United States Patent [19]

Pasternak

[11] **3,727,682**

[45] **Apr. 17, 1973**

[54] **HEAT EXCHANGERS AND THE METHOD OF MAKING THE SAME**

[75] Inventor: **Stephen F. Pasternak,** Park Ridge, Ill.

[73] Assignee: **Peerless of America, Incorporated,** Chicago, Ill.

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[21] Appl. No.: **13,297**

[52] **U.S. Cl.** **165/183**

[51] **Int. Cl.** **F28f 1/14**

[58] **Field of Search** 165/181, 183, 184

[56] **References Cited**

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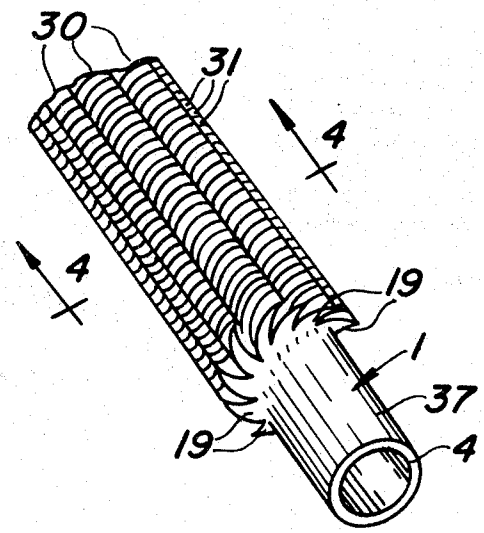
Primary Examiner—Charles Sukalo

Attorney—Johnston, Root, O'Keeffe, Keil, Thompson & Shurtleff

[57] **ABSTRACT**

A tubular heat exchanger having spine-type fins formed integrally from the wall thereof and disposed therearound, with the fins cut from ribs extending longitudinally of the heat exchanger, and a method of manufacture which includes rotary movement between a tool and an elongated, ribbed tubular member relative to the longitudinal axis of the latter.

7 Claims, 14 Drawing Figures



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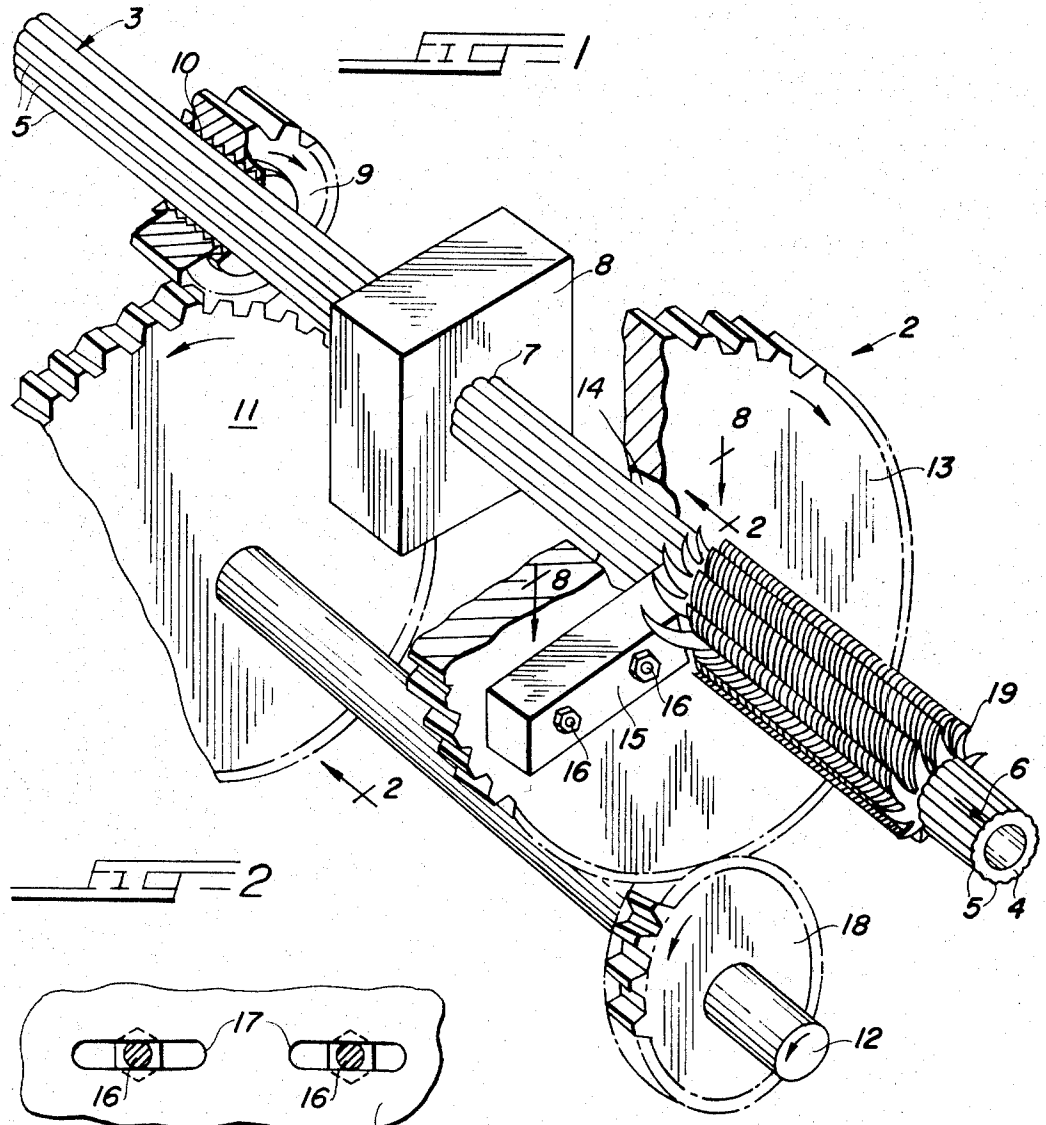
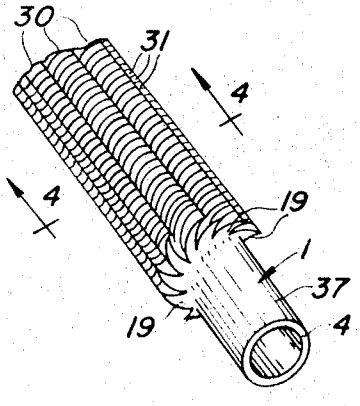


