Nov. 17, 1936. R. E. BROWN 2,061,501

METHOD AND APPARATUS FOR ROLLING BELLOWS

Filed July 29, 1932 3 Sheets-Sheet 1

FIG. 1.

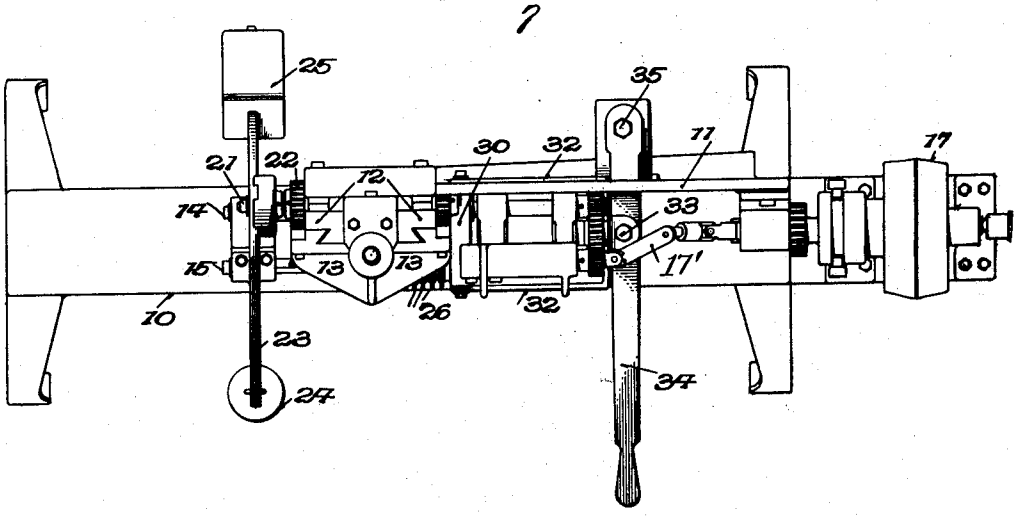
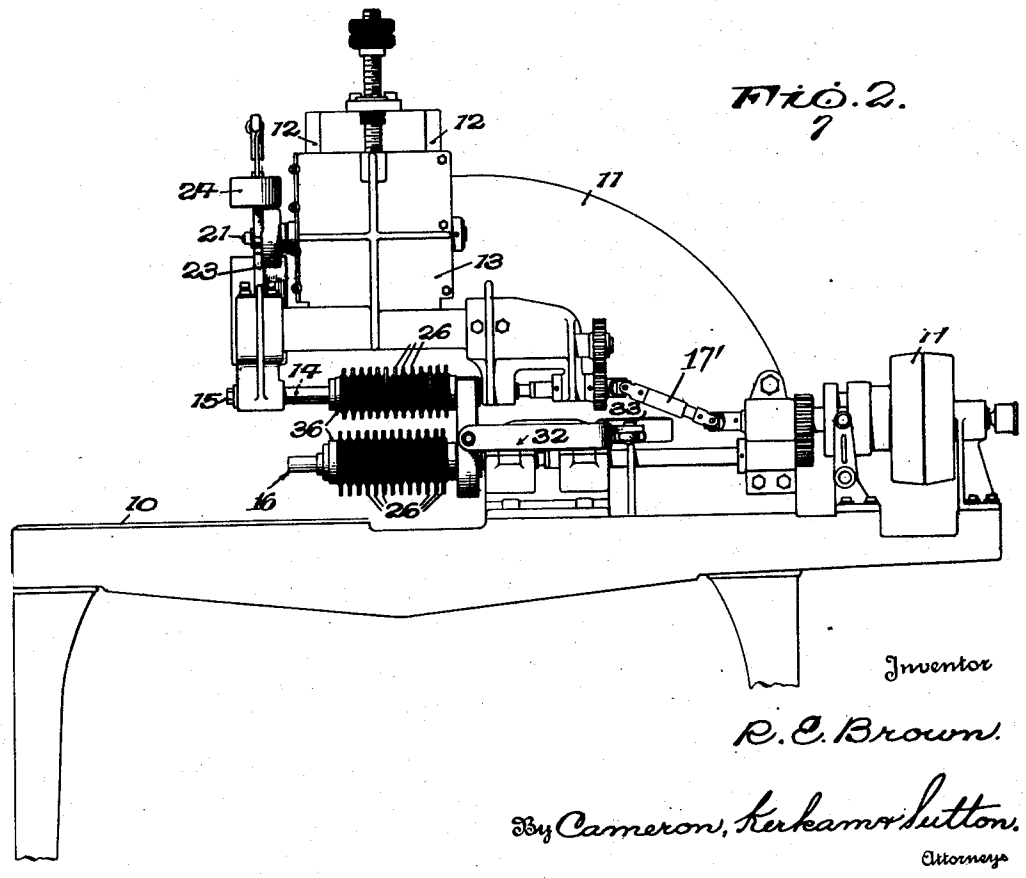


FIG. 2.



Inventor

R. E. Brown.

By Cameron, Kerkam & Sutton.

