Nov. 15, 1960 J. N. HINDE 2,960,114

INNERFINNED HEAT TRANSFER TUBES

Filed April 26, 1957 2 Sheets-Sheet 1

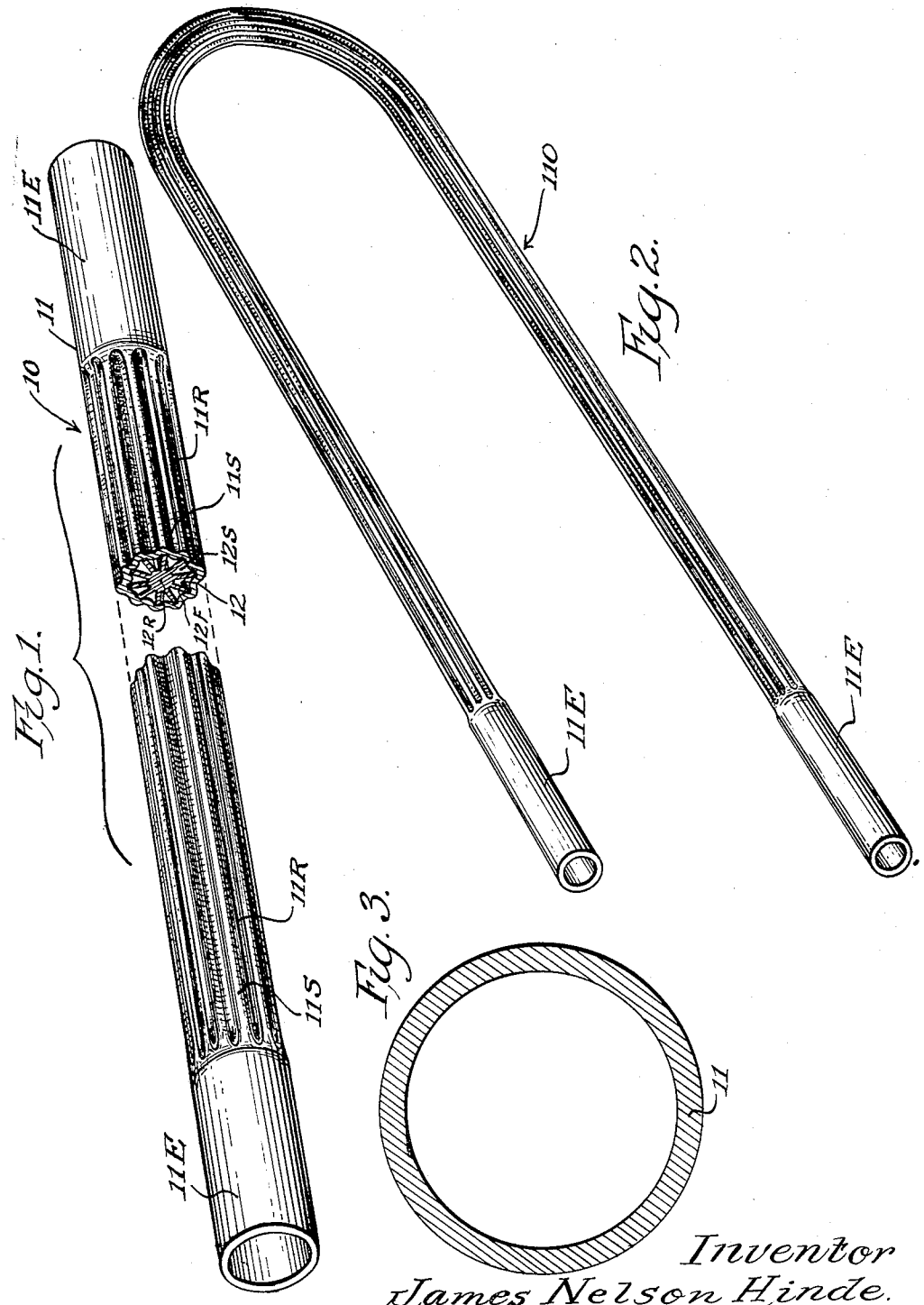


Fig. 1.

Fig. 2.

Fig. 3.

