COAXIAL CABLE FORMING APPARATUS

Filed Nov. 12, 1965 6 Sheets-Sheet 1

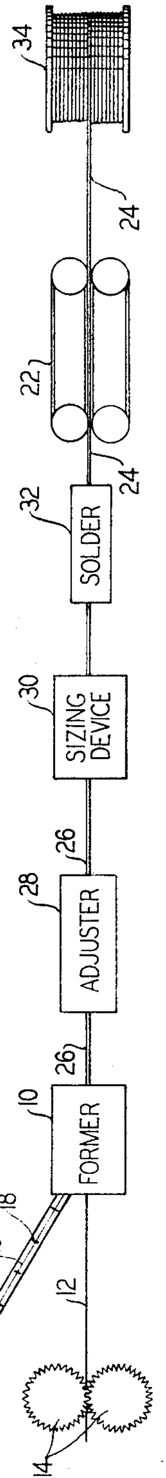


FIG. 1

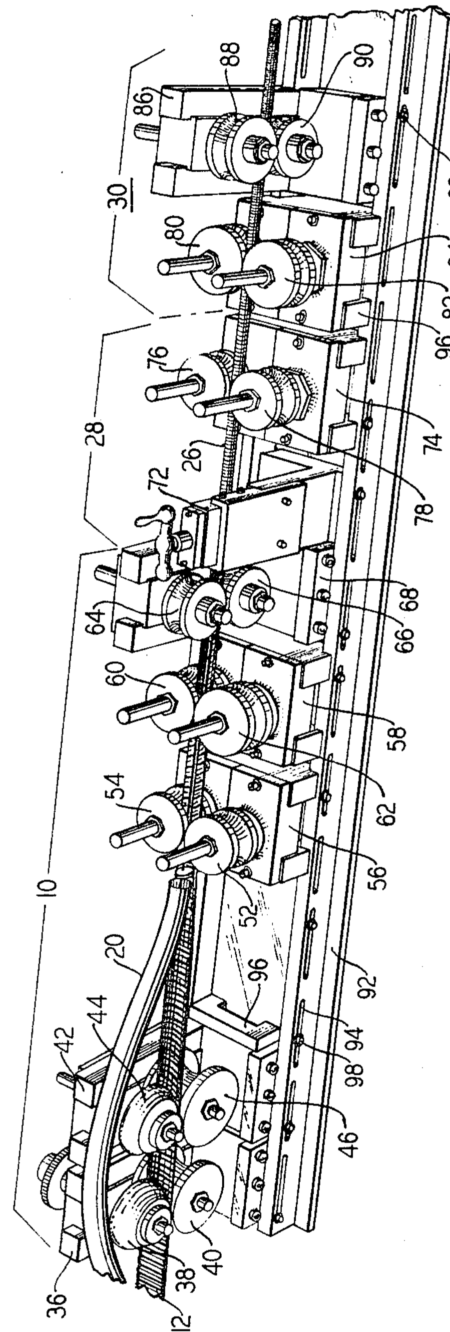


FIG. 2

INVENTOR
T. J. McGEAN
BY Leo Stanger
ATTORNEY

Aug. 20, 1968 T. J. McGEAN 3,397,442

COAXIAL CABLE FORMING APPARATUS

Filed Nov. 12, 1965 6 Sheets-Sheet 2

FIG. 3

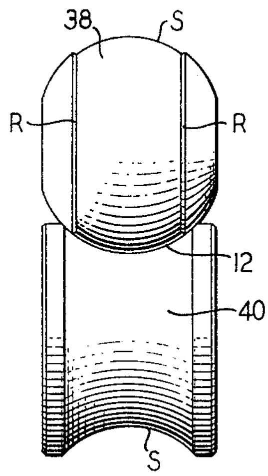


FIG. 4

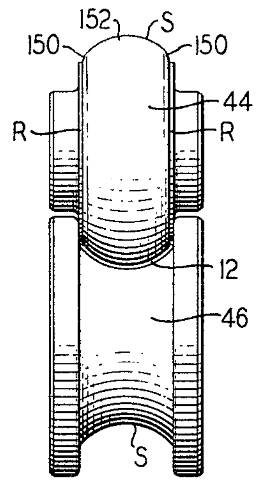


FIG. 5

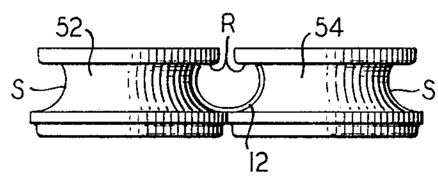


FIG. 6

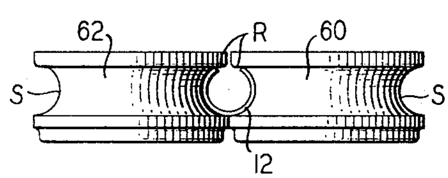
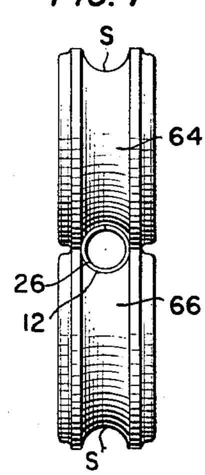