Attorneys

Nov. 17, 1936. R. E. BROWN 2,061,501

METHOD AND APPARATUS FOR ROLLING BELLOWS

Filed July 29, 1932 3 Sheets-Sheet 2

Fig. 5.

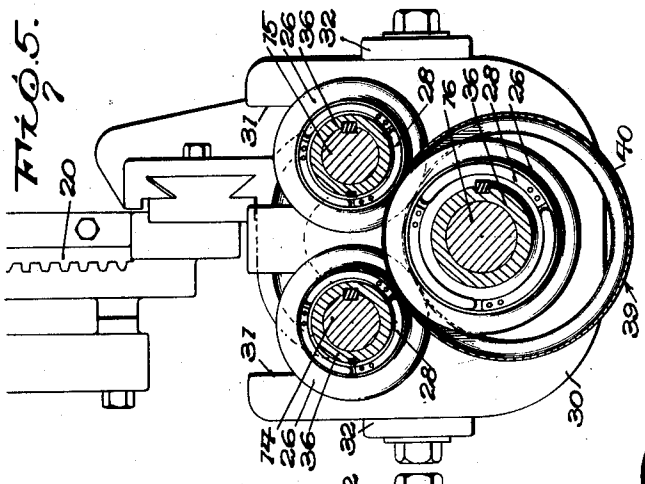


Fig. 6.

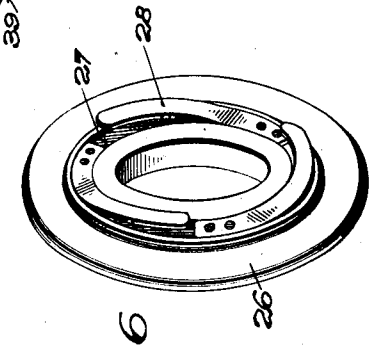


Fig. 4.

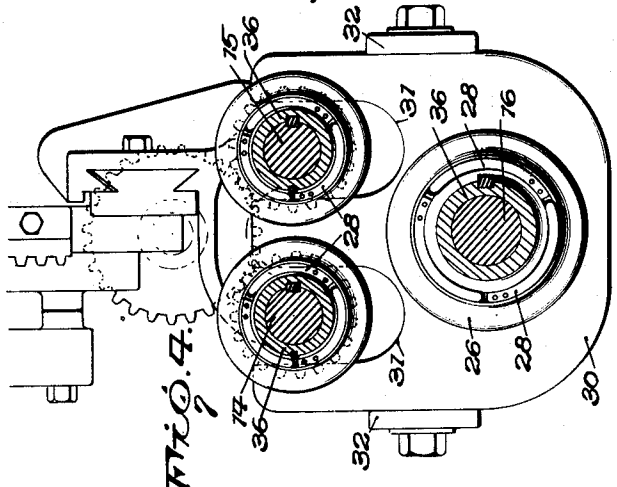
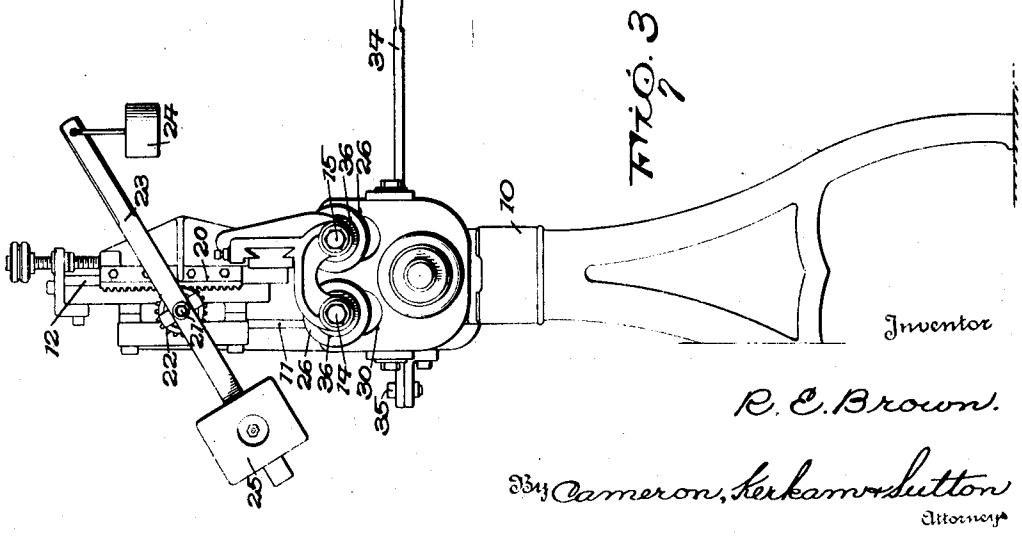


Fig. 3.



Inventor

R. E. Brown.

By Cameron, Kerkam & Sutton

Attorneys

Nov. 17, 1936. R. E. BROWN 2,061,501

METHOD AND APPARATUS FOR ROLLING BELLOWS

Filed July 29, 1932 3 Sheets-Sheet 3

FIG. 7.

