United States Patent

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[72] Inventors Henry William Holdup Southampton; John Alfred Baskwell, Winchester; Reginald Henry Lush, Midanbury, Southampton; James Arthur Francis Donelan, Alton, England

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[73] Assignee Pirelli General Cable Works Limited
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[33] Great Britain
[31] 1266/68 and 35552/68

[54] **CORRUGATING METHODS AND APPARATUS**
4 Claims, 9 Drawing Figs.

[52] U.S. Cl. 72/77
[51] Int. Cl. B21d 15/04
[50] Field of Search 72/77, 78, 115

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Primary Examiner—Richard J. Herbst
Attorney—Alexander & Dowell

ABSTRACT: For producing annular corrugations in metal tubing, such as an electric cable sheath, an apparatus is disclosed which includes an annular corrugating member having a helical-working ridge on its inner circumference and mounted so as to encircle the tubing eccentrically with the working ridge bearing against the tubing. The corrugating member is mounted for free rotation in its own plane within a head which is itself rotatable about the tubing axis so as to move the geometric center of the corrugating member in a circle around the tubing axis. The working ridge bears against successive portions of the tubing to form annular corrugations as the head is rotated and the tubing is moved through the corrugating member.

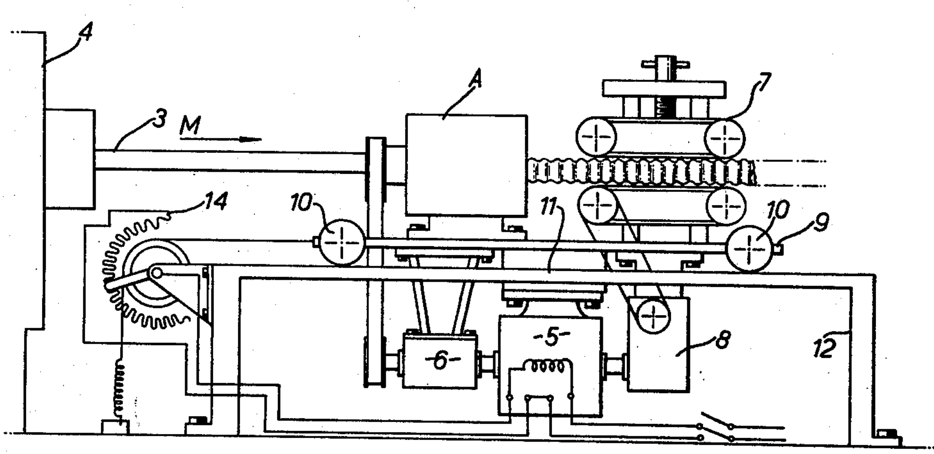
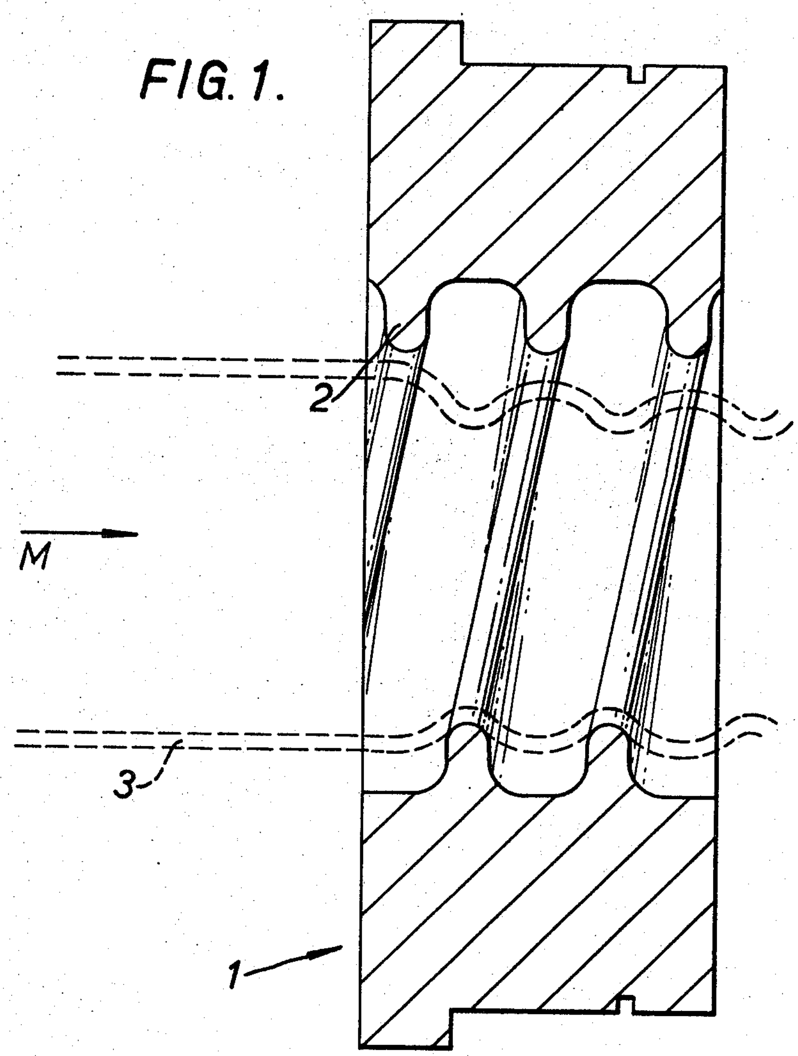


FIG. 1.



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Reginald Henry Lush
James Arthur Francis Donelan

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FIG. 2.

