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[45] **May 27, 1975**

[54] **HEAT EXCHANGER TUBE**

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[22] Filed: **Mar. 4, 1974**

[21] Appl. No.: **447,735**

Related U.S. Application Data

[63] Continuation of Ser. No. 214,034, Dec. 30, 1971, abandoned.

[52] **U.S. Cl.** **165/179;** 29/DIG. 23; 138/38

[51] **Int. Cl.** **F28f 1/40**

[58] **Field of Search** 29/DIG. 23; 165/179, 185, 165/186, 177; 277/87; 72/366, 7; 138/38, 171

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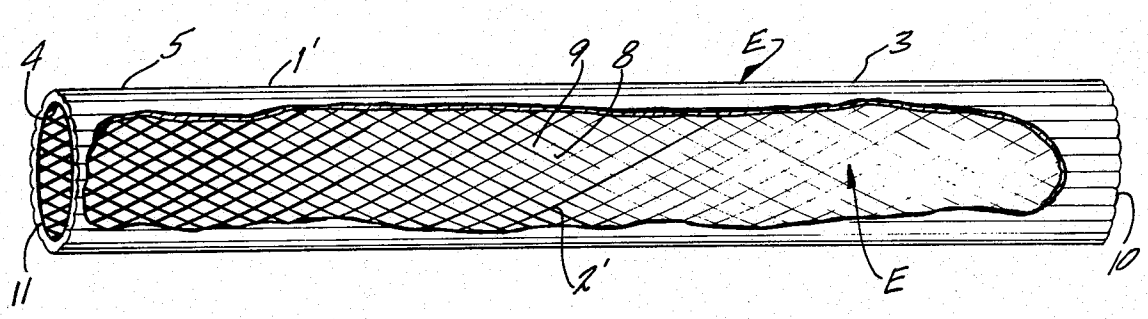
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[57] **ABSTRACT**

Heat exchanger tube wherein the outside and/or inside surfaces of the tube have a heat exchange enhancement pattern formed in them. The heat exchange enhancement pattern does not extend through the full wall thickness. It is possible for the heat exchange enhancement pattern to include longitudinally extending variations in the type of enhancement. A process and apparatus for forming the tube provide for patterning metal strip and then forming the strip into the shape of a tube and then joining the longitudinally extending edges of the strip to form the complete tube.