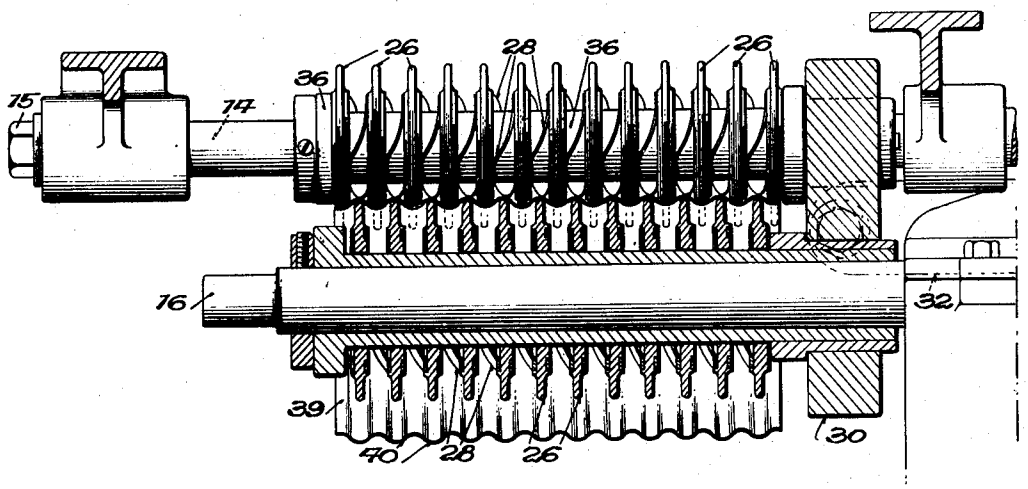
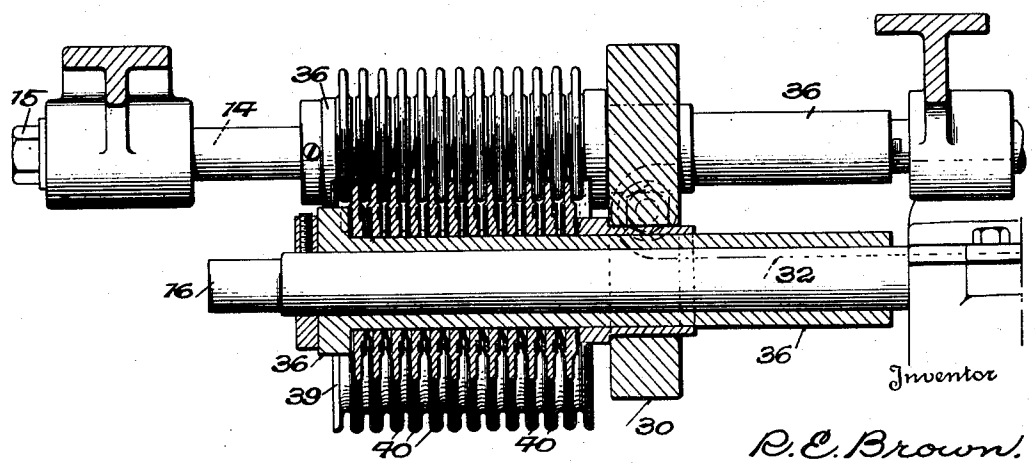


FIG. 8.



Inventor

R. E. Brown.

By Cameron, Kerkam & Sutton

Attorneys

Patented Nov. 17, 1936 2,061,501

UNITED STATES PATENT OFFICE

2,061,501

METHOD AND APPARATUS FOR ROLLING BELLOWS

Robert E. Brown, Knoxville, Tenn., assignor to The Fulton Sylphon Company, Knoxville, Tenn., a corporation of Delaware

Application July 29, 1932, Serial No. 626,051

28 Claims. (Cl. 153—73)

This invention relates to the production of axially expansible and collapsible, corrugated, tubular, metallic walls, which are commonly called bellows, and more particularly it relates to an improved method and apparatus for producing such walls by a rolling operation.

It has heretofore been the practice in the rolling of bellows to form the corrugations progressively between successive sets of coacting rolls provided with ribs of such shape and size that each succeeding set is adapted to deepen and narrow the corrugations as formed by the preceding set. Sometimes the corrugations are acted upon one at a time by the succeeding sets of rolls, sometimes all of the corrugations are acted upon simultaneously by the succeeding sets of rolls, and sometimes the corrugations are acted upon individually but in succession by progressively differentiated and simultaneously acting ribs on the cooperating rolls, but in all cases the rolling has been characterized by the subjecting of each corrugation to the progressive and successive action of a plurality of rolling operations in order to gradually deepen and narrow the corrugations. Thus in the forming of bellows of 2½" outside diameter and over it is customary to subject the metal to at least five successive rolling operations. These succeeding rolling operations tend to render the metal hard and brittle, and therefore it is usual to anneal the wall at some stage in its formation, and sometimes it is desirable to subject the wall to a plurality of annealing operations, in order that the resulting product may not have its walls overstrained and therefore lacking in the capacity to withstand a relatively great number of flexures without rupture.

