June 16, 1936. J. G. C. MANTLE 2,044,711

METHOD OF AND APPARATUS FOR MAKING CORRUGATED DIAPHRAGMS

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Fig. 1.

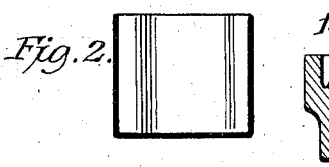


Fig. 2.

Fig. 3.

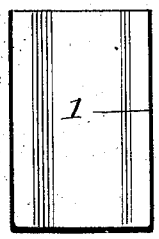


Fig. 4.

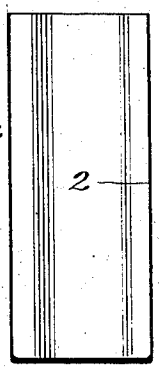


Fig. 5.

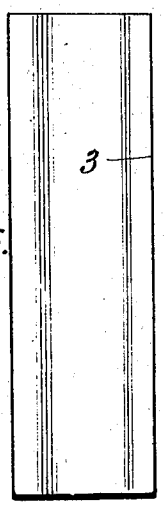


Fig. 6.

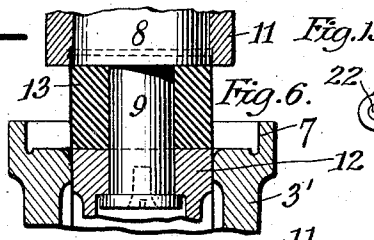


Fig. 7.

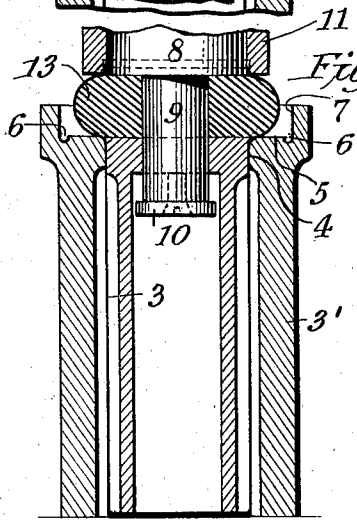


Fig. 8.

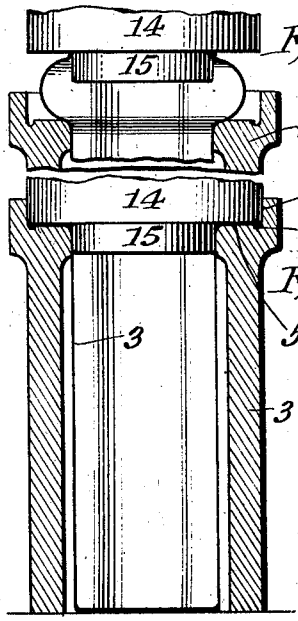


Fig. 9.

Fig. 15.

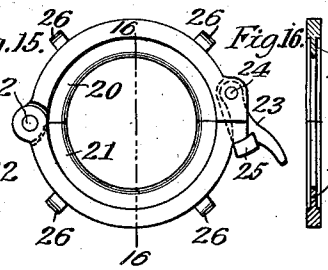


Fig. 16.



Fig. 10.

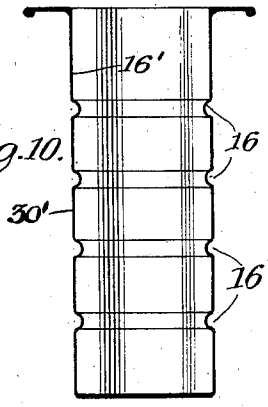


Fig. 11.

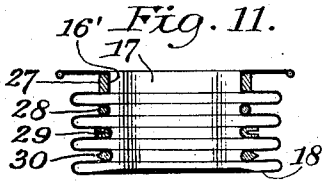


Fig. 12.

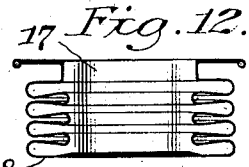


Fig. 13.