6 Claims, 14 Drawing Figures



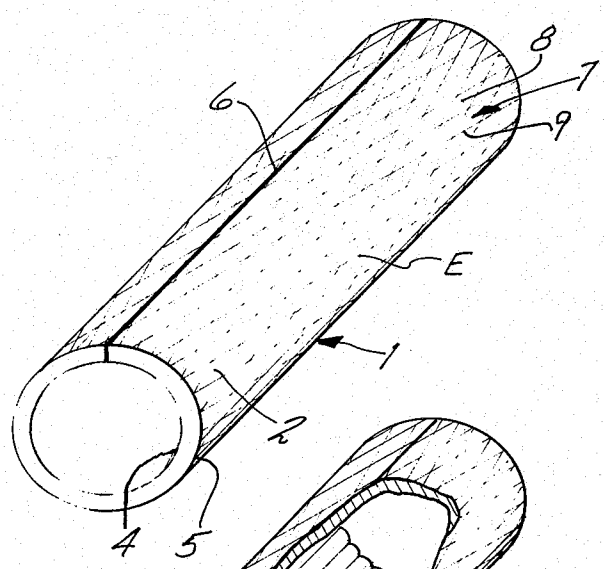


FIG-1A

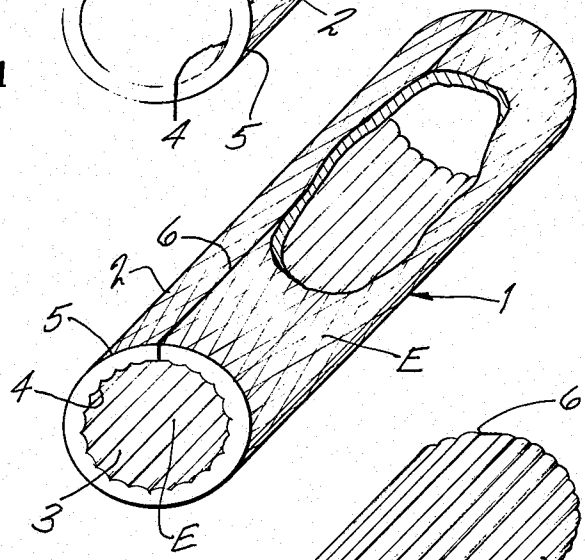


FIG-1B

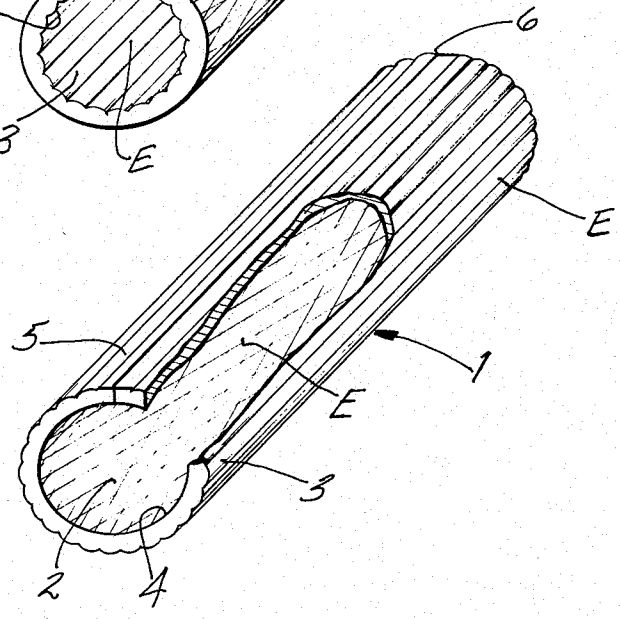


FIG-1C

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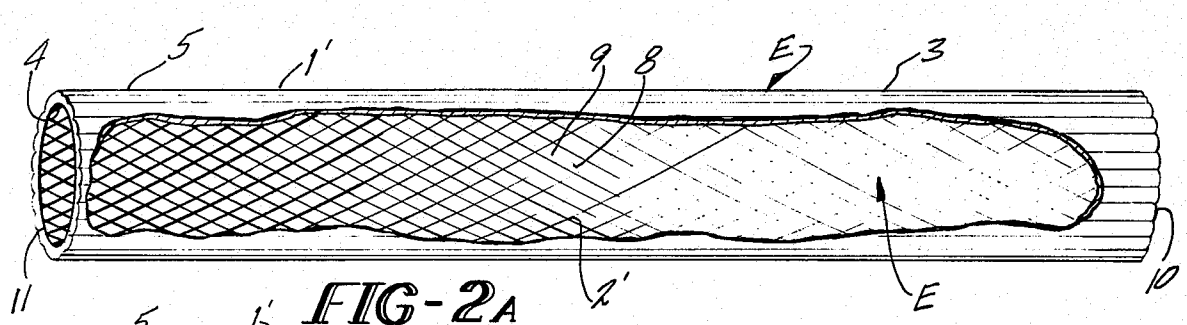