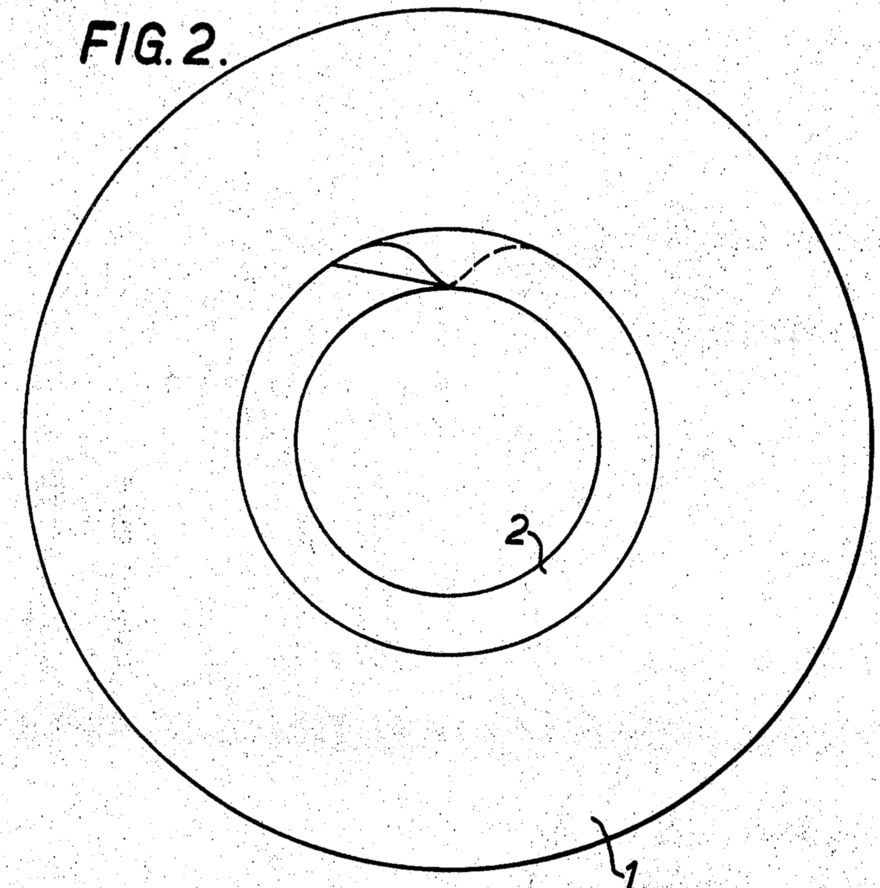


FIG. 5.

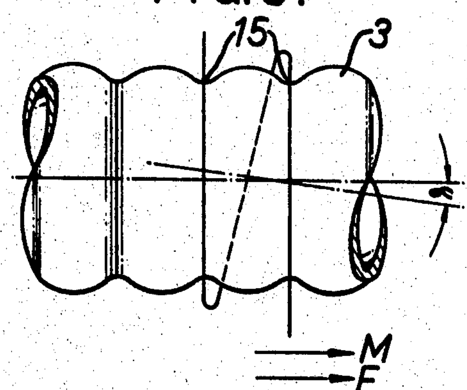
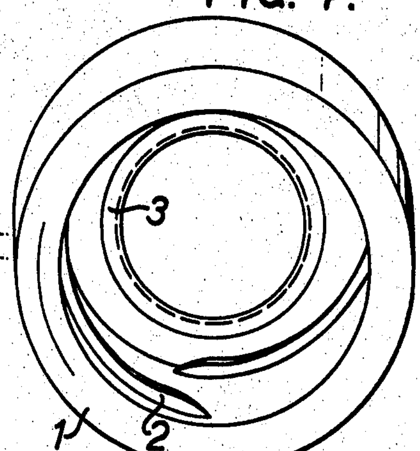


FIG. 4.



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Reginald Henry Leah
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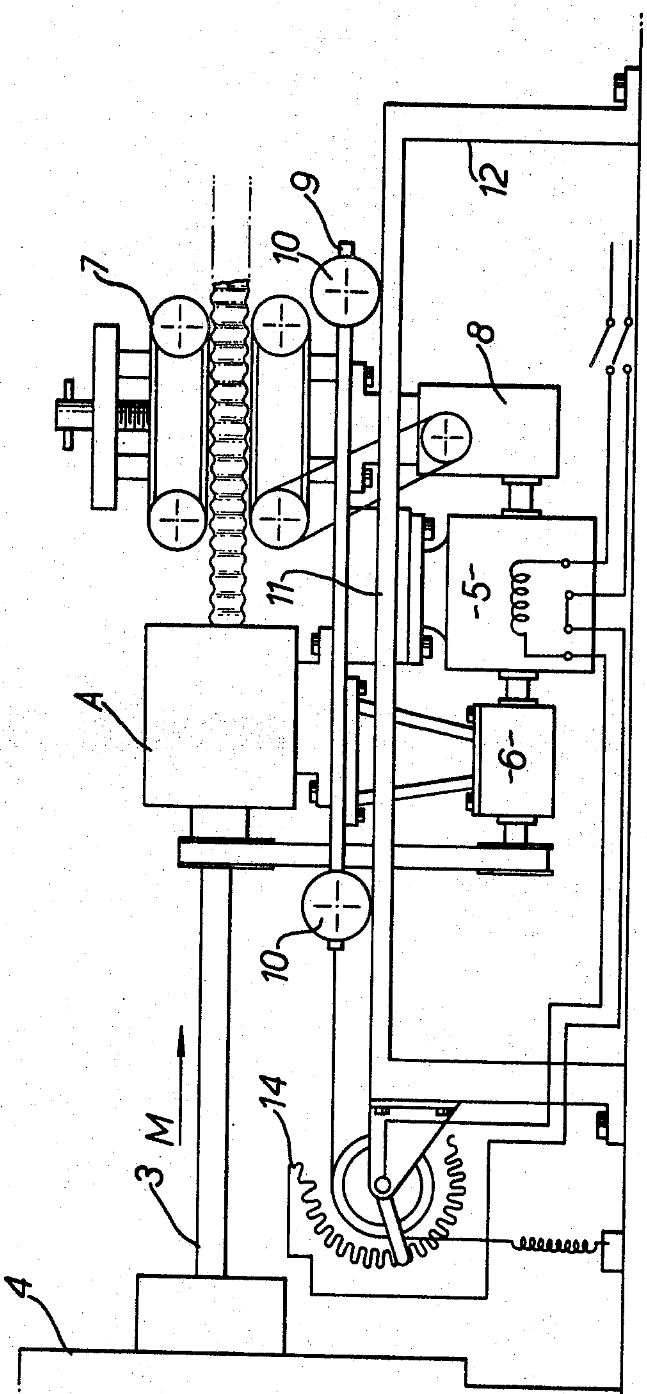
FIG. 3.