FIG. 7

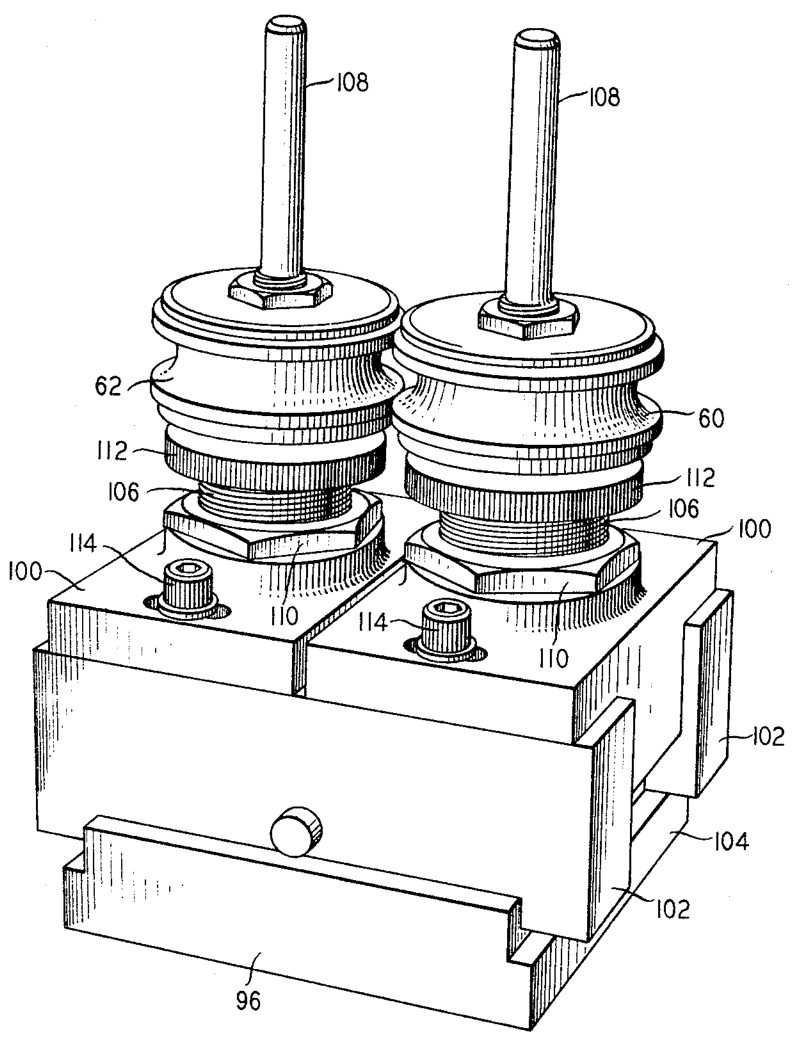


Aug. 20, 1968 T. J. McGEAN 3,397,442

COAXIAL CABLE FORMING APPARATUS

Filed Nov. 12, 1965 6 Sheets-Sheet 3

FIG. 8



Aug. 20, 1968 T. J. McGEAN 3,397,442

COAXIAL CABLE FORMING APPARATUS

Filed Nov. 12, 1965 6 Sheets-Sheet 4

FIG. 9

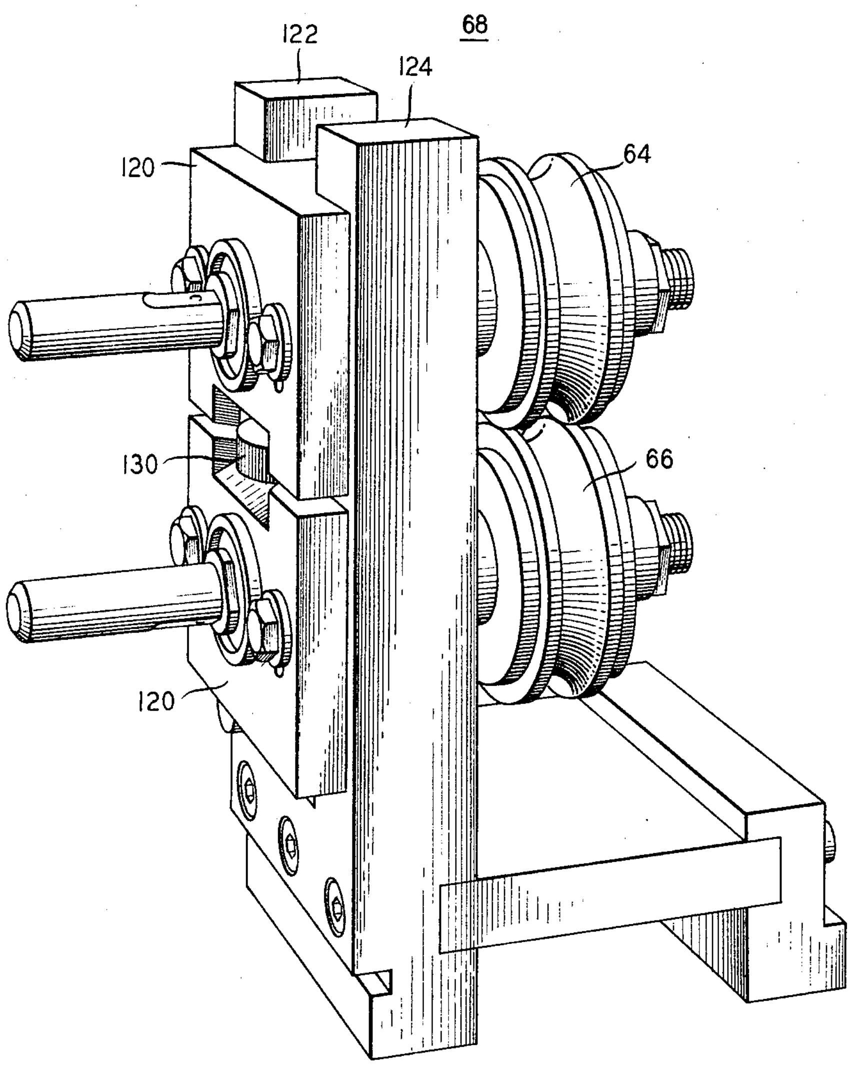


FIG. 10

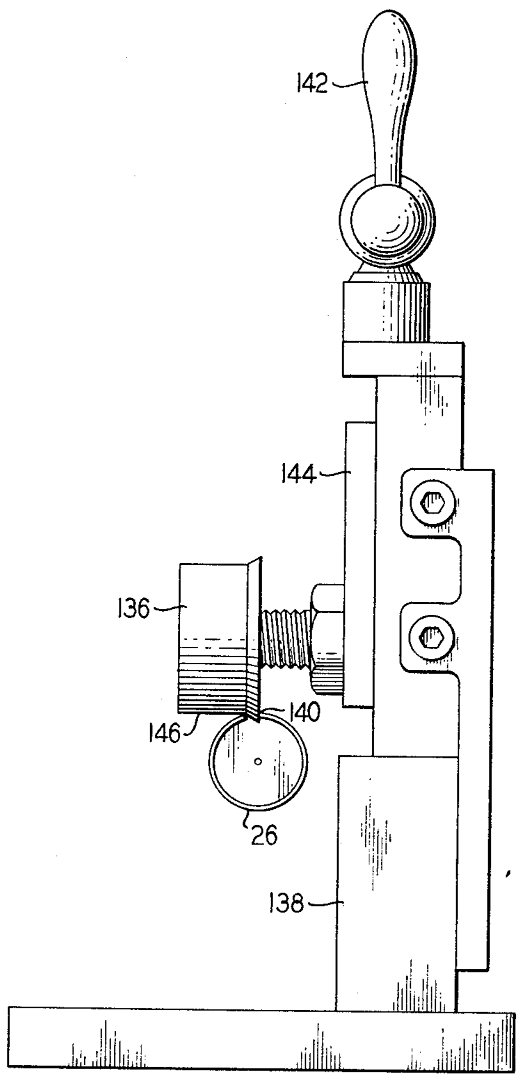


FIG. 11

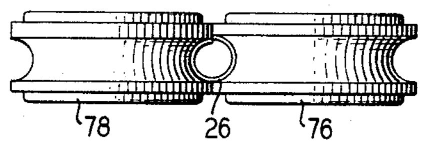


FIG. 12

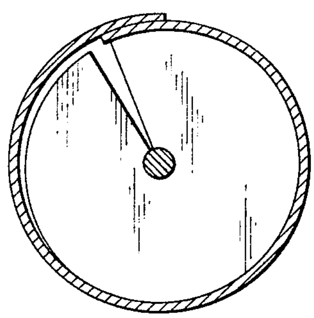


FIG. 13

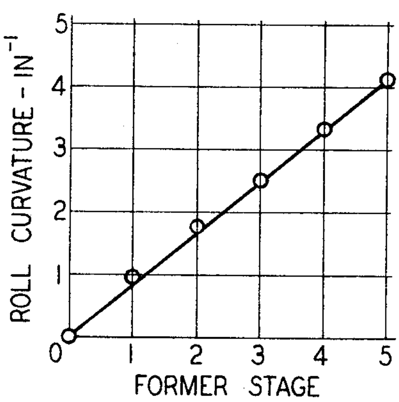
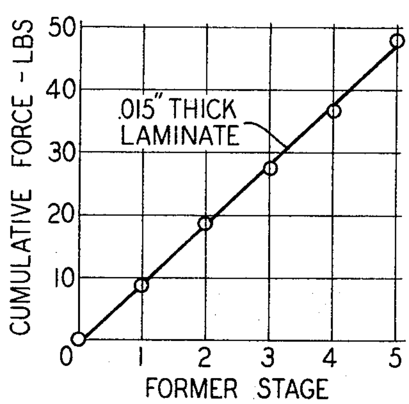


FIG. 14



United States Patent Office

3,397,442

Patented Aug. 20, 1968

3,397,442

COAXIAL CABLE FORMING APPARATUS

Thomas J. McGean, East Orange, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Nov. 12, 1965, Ser. No. 507,330
9 Claims. (Cl. 29—202.5)

ABSTRACT OF THE DISCLOSURE

A transversely corrugated ribbon is shaped into a tube by passing it between two radially adjacent rolls, one of whose peripheral edges has a concave profile and the other a convex profile, to bend the ribbon transversely. The edges of succeeding pairs of radially adjacent rolls continue curving the ribbon transversely about a spacer-carrying center conductor until the ribbon surrounds the center conductor. The profile radius in the edges of each of the successively arranged pairs is inversely proportional to the sequential position of the pair.

This invention relates to coaxial cable manufacturing apparatuses, particularly the portions of such apparatuses that advance a ribbon and bend it transversely about a spacer-carrying center conductor until it forms a tube-like outer conductor of an individual coaxial. The invention has for its principal object to bend transversely corrugated ribbons into corrugated outer conductors and thus make coaxials such as those described in the copending application of M. C. Biskeborn et al., Ser. No. 507,391, filed Nov. 12, 1965, assigned to the same assignee as this application and being filed concurrently herewith.