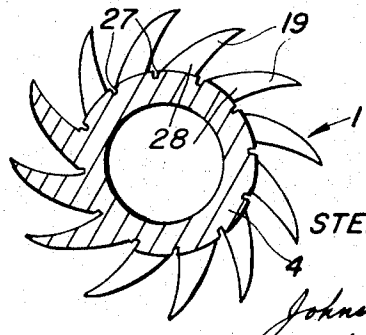
FIG 1

FIG 2

FIG 3

FIG 4





INVENTOR.
STEPHAN F. PASTERNAK

Johnston, Root, O'Keefe, Keil
BY Thompson & Shurtleff

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FIG 5

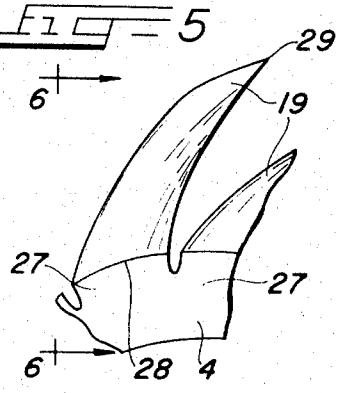


FIG 6

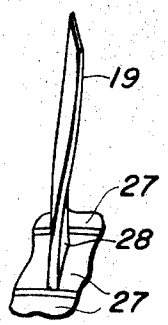


FIG 7

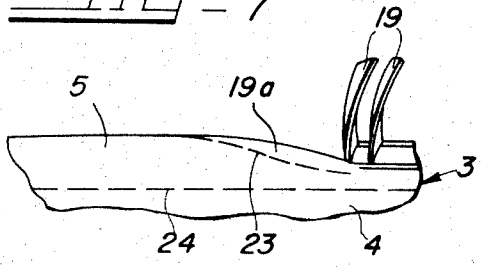


FIG 8

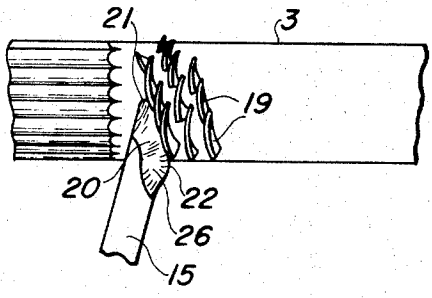


FIG 9

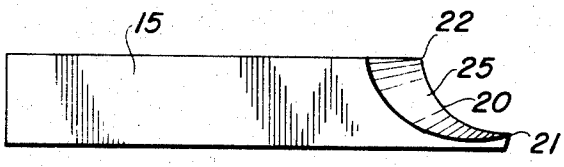


FIG 11

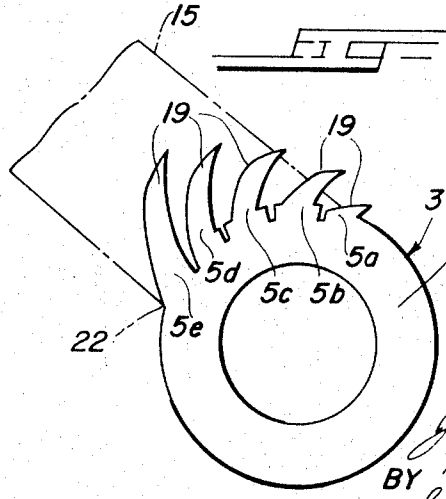
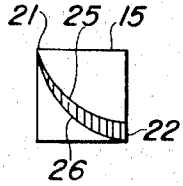