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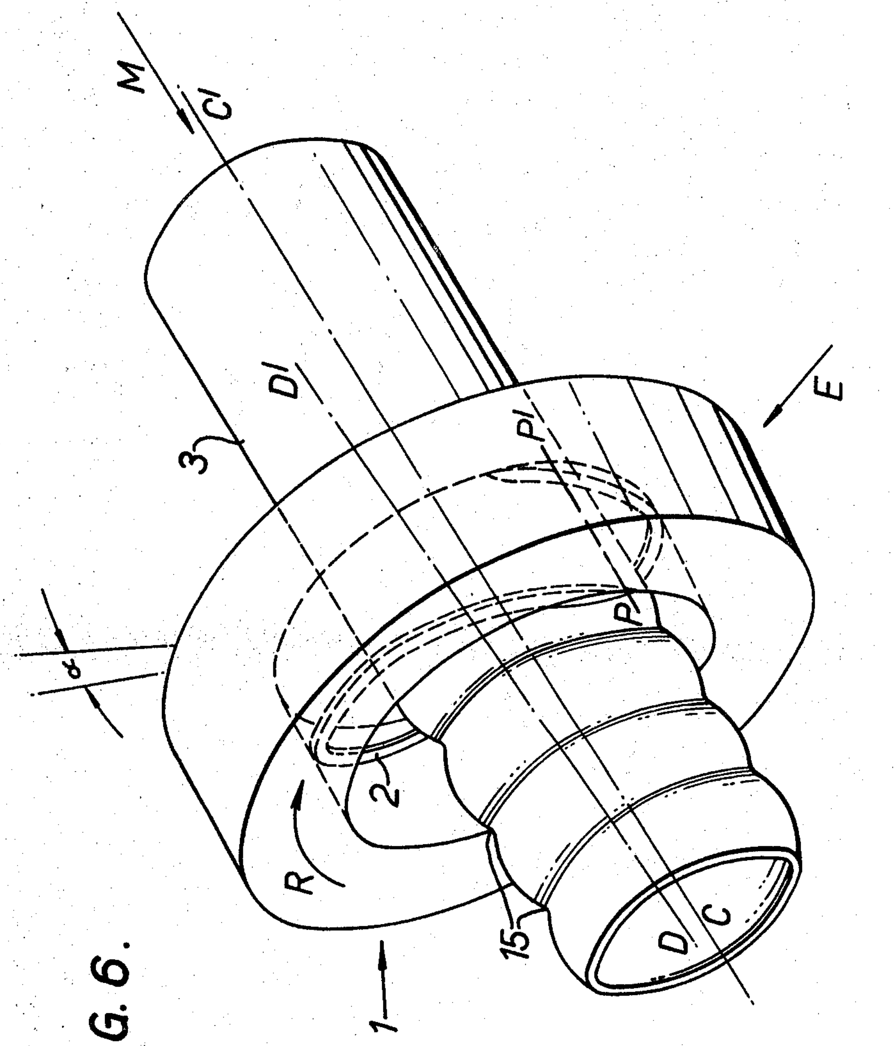

FIG. 6.

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John Alfred Boshwell
Reginald Henry Lush
James Arthur Francis Donelan

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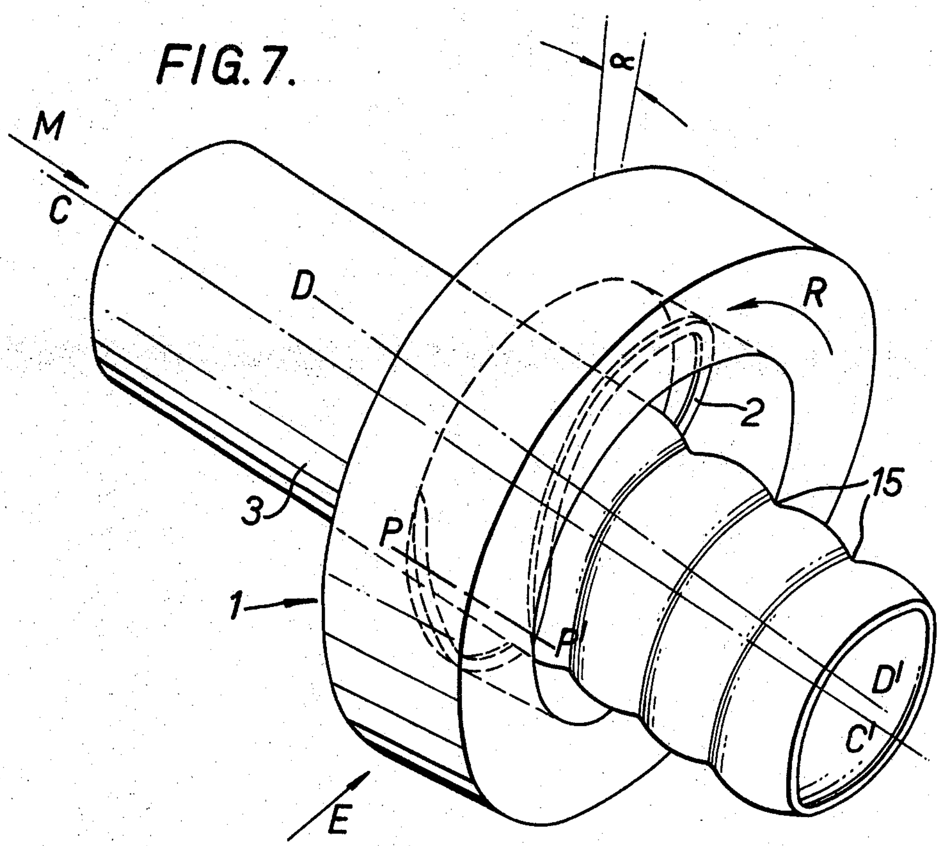
FIG. 7.



