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METHOD OF AND MEANS FOR THE PRODUCTION OF RIBBED TUBES

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Fig. 1

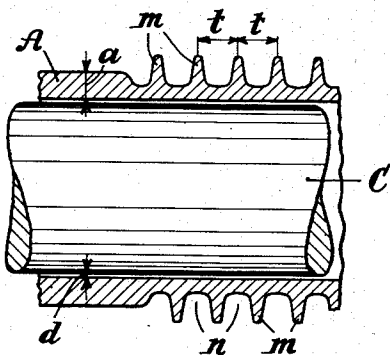


Fig. 2

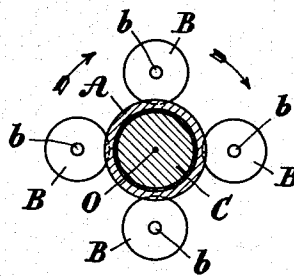


Fig. 3 Fig. 6 Fig. 4 Fig. 7 Fig. 8 Fig. 9

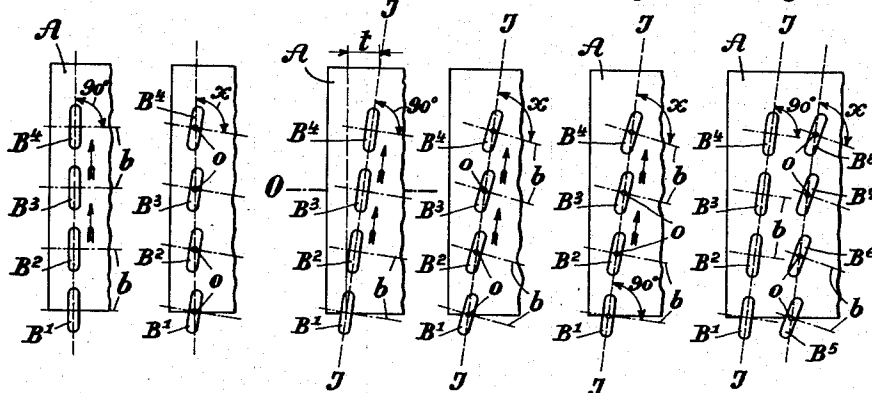


Fig. 5

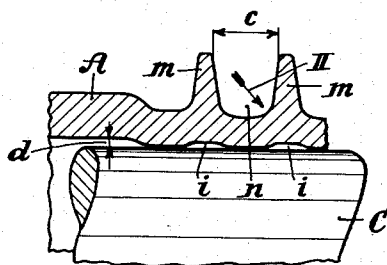
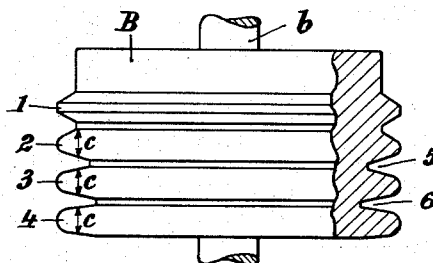


Fig. 10



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## UNITED STATES PATENT OFFICE

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## METHOD OF AND MEANS FOR THE PRODUCTION OF RIBBED TUBES

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This invention relates to a method of and means for the production of ribbed tubing rolled on a mandrel. In steam generators, flue-gas preheaters, and the like the transmission of heat from the combustion or heating gases to the metal takes place, as is well known, much more slowly than from the metal to the water or steam. In order to take account of this fact it has been the practice to provide the cast iron tubes of pre-heaters that are not under steam pressure, with annular ribs cast thereon. It has also been proposed to enlarge the heat absorbing surface in the case also of mild steel boiler- or preheater-tubes maintained under pressure, by providing the same with annular ribs produced by the rolling method. For a number of reasons, however, these proposals have not hitherto become adopted in practice, in spite of the fact that with the retention of at least the same efficiency a very considerable saving of material and space would have been attainable.