FIG 10



INVENTOR.
STEPHAN F. PASTERNAK

BY Johnston, Root, O'Keefe, Keil, Thompson & Shurtleff ATTYS

FIG — 13

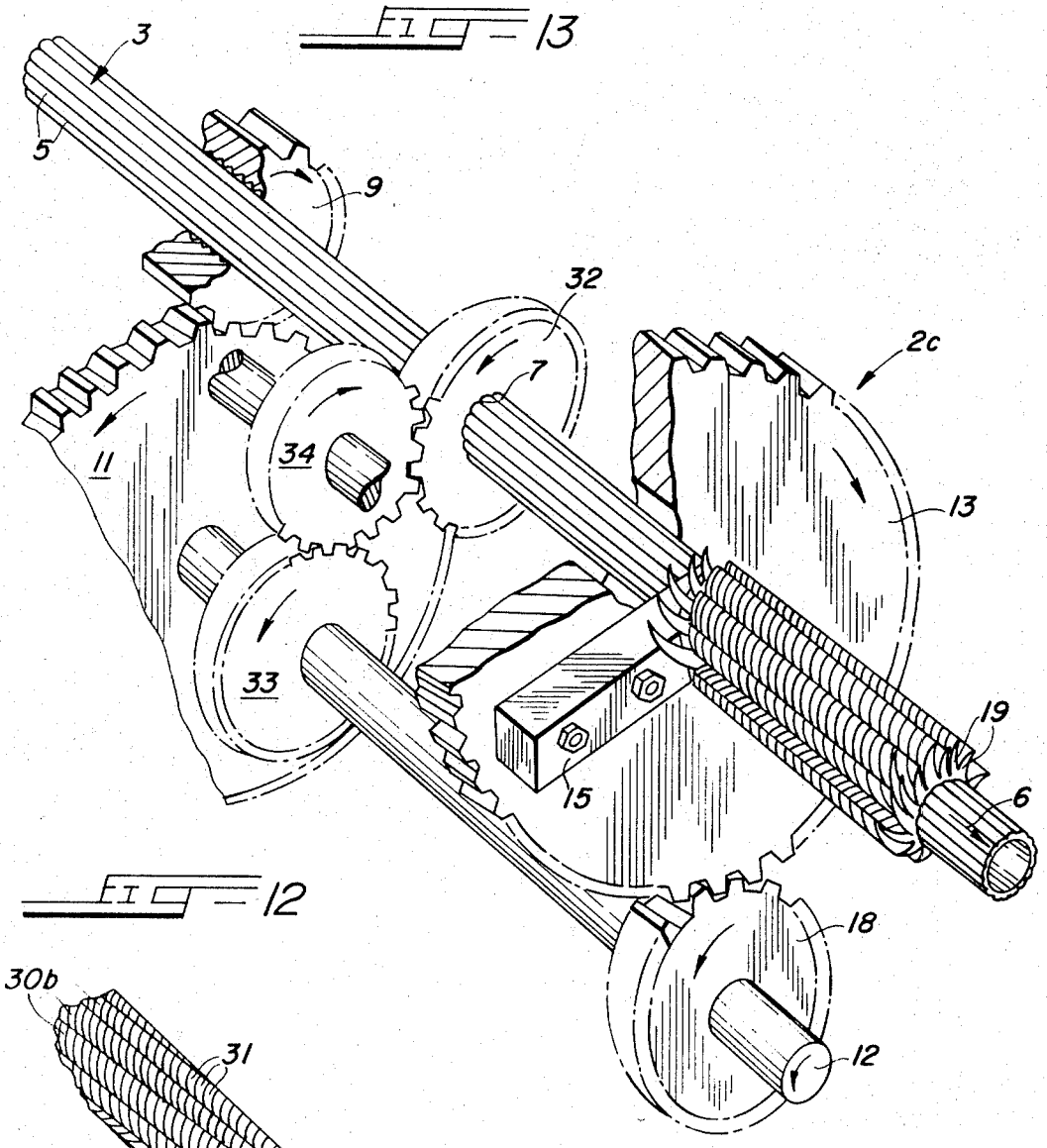
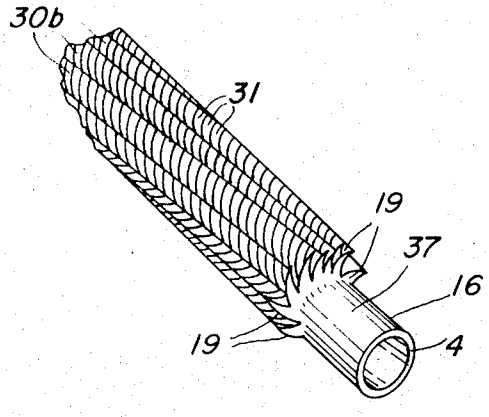


FIG — 12

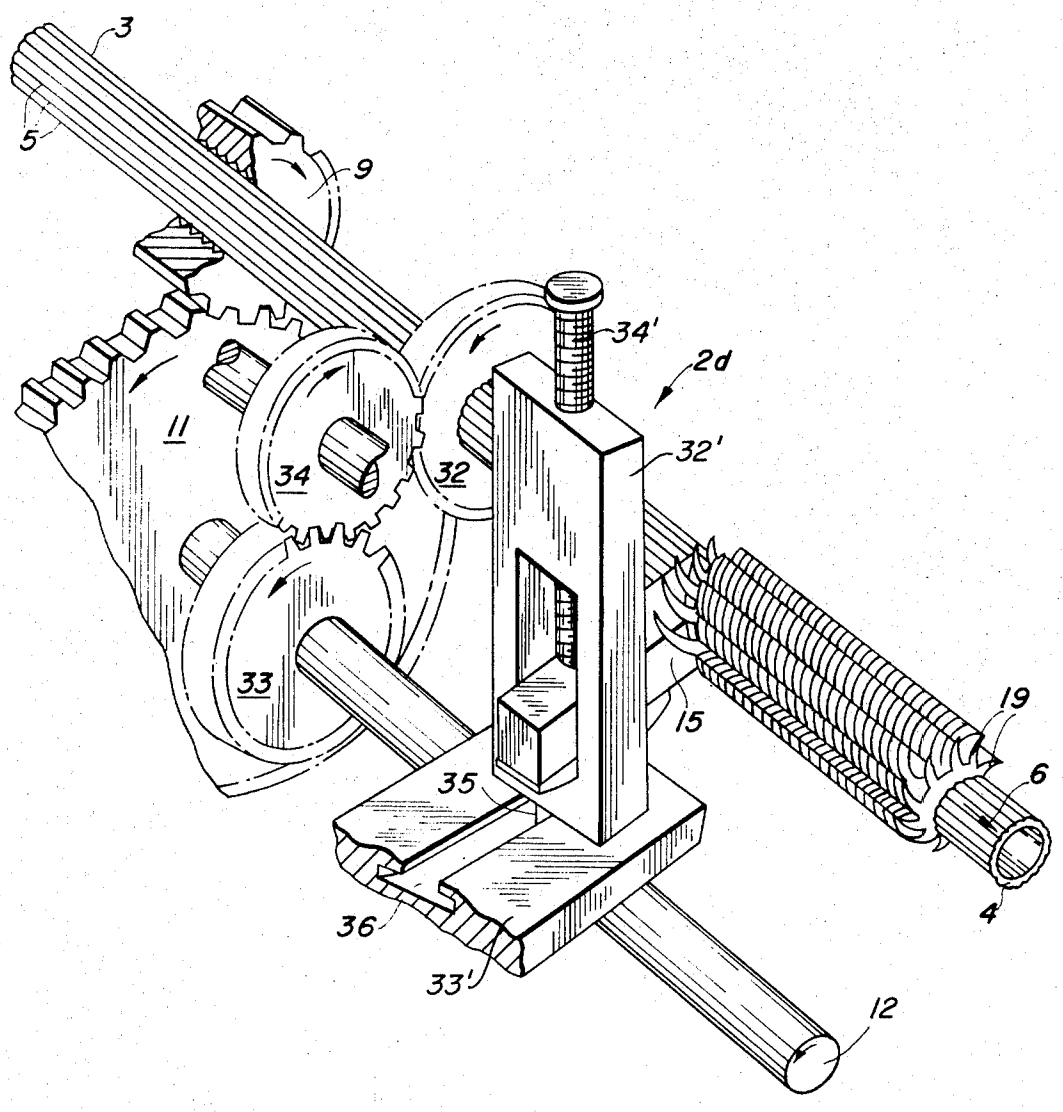


INVENTOR.
STEPHAN F. PASTERNAK

Johnston, Root, O'Keefe,
BY Keil, Thompson & Shurtleff

Attys

FIG — 14



INVENTOR.
STEPHAN F. PASTERNAK

Johnston, Root, O'Keefe,
BY Keil, Thompson & Shurtleff

Attys.