Henry William Holdup
John Alfred Baskewell
Reginald Henry Fush
James Arthur Francis Donelan

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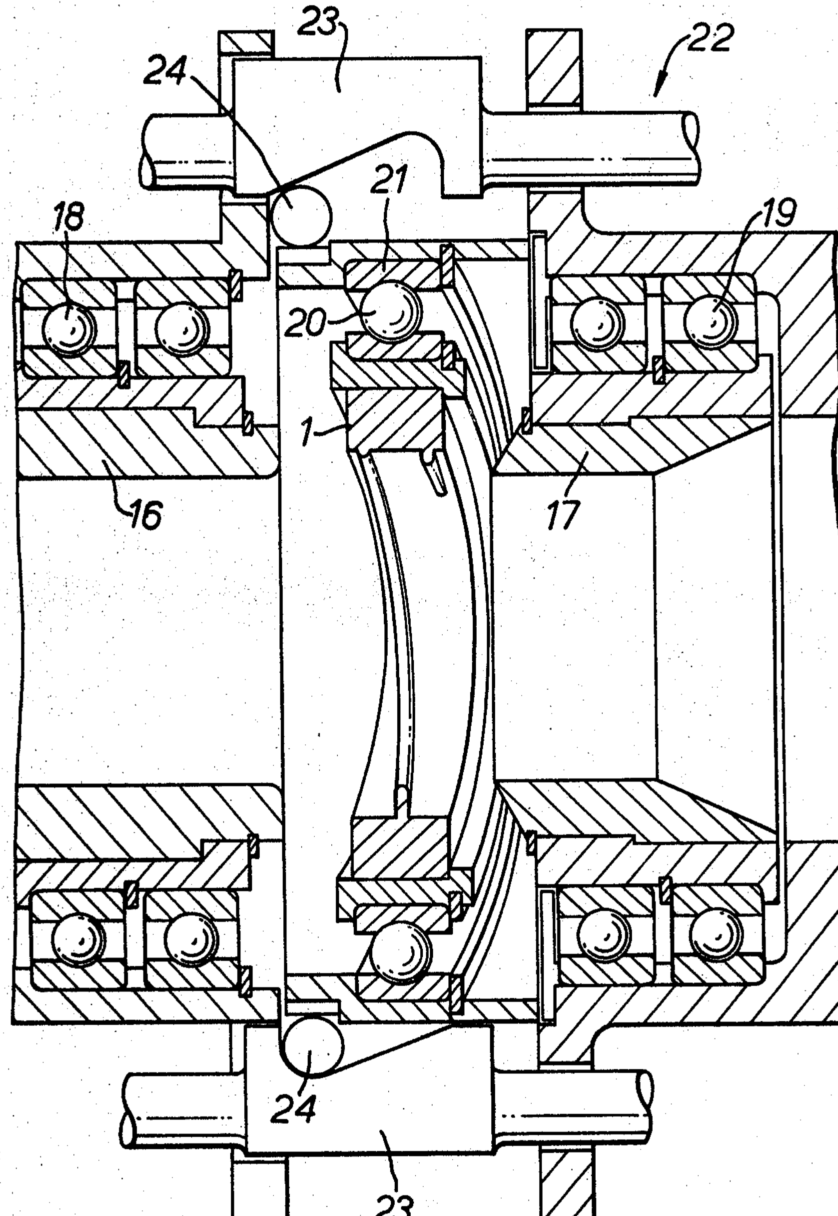
FIG. 8.



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Reginald Henry Lush
James Arthur Francis Donelan
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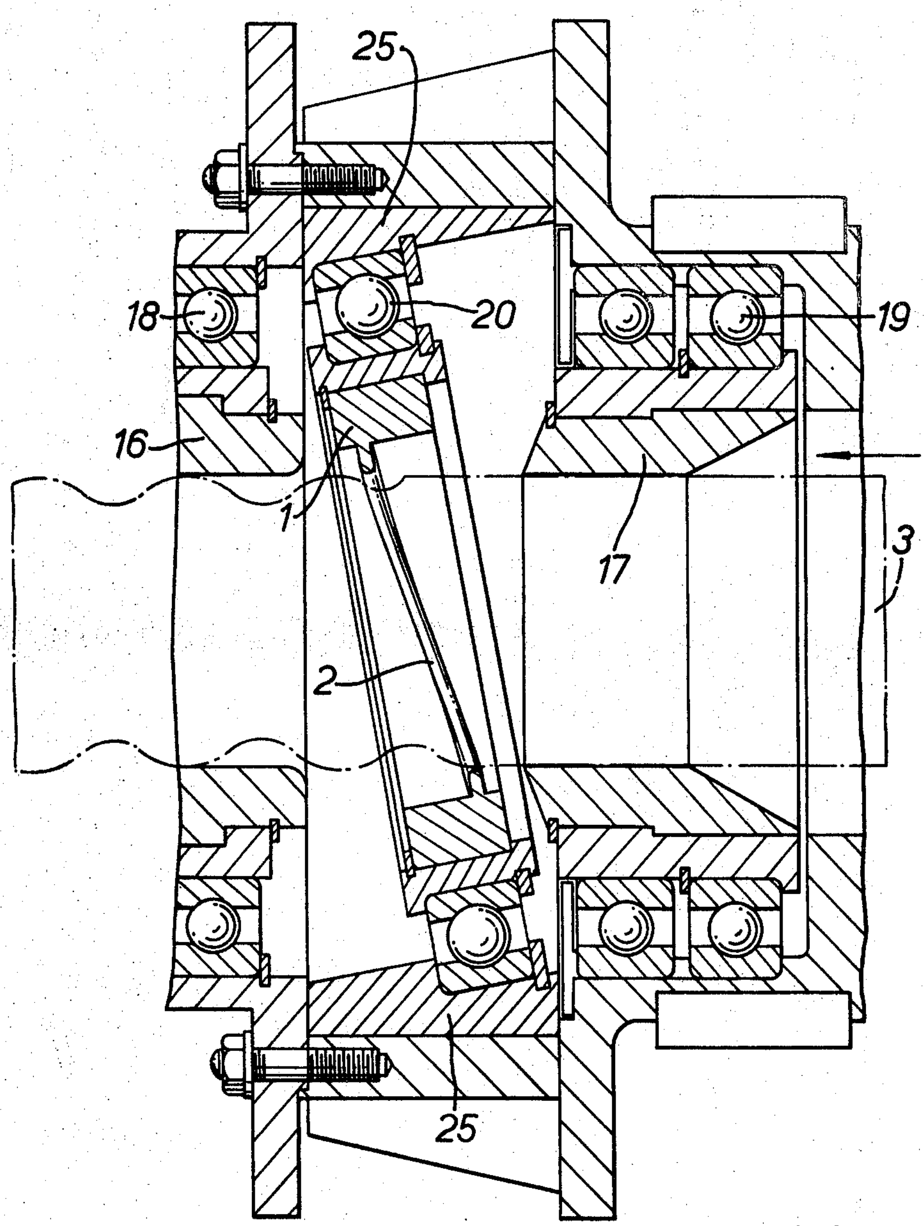
FIG. 9.



