

W. M. FULTON.
PROCESS OF MAKING TUBULAR METAL WALLS.
APPLICATION FILED JULY 22, 1909.

971,838.

Patented Oct. 4, 1910.

Fig. 2.

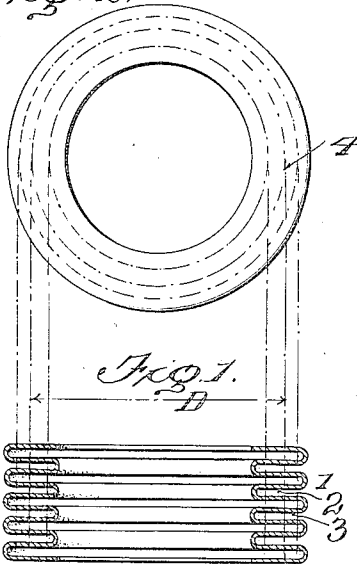


Fig. 3.

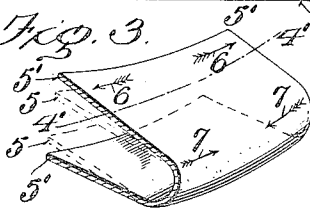


Fig. 4.

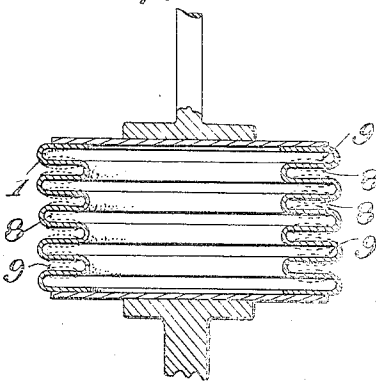


Fig. 5.

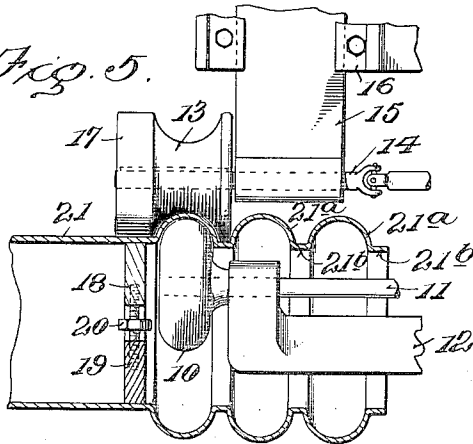


Fig. 6.

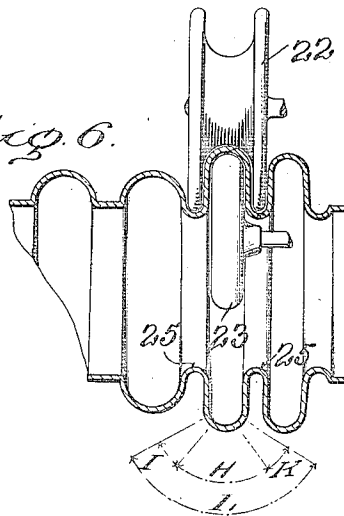
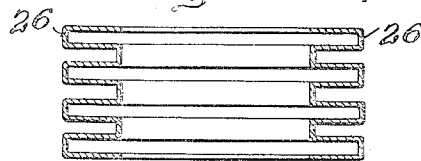


Fig. 7.



Witnesses

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PROCESS OF MAKING TUBULAR METAL WALLS.

971,838.

Specification of Letters Patent.

Patented Oct. 4, 1910.

Original application filed April 3, 1907, Serial No. 366,207. Divided and this application filed July 22, 1909. Serial No. 509,067.

To all whom it may concern:

Be it known that I, WESTON M. FULTON, a resident of Knoxville, Tennessee, have invented a new and useful Improvement in the Process of Making Tubular Metal Walls, which invention is fully set forth in the following specification.

This invention relates to processes of making flexible corrugated metal walls for collapsible and expansible vessels, particularly of the class adapted for confining fluids under pressure, and has for its object the production of corrugated metal walls of high resilience, of great strength and durability and which can be collapsed and expanded many times while confining fluids under pressure without material injury to the wall.