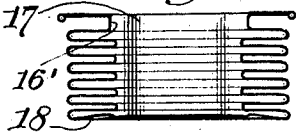
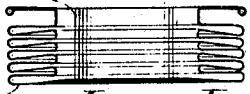


Fig. 14



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Fig. 17.

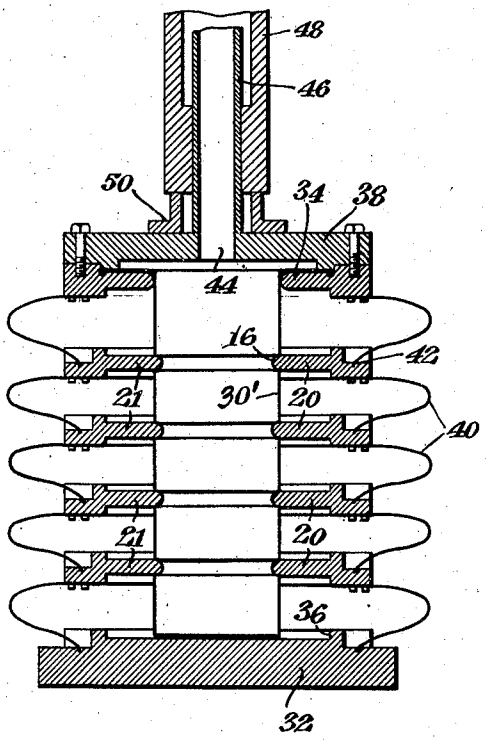
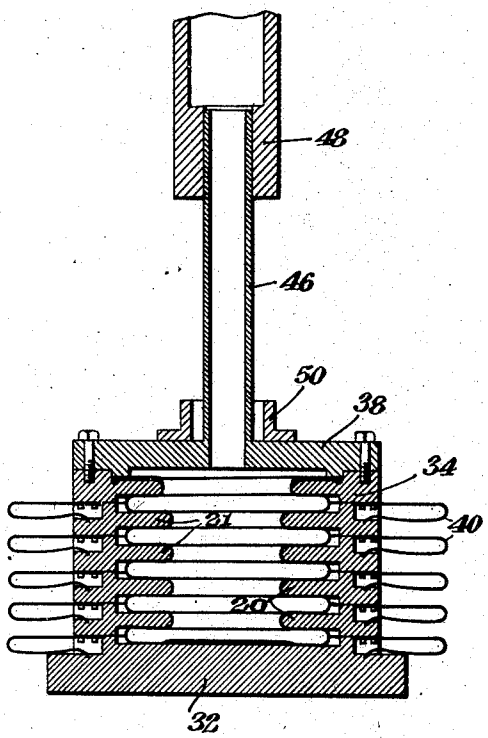


Fig. 18.



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UNITED STATES PATENT OFFICE

2,044,711

METHOD OF AND APPARATUS FOR MAKING CORRUGATED DIAPHRAGMS

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Application November 11, 1924, Serial No. 749,208

14 Claims. (Cl. 153—73)

This invention relates to a method of and apparatus for making expansible-contractible metal elements such as are adapted for use in pumps, motors, or in pressure-sensitive or heat-sensitive devices in general.

The form of the article consists of a circumferentially-corrugated tubular wall having a closed end, the annular outer portion of which end is of the same thickness as the tubular wall, and the central portion of this end being of appreciably greater thickness, and the open end of the tubular wall being folded on itself and forming an outwardly projecting gasket-flange.

The article is manufactured by first forming a shell from sheet metal, then forming the outwardly projecting gasket-flange, and then converting the shell to its final shape by placing the shell under internal pressure in a contractible mold and collapsing the shell while it is in the contractible mold.

In the drawings:—

Figures 1 to 5 inclusive, show the successive stages of the operation of forming the shell from sheet metal.

Figures 6 and 7 illustrate the start and the finish of the first stage of the operation for forming the outwardly-projecting gasket-flange.