Henry William Holdup
John Alfred Bashwell
Reginald Henry Fush
James Arthur Francis Donelan

by Alexander & Dowell

CORRUGATING METHODS AND APPARATUS

This invention relates to a method and apparatus for corrugating tubing and is especially, although not exclusively, applicable to tubing which constitutes an electric cable sheath.

In out earlier Specification No. 791,513 we describe a method of corrugating an electric cable sheath, by bending it to form a helical trough in its wall, comprising the steps of subjecting the exterior of the sheath to the action of an annular corrugating member, surrounding the sheath, which extends in a plane transversely of the sheath at an angle to its axis other than a right angle, and whereof the distance of the nearest point on the internal-working ridge of the annular member to the axis of the sheath is less than the external radius of the sheath as uncorrugated and the radius of the curvature of the ridge is equal to or greater than the external root radius of the sheath after corrugation, moving the sheath in the direction of its axis and simultaneously producing relative rotation between the ring and the sheath. Our specification No. 791,513 also describes apparatus for corrugating an electric cable sheath, by bending it to form a helical trough in its wall, comprising means for supporting the sheath and permitting its movement in the axial directional, an annular corrugating member surrounding the sheath and having an internal-working ridge bearing on the exterior of the sheath, the ring extending in a plane transversely of the sheath at an angle to its axis other than a right angle, and whereof the distance of the nearest point on the working ridge to the axis of the sheath is less than the external radius of the sheath as uncorrugated and the radius of curvature of the ridge is equal to or greater than the external root radius of the sheath after corrugation, and means for moving the sheath in the direction of its axis and for simultaneously producing relative rotation between the ring and the sheath.

In specification No. 791,514 there is described a similar method and apparatus as applied to the manufacture of corrugated tubes other than those intended to act as sheaths. The present invention, however, is applicable to the manufacture of corrugated tubing in general irrespective of its intended end use as an electric cable sheath or otherwise.

In the machines described in Specifications Nos. 791,513 and 791,514 the annular corrugating member is mounted in a rotatable head eccentrically of the longitudinal axis of a tube in which corrugations are to be formed by said member, the tube being arranged for displacement along said longitudinal axis through the annular member. The annular member is also tilted at a small angle to the plane perpendicular to this longitudinal axis.

The relative diameters of the annular member and tube are such that, on rotation of the head and displacement of the tube along its longitudinal axis through the annular member, the ridge profile of the annular member bears on and presses in the external surface of the tube over an arc depending interalia upon the degree of eccentricity of the axis of the annular member with respect to the tube axis. The ridged inner profile of the annular member thus creates a corrugation in the external surface of the tube, the contour of the corrugation depending on the profile of the ridge and the pitch depending on the relative rates of rotation of the annular member and longitudinal displacement of the tube, and the tilt angle.

Out later Specification No. 1,097,709 is directed to an improvement in the method and apparatus of Specifications Nos. 791,513 and 791,514 whereby the depth of corrugation may be continuously adjusted as desired during the course of a run.

It will be appreciated from the above discussion, that the methods and apparatus described in these earlier proposals are capable of providing helical corrugations only. The production of annular corrugation, in particular on a continuous basis, is inherently more difficult. On the other hand annularly corrugated cable sheaths, in particular when the metal is aluminum, have certain advantages over helically corrugated sheaths. In particular an annularly corrugated sheath may have superior flexibility to a helically corrugated sheath having the same corrugation profile; the presence of helical corrugations may also give rise to difficulties as regards jointing cable lengths together, or securing end terminals thereto, and may allow moisture to penetrate along a cable if damaged at any point.

Amongst prior proposals for the production of annular corrugations mention may be made of specifications Nos. 711,305, 896,163 and 1,051,429.

Specification No. 711,305 discloses the use of a plurality of synchronously driven gear-toothed rollers disposed in a stationary frame around the circumference of the tubing, each roller having an arcuate periphery embracing a corresponding portion of the tube circumference. On the drawing of the tube through the roller assembly the gear teeth bite into the tubing surface and jointly form an annular corrugation.

Specification No. 896,163 suggests the employment of a rotatable roller itself carried in a head which itself rotates around the tubing, the roller carrying a working helical thread member, such as ridge, arranged so that as the head rotates and the tubing is drawn through it the operative part of the helical thread member bearing against the tubing always lies in a plane at right angles to the tubing axis.

Specification No. 1,051,429 discloses a considerably more complex machine, which may be regarded as a development over that of Specification No. 896,163in which a series of working rollers are located in spaced circumferential locations around the rotating head, each roller moreover hearing against the tubing at a series of pressing locations along the tubing axis so that the corrugation depth desired is gradually obtained.

