HEAT EXCHANGERS TUBING MANUFACTURE

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Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

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Our invention relates to heat exchanger tubing manufacture, and more specifically to methods for forming internal and external sheathed heat exchanger tubing, both finned and unfinned. Even more specifically, our invention relates to methods for forming sheathed heat exchanger tubing in which the tubing is formed with a sheathing covering substantially the entire inner surface or substantially the entire peripheral surface of the tubing, or both, but in each case is united with the tubing in a physical metal-to-metal interlock or interengagement. Further, this application is a division of our co-pending application Serial No. 862,997, filed December 30, 1959, now abandoned.

In certain uses of heat exchanger tubing and particularly heat exchanger tubing having fins formed on the outer surface thereof for use in various forms of heat exchangers of various constructions and for various uses, it has been necessary to use steel tubing in order to withstand the high pressures of the fluids flowing through the tubing. This is becoming more and more prevalent in modern heat exchanger design, in view of the higher and higher pressures encountered and the necessity of using the steel tubes in order to gain the strength necessary to withstand these high pressures.

Furthermore, in certain cases where it is absolutely necessary to use the steel tubing in order to withstand the high pressures, the fluids within or surrounding the tubes are highly corrosive to the steel, thereby swiftly corroding and deteriorating the steel tubing and requiring frequent replacement resulting in high maintenance cost and frequent periods during which the heat exchanger equipment cannot be used. Thus, it becomes vital in such constructions to provide some form of protection for the steel tubing, but yet this protection must be such as to provide efficient heat flow in order that the tubing may accomplish its heat exchanging function.

One such form of heat exchanger tubing construction having protection from surrounding fluids has been provided which is relatively satisfactory under certain restricted conditions. In this construction, the steel tubing is outwardly sheathed with a material not subject to the rapid corrosion, such as aluminum or copper, to thereby protect the steel tubing from the corrosive fluids.

This prior construction of outwardly sheathed tubing has been formed by telescoping the steel tubing with aluminum or copper tubing and, in some manner, providing a tight "interference" fit between the steel and the aluminum or copper tubing. One method by which this might be done is to extrude aluminum or copper tubing directly over the steel tubing and thereby provide the tight fit required therebetween for proper heat flow between the two materials.

The principal difficulty with this prior form of outwardly sheathed tubing is that the maximum temperature to which this construction will provide efficient heat transfer is greatly limited in view of the variations between the coefficients of thermal expansion of the steel and the aluminum or copper. In view of these differences of coefficients of thermal expansion between the two materials used, the tight fit between the inner steel tubing and the outer aluminum or copper sheathing will only be maintained sufficient to supply proper heat flow up to a certain maximum temperature after which the aluminum or copper, expanding at a greater rate, will pull away from the steel inner tubing, resulting in decreasingly poorer heat transfer as the temperatures increase.

It is, therefore, desirable to provide methods for making an outwardly sheathed tubing of the foregoing general construction in which an interlock is formed between the inner steel tubing and outer aluminum or copper sheathing which will prevent separation of the sheathing from the steel tubing despite the temperatures to which the construction is subjected.

One form of prior construction which eliminates certain of the difficulties of the foregoing prior sheathed tubing construction is disclosed in the co-pending U.S. application entitled "Finned Tubing Manufacture," Serial No. 796,794, filed March 3, 1959, of one of the inventors of which is a co-inventor of the present application. In the construction of this co-pending application, generally L-shaped cross-section or "footed" fins, formed of preferably aluminum or copper, are wound on the steel tubing, with the foot portions of the fins abutting to provide an unbroken sheathing covering the steel tubing. The foot portions of these fins are then formed into grooves provided in the steel tubing outer surface to thereby interlock the fins with the tubing in a metal-to-metal interengagement which will resist separation between the fins and tubing at the higher temperatures.

Although this prior footed fin construction provides satisfactory results and is a marked improvement over the prior constructions, it necessitates the maintaining of proper abutment of the foot portions on the fins with adjacent fins in order to provide the fluid-tight sheathing for the steel tubing and supply the desired corrosion protection. Thus, relatively close tolerances must be maintained in the fin winding operation, and close inspection standards must be observed to be sure that the construction is properly formed.