HEAT EXCHANGERS AND THE METHOD OF MAKING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to heat exchangers and the method of making the same.

It is primary object of the present invention to afford a novel heat exchanger.

It is another object of the present invention to afford a novel method of making heat exchangers.

Another object is to enable a novel heat exchanger of the type embodying integrally formed spine-type fins to be afforded in a novel and expeditious manner.

Heretofore, the integral spine-fin type of heat exchangers used in the heat exchanger fields commonly have been of three types, namely, heat exchangers embodying needle-like spines, such as, for example, those disclosed in R. W. Kritzer U.S. Pat. No. 2,247,243; heat exchangers embodying spines cut or gouged out from one side, or from opposite sides, of a heat exchanger body, such as, for example, those disclosed in R. W. Kritzer U.S. Pat. No. 3,202,212; and heat exchangers formed by transversely slitting longitudinally extending fins, such as, for example, those shown in R. W. Kritzer U.S. Pat. No. 3,360,040.

Although spine-type heat exchangers of the aforementioned types heretofore known in the art have been highly successful and have had much commercial success, they have certain inherent disadvantages. For example, in the manufacture of heat exchangers of the type shown in the aforementioned Kritzer U.S. Pat. No. 2,247,243 the needle-like spines are cut or gouged from the tubular wall of the heat exchanger in relative thin, sharp slivers, with rotary cutters, traveling on a planetary path relative to the tubular member being commonly used for this purpose. The speed of production commonly realized in forming such heat exchangers has been relatively slow, being in the nature of one or two linear feet of tubing per minute.

Similarly, in the production of heat exchangers of the type shown in the aforementioned Kritzer U.S. Pat. No. 3,202,212 spines are gouged from ribs on one face or opposite faces of tubular members which are preferably rectangular in shape. A method commonly used for producing such spines has been to use reciprocating cutters, which reciprocated longitudinally of the heat exchanger. Such a method of production, of course, has several disadvantages, such as, for example, that no work is performed on the return stroke of such cutters. The speed of production for such heat exchangers also has been relatively slow, commonly being in the nature of two to four linear feet of tubing per minute.

Also, although the production of heat exchangers of the type shown in the aforementioned Kritzer U.S. Pat. No. 3,360,040, wherein spines are formed by transversely slitting elongated fins, may, under proper conditions, be relatively high, such types of heat exchangers have certain inherent disadvantages, such as, for example, that they are limited as to the number of spines which may be formed around the periphery of the tubular member, when such relatively good production speed is afforded, because of the necessity of affording space therearound for the spine-forming mechanisms to engage the separate fins.

It is an important object of the present invention to overcome difficulties heretofore known in the art, and to enable heat exchangers having integral spine-type fins to be commercially produced in a novel and expeditious manner at a production speed substantially higher than the speeds heretofore known in the art.

An object ancillary to the foregoing is to enable heat exchangers having integral spine-type fins to be commercially produced at production speeds several times greater than commercial production speeds heretofore known in the art.

Heat exchangers of the type embodying spine-type fins projecting outwardly from a tubular member and disposed therearound have been heretofore known in the art in the form of heat exchangers wherein the fins are formed separately from the tubular member in ribbon-like form, and the ribbons are then wrapped around the body portion and attached thereto. This, of course, has the inherent disadvantage of requiring a plurality of separate operations, and affording a fin structure which must be attached or bonded to the tubular member, with the attendant danger of poor heat transfer between the fins and tubular member. It is another object of the present invention to overcome such disadvantages.

Another object of the present invention is to enable a novel heat exchanger to be afforded, which is of the type which embodies spine-type fins projecting outwardly from and disposed completely around the body portion thereof, and wherein the fins are formed integral with the body portion as distinguished from fins formed separately and then attached to a body portion.

Another object of the present invention is to afford a novel heat exchanger embodying a tubular body portion having elongated ribs extending longitudinally thereof and spaced therearound, with spine-type fins projecting outwardly from the ribs.

An object ancillary to the foregoing is to enable such ribs to be closely spaced around the body portion.

Another object is to enable spine-type fins to be formed in a novel and expeditious manner from ribs extending longitudinally of a tubular body member.

Yet another object is to afford a novel method of producing a heat exchanger having a tubular body portion with spine-type fins projecting therefrom, wherein a cutting tool and a tubular member are rotated relative to each other in such a manner that the tool passes around the peripheral surface of the tubular member in a manner effective to cut the fins from the peripheral surface and to raise them into outwardly projecting position.

A further object is to afford a novel method of the aforementioned type wherein such fins are cut and raised in the aforementioned manner from laterally spaced, longitudinally extending outwardly projecting ribs on the periphery of such a tubular member.

Another object is to enable such fins to be so cut and raised from ribs in a novel and expeditious manner whereby the same cutting tool simultaneously cuts and raises fins on a plurality of adjacent ribs.

A further object of the present invention is to afford a novel heat exchanger having spine-type fins projecting therefrom and spaced around and longitudinally of the tubular body portion thereof, and wherein the shape and configuration of the fins may be controlled in a novel and expeditious manner.

Another object is to enable a novel heat exchanger having spine-type fins cut from the material on the outer periphery of a tubular body member, and wherein the length of the fins is substantially the same as the length of the cut made in the body member.

Another object of the present invention is to afford a novel heat exchanger of the aforementioned type, which is practical and efficient in operation and which may be readily and economically produced commercially.

