

April 21, 1931.

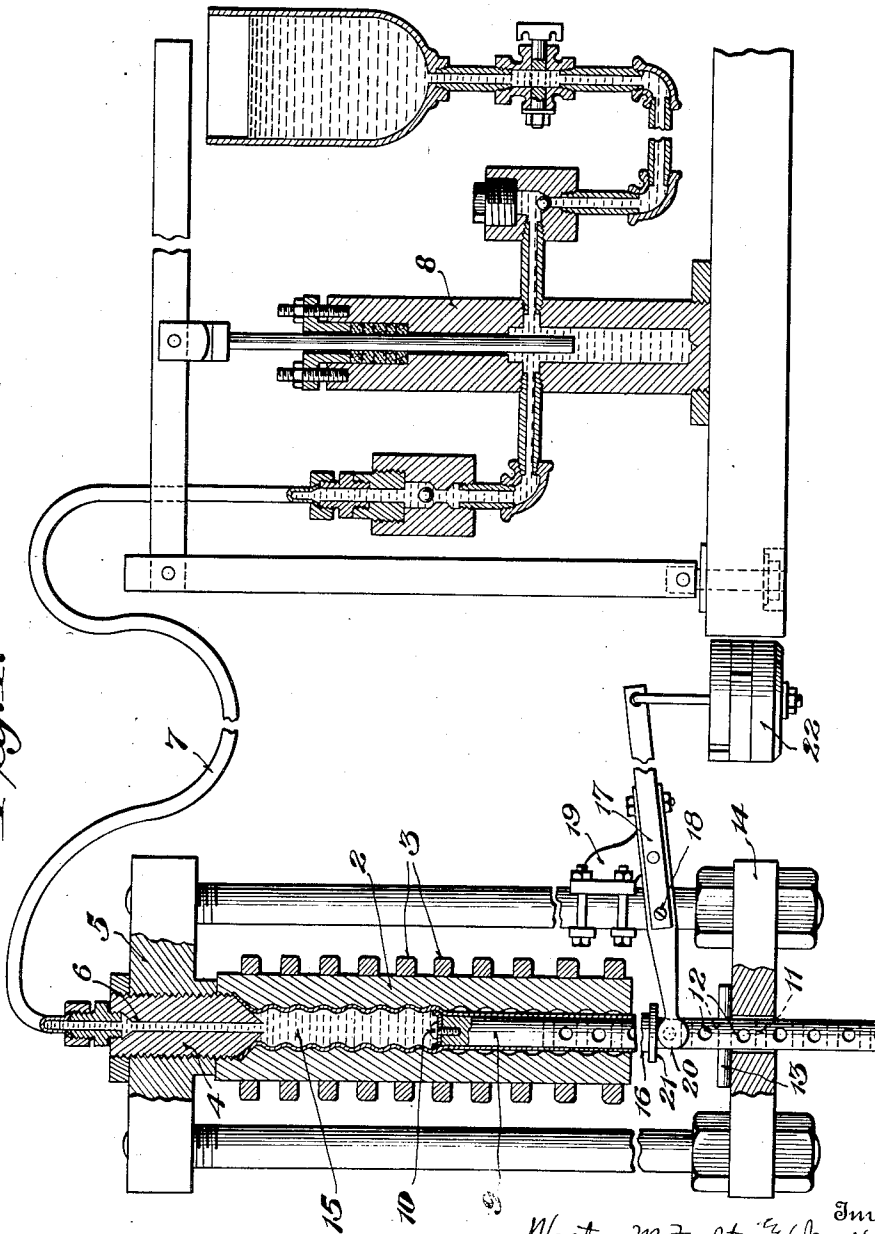
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FLEXIBLE TUBULAR CORRUGATED WALL

Original Filed Dec. 6, 1924 4 Sheets-Sheet 1

Fig. 1.