It has also been proposed, in order to expedite and simplify the rolling of bellows, to roll a tube between external and internal rolls provided with a series of axially shiftable roll elements, and form the corrugations by bringing the axes of the roll elements radially toward each other, while permitting the individual roll elements to float axially, and therefore approach each other, in order to as nearly as may be form the bellows in a single rolling operation. While this procedure may reduce the number of rolling operations and eliminate an intermediate anneal, it has been found impossible to produce a parallel walled corrugation by this procedure, while if the rolling operation is carried very far there is a tendency to stretch, thin or overstrain the metal to an undesirable extent. Hence the rolling operation has had to be stopped when the corrugations had reached a V-shaped formation, and the tube thereafter subjected to a further collapsing operation in order to bring the corrugations into the desired final form.

In the procedure last referred to the movement of the axes of the rolls toward each other radially has been positive, but the movement of the roll elements axially in order to narrow the corrugations as they deepen has been effected by permitting the rolls to float axially, and therefore their axial movement has been due entirely to the pull exerted by the tube on the roll elements. In other words, considering what is taking place at any one trough being formed, as the outside roll element enters the space between two inside roll elements to form the metal into a V, the sides of the V tend to move about the apex of the V and therefore to slide the two inside roll elements along their arbor toward each other and the intermediate outside roll element. Disregarding the frictional opposition to the roll elements so sliding along their arbors, it will be perceived that the component of the force exerted by the outside roll element on the metal which tends to draw the two inside roll elements toward each other varies with the angle made by the metal to said roll elements. At the beginning of the operation when the metal is substantially parallel to the axis, the tendency to draw the roll elements toward each other is commensurate with the force exerted to move the axes of the roll elements toward each other, but as the angle of the side of the trough to the normal to the axis decreases, the component of force tending to move the roll elements toward each other decreases rapidly, as a function of the angle, and to move the sides of the trough into parallelism in this manner the radial force would have to be infinite. Hence of necessity the forming of the corrugations has to be stopped before the corrugations have parallel lateral walls.

Moreover, as the component of the radial force tending to move the roll elements toward each other decreases, the tendency of the metal to be stretched by the forcing of the roll elements radially toward each other increases, and therefore the roll elements cannot form the metal into very narrow V-shaped troughs without a considerable increase in the stretching tendency of the radial force then acting on the metal. With metal of considerable thickness, this stretching tendency within limits may not be important because the percentage of change in circumferential dimension as the V-shaped troughs are narrowed does not produce such a percentage of thinning

of the wall, if the narrowing is not carried too far, as to seriously affect the functional capacity of the corrugated wall. With metal of the thinness such as is conventionally used in bellows, however, and which is usually less than .010", and may be half of that thickness or even less, this tendency of the metal to stretch as a result of the procedure under discussion becomes critical, because the percentage change in thickness is sufficient to produce a thinning of the metal that has a serious effect upon the functional capacity of the resulting wall. Moreover, with thin metal the imposition upon said metal of the entire duty of pulling the rolls toward each other as the troughs between the roll elements are narrowed tends to overstrain the metal and shorten the life of the resulting product.

In the corrugating of sheets it has been proposed to take from the metal the duty of pulling the roll elements toward each other, and to provide the roll elements with a positive feed, whereby they are made to approach each other by reason of an external drive, as by a nut and screw connection between each roll element and its arbor, as the corrugating operation proceeds. In the corrugating of tubes, however, a quite different problem is presented, because the positive feed of the roll causes the roll to form a helix with respect to the tube, and therefore at the end of a complete revolution of the arbor the point on the roll element in contact with the tube would trace a helical line upon the tube, whereas the corrugation to be formed is a closed circle. Therefore, the positive axial feed of the roll elements during the corrugating operation has been found to be unsatisfactory in the corrugating of tubes, and this has been particularly true in the corrugating of bellows, wherein the very thin metal being treated is particularly susceptible to distortion and injury by reason of the tendency of the rolls to change the partly forming corrugations from closed circles into helices.

It is an object of this invention to provide a method and apparatus for rolling bellows which eliminates the numerous rolling operations heretofore employed and which are effective to roll the corrugations to their final shape in a single rolling operation without unduly stretching or stressing the metal.

Another object of this invention is to provide a method and apparatus for rolling corrugations which can be used to bring the lateral walls of the corrugations into substantial parallelism in one rolling operation.

Another object of this invention is to provide a method and apparatus for rolling bellows in a single rolling operation which eliminates the tendency to unduly stretch and overstrain the metal of the wall whether or not the lateral walls of the corrugations are carried to substantial parallelism.

Another object of this invention is to provide a method and apparatus for rolling bellows in a single rolling operation which so treats the metal being formed that the tendency to produce localized thinning of the metal is largely overcome.

Another object of this invention is to provide a method and apparatus for rolling bellows in a single rolling operation whereby the metal is so treated that the metal of the resulting product is not overstrained, and therefore has increased durability as compared with the products of rolling operations heretofore employed.

Another object of this invention is to provide a method and apparatus for rolling bellows in a single rolling operation which utilizes a drive of the roll elements in the direction of their axes without introducing the difficulties incident to the positive feeding of the roll elements.

Another object of this invention is to provide a method and apparatus for corrugating bellows in a single rolling operation which produces a durable, highly flexible, and resilient bellows.