Another prior form of heat exchanger tubing, in this case providing protection for the basic steel tubing against internal corrosive liquids, has been formed by telescoping a basic steel tube over a sheathing tube formed from the aluminum or copper and providing the tight "interference" fit therebetween. Here again it is merely the tight abutment of the outer surface of the sheathing tube and the inner surface of the basic steel tube which provides the heat flow path through the final internally sheathed tubing.

Such construction is also relatively satisfactory under certain restricted conditions, that is, if the temperature differentials encountered are within restricted limits. If the outer basic tube is formed of steel and the inner sheathing tube is formed of aluminum or copper, in this particular internally sheathed tubing construction, the first time that this tubing construction is heated to relatively high temperatures, the inner sheathing tube will tend to force more tightly against the outer basic tube again, in view of the variations between the coefficients of thermal expansion of the steel and the aluminum or copper.

After this first heating, however, if the internally sheathed tubing is then used at a lower temperature, the inner sheathing tube of aluminum or copper, after having once expanded, will contract inwardly away from the basic steel tube, thereby interrupting the heat flow path through this combined tubing construction. This same condition is present where the internally sheathed tubing is used in a heat exchanger which operates at temperatures lower than that at which the internally sheathed

Our invention is, therefore, directed to methods for forming internally and externally sheathed heat exchanger tubing in which the outer sheathing is a material such as copper or aluminum which will provide proper heat transfer at the higher temperatures encountered in modern heat exchanger design, and at the same time maintain sufficient abutment between the inner steel tubing and the outer sheathing to prevent separation of the sheathing from the steel tubing despite the temperatures to which the construction is subjected.
tubing construction is fabricated, such as, for instance, in refrigeration plants.

Thus, the same basic problem is involved in sheathed tubing construction whether the construction is internally sheathed, externally sheathed, or sheathed both internally and externally. This problem is, of course, one of maintaining the basic tube and sheathing tube, each formed of materials having different coefficients of thermal expansion, in tight abutment under varying temperature conditions in order to maintain a proper heat flow path therethrough.

It is, therefore, a general object of the present invention to provide methods for forming a sheathed tubing construction in which a substantially continuous sheathing is formed internally or externally on the tubing to be protected and is tightly secured to the outer or inner tubing in a manner such that proper heat transfer through the tubing and sheathing will be maintained at all times and under greatly varying temperature conditions.

It is a primary object of the present invention to provide methods for forming a sheathed tubing construction in which a substantially continuous tubular sheathing and outer or inner tubing to maintain the sheathing and tubing in close and proper heat transfer relationship.

It is a further object of the present invention to provide methods for forming a sheathed tubing construction in which the final tubing may be formed finned or unfinned, as desired, and without altering the basic construction, but rather merely by including the additional step of adding the fins to the basic construction whether the tubing exposed is the sheathing or the tubing itself.

It is still a further object of the present invention to provide methods for forming sheathed tubing in which many of the operations of the method may be carried out at the tube mill where the tube is originally formed, and it may be only necessary to add the fins to the tubing, if desired.

It is also an object of the present invention to provide methods for forming a sheathed tubing construction in which the metal-to-metal interengagement or interlock between the sheathing and tubing may be increased or decreased in strength as is required for the particular final temperature conditions under which the sheathed tubing will be used.

Finally, it is an object of the present invention to provide methods for forming sheathed tubing which satisfies all of the above objects yet comprises a minimum of procedure steps and requires a minimum of inspection procedure for maintaining a quality product.

These and other objects are accomplished by the parts, constructions, arrangements, combinations, subcombinations, methods and procedural steps comprising the present invention, the nature of which is set forth in the following general statement, preferred embodiments of which—illustrative of the best mode in which applicants have contemplated applying the principles—are set forth in the following description and illustrated in the accompanying drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming a part hereof.