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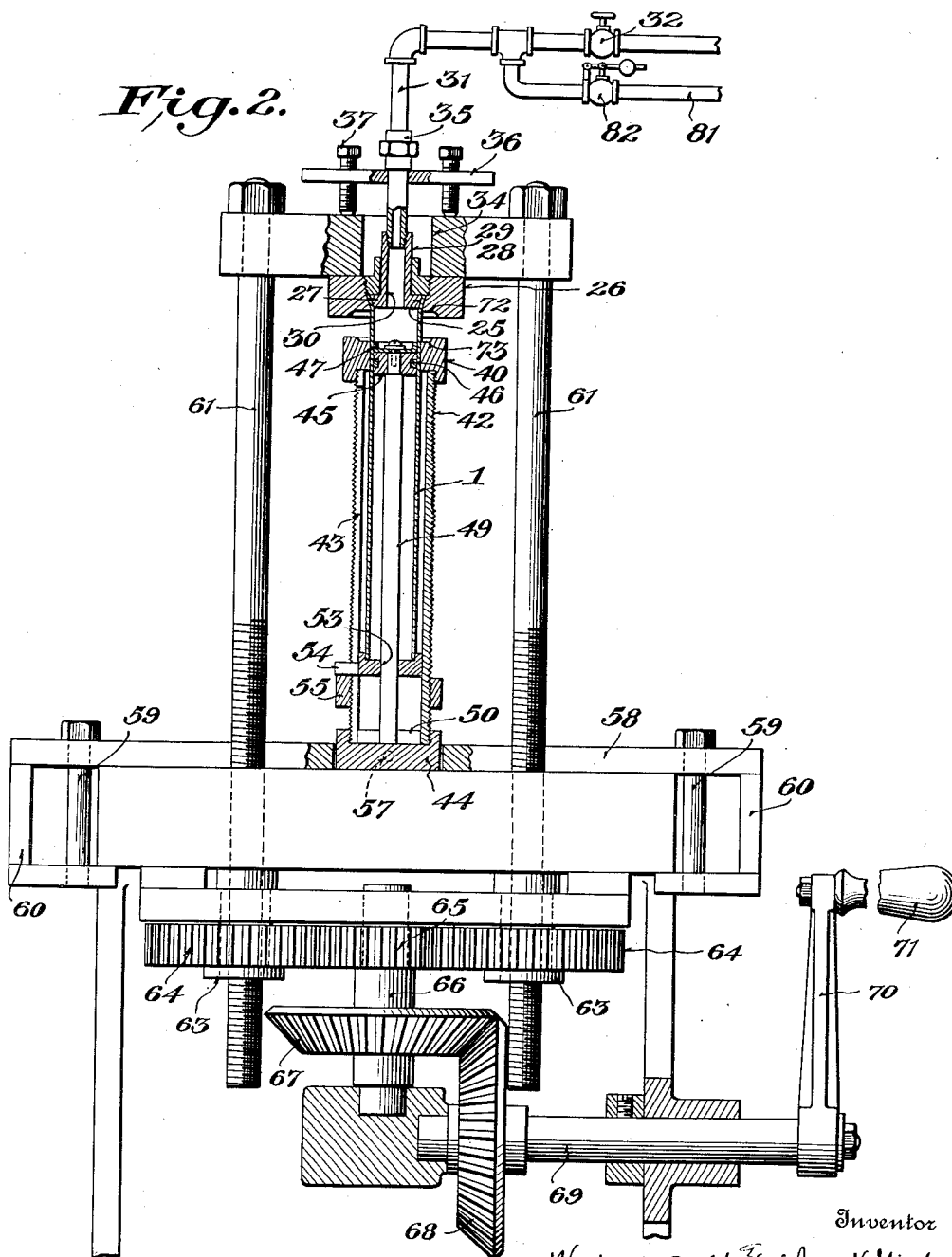
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FLEXIBLE TUBULAR CORRUGATED WALL

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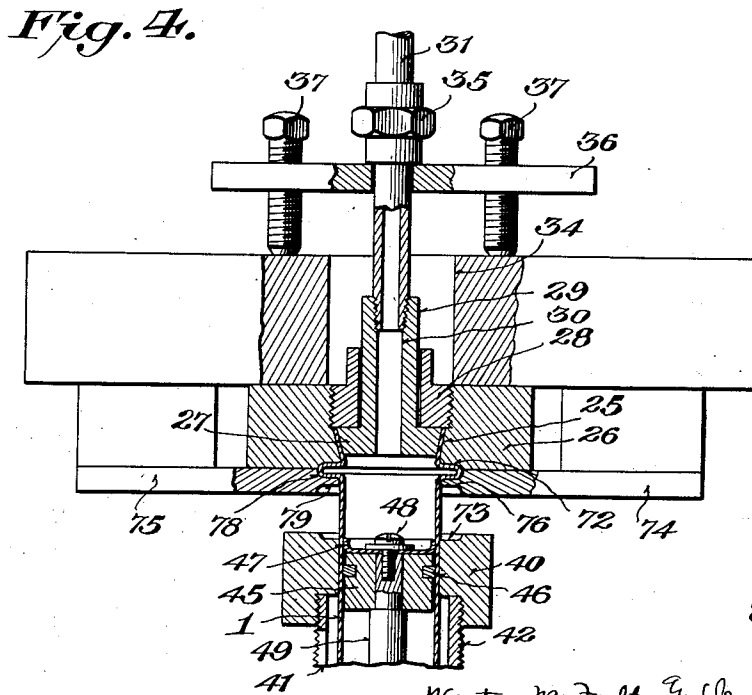
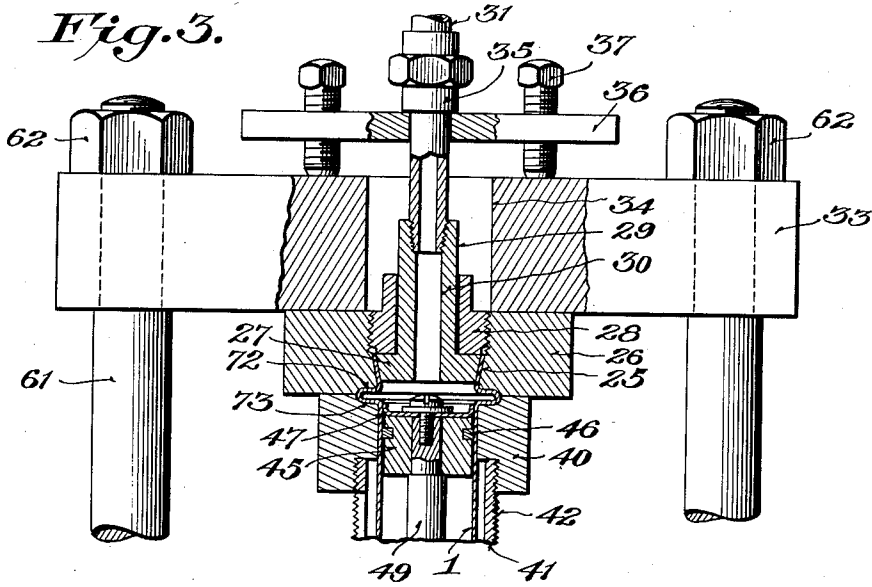
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FLEXIBLE TUBULAR CORRUGATED WALL