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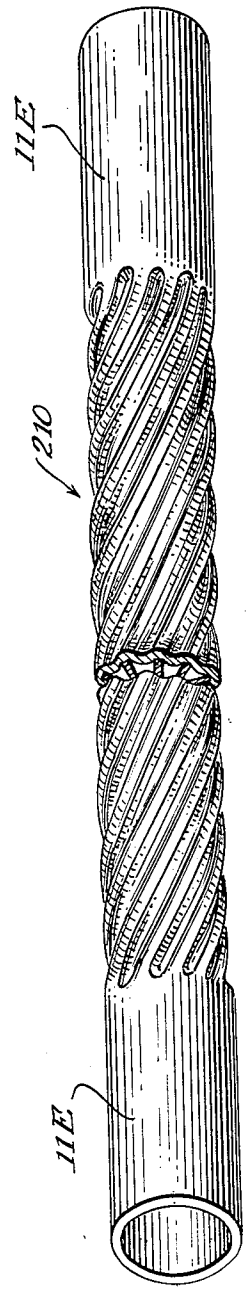


Fig. 6.

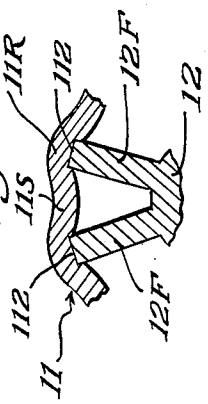


Fig. 7.

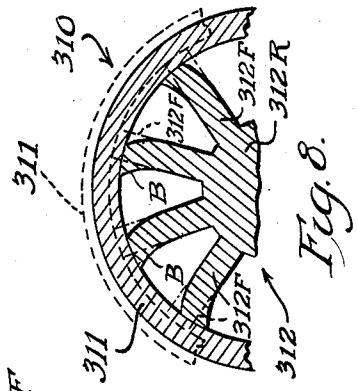


Fig. 8.

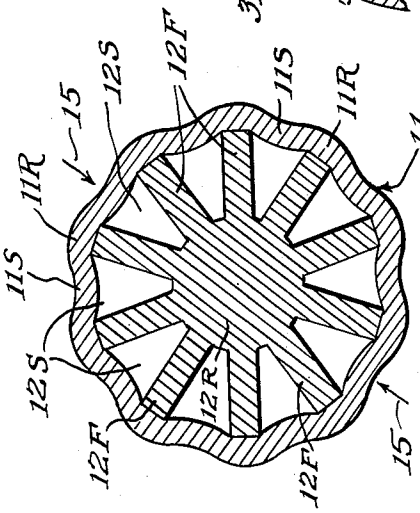


Fig. 5.

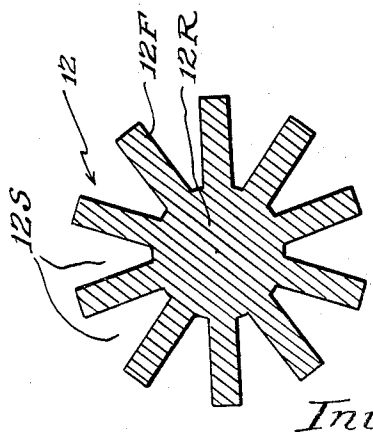


Fig. 4.

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United States Patent Office 2,960,114 Patented Nov. 15, 1960

2,960,114

INNERFINNED HEAT TRANSFER TUBES

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Filed Apr. 26, 1957, Ser. No. 655,285

11 Claims. (Cl. 138—38)

This invention relates generally to heat transfer tubes and particularly to such tubes having inner fins.

In attaining maximum efficiency in heat exchangers of the tube type, one of the most troublesome problems has been to substantially equalize the internal and external heat transfer capacity of the tubes where the fluids on the inside and outside of the tube differ widely in their heat transfer characteristics. The fluids between which heat transfer may be desired may, of course, be in the form of liquids or gases or mixtures thereof, and the heat transfer characteristic of such fluids may vary because of difference in the conductivity as well as the film coefficient of the fluid.

One common instance in which the problem of equalizing the internal and external heat transfer capacity of a tube is where there is to be a heat transfer between a liquid such as water and a gaseous or liquid refrigerant. Where the refrigerant is Freon in the usual oil-Freon and Freon gas mixture that is present in refrigerating systems, the heat transfer characteristics of the water are usually considered to be about five times better than the heat transfer characteristics of the oil-Freon and Freon gas mixture. Where heat is to be transferred from the water to the refrigerant, as in an evaporator, this requires additional heat transfer area on the inside of the heat transfer tube, and to provide such additional area it is known that various kinds of internal fins have been provided in heat transfer tubes.