In general terms, the sheathed tubing construction formed by the methods of the present invention may be stated as including a basic tubing, preferably formed of steel, encased in an outer tubing or telescoped over an inner sheathing tubing, with this sheathing preferably being formed of a relatively non-corrosive material, such as aluminum or copper, and which sheathing material is preferably softer than the basic tubing material. Furthermore, the construction includes a physical metal-to-metal interengagement or interlock between the basic tubing and sheathing tubing, preferably comprised of dovetail cross-section grooves formed on the surface of the basic tubing adjacent the sheathing tubing with the sheathing tubing formed into the dove-tail grooves to provide the metal-to-metal interengagement or interlock.

Finally, the construction may include fins secured to the outer tubing, whether the basic or sheathing tubing, with these fins being preferably secured in grooves formed in the tubing for such fins. The methods of the present invention may be stated generally as including the steps of first forming preferably dove-tail, cross-section grooves in the inner or outer surface of the basic tubing, and these grooves except as limited by internal accessibility may be formed as axially spaced circumferentially extending grooves, circumferentially spaced axially extending grooves, helically extending grooves, or variations and combinations of these forms of grooves as the particular conditions demand. The method further may include the steps of then telescoping the basic tubing with a second sheathing tubing and forming the second sheathing tubing into the grooves formed on the adjoining surface of the basic tubing to provide a metal-to-metal interengagement or interlock between the basic and sheathing telescoped tubing. Finally, the method may include the step of applying fins to the tubing in the outer position preferably in a conventional manner.

By way of example, embodiments of the heat exchanger tubing construction and the steps of certain methods of the present invention are illustrated in the accompanying drawings forming a part hereof, wherein like numerals indicate similar parts throughout the several views, and in which:

FIG. 1 is a fragmentary radial sectional view of the basic tube after originally forming circumferentially spaced, axial or longitudinal, generally U-shaped grooves in the outer surface thereof; FIG. 2, a view similar to FIG. 1 with the grooves of FIG. 1 formed into dove-tail cross-section; FIG. 3, a view similar to FIG. 2, with an outer sheathing tube telescoped over the basic tube and prior to portions of this outer sheathing being formed into the grooves of FIG. 2; FIG. 4, a view similar to FIG. 3, but with the outer sheathing formed into the dove-tail grooves in finished form providing externally sheathed tubing according to the present invention; FIG. 5, a fragmentary axial sectional view of the externally sheathed tubing of FIG. 4, with helical fins secured to the outer sheathing tube; FIG. 6, a fragmentary radial sectional view, showing the forming of the U-shaped grooves of FIG. 1; FIG. 7, a fragmentary radial sectional view, part in elevation, showing the forming of the dove-tail grooves of FIG. 2; FIG. 8, a fragmentary radial sectional view, part in elevation, showing the forming of the outer sheathing tube into the dove-tail grooves for forming the tubing of FIG. 3 into the tubing of FIG. 4; FIG. 9, a fragmentary side elevation of the basic tube with one form of circumferentially spaced, circumferentially staggered, and axially extending grooves formed in the outer surface thereof; FIG. 10, a view similar to FIG. 9, but with helical grooves formed in the outer surface of the basic tube; FIG. 11, a view similar to FIG. 9, but with the combination of circumferentially spaced, axially extending and circumferentially extending, axially spaced grooves formed in the outer surface of the basic tube; FIG. 12, a fragmentary sectional view, part in elevation and with parts broken away, showing a construction of the sheathed tubing of the present invention mounted in a heat exchanger tube sheet; FIG. 13, a fragmentary sectional view, part in elevation and with parts broken away, looking in the direction of the arrows 13—13 in FIG. 12; FIG. 14, a fragmentary radial sectional view of the basic tube after originally forming circumferentially
spaced, axial or longitudinal, generally dove-tail cross-
section grooves in the inner surface thereof;

FIG. 15, a view similar to FIG. 14, with an inner sheathing tube telescoped within the basic tube and prior to portions of this inner sheathing being formed into the grooves of FIG. 14;

FIG. 16, a view similar to FIG. 15, but with the inner sheathing formed into the dove tail grooves in finished form, providing internally sheathed tubing according to the present invention; and

FIG. 17, a fragmentary axial sectional view of the internally sheathed tubing of FIG. 16 with helical fins secured to the outer basic tube.