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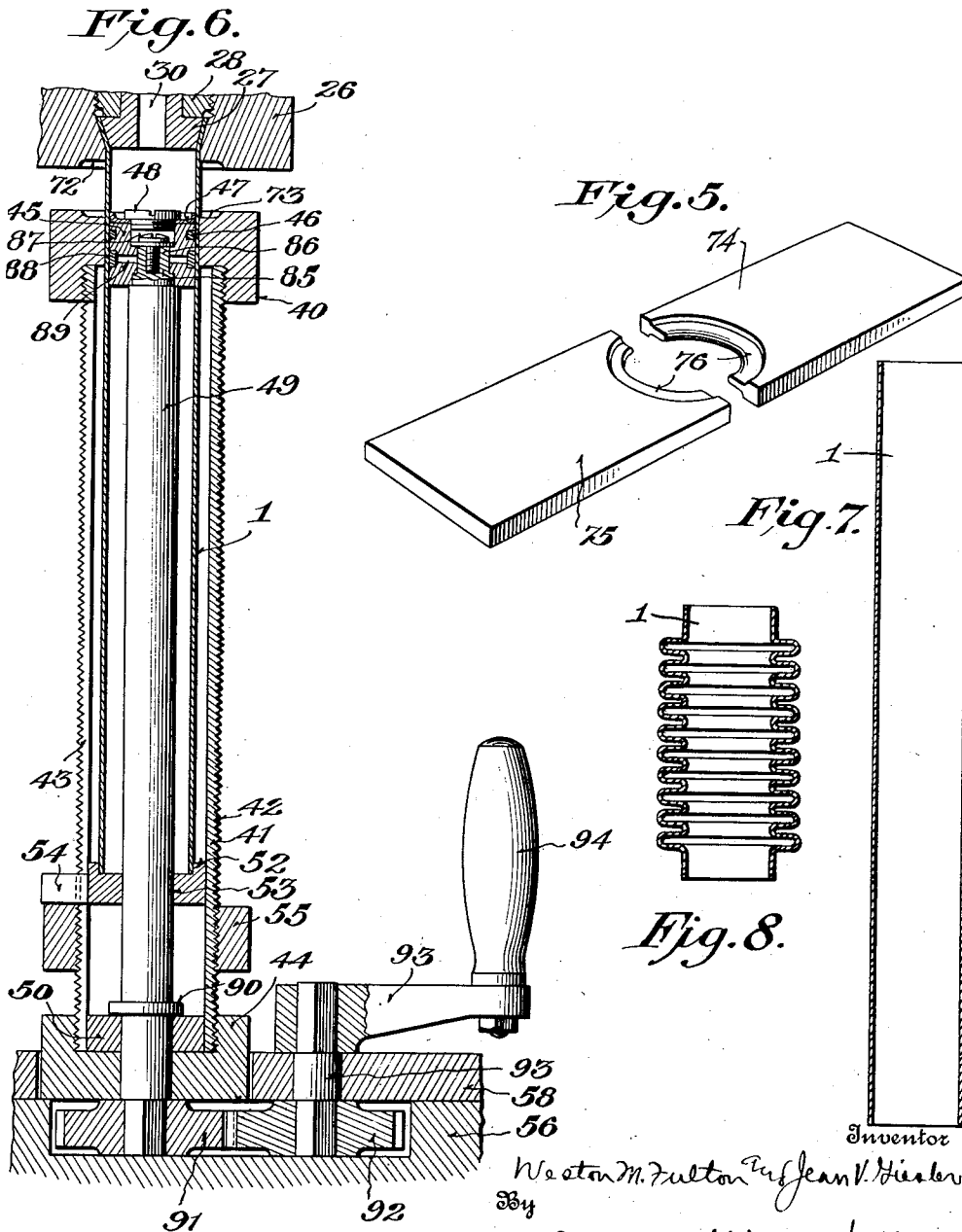
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FLEXIBLE TUBULAR CORRUGATED WALL

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UNITED STATES PATENT OFFICE

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FLEXIBLE TUBULAR CORRUGATED WALL

Original application filed December 6, 1924, Serial No. 754,444. Divided and this application filed April 20,
1927. Serial No. 185,312.

This invention relates to relatively-thin, flexible, tubular corrugated walls, this application being a division of our application Serial No. 754,444, filed December 6, 1924, for flexible tubular corrugated walls and method and apparatus for making the same.

Corrugated walls have heretofore been manufactured by various mechanical methods, such as by stamping, spinning, rolling, the use of expanding dies, etc. These methods, however, owing to the character of the treatment of the wall by the mechanical elements engaging the same, have resulted to a greater or less extent in an undesirable stretching and thinning of the material of the wall. These methods have tended to produce corrugated walls of irregular and uncertain thickness and to develop weak spots in the material of the wall. It has also been suggested to corrugate walls by forcing the wall by hydrostatic pressure into a corrugated die or form. If the wall has been held against longitudinal displacement during the pressing operation, the formation of the corrugations has been attended by an undue stretching and thinning of the material as much or more than in the mechanical methods heretofore discussed. Similarly, if the wall has been subjected to hydrostatic pressure throughout its extent at the surface to be corrugated, a similar result has been obtained because the application of equal force on each side of the respective ridges in the die has displaced the material of the wall transversely without permitting a corresponding longitudinal movement thereof.