FIG-2A

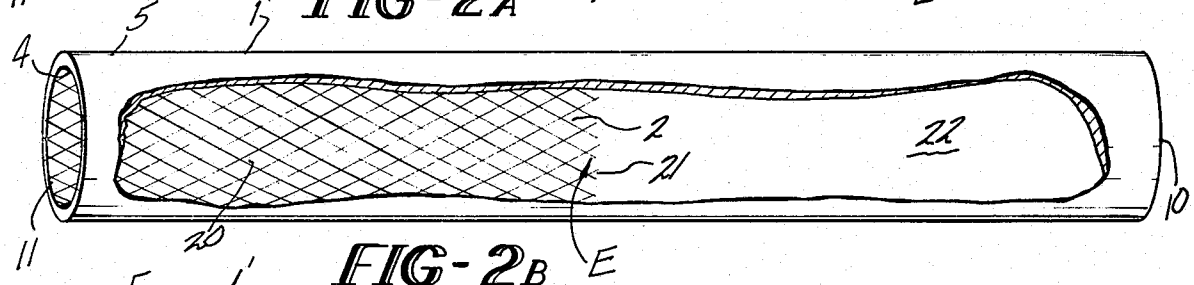


FIG-2B

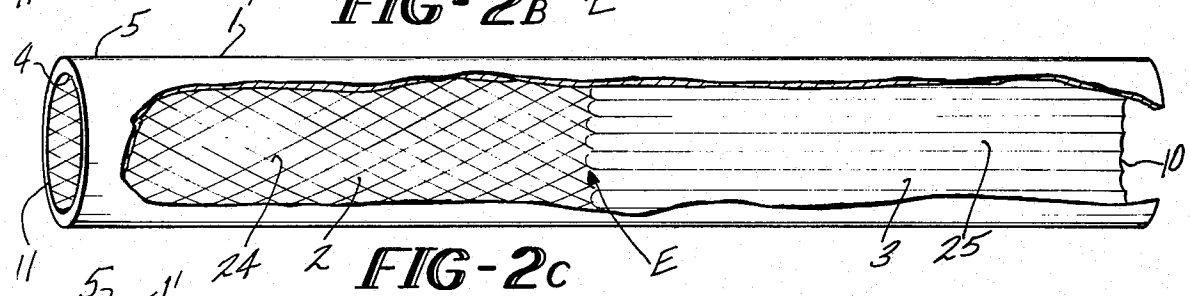


FIG-2C

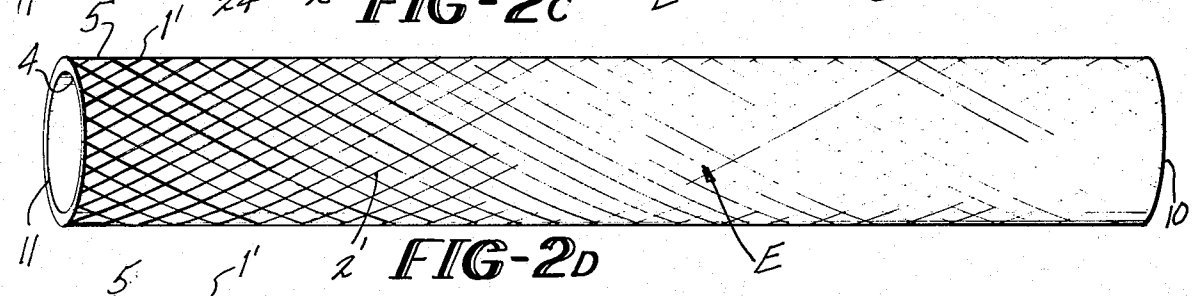


FIG-2D

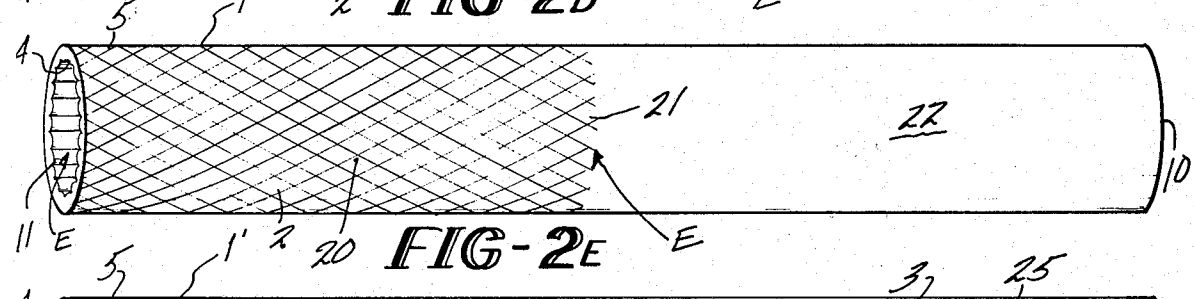


FIG-2E

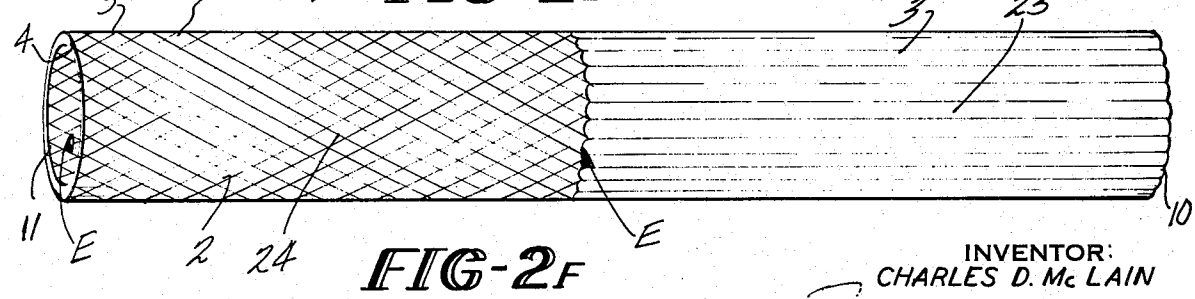


FIG-2F

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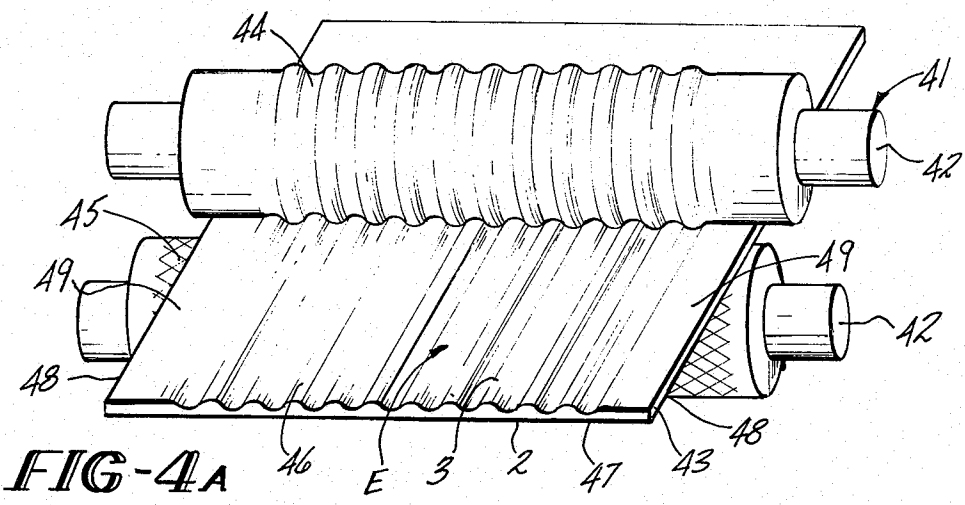