Figures 8 and 9 show the start and the finish of the second stage of the operation for forming the outwardly-projecting gasket-flange.

Figure 10 shows the gasket-flanged shell after having undergone a rolling operation.

Figures 11 to 14, inclusive, show different forms of the complete articles when converted into final shape.

Figure 15 is a view of a mold part used in forming corrugations.

Figure 16 is a sectional view through 16—16 of Figure 15.

Figure 17 represents a vertical section of a contractible mold with the grooved or rolled tube therein at the beginning of the forming operation; and

Figure 18 represents a vertical section of the contractible mold which has been collapsed to form the corrugated tubular wall.

Figure 1 shows the blank from sheet metal, and which is converted to shape, figure 2, in the first stage of the operation of forming the shell. It will be noted that the closed ends of Figures 2, 3, 4 and 5 are all of similar thickness, and that the tubular walls 1, 2 and 3 (Figures 3, 4 and 5) diminish in thickness. The manner and means for drawing the shell from the blank of Figure 1 is well known and needs no explanation.

Referring to Figures 6 and 7, a receptacle 3' has an opening 4 such that the shell may be slid therein. Adjacent this opening is an annular face 5 which terminates in an annular recess 6 bounded by a wall 7. The face, recess and wall serving as a former to form the outwardly-projecting gasket-flange, as may be seen in Figure 9. A plunger 8 has a reduced end 9, to which a washer 10 is secured. Surrounding and secured to the plunger 8 is a counter bored ring 11, the counterbore forming an annular recess for retaining the open end of the shell in position. It should be noted (Figure 6) that the open end of the shell but partially extends into the recess. Surrounding the end 9 and having a close sliding fit thereon, is a sleeve 12, and which is retained thereon by a washer 10. Betwixt this sleeve 12 and plunger 8 is a cylindrical portion of compressible material, such as rubber, 13. Figure 6 shows the shell and apparatus at the start of the first stage of the operation of forming the outwardly-projecting gasket-flange, and Figure 7 shows the same at the finish. Upon the withdrawal of the plunger 8, the rubber 13 regains its original shape shown in Figure 6, and the shell has had its form converted to that shown in Figure 8.

Referring to Figures 8 and 9, a plunger 14 having a close sliding fit in the surrounding wall 7 of receptacle 3' has a reduced end 15 having a close sliding fit in the shell 3. This plunger 15 in conjunction with the receptacle 3' serves as a former to complete the operation of forming the outwardly-projecting gasket-flange. Figure 8 shows the shell and parts of the apparatus at the commencement of this stage of the operation, and Figure 9 shows the same at the finish.

When the inner curves of the corrugations are nearer the axis of the diagram than the inner surface of the opening 16', then the shell is recessed inwardly, as is shown at 16 in Figure 10 by a rolling operation. The manner and means for rolling these recesses is well known, and needs no explanation.

Either of the shells shown in Figures 9 and 10 may be converted to any one of the final shapes shown in Figures 11, 12, 13 and 14, by using the hydraulic method disclosed in my application for Method of making hollow articles Serial No. 726,671, filed July 18, 1924.

The grooved or rolled shell shown in Fig. 10 is adapted to be placed in an apparatus comprising a contractible mold, as shown in Figure 17 to convert the rolled or grooved shell into corrugated shape as shown in Figure 18. This mold includes

a bottom mold part 32, a separable hinged top mold part 34, and a plurality of intermediate separable, hinged mold parts 20, 21. The mold parts 20 and 21 are placed in the grooves 16 of the shell or tube and are held together in this position by a wedge or cam projection 25 on one of the mold parts. A hinged mold part is shown in Figs. 15 and 16 and comprises parts 20 and 21 hinged at 22 and secured together by a lever 23. The lever 23 is fulcrumed at 24 and is provided with the wedge or cam projection 25 adapted to engage member 21 of the mold part. The bottom mold part 32 is provided with a central depression or cutaway portion 36 upon which the closed end of the shell or tube is adapted to rest. The flange of the shell or tube 30' is clamped between the top mold part 34 and the top holder 38. These two parts 34 and 38 are securely held together by screws or other suitable means.