It is a main object of the present invention to provide a new apparatus for producing annular corrugations, which is of simple character and which can moreover be achieved by modification of the basic machine of specification Nos. 791,513 and 791,514. This earlier machine has achieved considerable success and its adaptation to the production of annular corrugations represents a considerable advance.

According to the present invention there is provided a method of forming annular corrugations in metal tubing in which an annular corrugating member surrounds the tubing and has an internal-working ridge bearing on the exterior of the tubing, and relative movement is effected in the direction of the tubing axis between the tubing and the annular member, simultaneously with relative rotation between the annular member and the tubing, the internal-working ridge being of such curvature and configuration that, on passage of the tubing through the annular member, successive portions of the ridge bear against successive circumferential portions of the tubing in planes perpendicular to the tubing axis to form successive annular troughs in the tubing. The curvatures of the tubing and the tube-engaging surface of the working ridge are of the same hand, as distinct from the arrangements of Specifications Nos. 896,163 and 1,051,429, in which the working ridge has curvature of opposite hand from that of the tubing. Consequently the ridge and the tubing meet at a lower contact angle; this feature in turn enables both a simplification of the corrugating apparatus and improved corrugating efficiency to be obtained.

The present invention also provides apparatus for forming annular corrugations in metal tubing, comprising an annular corrugating member supported so as to surround the tubing and having an internal-working ridge adapted to bear on the exterior of the tubing, means for effecting relative movement in the direction of the tubing axis between the tubing and the annular member, and simultaneously effecting relative rotation between the annular member and the tubing, the internal-working ridge being of such curvature and configuration that, on passage of the tubing through the annular member, successive portions of the ridge, each having a radius of curvature equal to or greater than the external root radius of the tubing after corrugation, bear against the tubing in planes perpendicular to the tubing axis to form successive annular troughs in the tubing.

Preferably the working ridge is helical. Preferably also the annular member is mounted eccentrically with respect to the tubing axis. In this case the radius of curvature of the ridge is constant and suitably greater than that of the uncorrugated tubing, according to the degree of eccentricity. As the tubing is then drawn through the relatively rotating annular member successive portions of the working ridge bear against the tubing, the advancement of the tubing being compensated for by the advancement of each successive portion of the working ridge along its helix; the working ridge thus always instantaneously bears against the tubing in a direction at right angles to the tubing axis, so producing an annular as opposed to a helical trough in the tubing.

The helical-working ridge need extend once only around the corrugating ring. In this case, once the forward end of the working ridge is reached a complete annular corrugation has been formed and the trailing end of the ridge is about to commence formation of the succeeding annular groove. Alternatively, if a superior degree of uniformity in the corrugations is required the helical working ridge may continue over one of more further turns, in which case such further turn or turns serve essentially to iron out irregularities created by the first turn.

Another possibility is for the corrugating annular member to be provided with two or more helical-working ridges so as to form two or more annular corrugations simultaneously, or consecutively if each helical-working ridge occupies part only of the circumference of the corrugating member. In this respect the present invention provides a considerable advantage over the apparatus of Specifications Nos. 791,513; 791,514 since if multiridged annular members are used in the latter the effect is to increase correspondingly the lead angle of the corrugations and so diminish the eventual flexibility of the tubing.

The precise cross section of the helical-working ridge will depend on the shape of the desired corrugation. It will be appreciated, however, that this shape and the ridge cross section must be such that the successive portions of the ridge, as they rise from the valley of the corrugation in which they have been working clear the longitudinally advancing sidewall of the corrugation. A further factor which applies here will be the ratio between the external root radius of the corrugated tubing and the radius of curvature in the plane of the annular member of the working ridge since this in turn affects the time during which the successive working portions will remain in the indented space between the crest and valley as a whole.

In one embodiment of the invention the annular member is mounted for rotation around the tubing in a plane perpendicular to the tubing axis, independent driving means being provided for advancing the tubing through the annular member and for rotating the annular member.

It has, however, been found that the efficiency and adaptability of the corrugating method and apparatus can in certain instances be improved if the corrugating annular member is mounted for rotation around the tubing in a plane inclined to the plane perpendicular to the tubing axis at an angle of tilt such that rotation of the annular member induces axial displacement of the tubing relative to the annular member.

Where the annular member has a helical-working ridge or ridges the pitch angle of the or each helical-working ridge should be less than or equal to the said angle of tilt of the annular member.

Thus, if an appropriate angle of tilt is employed, the apparatus of Specification No. 791,513 can be employed directly, with substitution only of the appropriate corrugating annular member, separate means for advancing the tubing being unnecessary.

In practice, the corrugating annular member may conveniently be inclined to the tubing axis at an angle within the range 4°—8°, usually around 5°, but angles outside this range may also be employed, in particular when the annular member has more than one helical-working ridge.

Where, in such an arrangement, the annular member has a left-handed helical-working ridge or ridges and is rotated in an anitclockwise sense viewed from the direction of relative movement of the tubing, the annular member is tilted from the plane perpendicular to the tubing axis in an anticlockwise sense viewed from the direction in which the axis of the annular member is displaced relative to the tubing axis.

Conversely, where the annular member has a right-handed helical-working ridge or ridges and is rotated in a clockwise sense viewed from the direction of relative movement of the tubing, the annular member is tiled from the plane perpendicular to the tubing axis in a clockwise sense viewed from the direction in which the axis of the annular member is displaced relative to the tubing axis.

In preferred embodiments of the invention the annular member is mounted on a rotatable carrier provided with axially adjustable cam means which are effective to adjust the eccentricity of the annular member.