Generally for forming of the coaxials such apparatuses fold the outer conductor about the center conductor by pulling a metal ribbon either through a conical die, or between pairs of rolls that are set up in successive stages and wherein the peripheral surfaces of the rolls in each pair have concave profiles whose radii also decrease conically, that is linearly, from stage to stage. This operation is acceptable for forming smooth outer conductors from flat ribbons. However, if a resulting coaxial is to exhibit the advantageous flexibility and uniform electrical stability available from corrugated outer conductors, additional expensive steps are necessary. For example, it is possible to corrugate the smooth outer tube after forming it. Since this involves changes in the inner diameter of the tube and the total tube length, this process has been found extremely difficult and may harm the dielectric spacers.

On the other hand, corrugating the ribbon prior to forming creates other problems. In particular, the forces pulling the corrugated ribbon through the conical die or the linearly decreasing profiles of successive roll pairs, which forces are normally insufficient to affect a smooth ribbon adversely, are sufficient to pull out the corrugations in the ribbon. Attempts to allevate corrugation pull-out by multiplying the number of roll formers so as to change the ribbon curvatures only gradually have failed to produce desired results. Also powering the individual roll stages by turning them and thereby providing some of the forward force so as to alleviate the need for heavy pulling forces results in relatively complicated forming devices requiring strict control and regulation of pulling speeds and roll speeds.

A general object of the present invention is to improve apparatuses of this type.

Another object of this invention is to wrap an elongated and transversely corrugated ribbon across its length about a center conductor and into a tube without complicating the forming device, particularly without applying power

to former rolls, while nevertheless maintaining the corrugations.

Yet another object of the invention is to form such a tube from a corrugated ribbon without pulling out the corrugations, while nevertheless supplying the forming energy only by pulling on the tube and ribbon.

According to the invention these objects are obtained not by making the curving process more gradual with extra pairs of rolls but by making it more acute, so that each pair bends the corrugated ribbon far more than generally considered feasible, thereby minimizing the number of roll stages and the necessary pulling force. This is done by drawing corrugated ribbon between the peripheral surfaces of radially adjacent rolls in successive stages as previously, but imparting to the peripheral surfaces of each pair of rolls, profiles whose radii decrease not linearly as in the past, but radii that decrease hyperbolically from stage to stage. More particularly, according to the invention, the profile in each stage adds the same amount of curvature to the ribbon. Preferably the number of stages is such that this constant curvature per stage is the maximum possible for forming the ribbon without buckling it. The former then has the minimum number of stages necessary for forming the tube.

The invention is based upon the recognition that the usual practice of linearly decreasing the profile radii comparable to the method of a conical die concentrates most of the forming work near the final roll stage. The invention is based on the further recognition that in addition to the impedance of the rolls associated with formation of the tube, each roll pair imparts an impedance that is connected with restoring the departure in shape from the shape imparted to it in the previous roll stage due to the ribbon's inherent elasticity and the work in overcoming the friction of the rolls against the ribbon arising from differences in linear speeds along the roll surface, as well as overcoming the forces on the ribbon edges required to maintain the angular position of the partially formed tube. This involves, therefore, the recognition that multiplying the number of rolls increases the total decorrugating pull. It also involves the recognition that by bending the ribbon the maximum amount possible at each stage the number of stages, and hence the above residual resistance is minimized.

Moreover, the invention involves the discovery that the bending limits associated with flat ribbons, contrary to appearances, are inapplicable to corrugated ribbons. Corrugated ribbons can be bent transversely far more than flat ribbons. This is so because while a pair of rolls is bending the ribbon, the ribbon edges stretch longitudinally between entrance and exit of the pair of rolls so that if the degree of curvature is not limited the stretch edges may not be returnable to their previous dimensions. This results in tubes having scalloped edges along the seams. On the other hand, corrugated ribbons are free from this source of distortion due to the ability of the corrugations to accept considerable stretch and restoration.

The invention is based on the further discovery that the maximum curvature that each stage can safely impart to a corrugated ribbon is approximately the same. Thus, after the maximum change in curvature is established the number of rolls and the radii of the rolls can be established by making them impart the same change in curvature to the ribbon. This involves linearly increasing the ribbon curvature rather than linearly decreasing the diameter.

The above and other features of the invention are pointed out in the claims. Other objects and advantages of the invention will become obvious from the following detailed description when read in light of the accompanying drawing wherein:

FIG. 1 is a schematic and block diagram of a forming operation that produces coaxials and embodies features of the invention;

FIG. 2 is a perspective view of a roll former in FIG. 1;

FIGS. 3, 4, 5, 6, and 7 are end views of the rolls in the respective sequential five staegs of the former in FIG. 2;

FIG. 8 is a perspective view showing details of a roll stage having rolls with vertical axes and forming part of the structure in FIG. 2;

FIG. 9 is a perspective view showing details of a stage in FIG. 2 having rolls with horizontal axes;

FIG. 10 is an elevation of a seam adjuster in FIG. 2;

FIG. 11 is an end view of a roll stage in FIG. 1 that assures an overlapping edge on the corrugated outer conductor;

FIG. 12 is a cross section showing a coaxial manufactured according to the invention by the apparatus of FIG. 1;

FIG. 13 is a graph illustrating the average curvatures of rolls as a function of the stage; and

FIG. 14 is a diagram illustrating the cumulative force necessary for drawing ribbon through the former at various stages.