The primary object of the present invention is to provide an improved innerfinned heat transfer tube wherein maximum efficiency of operation and economy of production may be readily attained.

Another and related object of the present invention is to provide an innerfinned heat transfer tube in which the innerfin structure is provided by a separately formed core member that is so related to the external tube that substantially perfect heat conductive contact is maintained between the fin structure and the tube under the various conditions encountered in fabrication and use of the structure. A related and more specific object is to provide an innerfinned heat transfer tube in which the desired heat transfer contact between the innerfin member and the tube is maintained by yielding forces that act independently in respect to each of the fins.

Another important object of the present invention is to provide an improved innerfinned heat transfer element wherein the materials to be used for the outer tube and for the finned inner core may be selected more or less freely so as to obtain the best performance in respect to heat transfer characteristics, corrosion resistance and cost.

Other and further objects of the present invention will be apparent from the following description and claims, and are illustrated in the accompanying drawings, which, by way of illustration, show preferred embodiments of the present invention and the principles thereof, and what is now considered to be the best mode in which to apply these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the invention.

In the drawings:

Fig. 1 is a perspective view of an innerfinned heat transfer tube embodying the features of the invention.

Fig. 2 is a perspective view of such an innerfinned tube bent to a U-shaped form for use in a U-tube type evaporator.

Fig. 3 is a cross-sectional view of the outer member of the innerfinned tube before assembly.

Fig. 4 is a cross-sectional view of the core or innerfin member.

Fig. 5 is a cross-sectional view of the outer tube and fin member after assembly.

Fig. 6 is a view illustrating the innerfinned tube of the present invention wherein helical inner passages are provided.

Fig. 7 is a fragmentary view similar to Fig. 5 and showing a somewhat different arrangement of the elements of the tube; and

Fig. 8 is a fragmentary view similar to Fig. 5 and showing an alternative embodiment of the invention.

For purposes of disclosure the invention is illustrated in Fig. 1 as embodied in an innerfinned heat transfer tube 10 of a form adapted for use in a straight tube heat exchanger, and this heat transfer tube 10 comprises an outer tubular member 11 and an internal member core 12 that extends through the tube so as to be spaced somewhat from each of the opposite ends of the tube 11. Thus, the tube 11 has cylindrical or straight mounting ends 11E that are adapted for mounting in conventional tube sheets in the usual manner.

In the production of the innerfinned tube of Fig. 1, the outer tube member 11 is initially obtained in the usual straight tube form, as indicated particularly in Fig. 3 of the drawings, and the core member 12 is separately formed so that it may be inserted endwise into the tube 11 to the proper position within the tube 11, and is arranged so that when it is thus inserted it has a relatively snug fit within the tube 11. The tube 11 is usually made from copper, but other materials may be employed to meet specific conditions that are to be encountered in use.

The core 12 is adapted to be formed from a suitable metal such as aluminum by economical processes such as the process of extrusion, and the core 12 is formed with a solid central body or rod 12R having integral outwardly projecting radial fins 12F that are spaced equally about the axis of the central member 12R of the core. Other metals may be employed for the core as dictated by the proposed use. In the illustrated embodiment of the invention the core 12 has ten equally spaced fins 12F so that between these fins 12F a series of ten spaces 12S are afforded. It will be understood that the number of fins on the core 12 may be varied as desired to afford the most advantageous ratio of the inside to outside heat transfer areas.

The core 12, after insertion into the tube 11, preferably has a relatively snug fit, but there is inevitably a somewhat irregular contact with the inner surfaces of the tube 11. However, if effective and efficient heat transfer or flow is to be attained between the fins 12F and the tube 11, the contact between the fins 12F and the tube 11 must be a perfect metal to metal contact. Stated another way, this contact must be so perfect and firm that there is no space between the two surfaces where there might be a layer of heat insulating gas or air. As a practical matter, this contact must be so firm and tight

that there is in effect a gas tight seal between the edges of the fins 12F and the inside surface of the tube 11.