Top mold part 34 and the intermediate mold parts 20, 21 are held in spaced relation by the interposed curved leaf springs 40, one end of each spring being connected to the bottom portion of the mold parts and the other or free end of the spring being adapted to fit in the slot 42 provided in the upper surfaces of each of the parts 20, 21, and the bottom mold part 32. These springs 40 are adapted to permit independent movement of each set of mold parts and to sustain the mold parts in correct relation to each other, and also act as guides in preventing lateral movement of the mold parts. The top holder 34 is provided with an opening 44, communicating with a pipe or tube 46 which telescopes into reservoir 48 containing fluid under pressure. Between the reservoir 48 and the top holder 38 is a removable stop piece 50.

After the shell or tube 30' is rolled or grooved, it is placed in the contractible mold, as shown in Figure 17 with the mold parts in the grooves 16. The flange of the shell or tube is then clamped between the top mold part 34 and top holder 38. The interior of the shell or tube is then subjected to fluid pressure from the reservoir 48, and while the tube is under this pressure, the top plate 38 is forced downwardly to collapse the contractible mold and to form the corrugated tubular wall shown in Figure 18.

It can be readily understood that with a shell of given diameter and material, a deeper final corrugation may be obtained by a prior corrugating of the shell, as shown in Figure 10. Also, as a rolling operation increases the hardness, a higher temper is induced in the corrugation nearest the axis. It will be seen that when the shell is placed in a contractible mold and subjected to internal fluid pressure there is an analogy to an uniformly loaded and equidistantly supported beam, and that the stress is greatest, and consequently the shell is thinnest and hardest, at the portions midway between the supporting surface of the mold parts of the contractible mold and is thicker and softer the nearer it is to the mold parts. Now, the degree of this variation of hardness, due to the thinning of the material, is of course dependent upon the nature of the material and upon the applied pressure. Were the material soft pure rubber, there would be practically no variation in thickness. With low brass (low percentage of zinc), it is found that there is but a very gradual increase in thickness and decrease in hardness of the material from the outer to the inner corrugations, and that they are fairly uniform throughout their lengths. By the prior rolling of the inner corrugations, as in Figure 10 of this application, and by suitably adjusting the internal fluid pressure, the inner and outer corrugations may be given any relative degree of hardness as may be desired. At the completion of the operation of corrugating the diaphragm, the thickness of the material throughout the length of the corrugations is appreciably less than that of the original wall. The amount of this diminution is dependent upon the kind of material. It is found that brass consisting of 85% copper, 15% zinc, may be safely stretched fully 20%, or, in other words, until its thickness is about 83% of its original thickness. This amount of stretch is well within its safe limit, for a series of diaphragms so made have already performed over 700,000,000 pumping operations (an extension and contraction), and are now apparently still in sound condition. The safe limit of circumferential stretch is dependent upon the chemical and physical nature of the material, chiefly upon the chemical. For the aforementioned kind of brass, it is about 50% of the original, and when the inner corrugations are primarily rolled as shown in Figures 10, 11 and 13, the circumference of the outer corrugations may be fully 60% greater than the circumference of the inner ones. This data is of value in determining the initial position of the mold parts with relation to their final position, or, which is the same thing, in determining the spacings of the prior corrugations of Figure 10.

It is to be noted that the circumferential stretch (about 50%) is greater than the longitudinal stretch measured along the corrugations which is but about 20%. This is accounted for by the axial compression (given by the axial movement of the mold parts) assisting the internal fluid pressure in the circumferential stretch. It is obvious that for a given material when the limits of longitudinal and circumferential stretch are known, then all the possible forms of the corrugations of a diaphragm are easily determined. It must be remembered, however, that each particular material has its own values and which can only be determined (except very approximately) by actual test or experiment.

