United States Patent [19]

Sirois

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[54] **PRODUCTION OF INTERMITTENTLY FLUTED TUBES**

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[52] **U.S. Cl.** **72/283,** 72/276

[51] **Int. Cl.** **B21c 3/06**

[58] **Field of Search** .... 72/283, 276, 75; 29/157.4; 113/118 R, 118 A

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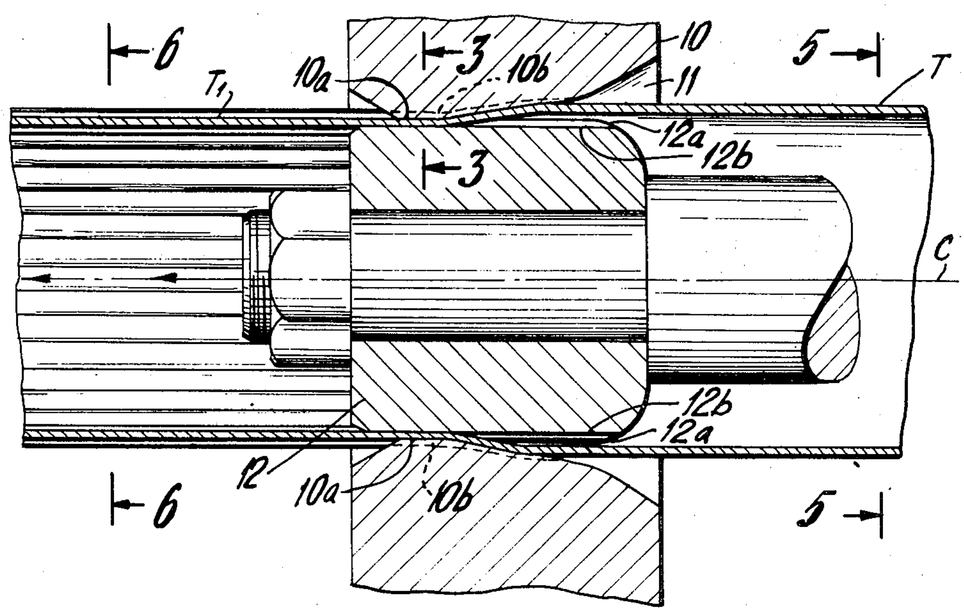
[57] **ABSTRACT**

A fluted mandrel is movable axially within the tube which is drawn through a fluting die, the ridges of the fluted mandrel being aligned with the valleys formed by the fluted die. In one axial position of the mandrel, where it is fully within the die, its ridges and valleys are radially opposite the valleys and ridges, respectively, of the die, whereby the tube is fluted internally and externally as it is drawn through the die. However, when the mandrel is withdrawn axially from this fluting position and the tube moves through the die, the tube-fluting operation is interrupted and the die merely forms shallow impressions in the external surface of the tube.