Some embodiments of the invention will be described, merely by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is an axial cross section of an annular corrugating member employed in one embodiment of the invention;

FIG. 2 is an end view of the annular corrugating member shown in FIG. 1;

FIG. 3 is a diagrammatic elevation of an apparatus according to the invention employing the corrugating member of FIGS. 1 and 2;

FIG. 4 is an end view of an annular corrugating member and cable sheath as employed in another embodiment of the invention;

FIG. 5 is a diagrammatic side view of an annularly corrugated sheath formed using the corrugating member shown in FIG. 4, and illustrating the forces acting on the sheath as a result of the relative rotation of the annular member (not shown);

FIG. 6 is a diagrammatic perspective view illustrating the operation of an annular corrugating member having a left-handed helical working ridge;

FIG. 7 is a diagrammatic perspective view illustrating the operation of an annular corrugating member having a right-handed helical working ridge;

FIG. 8 is an axial sectional view of part of an apparatus according to the invention employing the corrugating member of FIG. 6, viewed from above; and

FIG. 9 is an axial sectional view of part of the apparatus of FIG. 8, viewed from one side.

In the drawings the same reference numerals are used throughout to indicate the same or corresponding parts.

FIGS. 1 and 2 illustrate in axial cross section and plane respectively one particular form of annular corrugating member 1 for use in apparatus in accordance with the present invention, having a helical-working ridge 2 which extends around two complete turns.

This annular member 1 can be employed directly in the apparatus shown in Specification No. 791,513in substitution of corrugating ring 23. In the apparatus according to the first embodiment described herein the annular member is not inclined to the tubing axis but instead is disposed at right angles to the tubing axis, that is, with its axis parallel to the tubing axis, in which case no inclined surface need be provided in the mounting block (i.e. 21 in specification No. 791,513) for inclining the annular member 1.

The helical-working ridge 2 has substantially the same pitch as that required for the eventual annular corrugations of the tubing, the latter being indicated at 3 in broken lines. The annular member 1 is mounted coaxially in a ball race (not shown) which in turn is housed coaxially in a rotatable carrier block. Means, preferably cam means (not shown) are provided for adjusting the eccentricity of the axis of the annular member 1 with respect to the axis of the tubing 3 to effect variation of the depth of corrugation, the tubing 3 itself being supported in guide bushes.

In operation of the apparatus, the annular member 1 is rotated eccentrically about the axis of the tubing 3 and at the same time the latter is advanced continuously through the member 1. Successive parts of the helical-working ridge 2 engage and deform successive parts of the circumference of the tubing 3, the rate of feed of the tubing 3 being such in relation to the rate of rotation of the annular member 1 that the advance of the tubing is maintained in step with the advance of the region of contact of the helical ridge 2 upon rotation of the annular member 1, so that a circumferential annular trough is formed by the ridge 2 in the tubing 3 upon each rotation of the member 1. As the leading edge of the ridge 2 finishes one trough the trailing edge of the ridge 2 is just commencing the next trough.

In this arrangement, separate means are necessary for feeding the tubing 3 through the annular member 1, and in synchronism with the rotation of the member 1, as described above.

When apparatus in accordance with the present invention is used to corrugate tubing at the time of formation, as distinct from being used to corrugate preformed lengths, it may be necessary to provide means for mutually controlling the position of the corrugating apparatus and the rate of rotation of the annular corrugating member 1 in relation to the tube-forming apparatus. The rate of tube formation may be irregular, particularly when the tubing is being made by an extrusion press of hydraulic type, as normally employed in, for example, the manufacture of aluminum tubing.

When corrugating annularly corrugated tubing in the form of an aluminum sheath for an electric cable the present apparatus, indicated generally at A in FIG. 3, will be positioned immediately in front of an hydraulic extruder 4 from which the cable, comprising a core within an oversize cylindrical cable sheath 3, emerges.

Apparatus enabling the rotational speed of the corrugating member 1 to be correctly synchronized with the variable linear speed of the tubing 3 is illustrated in FIG. 3.

The corrugating member 1 is rotated by an electric motor 5 through a fixed speed gearbox 6. The same motor 5 also drives a caterpillar drive unit 7 through a variable speed drive (e.g. a p.i.v. box) 8. Items A, 5, 6, 7, and 8 are rigidly mounted on a trolley 9 which is free to move on wheels 10 in a fixed line parallel to the movement of sheath 1, on fixed rails 11 on a table 12.

The trolley 9 is directly linked to a speed control rheostat or similar device 14 which varies the speed of the motor 5. The effect of this is such that if the trolley 9 moves towards extruder 4 its speed is reduced by the device 14 until it eventually stops completely; alternatively, if the trolley 9 moves away from the extruder 4 the trolley speed is increased up to a certain set limit. The purpose of the caterpillar drive unit 7 is that, before cable sheathing commences, the gearbox 8 is adjusted to give the required ratio between the rotational speed of the annular member (not shown in FIG. 3) of the apparatus A and the linear speed of the tracks of the caterpillar drive unit 7. This ratio is maintained irrespective of changes of motor speed.

When cable sheathing commences the caterpillar drive unit 7 is closed to grip the sheath 3.

The resulting effect is that if the sheath 3 is moving faster than the unit 7, the whole assembly on the trolley 9 is carried forward until the speed of the unit 7, increased by the rheostat device 10, equals that of the sheath 3. The trolley 9 then remains in that position until there is a sheath speed change. If the sheath 3 initially, or at any time during operation, moves slower than the caterpillar drive unit 7, the latter moves the whole trolley assembly towards the extruder 4 with a consequent reduction in motor speed. Throughout all these speed changes, the ratio of linear to rotational speed in the apparatus A remains constant and thus the spacing of the resulting annular corrugations remains constant and correctly related to the dimensions of the annular member 1.

Where the tube 3 being corrugated is relatively thick, the working of the corrugating annular member 1 against the tubing 3 will set up considerable torsion. To counteract this a second corrugating apparatus may be provided, following the first apparatus, in which the corrugating annular member 1 rotates in opposite direction of rotation to that of the corrugating member 1 in the first apparatus. Consequentially the helical internal-working ridge 2 in the second member 1 will have to be of opposite hand to that in the first ring. The second corrugating member 1 will not form any additional new corrugations but as the successive portions of the internal-working ridge 2 bear against the valley and walls of the corrugations already formed by the first annular member 1 a smoothing out effect will be obtained.