One embodiment of the sheathed tubing construction formed by the methods of the present invention is shown at various stages of manufacture in FIGS. 1, 2 and 3, with the finished construction being shown in FIGS. 4 or 5, dependent on whether or not it is desired to provide merely sheathed tubing according to the principles of the present invention or sheathed finned tubing. Further, in this case the tubing is externally sheathed tubing.

Referring to the sheathed tubing construction of FIG. 4, an inner basic tube 15, preferably of steel for gaining the high strength required, is telescoped within the relatively thin outer sheathing tube 16, with the sheathing tube 16 being formed from any non-corrosive material, such as aluminum or copper. Further, preferably an “interference” fit is provided between the basic tube 15 and sheathing tube 16 by any usual means such as originally extruding the sheathing tube 16 over the inner basic tube 15 or by telescoping the two tubes, then removing the sheathing tube 16 tightly against the inner basic tube 15. If the construction of sheathed tubing thus far described were used in heat exchanger apparatus, although the “interference” fit between the sheathing tube 16 and inner basic tube 15 would maintain these tubes tightly together under relatively low-temperature conditions, in high-temperature work, due to the variations between the coefficients of thermal expansion of the materials forming these tubes, these tubes will separate and thereby interrupt the path of heat flow between the tubes resulting in poor performance and undesirable heat transfer characteristics for the combined structure. Thus, it is necessary to provide some permanent bond, resistant to the forces created by these variations between the coefficients of thermal expansion of the various materials, and thereby also provide proper heat flow under high-temperature conditions.

And sheathing tube 16 axial-laxially or longitudinally is, therefore, provided by the preferably dove-tail grooves 17 formed in the outer surface of the basic tube 15 and into which have been formed the sheathing metal portions 18, which portions 18 are formed integral with the remainder of the sheathing tube 16. In this first embodiment construction, the grooves 17 are circumferentially spaced and extend generally axially or longitudinally of the tubes 15 and 16, and the sheathing metal portions 18 are properly formed into the dove-tail contour of these grooves in order to provide the secure metal-to-metal interlock or interengagement between the inner basic tube 15 and sheathing tube 16 which will maintain these tubes together despite the variations of the coefficients of thermal expansion of the materials forming the tubes.

A further important factor is that the generally-radially extending sides 19 of the sheathing metal portions 18 are tightly interlocked generally radially extending side walls 20 of the grooves 17 in order to insulate a proper path of heat flow between the inner basic tube 15 and sheathing tube 16, even though portions of the sheathing tube might separate from the inner basic tube at locations spaced between these grooves 17 under the high-temperature conditions.

Finally, a further preferable limitation is that the completely extending lengths of the sides 19 of the sheathing metal portions 18 in abutting contact with the side walls 20 of groove 17 are at least as great as the generally circumferential width of the sheathing metal portions 18 at the outer surface of the inner basic tube 15, in order to provide at least an equal path of heat flow between the sheathing metal portions 18 and inner basic tube 15 as is provided between the main portions of the sheathing tube 16 and the sheathing metal portions 18. Where fins are desired on this first embodiment sheathed tubing construction, such fins may be mounted on the outer surface of the sheathing tube 16 in any conventional manner, preferably in grooves formed in this outer surface, and these fins also would preferably be of the same material as the sheathing tube 16, such as the aluminum or copper, to thereby have the same coefficient of thermal expansion as the material of the sheathing tube. For instance, axially or longitudinally extending fins may be added to the sheathing tube 16 according to the R. C. Jones et al. patents Nos. 1,921,928 and 1,921,975, or helical fins may be added to the sheathing tube 16 according to the E. A. Dewald Patent No. 2,004,588.

As shown in FIG. 5, helical fins 21 have been hounded on the sheathing tube outer surface 22 by forming the fin grooves 23 and securing fins 21 therein in the conventional manner. Thus, a finned sheathed tubing construction is provided from the sheathing tube construction of FIG. 4 in a similar and conventional manner. It is preferred, where fins such as the fins 21 have been added to the sheathed tubing construction, that the combined generally radially extending lengths of the sides 19 of the sheathing metal portions 18 in abutting contact with the side walls 20 of groove 17, as shown in FIG. 4, are at least as great as the generally axial or longitudinal widths or thicknesses of the fins 21 at the outer surface 22 of the sheathing tube 16. Furthermore, it is preferable to have the total lengths of the inner basic tube grooves 17 at least as great as the total lengths of the fins 21 in order to have the total lengths of insulated contact under any temperature conditions between the inner basic tube 15 and sheathing tube 16. Particularly, again insuring a proper path of heat flow between the fins 21 and the inner tube 15.

