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CORRUGATED METAL WALL FOR COLLAPSIBLE EXPANSIBLE VESSELS.

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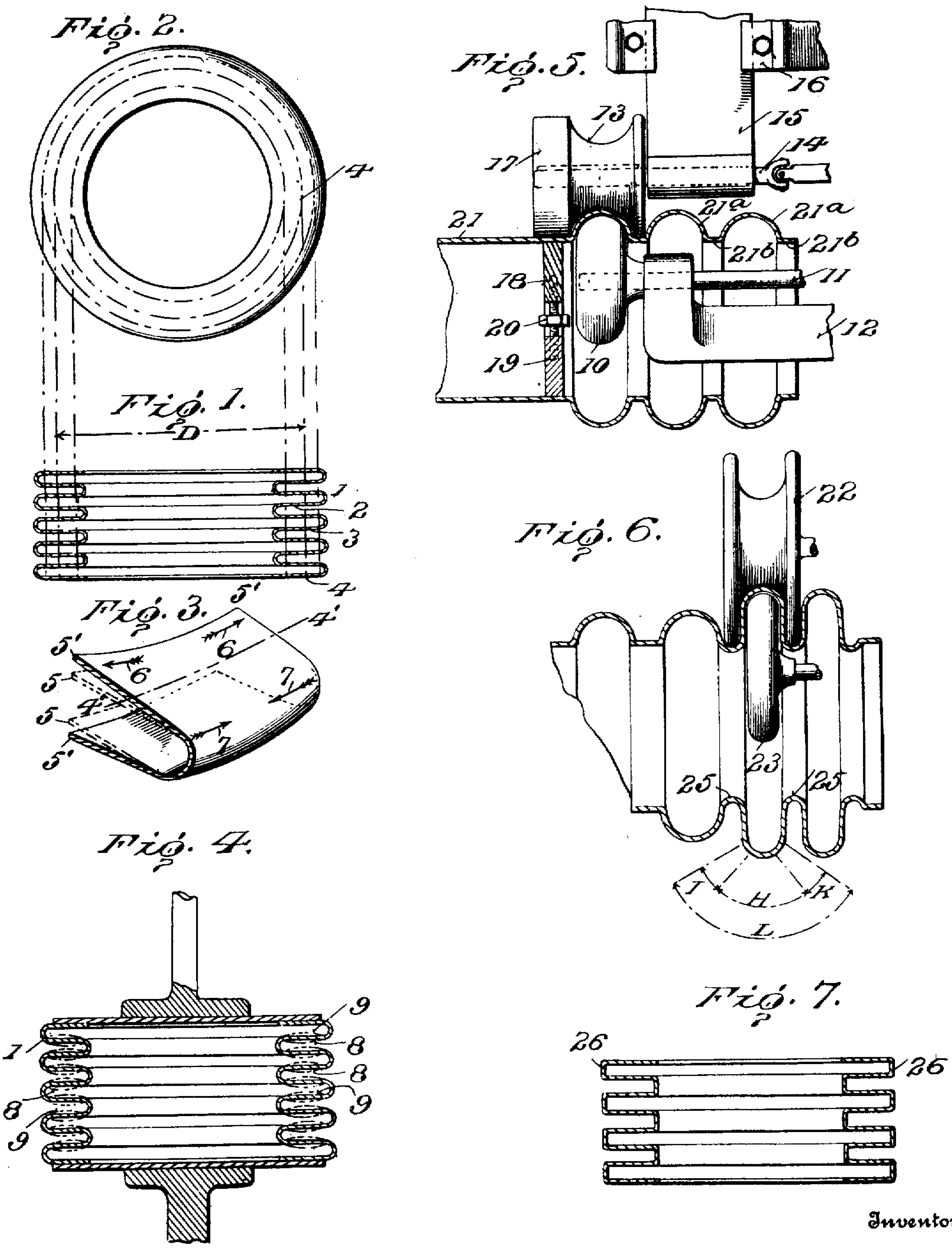
947,229. **Patented Jan. 25, 1910.**



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CORRUGATED-METAL WALL FOR COLLAPSIBLE EXPANSIBLE VESSELS.

947,229. Specification of Letters Patent. **Patented Jan. 25, 1910.**

Application filed April 3, 1907. Serial No. 366,207.

To all whom it may concern:

Be it known that I, WESTON M. FULTON, of Knoxville, Tennessee, have invented new and useful Improvements in Corrugated-Metal Walls for Collapsible and Expansible Vessels, which improvements are fully set forth in the following specification.

This invention relates to flexible corrugated metal walls for collapsible and expansible vessels, particularly of the class adapted for confining fluids under fluctuating 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.

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 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, I have devised a collapsible and expansible corrugated metal wall 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 the lateral portions of the corrugations joining the bends are strengthened and made resilient in the vicinity of the bends.

The inventive idea involved is capable of a variety of expressions, one of which, for the purpose of illustrating the invention, is hereinafter specifically described, and in the accompanying 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 the advantages of my improvement 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 are 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 lies across the corrugations and is 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.

While my collapsible and expansible wall may be made in a variety of ways, I have herein described one way in which I may make it, and the way which I preferably employ. 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 applications Sr. No. 273,766, filed August 11, 1905, and Sr. No. 354,300, filed January 26, 1907. 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 semicircular 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 repeated 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. Furthermore, the lateral walls being toughened and tempered by the rolling process 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 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. 8. 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.

What I claim is:—

1. A flexible corrugated tubular metal wall, said corrugated wall having its outer corrugations made up of deep folds formed in the blank tube wall and having the inner alternating corrugations made up of shallow folds in said blank wall, the metal in said outer bends and lateral portions which merge into said bends being toughened and tempered in excess of the inner bends by working the metal in these portions.

2. A flexible corrugated tubular metal wall, said corrugated wall having its outer corrugations made up of deep folds formed in the blank tube wall, and having the inner alternating corrugations made up of shallow folds in said blank wall, the metal in said outer bends and lateral portions which merge into said bends being toughened and tempered in excess of the inner

bends by working the metal in these portions, the toughness and temper being distributed in said bends and lateral portions to meet the bending strains at these points.

3. A flexible corrugated tubular metal wall of the character described, comprising a plurality of outer and inner curved portions, the outer curved portions having a different temper and toughness imparted thereto by working than the temper and toughness in the inner curved portions and flat portions connecting said curved portions.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

WESTON M. FULTON.

Witnesses:
E. T. MANNING,
W. E. MYNDERSE.