4 Claims, 9 Drawing Figures



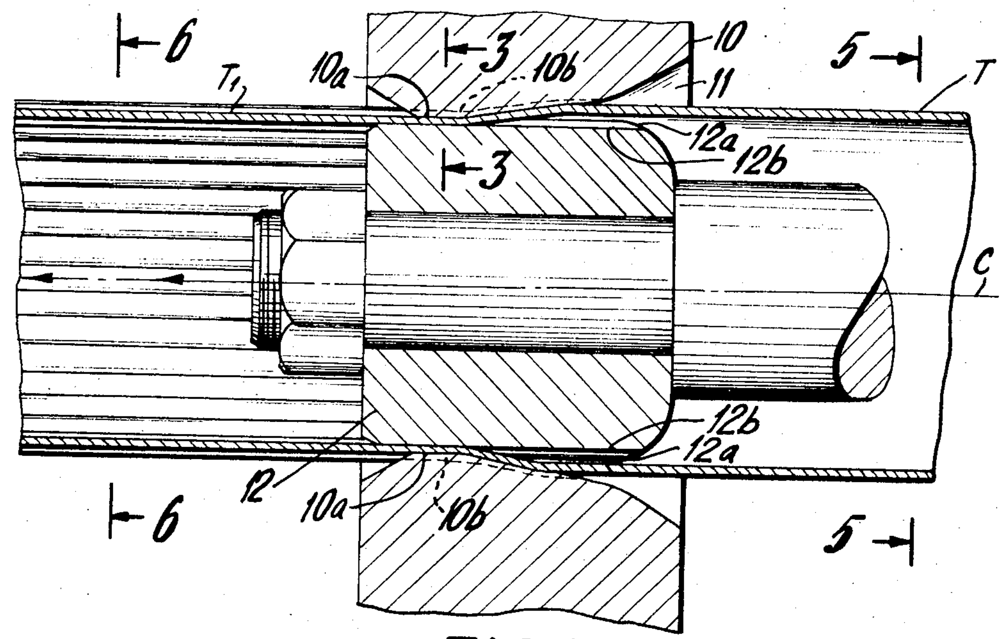


FIG. 1

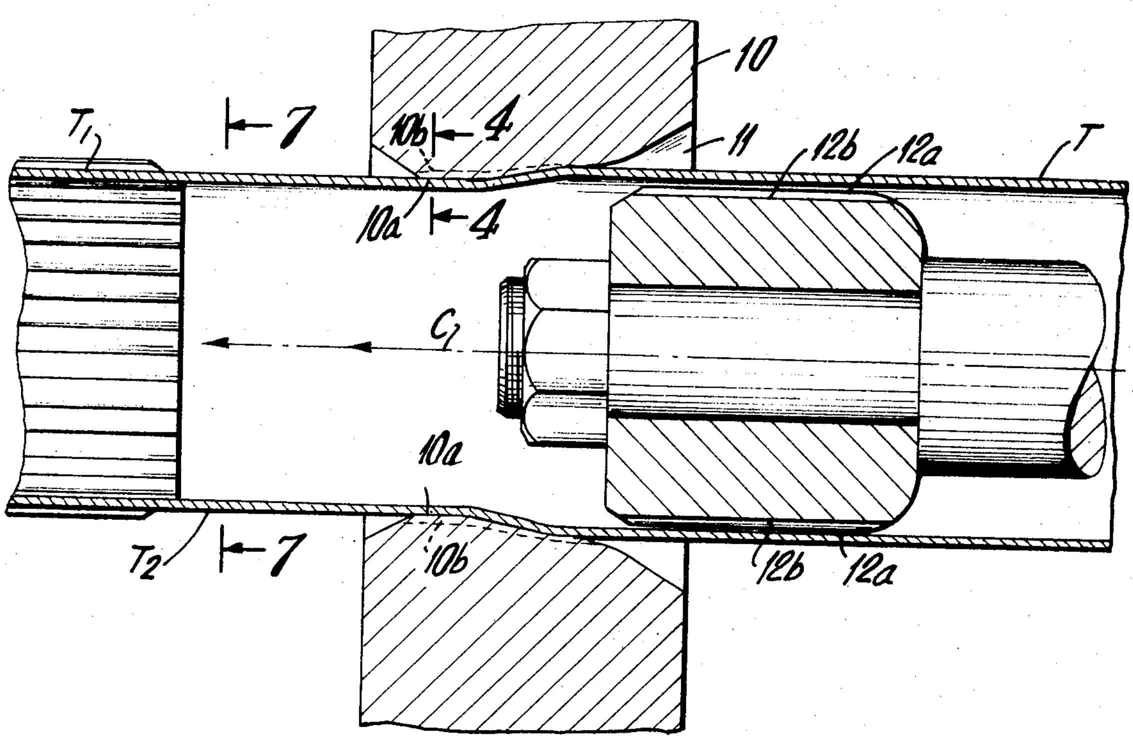


FIG. 2

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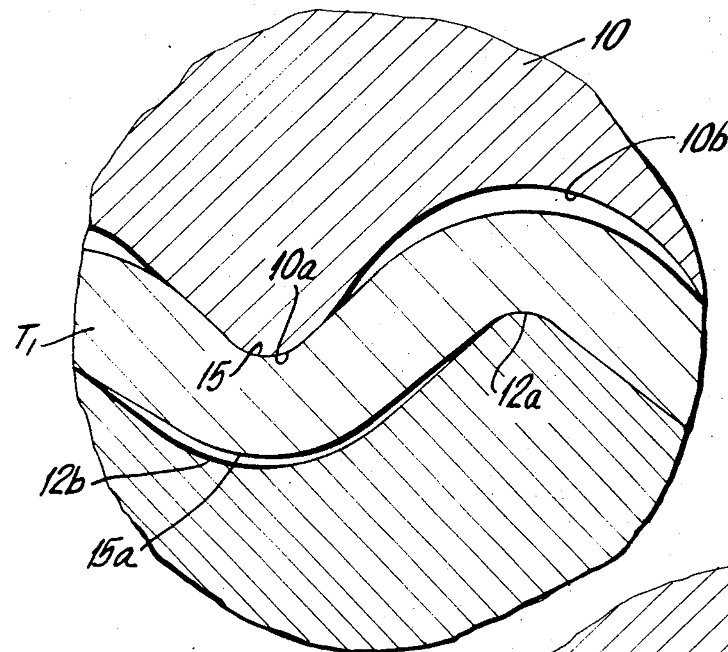