Various other forms of the sheathed tubing construction of the present invention may be made as desired and dependent on the particular final use of the tubing. For instance, as before described, the helical fins 21, as shown in FIG. 5, may be replaced by other forms of fins, for instance, axially or longitudinally extending fins, or fins merely tension wrapped around the outer surface 22 of the sheathing tube 16, all of which substitutions are common in the heat exchanger tubing art.

Furthermore, rather than the straight continuously axially or longitudinally extending grooves 17 on the outer surface of the inner basic tube 15, various other patterns of such grooving, to form the interengaging or metal-to-metal interlock between the basic tube 15 and sheathing tube 16, may be used, again dependent on the particular use of the fins described herein. Of course, sheathing tubing or finned sheathed tubing and for convenience in construction and fabrication as desired. Various other forms of the grooves 17 on the basic tube 15 are illustrated for specific examples in FIGS. 9, 10, and 11.

In FIG. 9, circumferentially spaced, staggered, axially or longitudinally extending grooves 24 are shown formed in the outer surface of the basic tube 15. In FIG. 10, helically extending grooves 25 are shown formed in the
8, 100,980 7 outer surface of the basic tube 15. Finally, in FIG. 11, both circumferentially spaced, straight, axially or longitudinally extending grooves 26 are shown in combination with axially or longitudinally spaced, circumferentially extending grooves 27.

Also, these combinations of circumferentially spaced axially or longitudinally extending grooves which are continuous or staggered, helical grooves, and axially or longitudinally spaced, circumferentially extending grooves may be made as circumstances dictate. In every case, however, it is preferred to form the grooves generally dove-tail in cross section, as previously described, with reference to the sheathed tubing construction of FIG. 4.

In FIGS. 12 and 13, a still further modification of the sheathed tubing construction is shown in combination with a heat exchanger tube sheet. In this case, the inner basic tube 15 is telescoped with the sheathing tube 16 and circumferentially spaced, straight, axially or longitudinally extending grooves 28, preferably having dove-tail cross sections, are formed in the outer surface of the inner basic tube, with the sheathing tube being embedded therein to form the interengagement or metal-to-metal interlock between the inner basic tube 15 and sheathing tube 16.

Furthermore, the grooves 28 terminate short of the tube sheet 29, with the portion of the inner basic tube 15 extending within the tube sheet being free of such grooves, although still having the sheathing tube 16 encasing and protecting and continuing into the tube sheet 29. The purpose of discontinuing the grooves 28 short of the tube sheet 29 is to eliminate paths for leakage of fluid through the inner basic tube 15 and sheathing tube 16 through these grooves 28, and it is impossible for the fluid to work into these grooves 28 which could cause separation between the inner basic tube and sheathing tube.

Another embodiment of the sheathed tubing construction of the present invention is shown at various stages of manufacture in FIGS. 14 and 15, with the finished construction being shown in FIGS. 16 and 17, dependent on whether or not it is desired to provide sheathed tubing or sheathed finned tubing. This particular embodiment illustrates an internally sheathed tubing construction according to the principles of the present invention.

Referring to the sheathed tubing construction of FIG. 16, an outer basic tube 115, preferably of steel for strength, as previously discussed, is telescoped over the relatively thin inner sheathing tube 116, with the sheathing tube being preferably formed of the softer relatively non-corrosive material, such as aluminum or copper.

A preferably tight "interference" fit is provided between the outer basic tube 115 and the inner sheathing tube 116, and this tight fit may be provided in numerous conventional ways, such as, for instance, by expanding the inner sheathing tube outwardly against the outer basic tube. Despite this tight fit, however, if the internally sheathed tubing construction thus far described were used in a heat exchanger construction under varying temperature conditions, the differences of coefficients of thermal expansion between the steel and aluminum or copper would cause the inner sheathing tube to pull away from the outer basic tube, thereby interrupting the proper heat flow path therebetween.