Under the present invention this perfect metal to metal contact of the tube 11 and the fins 12F is attained in such a way that the contact will be maintained even though the tube 11 and the core 12 may be subjected to unequal amounts of radial expansion, and the way in which this contact is attained also adapts the tube for bending without destroying the metal to metal contact of these surfaces. To attain such contact the parts are so formed and assembled that there is a constant resilient force acting to maintain such contact.

Thus, as shown particularly in Figs. 1 and 5, the tube 11 is subjected to inward forces in those areas that are opposite the space 12S of the core 12 so that opposite these spaces 12S the tube 11 is bent inwardly to form inwardly concave portions 11S that are, of course, continuations of outwardly convex portions 11R that are located directly opposite and in firm and uniform contact with each of the fins 12F. The inward pressure that is necessary to produce such form in the tube 11 may be provided in different ways, but I have found that one advantageous way of accomplishing this is through the use of ball bearing dies or roller dies applied inwardly at opposite sides of the tube 11 at points such as those indicated by the arrows 15 in Fig. 5, and such dies are forced radially inwardly while being moved longitudinally of the tube. Such longitudinal reciprocation may be repeated as required. The inward deformation of the portions 11S is carried to such a point that the portions 11S and the portions 11R are under tension so that these portions act as springs tending to urge the outwardly rounded portions 11R inwardly and into firm metal to metal contact with the edges of the fins 12F. The rolling operation, of course, acts initially to establish the desired continuous metal to metal contact throughout the length of the fins 12F, and the yielding forces, that are introduced into the assembly when the portions 11S of the tube are bent inwardly, are effective to maintain such perfect metal to metal contact. With the present construction, the yielding action in maintaining perfect contact of the fins and the tube renders the selection of the materials for the tube 11 and the core 12 more or less independent of the thermal expansion characteristics of such materials, and hence these materials may be rather freely selected so that such materials will have the best and most desirable characteristics insofar as corrosion resistance, heat transfer characteristics and cost may be concerned.

The selection of the materials for the core and the tube may also provide for cathodic protection for the outer tube. Thus, where an aluminum core is used with a copper outer tube, the combination of these two metal affords cathodic protection for the tube, and while the aluminum spline will be gradually eaten away during use, this will not materially affect the characteristics of the heat exchange element, and the outer tube will be protected so that it will give years of service without leakage. This is particularly advantageous where the heat exchange element is used for oils with sulphur and small amounts of water are present therein. In other instances, to meet conditions presented in the proposed use of the heat exchange element, cathodic protection may be afforded by using magnesium or magnesium alloys in making the core of the element, and it will be apparent that other combinations of metals for the core and the tube may be employed to meet special conditions of use that are contemplated.

In Fig. 5 of the drawings it will be noted that the outer ends of the fins 12F have not penetrated the inner surface of the tube 11 to any appreciable extent, but in some instances, the relative hardness of the metal of the core and the tube may be such that the edges of the fins 12F may penetrate the inner surface of the tube 11 to some extent as indicated at 112 in Fig. 7 of the drawings. The embodiment of the invention illustrated in Fig. 7 is particularly advantageous where the heat exchange element is to be bent to provide a U-tube 11 of the general character shown in Fig. 2, and it is found that where the fins 12F have penetrated the inner surface of the tube 11, as shown in Fig. 7, the tube may be bent to provide a smaller diameter of the U-bend in a U-tube than would be possible with the structure shown in Fig. 5.

The embodiment of the invention shown in Fig. 7 also embodies an advantageous response to differences in internal and external pressure applied to the heat exchange tube. Thus, where a greater pressure is effective on the outside of the tube 11, the concavity of the portions 11S will be increased so that added pressure will be applied by the tube 11 to the edges of the fins 12F. Under the opposite conditions, where greater pressure is exerted on the inside of the tube 11, such pressure tends to flatten or reduce the concavity of the portion 11S, thus to exert lateral pressure against the sides of the fins 11F where these sides have penetrated the tube 11.

As hereinbefore pointed out, the yielding forces that act between the tube 11 and the core 12 are such that the desired metal to metal contact is maintained between the fins 12F and the tube 11 even though there may be considerable movement of the parts with respect to each other. This is, of course, important where the temperature differential and expansion coefficient of the elements cause unequal radial expansion of the core and the tube, but it is also important where the tube is to be formed for use in a U-tube type evaporator. Thus, as shown in Fig. 2, a completed innerfinned heat exchange tube 10 may be bent to a U-form to provide a U-tube 110, and in the required bending operations, the desired metal to metal contact between the fins 12F and the tube 11 is maintained.

