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METHOD OF MAKING PRESSURE VESSELS

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Fig.1.

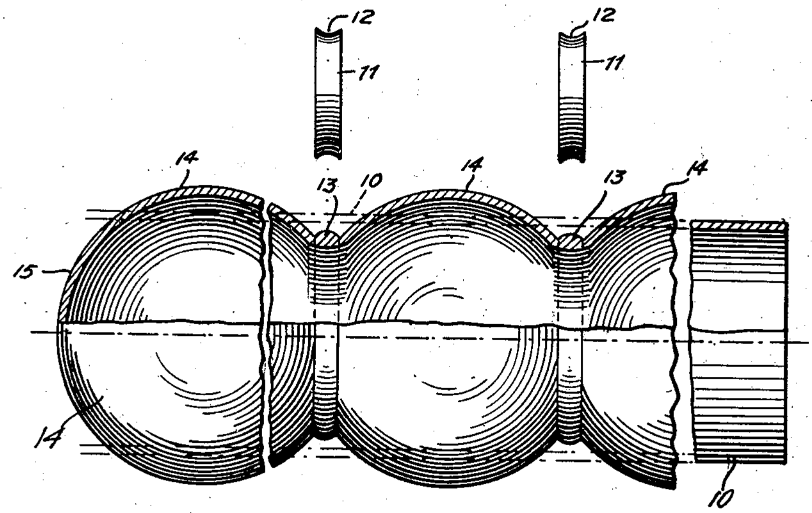
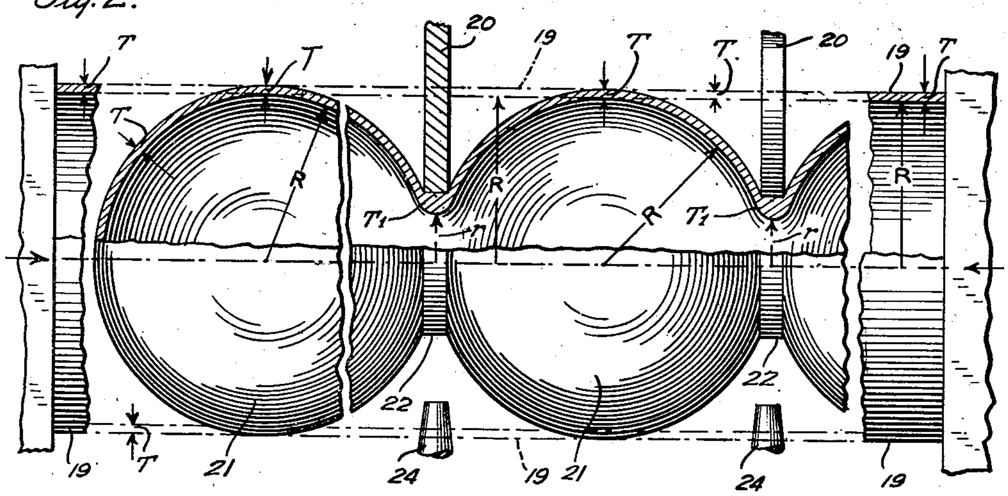


Fig.2.



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METHOD OF MAKING PRESSURE VESSELS

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15 Claims. (Cl. 29—148.2)

The present invention relates to pressure vessels for compressed fluids, and more particularly to the fabrication of containers for the storage and transportation of fluids such as compressed or liquefied gases.

Desirable characteristics of containers which are to be used for the storage and transportation of compressed or liquefied gases are low weight and small surface area for a given capacity, and great mechanical strength, such as a high resistance to internal pressure.

The requirement of a small surface area for a given capacity follows from the desirability of minimizing the exchange of heat between the medium surrounding the container and the fluid contained therein (which latter, in the case of liquid oxygen, for example, is at a temperature of −182.5° C. at atmospheric pressure), whereby losses of the liquefied gas, caused by the evaporation thereof, are substantially minimized.

The requirement of maximum mechanical strength for a given weight assumes particular significance in the case of the storage and transportation of gases having a low boiling point, since at the low temperatures involved, iron and steel have the tendency to become embrittled, and containers of ordinary mechanical strength may break under slight impacts or vibration and may thus constitute a hazard to life and property.