FIG. 3

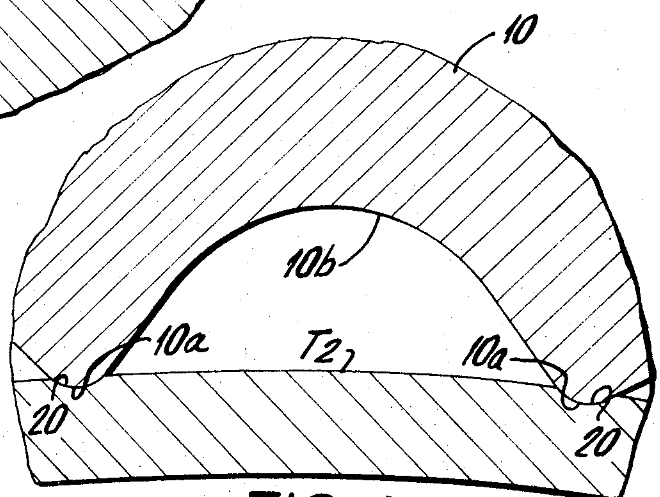

FIG. 4

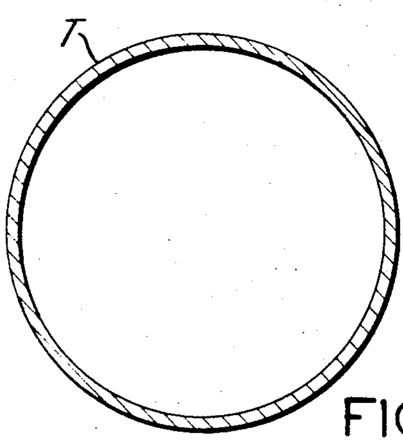

FIG. 5

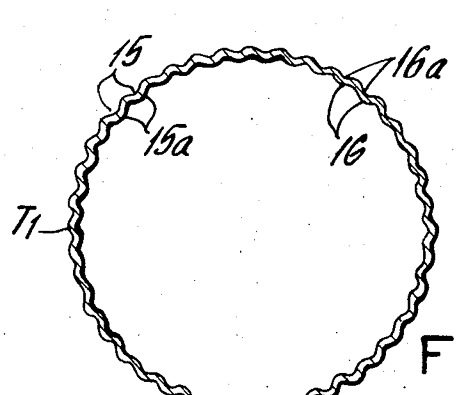

FIG. 6

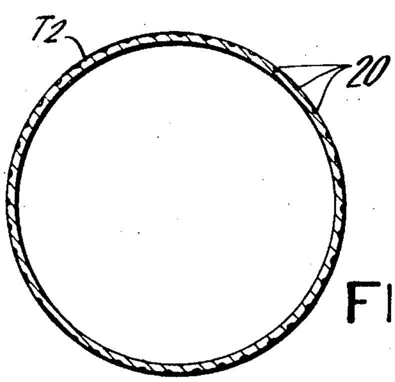

FIG. 7

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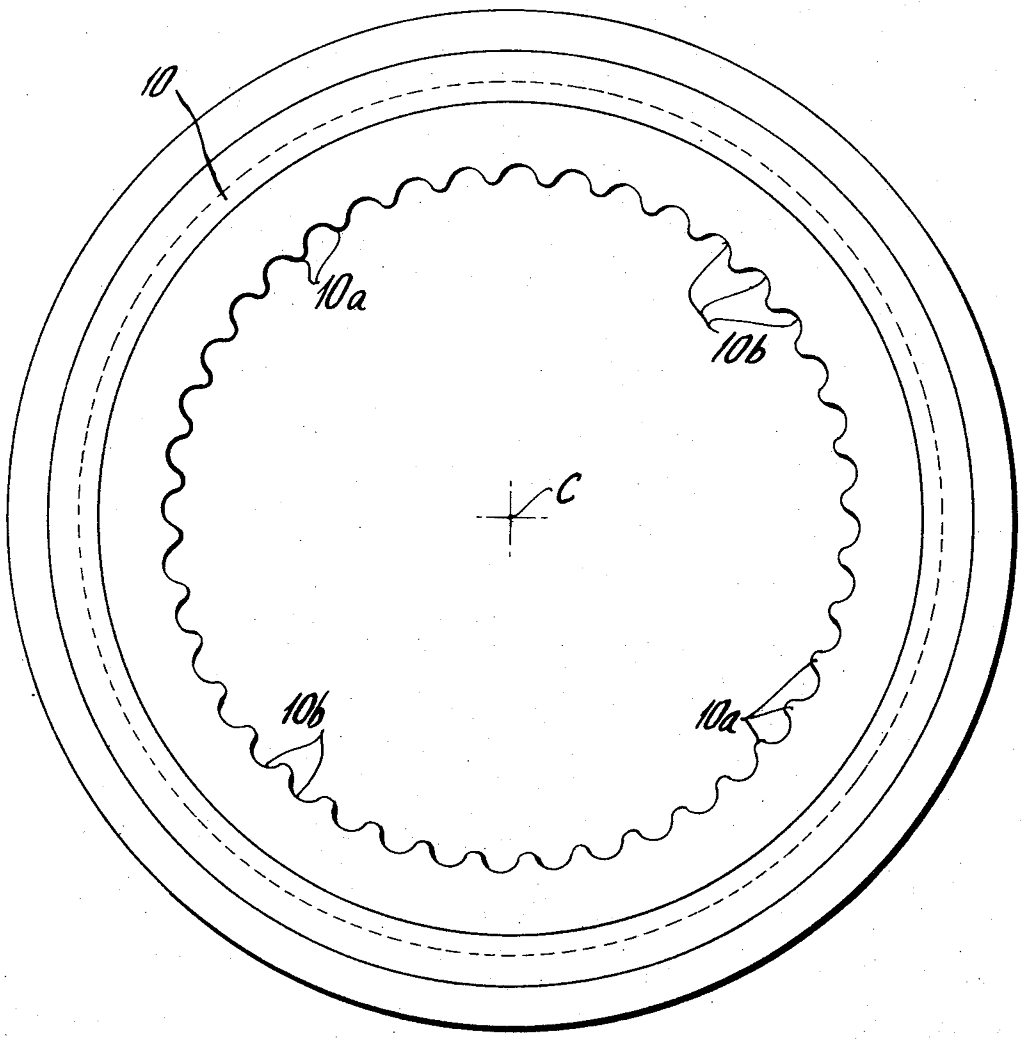

FIG.8

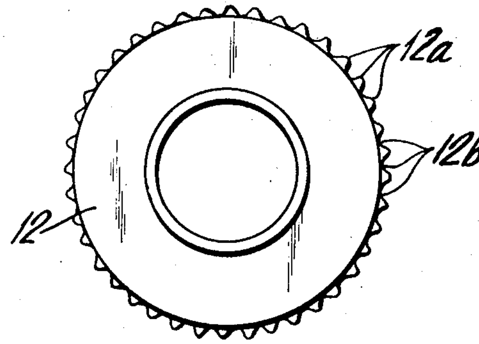

FIG.9

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PRODUCTION OF INTERMITTENTLY FLUTED TUBES

This invention relates to the production of tubes which are longitudinally fluted internally and externally except for portions of their length which form smooth lands. More particularly, the invention relates to a novel method and apparatus for producing such tubes.

Evaporators for making fresh water from sea water vary in design depending on the distillation process used. Distillation systems known as Long Tube Vertical (LTV) or Falling-Film Multi-Effect (FF-ME) make use of heat exchanger tubes with diameters ranging up to 3 inches. In these systems, the heat exchange tubes are arranged vertically. Many studies have shown that for this particular system, tubes with longitudinal flutes on the inner and outer surface (double fluted tubes) improve the rate of heat transfer over that obtained with smooth round tubes having the same external diameter and wall thickness as the fluted tubes.

