Sept. 2, 1947. L. M. PUSTER 2,426,949

APPARATUS AND METHOD FOR FORMING CORRUGATIONS

Filed June 29, 1944 2 Sheets-Sheet 1

FIG. 1.

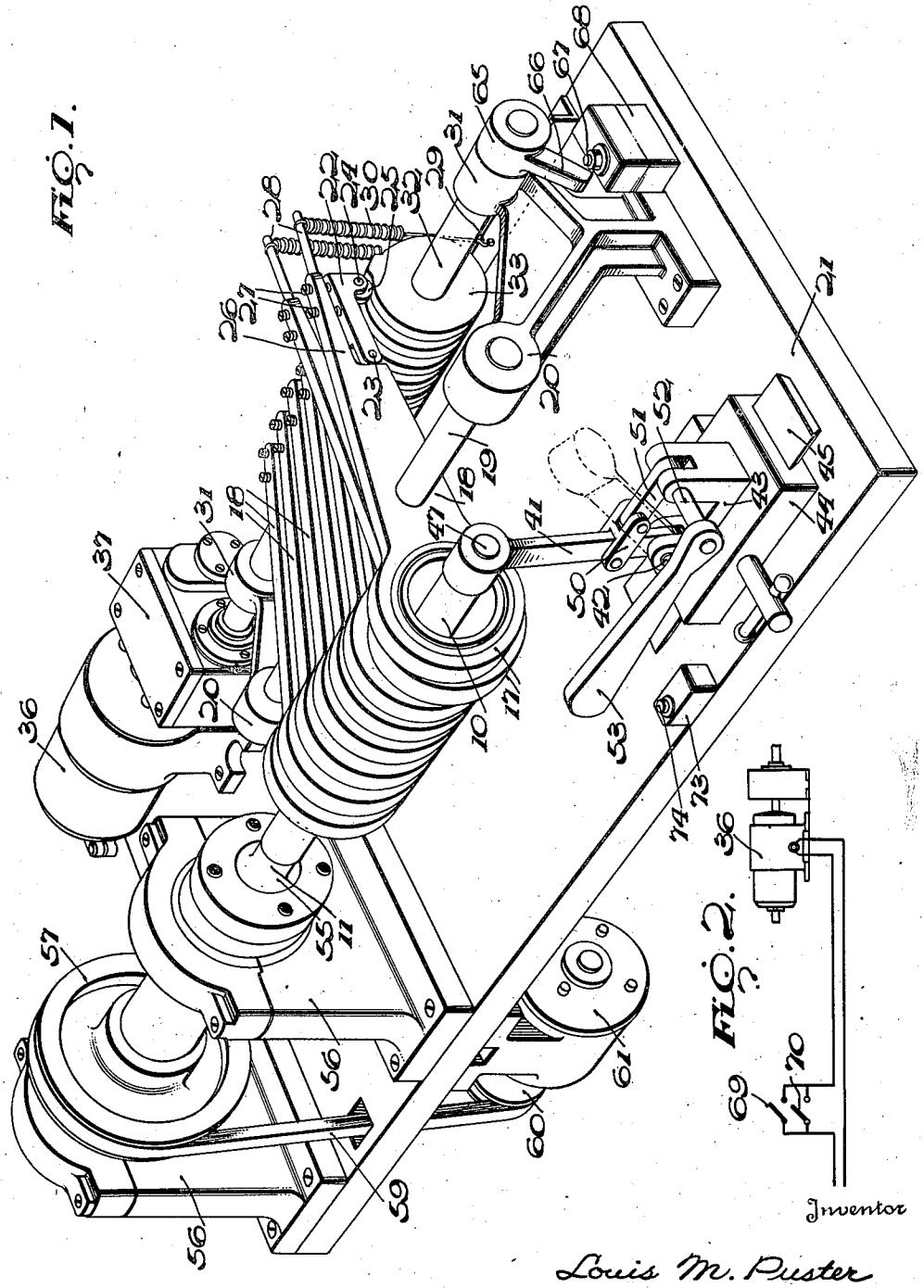


FIG. 2.

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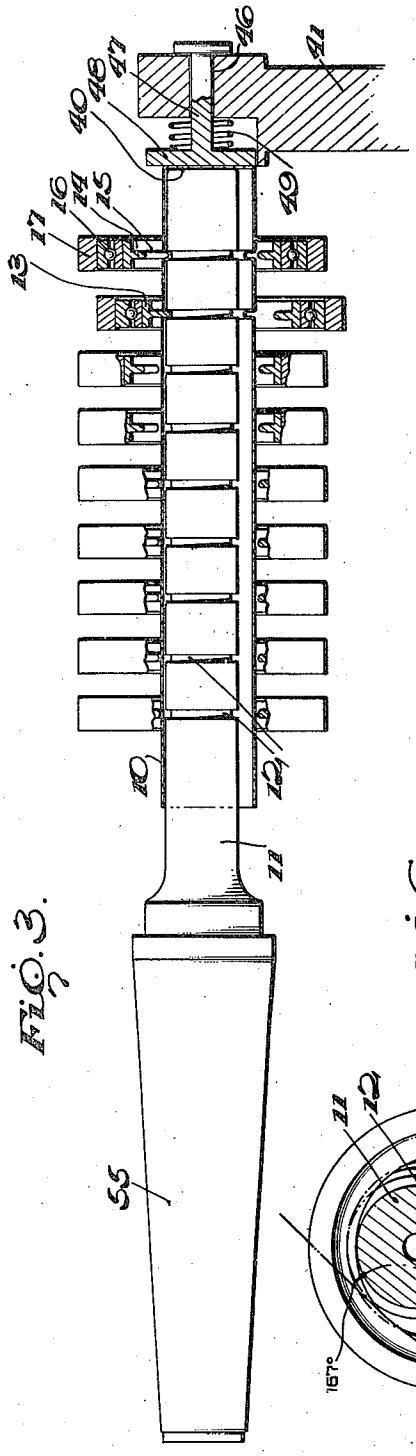


Fig. 3.

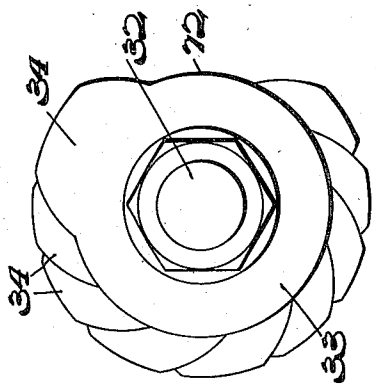


Fig. 5.

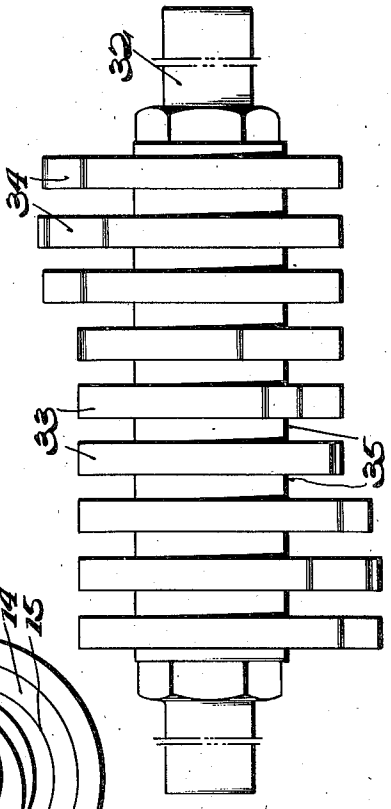


Fig. 4.

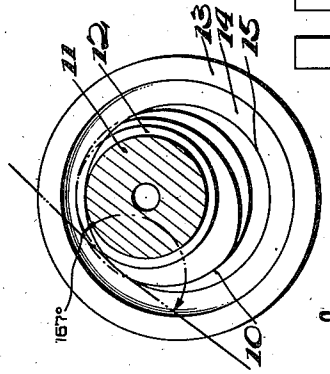


Fig. 6.

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UNITED STATES PATENT OFFICE

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APPARATUS AND METHOD FOR FORMING CORRUGATIONS

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Application June 29, 1944, Serial No. 542,744

13 Claims. (Cl. 153—73)

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This invention relates to the production of expansible and collapsible corrugated tubular metal walls, or bellows, and more particularly to an improved apparatus and method for forming corrugations in a tube or performing the initial stages of corrugating a tube. This application is a continuation in part of my application Serial No. 442,991, filed May 14, 1942, for Method and apparatus for producing bellows.

Bellows are commonly made by mounting a tube of relatively thin metal, on the order of from .005" to .010", within a series of surrounding die rings held at suitably spaced distances along the tube, and the tube is bulged between said die rings by hydrostatic pressure applied interiorly of the tube, after which the corrugating operation is completed by releasing the die rings and applying further hydrostatic pressure to force the corrugations outwardly as the die rings approach. Thus the corrugations are formed entirely outwardly with respect to the cylinder of the original tube. As the flexibility of the bellows varies with the depth of the corrugations and as there is a limit beyond which the corrugations cannot be safely forced outwardly because of the increase in circumferential dimensions and consequent thinning of the metal when using metal of the thinness commonly employed in bellows, this procedure imposes a limitation on the ultimate flexibility obtainable for a bellows of a given size and wall thickness. It is frequently desirable to obtain bellows of a predetermined outside diameter and wall thickness which is of greater flexibility than has been obtainable by the procedure referred to, and it is an object of this invention to provide an apparatus and method for accomplishing this result.

Increased flexibility of the bellows within given outside dimensions may be obtained by initially forming inwardly directed grooves in the tube to be corrugated, which grooves will constitute a larger or smaller portion of the final corrugations, by working the metal inwardly from the cylinder of the original tube. These inwardly extending grooves may be formed in a cylinder of the diameter heretofore used and at the spacing suitable for receiving the die rings of the hydrostatic corrugating apparatus referred to, but using die rings of smaller inside diameter, and then the corrugating operation may be effected hydrostatically as before explained. Thus, while the outer diameter of the corrugations will be the same as before, the total depth of the corrugations can be increased by the depth to which the metal has been worked inwardly in the formation of the initial grooves. Hence a material increase in flexibility can be obtained while using metal of the same thickness as before and

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with no increase in the outside diameter of the bellows.

When using metal of the thinness employed in bellows, great difficulty has heretofore been experienced in working the metal inwardly without injuring the metal. All points on the inwardly worked metal lie on circles of smaller diameter than the original tube, so that the metal has to be so worked as to effect a contraction of all circumferences at the grooves, and as the great tendency of the metal when contracted circumferentially is to wrinkle, this contraction must be effected without wrinkling the metal, because such wrinkling imposes stresses in the metal which cause the bellows to rupture prematurely while the irregularities introduced by the wrinkles interfere with the desired operation of the corrugations.

If an effort is made to roll an inwardly extending bead or groove into a thin metal tube as referred to, as by use of the usual type of beading roll, the tendency to wrinkle is accentuated because of the small arc through which the beading roll operates on the thin metal, so that however efficiently such a beading roll may act with relatively thick metal such as commonly used in cans, containers, etc., it so injures metal of paper-like thickness as conventionally used in bellows, unless fed inwardly so slowly as to make the time element prohibitive from the standpoint of cost of production, that even when satisfactory inwardly formed grooves are obtainable part of the time, the wastage in metal is very great because of the number of tubes that are destroyed by the beading roll, due to wrinkling or cutting through the metal, before all of the grooves are formed in the tube.

It has also been proposed to roll a plurality of inwardly directed corrugations into a tube by forming all of the corrugations simultaneously or by working on at least two of the corrugations simultaneously so as to stretch the intercorrugation metal and thereby minimize wrinkling by the imposition of tension on the inwardly worked metal. While such procedures may be satisfactory where the thickness of the metal is such as to provide for the thinning of the metal in the intercorrugation space as the two or more corrugations are simultaneously worked inwardly, such procedures accentuate the loss and wastage when applied to thin metal of the character above referred to because of the increased likelihood of the rolls cutting through the metal.

I have discovered that inwardly formed grooves may be economically and satisfactorily produced without injury to the metal by greatly increasing the arc of contact between the matrix die member and the tube being worked while forming the inwardly directed grooves one at a time under conditions that enable the tube to draw up

from its uncorrugated end toward the corrugation being formed so as to avoid undesirable thinning of the metal such as arises when the intercorrugation metal is being stretched between two or more corrugations being worked upon simultaneously. It is therefore an object of this invention to provide an improved apparatus and method for increasing the flexibility of bellows by forming inwardly directed grooves in a blank cylinder one at a time under conditions which increase the circumferential extent of engagement between the tube and its forming elements to minimize wrinkling, cutting through and other injury of the metal, while permitting the tube to contract lengthwise so as to minimize undesired thinning of the metal.

Another object of this invention is to provide an apparatus and method of the type characterized which can be economically used without the increase in time element or the wastage of metal characterizing earlier proposals, so that more flexible bellows can be obtained with little or no addition to the manufacturing costs.

Another object of this invention is to provide an apparatus and method of the type characterized which do not require the use of highly skilled labor, so that more flexible bellows can be obtained by a relatively simple operation.

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

This invention is capable of receiving a variety of expressions, one of which is 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 used to designate corresponding parts in the several figures,

Fig. 1 is a perspective elevation of apparatus embodying the present invention;

Fig. 2 is a diagrammatic view on a smaller scale to illustrate the electrical control of the apparatus;

Fig. 3 is an elevation partly in section of the die roll and matrix rings in the course of forming inwardly directed grooves or corrugations;

Figs. 4 and 5 are respectively side and end views of the cam mechanism of the apparatus of Fig. 1 but shown to a larger scale; and

Fig. 6 is a diagrammatic view illustrating the formation of an inwardly directed groove or corrugation.

In conformity with the present invention the cylindrical tube 10 to be corrugated, which may be of any suitable metal, length, diameter, and wall thickness, is mounted on a die roll 11 provided at suitably spaced distances, to define the metal that is to go into each finished corrugation as well understood in the art, with a plurality of grooves 12 whose wall in cross section is smoothly curved and whose depth is at least as great as the extent to which inwardly directed corrugations are desired.

Surrounding the die roll 11 and the tube mounted thereon is a plurality of matrix rings 13 corresponding in number to the number of grooves 12. Each matrix ring 13 is provided interiorly with a circumferentially extending rib 14 having a smoothly curved inner periphery 15 suitably sized and shaped to cooperate with the groove 12. The inner diameter of the rib 14 is somewhat larger than the outside diameter of the tube 10, the difference in their respective diameters varying somewhat with the diameter of the tube to be operated upon, but for most satisfactory operation this difference should not exceed a fraction of the diameter of the tube as shown in Fig. 6.

Each matrix ring 13 is mounted in any suitable way so that it may rotate freely. As shown, each matrix ring is mounted by means of a ball bearing 16 inside of a surrounding holder 17 carried by an arm 18. The several arms 18 are pivotally mounted on a shaft or rod 19 with suitable spacing rings or collars between the arms 18 to hold the ribs 14 in alignment with the grooves 12. Shaft 19 may be mounted in any suitable way as by brackets 20 projecting from a suitable base 21. The arms 18 extend beyond the pivot shaft or rod 19 for cooperation with cam mechanism to be described, and each of said arms is provided with a follower-carrying member 22 pivoted to the arm at 23 and carrying an axle or pivot pin 24 upon which is mounted a cam follower 25. The body of the arm proper extends over the member 22 as shown at 26 and carries adjusting screws 27 for a purpose to be described. Portion 26 of each arm 18 has integral therewith or suitably attached thereto an extension 28 between which and a suitable attachment 29 on the base 21 extends tension means including a coil spring 30 for urging the cam follower 25 into contact with its cam.

Also suitably mounted on the base 21, as by brackets 31, is a cam shaft 32 carrying a series of cams 33 (see particularly Figs. 4 and 5) each of which carries a cam projection 34. As shown in Fig. 5 said cam projections 34 are staggered circumferentially so that the cam followers, which are in alignment lengthwise of the cam shaft 32, will be operated in succession during a single revolution of the cam shaft 32, but only one matrix ring 13 will be depressed at a time into cooperative engagement with the tube 10 carried by the die roll 11. The cams 33 are spaced on the shaft 32 by spacing rings or collars 35 to hold said cams in alignment with the arms 18.

Cam shaft 32 is driven in any suitable way as by an electric motor 36 and suitable transmission gearing at 37. Motor 36 is internally fitted with a magnetic brake so as to prevent any coasting of the cam shaft when the electrical circuit is interrupted as hereinafter explained.

In order to prevent displacement of the tube 10 during the grooving or corrugating operation means are provided for holding the end 40 of the tube 10 against the end of the die roll 11. In the embodiment shown an arm 41 is pivotally mounted at 42 on a bracket 43 carried by a movable base 44 that is slidable on a way 45. The end of arm 41 (see Fig. 3) is apertured at 46, and projecting through said aperture is a pin 47 carrying a plate 48 between which and the end of the arm 41 is a coil spring 49. When arm 41 is in the position shown in solid lines in Fig. 1, plate 48 holds the end 40 of tube 10 against the end of die roll 11 under a spring tension imposed by the spring 49 as it is compressed during the movement of the arm 41 into position. Arm 41 may move around its pivot 42 to the dotted line position shown in Fig. 1, in which position its end carrying the spring pressed plate 48 is sufficiently lowered and withdrawn so as not to interfere with the movement of tubes onto and off the die roll 11. For operating and locking the arm 41, pivotally connected links 50 and 51 are pivoted to the arm 41 and to a part of the bracket

43, and the pivot of link 51 is extended at 52 and provided with a handle 53. Links 50 and 51 move into alignment to lock the arm 41 in solid line position, as shown in Fig. 1, but by moving the handle 53 in a clockwise direction the lock may be broken at the pivotal connection between said links and the arm 41 moved to the dotted line position there shown.

Die roll 11 is mounted for rotation, and rotated, in any suitable way. As shown said die roll is mounted on a spindle 55 carried by pillow block bearings 56, said spindle also carrying a pulley 57 driven by a belt 59 from a pulley 60 on the shaft of an electric motor 61 carried by the base 21, although as is apparent any other suitable means for driving the spindle 55 may be employed.

Cam shaft 32 is provided with an additional cam 65 having a projection 66 designed to operate a switch plunger 67 projecting exteriorly of a switch block 68. An additional switch box 73 having a manually operable switch button 74 projecting therefrom is located at a point convenient to the operator. The switches operated by button 74 and plunger 67 are shown diagrammatically in Fig. 2 at 69 and 70 respectively. As here shown, the motor 36 has in circuit with its leads two parallelly connected switch elements 69 and 70. Swith 69, which is preferably spring-urged to open position, is provided with the manually operable button 74 before referred to for the purpose of closing the circuit through the motor 36 by hand. Switch 70, which is preferably spring-urged to closed position, is so connected to the plunger 67 that when said plunger 67 is engaged and depressed by the projection 66 on cam 65 the switch 70 is opened. When said switch 70 is open, however, the motor can be started by completing the circuit through switch 69 manually operated. Projection 66 on cam 65 is so arranged that it will engage and operate plunger 67 after all of the cam projections 34 on the cams 33 have finished their successive operation of the matrix-ring-carrying arms 18.

With the arm 41 in dotted line position in Fig. 1, the tube 10 to be corrugated can be moved over the die roll 11 and through the centers of the matrix rings 13, the latter being then disposed concentrically with the die roll because all of the cam followers 25 are in contact with the portions 72 of the cams 33. The arm 41 is then moved to its solid line position in Fig. 1 where the spring pressed plate 48 engages the end 40 of the tube and holds it against the end of the die roll 11 under resilient pressure. Arm 41 is locked in this position by the links 50 and 51 coming into alignment as shown in Fig. 1. The extent of tension imposed on the end of the tube can be varied by sliding the base 44 on its way 45, and said way 45 is also preferably made of such length that the base 44 can be adjusted lengthwise thereof so as to take care of die rolls of different lengths.

Assuming that motor 61 is in operation so that spindle 55 is being driven therefrom through the medium of the belt 59, the operator closes switch 69 so as to initiate operation of the motor 36. As soon as motor 36 starts to rotate the cam shaft 32 the projection 66 of cam 65 is withdrawn from the plunger 67, and switch 70 which has been held open by the engagement of projection 66 with said plunger 67 now closes, preferably by spring action, to close the circuit through the motor 36, whereupon the manually operated switch 69 may be released and preferably moves to open

position by spring action. As cam shaft 32 rotates each of the cam projections 34 in succession engages a cam roller 25 so as to move its corresponding arm 18 around the pivot rod or shaft 19 and depress the corresponding matrix ring 13 so as to move its circumferential rib 14 into cooperation with the tube 10 and the aligned groove 12 in roll 11. Each cam follower 25 is held in contact with its corresponding cam 33 by the action of associated spring 30, and the extent of movement of the matrix ring around the pivot shaft 19 may be predetermined by adjusting the member 22 that carries the cam roller through the instrumentality of the screws 27. Owing to the staggered relation of the cam projections 34 each matrix ring 13 is brought in succession into contact with the tube 10, progressively from one end of the tube to the other.

Each matrix ring is held in contact with the tube 10 until a complete groove is formed throughout the circumference of the tube, the length of the cam propections 34 being such as to assure depression of the matrix ring for the proper time to effect this result. As only one matrix ring is in contact with the tube at a time, the tube is free to and does draw up from the direction of its free end. Thus as shown in Fig. 3 the first corrugation or groove to be formed is that adjacent the end of the die roll 11, and during the formation of this groove or corrugation the unworked portion of the tube 10 from the first matrix ring 13 to the end of the tube is free to draw up (toward the right as viewed in Fig. 3) decreasing the overall length of the tube. Thereby the matrix ring can cause the metal to flow into the groove 12 without stretching the metal lengthwise of the tube. The staggering of the cam projections 34 assures that the first matrix ring is withdrawn from its operative relationship with respect to the tube before the second matrix ring is depressed to form the next inwardly directed groove or corrugation, and this sequence of successively operated matrix rings is continued until all of them have been depressed in sequence to form an inwardly extending groove or corrugation. At the end of one complete revolution of the cam shaft 32 projection 66 on cam 65 reengages the plunger 67 and opens the switch 70, and as the motor 36 has an internal magnetic brake as before referred to, the motor comes to rest almost instantaneously so as to prevent coasting of the cams beyond the position wherein all of the cam followers are in contact with the portions 72 of said cams. The lock at the pivotal connection between the links 50, 51 may then be broken by the operator swinging the handle 53 in a clockwise direction, which also moves the arm 41 downwardly to the dotted line position of Fig. 1, in which position the corrugated tube may be withdrawn axially over the die roll 11 and from within the matrix rings 13. It will of course be understood that the diameter of the tube to be corrugated must always be such that the inside diameter of the inwardly directed corrugations is not smaller than the diameter of the die roll 11.

When each matrix ring 13 is moved as described, pressure is applied by the rib 14 to the outer periphery of the tube, forcing it into the corresponding groove over a relatively long arc at the peripheral surface of the tube as illustrated in Fig. 6. By using a matrix ring whose inner diameter is little larger than the outside diameter of the tube, this arc of contact may be a sizeable fraction of the circumference of the tube. Even

during the initial contact between the rib 14 and the tube, their engagement is relatively flat because of the relatively small difference in their radii of curvature, and therefore there is no high concentration of pressure tending to cut through the metal such as exists when an exterior beading roll is pressed against a tube, while the spreading of the pressure over a relatively long arc during the forming operation minimizes the tendency of the metal to wrinkle. Experience has demonstrated that the inwardly directed grooves can be formed in thin metal of the order of .005" to .010" without loss of time arising from the extreme care and slowness of approach required when an exterior beading roll is used, while the wastage of metal resulting from working the metal inwardly according to the present invention is negligible. Therefore, the inwardly directed grooves or beads may be safely formed throughout the length of the tube during a single rotation of the cam shaft 32, whereby inwardly corrugated tubes may be formed at a speed that adds little to the cost of production. Also the involved operation is relatively simple, because the machine is substantially automatic in operation, the operator merely having to lock a tube on the die roll and depress the switch 69 until switch 70 becomes automatically closed, whereupon all further operation of the machine is entirely automatic. Hence the machine may be operated safely by unskilled labor.

While the apparatus and method as heretofore described may be used if desired for the purpose of forming desired final corrugations, or a tube may be progressively corrugated inwardly upon successive machines of the type described provided with grooves 12 properly shaped and spaced for forming the desired final corrugations in successive steps, the preferred procedure is to use the aforesaid machine and method for forming only the inner parts of the final corrugations. In this event the tube as grooved in conformity with the foregoing description may have its grooves properly spaced for engagement with the die rings of a hydrostatic corrugating apparatus as hereinbefore referred to. In this event the partly corrugated tube as described will then be mounted in association with the die rings of the hydrostatic corrugating apparatus, such for example as now commonly used in the manufacture of bellows, and outwardly extending corrugations may then be formed from the metal between the grooves or corrugations formed as above described as the die rings move toward each other as understood in the art. Hence the corrugations may be formed entirely inwardly from the original tube or the corrugations may project both inwardly and outwardly with respect to the original tube, the preferred procedure being the latter.

It will therefore be perceived that the present apparatus and method provide for increasing the depth of the corrugations without increasing the diameter of the bellows whereby increased flexibility may be obtained, and this is accomplished in a simple and expeditious manner that does not add materially to the cost of production.

While a preferred apparatus has been described with considerable detail, it will now be apparent to those skilled in the art that the invention may be embodied in a variety of ways, and reference is therefore to be had to the appended claims for a definition of said invention.

What is claimed is:

1. In an apparatus for forming inwardly directed grooves or corrugations in a tube of relatively thin metal, the combination of a die roll provided with a plurality of grooves corresponding in number to the inwardly directed grooves or corrugations to be formed, a corresponding plurality of matrix rings mounted in alignment with said grooves and in surrounding relationship with said roll, and means for moving each of said matrix rings individually into contact with a tube on said die roll to press a relatively large extent of the inner periphery of each matrix ring into engagement with the periphery of said tube and work the metal of said tube into the corresponding groove in said die roll.

2. In an apparatus for forming inwardly directed grooves or corrugations in a tube of relatively thin metal, the combination of a die roll provided with a plurality of grooves corresponding in number to the inwardly directed grooves or corrugations to be formed, a corresponding plurality of matrix rings mounted in alignment with said grooves and in surrounding relationship with said roll, and means for moving each of said matrix rings in succession into engagement with a tube on said die roll, said means engaging only one matrix ring at a time with said tube to enable the unworked portion of the tube to be drawn up lengthwise of the die roll while each inwardly directed groove or corrugation is being formed.

3. In an apparatus for forming inwardly directed grooves or corrugations in a tube of relatively thin metal, the combination of a die roll provided with a plurality of grooves corresponding in number to the inwardly directed grooves or corrugations to be formed, a corresponding plurality of matrix rings mounted in alignment with said grooves and in surrounding relationship with said roll, and cam means for progressively moving said matrix rings individually and in succession into engagement with a tube mounted on said die roll and adapted to move all of said matrix rings into engagement with said tube during a single revolution of said cam means.

4. In an apparatus for forming inwardly directed grooves or corrugations in a tube of relatively thin metal, the combination of a die roll provided with a plurality of grooves corresponding in number to the inwardly directed grooves or corrugations to be formed, a corresponding plurality of matrix rings mounted in alignment with said grooves and in surrounding relationship with said roll, means for moving each of said matrix rings successively into contact with a tube on said die roll to press a relatively large extent of the inner periphery of each matrix ring into engagement with the periphery of said tube and work the metal of said tube into the corresponding grooves in said die roll, and means for holding the tube on said die roll against endwise displacement in one direction during the operation of said matrix rings.

5. In an apparatus for forming inwardly directed grooves or corrugations in a tube of relatively thin metal, the combination of a die roll provided with a plurality of grooves corresponding in number to the inwardly directed grooves or corrugations to be formed, a corresponding plurality of matrix rings mounted in alignment with said grooves and in surrounding relationship with said roll, means for moving each of said matrix rings successively into contact with a tube on said die roll to press a relatively large extent of the inner periphery of each matrix ring into

engagement with the periphery of said tube and work the metal of said tube into the corresponding grooves in said die roll, and means for discontinuing operation of said last named means after all the matrix rings have been moved into cooperative relationship with their corresponding grooves.

6. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a member upon which each matrix ring is rotatably mounted, and means for individually operating said members to engage the corresponding matrix rings with a tube on said die roll.

7. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a member on which each of said matrix rings is rotatably mounted, cam means cooperating with each member, said cams being related to operate said members one at a time and in succession to move the several matrix rings into cooperative relationship with a tube on said die roll, and means for driving said cam means in unison.

8. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a member on which each matrix ring is rotatably mounted, a cam individual to each member, said cams being arranged to operate only one member at a time to engage its corresponding matrix ring with a tube on said die roll, and means for rotating said cams in unison.

9. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a member on which each matrix ring is rotatably mounted, a cam individual to each member, said cams being arranged to operate only one member at a time to engage its corresponding matrix ring with a tube on said die roll, and means for rotating said cams in unison, said cams being mounted on a common shaft and operating all of said members during a single revolution of said shaft.

10. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said

grooves and disposed in surrounding relationship to said die roll, a member upon which each matrix ring is rotatably mounted, means for individually operating each of said members to engage its corresponding matrix ring with a tube on said die roll, and means for resiliently locking a tube against displacement in one direction on said die roll.

11. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed in a tube, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a member upon which each matrix ring is rotatably mounted, means for individually operating each of said members to engage its corresponding matrix ring with a tube on said die roll, and means for discontinuing operation of said last named means after all of said matrix rings have been engaged with said tube.

12. In a machine of the character described, a die roll provided with a plurality of circumferentially extending inwardly directed grooves corresponding in number to the number of inwardly directed grooves or corrugations to be formed, means for rotating said die roll, a series of matrix rings corresponding in number to said grooves and disposed in surrounding relationship to said die roll, a lever individual to each of said matrix rings, and a cam individual to each lever, said cams being mounted on a common shaft and adapted to engage said levers in succession to actuate said matrix rings one at a time for pressing a relatively large extent of the inner periphery of each matrix ring onto a tube mounted on said die roll to work the metal of the tube into the successive grooves of said die rings.

13. In a method of making expansible and collapsible corrugated tubular metallic bellows from tubes having a wall thickness on the order of .005" to .010" and which includes working the metal of the tube outwardly with respect to its original diameter to form a plurality of corrugations, the steps of increasing the flexibility of the corrugated tube for a given outside diameter of the finished corrugations which include, preliminarily to working the metal outwardly, mounting the tube on a rotating grooved die roll, and individually and successively moving matrix rings in surrounding relationship to said tube and die roll into engagement with said tube to apply inwardly directed pressure to the periphery of said tube along a relatively long concave arc to work the metal of said tube progressively into each of said grooves in the roll, one at a time and in succession, while avoiding substantial thinning of the wall of said tube by allowing the unworked portion of said tube extending beyond the groove being formed to the free end of the tube to draw up lengthwise of the roll throughout the engagement of each matrix ring with the tube.

LOUIS M. PUSTER.

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