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

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a somewhat diagrammatic, perspective view illustrating one embodiment of the present invention and apparatus suitable for carrying out certain steps employed in the practice of the method of the present invention;

FIG. 2 is a fragmentary, detail sectional view taken substantially along the line 2—2 in FIG. 1;

FIG. 3 is a fragmentary perspective view of a heat exchanger embodying the principles of the present invention;

FIG. 4 is an enlarged, detail sectional view taken substantially along the line 4—4 in FIG. 3;

FIG. 5 is an enlarged, fragmentary, detail elevational view of a portion of the heat exchanger shown in FIG. 4;

FIG. 6 is a fragmentary, elevational view looking in the direction of the arrow 6—6 in FIG. 5;

FIG. 7 is a fragmentary, side elevational view of a portion of the stock shown in FIG. 1;

FIG. 8 is a fragmentary, top plan view looking substantially in the direction of the arrows 8—8 in FIG. 1;

FIG. 9 is a bottom plan view of the tool shown in FIG. 8;

FIG. 10 is an end elevational view of the tool shown in FIG. 8;

FIG. 11 is a diagrammatic view illustrating the operation of the tool shown in FIG. 1 on the work piece shown therein;

FIG. 12 is a fragmentary perspective view, similar to FIG. 3, but showing a modified form of the heat exchanger;

FIG. 13 is a perspective view similar to FIG. 1, but illustrating other apparatus suitable for carrying out steps employed in the practice of the method of the invention; and

FIG. 14 is a perspective view similar to FIGS. 1 and 13, but illustrating still other apparatus suitable for carrying out steps employed in the practice of the method of the invention.

DESCRIPTION OF THE EMBODIMENTS SHOWN HEREIN

In FIG. 3 of the drawings is shown a presently preferred form of heat exchanger 1, embodying the principles of the present invention; and in FIG. 1 is illustrated apparatus 2 for carrying out certain steps employed in the practice of the method of the present invention.

In FIG. 1, ribbed tubular stock 3 is shown being fed through the apparatus 2 to afford a heat exchanger 1 of the form shown in FIG. 3. The tubular stock 3 embodies a wall 4 having a plurality of outwardly projecting, closely spaced, elongated ribs 5 on the periphery thereof, the ribs 5 extending parallel to the longitudinal axis of the tubular stock 3.

In the operation of the apparatus 2 shown in FIG. 1, the tubular stock 3 is fed longitudinally in the direction of the arrow 6 through an opening 7 in a holding member 8 by a feed member 9. The holding member 8 is a stationary part of the apparatus 2, and the opening 7 is fluted, and is complementary in shape to the outer periphery of the ribbed stock 3, being of such size that the stock 3 fits therein with a relatively snug, but freely slidable fit. Thus, the holding member 8 is effective to hold the stock 3 against rotation during the passage thereof through the apparatus 2.

The feed member 9 may be of any suitable type, but is shown in FIG. 1 as a gear disposed around the tubular stock 3 and having internal threads 10 bitingly engaged with the outer periphery of the ribs 5 on the stock 3. The gear 9 is suitably journaled in the apparatus 2 and is operatively meshed with a gear 11 mounted on a drive shaft 12. Rotation of the drive shaft 12 in a counterclockwise direction, as viewed in FIG. 1, is effective to drive the gear 11 in a counterclockwise direction and thereby drive the feed member 9 in a clockwise direction. Such rotation of the feed member 9, through the engagement of the threads 10 with the outer periphery of the tubular stock 3, is effective to advance the tubular stock 3 through the holding member 8 in the direction of the arrow 6.

Another gear 13, having an opening 14 therethrough, is suitably journaled in the apparatus 2 on the opposite side of the holding member 8 from the feed member 9, and with the opening 14 in axial alignment with the opening 7 in the holding member 8, FIG. 1. The opening 14 is substantially larger in diameter than the outside diameter of the tubular stock 3, and during operation of the apparatus 2, the stock 3, which is fed through the holding member 8 by the feed member 9, is advanced through the opening 14 in the gear 13. A tool 15 is adjustably mounted on the face of the gear 13 remote from the holding member 8 by suitable means such as bolts 16 extending through slots 17 in the gear 13, FIGS. 1 and 2. The gear 13 is operatively meshed with a gear 18 mounted on the drive shaft 12, and the aforementioned counterclockwise rotation of the drive shaft 12 is effective to similarly drive the gear 18, and thereby rotate the gear 13 in a clockwise direction, as viewed in FIG. 1. Such rotation of the gear 13 around the tubular stock 3 is effective to move the tool 15 around the periphery of the stock 3 in a cutting and forming operation effective to cut and raise spine-type fins 19 on the tubular stock 3 as the latter moves away from the gear 13, as will be discussed in greater detail presently.

The tool **15**, preferably, is of a type which embodies an elongated cutting edge **20**, as illustrated in FIGS. **8–11**, which cutting edge **20**, when the tool **15** is properly disposed in operative position relative to the tubular stock **3** during operation of the apparatus **2**, is operatively engaged with a plurality of the ribs **5**, FIGS. **8** and **11**, so that spines **19** are being simultaneously formed on these ribs. Thus, as diagrammatically illustrated in FIG. **11**, as the leading end **21** of the cutting edge **20**, during rotation of the tool **15** in a clockwise direction around the tubular stock **3**, operatively engages a rib, such as the rib **5***a*, and begins to form a spine **19** thereon, the other portions of the tool **15** disposed between the leading end **21** and the trailing end **22** of the cutting edge **20** are in progressively further advanced engagement with ribs such as the ribs **5***b*, **5***c*, **5***d* and **5***e* disposed in a counterclockwise direction to the rib **5***a*, as viewed in FIG. **11**.