It should be noted that the corrugations in Figures 11, 12, 13 and 14 are of different relative sizes and also shapes. With a given thickness of metal, the stiffness or resistance to extension and compression is increased as the radius of the corrugation is increased. It is still further increased by so forming the corrugations that their inner surfaces diverge outwardly from the axis of the diaphragm, as shown in Figure 12. In Figure 14 the alternate inner surfaces, only, of the corrugations diverge outwardly, and this is a useful form in a diaphragm pump for liquids, as it prevents the formation of air-pockets in the pumping chamber.

Referring again to Figures 11, 12, 13 and 14, it will be seen that the central portion of the closed ends have approximately the original thickness of metal and taper into the outer portion of the closed end which consists of an annular ring of the same thickness as the corrugations of the wall of the diaphragm. This is a great advantage as it practically gives an additional corrugation without increasing the length of the shell or of the diaphragm. Moreover, corrugated articles having this form of closed end are obtained by placing a shell in a contractible mold and collapsing the mold while the shell is under sustained internal pressure.

Referring to Figure 13, it will be seen that the entire closed end is not flattened out as is those shown in Figures 11, 12 and 14. To obtain this shape a much less fluid pressure is needed and the apparatus may be of a simpler form as not requiring a supporting surface for the outer surfaces of the outer corrugations.

It is essential that the mold parts of the contractible mold be held closely and unyieldingly together, otherwise the internal fluid pressure would cause the formation of ridges on the outer surface of the inner corrugations which would greatly impair the durability and other functions of the diaphragm. In forming such articles as diaphragms the two members of the mold part are preferably hinged and closely and unyieldingly held together. By inspection of Figures 15 and 16 it will be seen that the two members 20 and 21 are hinged at 22 and secured together by a lever 23, fulcrumed at 24, and that the lever is provided with a wedge or cam projection 25 adapted to engage member 21 of the mold part and hold it closely and unyieldingly in contact with member 20.

In forming a diaphragm where the corrugations are required to be equidistant, it has been found to be unnecessary to provide means for positively controlling the relative movements of the mold parts towards each other during the operation of forming the corrugations, but, when they are required to be very unequally spaced, or are of varying forms, then such positively controlling means are necessary and the two member mold parts shown in Figure 15 is provided with lugs or other means adapting it to be actuated by a control means to positively control the movement of the mold parts.

In instances, among its various uses, where the diaphragm has to contain a high pressure fluid, the outer surface of the inner corrugations are reinforced by supporting rings which may be of any desired section as shown (in Figure 11, at 27, 28, 29 and 30). Of course, where the supporting rings are applied, the shell is not subjected to a prior rolling operation. They are supported and sustained in position by the mold-parts and for the time being form a part of the mold parts; but, they are not removable and they remain in position on the diaphragm, and thus constitute unitary parts of said diaphragm.

The flexibility and amplitude of these diaphragms increases in proportion to their diameters and in more than arithmetical proportion. The flexibility also increases as the depth of the corrugations. With a given form and size of corrugation, the amplitude, viz. the difference in axial length of the diaphragm when extended and when compressed, varies in proportion to the number of corrugations.

Attention is called to the uncorrugated portion next to the outwardly extending gasket-flange. Though increasing the axial length of the diaphragm, yet it is of value, for when the diaphragm is inverted and used in a pump connected with a gasoline or other tank in which water is apt to enter, the water when drawn into the pump will sink and occupy a space adjacent the uncorrugated portion of the diaphragm and in the event of the freezing of the water will not interfere with the movements of the corrugations nor injure the diaphragm. The recess 6 in the receptacle 3' is of such size that the wall of the shell when folded on itself, as shown in Figure 9, forms a ring-shaped hollow space, and thus serves as a gasket to the flange.

It is to be understood that these diaphragms may be made of any suitable material for the purpose required.

Having thus fully described the invention, what I claim as new and desire to secure by Letters Patent is:

1. In a method of making metallic bellows, the steps which consist in forcing spaced portions of a tubular metal wall inward to form inwardly extending corrugations therein, and then expanding the tubular wall between said first-named inner corrugations to form outwardly extending corrugations between said first-named inner corrugations.