It has also been suggested in the manufacture of tubular corrugated walls to position the wall in operative relation to a corrugated tubular die and progressively expose successive portions of the wall to the hydrostatic pressure. This method has been productive of corrugated walls wherein the material has been stretched and thinned to a less extent but has not entirely overcome the undesirable stretching and thinning of the material because of frictional opposition to axial movement of the wall. It has also been suggested to corrugate tubular walls by subjecting the wall to end pressure while the

tube is filled with liquid. This method has effected the corrugations by subjecting the material of the wall to a crushing or buckling pressure, the contained liquid constituting a variable counter-die that prevents collapse of the wall other than into the corrugations of the forming die. But this method of procedure is defective when applied to relatively thin walls because of the tendency of the wall to buckle at its weaker portion and the consequent formation of "body wrinkles."

It is an object of this invention to provide a relatively-thin, highly-flexible tubular corrugated wall which has not been unduly stretched or thinned and which is also free of body wrinkles.

Another object of this invention is to provide a relatively-thin, highly-flexible tubular corrugated wall with a superficial area or mean thickness, or both, not substantially less than the superficial area or thickness of the tube from which said wall is formed.

Another object of this invention is to provide a relatively-thin, highly-flexible tubular corrugated wall whose longitudinal elements are shorter than the longitudinal elements of the tube from which said wall is formed, or whose superficial area is less or whose mean thickness is greater, or both, than the superficial area or thickness of the tube from which the corrugated wall is formed.

Another object of this invention is to provide a relatively-thin, highly-flexible tubular corrugated wall of the character set out in any of the foregoing objects which is of substantially uniform thickness; or which has corrugations the bends of which have been rendered predeterminately resilient.

One suitable method and apparatus by which a relatively-thin, highly-flexible tubular corrugated wall as characterized in the foregoing objects may be produced is illustrated on the accompanying drawings and described in detail, but it is to be expressly understood that such method and apparatus have been selected for purposes of illustration only and are not to be taken as restricting the invention beyond that defined in the claims, as other suitable methods and apparatus for producing such a wall as defined

will readily suggest themselves to those skilled in the art.

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

Fig. 1 is a more or less diagrammatic view of suitable apparatus for producing walls in conformity with the present invention;

Fig. 2 is a more or less diagrammatic view of a second apparatus for producing walls in conformity with the present invention;

Fig. 3 is an enlarged fragmentary view corresponding to Fig. 2 but illustrating the position of the parts after one corrugation has been formed in the tubular wall;

Fig. 4 is a corresponding view illustrating the position of the parts when a second corrugation is about to be formed in the tubular wall;

Fig. 5 is a perspective view of the elements which are moved into position to protect the formed corrugations and constitute a die element in the formation of a succeeding corrugation;

Fig. 6 is a detail view illustrating means for clamping a tube in one of the die elements when a predetermined stretching of the material is desired; and

Figs. 7 and 8 respectively illustrate diagrammatically a blank tube and a tube that has been corrugated in conformity with the present invention.

The wall to be corrugated, which may be of any suitable thickness and of a wide variety of shapes, is mounted in operative relation to a suitable die or form. In the construction shown in Fig. 1 a tubular wall 1 is positioned in operative relation to a tubular corrugated form or die 2 which may conveniently be made in halves and the halves clamped firmly together by a plurality of rings 3 driven onto the tapered external surface of the form or die 2. One end of the wall is suitably clamped fixedly in the die, as by a threaded tapered plug 4 which has threaded engagement with both the die 2 and the frame work 5. Said plug is shown as provided with a passage 6 with which communicates suitable piping 7 leading from any suitable apparatus for developing pressure, such as the pump diagrammatically illustrated at 8 for developing hydrostatic pressure, this term being used as generic to the application of pressure by the use of oil, water, or any other suitable fluid. It is to be expressly understood, however, that the apparatus shown for developing pressure is to be taken as typical of any suitable means for supplying pressure to effect the corrugating of the wall.

Mounted within the tubular wall 1 in the form shown, is a piston or plunger 9 provided with a suitable packing 10 to prevent the leakage of fluid between said plunger and the wall of the tube. The rod or stem 11 of

said plunger is shown as provided with a plurality of apertures 12 which are spaced by distances equal to the spacing of the ridges of the form or die 2. A pin 13 is adapted to be inserted in the respective apertures 12 and to coact with the base 14 of the frame to predetermine the position of the plunger 9 and prevent the pressure within the confined space 15 from forcing the plunger beyond its predetermined position. The illustration of the pin 13 insertible in the apertures 12 for cooperation with frame 14 is to be taken, however, as merely typical of any suitable device for indexing or predetermining the extent of movement of the plunger 9 each time a fresh portion of the wall is to be exposed to the hydrostatic pressure.

Cooperating with the free end of the tube 1 is any suitable means employing weight, spring, hydraulic, pneumatic or other pressure for exerting a longitudinal force on said wall to overcome frictional opposition to longitudinal movement thereof and insure that the wall shall move longitudinally and flow freely into the corrugations of the die under the transverse pressure exerted thereon. In the form shown, a collar 16 is mounted freely on the rod or stem 11 of the plunger 9 so as to engage the lower end of the tubular wall 1, and means of any suitable construction are provided to exert a predetermined axial pressure on said collar 16 and wall 1. The apparatus illustrated comprises a lever 17 pivoted at 18 on a bracket 19 projecting from the frame and formed at its inner end as shown at 20 to engage a flange 21 on the collar 16. The other end of the lever carries a weight 22 which may be varied predeterminedly. It is to be understood, however, that the weight is only shown as typical of any suitable means for exerting a force of compression on the wall 1.

