W. M. FULTON.

FLEXIBLE CORRUGATED METAL WALL.

APPLICATION FILED MAR. 4, 1907.

967,010.

Patented Aug. 9, 1910.

Fig. 1.

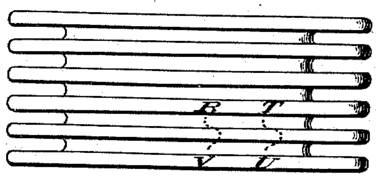


Fig. 2.

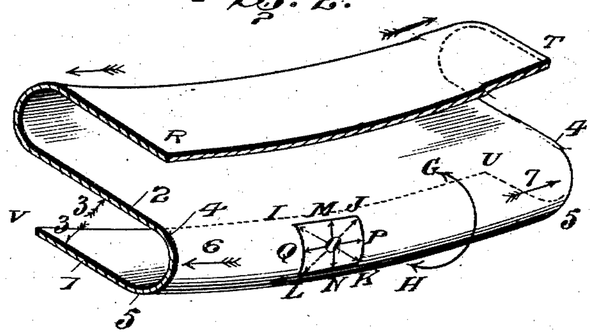


Fig. 3.

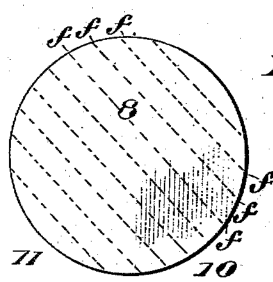


Fig. 4.

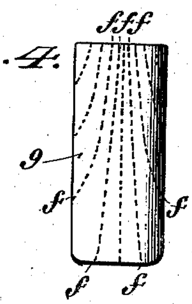


Fig. 5.

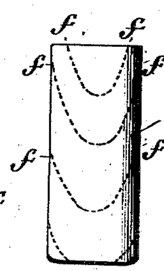


Fig. 6.

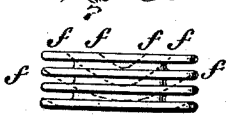


Fig. 7.

Fig. 8.

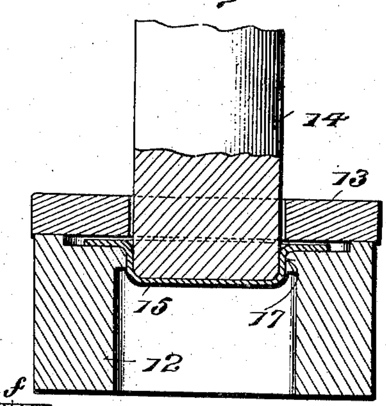


Fig. 9.

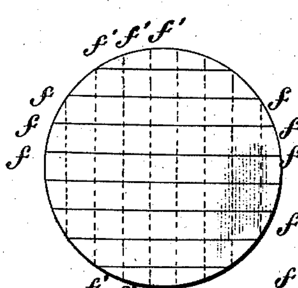


Fig. 10.

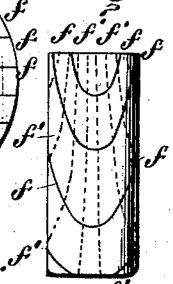
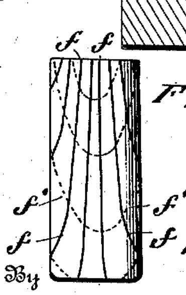


Fig. 11.



Witnesses

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UNITED STATES PATENT OFFICE.

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FLEXIBLE CORRUGATED-METAL WALL.

967,010. Specification of Letters Patent. **Patented Aug. 9, 1910.**

Application filed March 4, 1907. Serial No. 360,452.

To all whom it may concern:

Be it known that I, Weston M. Fulton, of Knoxville, Tennessee, have invented a new and useful Improvement in Flexible Corrugated-Metal Walls, which improvement is fully set forth in the following specification.

This invention relates to vibratory corrugated metal walls, particularly of collapsible and expansible vessels for confining fluid under pressure, and to the method of making such walls, and it has for its primary object to provide a metal corrugated wall which is very thin and flexible, while securing at the same time strength and durability to a marked degree.

It is well known in the art of metal working, that drawing or rolling metal, originally homogeneous in texture, rearranges the particles or molecules of the metal along the lines or in the direction of drawing or rolling, and produces therein what is technically termed a grain in the metal. This grain is particularly noticeable in thin sheet metal, whether rolled from a billet or in the form of a drawn tube. Metal having this grain is also known to have a greater tensile strength along the grain than across it; likewise resilience, durability and the coefficient of expansion of the metal are not the same along the grain as in other directions. Metal tubes made from drawn or rolled metal possess, therefore, this grain to a more or less marked degree, and its presence lends tensile strength to the tube in directions parallel to the grain. In the manufacture of flexible corrugated sheet metal walls for collapsible and expansible vessels as heretofore practiced, the grain of the metal which was lengthwise of the uncorrugated tube retains this direction in the corrugated tube and therefore crosses the planes of the transverse corrugations substantially at right-angles thereto. If such a wall confines a fluid under pressure, as in the case of a collapsible and expansible vessel, the greatest strains in the metal at the bends when the corrugations are extended and collapsed, are not normal to the corrugations, but are more or less displaced from a true normal direction and make more or less acute angles with the planes of the corrugations. As a result of thus shifting the working strains in the metal at the bends into a direction more or less across the grain where the tensile strength of the metal is less than in the direction of the grain, the endurance of the flexible corrugated wall does not reach its maximum.