During operation of the apparatus **2**, the tool **15** is so disposed relative to the tubular stock **3**, that during such rotation of the tool **15** around the stock **3**, as the leading end **21** of the cutting edge **20** moves into engagement with one of the ribs **5**, and then the cutting edge **20** moves in a longitudinal direction, transversely across the thus engaged rib, to a point wherein the trailing edge **22** moves away from that particular rib, the cutting edge **20** slices downwardly through the rib **5** along a downwardly and forwardly projecting path relative to the length of the tubular stock **3**, as illustrated by the broken line **23** in FIG. **7**. Such movement of the tool **15** relative to the rib **5** is effective to slice a portion of the rib **5**, such as that represented by the reference numeral **19***a* in FIG. **7**, from the rib **5**, the slicing by the tool **15** preferably terminating at its lower end in upwardly spaced relation to the bottom **24** of the rib **5**, as illustrated in FIG. **7**. During such operation of the tool **15**, the lower face **25** of the cutter portion thereof, FIG. **9**, rides downwardly along the rib **5** on the side of the tool remote from the portion **19***a* being sliced therefrom, and the upper face **26** of the cutter portion, FIG. **8**, rides along the lower face of the portion **19***a*, in engagement therewith, and is effective to raise the portion **19***a* into outwardly projecting position to thereby afford an outwardly projecting spine, such as the spines **19** shown in FIG. **7** on the wall portion **4** of the tubular stock **3**.

Thus, it will be seen that the spines **19** are cut from the ribs **5** in the apparatus **2** with a slicing action, as distinguished from the gouging action, as occurs when a cut is made with a cutter that reciprocates along the path of cut, such as, for example, in a planing type of action.

One of the difficulties in forming spines on heat exchangers, such as, for example, the spines on heat exchangers of the form shown in the aforementioned Kritzer U.S. Pat. No. 3,202,212, by gouging the spines from the underlying body portion of the heat exchanger, has been that it is difficult to control the thickness and length of spine for various depths of cut, because of the tendency of such operations to compact the spines, longitudinally, during such formation thereof. Because of this compacting action in so gouging spines, it commonly has been necessary to afford a length of cut in such operations that was as much as twice the length of the finished spine.

One of the advantages of forming spines on heat exchangers in accordance with the preferred practice of the method of the present invention is that it may be accomplished with relatively little, if any, such compacting. With the spines **19** formed by a tool such as the tool **15**, in the previously described manner, the individual spines **19** are severed or cut from the respective ribs **5** with a slicing action, wherein the cutting edge moves longitudinally through the material being cut, and the thus severed portion of the rib is then turned upwardly so that very little force, in a compacting direction, is applied to the spine during the formation thereof. Such a method of operation even enables spines to be formed which are of relatively small thickness, such as, for example, ten-thousandths of an inch, with the spines having an over-all finished length which is little, if any, less than the length of cut used in forming the spines.

It will be remembered that another common disadvantage in methods heretofore known in the art for producing heat exchangers having spine-type fins thereon, has been the relatively low speed of production inherent in the methods used and the types of heat exchangers formed, such speeds commonly being as little as less than a linear foot of tubing per minute and a maximum of three or four feet per minute. It is anticipated that in the manufacture of heat exchangers in accordance with the principles of the present invention, production speeds of 25 to 30 linear feet of tubing per minute, and more, may be realized.

In the preferred form of heat exchanger **1** shown in the drawings, FIGS. **3–6**, the spines **19** project outwardly from the wall portion or tubular body member **4** in a relatively gently curving arc, transversely to the length of the wall **4**, throughout substantially the entire lengths of the spines **19**. In the formation of the spines **19**, the ribs **5** of the tubular stock **3** have been reduced to relatively small outwardly projecting remainders **27**, FIGS. **4** and **5**, throughout the entire length of the heat exchanger **1** disposed between the spines **19** at the opposite extremities thereof. The base portions **28** of the fins **19** are integral with the respective rib remainders **27** to afford good heat transfer connection between the fins **19** and the wall portion **4** of the heat exchanger **1**.

The ribs **5** on the tubular stock **3** are preferably rounded at their radially outer extremities. With this construction, and with the spines **19** formed in the aforementioned manner, the width of the spines **19**, transversely to the length of the wall **4**, tapers inwardly somewhat between the base **28** and the outer extremity **29** thereof, tending to terminate in a relatively narrow point at the outer extremity **29**, FIG. **5**. With the spines **29** being formed in the manner heretofore described with respect to the operation of the apparatus **2**, wherein the tool **15** is rotated around the longitudinally advancing tubular stock **3**, the spines **19** are sliced and formed from the ribs **5** along a helical path, with the pitch of the helix being equal to the longitudinal advance of the tubular stock **3** relative to the tool **15** during each revolution of the tool **15** around the tubular stock **3** and between each successive operative engagement of the tool **15** with each of the respective ribs **5**.

Preferably, the shape of the cutting tool **15** is such that during the initial engagement of the cutting edge **20** thereof with the outer face of each respective rib **5**,

the cut 23, FIG. 7, is formed at a shallow angle, such as 2° to 3°, to the outer peripheral surface of the respective rib 5, with the cut thereafter progressing at an ever increasing angle to thereby afford a relatively smoothly arcuate cut. With the tool 15 thus shaped, the thickness of the fins 19, longitudinally of the ribs 5, tapers from a narrow thickness at the outer extremities thereof to a greater thickness at the base portions thereof. The increased width and increased thickness of the fins 19 from the outer extremities thereof to the bases thereof afford effective heat transfer paths for the transfer of heat between the wall portion 4 of the heat exchanger 1 and the surrounding working fluid, such as, for example, air or liquid.

The tool 15, also is preferably so formed that the wiping action of the top face 26 thereof against the lower face of the fin 19 being severed and raised from a respective rib 5 is such that during the raising of the fin 19 it is relatively smoothly curved substantially throughout its entire length into an arcuate shape, FIG. 4. Also, the shape of the tool 15 preferably is such that the stresses exerted on the fins 19 as they are severed and raised from the respective ribs 5 is such that they are twisted axially through a partial turn between the bases and the outer extremities thereof, with the outer extremities being displaced around their axes from the bases at an angle of 10° to 30°. With such construction of the heat exchanger 1, a relatively small overall outside diameter is afforded with relatively long fin lengths. Also, the fins are so disposed that they tend to effect turbulence in the air or other fluid passing therebetween longitudinally of the wall 4, as well as turbulence in the air or fluid passing therebetween transversely to the length of the wall 4.