To corrugate a tubular wall in the apparatus so far outlined, the wall is clamped in the die or form 2 by the plug 4 and the plunger 9 is inserted into said wall until only that portion of the wall overlying the uppermost corrugation of the die is exposed within the confined space between the plug 4 and the plunger 9. The plunger is retained in this position by insertion of the pin 13 in the aperture 12 which is flush with the surface of the base 14, the frame being adjusted if necessary to properly position the aperture with respect to the frame. Collar 16 being engaged with the free end of the tube 1 and weight 22 applied, hydrostatic pressure is admitted to the confined space between plug 4 and plunger 9, the pump illustrated providing means for gradually applying and increasing this pressure, and the wall is forced into the corrugation or inter-ridge space of the die by the combined action of the hydrostatic pressure acting radially and the pressure of the weight acting axially or

longitudinally of the tube, the uncorrugated portion of the wall slipping over the plunger and die to supply the material which forms the corrugation. The pin 13 is then withdrawn from its aperture and introduced into the next adjacent aperture. Hydrostatic pressure is then again admitted to the confined space between the plug and plunger and its first operation is to move the plunger until the plunger is displaced by the predetermined amount which is represented by the spacing of the aperture 12 and which conforms with the spacing of the ridges or corrugations of the die. When the pin 13 engages the base 14 the plunger can be displaced no further and the hydrostatic pressure is increased to force the wall into the next corrugation of the die under the combined action of the bending and compression forces. This procedure is repeated, alternately predetermining the extent of displacement of the plunger and forming the corrugations by the combined action of the radially and axially acting forces until the entire wall has been progressively corrugated by intermittent application of pressure.

During the formation of these corrugations the longitudinal force exerted on the wall 1 tends to compress said wall into the corrugations of the die and aids the transverse pressure or bending force in forming the corrugations. The quantity of force exerted longitudinally of the wall can be varied considerably in accordance with the nature of the wall being operated upon. It should be less than the strength of the material of the wall to resist crushing or buckling so as to insure against any tendency to buckling or the formation of "body wrinkles", while on the other hand, it should be at least as great as the frictional opposition to movement of the wall longitudinally of the die so as to insure that the wall shall flow freely under the transverse bending pressure and prevent any undesirable stretching and thinning of the material of the wall. By selecting a longitudinal force between these extremes the formation of the corrugations under the transverse bending pressure is greatly facilitated and this longitudinal force may be selected of such a value as to enable the formation of the corrugations by hydrostatic pressure much less than would be necessary if the longitudinal forces were not employed. In fact, it has been found from experience that, particularly in the manufacture of relatively thick corrugated tubes of small diameter, the hydrostatic pressure may be reduced as much as seventy-five per cent (75%) or more when applying longitudinal force to the wall, and at the same time a wall of more uniform thickness be obtained than when using the higher hydrostatic pressure in the absence of longitudinal force.

The method heretofore described of corru-

gating walls may be employed to form the final or relatively-deep, narrow corrugations in the wall in the first instance, or it may be employed for the formation of initial corrugations in the wall as illustrated, and the corrugations are thereafter deepened by similar or other suitable corrugating operations. In the preferred practice of this invention the initial corrugations formed by the above-described method are deepened and narrowed by one or more rolling operations, such for example as described in Fulton Patent No. 971,838, granted Oct. 4, 1910, so as to work resilience to the desired extent into the bends of the corrugations. This rolling method may also be employed to complete corrugated walls which are formed by hydrostatic pressure alone whether with or without the application of a longitudinal force.

In the apparatus shown in Figs. 2 to 5 inclusive, the tube 1, which may be of any suitable length, size, shape, etc., is suitably clamped at its end 25 in a die element 26 by means of a tail-piece 27 which is tapered to clamp the tube end 25 against a correspondingly tapered surface in the die element 26, said tail-piece 27 being retained in clamping position by means of an annular nut 28 which surrounds the stem 29 of the tail-piece and engages interior threads on the die element 26. A passage 30 extends through said tail-piece 27 and communicates through a pipe 31 with any suitable source of pressure, such as a pump as diametrically illustrated in Fig. 1 or an accumulator, whereby any suitable liquid or gas under pressure may be admitted through the pipe 31 and passage 30 to the interior of the tube 1. A valve 32 is interposed in the pipe 31 at a suitable point in order to control the time and extent of application of the pressure as hereinafter explained.

Die element 26 with its tail-piece 27 is supported in any suitable way, being shown as attached to a yoke member 33 provided with a centrally arranged aperture 34 through which the pipe 31 communicates with the passage 30 in said tail-piece. Pipe 31 is provided in any suitable way, in the construction illustrated, with a collar 35 against which abuts a strap 36, and a plurality of screws 37 threaded through said strap 36 engage the face of the yoke member 33 to clamp the die element 26 and parts carried thereby fixedly in position. By tightening the screws 37 the strap 36 can be forced against the collar 35 so as to hold the die element 26 firmly and tightly in unitary relation with the yoke member 33.