2. The process of making bellows consisting in providing a tube of thin metal, forming a series of inwardly pressed spaced apart annular grooves in and around said tube with connecting sections of said tube between said grooves, and then acting upon said grooved tube to form it into a flexible longitudinally expansible and contractible bellows.

3. The process of making bellows consisting in providing a plain elongated tube having a thin wall, rolling a series of spaced apart inwardly extending annular grooves with unworked and unchanged connecting sections of said tube between the grooves having the diameter of said tube, and then working said connecting sections to form outwardly extending corrugations from said connecting sections.

4. The process of making bellows consisting in providing a plain elongated tube having a thin wall, forming a series of spaced apart inwardly extending annular grooves therein with uncorrugated connecting sections of said wall between the grooves, and then subjecting said connecting sections to operations which form outwardly extending corrugations from said connecting sections.

5. The process of making bellows consisting in providing a tube of thin metal, forming a series of inwardly pressed spaced-apart annular grooves in and around said tube with connecting sections having the diameter of the tube between said inwardly pressed grooves, and then forming said connecting sections into outwardly extending corrugations.

6. The process of making bellows consisting in providing a thin walled metal tube, rolling the metal of the tube inward to form grooves with connecting portions having the same diameter as the tube between said grooves, and forming said connecting portions into outwardly extending corrugations while enlarging the diameter of the same.

7. In the art of making a diaphragm embodying a circumferentially corrugated tubular wall and a head integral therewith, the process which consists in drawing the material into a seamless shell, then by a rolling operation forming circumferential recesses extending inwardly in the wall of the shell, and then, whilst externally supporting said recesses and externally applying pressure to shorten the axial length of the shell, expanding the wall by internal fluid pressure to form circumferential corrugations extending from said recesses and outwardly beyond the wall of the shell.

8. The method of making articles from metal shells or tubes, which comprises rolling a plurality of grooves in the wall of a shell or tube, placing a plurality of mold parts in the grooves, and then collapsing the shell or tube while under the influence of internal fluid pressure to out-

wardly expand the wall of the shell or tube between the grooves.

9. The method of making articles from metal shells or tubes, which comprises rolling a plurality of grooves in the wall of a shell or tube, arranging a plurality of mold parts in the grooves, applying pressure to the interior of the shell or tube, and then collapsing the shell or tube to expand the portion of the wall of the shell or tube between the grooves while maintaining an internal pressure.

10. The method of forming articles from metal shells or tubes, which comprises rolling a plurality of inwardly extending grooves in the wall of a shell or tube, placing the grooved shell or tube in a contractible mold, exerting pressure interiorly of the shell or tube, and applying axial external pressure to the shell or tube to form a corrugated shell or tube.

11. The method of forming articles from metal shells or tubes, which comprises rolling a plurality of spaced grooves in the wall of a shell or tube, placing a plurality of mold parts in such grooves, applying pressure interiorly of the shell or tube and axially collapsing the wall of the shell or tube while under sustained internal pressure to bring the mold parts together to form a corrugated shell or tube.

12. A method of making expansible and contractible walls, which comprises, positioning a circumferentially grooved tube or shell in a contractible mold, applying internal fluid pressure to the shell or tube, and then collapsing the contractible mold while the shell or tube is under sustained internal pressure.

13. A method of making expansible and contractible walls, which comprises, placing mold parts of a contractible mold in the spaced grooves of a circumferentially rolled tube or shell, applying pressure internally of the tube or shell, and then collapsing the tube or shell while the tube or shell is under sustained internal pressure.

14. Apparatus for producing bellows tubing comprising a series of partible hinged die plates, the sections of each die plate having complementary recesses adapted to encircle the tube when the die plate is closed, and yielding means interposed between the die plates on opposite sides of the tube-encircling recesses to preserve substantial parallelism of the die plates while permitting independent movement toward and from one another.

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