In FIG. 1, showing a coaxial manufacturing apparatus according to the invention, a roll former **10** continuously receives a longitudinally advancing ribbon **12** that has been transversely corrugated by passing between the peripheral teeth of two corrugating rolls **14**. Also arriving at the former **10** is a center conductor **16** coaxially carrying longitudinally separated disc-shaped spacers **18** made of a dielectric material. The center conductor **16** and the spacers emerge from a hollow plastic guide **20**. Constituting the source of advancing power for the ribbon **12**, as well as the spacer-carrying center conductor **16**, is a capstan **22** that pulls both of these when they have been combind to form the final coaxial **24**.

The former **10** transversely wraps the longitudinally advancing ribbon **12** about the spacers **18** on the longitudinally advancing center conductor **16** until the ribbon takes the shape of a tube **26** having abutting edges that form a longitudinal seam. An adjustor **28** through which the tube **26** is drawn overlaps the seam edges. Creating the final diameter of the tube **26** with the overlap edges is a sizing device **30** that forces the tube to assume its final size before guiding it to a solder device **32** for closing the seam. A take up reel **34** stores the finished coaxial as it emerges from the capstan **22**.

FIG. 2 illustrates the former **10**, the adjuster **28**, and the sizing device **30**, as well as their relations to each other in the apparatus of FIG. 1. In FIG. 2 a first forming, or roll stage **36** includes a top roll **38** whose peripheral surface has a convex profile and a bottom roll **40** whose peripheral surface has a concave profile of a diameter somewhat smaller to accommodate the corrugation depth of ribbon **12**. The stage **36** bends the transversely corrugated metal strip or ribbon **12** that is being pulled between the rolls from left to right by the capstan **22**, to approximately five times the diameter of tube **26**. A second roll stage **42** having a top roll **44** whose peripheral edge has a convex profile and a concave-profile roll roll **46** further bends the horizontally pulled ribbon **12** to 5/2 the diameter of the tube **26**. Both of these first two stages start to shape the ribbon when the convex-profile top rolls **38** and **42** exert a positive force to the center of the ribbon **12** while the rolls **40** and **46** exert forces on the edges.

The stationary plastic tube **20** guiding the moving conductor **16** surrounded by longitudinally separated disc-shaped spacers **18** feeds the center conductor onto the trough of the now-bent ribbon **12** as the ribbon passes into the nip of two horizontally oriented and radially adjacent rolls **52** and **54** of a roll stage **56**. The hollow profiles of the peripheral surfaces on the rolls **52** and **54** squeeze the edges of the semicircular ribbon together to a radius substantially 5/3 of the radius of tube **26**. The ribbon now carrying the center conductor **16** is drawn to a second stage **58** of the horizontally oriented rolls **60** and **62**. The profiles of the peripheral surface ino the latter two rolls **60** and **62** are both concave but exhibit substantially 5/4 of the radius of tube **26** for further compressing the sides of the ribbon **12**. A pair of vertically oriented rolls **64** and **66** form part of a roll stage **68** and possess peripheral surfaces with profiles of still greater curvatures, that is to say, the radius of tube **26**. The ends of the peripheral surface force the edges of the ribbon together until they substantially abut. The ribbon now constitutes the tube **26**.

As stated, and according to the invention the profiles of the peripheral surfaces on the rolls **38** and **40** in the first stage have a radius substantially five times the final radius of the tube **26**, that is to say that the convex peripheral surface of roll **38** has a profile radius of five times the radius of the tube **26** and the concave peripheral surface of the roll **40** has a profile radius five times the desired radius of the tube **26**. Moreover, the succeeding stages have respective peripheral surfaces with respective profile radii 5/2, 5/3, 5/4, and one times the desired radius of the tube **26**. Thus, the curvature of the profiles on each roll increases from 1/5, to 2/5, to 3/5, to 4/5, to 5/5 of the final curvature, i.e., linearly from stage to stage. Generally each profile radius is n/s times the final radius r where n is the number of stages and s is the stage number.

If the final coaxial to be formed needs only a seam with abutting edges the tube **26** emerging from the former **10** is the final product. The adjuster **28**, the sizing device **30**, and the soldering device **32** then can be dispensed with. If the tube **26** with the abutting edge seam must be soldered, only the solder device **32** is necessary. However, where the ribbon **12** is laminar and the seam in the final product overlapped as in the before-mentioned copending Biskeborn et al. application, the adjuster **28** and the sizing device **30** are also essential. In that case, the tube **26** passes into the adjuster **28**. The latter includes a seam positioner **72**. As the tube **26** is pulled the seam positioner **72** places a knife edge between the ribbon edges and partially depresses one edge. An overlap stage **74** having two horizontally adjacent rolls **76** and **78** whose respective peripheral surfaces have different curvatures forces the depressed edge under the other edge so as to properly initiate the overlap.

Two horizontally adjacent rolls **80** and **82** form the first stage **84** of the sizing device **30**. These rolls are sizing rolls and apply the marginal force needed to close up the seam. The final sizing stage **86** is comprised of two vertically aligned sizing rolls **88** and **90** which force the corrugated edges to nest inside each other and provide the tight joint essential to proper soldering.

The entire former **10**, adjuster **28** and sizing device **30** rest on a base **92** having horizontally-slotted rails **94**. Each stage in the former **10**, adjuster **28** and sizing device **30** includes a stand **96** which is movable between the rails **94** but which is secured to the desired position by suitable bolts **98**. The nips of the rolls in the stages are all aligned.