A basic requirement of the double fluted tube, to permit lacing it into the tube-sheets of the heat exchange chamber, is the provision of smooth lands on both ends of the fluted tube for rolling and sealing it into the tube-sheet. For this purpose, the external diameter of the smooth portion of the tube ends must be essentially the same as the external diameter of the fluted portion of the tube.

Such double fluted or "enhanced" tubes for heat exchangers normally require relatively thin walls of 0.030 to 0.060 inch. Therefore, it is important in the production of these tubes that the stresses created in them during drawing thereof are carefully limited to avoid rupturing of the tubes. The procedures heretofore proposed for their production are not entirely adequate in this respect. Also, these prior procedures leave much to be desired with respect to efficiency and low cost of production.

The principal object of the present invention is to provide a method and apparatus which overcome these deficiencies in the prior art of producing such tubes.

According to the method of the present invention, the tube is passed through a fluting zone where there is formed in the tube, from outside thereof, a first series of deep longitudinal grooves and corresponding ridges spaced circumferentially around the tube. Simultaneously with this forming operation, the tube is formed from inside thereof with a second series of depp longitudinal grooves and corresponding ridges alternating with the grooves and ridges of the first series. In this way, the tube is provided with longitudinal flutes on its inner and outer surface as it proceeds through the fluting zone. In order to provide a smooth land on the tube, the formation of grooves and corresponding ridges from inside the tube is discontinued during further passage of the tube through the fluting zone, at which time is impressed from outside thereof with only shallow grooves aligned longitudinally with respective deep grooves of the aforementioned first series. As a result, the double fluting of the tube is interrupted by an unfluted length of the tube having an external diameter essentially the same as the external diameter of the fluted portion of the tube, the outer surface of this unfluted length having only slight and unobjectionable draw marks left by the fluting die which contributes to the double fluting operation.

An apparatus made according to the invention comprises a fluting die forming a passage through which the

tube is movable longitudinally and having a central longitudinal axis. The die has a series of longitudinal ridges spaced around this axis and partly defining the aforementioned passage, there being valleys between adjacent ridges. A mandrel movable along the axis has a series of longitudinal peripheral ridges aligned with respective vallyes in the die, the mandrel ridges forming valleys aligned with respective ridges of the die. Means are provided for moving the mandrel along the axis from a first position within the die, wherein the ridges of the mandrel and die are received in respective aligned valleys but with a clearance sufficient to accommodate movement of the tube through the die passage, to a second position in which the mandrel is withdrawn from the die so that it does not act upon the tube surrounding the mandrel and passing through the die passage.

These and other features of the invention may be better understood by reference to the following detailed description in conjunction with the accompanying drawings. In the drawings:

FIG. 1 is a longitudinal sectional view of a preferred form of the new apparatus, showing the tube passing through the fluting die with the mandrel positioned in the tube to effect the double fluting operation;

FIG. 2 is a view similar to FIG. 1 but showing the mandrel withdrawn from the die to provide a smooth land interrupting the double fluted portion of the tube;

FIG. 3 is an enlarged sectional view on line 3—3 in FIG. 1;

FIG. 4 is an enlarged sectional view on line 4—4 in FIG. 2;

FIGS. 5 and 6 are sectional views on lines 5-5 and 6—6, respectively, in FIG. 1;

FIG. 7 is a sectional view on line 7—7 in FIG. 2;

FIG. 8 is an enlarged end view of the fluting die shown in FIGS. 1 and 2, and

FIG. 9 is an end view of the mandrel shown in FIGS. 1 and 2.

Referring to FIGS. 1 and 2, the apparatus there shown comprises a fluting die **10** forming a passage **11** through which the tube T is movable longitudinally, this passage having a central longitudinal axis C. As shown particularly in FIG. **8**, the die **10** has a series of longitudinal ridges **10*a*** spaced around the axis C and partly defining the passage **11**, a valley **10*b*** being formed between each pair of adjacent ridges.

A mandrel **12** is movable along the axis C of the die passage and has a series of longitudinal peripheral ridges **12*a*** aligned with respective valleys **10*b*** in the die. As shown particularly in FIG. **9**, the mandrel ridges **12*a*** form valleys **12*b***, the latter being aligned with respective ridges **10*a*** of the die.