In United States patent application Serial Number 458,435 filed May 31, 1930, by Hermann Debor, there is disclosed a novel container, and a method of producing such a container from a cylindrical metallic blank, by the outward expansion, at properly spaced intervals, of peripheral sections of the cylindrical blank. As compared to the original cylindrical body, such a container may have its capacity increased at least 50 percent while its strength per unit of area remains the same.

The spherically expanded sections which are thus obtained are possessed of the favorable mechanical properties of a sphere which has twice the mechanical strength of a cylinder for the same internal stress per unit of area. The spherically expanded sections also exhibit a favorable ratio of capacity per unit of weight of the container, and of capacity per unit of surface area. This follows from the fact that of all geometrical structures, the sphere has the smallest surface area for a given capacity, its surface being substantially 25 percent smaller than the surface of a cube of the same capacity, and appreciably smaller than the surface of a cylinder of the same capacity.

However, the portions between the spherically expanded zones do not share these favorable mechanical strength characteristics per unit of area for a given internally applied force, and may even be weakened by the tendency of the metallic material to be somewhat displaced toward the spherical zones during the expanding operation.

An object of this invention is to prevent or reduce the weakening effect incident to the expansion, at intervals, of the walls of a cylinder, upon the wall portions intermediate the spherically expanded sections.

Another object of this invention is to transform, in a single heating operation, a metallic cylindrical blank, into an elongated container comprising a plurality of spherical zones, the wall thickness of the intersections of the zones being enlarged or strengthened.

In accordance with this invention, an enlargement of the wall thickness at the constrictions may be effected by a suitable rolling or pressing process whereby there is obtained a concentration of material at the points of constriction. The rolls or pressure dies may suitably be provided with grooves or similar cavities, whereby they produce not only an enlargement of the wall thickness due to the diametrical reduction in the cross-section of the original cylinder, but also and simultaneously, a substantial peripheral concentration of material at the constrictions caused by the tendency of the rolled or pressed material to fill up the groove or cavity in the roll or die. The portions of the cylinder intermediate the constrictions thus produced are then expanded in the usual manner.

Alternately, instead of expanding a cylinder, at intervals, until the wall thickness of the expanded portions corresponds to the stress characteristics of a sphere, use may also be made, in accordance with a modification of this invention, of a metal blank or cylinder whose original diameter and wall thickness have the dimensions desired in the final spherically expanded portions of the completed container. The diameter of this cylindrical blank is then reduced, at properly spaced intervals, by rolling, pressing, or forging down the cross-sectional dimensions of the cylinder at the points corresponding to the intersections or necks of the completed container. This gradual reduction in the cross-section of the cylindrical blank produces the spheroidal shape of the portions between the necks or constrictions, in such a manner that in the spheroidal sections thus obtained the wall thickness of the original cylindrical blank is substantially preserved, while at the points of transition between two spherical zones, the wall thickness is increased preferably in a ratio inversely proportional to the ratio of the minimum diameter to the maximum diameter.

The methods of shaping cylindrical containers which have been described above may be combined with an "upsetting" operation (i. e. an enlargement of the wall thickness at the planes of intersection of the spheroids), for the purpose of further increasing the wall thickness of the completed container at the constrictions.

The invention may be better understood from the following description taken together with the accompanying drawing in which:—

Fig. 1 represents a schematic view, partly in longitudinal axial section, of a container or pressure-vessel during one process of manufacture;

Fig. 2 represents a view, partly in longitudinal axial section, of a container which is being produced in accordance with a modification of the process of manufacture which is shown in Fig. 1.

Referring now more particularly to Fig. 1, there is shown, partly in longitudinal axial section and partly in plan view, a container produced in accordance with one method of this invention from a cylindrical blank which is indicated at **10**. The peripheral constrictions or necks **13** are produced by means of rolls **11** having grooves **12**. The cross-section of cylinder **10** is reduced, at suitably spaced intervals, in a substantially diametrical direction, by means of the rolls **11**. This rolling operation produces a concentration of material in the groove of the roll, and the portions intermediate the constrictions **13** are then expanded by the internal application of a fluid expanding force, such as compressed air, for example, whereby spherical zones **14** are formed. To complete the container, the ends of the spheroidal cylindrical structure thus obtained are then suitably closed as illustrated at **15**.