An indispensable precondition for the technical serviceability of ribbed tubes as water tubes is that their inside surface be practically speaking perfectly smooth, since even a slight internal grooving would result in the deposition of scale and would prevent cleaning of the tubes. The material displacement brought about by the rolling operation is propagated however through the entire wall thickness of the tubes and has the effect of forming grooves in the inner surface at zones corresponding to the position of the ribs on the outside of the tubes. This grooving can not be prevented by the insertion of a mandrel into the tube under treatment, since a clearance of at least some tenths of a millimetre must be left between this mandrel and the inside surface of the tube, while internal grooves of even such slight depth as this must be avoided. The formation of internal grooving could only be prevented by causing only a thin outer layer of the tube wall to participate in the flowing of the material required for the formation of the outside ribs. In this case either tubes of very considerably greater wall thickness than would otherwise be necessary for reasons of strength under the same conditions could be used, or in the case of tubes of wall thickness not exceeding the necessary amount a very delicate rib and groove profile could be adopted (that is to say ribs of slight height and grooves of slight breadth). Both courses, however, are unfeasible from a practical point of view. One reason for this is that it is a precondition for the attainment of a saving of material by the use of wrought iron ribbed tubes in steam generators, superheaters, and the like, that the mean wall thickness of such ribbed tubes be not greater or not appreciably greater than the wall thickness of smooth tubes required for reasons of strength

and safety under otherwise the same conditions. On the other hand, the ribs must be relatively high as compared with the normal wall thickness, if the enlargement of the superficial area of the outside of the tube is to be worth while; furthermore, the grooves formed between the ribs must be relatively wide and must approximate as nearly as possible to the U-shape in profile, if satisfactory and effective bathing by the hot gases is to be achieved, dead corners avoided, and clogging of the grooves with soot and ash particles prevented.

The present invention provides a method of producing ribbed tubes rolled on a mandrel, by which it is rendered possible in an extremely simple manner, and with the fulfilment of all the conditions recited, to obtain with certainty a smooth inner surface in rolled ribbed tubes, and to take into account all circumstances, including those of an incidental nature and those not calculable in advance, on which the formation of internal grooving depends. The invention is based upon the discovery that the formation of internal grooving can be prevented with certainty by supplementing the displacement of material set up by a purely rolling movement of the profile rollers by an additional displacement of material directed counter to the zone of the internal grooves to be inhibited running on the inner surface of the tube concurrently with the outside ribs. In accordance with the invention this supplementary displacement of material is brought about by setting the axes of the profile rollers, relatively to the direction of movement of the individual points on the axes, to an angle deviating from 90°, the extent of this deviation of the setting angle from 90° being dependent on the circumstances affecting internal groove formation and amounting, at the most, to a few degrees of arc.

The invention will now be explained in greater detail with reference to the accompanying drawing, in which:

Fig. 1 is a longitudinal section through a tube and mandrel showing the manner in which the ribs are formed;

Fig. 2 is a transverse section of a tube and mandrel showing also the rib-forming rolls;

Fig. 3 is a diagrammatic view illustrating the action of rolls when running true in the formation of non-inclined ribs;

Fig. 4 is a diagrammatic view illustrating the action of rolls when running true in the formation of inclined or helical ribs;

Fig. 5 is an enlarged sectional view of a portion of one side of the tube shown in Fig. 1 to illustrate the action of the rolls in eliminating interior grooves beneath the ribs;

Fig. 6 is a companion view to Fig. 3 illustrating the action of rolls when inclined at an angle

to the axis of the rib according to the present invention;

Fig. 7 is a companion view to Fig. 4 illustrating the action of rolls when inclined at an angle to the axis of the rib according to the present invention;

Fig. 8 is a view similar to Fig. 7 but in which the rolls are arranged at progressive angle of inclination;

Fig. 9 is a view similar to Fig. 7 but showing one set of rolls running true and a follow-up set inclined at an angle to the axis of the ribs; and

Fig. 10 shows a construction of the profile rollers particularly well suited for the carrying out of the method according to the invention.

The wall thickness of the usual water tubes of steam generators and preheaters kept under pressure, as also of superheater tubes, amounts, according to the steam pressures used and the diameter of the tubes, to between 5 and at the most 10 millimetres. Fig. 1 shows on a full-size scale, by way of example, a tube A of about 6 mm. wall thickness, which is to be provided by means of a rolling process with peripheral external ribs *m*. In accordance with the known fact that the strain in a peripheral seam is half as great as in a longitudinal seam the original wall thickness *a* may be reduced to half in the region of the grooves *n*, that is to say between the ribs *m*, while owing to the armouring effect of the ribs *m* the strength of the tube in the longitudinal seam remains approximately the same as in the case of the smooth tube. The sides or flanks of the ribs *m* must merge without the formation of corners in the hollows of the intervening grooves *n*, which are preferably likewise gently arched, so that the profile of the grooves *n* is substantially in the shape of a U. For the production of the ribs and grooves there serve, in a manner known per se, a plurality of, for example four, profile rollers B (Fig. 2) distributed over the circumference of the tube A and mounted in a very strong frame (not shown in the drawing) which is caused to carry out a rotational movement about the axis O of the tube A. The rolling is effected in a manner likewise known per se over a mandrel C (Figs. 1 and 2) inserted with slight clearance *d* in the tube A.