The fins 19 of the heat exchanger 1, shown in FIG. 3, are spaced along each of the ribs 5, with the ribs 5 being disposed in substantially parallel relation to the longitudinal axis of the wall 4. In addition, in the heat exchanger 1, adjacent fins 19 on adjacent ones of the ribs 5 are spaced from each other in rows extending along a helical path extending around the wall 4, with the adjacent ones of the rows of transversely spaced fins 19 being disposed on respective turns of the aforementioned helical path.

As will be appreciated by those skilled in the art, although the form of heat exchanger 1 shown in FIG. 3 illustrates the presently preferred form of heat exchanger embodying the present invention, it is shown only by way of illustration and not by way of limitation and other forms of heat exchangers may be afforded, such as, for example, heat exchangers wherein the fins are disposed on two or more helical paths, or are disposed on spaced rows extending around the wall 4 in substantially perpendicular relation to the longitudinal axis thereof, without departing from the broader aspects of the present invention.

In FIG. 12 a modified form of heat exchanger 1*b* is shown. The heat exchanger 1*b* is similar in many respects to the heat exchanger 1 shown in FIG. 3, and parts which are identical to parts shown in FIG. 3 are indicated by the same reference numerals and parts which are similar, but have been substituted for corresponding parts are indicated by the same reference numerals with the suffix "*b*" added.

The heat exchanger 1*b* is identical in construction to the heat exchanger 1 except that the rows 30*b* of fins 19, which extend longitudinally of the wall 4 are helically disposed relative to the longitudinal axis of the wall 4 of the heat exchanger 1*b* rather than being disposed in substantially parallel relation thereto, as in the heat exchanger 1. Such construction may be afforded in any suitable manner, such as, for example, by extruding the longitudinal ribs on the tubular stock from which the heat exchanger 1*b* is formed in the aforementioned helical paths. However, preferably, the tubular stock is extruded with the ribs 5 thereon disposed in parallel relation to the longitudinal axis of the stock, in the same manner as the tubular stock 3 shown in FIG. 1, and the stock is subsequently twisted around its longitudinal axis to afford the helical curvature of the ribs. Such stock may be fed through the apparatus 2 in the same manner as the stock 3 shown in FIG. 1, to thereby afford the heat exchanger 1*a* shown in FIG. 12, the fluting in the opening 7 of the holding member 8 merely being changed to accommodate the helical shaped ribs on the tubular stock.

In FIG. 13 a modified form of apparatus 2*c* is shown, and parts thereof which are the same as parts shown in FIG. 1 are indicated by the same reference numerals. In the apparatus 2*c*, as in the apparatus 2, a drive shaft 12, rotating in a counterclockwise direction is effective through a gear 18 mounted thereon to rotate a gear 13 in a clockwise direction and thereby correspondingly rotate a tool 15 around tubular stock 3 having longitudinally extending ribs 5 thereon. A feed member 9 is driven by a gear 11 mounted on the drive shaft 12 to advance the tubular stock 3 through the gear 13 in the direction of the arrow 6, as indicated in FIG. 13. Thus, in all these respects, it will be seen that the apparatus 2*c* is the same as the apparatus 2.

However, in the apparatus 2*c*, the holding member 8 is omitted and a gear 32 having an opening 7 therethrough is journaled in the apparatus 2*c*. A gear 33 mounted on the drive shaft 12 is operatively meshed with an idler gear 34, which is in mesh with the gear 32, to thereby rotate the gear 32 in a counterclockwise direction upon corresponding rotation of the drive shaft 12. Like the opening 7 in the holding member 8 of the apparatus 2, the opening 7 in the gear 32 is complementary in size and shape to the outer periphery of the tubular stock 3. The tubular stock 3 in the apparatus 2*c* extends through the opening 7 in the gear 32, between the feed member 9 and the gear 13 so that during operation of the apparatus 2*c*, when the drive shaft 12 is causing the tool 15 to rotate in a clockwise direction around the tubular stock 3, it is also causing the gear 32 to rotate in the opposite, or clockwise, direction and thus turn the tubular stock 3 around its longitudinal axis.

The tool 15 in the apparatus 2*c*, shown in FIG. 13, is effective to slice and form the spines 19 on the tubular stock 3 mounted therein in the same manner as the tool 15 is effective to operate in the apparatus 2, shown in FIG. 1. The primary difference between the apparatus 2*c* and the apparatus 2 is that during the operation of the apparatus 2*c* both the tubular stock 3 and the tool 15 are being physically rotated, with the rotation being in opposite directions so that the tool 15 in the apparatus 2*c* may rotate at a slower speed than the tool 15

in the apparatus 2 while still affording the same speed of production as in the apparatus 2. On the other hand, if desired, it will be seen that the speed of production may be increased by using the apparatus 2*c* and driving the tool 15 thereof at the same speed of rotation as that of the tool 15 of the apparatus 2.

In FIG. 14 of the drawings is shown another form of apparatus 2*d* for carrying out the method of the present invention. This apparatus, also, is similar to the apparatus 2 shown in FIG. 1, and parts which are the same as parts of the apparatus 2 are indicated by the same reference numerals.

The apparatus 2*d* embodies the same drive as the apparatus 2*c*, shown in FIG. 13, for the tubular stock 3. This drive includes the drive shaft 12 and the gear 11 for driving the feed member 9, and the gears 33 and 34 for driving the gear 32, so that, in the operation of the apparatus 2*d*, the tubular stock 3 is rotated in a counterclockwise direction, as viewed in FIG. 14, and is fed longitudinally in the direction of the arrow 6. However, unlike the apparatuses shown in FIGS. 1 and 13, the tool 15 in the apparatus 2*d* is adjustably, but stationarily mounted. Such mounting of the tool 15 may be accomplished in any suitable manner, but is shown in FIG. 14 as being effected by means of a clamp 32′ mounted on a carriage 33′, which may be stationarily positioned in the apparatus 2*d*. The tool 15 in the apparatus 2*d* is releasably secured in the clamp 32′ by a bolt 34′, and the clamp 32′ is adjustable longitudinally of the carriage 33′, and may be secured thereto by any means well known in the art, such as, for example, a clamp 35 engageable in a longitudinal slot 36 in the carriage 33′.