Cooperating with the die element 26 is a second die element 40 which is mounted on an upstanding tubular support 41 provided with exterior threads as shown at 42. Said tubular support is provided with one or more longitudinally extending slots 43 for a pur-

pose to be explained, and at its lower end said tubular support is threaded into a supporting member 44. Axially arranged within said tubular support 41 is a piston 45 provided with one or more suitable packing rings 46 and a cup leather 47 suitably attached thereto as by a screw 48. Piston 45 is supported by a rod 49 which extends axially of the tube 41 and is suitably supported in the supporting member 44, as by an annular block 50 which fits the interior of the tubular support 41 and the exterior of the end of the piston rod 49. Said piston with its packing ring and cup leather, however, is to be taken as typical of any suitable means for providing a fluid-tight joint with the interior of the tube in radial alignment with the die element 40. The piston 45 is thereby fixed in position with respect to the die element 40 with the tube 1 projecting within the tubular support 41 between said piston 45 and the die element 40, said piston forming a fluid-tight joint with said tube.

The lower end of the tube 1 is received in a thrust element 51 which is provided with a peripheral upstanding collar 52 to guide the end of the tube. Thrust element 51 fits slidably within the tubular support 41 and has a central aperture 53 through which the piston rod 49 extends. Said thrust element 51 also has one or more radially projecting lugs 54, corresponding in number with the slots 43, which project through said slots and cooperate therewith to prevent rotation between said thrust element and tubular support while permitting relative axial movement thereof. Mounted below said thrust element 51 on the tubular support 41 is an annular nut 55, threaded on the threads 42 of said tubular support and adapted to be brought into contact with the lug or lugs 54 of the thrust element 51 to constitute an abutment therefor during the formation of the corrugations as will be explained hereinafter. The supporting member 44 is mounted in any suitable way on a plate 56, the same being shown as removably retained in position, as by a set screw 57, in an aperture in a strap piece 58 which is clamped to the face of said plate 56 in any suitable way, as by means of bolts 59 and spacing pieces 60.

The yoke member 33 and plate 56 are so arranged that one may be moved with respect to the other in the direction of the axis of the tube 1 so that an axial thrust may be exerted on said tube to apply a force of compression longitudinally of the same. In the form shown, the yoke member 33 is the movable member, and is mounted on a pair of screw threaded rods 61, being suitably retained thereon as by nuts 62. Said screw threaded rods pass through apertures in the plate 56 and on the opposite side of said plate cooperate with nuts 63 which are suitably provided, preferably integrally there-

with, with surrounding gears 64 of equal size. The two gears 64 mesh with an intermediate gear 65 mounted on a stub-shaft 66 which is suitably journaled in the frame of the machine and carries a beveled gear 67 that meshes with a second beveled gear 68 on an operating shaft 69. In the form shown said shaft 69 is provided with an operating crank 70 terminating in a handle 71 whereby the axial pressure or thrust to be exerted on the tube 1 may be applied by hand, and the time and extent of application of such forces thereby left to the skill of the operator. It is to be understood, however, that the shaft 69 may be operated in any other suitable way and the crank 70 is therefore to be taken as typical of any suitable apparatus for controlling the application of axial force to the tube so that the said force may be gradually applied to the tube in the manner hereinafter described. When the crank 70 is rotated, the gears 68, 67, 65 and 64 cause simultaneous and equal rotation of the nuts 63, and the two threaded rods 61 are thereby caused to move simultaneously and equally to move the yoke member 33 toward or away from the plate 56, the former movement exerting a force of compression axially of the tube 1 which is abutted on the thrust piece 51 and clamped at its opposite end between the die element 26 and the tail-piece 27.

The die element 26 and the die element 40 are suitably formed, as shown at 72 and 73 respectively, to constitute a die for a corrugation of the character to be formed, so that when said die elements are brought into contact with each other, the two surfaces 72 and 73 together form a recess conforming with the shape of the corrugation to be made, as shown in Fig. 3. This corrugation is preferably made of final depth and width at one operation, i. e. it is made as a relatively-deep, narrow corrugation having lateral sides which are at substantially right angles to the axis of the tube, as illustrated in Fig. 3.

Also mounted on the machine in any suitable way, preferably so that they can be moved rectilinearly into and out of operative position, are a plurality of pairs of plates 74 and 75 which are shaped at their adjacent ends, as shown in Fig. 5, so that when brought into endwise engagement the abutting ends form a circular opening into which projects a circular rib 76 which exactly corresponds with the shape of the space to be left between two outwardly directed corrugations. In other words, as shown in Fig. 4, the formed surface 78 on the upper face of said rib 76 mates with the formed surface 72 on the die element 26 and completely and accurately encases the first corrugation, while the oppositely formed surface 79 corresponds with the formed surface 72 on die element 26 and is in position to cooperate with the formed surface 73 on die element 40

to form a second corrugation. As many pairs of die elements 74 and 75 are provided as there are corrugation to be formed in a tube 1 and after each corrugation is formed a pair of these die elements is moved into operative position as shown in Fig. 4, where they become in effect a part of the die element 26 and not only protect the corrugation or corrugations which are already formed from being deformed by subsequent operations, but also cooperate with the die element 40 to constitute dies for the succeeding corrugations to be formed.

In operation a tube 1 is mounted within the tubular support 41 with its upper end projecting between the die element 40 and the piston 45, the latter forming a fluid-tight joint therewith. Said end is clamped in the die element 26 by means of the tail-piece 27 and nut 28 so as to form a second fluid-tight joint between said die element and the end of said tube. Die element 40 and die element 26 are so spaced that the length of the tube 1 between the formed surfaces 72 and 73 exactly corresponds with the amount of metal which is to go into the first corrugation, this amount being determined in the manner to be explained, and the lower end of the tube 1 is engaged with the thrust element 51 with the nut 55 in abutting engagement therewith by rotating said nut on the tubular support 41.