In producing closed annular peripheral ribs the axes *b* of the profile rollers B are parallel to the tube axis O, and, as Fig. 3 shows in a development of the cylindrical surface and diagrammatic representation, the four rollers B<sup>1</sup>, B<sup>2</sup>, B<sup>3</sup>, B<sup>4</sup> run in one and the same plane at right angles to the tube axis O. In producing tubes having ribs *m* following a helical line, for which the present invention is primarily intended, the axes *b* of the profile rollers B<sup>1</sup>, B<sup>2</sup>, B<sup>3</sup>, B<sup>4</sup> are inclined to the tube axis O according to the pitch of the helical line indicated by the broken line I—I in Fig. 4, and the profile rollers are in offset relation to each other in the direction of the length of the tube A, and that, when four profile rollers are used, to the extent of one-quarter of the pitch *t* (Figs. 1 and 4) equalling the spacing of the ribs *m*. In both cases (Figs. 3 and 4) the points of the roller axes *b* are thus conducted in paths which are at right angles to the axes *b* themselves, and it will be found that this is the generally adopted practice in the rolling method, and implies a perfect generating (rolling) movement.

The displacement of material occurring in the wall of the tube A in response to such genuine

generating (rolling) movement is shown on an enlarged scale (i. e. exaggeratedly) in Fig. 5. In the zone of the grooves *n*, that is to say approximately over the breadth *c* (Fig. 5), the material is forced away towards the tube axis O and firmly pressed against the mandrel C. Between these zones, that is to say at the parts corresponding to the position of the ribs *m* on the outside, the material yields to the pressure of the rollers in a direction radially outwards and forms the ribs *m*. At these parts no flow of material or only but very slight flow of material takes place towards the tube axis O. On the inner surface of the tube A along or in the zone of the external ribs *m* there are consequently formed peripheral depressions or grooves which are denoted by *i* in Fig. 5. With the usual water tube wall thickness *a* of 5-8 mm., and with a clearance *d* between mandrel C and tube A amounting to about 0.5 mm. (and it is hardly possible, for practical reasons, to go below this figure) the depth of these internal grooves *i* amounts at the most to 0.5 mm., but is as a rule somewhat less. This is sufficient however to render a ribbed tube of this description unfit for use as a water tube for heat exchangers, since such a tube must have a smooth inner surface.

That in spite of the pressing of the material against the mandrel C in the zone of the grooves *n* the tube A is not caused by the rolling operation to seize on the mandrel is due, as is well known, to the resilient deformation of the circular tube cross-section by the profile rollers B distributed over its circumference. After the tube A has passed between the profile rollers B the elasticity of the material is adequate to enable the same to regain its condition before deformation, with the result that the parts pressed against the mandrel C during the rolling operation become detached again therefrom, and the travelling on of the tube A over the mandrel C is rendered possible.

Now I have found that the formation of the internal grooves *i* can be prevented with absolute certainty by setting the axes *b* of the profile rollers B not at a right angle (Figs. 3 and 4) to the (tangential) direction of movement of the individual points of the axes but at an angle deviating slightly from 90°. In Figs. 6 and 7 of the drawing the setting angle deviating from 90° is denoted by *x* and shown exaggeratedly large. In actual fact the deviation from 90° amounts at the most to a few degrees of arc; it is never as great for example as the pitch *t* (Fig. 4) of the helical line in the case of ribs *m* following helical lines, but is considerably less. The profile rollers B<sup>1</sup>, B<sup>2</sup>, B<sup>3</sup>, and B<sup>4</sup> are mounted in the frame or housing revolving about the tube axis O by means of bifurcated carrying members (not shown in the drawing) which admit of a slight angular adjustment about the axes denoted by *o*<sup>1</sup>, *o*<sup>2</sup>, *o*<sup>3</sup>, *o*<sup>4</sup> in Figs. 6 and 7, so that the profile rollers can be set both at right angles to the (tangential) direction of movement (Figs. 3 and 4) and also, within certain limits) to an angle *x* (Figs. 6 and 7) deviating from 90°.