It will be understood that the tube T is passed through the fluting die **10** while surrounding the mandrel **12**. In the double fluting operation, the mandrel **12** is positioned within the die (FIG. **1**) so that the die ridges **10*a*** are received in respective aligned valleys **12*b*** of the mandrel, and the mandrel ridges **12*a*** are received in respective aligned valleys **10*b*** of the die. However, the ridges are received in their respective valleys with sufficient clearance to accommodate movement of the tube through the die passage **11**, this movement occurring from right to left in FIGS. **1** and **2**.

Thus, with the mandrel **12** positioned as shown in FIG. **1**, and with the tube moving through the die as previously mentioned, the die ridges **10***a* act upon the outside of the tube to impress a first series of deep longitudinal grooves and corresponding ridges spaced circumferentially around the tube, these grooves and ridges being shown at **15** and **15***a*, respectively, in FIG. **6.** At the same time, the mandrel ridges **12***a* act upon the inside of the tube to impress a second series of deep longitudinal grooves and corresponding ridges indicated at **16** and **16***a*, respectively, in FIG. **6**, the grooves and ridges of this second series alternating with those of the first series.

This double fluting operation is further illustrated in detail in FIG. **3.** As there shown, each die ridge **10***a* engages the outer surface of the tube to press it inwardly into an opposing valley **12***b* of the mandrel, while each mandrel ridge **12***a* engages the inner surface of the tube to press it outwardly into an opposing valley **10***b* of the die. The resulting double fluted portion of the tube is indicated at **T1** and will extend over the length of the tube which passes through the die while the mandrel **12** is in its FIG. **1** position.

When the double fluting of the tube is to be interrupted, the mandrel **12** is withdrawn from the die along the central axis C until it assumes the position shown in FIG. **2.** In this position, the mandrel is located within the part of the tube which is advancing toward the die **10**, and the mandrel ridges **12***a* are disengaged from the inner surface of the tube. Consequently, although the die ridges **10***a* continue to engage the outer surface of the tube, this engagement is relatively light so that it merely draws the tube to a somewhat reduced diameter while forming very shallow grooves or draw marks in the outer surface of the tube. These draw marks, indicated at **20** in FIG. **7**, are not objectionable. Accordingly, the operation as illustrated in FIG. **2** provides the tubes with an essentially smooth portion **T2** extending over the desired length of the tube. By cutting the tube between the ends of its smooth portion **T2**, the desired smooth lands are provided for rolling and sealing the tubes into a tube-sheet.

The operation illustrated in FIG. **2** is shown in further detail in FIG. **4**, from which it will be observed that the tube is engaged only by the die ridges **10***a*. This relatively light engagement does not distort the tube but merely indents its outer surface slightly to form the draw marks **20.**

The axial movements of mandrel **12** within the tube T are accomplished by means of a rod **13** connected to the mandrel and extending through the tube to any suitable mechanism for actuating the rod. An example of such a mechanism is disclosed in U. S. Pat. No. 2,258,242 granted Oct. 7, 1941, and entitled "Apparatus for Drawing Tubes of Multiple Wall Thickness". Of course, the mechanism for pulling the tube T through the die **10** may be of any conventional type used in the drawing of tubes.

By the practice of the present invention, thin-walled tubes can be produced which have a smooth cylindrical portion adjacent a double fluted portion in which the flutes are uniformly distributed around the tube periphery. Examples of the nominal outer diameter (OD) of such tubes and the number of flutes in their double fluted portions are set forth in the following table:

Nominal Tube OD Inches	Typical Number of Uniformly Spaced Flutes
1	10–25
2	20–50
3	30–75

While the procedures described above are intended primarily for use with ductile copper and copper alloys, these same procedures may be used for forming double fluted tubes of other ductile metals, such as aluminum, steel, etc.

The fluting operation using matching dies and mandrels may be performed in one or more drawing operations. Normally, the fluting operation is followed by one or more sink draws in which the fluted tube is drawn through smooth unfluted round dies in order to reduce the fluted tube to the desired final external diameter. The following is a typical procedure used in making Copper Alloy No. 687 double fluted tubes:

Starting Round Tube Prior to Fluting	2.65" OD × 0.040" annealed temper
Draw and Flute	2.6" OD × 0.035" (44 flutes)
Draw — Flute	2.5" OD × 0.035" (44 flutes)
Sink draw with Smooth Round Die	2.34" OD × 0.035" (44 flutes)
Draw over Smooth Round Mandrel to Final Size	2.0" OD × 1.83" ID (under flutes) × 0.035" wall
Anneal	

A tube made according to the above-described procedure is not satisfactory if the longitudinal flutes extend over its entire length. That is, in fabricating the heat exchanger, the tube must be rolled into a tube-sheet at each end; and rolling of an "as-fluted" tube into the tube sheets is difficult and, for certain metals, the rolled "as-fluted" tube ends could fail prematurely when made from alloys susceptible to stress cracking. This is due to the high level of unbalanced residual stresses left in the tube at the end of the tube roll.