In my co-pending application, filed April 3, 1907, Ser. No. 366,207, of which this application is a division, I have shown, described and claimed the article herein disclosed, and, therefore, do not claim the same in this application.

Flexible tubular corrugated metal walls for collapsible and expansible vessels are subject to repeated strains of tension and compression, of varying intensity in different portions of the metal composing the corrugations, which in walls as heretofore made result in the occurrence of cracks, particularly in the curved portions or bends, and also where the lateral portions of the corrugations merge into the curved portions. Flexible corrugated tubular walls are usually made of copper, brass or steel, and in order that these walls may be possessed of flexibility, advantage has heretofore been taken of the fact that annealing imparts pliability to the metal of the corrugated wall, hence, in making corrugated walls where great flexibility is desired, as in thermosensitive or pressure-sensitive vessels, care is usually taken to avoid working temper into the metal during the formation of the wall and to remove any temper unavoidably formed therein by subsequent annealing of the finished wall. It is well known that metals of the kind referred to, when in the annealed state, possess a very low elastic limit; consequently the strains to which the corrugations of collapsible and

expansible vessels are subjected continuously, carry the metal beyond this elastic limit, particularly in the lateral portions near the bends, causing the metal to crystallize and crack, and thus destroy the wall. A further disadvantage of employing annealed corrugated walls is that it detracts from the efficiency of the collapsible and expansible vessel and limits its utility. Where such walls are used in vessels containing a liquid responsive to slight changes in temperature, there is lost motion in the lateral portions of the corrugations which connect the curved portions. This results from the pliable condition of the metal in these lateral portions which permits them to buckle in or out as the vessel expands or contracts, thereby detracting from the longitudinal movement of the walls of the vessel. This buckling of the lateral portions throws more strain on the corrugations where they merge into the curved portions, thereby contributing to the deterioration and ultimate fracture of the walls when the vessel is in operation.

To overcome the above objections and to secure the benefits of my invention, I have devised a method of making flexible tubular metal walls in which the metal at the bends is toughened and hardened in proportion to the strain sustained therein when the wall is in operation, and in which the lateral portions of the corrugations joining the bends are strengthened and made resilient in the vicinity of the bends; said method consisting in taking a tubular metal wall and forcing portions of the tubular wall radially outward to form broad shallow corrugations, leaving narrow uncorrugated connecting portions, deepening and narrowing said shallow corrugations and swaging inward the narrow connecting portions by successive rolling operations, which toughen and harden the metal at the bends while transferring portions of the latter to the side or lateral portions of the corrugations to there strengthen and render the wall resilient in proportion to the relative share of the strain sustained thereat when in operation.

The inventive idea involved is capable of expression in a variety of methods, one of which for the purpose of illustration is hereinafter specifically described, and in the ac-

companying drawings I have illustrated one way of carrying the same into effect.

In said drawings, Figure 1 is a view in central longitudinal section of a flexible corrugated vessel, and Fig. 2 is a complete plan view of such a vessel. Fig. 3 is a fragmentary view in perspective of a single corrugation. Fig. 4 is a longitudinal sectional view of a flexible vessel showing the effects of pressure on the lateral portions of the corrugations. Figs. 5 and 6 are views partly in vertical section and partly in elevation, showing means for corrugating a thin metal tube. Fig. 7 shows in central vertical section another form of corrugated wall.

Referring first to Figs. 1, 2 and 3, I have therein shown the location and direction of the principal strains which occur in the corrugations of a flexible corrugated vessel when in operation, in order that my method may be better understood.