Another object of this invention is to provide a method and apparatus for rolling bellows in a single rolling operation which planishes the lateral walls of the corrugations and therefore tends to add to their capacity to resist the stresses and strains of repeated flexure.

Another object of this invention is to provide a method and apparatus for rolling bellows which enables a substantial reduction in the forces employed in the direction of the radius of the tube, and therefore in the tendency to stretch the metal, and wherein the flowing of the metal into its ultimately corrugated form is facilitated and aided by axial forces.

Another object of this invention is to provide a method and apparatus for rolling bellows wherein the corrugations may be formed to the desired depth and width in a single rolling operation and wherein the forces exerted both radially and axially of the tube for forming the corrugations act through the metal itself to produce a proper flow of the metal, while the roll elements approach each other by reason of a pushing force, as distinguished from a pulling force, exerted through the metal.

Another object of this invention is to provide a method and apparatus for rolling bellows whereby a bellows may be rolled in a single operation to the desired final depth and width of corrugation and the resulting product will be possessed of improved characteristics as respects durability, uniformity of wall thickness, resiliency, etc.

Other objects will appear as the description of the invention proceeds.

The invention is capable of being carried out in a variety of ways and of being embodied in a variety of apparatus, one of which has been illustrated on the accompanying drawings, but it is to be expressly understood that the drawings are for purposes of illustration only, and are not to be construed as a definition of the limits of the invention, reference being had to the appended claims for that purpose.

Referring in detail to the drawings wherein the same reference characters are employed to designate corresponding parts of the several figures,

Fig. 1 is a somewhat diagrammatic plan view of an apparatus embodying the present invention and for carrying out the method of the present invention;

Fig. 2 is an elevation of said apparatus;

Fig. 3 is an end view of said apparatus;

Fig. 4 is an enlarged fragmentary cross section to illustrate the relationship of the roll elements at the beginning of the operation;

Fig. 5 is a corresponding enlarged fragmentary cross section to illustrate the position of the roll elements at the end of the corrugating operation;

Fig. 6 is a perspective of one of the roll elements to illustrate the spring members for initially spacing the roll elements;

Fig. 7 is a somewhat schematic view illustrating the axial position of the roll elements at

or soon after the beginning of the rolling operation; and

Fig. 8 is a corresponding view illustrating the axial position of the roll elements at the end of the rolling operation.

In accordance with the present invention the bellows is formed in a single rolling operation by subjecting the tubular wall, preferably provided with preliminary shallow corrugations for the purpose of properly positioning the roll elements, to a radial force tending to bend the tubular wall around the periphery of the roll elements, said radial force, however, being preferably insufficient in magnitude to bend the metal out of its tubular form—although the magnitude of the radial force may be greater if preferred—and simultaneously to an endwise or axial force sufficient to cause the metal to flow into deeply corrugated form, the roll elements moving axially with respect to each other as the corrugations are formed but the axial force being applied through the tube to the roll elements so that the metal maintains the roll elements in their proper relationship during the forming of the corrugations. Thereby, under the combined action of the radial and axial pressures exerted upon the metal, the metal of the tube flows readily into the deeply corrugated form, while the roll elements move axially concurrently with the metal flow and without imposing any undue strain or constraint thereon, and hence, by a single rolling operation, the corrugations can be shaped to final depth and width, with their lateral walls in substantial parallelism if desired, without any undue straining or thinning or stretching of the metal. This method and the principle underlying the same will be somewhat clearer from an explanation of a suitable apparatus for practicing the same.

Referring in detail to the drawings, Figs. 1, 2 and 3 illustrate more or less diagrammatically a machine which may be employed to practice the present invention and which, as to its general features of construction, may as shown be similar to machines now commonly used for performing each of the several successive rolling operations in the production of bellows. Mounted on any suitable bed or framework **10** is an overhanging head **11** provided with ways **12** on which may move vertically a reciprocating carriage **13** which carries the arbor or arbors, here shown as two arbors **14** and **15**, for the external roll elements. Disposed in suitable radial alignment with said arbor or arbors **14** and **15**, is the arbor **16** for the internal roll elements suitably carried by the relatively stationary framework of the machine.

Any one or more of said arbors may be positively driven. As shown the arbor **14** is suitably driven through a shaft **17'** from any suitable source of power, here shown as a belt pulley **17**. If desired the arbor **15** may also be driven positively from the arbor **14**. When the external arbor or arbors are driven positively, the internal arbor or the roll elements thereon are preferably freely rotatable, and if the internal arbor is the driven element the external arbor or arbors or the roll elements thereon are preferably freely rotatable.

The external arbor or arbors **14** and **15** are movable radially toward and away from the arbor **16** by reciprocation of the carriage **13**, and said carriage may be driven in any suitable way. As shown, said carriage is provided (see Fig. 3) with a rack **20**, and suitably mounted in bearings in the head **11** is the spindle **21** of a pinion **22** which cooperates with said rack. Fixedly mounted on the spindle **21** of pinion **22** is a lever **23**, here shown as provided with weights **24** and **25** at its opposite ends, but if preferred, a single weight at one extremity can be used. The weight or weights on said lever **23** are preferably so selected and disposed that they tend to rotate the lever **23** and the pinion **21** in a direction to cause the rack **20** and carriage **13** to move downwardly and therefore cause the arbor or arbors **14** and **15** to approach radially toward the arbor **16**, although if desired the downward or radially inward movement of said arbor or arbors **14** and **15** can be effected by hand or by any other suitable motive force.