FIG-4A

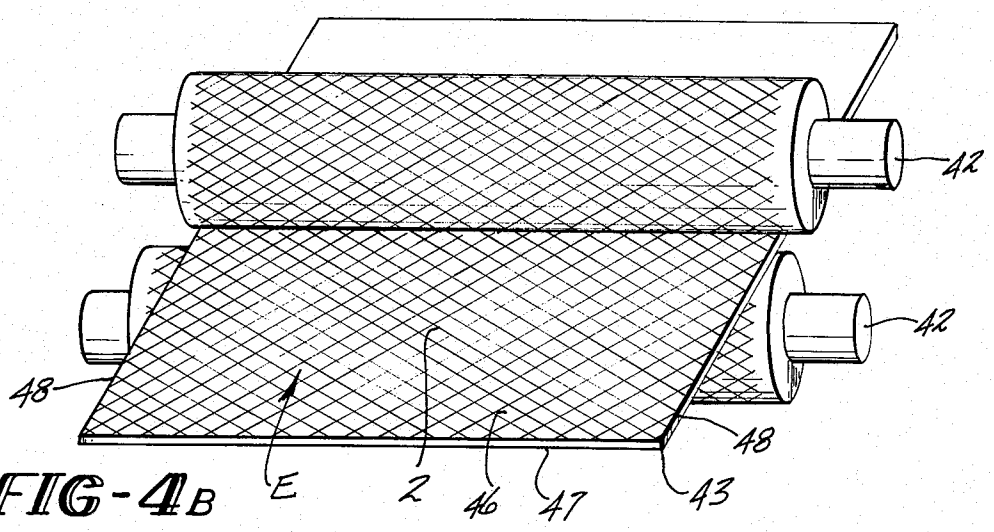


FIG-4B

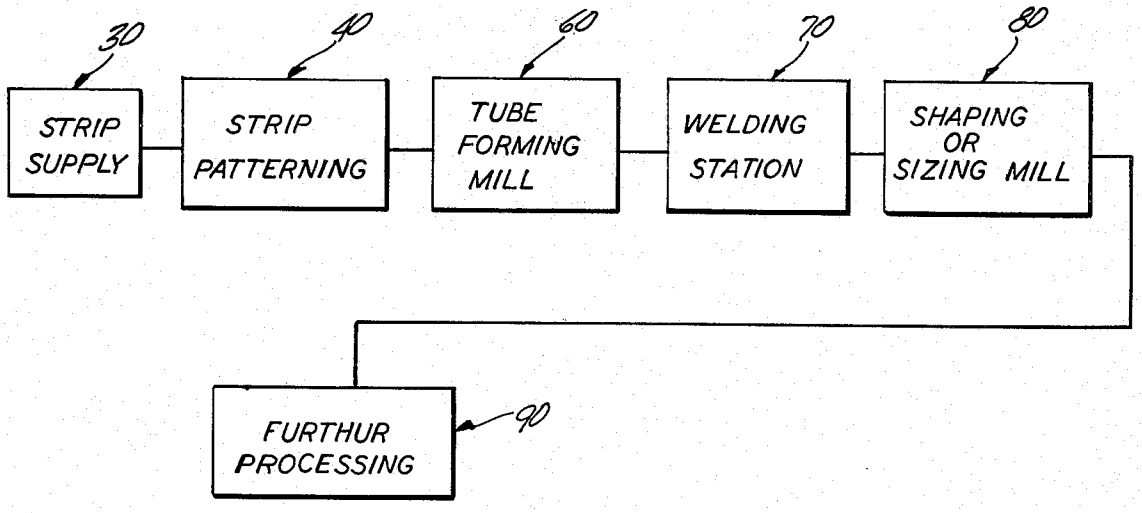


FIG-3

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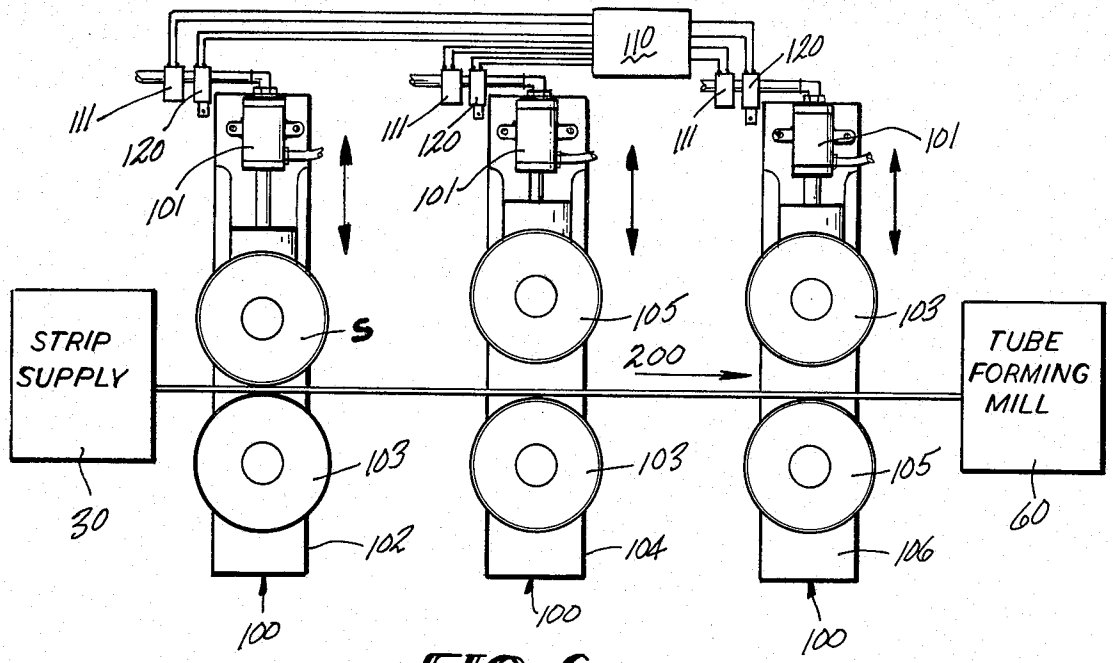


FIG-6

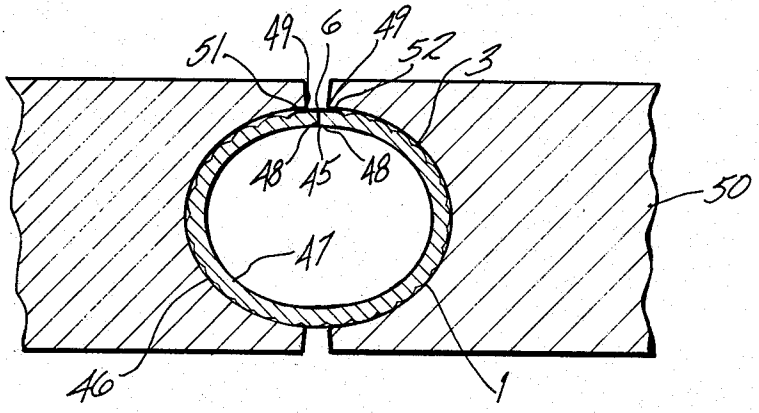


FIG-5

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HEAT EXCHANGER TUBE

This is a continuation of application Ser. No. 214,034, filed Dec. 30, 1971, now abandoned.

BACKGROUND OF THE INVENTION

This invention deals with a process and apparatus for forming heat exchanger tubing having an enhanced surface for improved heat exchange efficiency. Enhanced surface heat exchange tubing is also part of the instant invention. Preferably, the tubing in accordance with this invention is made by a process of welding metal strip having an enhanced surface into tubing as, for example, by the use of high frequency welding.

It is known in the art to weld metal strip into tubing by high frequency welding. A typical example of a prior art apparatus and process is set out in U.S. Pat. No. 3,037,105, granted May 29, 1962.

SUMMARY OF THE INVENTION

In accordance with this invention, a process has been developed wherein strip is patterned on at least one of its major faces in such a manner as to improve its heat transfer properties when employed in a heat exchanger environment.

The patterned strip is formed into a tube and the strip edges are welded together. Preferably, the welding is done by the forge welding technique and set out in U.S. Pat. No. 3,037,105. By this process, it is possible to obtain heat exchanger tubing having enhanced heat exchange surfaces of a unique nature.

Since the enhanced heat exhange surface is formed by patterning metal strip, it is possible to obtain heat exchanger tubing having enchancement patterns which vary in degree of enhancement or which vary from one enhancement pattern to another. These variations preferably occur in the longitudinal direction as will be illustrated herein.

In accordance with this invention, the enhancement patterns on the inside and/or outside of the tube do not extend throughout the thickness of the tube wall. Therefore, it is possible to have different enhancement patterns on the inside and outside of the tube. The types of patterns which can be formed are unlimited since the enhancement is done on strip which is then formed up and welded into tube. Therefore, it is possible to form patterns such as a knurled diamond pattern on the inside surface of a tube which could not otherwise be formed.