In the operation of the apparatus 2*d*, shown in FIG. 14, the rotation of the tubular stock 3 around its longitudinal axis is in a counterclockwise direction, so that the relative movement between the tool 15 and the stock 3 in the apparatus 2*d* is the same as that of the apparatus 2 shown in FIG. 1. Thus, during operation of the apparatus 2*d*, spines 19 are formed on the ribs 5 projecting radially outwardly from the wall 4 of the tubular stock 3 in the same manner as the fins 19 are formed in the operation of the apparatus 2, the only difference in operation being that, in the apparatus 2, the tool 15 rotates and the tubular stock 3 does not, and, in the apparatus 2*d*, the reverse occurs, namely, the tubular stock 3 rotates and the tool 15 does not.

It is to be observed that in FIGS. 1, 13 and 14 the first spines 19 formed on the tubular stock 3 shown therein are shown as formed in inwardly spaced relation to the leading end of the stock 3 as it moves through the respective apparatuses. As will be appreciated by those skilled in the art, this is merely by way of illustration, and not by way of limitation, and the first spines 19 may be formed on the tubular stock in closely adjacent relationship to the leading end thereof, if such construction is desired. However, with the spines 19 formed on the tubular stock 3 in the manner shown in FIGS. 1, 13 and 14, after the spine-forming operations have been completed on the tubular stock 3, the ribs extending ahead of the first spines 19 may be removed from the periphery of the wall 4, such as, by grinding, to afford an end portion having a smooth peripheral surface 37, as shown on the heat exchangers 1 and 1*b* illustrated in FIGS. 3 and 12, respectively, to thus afford a connecting nipple, or the like, at the end of the heat exchanger 1. On the other hand, if desired, the stock 3 may be cut off between the adjacent rows 31 of spines 19 or immediately adjacent the leading spines 19, so as to afford a heat exchanger, not shown, wherein the spines 19 are disposed immediately adjacent to the end of the wall 4. It will be understood, of course, that any one of these constructions may be afforded at either one or both ends of the completed heat exchangers 1 and 1*a*.

From the foregoing it will be seen that the present invention affords a novel method for manufacturing heat exchangers of the integral spined-fin type. It is well adapted for use on various materials, such as, for example, the softer metals, such as, for example, copper and aluminum tubing, as well as the harder metals, such as, for example, stainless steel tubing.

Also, it will be seen that the present invention affords a novel method of making heat exchangers of the spined-fin type, which is well adapted for high speeds of production.

In addition, it will be seen that the present invention affords a novel method of manufacturing heat exchangers of the aforementioned spined-fin types at high production speeds, with the spines spaced from each other around the wall of the heat exchanger at substantially any desired distance, and with the spacing being uniform or non-uniform, as desired. Also, if desired, this may be accomplished with only one cutting tool, the spacing of the longitudinally extending ribs on the tubular stock from which the heat exchanger is formed, determining the spacing of the spines around the wall of the heat exchanger.

Furthermore, it will be seen that the present invention affords a novel method for forming heat exchangers of the aforementioned type, which is well adapted to handle tubular stock of substantially any practical, desired length. Thus, it will be seen that straight tubular stock of various lengths may be fed through any of the apparatuses shown in FIGS. 1, 13 and 14, and, if desired, tubular stock even could be fed from a coil, or the like, through apparatus of the type shown in FIG. 1, in the practice of the method of the present invention.

In addition, it will be seen that the method of the present invention affords a novel method of forming heat exchangers having spined-fins disposed therearound, with the fins being of various selected or desired shapes. This, of course, can be accomplished by the proper formation of the tool 15. However, equally, if not more importantly, this also can be accomplished by varying the shapes of the ribs 5 on the tubular stock 3.

Furthermore, it will be noted that the present invention affords a novel heat exchanger of the aforementioned spined-fin type, wherein the fins are spaced longitudinally along ribs on the heat exchanger, and, in addition, may be spaced, at substantially any desired spacing, around the entire periphery of the heat exchanger.

Thus, it will be seen that the present invention affords a novel heat exchanger, which is practical and efficient in operation and which may be readily and economically produced commercially; and, in addition, affords a novel method of making heat exchangers.

Thus, while I have illustrated and described the preferred embodiments of my invention, it is to be un-

derstood that this is capable of variation and modification, and I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. A heat exchanger element comprising
   a. a tubular member having an elongated wall,
   b. a plurality of outwardly projecting ribs integral with and extending longitudinally of said wall in laterally spaced relation, and
   c. a series of spines projecting outwardly from the outer longitudinal edges of said ribs,
   d. said spines
      1. having base portions integral with said ribs,
      2. being spaced apart along the length of said ribs, and
      3. being longitudinally curved transversely to the length of said ribs.

2. A heat exchanger element as defined in claim 1, and in which
   a. said spines are twisted around their longitudinal axes.

3. A heat exchanger element as defined in claim 1, and in which
   a. said spines are spaced from each other, laterally of the length of said wall, along a helix.

4. A heat exchanger element as defined in claim 1, and in which
   a. said ribs extend along said wall in a helix.

5. A heat exchanger as defined in claim 1, and in which
   a. said base portions are wider in a direction transverse to the length of said respective ribs to which they are integral than in the direction longitudinally of said respective ribs.

6. A heat exchanger comprising
   a. a tubular member having an elongated wall, and
   b. a plurality of spines projecting outwardly from said wall,
   c. said spines
      1. being spaced apart longitudinally of said wall in rows which are substantially parallel to each other,
      2. in said rows being spaced apart laterally around said wall in other rows which are substantially parallel to each other,
      3. being substantially rectangular in transverse cross section and having a width greater than their thickness, and
      4. being bent transversely to the length of said wall in a direction transverse to the thickness of said cross section of the base of said spines.

7. A heat exchanger as defined in claim 6, and in which
   a. the bends in said spines transverse to the length of said walls are curves extending substantially the full length of said spines.

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