It is therefore the primary object of this invention to overcome this objection and to provide a flexible corrugated wall and method of making the same, whereby the grain of the metal may be so distributed in the corrugations, particularly at the bends, as to afford the maximum strength along lines of greatest strains, thereby giving to the wall a greater endurance, while retaining therein the desirable quality of thinness and flexibility.

These, together with other objects, will more fully appear in the detailed description and be pointed out in the claims.

The inventive idea involved is capable of expression in a variety of ways or methods of procedure, one of which, for the purpose of illustrating the invention, is hereinafter specifically described, but is given solely for the purpose of illustrating the invention, and not for the purpose of defining the limits thereof, reference being had to the claims for this purpose.

In order that the invention may be more readily understood, reference is had to the accompanying drawings, in which—

Figure 1 is a view in elevation of a corrugated metal wall; Fig. 2 is a perspective view of a portion of the wall highly magnified; Figs. 3 and 9 are views showing rolled sheet metal blanks; Figs. 4, 5, 10 and 11 are elevational views of the cups; Figs. 6 and 7 are views showing the cup after being corrugated; and Fig. 8 is a vertical sectional view of a die for forming the blank cup.

In Fig. 2 I have shown an enlarged view of a portion R, T, U, V of the side wall of a collapsible and expansible corrugated metal vessel, the walls of which are subject to internal fluid pressure, for the purpose of indicating the direction of the strains to which the various portions of the wall are subjected under such conditions.

Fluid pressure within the vessel will exert on lateral walls 1, 2, equal and opposite forces 3, normal to their inner surfaces tending to separate them. These lateral walls 1, 2 being united by the curved portion 4, 5 constituting the bend of the corrugations, this portion 4, 5 will be subjected to a tensile strain in the direction G—H. Further-more, when the flexible wall is collapsed and expanded, the curved portion 4, 5 will be still further subjected to a bending stress acting parallel to G—H.

The fluid pressure within the vessel also exerts what is commonly termed a "bursting strain," tending to increase the circumference of the confining walls and put the wall under tension in the directions indicated by the arrows 6, 7.

Considering now any small unit of area I, J, K, L, on the curved portion 4, 5 of the wall joining lateral portions 1, 2, and fixing attention upon any point O within this unit area, there are acting thereat two equal and opposite forces which may be represented in magnitude and direction by the lines O M, O N, and two other equal and opposite forces O P, O Q. The resultant or vector sum of any two forces, O M, O P, acting approximately at right angles to each other, is greater than either and is represented by a line O J. In like manner, the vector sums O K, O L, and O I, are each greater than either of the forces O P, O N, O Q and O M. It is evident that the greatest strains sustained in the bends of a flexible collapsible and expansible wall intended to sustain fluid pressure from within or from without, are along the lines L O J and I O K. What has here been stated in respect to the portions of the outer corrugations equally applies to curved portions of the inner corrugations. The metal along these lines, therefore, should be especially strong, and one of the main objects of the present invention is to secure this needed strength while at the same time retaining thinness of the wall.