In many instances it may be desirable to employ a spiral path for the refrigerant that is to pass through the heat exchange tube, and the present invention lends itself to the formation of a twisted innerfinned tube 210, as shown in Fig. 6 of the drawings, whereby such spiral flow of the refrigerant may be attained. In producing the twisted innerfinned tube 210 of Fig. 6, the core 12 is formed so that the fins 12F thereof have a spiral form of desired lead, and this may readily be done by application of twisting forces to the core 12. The twisted core is then inserted endwise into a plain tube such as that shown in cross-section in Fig. 3, and the inward deforming forces are then applied to the tube 11 in the manner hereinbefore described to produce the twisted innerfinned tube 210.

In the use of a spiral or twisted heat exchange tube such as the tube 210, the mixture of liquid and gaseous refrigerant flows along the several spiral paths defined between the fins 12F, and since the rate of refrigerant flow is relatively high, the liquid refrigerant is separated by centrifugal force so as to flow along the inner surfaces of the tube 11, while the gaseous component of the refrigerant mixture flows along the inner portions of these spaces.

In the forms of the invention hereinbefore described the resilient forces that are applied to maintain the perfect contact between the outer tube and the fins have been obtained by the action of stressed resilient portions of the outer tube, but such resilient forces may be provided through special formation of the finned core member. Thus in Fig. 8 of the drawings, an alternative embodiment of the invention has been illustrated in which an innerfinned heat transfer element 310 has an outer tube 311 within which a core 312 is positioned. The core 312 has a cylindrical central member 312R from which radially extended fins 312F project so as to extend longitudinally throughout the length of the core, and since the core 312 in this embodiment is to exert the desired resilient forces between the core and the

tube, the core is made from a metal that has resilient properties. Certain of the resilient aluminum alloys may be used, or other metals may be selected where specifically different corrosion resistance characteristics are desired. Initially these fins **312F** have the form indicated in dotted outline in Fig. 8, and the tube **311** has a somewhat greater diameter as indicated in dotted outline. The core **312** is inserted into the tube **311**, and the tube **311** is then drawn or otherwise pressed inwardly so as to reduce its diameter, and the forces are so applied to the tube **311** that the outer radial portions of the fins **312F** are bent laterally from their initial form as indicated at B of Fig. 8. This deforming operation is carried to such an extent that the fins **312F** will exert a resilient pressure outwardly against the inner surface of the tube **311**, and thus, the metal to metal contact that has been established by the drawing operation between the tube **311** and the edges of the fins **312F** will thereafter be maintained by resilient or yielding forces that are applied by the torsionally bent fins B.

The innerfinned tube **310** that is thus provided may be embodied as a twist type tube by twisting the core **312** prior to insertion in the outer tube **311**; and where the bend required in making a U-tube is not unduly sharp, such bend may be made without destroying the heat conductive relation between the core and the tube. For smaller diameter bends in U-tubes the form of the invention shown in Fig. 7 attains best results without losing fin-tube contact.

From the foregoing description it will be apparent that the present invention provides an improved innerfinned heat transfer tube whereby maximum efficiency of operation may be attained and which is of such a character that it may be economically produced so as to attain such efficiency. It will also be evident that the heat flow path between the core of the tube is maintained under the present invention by yielding forces provided by one of the elements of the heat transfer unit, and hence unequal expansion or contraction of the two elements of the unit does not interfere with maintenance of such heat conduction paths between the inner fins and the outer tube. The relatively free selection of the core and tube materials that is rendered possible under the present invention further enables cathodic protection to be provided as required by the contemplated use of the heat exchange elements.

Thus, while I have illustrated and described preferred embodiments of my invention it is to be understood that changes and variations may be made by those skilled in the art without departing from the spirit and scope of the appending claims.

I claim:

1. In a heat exchange tube of the innerfin type, an elongated core having a central member and a plurality of integral radially projecting fins extending longitudinally thereof, and an elongated tube surrounding said core and depressed inwardly between said fins to form external flutes throughout the length of said fins under resilient tension acting to hold said core in position in said tube and yieldingly hold said tube in heat conducting relation to said fins.