Pressure is now admitted to the confined space within the tube 1 between the piston 45 and the tail-piece 27 by manipulation of the valve 32, the amount of pressure thus admitted to said confined space preferably being such as to place the metal of the wall 1 under a slight tension but without imposing any set or stretch therein such as would be produced if the pressure were sufficient to cause the tube 1 to bulge to any considerable extent. The pressure in said confined space is then gradually increased, as by manipulation of the valve 32, at the same time actuating the operating shaft 69 to exert an axial thrust on said tube through the yoke member 33 and die element 26. It is preferable to increase both of these pressures gradually and simultaneously, as experience has demonstrated that an application of the axial pressure without increase of the radial pressure exerted by the fluid tends to produce a buckling or wrinkling of the section of the tube between the die elements 26 and 40, while an increase of the radial pressure without application of the axial pressure tends to produce an undesirable stretching of the section of tube between said die elements. Experience has also demonstrated that the radial pressure should rise rather rapidly but gradually for approximately the first third of the time that the die element 26 is being moved toward the die element 40, after which the radial pressure may be and preferably is

maintained substantially constant, and to this end a by-pass 81 is provided in communication with the inlet pipe 31 and includes an adjustable relief valve 82 of any suitable character so as to maintain a substantially constant predetermined pressure on the fluid in the confined space between the piston 45 and the tail-piece 27 during the remainder of the operation. The axial pressure on said tube should also increase rather rapidly but gradually for approximately the first seventh of the time that the die element 26 is being moved toward the die element 40, and then should continue to increase more slowly for approximately the next three-sevenths of this period, after which the axial pressure should remain substantially constant or even be slightly diminished during the remainder of the operation. As the metal of the tubular wall bends into corrugated shape its effective area at an angle to the axis of the tube is increasing, and this results in a gradual increase in the resistance to the movement toward each other of the lateral elements of the corrugation being formed; because of the increasing effective area upon which fluid pressure may act; hence there should be a gradual increase of the pressure longitudinally of the metal in order to cause it to flow into the space between the die elements 26 and 40 without an undesirable stretching of the metal. If the radial pressure is also increasing there is a consequent increase in the resistance of the movable elements toward each other which must also be taken into consideration.

The combined radial and axial pressures are applied until the die elements 26 and 40 come into contact with each other, at which time the formed surfaces 72 and 73 constitute a completed die for the corrugation, and during the approach of said die elements the metal of the tube between the same has under the combined action of the radial and axial forces been bent and compressed so that it flows into and assumes the corrugated form determined by the shape of the formed surfaces 72 and 73.

The first corrugation having thus been formed, the yoke member 33 with its die element 26 is backed off, pulling the tube 1 between the piston 45 and the die element 40 until a fresh section of the tube, equal in length to that formerly acted upon, is exposed between said die elements 26 and 40. Any suitable means, as a pawl and ratchet mechanism (not shown), may be provided for limiting the extent of the backward movement of the yoke member 33 or its actuating mechanism, so as to index the advancement of the tube and exactly position the die element 26 with respect to the die element 40 so that a predetermined length of tube is exposed between the same. A pair of die plates 74 and 75 are now moved into position to embrace the first corrugation between the

formed surfaces 72 and 78 as illustrated in Fig. 4, and to present a pair of die surfaces 79 and 73 for the formation of the next corrugation. The advancement of the tube 1 by the backward movement of the yoke member 33 has withdrawn the end of tube 1 from the thrust piece 51 or, if the latter fits snugly on the end of said tube, has withdrawn the thrust element 51 from contact with the nut 55. In either event the nut 55 is advanced by rotation on the tubular support 41 until the thrust element 51 and nut 55 constitute an abutment for the end of the tube 1 during the next application of axial pressure. Radial pressure is again admitted to the confined space between the piston 45 and the tail-piece 27 and this pressure holds the first corrugation in contact with the formed surfaces 72 and 78 so that the subsequent application of axial pressure does not cause a collapse or deformation of the corrugation already formed. As previously pointed out, this pressure should not be such as to cause any substantial stretching of the metal in the portion of the tube about to be corrugated. The second corrugation is now formed in the manner heretofore described by the gradual application of increasing axial and radial pressures until the die elements are again brought into contact, after which the movable die element is again backed off to the predetermined amount, a fresh pair of die plates 74, 75 are moved into position, and these operations repeated until the entire tube or the desired portion thereof has been corrugated.

It is sometimes desirable to positively prevent slippage between the piston 45 and the tube 1, particularly when a predetermined amount of stretching is to be given the tube during the formation of the corrugations. In the embodiment shown in Fig. 6 provision is made for thus positively clamping the tube 1 between the piston 45 and the die element 40. As here shown, the piston rod 49 is provided with an extension 85 which has a plurality of cam surfaces 86, the piston being shown as secured to the rod 49 by means of a screw and washer 87. The piston 45 carries one or more clamping rings 88, and between said rings 88 and the cam surfaces 86 are a corresponding number of pins or lugs 89 which when actuated by the cam surfaces 86 exert a thrust on the clamping rings 88 and force the latter into clamping engagement with the tube 1.

The opposite end of the piston rod 49 is provided with a thrust collar 90 and is extended beyond the supporting member 44, where it carries a pinion 91 secured thereon by spline or equivalent means. Pinion 91 is in mesh with a pinion 92 on a stub-shaft 93 which carries a crank 94 provided with a handle 95. By oscillating the crank 94 the piston rod 49 is rotated through the pinions 91 and 92 so as to actuate the cam surfaces

86 and either relieve or exert thrust on the pins 89 to respectively release the clamping rings or cause them to be forced into clamping engagement with the tube 1.