FIGS. 3, 4, 5, 6, and 7 illustrate the rolls **38**, **40**, **44**, **46**, **52**, **54**, **60**, **62**, **64**, and **66** and their working relationship. Each roll has a peripheral forming surface S. The ribbon **12** appears between each pair of rolls as they shape the ribbon. The forming surface S in the rolls terminates in ridges R against which the edges of ribbon **12** abut. The ridges R maintain the angular position of the ribbon. In stage **68** no such ridges exist because the ribbon edges abut against each other as they pass through the rolls **64** and **66**.

The stage **58** representing a typical stage having horizontally oriented rolls, that is rolls with vertical axes, appears in FIG. 8. Here the stand **96** comprises two T-blocks **100**, both of which slide on two steel ways **102** seated on a mounting platform **104** that rides between the rails **94**. Two hollow tubes **106** form bearing blocks cantilever-supporting the axles **108** of the rolls **60** and **62**. The hollow tubes **106** are threaded on the outside into the T-blocks **100** and held by lock nuts **110**. Knurled shoulders **112** permit vertical positioning of the rolls **60** and **62**. Lock bolts **114** allow horizontal adjustment of the T-blocks **100** in the ways **102** for purposes of providing proper clearance between the rolls **60** and **62**. The rolls **60** and **62** have horizontal flat surfaces **115** which engage the upwardly curving edges of the ribbon **12** so as to maintain the angular position of the ribbon and prevent it from twisting.

Details of the roll stage **68** representing a typical stage with vertically adjacent rolls are illustrated in FIG. 9. Here the roller bearings are mounted in T-blocks **120** which can slide up and down on two columns **122** and **124** for adjustment of the roll height. The rolls **64** and **66** are cantilevered off the T-blocks. A knurled wheel **130** between the T-blocks **120** rotates a left-hand and right-hand thread stud in the T-blocks to move the rolls apart or together so as to furnish an accurate, infinitely adjustable roll clearance. The columns **122** and **124** form part of a chair-shaped support **132** that rides between the rails **94**.

FIG. 10 illustrates the seam positioner **72** in detail. Here a vertically oriented wheel **136** cantilevered out along a horizontal axis from a stand **138** possesses a knife edge **140**. An adjusting handle **142** turns a worm that raises or lowers the bearing assembly **144** of the wheel **136** until it fits into the seam of the tube **26**. In FIG. 10 the axial width of the knife edge has been exaggerated for clarity. Since the tube **26** has previously been oriented to place the seam at the very top, the knife edge places a peripheral counter-clockwise torque on the tube. The ribbon edge of the seam abutting the vertical portion of the knife edge **140** is thus continuously biased against this edge. The flat part **146** of the wheel **136** lightly depresses the underlap side.

The overlap rolls **76** and **78** on the stage **74** shown in detail in FIG. 11 immediately take advantage of this depression and torque. The roll **78** on the underlap side of the seam has a radius .014 inch smaller than the roll **76** on the overlap side. This results in a tube **26** whose overlapped side is .028 inch greater than the underlapped side shown in FIG. 12 where the dimensions have been exaggerated for clarity. The counter-clockwise torque developed by the knife edge wheel **136** preceding this pair of rolls assures driving of the overlap edge against the edge of the roll **78** whose peripheral surface has a profile with the smaller radius. The thus displaced edges furnish assurance that the overlapped tube will be formed to final size without crosslap.

The rolls **44** and **46** possess an additional detail necessary for assuring proper overlap of the tube edges and nesting of the corrugations. On these rolls, the profile of surfaces has an average radius equal to 5/2 of the radius of the tube **26**. However, the ends **150** of the profile forming the edges of the ribbon **12** have radii slightly smaller than the average while the radii of the center portion **152** are larger. The edge profiles blend in tangentially with the radii along the major central portion of the profile. In effect, therefore, the rolls **44** and **46** are multiradius rolls. The purpose of the additional radius sections is to bend the edges of the ribbon **12** while a positive force could still be applied to the interior of the ribbon. This overcomes any tendency on the part of succeeding stages to concentrate too much of their bending energy in the major central area of the ribbon and leave the edges of the ribbon flatter than they ought to be. The term average radius is used herein in the sense that the smaller curvature along the center portion is weighted more heavily, i.e., proportional to the ribbon surface it operates on, than the larger curvature of the ends **150**.

For holding the tube **26** at the best soldering angle the entire assembly of FIG. 2 may be rotated about its longitudinal axis.

In operation the capstan **22** pulls the tape **12** through the corrugated rolls **14** and through the first two stages **36** and **42** which respectively impart curavture to the tape **12** whose radii are respectievly five times the radius of the tube **26** and 5/2 times the radius of the tube **26**. A tube **20** feeds a center conductor **16** carrying spacers **18** into the thus formed trough. The roll stage **56** curves the ribbon **12** inwardly to a radius equal to 5/3 times the radius of the tube **26**. The succeeding stages **58** and **68** further decrease the ribbon radius to values equal to 5/4 and one times the radius of the tube **26**. The capstan continues pulling the tube **26** past the knife edge wheel **136** which places sufficient torque onto the tube **26** so that when the latter enters the nip between the rolls **76** and **78** as shown in FIG. 11 an overlap and underlap can be obtained. Without this torque the right edge of the tube **26** shown ing FIG. 11 may enter the left-hand roll **76**.