In the carrying out of the method according to the invention the profile rollers B<sup>1</sup>, B<sup>2</sup>, B<sup>3</sup>, B<sup>4</sup> are first set exactly to the right angle (Figs. 3 and 4) to produce a perfect generating (rolling) movement, pressed towards the tube axis O so that their periphery eats into the material of the tube A to the desired depth, and the machine is then set in operation. Then either during the operation of the machine or while the machine

is temporarily stopped the setting angle of  $90^\circ$  is gradually increased to such a value  $\alpha$  (Fig. 6 or 7) at which it is found that the internal grooves  $i$  (Fig. 5) are no longer formed and the ribbed tube has a perfectly smooth inside surface. The work is then continued with this setting of the profile rollers  $B^1, B^2, B^3, B^4$ , and this angle of setting may be retained as long as ribbed tubing of the same nature is to be turned out.

In the production of ribbed tubes with annular ribs the profile rollers  $B^1, B^2, B^3, B^4$  are not of course arranged in off-set relation to each other longitudinally of the tube A (Figs. 3 and 6) but are merely additionally set to the axial angle  $\alpha$  (Fig. 6). In the production of tubes with helical ribs the profile rollers  $B^1, B^2, B^3, B^4$  retain their mutual axial displacement to the extent of one-quarter of the pitch  $t$  or of the rib spacing (Figs. 4 and 7), according to the pitch of the helical line, while being additionally set to the angle  $\alpha$  of axial deviation (Fig. 7). Thus in both cases (Figs. 6 and 7) the surfaces in which the individual points of the profile rollers revolve about the tube axis O form with the planes in which they revolve about the roller axes  $b$  a very small acute angle of at the most a few degrees of arc. Another way of expressing this is to say that the forming or roller elements are narrower than the grooves and are inclined or have their planes inclined at an angle to the axis of the groove or rib and press against the sides of two ribs at circumferentially spaced points. There therefore no longer takes place a perfect generating (rolling movement of the profile rollers  $B^1, B^2, B^3, B^4$ , in which the rollers act symmetrically to both sides, but there is compounded with this movement a kind of sliding or slip movement as a result of which each profile roller has a biased action. The displacement of material brought about by the supplementary setting to the angle  $\alpha$  (Figs. 6 and 7) and the above-mentioned slip takes place approximately in the direction indicated by the arrow II in Fig. 5, and the consequence thereof is that in the zone of the outer ribs  $m$  an increased flowing of material towards the tube axis O takes place, so that the material is pressed against the mandrel C in this zone also and the inner grooves  $i$  (Fig. 5) do not arise.

The invention may also be put into practice by making the setting angle  $\alpha$  greater than  $90^\circ$  in the case of some but not all of the profile rollers. For example, as Fig. 8 shows for helical ribs, the first roller  $B^1$  may remain set to an angle of  $90^\circ$ , while only the following rollers  $B^2, B^3$ , and  $B^4$  are given the supplementary bias, if desired with progressive increase in the angle  $\alpha$  from one to the other. The first, and possibly also the second, profile roller  $B^1$  and  $B^2$ , respectively, thus work in the usual manner with perfect generating (rolling) movement, with the result that where they are acting the inner grooves  $i$  (Fig. 5) become formed, while the succeeding rollers  $B^3$  and  $B^4$ , owing to their bias, cause these inner grooves  $i$  to disappear again.

A further form of construction of the invention is shown in Fig. 9, and consists in adjusting one set of profile rollers  $B^1, B^2, B^3, B^4$  to the usual setting for straightforward generating (rolling) movement, and getting rid of the resulting inner grooving  $i$  (Fig. 5) by means of a second following-up set of profile rollers  $B^5, B^6, B^7, B^8$  adjusted in accordance with the invention to an angle  $\alpha$  deviating from  $90^\circ$ .