In accordance with this invention, it is possible to form tubing wherein the enhancement patterns on the inside and outside surfaces are selected to provide maximum efficiency for the different heat exchange functions which the inside and outside surfaces provide. For example, the tube might have a diamond pattern on its inside surface which provides a highly efficient nucleate boiling surface which is highly effective for evaporation purposes and a longitudinally extending rib pattern on its outer surface which is highly effective for condensing applications.

Other combinations are possible such as a diamond pattern on the inside or outside surface of the tube which is enhanced to a lesser degree along the longitudinal direction of the tube. This would provide an improved condensing surface since most of the condensation occurs at the beginning of the tube. The enhancement to a lesser degree in the latter portion of the tube would reduce drag and therefore increase efficiency.

In such a tube, it is possible that the other surface of the tube may be either unpatterned or patterned as desired. It is further possible in accordance with this invention that both the inside and outside surfaces of the tube may have the same enhancement pattern.

The patterned strip for welding into tubing in accordance with this invention may be formed off line or in line with the welding apparatus. When the patterning operation is performed in line, several advantages are provided in that one may change from one pattern to another or change the degree of enhancement more readily.

While high frequency welding is preferred in accordance with this invention, other well known joining processes could be employed. High frequency forge welding, however, provides a marked improvement by virtue of its extremely narrow weld zone.

The apparatus in accordance with this invention is directed to the in line patterning approach and comprises a strip patterning means located in line with the tube forming means and joining means. The strip patterning means preferably comprises embossing rolls. To obtain the aforenoted variations in enhancement patterns, it may comprise a plurality of embossing roll stands.

It is accordingly an object of this invention to provide a process and apparatus for forming a heat exchange enhancement pattern on metal strip which is then formed into welded tubing.

It is another object of this invention to provide a process and apparatus as above which enables the enhancement pattern on the strip to be varied in either degree of enhancement or from one pattern to another.

It is another object of this invention to provide heat exchanger tubing having a surface with an enhancement pattern which varies in degree or type of pattern along the length of the tube.

It is a further object of this invention ot provide a heat exchanger tube having an enhancement pattern on its inside and/or outside surfaces.

It is a still further object of this invention to provide a heat exchanger tube as above, wherein the enhancement pattern on the outside surface of the tube is different from the enhancement pattern on the inside surface of the tube.

Other objects and advantages will become apparent from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a series of perspective views illustrating exemplary heat exchanger tubing in accordance with this invention.

FIG. 2 shows a series of perspective views illustrating other embodiments of heat exchanger tubing in accordance with this invention.

FIG. 3 is a schematic representation of an apparatus in accordance with this invention.

FIG. 4 shows a series of perspective views illustrating roll embossment of the enhancement pattern in the metal strip.

FIG. 5 is a cross section of the welded tube at the point of welding for a tube having a ribbed outer surface.

FIG. 6 is a side view of a strip patterning apparatus in accordance with this invention for varying the enhancement patterns along the length of the strip.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and especially to FIG. 1, there is shown a plurality of tubes 1 in accordance with this invention having heat exchange enhancement patterns E on their inside 4 and/or outside 5 surfaces. All of the tubes 1 have in common a longitudinally extending weld seam 6 since they are formed from metal strip which has been patterned and then welded into tubing.

FIG. 1A shows a tube having a diamond type pattern 2 which is better described as a flat face diamond knurled type pattern on its outside 5 surface. The pattern 2 may be formed in any desirable manner; however, it is preferred, as will be shown herein, to form the pattern by roll embossing.

FIG. 1B shows a tube having a diamond type pattern 2 on the outside surface 5 and a longitudinally extending rib type pattern 3 on the inside surface 4.

FIG. 1C shows a tube having a diamond type pattern 2 on the inside surface 4 and a longitudinally extending rib type pattern 3 on the outside surface 5.

Therefore, it can be seen that in accordance with one embodiment of this invention that tubing 1 is formed by welding so that it has a longitudinally extending weld seam 6 with a heat exchange enhancement pattern E on its inside 4 and/or outside 5 surfaces. The enhancement pattern E may be the same on both the inside 4 and outside 5 surfaces or the enhancement pattern E may be different one from the other.

Referring again to FIG. 1A, the diamond pattern 2 shown therein comprises diamond shaped areas 7 having a flat face 8 separated by grooves 9. The pattern is relatively easy to form using conventional knurling rolls; however, the knurling operation is not carried out to the full depth of the pattern in the knurling rolls in order to form the flat faced diamond as shown.

The surface shown in a highly efficient heat transfer surface. The formation of this type of surface on the inside of a tube would be virtually impossible except by the use of a method which welds patterned strip into tubing.

It should be evident from the tubes 1 shown in FIG. 1 that the depth of the heat exchange enhancement pattern E in the tube surfaces 4 and 5 is substantially less than the thickness of the tube walls, thus making it possible for the enhancement pattern E on the inside surface 4 of the tube to be different from the enhancement pattern E on the outside surface 5 of the tube.

The longitudinally extending rib type pattern 3 shown in FIGS. 1B and 1C is a highly effective heat transfer surface somewhat analogous to the heat transfer surface of U.S. Pat. No. 3,291,704, granted Dec. 13, 1966.

Therefore, it is possible in accordance with this invention to provide tubing for applications such as in U.S. Pat. No. 3,244,601, granted Apr. 5, 1966, wherein the inside and outside surface of the tube serve different heat exchange functions. For example, condensation takes place on one surface whereas evaporation takes place on the other. In accordance with the patent, the heat exchange surface is identical on both sides of the tube. In accordance with this invention, however, the enhancement patterns E on the heat exchange surfaces on the inside 4 and outside 5 of the tube 1 may be selected as desired for a specific heat exchange function such as condensation or evaporation, so as to provide optimum heat transfer qualties.

For example, it has been found that while the diamond type enhancement pattern 2 can be used for both evaporation or condensation, it is most effective when used for evaporation. Similarly, it has been found that the longitudinally extending rib type pattern 3 is most effective for condensation.