For this reason, an interengagement or metal-to-metal interlock is provided preferably by the dovetail grooves 117 formed in the inner sheathing tube 116 and into which have been formed the sheathing metal portions 118, formed integral with the remainder of the sheathing tube 116. In this internally sheathed tubing construction, it is preferred to form the dovetail grooves 117 extending generally axially or longitudinally of the tubes 115 and 116 and circumferentially spaced, as shown but it is also possible to provide the dovetail grooves 117 extending, for instance, helically, if desired, and it is not intended to limit the principles of the present invention to the specific form of the grooves shown.

Thus, with the interengagement or metal-to-metal interlock provided between the inner basic tube 115 and inner sheathing tube 116, a secure physical interengagement is provided between these tubes which will maintain the tubes together during varying temperatures conditions despite the variations of the coefficients of thermal expansion of the materials forming the tubes. This, therefore, insures at all times proper paths of heat flow between the tubes providing an efficient tubing construction for heat exchanger construction use.

As discussed with reference to the externally sheathed tubing construction of FIG. 4, this internally sheathed tubing construction of FIG. 16 is formed with the generally radially extending sides 119 of the sheathing metal portions 118 tightly abutting the generally radially extending side walls 120 of the grooves 117, in order to insure the proper path of heat flow between the outer basic tube 115 and inner sheathing tube 116, even though portions of the sheathing tube might separate from the outer basic tube at locations spaced between these grooves 117 under the varying temperature conditions. Thus, the broad principles involved in the construction of the externally sheathed tubing of FIG. 4, as discussed above, are substantially the same as the broad principles involved with the construction of the internally sheathed tubing of FIG. 16, and it is obvious that sheathed tubing in which the basic tube is sheathed both internally and externally could be provided merely by a combination of the FIG. 4 and FIG. 16 constructions.

If it is desired to provide fins on this internally sheathed tubing construction, it is merely necessary to apply conventional fins to the outer surface of the outer basic tube 115 in any conventional manner to provide the internally sheathed finned tubing of FIG. 17. In this case, if the outer basic tube were made of steel, it would be preferable to form these outer fins or steel, since they are secured to tube 115 and would thereby have the same coefficients of thermal expansion as the outer basic tube.

Referring to FIG. 17, the helical fins 121 could be mounted on the basic tube outer surface 122 by forming the fin grooves 123 and securing the fins 121 therein in the conventional manner and as previously discussed with reference to the externally sheathed tubing construction having fins formed thereon, as shown in FIG. 5. Furthermore, the preferable comparative sizes of the various members of this internally sheathed tubing construction are the same as in the foregoing externally sheathed tubing construction and as previously discussed.

An embodiment of one method of the present invention is shown in FIGS. 6, 7 and 8 and may be related to the various stages of the externally sheathed tubing construction shown in FIGS. 1, 2, 3 and 4. Certain steps of the method have not, however, been illustrated in view of these steps in and of themselves being conventional, other than in the particular order as set forth in the following.

As shown in FIG. 6, a conventional groove cutter 30 is illustrated forming the generally U-shaped grooves 31 in the outer surface of the inner basic tube 15 to provide the construction of FIG. 1, which is the first step in this one form of the method. The second step of the method is shown in FIG. 7 in which a roll 32, through rolling pressure and by bridging the U-shaped grooves 31, forms these U-shaped grooves into the outer surface of the basic tube 115, as shown in FIG. 7, and also in the second stage of the construction, illustrated in FIG. 2.

Then, in this particular form of the method, the sheathing tube 16 is telescoped over the inner basic tube 15 resulting in the construction of FIG. 3, and this may be accomplished by providing a usual slip fit between the basic tube and sheathing tube. Finally, to complete the sheathed tubing construction, as shown in FIG. 4, a roll 33, extending substantially coaxially with the basic tube
summarized as extruding or forming the dovetail grooves 17 in the outer surface of the inner basic tube 15, applying or telescoping or extruding the sheathing tube 16 over the inner basic tube 15 and forming the sheathing tube 16 into the basic tube dovetail grooves 17 to provide the metal-to-metal interlock, and, where desired, applying fins 21 to the outer surface 22 of sheathing tube 16 either within the fin grooves 23 or otherwise.