Fig. 10 shows a form of construction of the pressure rollers which is particularly well suited

for the carrying out of the described method, and in which two or more profiles 1, 2, 3, and 4 are provided designed to bring about the rib and groove formation in two or more stages, for which purpose there is a gradual transition of the profiles 1, 2, 3, 4 from an approximately triangular cross-section to U-shape. Without the biasing adjustment of the roller axes to an angle  $\alpha$  deviating from  $90^\circ$  in accordance with the invention the inner grooving  $i$  which it is desired to avoid would be formed even with the use of multi-stage profile rollers of this type. The additional setting or biasing of the axes  $b$  in accordance with the invention has a special effect in the case of such multi-stage pressure rollers (Fig. 10). By enlargement of the angle of adjustment  $\alpha$  to more than  $90^\circ$  (to the tangential direction of movement) the ratio between the breadth of the effective profiles 2, 3, 4 on the one hand and the breadth of the throats 5 and 6 situated between the profiles 2, 3, and 4 on the other hand is altered without any structural modification and without altering the pitch  $t$ . When the axes are set to an angle  $\alpha$  deviating from  $90^\circ$  the profiles 2, 3, and 4 do not work with the breadth  $c$  (Fig. 10) corresponding to the profile shape lying in the axial section of the pressure roller B, but with a breadth increased by minute fractions of millimetres. The greater the setting angle  $\alpha$  is the wider are the grooves  $n$  worked out by the profiles 2, 3, and 4, and the thinner and higher the ribs  $m$  become. Now it is on the ratio between the breadth of the grooves  $n$  on the one hand and the thickness and height of the ribs  $m$  on the other hand that the resistance to the flow of material in the various directions depends, and consequently also the distribution of the flow of material in the throats 5, 6 of the profile roller (Fig. 10) and in the opposite direction, that is to say, towards the zone of the internal grooving  $i$  (Fig. 5) which it is the purpose of the invention to avoid.

The present invention, the crux of which consists in the biased setting of the axes of the profile rollers to an angle deviating from  $90^\circ$ , thus provides the possibility of taking into account empirically all the factors on which the formation of the internal grooving  $i$  depends. These factors are not accurately predeterminable by calculation, not even singly, let alone in their mutual interactions, and are allowed for by the selection of the requisite angle of bias  $\alpha$ . Instances of these factors are the following: The extent of the clearance  $d$  between the tube A and the mandrel C, the depth and breadth of the grooves  $n$ , the thickness and height of the ribs  $m$ , as also the configuration of the groove and rib profile, and, finally, the nature of the material of which the tube is made.

The greater the height of the ribs  $m$  relatively to the wall thickness  $a$  of the smooth tube A (Fig. 1) used as starting material the greater is the danger of the ribs  $m$  becoming hair line cracked at their outermost edge, since with forgeable iron or steel in the cold state a flowing of the material can only take place to a limited extent. The smaller the clearance  $d$  between the mandrel C and the tube A the greater must the flow of material outwards in the ribs  $m$  be if these ribs are to attain a certain height.

In accordance with the invention the clearance  $d$  is preferably made greater than would be necessary in the interests of the sliding of the tube A relatively to the mandrel C, this

clearance being actually increased to one to two millimetres and in the case of large diameter tubes to still more. As a result, a larger proportion of the material is displaced towards the axis of the tube A, while the profile of the ribs  $m$  and of the grooves  $n$  remains the same. The outermost edge of the ribs  $m$  thereby becomes smaller in circumference than would be the case with a larger mandrel, while the height of the ribs  $m$  and the enlargement of the superficial area of the tube attained by the rolling process remain unaltered. In other words, this means that the internal diameter of the originally smooth tube A is greater by 1 to 2 mm. (or more) than the internal diameter of the finished ribbed tube, as indicated in Fig. 5. In this way the danger of the ribs  $m$  becoming cracked at their outermost edge is effectually obviated.

Nevertheless, there is obtained in this manner a ribbed tube which is smooth, or adequately smooth, on the inside, and that for the following reasons: The profile rollers B (Fig. 2) indent the tube A at four points towards the axis O and press it against the mandrel C. A flow of material is thereby brought about both towards the axis O and also outwards, that is to say, into the ribs under formation. This distribution of this flow of material outwards and inwards can however in its turn be so regulated, by alteration of the angle of bias  $\alpha$  at which the profile rollers work, that a smooth inside surface is obtained on the finished ribbed tube.