The overlapping stage **84** and the sizing stage **86** finish the tube sufficiently to allow it to pass to the solder device **32** after which the finished tube can be taken up on the reel **34**.

The invention achieves the notable result of forming a coaxial having a corrugated outer conductor with a passive forming device requiring only longitudinal pull. By virtue of the radii of the profile of the peripheral surface on the rollers in each successive stage decreasing hyperbolically, that is with linearly increasing curvatures, the number of stages is markedly decreased from that which would be necessary for forming noncorrugated tubing according to the principle which followed the linearly decreasing radius of a conical die. The invention is based upon, and the notable achievements thereof are based upon, recognition of several factors which are to some extent interdependent. The invention involves the recognition that the capstan **22** pulling the ribbon **12** must overcome not only a considerable work force that goes into plastically bending the metal and forming it, but must overcome a substantial drag due to such factors as the friction developing out of the different peripheral speeds along the profile of any one rotating roll, the frictional force of maintaining the tube in one angular control position, and the force necessary to return the ribbon to the dimension to which the previous stage had bent it and from which it resiliently departs. Such force may account for 30 to 40 percent of the force necessary to pull the ribbon through the former. To minimize these effects the invention reduces the number of forming stages.

The invention is also based on the recognition that the reduction in forming stages can go far further for corrugated ribbon than uncorrugated ribbon and that each stage can perform more work actually involved in plastically forming the tube than is possible with flat ribbons. This is based upon the further recognition that the limit to which flat ribbons can be formed transversely is defined by their ability to stretch at the edges when passing through rolls. Each ribbon when it passes through rolls has one form at the entrance and one form at the exit. From entrance to exit the shape at the middle does not change. However, the ribbon stretches at the edges in order to achieve its desired curvature. This stretching can be sufficient to prevent the ribbon edges from being returned to their normal dimensions. Scalloped seams occur in the final product. This defect in normal ribbon is sometimes overcome by placing an additional drag upon the ribbon being fed into the rolls and increasing the pull on the ribbon. This has the effect of actually drawing out the ribbon across its entire cross section and constitutes a drawing operation. The extra pull would pull out corrugation and thus be unsuitable for corrugated conductors. Thus, while ordinary formers are unsuitable for forming corrugated coaxials, the formers according to the invention may similarly be unsuitable for forming smooth outer conductors.

The apparatus of FIG. 1 was used to fold a tube **26** from a starting ribbon **12** of .003″ x 1.25″ copper aligned at one edge with .010″ x 1.375″ No. 1 temper tin-plated steel, and bonded thereto with Du Pont Alathon 80F copolymer.

The five stages of former **28** each impart one-fifth of the total curvature. This number of stages is necessary for forming the tube **26** from the before-mentioned ribbon unless each stage could impart one-fourth of the curvature without buckling the ribbon, in which case a four stage former would be possible. Stages capable of performing intermediate amounts of curving, i.e., between one-fifth and one-quarter of the final curvature, still establish the number of stages as five because there can be no stage numbers between four and five. Nevertheless, these intermediate values indicate that tolerances on the values of the profile radii are possible. In fact that one-fourth total curvature represents a limit that can be placed upon departures from the requirement that the curvatures imparted by each stage must be equal to one-fifth. This maximum tolerance would occur if for example four stages imparting equal curvatures to the ribbons were almost, but not quite, sufficient for forming the tube **26**. Thus, the differences in curvature between the profile radii from stage to stage in a five stage former cannot be greater than one-fourth of the total curvature.

This concept can be paraphrased for a general case. For an *n*-stage former having a final radius of *r*, and a final curvature $1/r$, whose rolls in successive stages have actual profile radii of R_S and R_{S+1}, the differences in curvature between successive stages, namely,

$$\left(\frac{1}{R_S+1}-\frac{1}{R_S}\right)$$

must be less than the share of the final curvature to be imparted by one stage in an ideal former having one stage less than *n*. The share for each stage in an $(n-1)$-stage ideal former is

$$\frac{1}{(n-1)}$$

times the final or total curvature $1/r$. Each stage must also produce some curvature. Thus,

$$0<\frac{1}{R_S+1}-\frac{1}{R_S}<\frac{1}{(n-1)r}$$

This formula represents the maximum stage-to-stage departure permissible from the rule that each stage adds the same curvature to the ribbon.

Moreover, it is possible within this tolerance to determine the possible maximum and minimum for the profile radius in each stage of an *n*-stage former. The profile radius in any stage, which ideally is n/s times the final radius *r*, can reach down to a minimum value (when it would do the most bending) equal to an ideal stage in an $(n-1)$-stage former, namely, reach down to

$$\frac{(n-1)r}{s}$$

It can reach up to a value where the other stages all follow the $(n-1)$ stage ideal former radii of

$$\frac{(n-1)r}{s}$$

and the stages in question merely repeat the previous stage $(s-1)$, namely, reach up to a radius

$$\frac{(n-1)r}{(s-1)}$$

This may be stated in terms of tolerances, i.e., departures from the desired values of

$$\left(\frac{nr}{s}\right)$$

Thus, in each stage the actual profile radius may exceed

$$\left(\frac{nr}{s}\right)$$

by

$$\left(\frac{(n-1)r}{s-1}-\frac{nr}{s}\right)$$

or

$$\frac{n-s}{s(s-1)}r$$

In each stage the profile radius may be less than

$$\left(\frac{nr}{s}\right)$$

by

$$\left(\frac{nr}{s}-\frac{(n-1)r}{s}\right)$$

or r/s.