Therefore, the tube 1 of FIG. 1B would be uniquely suited for use in an apparatus where the outside surface 5 provides evaporation and the inside surface 4 provides condensation. The tube 1 of FIG. 1C would be uniquely suited for a similar apparatus where the functions of the respective surfaces 4 and 5 are reversed.

To produce the tubing of FIG. 1 by means other than the welding of patterned strip into tubing would be expensive and difficult and in some cases impossible. The particular enhancement patterns 2 and 3 shown in FIG. 1 are those which are preferred in accordance with this invention, however, the invention is not limited to them. Any heat exchange enhancement pattern E which can be formed in metal strip which later to be welded int tubing could be employed.

FIG. 2 shows a series of perspective views illustrating other embodiments of heat exchange tubing 1'. In accordance with these embodiments 1', the heat exchange pattern E is varied over the inside 4 or outside 5 or both surfaces of the tube.

Because the tubing in accordance with this invention is formed from patterned strip, any desired pattern can be employed. Therefore, it is possible to vary the pattern on a given surface 4 or 5 of the strip. The pattern E may vary over the width of the strip or longitudinally along the strip or both. This will produce tubing 1' having a heat exchange enhancement pattern E varying about the circumference of the tube inside or outside or varying along the longitudinal length of the tube or a combination of theses variations.

It is preferred, however, in accordance with this invention, for purposes of heat exchange applications that the variations in heat exchange enhancement patterns E take place longitudinally along the tube 1'. The variations in enhancement pattern E generally fall into two preferred groups. In the first grouping, as shown in FIGS. 2A and 2D, there is a variation in degree or intensity of enhancement. By this it is meant that the depth of the enhancement pattern E is gradually decreased or the sharpness of the enhancement pattern E is gradually decreased or the enhancement pattern E is otherwise changed so as to gradually fade into a smooth surface.

Such an enhancement pattern E is shown on the inside surface 4 of the tube 1' of FIG. 2A wherein a damond pattern 2' is employed with the depth of the grooves 9 separating the flat diamond faces 8 gradually decreasing along the length of the tube until the diamond pattern at the far end 10 of the tube is almost obliterated. Such a pattern 2' is uniquely suited in applications where most of the heat exchange occurs at the upstream end 11 of the tube 1', whereas downstream in the tube, heat exchange is occuring to a lesser degree.

By varying the intensity or depth of the enhancement pattern E as in FIG. 2A, the tubing 1' has maximum

heat transfer efficiency at the upstream end 11 where most of the heat exchange is occurring and gradually changes over the length of the tube until the enhancement pattern E is virtually obliterated thereby providing less drag on the heat exchange fluid and, therefore, the overall tube is improved in heat exchange efficiency.

The outside surface 5 of the tube 1' of FIG. 2A has a longitudinally extending rib pattern 3; however, it could have any desired enhancement pattern E or any which will be described hereinafter or it could be left smooth as in FIGS. 2B and 2C.

FIG. 2D shows a similar pattern 2' as in FIG. 2A though it is on the outside tube surface 5 and the inside tube surface 4 has been left smooth.

The second general grouping of variations in enhancement patterns is illustrated in FIGS. 2B, 2C, 2E and 2F comprising tubes wherein the ehnancement pattern E is changed from one pattern to another or from an enhancement pattern E to an unenhanced surface along the longitudinal length of the tubing 1'.

FIG. 2B shows just such a tube 1'. In FIG. 2B, the internal surface 4 has a diamond pattern 2 extending longitudinally from the upstream portion 20 of the tube 1' up to line 21 and the remaining portion 22 of the tube 1' has a smooth unehanced internal heat exchange surface.

As with the tubing of FIG. 2A, the tubing 1' of FIG. 2B provides maximum heat exchange efficiency at the upstream portion 20 of the tube where the greatest amount of heat exchange is to occur while in the downstream portion 22 of the tube, enhancement has been eliminated so as to reduce drag on the heat exchange fluid which should thereby increase the overall efficiency of the heat exchanger tube. The outside surface of the tube 1' in this case has been left smooth and unenhanced; however, it may have have any enhancement pattern E in accordance with this invention.

In FIG. 2C yet another variation is shown wherein the upstream portion 24 of the tube 1' has a diamond pattern 2 and the downstream portion 25 of the tube has a longitudinally extending rib pattern 3. In this tube 1', the diamond patterned portion 24 could provide maximum heat exchange efficiency for a desired heat exchange function as, for example, evaporation and the longitudinally extending rib portion 25 could provide improved heat exchange efficiency with reduced drag on the heat exchange fluid. While the rib portion 25 may not be as efficient for this heat exchange function as compared to the diamond portion 24, the reduction of drag in the rib portion 25 of the tube should improve the overall heat exchange efficiency of the tube.

FIGS. 2E and 2F show the heat exchange enhancement patterns E in the outside surfaces 5 of the tubes 1' corresponding to the heat exchange enhancement patterns of FIGS. 2B and 2C which were on the inside surfaces 4. The enhancement pattern E or lack of it in FIGS. 2E and 2F on the inside surface may be chosen as desired.

It is also evident from a consideration of FIG. 2 that the variation in enhancement pattern E may be present in both the inside 4 and outside 5 surfaces of the tube 1' and the type of variation whether of the grouping of FIGS. 2A and 2D or the grouping of FIGS. 2B, 2C, 2E and 2F may be varied as between the inside 4 and outside 5 surfaces of the tube 1'.

Therefore, from a consideration of the above, it can be seen that a myriad of heat exchange patterns E and combinations of enhancement patterns and unenhanced regions may be provided in metal tube which is formed from patterned strip. The adaptability of the welded tube process to the formation of enhanced heat exchange tubing with the variations as shown in FIGS. 1 and 2 and those which could be readily thought of in the light of FIGS. 1 and 2 is unique.

Various combinations of enhancement patterns E could be readily thought of from a consideration of FIGS. 1 and 2 and the specific combinations shown therein are not meant to be limitive of the invention though they do represent the preferred embodiments in accordance with this invention.