I claim:

1. The method of forming ribbed tubing which is substantially free from internal grooves beneath the ribs, which comprises, rolling the tube circumferentially upon a mandrel to form grooves separated by ribs, and applying lateral pressure toward the base of the ribs by forming elements inclined at an angle to the circumferential axis of and engaging two adjacent ribs to eliminate internal grooves beneath the ribs.

2. The method of forming ribbed tubing which is substantially free from internal grooves beneath the ribs, which comprises, rolling the tube circumferentially upon a mandrel to form grooves separated by ribs, and simultaneously applying lateral pressure toward the base of the ribs by forming roll elements narrower than the grooves and engaging two adjacent ribs at an angle to their circumferential axes to eliminate internal grooves beneath the ribs.

3. The method of forming ribbed tubing which is substantially free from internal grooves beneath the ribs, which comprises, rolling the tube circumferentially by a roll the plane of which is inclined at an angle to the circumferential axis of the groove to form grooves separated by ribs, and simultaneously by the same action pressing material beneath the ribs to eliminate internal grooves thereunder.

4. The method of forming ribbed tubing which is substantially free from internal grooves beneath the ribs, which comprises, rolling the tube circumferentially by a roll aligned with the axis of the groove, and subsequently rolling the tube in the groove by a roll which is inclined at an angle to the axis of the groove, for the purposes described.

5. The method of forming ribbed tubing which comprises, rolling ribs in the tube by rolls having axes disposed at an angle different from  $90^\circ$  with respect to the axis of the ribs.

6. The method of forming ribbed tubing which comprises, rolling ribs on hard tubing such as

steel while cold by rolls having axes disposed at an angle different from  $90^\circ$  with respect to the axis of the ribs.

7. The method of forming ribbed tubing to avoid cracking of the ribs by expansion, which comprises, rolling an oversized tube circumferentially upon a mandrel to permanently reduce its internal diameter uniformly along its length, and at the same time forming grooves separated by ribs.

8. The method of forming ribbed tubing to avoid cracking of the ribs and to avoid objectionable internal grooves, which comprises, rolling an oversized tube circumferentially upon a mandrel to permanently reduce its internal diameter uniformly along its length and at the same time form grooves separated by ribs, and applying lateral pressure toward the base of the ribs to eliminate internal grooves.

9. The method of forming ribbed tubing which comprises, rolling an oversized tube circumferentially on a mandrel by a plurality of circumferentially spaced rolls some of which are inclined at an angle to the axis of the groove, for the purposes set forth.

10. Apparatus for forming ribbed tubing comprising in combination, a mandrel upon which the tube is placed, and a roll movable circumferentially around the tube to form grooves separated by ribs, said roll being out of alignment with the direction of rolling and the axis of the groove, for the purposes set forth.

11. Apparatus for forming ribbed tubing comprising in combination, a mandrel upon which the tube is placed, and a plurality of circumferentially spaced rolls movable circumferentially around the tube to form grooves separated by ribs, some of said rolls being out of alignment with the direction of rolling and the axis of the groove, for the purposes set forth.

12. Apparatus for forming ribbed tubing comprising in combination, an undersized mandrel for a tube, and a circumferentially moving roll inclined at an angle to the direction of rolling for pressing the tube down on the mandrel and forming spaced grooves and ribs and also for eliminating internal grooves beneath the ribs and avoiding cracking of the ribs.

13. The method of forming ribbed tubing to avoid cracking of the ribs by expansion, which comprises, placing upon a mandrel a tube whose interior diameter is greater than the exterior diameter of the mandrel by an amount sufficient to provide a reduction in the interior diameter after a circumferential rolling operation, and rolling the tube circumferentially on the mandrel by ribbed rolls to form ribs on the tube and permanently reduce its interior diameter uniformly along its length.

14. The method of forming ribbed tubing to avoid cracking of the ribs by expansion, which comprises, placing upon a mandrel a tube whose interior diameter is greater than the exterior diameter of the mandrel by an amount sufficient to provide a reduction in the interior diameter without any increase of the exterior diameter of the ribs as compared to the exterior diameter of the original tube after a circumferential rolling operation, and rolling the tube circumferentially on the mandrel by ribbed rolls to form ribs on the tube and permanently reduce its diameter uniformly along its length without increasing its external diameter.

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