The various stages of the construction of internally sheathed tubing are shown in FIGS. 14, 15, 16 and 17, and conventional metal working operations may be used for forming this construction. The outer basic tube, as shown in FIG. 14, may be formed with the dovetail cross-section grooves 117 in the inner surface thereof by originally extruding these basic tubes with the grooves therein in a mill operation, or by first forming the basic tubes and then removing the metal to form the grooves by usual means, such as by a conventional spider-type cutting tool. As before stated, these grooves may be formed extending in various paths as desired and as conditions demand for securing the final physical interengagement or metal-to-metal interlock discussed above.

As shown in FIG. 15, the inner sheathing tube 116 is then telescoped within the outer basic tube 115. This may be done by providing a slip fit between the two tubes or by originally extruding the inner sheathing tube 116 within the outer basic tube 115.

Finally, portions of the inner sheathing tube 116 are formed into the preferably dovetail cross-section grooves 117 of the outer basic tube 115. If a slip fit is provided between tubes 115 and 116 for the original telescoping assembly, the inner sheathing tube 116 is then expanded outwardly into preferably a tight "interference" fit with the outer basic tube 115, and at the same time the sheathing metal portions 118 are expanded into tight physical interengagement in the dovetail-cross section grooves 117.

This expanding of the inner sheathing tube 116 may be done by many conventional processes, such as by ball expanding, drawing pressuring or by applying a shock wave. If the inner sheathing tube 116 is originally extruded into the outer basic tube 115, then at the same time the sheathing metal portions 118 may be extruded and formed into the dovetail-cross section grooves 117, and this may be done despite the direction that these grooves 117 extend, by the proper application of pressure during this extrusion process.

Finally, after the internally sheathed tubing construction is formed, as shown in FIG. 16, by one of the foregoing processes or methods, conventional forms of fins 121 may be applied if and as desired in a conventional manner, such as secured within the fin grooves 123 formed in the outer basic tube 115 and as shown in FIG. 17. Other forms of fins, of course, could be provided dependent on the requirements of the particular use of the construction.

Thus, in this method for forming the internally sheathed tubing construction of FIG. 16 or 17, the method steps can be summarized as extruding or otherwise forming the preferably dovetail cross-section grooves 117 in the inner surface of the outer basic tube 115; telescoping or extruding the sheathing tube 116 within the outer basic tube 115, and forming the sheathing tube 116 into the basic tube dovetail grooves 117 to provide the metal-to-metal interlock. Where desired, the method can further include the applying of the fins 121 to the outer surface 122 of the outer basic tube 115 either within the fins grooves 123 or otherwise.

A still further method for forming the externally sheathed tubing construction of FIG. 4 or the internally sheathed tubing construction of FIG. 16 may be the combining of a coating step for forming a sheathing tube telescoped either externally or internally with the basic tube, and preferably then in some usual manner, such as extruding or other metal-working operations, forming
a relatively smooth exposed surface on the sheathing tube. In this case, the embedding or interengaging of the sheathing tube metal in the basic tube grooves would be accomplished, at least principally, during the coating step.

For instance, considering the externally sheathed tubing construction of FIG. 4, preferably the dough-tail cross-section grooves 117 would be first formed in the outer surface of the basic tube 115. This inner basic tube 15 could then be passed through a coating pot containing molten metal of the type forming the outer sheathing tube 16, to provide a complete coating of basic tube 15 with the metal of the sheathing tube 16 and thereby form the inner basic tube telescoped with the outer sheathing tube while at the same time the metal of the sheathing tube 16 would form properly into the basic tube dough-tail grooves 17 providing the physical interengagement or metal-to-metal interlock between the tubes.