The process in accordance with this invention comprises providing a flat metal strip which is then patterned to form a heat exchange enhancement pattern in one or both of its major faces. The particular patterns which may be formed may be chosen as desired to obtain the particular type of tubing as aforenoted. Therefore, for tubing of the first embodiment of FIG. 1, the strip is patterned on at least one of its major surfaces and for tubing of the second embodiment of FIG. 2, the tubing is also patterned on at least one of its major faces.

Any well known patterning method could be employed to obtain the desired enhancement pattern. The method may be mechanical such as machining, or chemical such as etching. It may include masking if desired. It may be done by abrasion such as sand blasting. However, it is preferred in accordance with this invention to provide a process wherein the enhancement pattern is embossed in the strip surface and, most preferably, the embossment is provided by a process of roll embossing.

The process is applicable to a wide range of metals including steels, stainless steels, aluminum and aluminum base alloys, copper and copper base alloys; however, it is preferably applied to copper and copper base alloys.

After the strip has been patterned, it is formed into the shape of a tube by well known tube forming techniques. Generally this comprises forming the strip gradually into the shape of a tube by passing it through a series of roll forming stands or dies. After the strip has been formed into the shape of a tube the longitudinally extending edges of the strip are joined together by conventional means, preferably, by welding and, most preferably, by high frequency welding.

The tubing thus formed may be subjected as desired to shaping and/or sizing by conventional means and any other further processing as, for example, cleaning, coiling and/or packaging.

The apparatus for practicing the process in accordance with this invention and for forming the tubing in accordance with this invention is shown schematically in FIG. 3. The apparatus comprises supply means 30 or a supply of metal strip; patterning means 40 for forming at least one heat exchange enhancement pattern on at least one surface of the metal strip; tube forming means 60 for forming the metal strip into the shape of a tube; and joining means 70 for joining the longitudinally extending edges of the strip to form the complete tube.

The apparatus may also include shaping and/or sizing means 80 as, for example, to correct out of roundness and properly size the joined tube. It may also include

means for further processing **90** the tubing as, for example, means for cleaning the tube, and means for coiling the tubing.

The particular apparatus for carrying out each of these functions may be of any conventional well known design. The supply means **30** generally comprises a supply of metal strip in the form of a coil. The tube forming means **60** generally comprises a plurality of in line tube forming roll stands or dies as are well known in the art.

The joining means **70** in accordance with this invention preferably comprises though it is not limited to a high frequency forge welding station as set forth in U.S. Pat. No. 3,037,105, granted May 29, 1962. The shaping and/or sizing means **80** generally comprises a series of in line roll or die stands.

The cleaning means **90** may be the one set forth in U.S. Ser. No. 167,687, filed July 30, 1971. The coiling means **90** may be any conventional means for coiling tubing.

The strip patterning means **40** is preferably in accordance with this invention a roll embossing apparatus **41** as shown in FIG. **4.**

FIG. 4A shows rolls **42** for embossing metal strip **43** wherein one operative roll surface **44** contains the longitudinally extending rib pattern **3** and the opposing operative roll surface **45** contains the diamond pattern **2.** It is significant as aforenoted that neither of the heat exchange enhancement patterns **2** or **3** which either roll embosses extends throughout the thickness of the strip **43,** thereby permitting the enhancement pattern **3** on one side **46** of the strip to be different from the enhancement pattern **2** on the other side **47** of the strip.

FIG. 4B shows a somewhat similar roll configuration which embosses both sides **46** and **47** of the strip **43** so it is patterned with the diamond pattern **2.** From FIGS. 4A and 4B it can be readily seen that the particular enhancement patterns E on each side of the strip **43** are strictly a function of the embossing roll **42** which is employed and, therefore, are readily changeable by changing embossing rolls.

In welding strip **43** into tubing, it is necessary to accurately align the strip edges **48** after the strip has been formed into the tube prior to welding. When an enhancement pattern E such as the diamond pattern **2** in FIG. 4B is employed, the degree of discontinuity on the surfaces **46** and **47** of the strip **43** is not sufficient to interfere with the normal welding process. When a rib pattern **3** or other type of pattern E which provides a marked discontinuity in the strip **43** surfaces **46** and **47** is employed, it is necessary to leave longitudinally extending edge portions **49** of the strip **43** upatterned in order to obtain accurate alignment of the strip edges **48** at the weld point.

Referring to FIG. **5,** it is shown why it is necessary to provide these upatterned edge portions **49** in order to maintain the alignment of the strip edges. FIG. **5** is a cross section of the tube **1** and weld rolls **50** at the point where the strip edges **48** are welded together. It is seen therein that the weld rolls **50** maintain the alignment of the strip edges **48** by contacting the strip surfaces **46** or **47** adjacent to the strip edges **48.** When the strip edge portions **49** are left unpatterned, the contact between the strip surface **47** and the weld rolls **50** is the same on both sides of the weld seam **6** so that accurate alignment is maintained.

It this were not the case and, for example, the longitudinal rib pattern **3** extended across the full width of the strip **43,** the strip surface at **51** contacting the weld roll **50** on one side of the weld seam **6** could be at a valley in the rib pattern **3** whereas the strip surface at **52** contacting the weld roll **50** on the opposing side of the weld seam **6** could be at a peak, therefore, providing a substantial misalignment of the strip edges **48** during welding. Such a problem is completely overcome in accordance with this invention by leaving longitudinally extending edge portion **49** of the strip **43** unembossed.

Referring again to FIG. **4,** it is seen that the heat exchange enhancement pattern E is readily changeable merely by changing embossing rolls **42.** Therefore, in accordance with this invention, it is possible to incorporate in the apparatus as shown in FIG. **6** a plurality of embossing roll stands **100.** Three are shown, however, any desired number could be employed to obtain any desired enhancement pattern E or combination of patterns in the strip surfaces **46** and **47.**

Each of the roll stands **100** shown is actuated by a pneumatic cylinder **101** which is capable of forcing it into embossing contact with the strip or removing it from contact with the strip. In FIG. **6,** the first roll stand is shown in embossing contact with the strip. If it were desired to form the tubing of FIG. **1,** a single roll stand would be sufficient although if it were desired to switch during continuous tube welding between the embodiments of FIGS. 1A through 1C, the plurality of roll stands shown would provide an easy approach.