In an exemplary embodiment the invention was, as stated, used for forming broadband cable whose outer conductor ribbon was composed of the before-mentioned .003″ x 1.25″ soft copper, bonded with a .002 inch Du Pont Alathon 80F copolymer to .010″ x 1.375″ No. 1 temper tin-plated steel. The laminate was corrugated about 12 corrugations per inch .014 inch deep peak to valley. Only the steel laminate was overlapped. The roll stages had the following characteristics.

Stage	Roll Diameter	Forming Roll Profile Radius in Inches
0	2.25	∞
1	2.25	1.029
2	2.25	[1] .561
3	2.25	.396
4	2.25	.296
5	2.25	.240

[1] Average value.

The results of forming the cable **24** at these dimensions is illustrated in FIG. 13. This diagram illustrates the linear increase in curvature from stage to stage. FIG. 14 illustrates the cumulative force necessary to draw the ribbon through the stages.

While an embodiment of the invention has been described in detail, it will be obvious to those skilled in the art that the invention may be otherwise embodied without departing from its spirit and scope.

What is claimed is:

1. A roll former for shaping a transversely-corrugated longitudinally-pulled ribbon into a tube, comprising a plurality of sequentially arranged roll stages each having two radially-adjacent freely-rotatable rolls between which a corrugated ribbon can be pulled, said rolls in each stage having peripheral forming surfaces with curved forming profiles spaced close enough to each other to bend the advancing ribbon transversely, the peripheral surface in one roll of each of said sequentially arranged stages having a concave forming profile, said concave forming profiles having respective average profile radii, the peripheral surface of the other roll in one of said sequentially arranged stages having a convex profile, the peripheral surfaces in the other roll of another later one of said sequential stages having concave profiles, the average profile radius in the first of said successive stages being substantially as many times greater than the final desired radius as the number of stages, the average profile radius in each of said successively arranged stages being substantially inversely proportional to the sequential position of each stage with the average profile radius of the final stage having the desired final radius, whereby said stages can bend said corrugated ribbon passing between the rolls to lesser and lesser diameters.

2. A roll former as in claim **1**, wherein the profile radii in each stage substantially contact the entire width of said ribbon.

3. A roll former as in claim 1, wherein the profile radii in each stage substantially contact the entire width of said ribbon, and wherein said rolls possess peripheral stops at the edges of said ribbons.

4. A device as in claim 1, wherein one of the stages with both convex and concave surfaced rolls has a multi-radius profile with edges having a smaller profile radius than the remainder of the profile, said smaller profile radius being substantially equal to the profile radius of the last stage in said former.

5. A roll former as in claim 1, wherein the profile radii have tolerances in their values limited in that differences between the curvatures of the forming profiles of said peripheral forming surface of adjacent stages is less than the difference in profile curvatures between adjacent stages in an otherwise identical former whose profile radii varied inversely with the stage position but which had one less stage and without any tolerances.

6. A former as in claim 5, wherein the differences between profile radii in adjacent stages is less than the final radius times the reciprocal of one less than the number of stages.

7. A former as in claim 5, wherein the profile radius of each stage is

$$\frac{nr}{s}+\frac{(n-s)r}{s(s-1)}$$

or

$$-\frac{r}{s}$$

8. An apparatus for forming coaxial cable from a transversely corrugated ribbon and a spacer-carrying center conductor comprising capstan means for longitudinally pulling said ribbon, a plurality of sequentially arranged roll stages each having two radially-adjacent freely-rotatable rolls applying force to the ribbon as it is being pulled, said rolls in each stage having peripheral forming surfaces with curved forming profiles spaced close enough to each other to bend the pulled ribbon transversely, the peripheral surfaces in one roll of each of said sequentially arranged stages having a concave forming profile, said concave forming profiles having different respective average profile radii, said peripheral surface of the other roll in one of said sequentially arranged stages having a convex profile, the peripheral surfaces in the other roll of another later one of said sequential stages having concave profiles, the average profile radius in the first of said successively arranged stages being substantially as many times greater than the last as the number of stages, the average profile radius in each of said successively arranged stages being proportional to the sequential position of the stage, the profile radius of the final of said stages being equal to the desired final radius, whereby said stages bend the corrugated ribbon passing between said rolls to lesser and lesser diameters, and means for guiding the spacer-carrying center conductor into the trough formed in said ribbon after said stage having said roll with a convex profile.

9. An apparatus as in claim 8 further comprising adjusting means between said capstan means and said roll stages for overlapping the edges of the seam formed on said tube, and sizing rolls for producing a final overlap diameter.

References Cited

UNITED STATES PATENTS

2,156,934	5/1939	Barrett	29—202.5
2,156,952	5/1939	Morsing	29—202.5 X
2,764,214	9/1956	Reynolds et al.	72—176
3,026,924	3/1962	Lunt et al.	29—202.5

THOMAS H. EAGER, *Primary Examiner.*

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,397,442 Dated August 20, 1968

Inventor(s) Thomas J. Mc Gean

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 9, line 24, after "is" insert --between--;
line 28, delete "or" and insert --and--;
lines 29 and 30, the formula should be

$$-- \frac{nr}{s} - \frac{r}{s} --.$$

SIGNED AND
SEALED
AUG 25 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents