

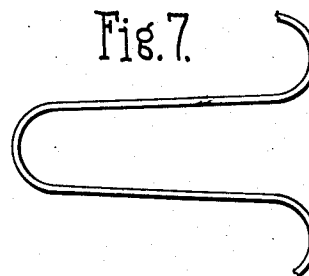
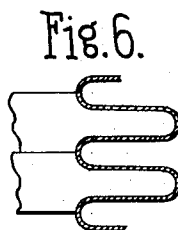
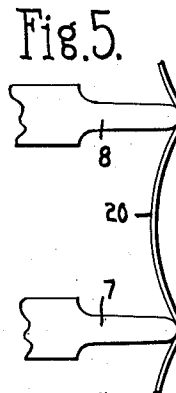
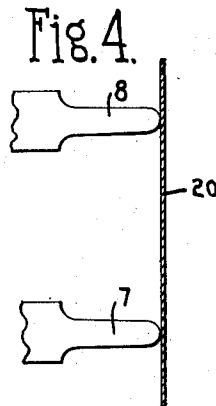
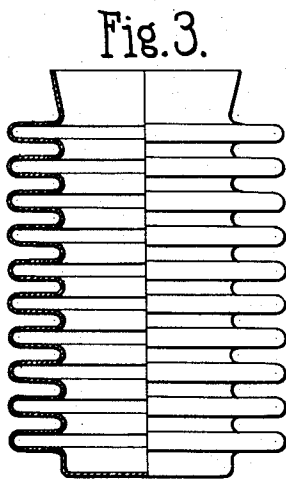
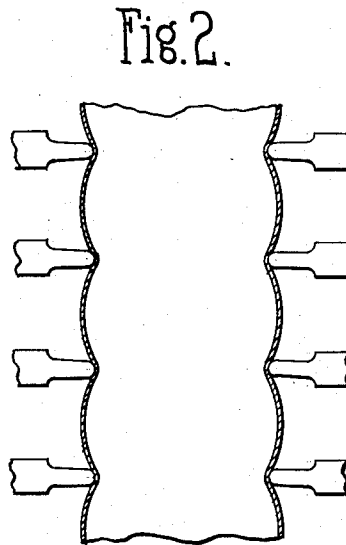
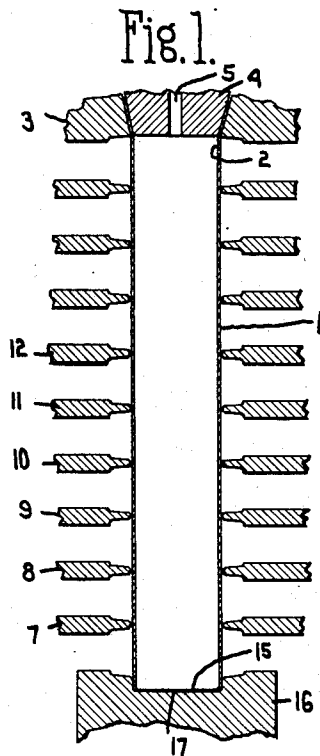
Jan. 8, 1929.

F. K. BEZZENBERGER

1,698,210

METHOD OF MAKING BELLOWS

Original Filed June 25, 1924 2 Sheets-Sheet 1



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METHOD OF MAKING BELLOWS

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2 Sheets-Sheet 2

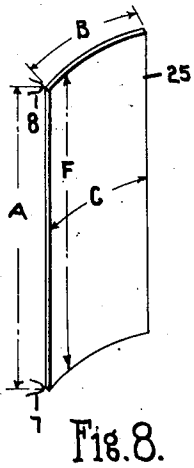


Fig. 8.

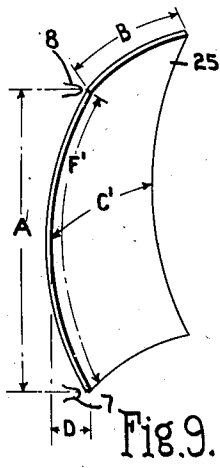


Fig. 9.

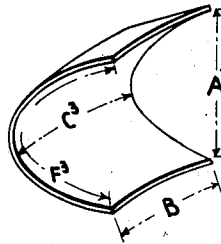


Fig. 10.

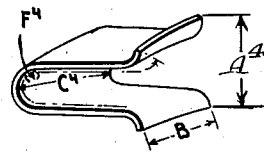


Fig. 11.

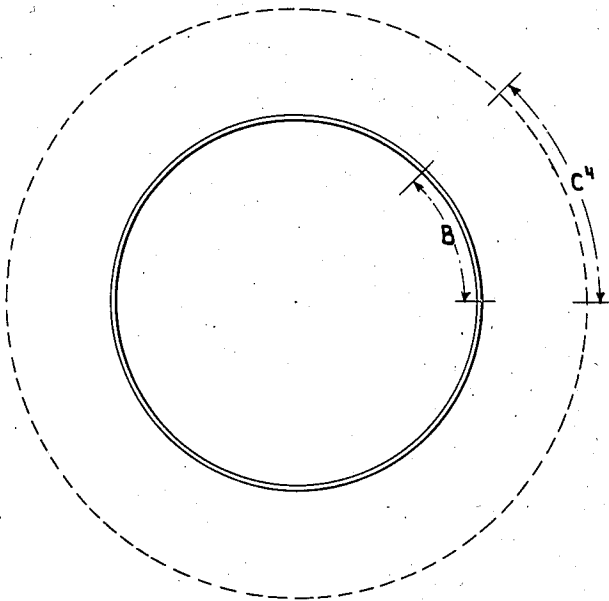


Fig. 12.

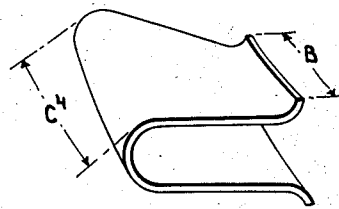


Fig. 13.

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METHOD OF MAKING BELLOWS.

Application filed June 25, 1924, Serial No. 722,357. Renewed May 26, 1928.

The present invention relates to a new and improved method of making expansible and collapsible hollow metallic walls, that is, metallic bellows, from tubes, in a single continuous operation, and is particularly directed to the maintaining of certain relationships between the internal and external pressures which I have found highly desirable in accurately controlling the form of the corrugations. To the accomplishment of the foregoing and related ends, said invention, then, consists of the means hereinafter fully described and particularly pointed out in the claims.

The annexed drawings and the following description set forth in detail one approved method of carrying out the invention, such disclosed mode, however, constituting but one of the various ways in which the principle of the invention may be used.

In said annexed drawings:—

Fig. 1 is a central vertical section through a tube mounted in position to be corrugated between axially movable forming dies or rings; Fig. 2 shows a section of the same tube on a somewhat enlarged scale after the initial bulge has been formed in the tube wall; Fig. 3 is a side elevation partially in section of a tube after formation into a bellows; Fig. 4 is a view on an enlarged scale showing a portion of the tube wall in contact with two adjacent forming rings before the formation of any bulge in the wall; Fig. 5 is a similar view showing this section of a tube wall after the initial bulge; Fig. 6 is a view of a section of the tube wall after its complete formation between two adjacent rings; Fig. 7 is a view of a single corrugation on an enlarged scale; Fig. 8 is a view in perspective of a portion of the tube wall in its initial condition; Fig. 9 is a similar view of the same portion of wall after the formation of the initial bulge; Figs. 10 and 11 are similar views showing the same portion of a tube wall in an intermediate and in a final condition after the formation into a complete corrugation; Fig. 12 is a plan view showing the tube in its original size and (in dotted lines) the expansion of a tube wall during the several stages shown in Figs. 8 to 10, inclusive; and Fig. 13 is a view in perspective showing a segment of the tube wall and the flow of the metal circumferentially therein during its expansion into a corrugation.

Various attempts have been made in the past to form metallic bellows from a tube by

setting up an internal pressure within a tube which is sealed at its two ends, except for a conduit through which the internal fluid pressure is allowed to flow, while simultaneously applying a pressure against the ends of the tube to collapse the tube during formation of the corrugation. In these attempts, which are described in several issued United States patents, spaced forming rings or dies are disposed about the tube in its original condition and the metal of the tube wall is then expanded outwardly into folds between these rings as the tube is collapsed longitudinally, and means are provided in these cases for allowing the rings to collapse with the tube. I have tried all of the methods described in these various patents and find that the machines there disclosed are inoperative to produce a commercially satisfactory bellows having uniform corrugations at any commercial rate of speed.

It is highly desirable in producing a commercial metallic bellows in a single continuous hydraulic operation to establish certain conditions and relations. These conditions and relations are as follows:—

1. The spaced forming rings or dies should be given a ratio between their initial point-to-point setting (by which I mean the initial distance between the points of contact of two adjacent rings with the tube wall) and the final point-to-point setting of the same two adjacent rings of not less than $2\frac{1}{4}$ to 1. If this relation is not maintained the corrugations which are produced are entirely too shallow to give the proper degree of flexibility and resiliency to the finished bellows to render it comparable to the bellows which are today in use as manufactured by other processes. This relationship (and those of the next two paragraphs) is further explained and illustrated in my Patent No. 1,506,966 granted Sept. 2, 1924.

2. The tube when first placed within the spaced forming rings should be given an initial bulge, which is produced by setting up an internal pressure in the tube which is sufficient to grip the edges of the forming rings and fix each ring at a given point along the tube wall. The depth of this initial bulge will depend upon the original point-to-point spacing between the rings and the contour of the rings at their points of contact with the tube, a ring having a sharp edge requiring a relatively shallower bulge than one

having a rounded edge; and a narrow original point-to-point setting requiring a shallower bulge than a longer setting. In experimenting with various types of rings and various initial spacing of these rings I have found that this initial bulge which is to be produced in the tube wall should not increase the tube diameter more than 40 per cent of the point-to-point initial spacing, but must be deformed some amount which varies with the original spacing of the rings and with the contour of the rings, as set forth above. Unless this initial bulge is produced in the tube the tube tends to slide up within the rings somewhat during the collapsing of the tube axially, and the resulting object is not then a bellows, but a tube having a portion of uniform diameter, and an irregular series of irregular corrugations or folds, which ordinarily occur between the fixed end of the tube and the nearest forming ring.

3. It is further desirable that the surface length of the tube measured along an elemental longitudinal line be not increased during the formation of the corrugations and the collapsing of the tube. This elemental surface length should be either maintained constant during this operation or should be actually decreased, and it is highly desirable in producing bellows of the types and sizes now in most general use to actually decrease this elemental surface length during the formation of the bellows from the tube. The explanation of this relationship is that the tube wall when formed into corrugations is subjected to two deforming actions, the first of which is that the tube wall is bent upon itself or doubled and collapsed at the same time, which is the only deforming action to which the tube wall would be subjected if it were a flat plate. This action requires little if any stretching of the metal and may be considered as chiefly a bending operation. The second deforming action to which the tube wall is subjected is the stretching circumferentially to allow for the increase in diameter of the outer portion of each corrugation or fold. If the elemental surface length of the tube wall is allowed to increase during the formation, that means that the section of metal between any two adjacent forming rings is being stretched during both the bending and the circumferential stretching operations, and the result will be that the outer portion of each corrugation will have been worked to such a degree that it will be hard and brittle and the resulting bellows will break during its forming. In order to prevent the metal from being worked beyond the desired extent, as would be the case if the surface length were allowed to increase, I actually decrease the surface length of the bellows during the forming operation, the excess metal, which was present in the tube wall over that required if the tube wall were

a flat sheet and were merely bent into the form of a fold, being allowed to flow circumferentially to compensate for the increased diameter of the bellows at the outer portion of the fold, with the result that I am enabled to maintain the temper of the metal in the outer fold at from 10 to 20 per cent, which renders the bellows fairly soft and capable of a great number of flexures before breakage.

4. A fourth condition which is highly desirable in order to accurately control the form of corrugations is a certain relationship between the internal pressure produced in the tube and the longitudinal pressure exerted against the ends of the tube to collapse it during the forming action. As I have already stated it is desirable to initially set up a slight bulge in the tube wall to fix the rings at the proper points against the wall. The pressure which is necessary to produce this bulge also acts against the ends of the tube, and if, as in the present case, one end of the tube is open and is sealed by a plug while the other end is closed by an end wall of the tube, it is there necessary at the beginning to exert only enough pressure against this closed end of the tube to counterbalance the downward pressure of the fluid pressure in the tube. This downward pressure is a product of the pressure per square inch in the tube times the effective area of the end wall, and an external force should be exerted axially against the end of the tube substantially equal to this internal axial force.

As the tube wall is forced upwardly to produce corrugations and as the tube is collapsed axially to assist in this formation some metal is forced to flow circumferentially in each corrugation to compensate for the increased diameter as the corrugation goes up. This operation is not a bending operation, but is an actual flowing of the metal and requires considerable force to accomplish. Accordingly, the axial pressure on the end of the tube should be progressively increased during the formation of the bellows, and at the finish of the operation should be materially higher than the internal pressure exerted against the effective area of the end wall of the bellows.

The penalty for not maintaining this relationship is the buckling inwardly of the tube wall if the axial pressure is too high in proportion to the internal pressure, and failure to form and collapse the tube at all if the axial pressure is too low compared to the internal pressure.

5. In order to make a bellows quickly and to accurately and quickly return the forming rings to their initial spaced position for repeating the operation it is highly desirable to positively and mechanically collapse and return the rings in time with the axial movement of the plunger or ram, which involves the interconnection of the ram with the means

for moving the rings. This desirable condition is met in the machine described in my patent heretofore identified.

Referring now to the drawings, in Fig. 1 there is shown a tube 1 which is open at the upper end 2 and which has this end sealed between frustro-conical members 3 and 4, the member 4 being provided with an opening 5, through which fluid pressure is forced into the tube. This tube is disposed between a series of spaced forming rings 7, 8, 9, 10, 11, 12, etc., which may be split and hinged to permit of the convenient introduction and removal of the tube, as described in my aforesaid patent. Disposed against the bottom 15 of the tube is an axially movable plunger 16, which is provided with a portion 17 adapted to snugly receive the end of the tube, and a forming surface corresponding to the forming surfaces of the various rings so that one corrugation is formed between the plunger 16 and the lowermost ring 7, the plunger in this case acting as both an axially movable ram to collapse the tube and as one of the forming rings.

The desirability for the relationship between the initial point-to-point setting of the rings and the final point-to-point setting, and also the desirability for the synchronizing of the movement of the axially movable ram and the rings has already been fully explained in my patent above referred to. I will therefore now take up the various other conditions, the desirability for which has already been explained.

When the tube is first disposed within the rings there is no gripping engagement between the rings and the tube wall, and the tube wall if collapsed axially by means of the ram would slide at least between certain of the rings and produce a very irregular object, which would certainly not be a bellows having uniform corrugations. Therefore, after the tube is disposed within the rings I induce a pressure in the tube which is sufficient to bulge the metal outwardly between the rings, as shown in Fig. 2, the bulge being sufficient to cause a positive engagement between each ring and a properly corresponding portion of the tube wall, which engagement is maintained during the remainder of the operation, and until the bellows is removed from the apparatus. During this initial expanding of the tube wall the metal is actually stretched and is not bent, since the rings are maintained at their original spacing and the metal is stretched both radially and slightly circumferentially during the action of throwing out this initial bulge. This condition is shown in Figs. 4 and 5, in which a section 20 of the tube wall is shown between rings 7 and 8 and these rings are maintained in the same relationship during this expansion, which is shown in Fig. 5.

If we consider the action to which any

portion of the original tube wall is subjected during the forming operation we find that such portion 25 of the wall (see Fig. 8) is first forced outwardly into the shape shown in Fig. 9, in which the edge of a longitudinally cut section is increased in length although maintained between dies 7 and 8, which are maintained at their original spacing. That is, the distances A and A' in Figs. 8 and 9 are the same, but the length F, which is the length of the section of the original tube measured along an elemental line, is less than the length F', which is the dimension of the same edge of the section 25 after the first bulging operation. Similarly, the dimension C, which is the width measured circumferentially of the segment 25 of the original tube is less than the dimension C', which is the width of the same section after the first bulging operation. As this section is still further formed into the corrugation, as shown in Figs. 10 and 11, the distance A successively becomes A² in Fig. 10 and A⁴ in Fig. 11, this distance representing the spacing between the rings as they are collapsed, while the dimension F actually decreases, and in Fig. 10 is slightly smaller than in Fig. 9, and is still smaller in Fig. 11 as indicated at F² and F⁴. The metal which would thus have to be compacted to thicken up the wall of the corrugation if a flat sheet were being bent is now forced circumferentially to compensate for the increased diameter which is represented by the increasing dimensions C² in Fig. 10 and C⁴ in Fig. 11, and which is shown still better in Figs. 12 and 13.

The initial width of the section 25 is shown at B in Fig. 12, and at the finish of the corrugating operation this portion of the tube wall has been expanded circumferentially until its width is C⁴ (see Figs. 12 and 13), and the excess metal which was initially disposed in the tube wall between the two adjacent rings is flowed circumferentially to provide for this increase in diameter of each corrugation.

The increase in diameter is thus produced by actually flowing the metal circumferentially in each corrugation, and this action should be accompanied by an increasing pressure longitudinally of the tube by both the rings 7, 8, 9, 10, etc., and the ram 16, and at the end of the corrugating operation the axial pressure exerted by the ram 16 should be approximately twice the original pressure and which was merely provided to balance the downward pressure exerted by the end wall of the tube 1.

In order to illustrate the relationship between the internal fluid pressure and the external axial pressure acting on the tube it may be stated that in the formation of a bellows from a tube of soft brass where the tube has an initial diameter of 1 3/8 inches and is expanded into a bellows having an outside diameter of 2 inches, I initially set up a pressure

of 390 pounds per square inch inside of the tube. In this same case the initial spacing between the rings is .750 of an inch, the final surface length of one corrugation is .696 of an inch, and the thickness of the tube wall initially is .0065 of an inch. In corrugating this tube the pressure is maintained constant within the tube at 390 pounds and the external axial pressure is initially sufficient to counterbalance the internal pressure exerted against the end of the tube, it being understood that a tube having either two open ends or a single open end may be corrugated. At the finish of the corrugating operation the external axial pressure has been increased by 373 pounds, that is, there is an absolute pressure exerted against the end of the tube of 373 pounds, which is the collapsing pressure employed to collapse the corrugations, shorten the surface length of each corrugation and force the metal into complete contact with the collapsed rings in the manner described.

Other modes of applying the principle of my invention may be employed instead of the one explained, change being made as regards the process herein disclosed, provided the step or steps stated by any of the following claims or the equivalent of such stated step or steps be employed.

I therefore particularly point out and distinctly claim as my invention:—

1. In a method of making a metallic bellows from a tube completely by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, initially establishing a fluid pressure within said tube sufficient to expand the tube wall slightly between said rings and then positively collapsing said rings and simultaneously, progressively and materially increasing the axial external pressure from a pressure balancing the axial internal pressure to a pressure materially above the same to collapse the tube into corrugations lying between said rings.

2. In a method of making a metallic bellows from a tube completely by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, initially establishing a fluid pressure within said tube sufficient to expand the tube wall slightly between said rings while maintaining said rings stationary and exerting an axial pressure against each end of said tube substantially equal to the product of the internal fluid pressure times the area, and then positively collapsing said rings and simultaneously, progressively and materially increasing the pressure exerted against the ends of said tube to collapse the same into corrugations lying between said rings.

3. In a method of making a metallic bellows from a tube completely by fluid pressure, the steps which consist in mounting a

tube concentrically within a series of spaced axially movable forming rings and between a fixed support at one end and a movable ram at the other end, establishing an initial fluid pressure within said tube and expanding the wall radially, e. g. a distance less than 20 per cent of the distance between said rings, while maintaining said rings stationary and exerting a pressure by said ram against one end of said tube equal to the internal fluid pressure acting axially on said end, and then progressively and positively collapsing said rings axially while progressively increasing the pressure of said ram sufficiently to overbalance the internal pressure exerted on said tube end and to flow the metal of the tube wall in the forming corrugations circumferentially to compensate for the increasing diameter of such corrugations and to shorten the longitudinal surface length of said tube wall.

4. In a method of making a metallic bellows from a tube by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, bulging said tube between said rings by exerting fluid pressure interiorly thereof without exerting pressure axially of the tube to collapse the same, and then forming the corrugations by the combined action of internal fluid pressure and a progressively increasing collapsing pressure acting axially of the tube.

5. In a method of making a metallic bellows from a tube by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, bulging the tube between said rings by internal fluid pressure while balancing said pressure in an axial direction, and then forming the corrugations by the combined action of internal fluid pressure and a progressively increasing collapsing pressure acting on the tube axially of the same.

6. In a method of making a metallic bellows from a tube by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, bulging the tube between said rings by internal fluid pressure while balancing the action of said pressure axially of the tube, and then exerting a progressively increasing axial pressure on the tube greater than the pressure therein to form the corrugations by the combined action of the collapsing pressure on the tube and the internal fluid pressure acting radially of the same.

7. In a method of making a metallic bellows from a tube by fluid pressure, the steps which consist in mounting a tube concentrically within a series of spaced axially movable forming rings, subjecting said tube interiorly to fluid pressure, and then while maintaining an internal fluid pressure exert-

ing a progressively increasing pressure axially of the tube to form the tubular wall into corrugated form.

8. The method of making flexible corrugated tubular walls which includes positioning a tube in operative relation to a die, applying a pressure axially of said tube, subjecting said tube to a separately applied radial pressure, and forming corrugations in said tube by the combined action of said pressures while gradually increasing said axial pressure.

9. The method of making flexible corrugated tubular walls which includes positioning a tube in operative relation to a die, subjecting said tube to fluid pressure, applying a pressure to said tube in the direction of its axis to aid said fluid pressure in collapsing said tube into said die, and increasing said axial pressure as the tube is being collapsed into said die.

Signed by me this 24th day of June, 1924.

FRED K. BEZZENBERGER.