The preferred method by which I secure the objects of my invention, I will now describe. A sheet of metal such as brass, copper or steel is rolled from a billet in the usual way, the grain of the metal lying parallel with the length of the sheet. A blank 8 is then cut from the sheet, shown in Fig. 3 as circular, though it may assume other forms such as oval or the like. The grain of the metal will then lie across the blank, as indicated by lines *f f f*. This blank is now shaped into a deep cup 9, preferably by means of a sheet metal drawing press having suitable drawing dies, diagrammatically indicated in Fig. 8. By successive drawings and occasional annealing of the metal, the cup can be given any desired depth. In the act of drawing the cup the original grain of the metal *f*, *f*, *f*, is shifted so as to lie along lines which are parallel neither to the axis nor the radius of the cup, as indicated in Figs. 4 and 5, in which, Fig. 4 shows the direction of the grain in the side corresponding to the side 10 of blank 8, and Fig. 5 shows the direction taken by the grain corresponding to side 11 of blank 8. Another important result of the drawing operation resides in the fact that the friction between the metal and the drawing dies toughens and strengthens the metal in directions more or less transverse to the direction of the original grain of the blank. Referring to Fig. 8, in which is shown a die 12, a flange holder 13, male die 14 and blank 15, it will be evident that the friction resulting from drawing the blank 15 between the flange holder 13 and lower die 12, and more particularly that resulting from drawing the blanks over the curved rim 17, produces in the metal a result similar to that produced by passing the blank through pressure rolls transverse to the grain of the blank, thereby strengthening the metal in directions transverse to the original grain. This die-drawn cup is peculiarly fitted for the next step of my process, which consists in deeply corrugating its walls by means of corrugating rolls or by any other suitable means capable of effecting the purpose. In Figs. 6 and 7, I have diagrammatically illustrated the cup with corrugations having their planes at right-angles to the axis of the cylinder, though they may be spiral in relation thereto. The lines *f*, *f*, *f*, indicate the direction taken by the shifted grain along which the metal has been chiefly strengthened to resist the principal bending strains. From what has preceded, it will, however, be manifest that the metal has also been strengthened to a somewhat lesser extent, however, in lines transverse to *f*, *f*, *f*, due to the act of drawing the cup in the die. The corrugating rolls have also a tendency to still further toughen the metal in the circumferential direction of the corrugations or across the general direction of the original grain, but it is to be understood that such toughening does not even approach that produced by the pressure rolls in rolling the sheet metal from the billet, and is far less than that produced by the drawing of the cup.

The method above described results in producing a flexible corrugated wall of superior endurance, whether the fluid pressure on the wall be from within or without, for the reason that the metal in the bends of the corrugations has been strengthened along the lines of greatest strain by shifting the original grain into these directions, and also by materially strengthening the metal along lines across the original grain. These results, it will also be noted, have been secured without sacrificing the advantages of thinness of wall and flexibility, which are very essential in a metallic collapsible and expansible vessel.

It has been stated above that the act of die-drawing the cup strengthens the metal across the original grain. The strength of the sheet metal may be developed in directions more or less across the original grain by other means than that above described. For example, I may pass the sheet metal once or twice between pressure rolls in the direction of its breadth to thin the sheet somewhat, thereby materially increasing the tensile strength and ductility in the direction across the grain, without materially decreasing the tensile strength and ductility in the direction of the original grain. By reference to Figs. 9, 10 and 11, this will be apparent. Fig. 9 shows a disk of metal in the form of a circular blank similar to that of Fig. 3, except that the sheet metal from which it was cut has been rolled once or twice at right-angles to the original grain. The heavy horizontal lines f, f, f, represent the original grain of the sheet metal in direction and tensile strength, and the broken lines f', f', f', in a similar manner represent the cross grain. This blank when drawn into a cup as described above, has a distribution of the two grains as indicated in Figs. 10 and 11, in which the dotted lines f', f', f', indicate the effect of the cross rolling. When this blank is formed into a corrugated wall, as shown in Figs. 6 and 7, it will be readily seen from what has preceded that the tensile strength in the metal of the bends has been increased along the lines of greatest strain, thereby securing in the bend the greatest endurance while retaining a thin wall. My process also strengthens the lateral portions of the corrugated wall, as I have amply demonstrated by suitable tests. The metal sheet may also be cross-rolled to strengthen the metal in directions other than the original grain, and then bent into tubular shape so that the original grain would lie at an angle to the plane of the corrugations. In such a case the edges of the seam would require cementing, which is rather a difficult task. Or I may take a mandrel-drawn tube having a grain parallel with its axis and thin its walls by rolling the tube spirally and then corrugating. I prefer, however, to die draw a sheet metal blank into cup form preparatory to corrugating, for such process accomplishes a three-fold result of (1) strengthening the metal in directions other than the original grain without materially weakening said grain; (2) shifting the original grain at an angle to the plane of the corrugations; and (3) making a seamless tube.

Where slight variations in the diameter of the flexible wall are permissible, as for example, in making oil cans such as described in my Patent No. 762,300, dated June 14, 1904, I may draw several tube walls together by placing several blanks in the die at one time, and then separately corrugating each cup, which it will be found possesses all the characteristics of a single die-drawn blank.

Before forming the corrugations, I may remove the end wall of the cup, thus leaving only the cylindrical wall, and I usually prefer to do so, and finally replace the bottom with a thicker wall.

What I claim is:

1. A vibratory corrugated tubular wall of metal having the grain of the metal in the bends of the corrugations directed in lines making acute angles with the axis of the tubular wall.

2. A vibratory corrugated tubular wall of rolled sheet metal having the grain of the metal in the bends of the corrugations directed in lines making acute angles with the axis of the tubular wall.

3. A vibratory corrugated tubular wall of metal for confining fluids under pressure, having the tensile strength of the metal in the bends developed in lines making acute angles with the axis of the tubular wall to correspond with the lines of greatest strain therein.

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

WESTON M. FULTON.

Witnesses:

E. J. S. Hyatt,

J. C. Tyler.