The magnitude of the force tending to move the arbor or arbors **14** and **15** radially toward the arbor **16** is preferably just short of that required to cause the deformation of the tube to be operated upon, although the magnitude of this force, which will be referred to as the radial force, may be varied within considerable limits, and if preferred, it can be increased so that it will of itself be sufficient to deform the tube to a certain extent.

Mounted on the arbors **14**, **15**, and **16** are a series of roll elements **26**. Where as shown two external arbors are used the roll elements thereon may be of somewhat smaller diameter than the roll elements on the arbor **16**, but it will be understood that, if preferred, only a single external arbor may be used, and in that event the roll elements on the two arbors can be of equal diameter. Each of the roll elements on each of the arbors is freely slidable on its arbor, and each of the roll elements is so shaped as to give to the corrugations the desired final width and depth. When it is desired that the corrugations be formed with their lateral walls substantially parallel, the side walls of the roll elements are made parallel, or at least do not extend beyond parallel planes whose spacing is equal to the desired final width of the corrugations, and the peripheries of the roll elements are transversely curved in conformity with the radius of curvature of the bends of the corrugations.

It is sometimes desirable to provide the roll elements with means whereby they will automatically space themselves at a proper distance apart at the beginning of the operation, and to this end the roll elements as shown are provided with resilient members which will automatically space the roll elements in their proper initial position when the roll elements are not otherwise restrained. As shown each roll element is provided adjacent its hub with an annular groove **27**, and mounted within said groove are one or more arcuate leaf springs **28** suitably fastened to the roll elements at one end and normally deflected so as to project out from the roll elements at their opposite ends by an amount that will properly give the desired initial spacing between the roll elements. These springs should not be of a stiffness much if any greater than that necessary to properly space the roll elements, so as to reduce to a minimum the resistance to the relative axial movement of the roll elements, and in many instances it may be found preferable to entirely omit the spacing elements **28** and rely upon manual positioning of said elements initially.

To collapse the roll elements axially with respect to each other a plate 30, which is provided with a suitable aperture through which the arbor 16 extends and with a suitable slot or slots 31 within which the arbors 14 and 15 may have movement, is mounted to slide axially of the arbors 14, 15 and 16. Any suitable means for effecting the axial movement of the plate 30 can be used. As shown the plate 30 is provided with a bifurcated thrust member 32 and suitably connected, as by the pivot 33, to a lever 34 pivoted at 35 on the frame of the machine and extending forwardly to the operator's position. By grasping the lever 34 and moving it in a clockwise direction, as viewed in Fig. 1, the plate 30 may be caused to move toward the left as viewed in Figs. 2 and 7, causing the roll elements 26 on each of the arbors 14, 15, and 16 to move axially, against the tension of the spring elements 28 when used, until they are brought into face to face contact at their hub portions, suitable stops 36 being provided on each of the arbors to hold the end roll element of each series axially stationary.

To carry out the process of the present invention it is preferred to provide the tube 39 to be corrugated in any suitable way, as by use of any of the expanding mandrels now commonly used in bellows manufacture, with a series of shallow corrugations, such as illustrated at 40 in Fig. 7, these shallow corrugations being of such pitch as to properly space the roll elements initially. For example the pitch of the initial shallow corrugations from crest to crest may be equal to two times the length of each lateral wall of the desired corrugation plus two times the arcuate length of the bend of each corrugation as measured on a radial cross section. The preliminary formation of these shallow corrugations, however, may not be necessary if the roll elements are accurately spaced initially so as to make certain that equal amounts of metal go into each of the corrugations to be formed, and the tube is initially restrained against axial movement.

Tube 39 having been placed on the roll elements 26 of the arbor 16, with the roll elements either suitably spaced by their interposed springs 28 or in any other suitable way, the carriage 13 is permitted to descend under the action of the weighted lever 23 so that the roll elements on the arbors 14 and 15, initially spaced at their proper distances, engage in the troughs of the corrugations or midway between the roll elements of the inner arbor 16 if no preliminary corrugations are formed. If, as preferred, the magnitude of the radial force exerted by the weighted lever 23 is insufficient to deform the tube, the tube and roll elements will now be rotated by their engagement, because of the positive drive of one or more of the arbors, but no change in the configuration of the tube 39 is being effected.