After the complete coating of the outer surface of the basic tube 15 is completed to form the sheathing tube 16 telescoped thereover, the telescoped tubes could then be passed through an extruding or similar die for forming the sheathing tube of substantially uniform thickness over the basic tube, or this operation could be accomplished by other usual metal-working operations, such as rolling and the like. Finally, if desired, the fins 21 could be formed on the outer surface 22 of the sheathing tube 16 to provide the construction of FIG. 5.

This same general method could be used to provide the internally sheathed tubing construction of FIG. 16, that is, forming the preferably dough-tail cross-section grooves 117 in the inner surface of the outer basic tube 115, substantially completely coating this basic tube inner surface with the metal of the sheathing tube 116 to form the outer basic tube internally telescoped with the inner sheathing tube, and at the same time forming the metal of the sheathing tube 116 outwardly into and physically interengaged with the basic tube grooves 117, and then preferably extruding or otherwise forming the metal of the sheathing tube of substantially uniform thickness. Again, where desired, the fins 121 can be applied to the outer surface 122 of the outer basic tube 115 to form the internally sheathed and finned tubing construction of FIG. 17.

This further alternate method for forming the externally or internally sheathed tubing constructions of FIG. 4 or 16 can, therefore, be summarized as forming grooves in an internal or external surface of a basic tube 15 or 115, substantially completely coating this basic tube surface to form a sheathing tube 16 or 116 telescoped externally or internally with the basic tube 15 or 115 and also forming the sheathing tube metal into the basic tube grooves 17 or 117, and then preferably extruding or otherwise forming a relatively smooth uniform surface on the sheathing tube 16 or 116 at the exposed surface thereof, that is, the surface spaced outwardly from the basic tube 15 or inwardly from the basic tube 115. Finally, to form the finned sheathed tubing constructions of FIG. 5 or 17, it would be merely necessary to add the step of applying the fins 21 or 121 to the outer surface of the sheathing tube 16 or the outer surface of the basic tube 115.

The methods of the present invention, an externally or internally sheathed tubing construction or finned sheathed tubing construction is provided in which the basic tube 15 or 115 may be formed of materials, such as steel, to provide the required strength for high-pressure applications, and this basic tube is completely coated by the metal of the sheathing tube 16 or 116 formed preferably of a softer metal not readily subject to corrosion. Further, whether external or internal, the sheathing tube 16 or 116 is interengaged with the basic tube 15 or 115 by a metal-to-metal interlock such as the metal-to-metal interlock of the materials forming the basic tube 15 or 115 and sheath-
heat transfer bond between said tubes for maintaining the tubes in intimate heat transfer contact under varying temperature conditions, and forming fin means on the outer surface of the outermost of said tubes in intimate heat transfer contact and extending generally radially from the outer surface of said outermost tube.

3. The method of forming sheathed tubing including the steps of forming groove means in the outer surface of a first metal tube with said groove means extending inwardly of the tube metal from said first tube surface and opening outwardly at said first tube surface, extruding a substantially continuous metal sheathing tube telescoped over the first tube outer surface with said sheathing tube tightly abutting the first tube outer surface, during the extruding of the sheathing tube telescoped over the first tube outer surface forming and embedding portions of the sheathing tube inwardly into and interlocking the sheathing metal with the first tube thereby providing an interlocking metal-to-metal heat transfer bond between said tubes for maintaining the tubes in intimate heat transfer contact under varying temperature conditions, and forming fin means on the outer surface of the sheathing tube in intimate heat transfer contact and extending generally radially from the outer surface of said sheathing tube.

4. The method of forming sheathed tubing including the steps of extruding groove means in a surface of a first metal tube with said groove means extending inwardly of the tube metal from said tube surface and opening outwardly at said tube surface, extruding a substantially continuous metal sheathing tube telescoped with the first tube surface with said sheathing tube tightly abutting the first tube surface, and during the extruding of the sheathing tube telescoped with the first tube surface forming and embedding portions of the sheathing tube inwardly into and interlocking the sheathing metal with the first tube thereby providing an interlocking metal-to-metal heat transfer bond between said tubes for maintaining the tubes in intimate heat transfer contact under varying temperature conditions, forming fin groove means in the outer surface of the outermost tube, and securing fin means in said fin groove means in intimate heat transfer contact with and extending generally radially from said outermost tube.

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