On the other hand, these difficulties are avoided when the tube is made according to the present invention. The sink drawing operations performed on the fluted tube draw the tube with its smooth ends to the designed outside diameter. Tubes so processed and annealed, whenever necessary depending on the alloy used, have been found by expensive laboratory tests to be free of the susceptibility to stress cracking after rolling into the tube-sheet.

Fluted tubes are normally required in short lengths, for example, 3 to 20 feet. Production of tubes with smooth ends in short individual lengths on conventional drawbench equipment substantially increases production costs. Lower production costs are achieved through practice of the present invention by forming long fluted tubes with interrupted flutes, where the smooth lands are needed, to make multiples of the designed lengths.

As previously mentioned, when mandrel **12** is withdrawn from die **10** to the position shown in FIG. **2**, the outer surface of tube T is engaged only lightly by the die ridges **10***a* so that the tube is drawn to a somewhat reduced diameter during formation of the shallow grooves or draw marks **20** (FIGS. **4** and **7**). This drawing action to reduce the tube's diameter, which is characteristic of a tube-drawing die, is provided in the present instance by the slope of the die's ridges and valleys as shown at **10***c* and **10***d*, respectively, the slope being toward the die's central axis C in the direction from the entrance end of the die toward its exit end. Thus, referring to FIG. **2**, the drawing action reduces the tube from its initial diameter at the entrance end of the die, as shown at T, to its substantially smaller diameter at the exit end of the die, as shown at T2. It is this drawing operation, of course, which allows ample clearance between the inner surface of tube T and the ridges **12***a* of the mandrel when the latter is retracted to its non-operating position (FIG. **2**) from its operating position (FIG. **1**) wherein these ridges engage and indent the inner surface of the tube.

I claim:

1. In an apparatus for producing intermittently fluted tubing, the combination of a tube-drawing die forming a passage through which a tube is movable longitudinally in one direction and having a central longitudinal axis, said die having integral therewith a series of fixed longitudinal ridges spaced around said axis and partly defining said passage, there being valleys between adjacent ridges, a mandrel movable along said axis and having integral therewith a series of fixed longitudinal peripheral ridges aligned with respective valleys in the die, said mandrel ridges forming valleys aligned with respective ridges of the die, and means for moving said mandrel along said axis in a direction opposite to said one direction and from a first position within the die, wherein said ridges are received in the respective aligned valleys but with a clearance sufficient to accommodate said movement of the tube through said die passage, to a second position wherein said mandrel ridges are withdrawn longitudinally from said valleys in the die.

2. In the production of intermittently fluted tubing, the method which comprises passing a tube lengthwise through a fluting zone while reducing the tube diameter and forming in the tube from a first sub-zone outside thereof a first series of deep longitudinal grooves and corresponding ridges spaced circumferentially around the tube and while forming in the tube from a second sub-zone, located inside the tube and within said first sub-zone, a second series of deep longitudinal grooves and corresponding ridges alternating with said grooves and ridges of the first series, and intermittently discontinuing said formation of said second series of grooves and corresponding ridges by moving said second sub-zone lengthwise of the tube to retract said second sub-zone from within the first sub-zone into an unreduced portion of the tube and while impressing in the tube from said first sub-zone, during passage of the tube therethrough, only shallow grooves aligned longitudinally with respective deep grooves of said first series.

3. The combination according to claim **1**, in which the die has an entrance end and an exit end, the ridges and valleys of the die sloping toward said central axis in the direction from said entrance end to said exit end, whereby the die effects said tube-drawing.

4. The combination according to claim **3**, comprising also a said tube extending through said die passage and containing the mandrel, the tube at said entrance end having an inner diameter sufficient to provide a clearance between the inner wall of the tube and said ridges of the mandrel, the tube at said exit end having its inner diameter reduced sufficiently for said mandrel ridges to engage and indent the inner surface of the tube.

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