The operator then moves the lever 34 to the left as viewed in Figs. 2 and 7, to move the plate 30 in the direction proper for causing the roll elements to move axially toward each other. The combined action of the axial force now exerted on the tube and the radial force exerted through lever 23 causes the metal to flow into corrugated form. Each corrugation is being shaped under the combined action of the radial force exerted at the bottom of the trough and the axial force exerted by the relative approach axially of the roll elements at the sides of the corrugation. While the roll elements are thus being moved toward each other by an external axial force, this external force is not acting positively on any of the roll elements except the end element of the series. In other words, the axial collapsing force is being exerted on the roll elements through the metal of the tube itself, and while the axial force exerted on the roll elements may not be sufficient to cause the collapse of the tube in the absence of the radial force, this axial force is not only exerted on the metal to tend to cause it to flow into the corrugated form with the assistance of the radial force, but it is also affirmatively moving the roll elements toward each other, so that the force required for the movement of the roll elements is not derived from the radial force and exerted on the roll elements by a pull transmitted through the metal as in practices heretofore employed. The roll elements being free to move as fast and only so fast as required by the metal as it flows into its corrugated form, no improper strain or constraint is imposed thereon, and therefore the deforming, overstressing and overstretching tendencies heretofore existing are avoided. At the same time the operation can be continued until the corrugations are brought to final depth and width, with the lateral walls thereof in substantial parallelism if desired, because the source of energy by which the roll elements move axially is independent of the varying angle between the wall of the tube and the normal to the axis. Also the lateral walls of each corrugation as it is brought to final form are rubbed or planished by the sides of the rolls as the operation comes to an end, as is apparent from Fig. 8, and thereby some cold working is imparted to these lateral walls.

It will therefore be perceived that in accordance with the present invention a bellows may be formed in tubular metal of any suitable thickness in a single rolling operation, and the corrugations brought to the desired final configuration so that no subsequent operation is necessary, without overstressing or overthinning the metal. Hence the use of a plurality of rolling operations with or without intermediate annealing operations has been avoided, and not only can the corrugations be brought with their lateral walls into parallelism by a single rolling operation, but the tendency to stretch and thin the metal which is characteristic of the latter part of previous efforts to use a single rolling operation, although only in the forming of V-shaped corrugations, is largely if not entirely eliminated. As the metal is caused to flow under combined radial and axial forces, it tends to remain more nearly uniform in thickness than characteristic of earlier procedures, while as the metal is not overstrained or unduly thinned the durability of the resulting product is materially increased. While the rolling elements are caused to move axially by reason of an external force, and are not therefore dependent for their movement upon a pull being transmitted through the wall of the metal, the yielding feed of the roll elements through the metal of the wall itself assures that there is no improper restraint or undue tendency to deform the metal by reason of the axial movement of the roll elements. As the force which moves the roll elements is transmitted through the metal of the wall itself, it exists as a thrust on the metal wall, rather than a pull as characteristic of earlier procedures, and therefore undue stressing and stretching of the metal is avoided.

While the embodiment of the invention illustrated on the drawings has been described with considerable particularity it is to be expressly

understood that the invention is not restricted thereto, as will be now readily apparent to those skilled in the art, while changes may be made in the procedure to be followed and the apparatus to be used can take a wide variety of forms without departing from the spirit of the present invention. Reference is therefore to be had to the appended claims for a definition of said invention.

What is claimed is:

1. The method of forming a bellows in a single rolling operation which includes rolling a tube between interior and exterior roll elements while moving said elements radially toward each other and simultaneously exerting an axial thrust on the tube and roll elements to corrugate the tube and move the roll elements axially by the thrust of the forming corrugations thereon.

2. The method of forming bellows in a single rolling operation which includes rolling a tube between interior and exterior roll elements which exert a radial corrugating force on the tube and simultaneously exerting an axial thrust through the tube on the peripheries of the roll elements to cause the same to approach axially and aid the flow of the metal into corrugated form.

3. The method of forming a bellows in a single rolling operation which includes exerting on a tube a radial rolling force which is insufficient to deform the tube into corrugated shape, and exerting an axial thrust on the rolls to move the same axially against a yielding force and cause the metal to flow into corrugated form.

4. The method of forming a bellows which includes rolling a tube in a single rolling operation between radially and axially movable interior and exterior roll elements while simultaneously exerting externally applied radial and axial forces on said roll elements to cause them to approach radially and slide axially with relative freedom.

5. The method of forming a bellows which includes rolling a tube in a single rolling operation between axially and radially movable interior and exterior roll elements while moving the roll elements radially toward each other and transmitting an axial thrust through the tube to said roll elements to cause said elements to move axially toward each other.

6. The method of forming a bellows which includes rolling a tube in a single rolling operation between axially and radially movable interior and exterior roll elements, while imposing a radial force on said roll elements to move said elements toward each other radially, said force being insufficient by itself to corrugate the tube, and subjecting the tube to an axial thrust to supplement the action of said radial force and cause said roll elements to move axially toward each other.

7. The method of forming a bellows in a single rolling operation which includes rolling a tube in a single operation between radially and axially movable interior and exterior roll elements and moving said roll elements radially while sliding them axially by the action of the forming corrugations thereon until the laterial walls of the corrugations are substantially parallel.

8. The method of forming a bellows which includes rolling a tube in a single operation between axially and radially movable interior and exterior roll elements while subjecting said tube to an axial force to move said roll elements relatively to each other axially and moving said roll elements radially until the lateral walls of the corrugations are substantially parallel.

9. The method of forming a bellows which includes rolling the tube between radially and axially movable interior and exterior roll elements, while moving said roll elements toward each other radially and exerting an axially directed thrust through the wall of said tube to cause said roll elements to move toward each other axially.