For example, the first roll stand **102** could have a diamond pattern **2** bottom embossing roll **103** and a smooth top roll S to form the tubing **1** of FIG. 1A. The second roll stand **104** could have a rib pattern **3** in the top roll **105** and a diamond pattern **2** in the bottom roll **103** to form the tubing **1** of FIG. 1B and the third roll stand **106** could have a diamond pattern **2** in the top roll **103** and a rib pattern **3** in the bottom roll **105,** thereby being capable of forming the tubing **1** of FIG. 1C.

Therefore, by employing three roll stands as shown in FIG. **6,** one could readily change from the manufacture of the tubing **1** of FIG. 1A to tubing of FIGS. 1B and 1C by merely actuating the appropriate roll stand so the embossing roll **103** or **105** contacts the strip.

The roll stand **100** of FIG. **6** are also suited for forming tubing in accordance with FIG. **2** and the like. The pneumatic cylinders **101** of each of the roll stands **100** would have to be controlled by a suitable sequencing mechanism **110** as are known in the art. When it is desired to change from one enhancement pattern E to another in the longitudinal direction of the strip **43,** this sequencing could include solenoid type valves **111** in the fluid lines to the pneumatic clyinders **101** and these solenoid valves **111** could then be actuated by some conventional type switching means **110** such as a computer, cam actuated switches, electric timer or other similar means.

In operation then, for example, the first roll stand **102** could be actuated to contact the strip **43** and emboss it during a first time period to form a diamond pattern **2.** During a second time period, all of the roll stands **100** could be out of contact with the strip, thereby leaving a smooth surface or perhaps the second roll stand **104** having a rib pattern **3** could be actuated. By appropriately sequencing the actuation of the respective roll stands **100,** any desired pattern could be obtained as shown in FIGS. **2B, 2C, 2E** and **2F** and any

of the variations which would be readily thought of from these Figures.

To obtain patterns varying in degree of intensity as in FIGS. 2A and 2D, one could employ a further solenoid valve **120** controlled by the sequencing mechanism **110** following the solenoid valve **111** which would act to bleed the system and gradually reduce the force exerted by the pneumatic actuator on the rolls S, **103** or **105** and, thereby, gradually reduce the depth of the enhancement pattern E in the strip **43.** In such a sequence then, the solenoid valve **111** would be opened to place a roll S, **103** or **105** into embossing contact with the strip followed by opening of the bleed valve **120** to gradually withdraw the roll from embossing contact with the strip, thereby yielding the pattern varying in degree as in FIGS. 2A and 2D.

The roll stands of FIG. **6** are situated in line in the welding apparatus and provide a marked improvement in flexibility as compared to an off line patterning system since it is possible to readily change from one heat exchange enhancement pattern to another or to change the degree of enhancement of any given enhancement pattern. This is readily accomplished in line appropriately sequencing the actuation of the roll stands **100.**

While the means for actuating the roll stands and the sequencing means have been described with respect to a specific embodiment, any desired sequencing means as are well known in the art and any desired means for actuating the roll stands as are known in the art could be employed. For example, in place of the pneumatic cylinder for actuating the roll stands, hydraulic means, mechanical means or a combination of these could be employed.

The above description assumes that the strip is traveling in the direction of the arrow **200.**

While the tubing shown in FIGS. **1** and **2** is enhanced throughout the complete length of the tubes, the tubing has been shown that way for purposes of example only and portions of the outside surface of the tube may be left smooth for connection to heat exchanger plates or for other known purposes in accordance with well known practices in the art. This particularly applies to the ends of the tube.

The tubing in accordance with this invention when joined by high frequency forge welding generally contains a weld bead on the outside and inside surfaces of the tube. These weld beads may be removed by well known scarfing techniques which can result in a narrow longitudinally extending region which has been scarfed and wherein the enhancement pattern has been removed. Sometimes the weld bead is insignificant and need not be removed. If a joining process other than forge welding is employed, there may be no weld bead. Therefore, this invention includes tubes which have inside and/or outside weld beads or have had them removed, or have essentially no weld beads at all.

In accordance with this invention, the heat exchange enhancement patterns do not extend throughout the full wall thickness of the tube. Therefore, the heat exchange enhancement pattern on the outside or inside surface of the tube does not show through on the opposing surface of the tube. This is meant to distinguish the tubing in accordance with the instant invention from corrugated tube such as shown in U.S. Pat. No. 3,217,799, granted Nov. 16, 1965, or fluted type tubing such as in U.S. Pat. No. 3,244,601, granted Apr. 5, 1966.

In the case of the corrugated or fluted tube, the enhancement patterns do extend through the full wall thickness in the sense of this invention since the corrugations or flutes on one surface of the tube form corresponding corrugations or flutes on the opposing surface of the tube.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. A welded hollow metal heat exchanger tube formed from metal strip material and having a longitudinally extending weld seam, said tube having a given wall thickness and an inside surface corresponding to one side of said strip material and an outside surface corresponding to the opposing side of said strip material, a heat exchange enhancement pattern extending throughout only a portion of the tube wall thickness embossed into at least the inside surface by embossing the corresponding side of said strip, whereby variation in enhancement pattern is provided by varying the embossment of the strip.

2. A tube according to claim **1** wherein said enhancement pattern is on the outside and inside surfaces of the tube.

3. A tube according to claim **1** wherein said heat exchange enhancement pattern comprises a flat face diamond knurled pattern.

4. A tube according to claim **1** wherein said heat exchange enhancement pattern comprises a longitudinally extending rib pattern.

5. A tube according to claim **1** wherein said enhancement pattern includes a longitudinally extending variation in the type or degree of enhancement.

6. A tube according to claim **5** wherein said longitudinally extending variation in said hehat exchange enhancement pattern comprises a first heat exchange enhancement pattern in a first longitudinally extending portion of a tube surface and a second heat exchange enhancement pattern in a second longitudinally extending portion of a tube surface.

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