2. In a heat exchange element, an elongated core having a central member with spaced radially projecting fins extended longitudinally thereof, and a cylindrical tube surrounding said core and having the ends thereof extended beyond the respective ends of said core with said tube being depressed inwardly into said spaces to form external flutes under resilient tension acting to maintain the opposed surfaces of said tube and said fins in firm heat conducting relation, said tube beyond the ends of said core being of cylindrical form for mounting in a tube sheet or the like.

3. In a heat exchange element, an elongated core having a central member with spaced radially projecting fins extended longitudinally thereof to define longitudinally extending spaces between the fins, and a cylindrical tube surrounding said core and having the portions of said tube between the edges of adjacent fins depressed inwardly into said spaces to place said portions under spring tension to maintain the opposed surfaces of said tube and said fins in firm heat conducting relation.

4. In a heat exchange element, a cylindrical tube having a longitudinally fluted portion and an elongated core having a central member with spaced radially projecting fins extended longitudinally thereof and disposed within said tube with said ribs interengaged with said fluted portion to place said fluted portion under tension to thereby maintain the opposed surfaces of said tube and said fins in firm heat conducting relation.

5. An innerfin heat exchange element comprising an extruded core having a central rod with radially projecting fins extended longitudinally thereof in circumferentially spaced relation, a cylindrical tube surrounding said core with the ends of the fins engaging the inner surface of the tube, the external surface of the tube being bent inwardly to an arcuate form between adjacent fins and throughout the length of said fins to establish and yieldingly maintain a heat conducting metal to metal contact between the tube and the edges of the fins.

6. An innerfin heat exchange element comprising an extruded core of a relatively hard metal having a central rod with radially projecting fins extended longitudinally thereof in circumferentially spaced relation, a cylindrical tube of a relatively soft metal surrounding said core with the ends of the fins engaging the inner surface of the tube, the external surface of the tube being bent inwardly to an arcuate form between adjacent fins throughout the length of said fins and with sufficient pressure to cause edge portions of said fins to slightly penetrate the inner surface of the tube and establish and yieldingly maintain a heat conducting metal to metal contact between the tube and the edges of the fins.

7. An innerfin heat exchange element comprising a core having a central rod with radially projecting fins extended longitudinally thereof in circumferentially spaced relation and twisted to impart a helical form to the fins of the core, an elongated cylindrical tube surrounding said core with the ends of the fins engaging the inner surfaces of the tube, said tube being bent inwardly to an arcuate or fluted form between adjacent fins to establish and yieldingly maintain a heat conducting metal to metal contact between the tube and the edges of the fins.

8. The method of making innerfin heat exchange elements for evaporators and the like which consists in forming an elongated core having a central rod and radially projecting fins extend longitudinally and in angularly spaced relation, inserting the core into a tube to locate the core with its ends spaced inwardly from the respective ends of the tube, and deforming that portion of the tube in which the core is located to bend the portions of the tube inwardly between adjacent pairs of fins so that such portions are under tension acting to maintain uniform metal to metal contact between the edges of the respective fins and said tube.

9. The method of making an innerfin heat exchange element which consists in forming a core having a central rod with radially projecting integral fins extended longitudinally thereof in circumferentially spaced relation, inserting the core into an elongated cylindrical tube with the ends of the fins engaging the inner surface of the tube, and bending the tube inwardly to an arcuate form between the edges of adjacent fins to establish heat conducting metal to metal contact between the tube and the edges of the fins.

10. The method of making an innerfin heat exchange element which consists in forming a core having a central rod with radially projecting fins extended longitudinally thereof in circumferentially spaced relation, twisting said core to impart a helical form to the fins of the

core, inserting the core into an elongated cylindrical tube with the edges of the fins engaging the inner surfaces of the tube, and bending the tube inwardly to an arcuate form between the edges of adjacent fins to establish heat conducting metal to metal contact between the tube and the edges of the fins.

11. The method of making innerfin heat exchange elements for evaporators and the like which consists in forming an elongated core having a central rod and radially projecting fins extend longitudinally and in angularly spaced relation, inserting the core into a tube to locate the core with its ends spaced inwardly from the respective ends of the tube, and deforming that portion of the tube in which the core is located to bend the portions

of the tube inwardly between adjacent pairs of fins so that such portions are under tension acting to maintain uniform metal to metal contact between the edges of the respective fins and said tube.

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