10. The method of forming a bellows which includes providing a tube with initial shallow corrugations and as a separate operation rolling said tube between axially and radially movable interior and exterior roll elements engaged in said shallow corrugations while externally applying axial and radial forces to said roll elements to cause them to approach each other relatively in both directions.

11. The method of forming bellows which includes providing a tube with initial shallow corrugations, and as a separate operation rolling said tube between radially and axially movable interior and exterior roll elements engaged in said shallow corrugations, moving said roll elements positively toward each other radially and simultaneously applying an axial force to said tube to move said roll elements axially toward each other.

12. The method of forming bellows which includes providing a tube with initial shallow corrugations, and as a separate operation rolling said tube between radially and axially movable interior and exterior roll elements engaged in said shallow corrugations, applying to said roll elements a force tending to move the same toward each other radially but insufficient of itself to corrugate the tube, and applying an axially directed force to said roll elements to supplement the radial force and cause the metal to flow into corrugated form.

13. The method of forming bellows which includes providing a tube with initial shallow corrugations, and as a separate operation rolling said tube between radially and axially movable interior and exterior roll elements engaged in said shallow corrugations, applying a radial force to said roll elements to cause said roll elements to approach each other radially and exerting a thrust axially on said tube to aid the metal of said tube in flowing into corrugated form and to move said roll elements toward each other axially.

14. The method of forming corrugations in relatively thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, subjecting said roll elements to a force tending to move them toward each other radially, and simultaneously subjecting said tube and roll elements to an external force tending to supplement said radially-acting force and cause said tube to move said roll elements toward each other axially.

15. The method of forming corrugations in relatively thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, and subjecting said roll elements to a force tending to move them toward each other radially, while simultaneously and yieldingly pushing said roll elements toward each other axially.

16. The method of forming corrugations in relatively thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, and subjecting said roll elements to a force tending to move them toward each other radially while simultaneously subjecting said tube to an axially directed thrust to cause said metal to flow into

corrugated form and said roll elements to approach axially.

17. The method of forming corrugations in relatively thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, and subjecting said roll elements to a force tending to move them toward each other radially while simultaneously subjecting said tube to an axially directed force to move said roll elements axially until the corrugations have substantially parallel lateral walls.

18. The method of forming corrugations in relatively thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, and subjecting said roll elements to a force tending to move them toward each other radially while simultaneously yieldably driving said roll elements toward each other axially.

19. The method of forming corrugations in relative thin tubular metal which includes rolling said tube between axially and radially movable interior and exterior roll elements, and subjecting said roll elements to a force tending to move them toward each other radially, said radial force being insufficient to form said tube into corrugated form, while subjecting said tube to an axially directed thrust to move said roll elements axially.

20. The method of forming relatively deep corrugations in a relatively thin metal tube which includes rolling said tube between radially movable and axially slidable interior and exterior roll elements while subjecting said tube to an axial force to slide said roll elements axially with relative independency determined by the yielding of the tube as the corrugations are formed.

21. The method of forming relatively deep corrugations in relatively thin tubular metal which includes rolling said metal between axially and radially movable interior and exterior roll elements, moving said roll elements radially toward each other by a predeterminately limited force and exerting an axial thrust on said tube to cause the metal to flow into corrugated form and to slide said roll elements axially thereof.

22. The method of forming relatively deep corrugations in a tube of relatively thin metal and in a single operation which includes rolling the tube between axially and radially movable interior and exterior roll elements, moving said roll elements radially toward each other, and sliding said roll elements axially toward each other by an axial force applied to said tube.

23. The method of forming relatively deep corrugations in a tube of relatively thin metal and in a single operation which includes rolling the tube between axially and radially movable interior and exterior roll elements, moving said roll elements radially toward each other, sliding said roll elements axially toward each other by an axial force applied to said tube, and continuing said operation until the walls of said corrugations are substantially parallel.

24. In an aparatus for rolling bellows, external and internal arbors, roll elements mounted thereon and adapted to slide axially thereof, means for moving said arbors radially toward each other, and means acting on an end roll element for sliding all of the roll elements axially thereof.

25. In an apparatus for rolling bellows, external and internal arbors, roll elements mounted thereon and adapted to slide axially thereof, means for exerting a constant predetermined force tending to move said arbors radially thereof but insufficient to corrugate a tube, and means acting on an end roll element for sliding all of said roll elements axially toward each other.

26. In an apparatus for rolling bellows, external and internal arbors, roll elements mounted thereon and adapted to slide axially thereof, means on each of said roll elements for yieldably spacing the same, means for moving said arbors radially toward each other, and means for moving said roll elements axially of said arbors.

27. In an apparatus for rolling bellows, external and internal arbors, roll elements mounted thereon and adapted to slide axially thereof, means for moving said arbors radially toward each other, and means for sliding the end roll elements and transmitting movement through the tube to the other roll elements to move all of said roll elements axially of said arbors.

28. In an apapratus for rolling bellows, external and internal arbors, roll elements mounted thereon and adapted to slide axially thereof, means for moving said arbors radially toward each other, and independent means for sliding the end roll elements and pushing the remainder of the roll elements axially of said arbors.

ROBERT E. BROWN.