In Figs. 1 and 2, I have shown in plan and in central vertical section respectively, a flexible corrugated cylindrical wall 1, having the portions connecting the bends in planes normal to the axis of the vessel. If a force be applied of sufficient amount to draw the walls of the vessel out till the corrugations disappear, there will result a plain uncorrugated cylinder having a diameter D which will be greater than the inner diameter and less than the outer diameter of the original corrugated cylinder. During this extension of the corrugated wall, the material in the disk portions 2, which is interior of or within the lines 4—4 of this plain cylinder is subject to tensile strains, while the material in portions 3 exterior to the lines 4—4 is subject to compression or crushing strains. It may be here observed that radial lines in the flat connecting portions which join the bends tend to rotate about an axis lying in the plane of the flat connecting portion and intersecting the lines 4—4. The direction of these attenuating and compressing strains is clearly indicated in Fig. 3, which shows a portion of a single corrugation much enlarged. In the dotted line position, the portions 5, 5 of the lateral wall are in their normal position and subject to no strains. In the full line position, the portions 5', 5' are being opened out as the wall of the collapsible vessel is extended. The material in the lateral portion which lies interior of the axial line 4', 4', or nearer the axis of the vessel, is placed under tension, as indicated by the arrows 6, 6, while the material in the portion exterior of the line 4' 4', or nearer the circumference of the vessel, is under compression, indicated by arrows 7, 7.

When the wall is collapsed to its initial position with the lateral portions normal to the axis, the strains will be reversed. It will

also be seen that during the collapsing from normal position to that where the bends contact with each other, strains of tension and compression will also occur; in fact, whenever the lateral portions are forced out of planes normal to the axis of the cylinder, these strains will appear, and their direction may be determined by noting the direction of oscillation of the lateral portions with respect to their intersection with the lines of the median cylinder. The bends of the corrugations not only participate in strains of attenuation and compression with the lateral portions, but also suffer bending strains as their radii of curvature shorten and lengthen during collapsing and extension. The resultant of these strains lie across the corrugations and are most active at the points where the lateral portions merge into the curved portions. Contributory to the effects of these last strains are those due to movements of the lateral walls themselves to bulge out to position 8 when internal pressure is excessive, and to bulge in to position 9 when external pressure predominates, as diagrammatically indicated in Fig. 4, where 1 designates a corrugated wall. The full line position shows the pressures balanced on the inside and outside, and the dotted line positions indicate the lateral walls bulged in or out where the pressures are greatest on the concave sides.

It is to be further noted that fluid pressure within the cylindrical vessel sets up bursting strains of greater intensity in the outer sets of corrugations than in the inner corrugations nearer the axis, in proportion to the diameter of the wall. It is therefore essential to provide for this difference of strain in the corrugations while making the wall.

With the above objects in view, my process results in the production and retention of resilience in the metal composing the wall, and in so disposing the metal during the formation of the corrugations as to intensify the toughness and tensile strength of the wall at points where the corrugations are subject to the greatest strains when in use.

In carrying out my invention I first form a tube of thin metal, preferably by bending the sheet into tubular form, and electrically brazing the seam in the manner indicated in my U. S. Patents No. 853,351 of May 14, 1907, and No. 916,140 of March 23, 1909. The resulting tube is then well annealed by heating it slowly to the annealing temperature of the metal to rid the metal, as far as possible, of all strains existing therein, so that the distribution of toughness and resilience produced by the subsequent steps of my process may not be offset or complicated by irregularities in the original tube wall. Next, broad circumferential corrugations

are formed in the tube wall by forcing the metal radially outward from the axis of the tube, preferably leaving at first narrow uncorrugated connecting portions between the broad corrugations. This step of the process may be carried out by use of various mechanical expedients. I prefer to use rolls, and have shown a pair of such rolls in Fig. 5 suitable for the purpose, in which a die roll 10 is loosely mounted on a shaft 11 having a bearing in a stationary arm 12. Mounted above the die roll 10, is a matrix roll 13 fast to a flexible power shaft 14, which permits of vertical adjustment by means of a hanger 15 movable in guides 16. The matrix roll 13 is shown provided with a cylindrical portion 17 which rolls on the perimeter of the tube to be corrugated. An expanding brace having two semi-circular members 18, 19, which when properly spaced apart by screws 20, to fit the interior of the tube, and positioned under the cylindrical portion 17, prevents the inward swaging of the tubular wall during the action of the rolls 10, 13.