The axial pressure exerted on the tube during the formation of the corrugations may be so selected with respect to the radial pressure that the superficial area of the resulting corrugations is substantially the same as that of the superficial area of the tube in which the corrugations are formed, or the mean thickness of the resulting corrugations is substantially the same as that of the thickness of the tube in which the corrugations are formed, or the axial pressure may be so selected as to actually reduce the superficial area, or decrease the length of the longitudinal elements of the wall, or thicken the metal of the wall. Not only is this true in the operation of the apparatus of Fig. 1, but the same conditions may also be obtained by use of the apparatus shown in Figs. 2 to 6 inclusive by predeterminedly spacing the relatively movable die elements between which the respective corrugations are formed. Taking L as the distance between the points where the two formed surfaces 72 and 73 engage the tube 1 at the initial setting of the die elements 26 and 40, said dimension may be readily determined by equating the superficial area of an outwardly directed corrugation, between parallel radially extending planes which pass through the centers of curvature of two successive inwardly directed bends, with the superficial area of a cylinder of L length, and solving for L —in the case where the final superficial area is to be the same as or have a predetermined relation to the original superficial area; or by equating the volumes of metal using the predetermined thicknesses and solving for L —in the cases where equality or a predetermined increase in the mean thickness of the metal is desired, etc.

From the dimension L , the predetermined spacing of the die elements 26 and 40 for the various cases can be readily determined, taking into consideration the depth in an axial direction of the forming surfaces which constitute the die; for example, where the sides of the corrugations are to be at substantially right angles to the axis of the tube and the radius of curvature is to be the same for the outer and the inner bends of the corrugations, the predetermined spacing of the die elements 26 and 40 is equal to L minus $4R$, where R is the radius of curvature of said bends. Where the superficial area of the resulting corrugations is to be no greater than the superficial area of the original tube, or the mean thickness of the corrugations is to be no greater than the mean thickness of the original tube, care must be exercised in applying the radial pressure so that it shall not be sufficient to unduly stretch the metal cir-

cumferentially while the axial pressure is being applied.

In these cases the radial pressure should be little more, if any, than is sufficient to prevent the formation of body wrinkles, the axial thrust doing the major portion of the work in forming the corrugations; but as the extent of the pressure which is necessary to prevent the formation of body wrinkles will vary with the thickness of the tube and the length of the tube section exposed to the fluid pressure, the limit of the radial pressure to be used cannot be definitely stated. The extent to which the axial pressure is increased will also vary with the amount of radial pressure used, the thickness of the tube, etc., but must be such as to cause the metal to flow into the shape of the die.

Whether the corrugated tube is made in the apparatus of Fig. 1 or of Figs. 2 to 6 inclusive, the corrugations may be, and preferably are, treated so as to obtain the desired distribution or amount of resiliency in the walls of the corrugations. This treatment may be of any suitable character and carried out in any suitable way, as by rolling or otherwise cold working the bends of the corrugations. During these rolling or cold working operations, the corrugations may be deepened and narrowed to a further extent if desired, or the shape and size of the corrugations may be left unchanged and the working of the metal effected by relative slippage of the rolls or otherwise. If desired, the process may be carried out with the wall raised above normal atmospheric temperature so as to reduce the amount of resilience that is imparted to the metal by the cold working operations.

It will therefore be perceived that a relatively-thin, highly-flexible tubular corrugated wall has been provided wherein the superficial area of the wall may be made no greater than, or less than, the superficial area of the tube from which the corrugated wall is formed, or the mean thickness of the wall may be made no less than, or greater than, the thickness of the tube from which the corrugated wall is formed, or the longitudinal elements of the corrugated wall may be made less than those of the tube from which the corrugated wall is formed. Thereby a wall of this character is provided which eliminates all of the disadvantages inherent in the undue stretching or thinning of the metal. The wall may be also made of substantially uniform thickness and the bends may be made predeterminedly resilient.

It is to be expressly understood that the invention is not limited to corrugations of any particular configuration or dimensions, or to walls of any particular material, thickness, size or shape. Reference is therefore to be had to the claims hereto appended for a definition of the limits of the invention.

What is claimed is:

1. A flexible corrugated tubular wall having a superficial area not substantially greater than that of the tube from which it is formed.

2. A flexible corrugated tubular wall having a mean thickness not substantially less than that of the tube from which it is formed.

3. A flexible corrugated tubular wall having its longitudinal elements shorter than those of the tube from which it is formed.

4. A flexible corrugated tubular wall having its wall of greater mean thickness than that of the tube from which it is formed.

5. A flexible corrugated tubular wall having a superficial area which is less than that of the tube from which it is formed.

6. A flexible corrugated tubular wall having a superficial area not substantially greater than that of the tube from which it is formed, and having bends rendered predeterminedly resilient.

7. A flexible corrugated tubular wall having a mean thickness not substantially less than that of the tube from which it is formed, and having bends rendered predeterminedly resilient.

8. A flexible corrugated tubular wall having its longitudinal elements shorter than those of the tube from which it is formed, and having bends rendered predeterminedly resilient.

9. A flexible corrugated tubular wall having its wall of greater mean thickness than that of the tube from which it is formed, and having bends rendered predeterminedly resilient.

10. A flexible corrugated tubular wall having a superficial area which is less than that of the tube from which it is formed, and having bends rendered predeterminedly resilient.

In testimony whereof we have signed this specification.

WESTON M. FULTON.
JEAN V. GIESLER.