In the embodiment described above, powered means are necessary to drive the tubing 3 through the apparatus, the force exerted on the tubing 3 by the working ridge 2 being opposite to the required direction of movement of the tubing 3, indicated by the arrow M in FIG. 1 broken lines).

It has been found that separate powered means for displacing the tubing 3 can be dispensed with if the axis of the annular member 1 is inclined at a small angle of tilt α at least equal to the pitch angle of the helical-working ridge 2, to the tube axis, as illustrated in FIG. 4 and 5. Such tilting causes the deforming force acting on the tubing 3 to have a component along the tubing axis in the desired direction of feed of the tubing, as illustrated in FIG. 5, in which the direction of tubing movement is indicated by the arrow M and the direction of the axial force component by the arrow F. The angle of tilt α for this purpose should not be less than the pitch or lead angle of the helical-working ridge 2 on the annular member 1, in order to achieve a self-driving action whereby the tubing 3 is advanced by the action of the rotary corrugating member 1 without the necessity of any independent tube driving means. Typically the angle of tilt α is about 5°.

FIG. 6 illustrates diagrammatically the relationship between the direction of rotation R of the annular corrugating member 1, the direction of tubing movement M, and the angle of tilt α of the annular member 1, for a left-handed helical-working ridge 2. The member 1 is rotated relative to the tubing 3 in an anticlockwise sense as viewed from the direction M of tubing movement. The axis of the tubing 3 is indicated at C–C′, while the axis of the annular member 1 is indicated at D–D′: it will be seen that the axis D–D′, as well as being inclined at the angle α to the tubing axis C–C′, is eccentric with respect to the axis C–C′, the direction of eccentric displacement being indicated by the arrow E, so that the helical-working ridge 2 engages the tubing 3 at a point P at which the ridge 2 lies in a plane perpendicular to the tubing axis C-C′ to form a succession of annular troughs 15 in the tubing 3. The axial separation of successive troughs, that is, the pitch of the resulting corrugations, is equal to the pitch of the helical-working ridge 2. As the tubing 3 is advanced in the direction M by the action of the rotating annular member 1, the point of contact P of the ridge 2 with the tubing 3 progresses axially along the line P–P′.

It will be seen in FIG. 6 that, in order to achieve the self-driving effect referred to above, the plane of the annular member 1 is tilted through the angle α from the plane perpendicular to the tubing axis in an anticlockwise sense as viewed from the direction of eccentric displacement E, α being greater than or equal to the pitch angle of the helical ridge 2.

FIG. 7 illustrates the relationship between the direction of rotation R of the annular member 1, the direction of movement of the tubing 3, the direction of eccentric displacement E and the sense of the tilt angle α for an annular corrugating member 1 having a right-handed helical working ridge 2. It will be seen that the member 1 is rotated in a clockwise sense as viewed from the direction of tubing movement M, and that the plane of the member 1 is tilted from the plane perpendicular to the tubing axis C–C′ through an angle of α in a clockwise sense as viewed from the direction of eccentric displacement E.

FIG. 8 and 9 illustrate a typical practical embodiment of the invention, the two figures being axial sectional views of a tube corrugating head in two planes at right angles to each other.

The tubing 3 (broken lines in FIG. 9) is maintained with its axis C–C′ fixed in the desired direction by means of two support bushes **16**, **17** which are carried in respective ball bearings **18**, **19**. The annular member **1**, which is of the form illustrated in FIG. **6**, is mounted for rotation about its axis D–D′ in a ball bearing **20** which is in turn supported in a carrier **21** connected to a rotary head **22**, part only of which is shown. The carrier **21** is mounted, with the annular member **1**, for transverse sliding movement relative to the head **22** in a plane perpendicular to the axis of rotation of the head **22** (which coincides with the tubing axis C–C′).

To adjust the eccentricity of the axis of the annular member **1** with respect to the axis of the tubing **3** a cam arrangement, similar to that described in the apparatus of our specification No. 1,097,709is provided. The head **22** carries two diametrically opposed cam members **23** which have parallel wedge-shaped cam surfaces inclined to the tubing axis C–C′. The cam members **23** are adjustable together in an axial direction to effect radial adjustment of the carrier **21** through cam follower rollers **24** which are captive on an outer cylindrical track on the carrier **21**. For this purpose the cam members **23** are attached to a rotating block (not shown) which is connected through a suitable bearing to an axially adjustable nonrotating sleeve by which axial movement may be transmitted to the block, if necessary while the latter is rotating.

The tilting of the plane of the annular member **1** with respect to the plane perpendicular to the tubing axis is determined by parallel wedge-shaped spacers **25** (FIG. **9**).

We claim:

1. Apparatus for forming annular corrugations in metal tubing, which comprises means for supporting metal tubing whilst permitting its axial movement, an annular corrugating member, a helical-working ridge formed on the inner surface of the annular corrugating member, a head in which the annular corrugating member is mounted so as to be freely rotatable in its own plane about its geometric center, means in which the head is mounted with the annular corrugating member encircling the tubing with its geometric center displaced from the tubing axis so that the helical-working ridge bears against the tubing and means for rotating the head so that the geometric center of the annular corrugating member moves around the tubing in a circular path in a plane perpendicular to the tubing axis whilst the tubing moves axially through the annular corrugating member and so that successive portions of the working ridge bear against successive circumferential portions of the tubing in planes perpendicular to the tubing axis to form annular corrugations in the tubing.

2. Apparatus according to claim **1** in which the annular corrugating member is so mounted in the head that its plane is inclined to the tubing axis but is parallel to the direction in which the geometric center of the annular corrugating member is displaced from the tubing axis, the angle of inclination of the plane of the annular corrugating member to the tubing axis being such that, said movement of the annular corrugating member induces axial movement of the tubing at the required rate relative to the rate of said movement of the annular corrugating member for forming said annular corrugations.

3. Apparatus according to claim **2** in which said angle of inclination is equal to or greater than the pitch angle of the helical-working ridge.

4. Apparatus according to claim **3** in which said angle of inclination is within the range of 4° to 8°.