion of the copper also takes place producing a filler material **52** that flows into the butt joint existing between fin **34** and tube **10** as shown in Fig. 7. There is also sufficient abundance of

cadmium to combine with the zinc and thereby produce opposed fillets **54** on opposite sides of the fin **34** as illustrated in Fig. 7.

The entire metallurgical bond **52—54** effectively transfers heat by virtue of a complete absence of any insulating oxides between the tube **10** and the fin **34** and the joint is extremely strong as compared with methods of joinder heretofore recommended in this field.

The finned tube is thereupon immersed in a washing fluid **56** as shown in Fig. 6 of the drawing to loosen any residue that might have deleterious effects upon the finished product by its corrosive action. Following the soaking step as shown in Fig. 6 of the drawing, 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.

It is seen that the zinc chloride forming a part of the fluxing material **20**, is converted to zinc metal and aluminum chloride. The brazing temperature 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 ammonium chloride in the flux also decomposes and the small amount of residual deposit is composed mostly of oxides of a noncorrosive nature.

Finned tubes made according to the invention hereinabove set forth, are especially well adapted for receiving relatively high temperature fluids and it has been found that the same may be subjected to temperatures as high as 600° F. without any deleterious effect upon the joint **52—54** that interconnects the tube **10** and the fin **34**.

Satisfactory results may also be obtained by eliminating the cadmium plating and mixing suitable powdered nonferrous metals with material **20** that will bond with both aluminum and copper at a temperature of between 750° F. and 850° F. Such powdered metals may be cadmium or zinc alloys included in the material **20** prior to applying the latter to the tube **10**. The method above described is not necessarily limited to spiral fins **34** 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 steel. It is to be understood that wherever used hereinabove, aluminum and copper shall be understood to include aluminum alloys and 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.

This is a continuation-in-part of my copending application, Serial No. 399,457, filed December 21, 1953, now abandoned.

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

1. A method of brazing an aluminum fin to a tube having an outer surface of copper comprising the steps of initially coating said outer surface of the tube with cadmium and a fluxing material, said fluxing material being adapted to remove interfering films and oxides; applying the fin to the tube with the inner edge surface thereof in close abutting relationship to said outer surface of the tube; and heating the finned tubing to a brazing temperature only, said temperature being above the melting point of the cadmium and below the melting point of the fin and the tube, said material including a metal compound which is capable of chemically reacting with the fin at said temperature to produce an intermediate brazing metal which combines with the molten cadmium to produce a bonding alloy, said bonding alloy flowing into said butt joint between the inner edge surface of the fin and said outer surface of the tube by capillary action and uniting with the fin and the tube to thereby present, upon cooling of the components, a sound interconnection of high heat conductivity between the fin and the tube.

2. A method of brazing an aluminum fin to a tube having an outer surface of copper comprising the steps of initially coating said outer surface of the tube with cadmium and a fluxing material, said fluxing material being adapted to remove interfering films and oxides; applying the fin to the tube with the inner edge surface thereof in close abutting relationship to said outer surface of the tube; and heating the finned tubing to a brazing temperature within the range of 750° F. to 850° F., said material including a metal compound which is capable of chemically reacting with the fin at said temperature to produce an intermediate brazing metal which combines with the molten cadmium to produce a bonding alloy, said bonding alloy flowing into said butt joint between the inner edge surface of the fin and said outer surface of the tube by capillary action and uniting with the fin and the tube to thereby present, upon cooling of the components, a sound interconnection of high heat conductivity between the fin and the tube.

3. A method of brazing an aluminum fin to a tube having an outer surface of copper comprising the steps of initially coating said outer surface of the tube with cadmium and a fluxing material, said fluxing material being adapted to remove interfering films and oxides; applying the fin to the tube with the inner edge surface thereof in close abutting relationship to said outer surface of the tube; and heating the finned tubing to a brazing temperature within the range of 750° F. to 850° F., said material consisting substantially of 16% of zinc oxide, 61½% of zinc chloride, 3% of ammonium chloride, 2% of sodium fluoride and 17½% of water, said zinc chloride reacting with the fin at said temperature to produce free zinc metal which combines with the molten cadmium to produce a zinc-cadmium bonding alloy, said bonding alloy flowing into said butt joint between the inner edge surface of the fin and said outer surface of the tube by capillary action to thereby present, upon cooling of the components, a sound interconnection of high heat conductivity between the fin and the tube.

4. A method as set forth in claim 3 wherein a relatively thin layer of cadmium is electrodeposited on the tube prior to application of the fluxing material.

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