In operation, the upper or matrix roll is raised to clear the die roll. The expanding brace is inserted into the annealed tube 21 and expanded into position near one end of the tube, leaving sufficient amount of tube projecting beyond the brace to form the first corrugation at the end of the tube. The tube is next passed over the die roll and under the matrix roll either by hand or by mechanically operated means, to bring the end of the tube into corrugating position. Matrix roll 13 is then lowered into contact with the tube, and pressed toward the die roll 10, while the power shaft 11 is rotated. The metal of the wall is thereby pressed outwardly from the axis of the tube into a broad circumferential corrugation. The brace within the tube prevents the tube wall from being swaged inward as the corrugation is being formed. The manner of mounting the corrugating rolls as above described enables them to turn together irrespective of difference of circumference, die roll 10 being driven by friction against the tube which itself is caused to revolve by matrix roll 13. After the first corrugation is formed, the rolls are separated, the brace loosened and moved along to allow for the next corrugation, and the corrugating operation repeated. The tube will now be provided with a series of broad, shallow, outwardly-extending corrugations 21^a united by narrow uncorrugated portions 21^b. Rolls 10 and 13 are next replaced by narrower rolls 22, 23, Fig. 6. The tube is again placed in corrugating position, the expanding brace being omitted, and each shallow corrugation is deepened and narrowed by the action of the narrower rolls, and these steps are re-

peated with successive sets of rolls, till the requisite proportions have been reached for rendering the wall duly flexible. During this process of corrugating, the narrow uncorrugated connecting portions 21^b are forced inward to form inwardly projecting corrugations, and may be somewhat narrowed, deepened and toughened by the swaging action of the narrower flanges of the matrix roll, but I prefer to swage the inner projecting corrugations much less in extent than the outwardly extending corrugations, as the inner corrugations do not need to be toughened to the same extent as the outer corrugations, for the latter have to sustain the greater strains, as heretofore explained.

The successive narrowing and deepening of the corrugations gives to the wall resilience and toughness at those places where it is most advantageous. Referring particularly to Fig. 6, the curved portion of the narrowed corrugation included within the angle L is tempered and toughened more than the straight portion connecting the inner and outer curved portions, for the reason that the pressure required in rolling the corrugation to greater depth is practically all exerted against this curved portion by the die roll 23, while the straight portion is subjected only to the moderate action of friction between the sides of the die roll 23 and the matrix roll 22. Likewise, the inwardly curved portions 25 are also toughened and tempered more than the straight portions, because of the action of the flanges of the matrix roll 22. When the corrugations of the second order are further narrowed and deepened, certain toughened portions I, K of the curved portion L will be carried over into the lateral wall to form an extension of the straight portion, leaving a portion within the angle H to constitute the bend. This curved portion H will be in a similar manner further toughened and hardened by the action of the die roll used to deepen and narrow the corrugation. As the result of these operations, the corrugations will be toughened and made resilient in the curved portions, and these qualities will be graduated for a considerable way into the lateral portions just where they need strengthening. Hence, this method of corrugating enables a corrugation to be made which is most resilient at the curved portions where the greatest amount of bending strains occur when the wall is in use; it also enables resilience and strength to be gradually increased in its lateral wall proceeding in both directions toward the curved portions where it reaches a maximum, and where, as previously pointed out, the strains in the corrugations reach their maximum effect. Furthermore, the lateral walls being toughened and tempered over a portion of their length as above de-

scribed have much less tendency to buckle back and forth with changes of fluid pressure than would be the case were the walls made in the usual manner or subsequently annealed.

It is to be understood that, while I much prefer the process of rolling in order to narrow and deepen the initial outwardly formed corrugations, I do not confine myself to any particular means for accomplishing this end, so long as such means serve the same end as the rolling process. For example, it is evident that if the corrugations were narrowed and deepened by spinning them into female dies of successively narrower and deeper shape, the spinning process thus applied, would produce the same result as my rolling process, viz., it would impart resilience and toughness to the corrugations and distribute same to desired points.

It is to be understood that the particular shape of the corrugations is not an essential feature of my invention. While I prefer to form them somewhat as indicated, the lateral walls thereof may be curved instead of straight, or they may be corrugated as described in my U. S. Patent No. 729,926, dated June 2, 1903. Likewise, the inner and outer curved portions may have any other desired shape, as for example, they may lie in a plane approximately parallel with the axis of the wall, as indicated at 26, 26, Fig. 7.

I have shown the corrugations as lying in planes perpendicular to the axis of the wall. I much prefer this method of arranging the corrugations, but they may be made in the form of an ascending spiral similar to the threads of a screw or otherwise, without departing from my invention.

The wall may be cylindrical or any other desired shape, as for example, elliptical in cross section.

Where the tube is made in the manner described in my Patents No. 853,351 and No. 916,140 above referred to I prefer to anneal the sheet before the tube is formed, instead of annealing the tube itself.

It is to be understood that it would be no departure from the spirit of my invention to apply my process only in part. For example, if the tube were annealed subsequent to the initial corrugating process, but previous to the final narrowing and deepening process, the wall would evidently be only slightly inferior to mine, and would be a very decided improvement over walls made according to old processes. Or, if a wall were made according to my process and then annealed at the conclusion of same, so as to deprive the wall of its resilience, it is evident that such a wall would still possess, to a very high degree, the toughness and tensile strength imparted to it by my process; and

these would be distributed in the corrugations so as to give strength at points most exposed to strains when the wall is in use, and while a wall so made would be inferior to mine, it would still be superior to walls made according to old processes.

What I claim is:—

1. The process of making flexible corrugated metal walls, consisting in forming a thin walled tube, forcing the metal of the tube outward from the axis of the tube to form broad corrugations therein with narrow uncorrugated portions connecting the broad corrugations, then deepening and narrowing said corrugations while subjecting the metal at the bends to a metal rolling operation to toughen and temper the metal in said curved portions.

2. The process of making flexible corrugated metal walls, consisting in forming a thin walled metal tube, forcing the metal of the wall outward to form broad corrugations, reducing the radius of curvature of the bends of said outwardly extending corrugations while transferring into the lateral portions, portions of said bends and subjecting said curved portions to swaging pressure to toughen and temper the metal in said curved portions.

3. The process of making flexible corrugated metal walls, consisting in forming a thin walled metal tube, forcing the metal of the wall outward to form broad corrugations, leaving narrow uncorrugated connecting portions between the outwardly extending corrugations, reducing the radius of curvature of the bends of said outwardly extending corrugations while transferring into the lateral portions, portions of said bends, and forcing the metal in said narrow uncorrugated portions into inwardly projecting corrugations, and subjecting the curved portions of said first-named bends to swaging pressure to toughen and temper the metal in said curved portions.

4. The process of making flexible corrugated metal walls, consisting in forming a thin walled metal tube, annealing said tube, forcing the metal of the wall outward to form broad corrugations, reducing the radius of curvature of the bends of said outwardly-extending corrugations while transferring into the lateral portions, portions of said bends, and subjecting said curved portions to swaging pressure to toughen and temper the metal in said curved portions.

5. The process of making flexible corrugated metal walls, consisting in forming a thin walled metal tube, annealing said tube, forcing the metal of the wall outward to form broad corrugations, leaving narrow uncorrugated connecting portions between the outwardly extending corrugations, reducing the radius of curvature of the bends

of said outwardly extending corrugations while transferring into the lateral portions, portions of said bends, and forcing the metal in said narrow uncorrugated portions into
5 inwardly projecting corrugations, and subjecting the curved portions of said bends to swaging pressure to toughen and temper the metal in said curved portions.

In testimony whereof I have signed this specification in the presence of two sub- 10 scribing witnesses.

WESTON M. FULTON.

Witnesses:

MARY L. JONES,
HARRY C. MALLERY.