Fig. 2 shows, partly in dotted lines, and partly in cross-section, a cylindrical blank **19** having a radius R and a wall thickness T. In this modification of the invention, the reduction of the diameter of the cylindrical blank may be effected by rolling it down by means of a substantially rectangular faced roll such as shown at **20**. In this manner there are obtained spherical zones or spheroids **21** having radii R and a wall thickness T, whereas at the constrictions **22** the radius is reduced to r and the wall thickness is increased to a value T1, T1 being R/r times the value of T. In accordance with a feature of this modification of the invention, the step of shaping the container may directly follow the production of the cylindrical blank, simply by reducing the cross-section of the cylindrical blank at suitably spaced intervals while it is still in the heated condition.

The methods of reinforcing the peripheral points lying in the planes of intersection of the spheroidal zones which have been described above may be combined with a further strengthening process which will now be described. In accordance with this method, heat is applied locally to the points of the periphery which are to be strengthened, whereupon or simultaneously, pressure is exerted upon the cylinder in the direction of its longitudinal axis, whereby the effect commonly known as "upsetting" (i. e. an increase in the wall thickness) takes place at the heated points. The heating may preferably be effected by directing the flame of one or more burners or blowpipes, such as shown at **24**, against the circumference of the cylinder. The cylinder may be rotated during this heat treatment. The several circumferential portions of the cylinder whose wall thickness is thus to be reinforced may be heated individually, or they may be heated simultaneously, and the pressure may be simultaneously exerted upon the ends of the cylinder in order to "upset" it at the several points. Simultaneously with this upsetting operation, the reduction in diameter of the heated circumferential portions may be accomplished by means of a suitable roll or by suitably applied external pressure, as described above. The cylindrical body thus reinforced is then subjected to the expanding operation of the portions between the reinforcements by suitably applying an internal expanding pressure, as described.

This method of producing spheroidal containers which is characterized by the "upsetting" of the points of intersection of two spherical zones, and the subsequent dilatation of the portions intermediate the reinforced points, possesses the advantage that it may be practiced in a single continuous operation. The "upsetting" of the points of intersection of the spherical zones has a tendency to concentrate surplus metallic material at the points of intersection, which material may be caused partly to displace itself toward the spherically expanded portions, during the process of dilatation, thus contributing materially to the enhancement of the mechanical strength of the container.

It has been found that depending upon the degree of the dilatation of the original cylinder, the increase in cross-section along the circumferential planes of intersection is about 1.8 to 2.4 times the wall thickness of the original cylinder. The dilatation of the spheroidal portions between the planes of intersection may be such that the radius of the spheroidal parts is $\sqrt{2}$ times that of the radius of the original cylinder, since in this case, the spheroidal sections exhibit the same unit stress as the original cylinder, the weight being unchanged. If the diameter remains unchanged, the wall thickness of the original cylinder may be substantially one-half of what would be required if the original cylinder itself were to be submitted to the same stress as is applied to the finished spheroidal structure. This reduced thickness of the original cylinder is permissible when it is realized that a sphere can withstand twice as much pressure as can a cylinder of the same diameter and wall thickness.

The decrease in the volume of the container, which is caused by the "upsetting" and attending shortening of the cylinder, is very small, since the ratio of the length of the constrictions or necks to the total length of the container is only a few percent, and since consequently the increase in the wall thickness of the necks by doubling it corresponds to a loss in volume of only a few percent, as compared to a gain in volume of the completed container of about 50 percent.

I claim:—

1. The method of producing containers for compressed gases comprising expanding a hollow cylindrical blank at properly spaced intervals to form spherically expanded zones separated by constrictions or portions having a diameter substantially less than the diameter of said spherical zones; and, increasing the wall thickness of the portions corresponding to the subsequent constrictions.

2. Method as defined in claim 1, characterized in that prior to the expanding operation the

original diameter of the cylindrical blank is reduced in a substantially radial direction to produce an annular connecting portion having at least one face curved outward transversely, whereby the wall thickness of the cylinder at the points having a reduced cross-section is increased.

3. The method of producing a compressed gas container by shaping a hollow cylindrical blank to form a series of intersecting hollow spheroids, said method being characterized in that use is made of a cylindrical blank having a diameter corresponding to that of the container when in final shape, the shaping of said container being effected by a suitable swaging, rolling, or pressing operation, in such a manner that the points of intersection of two successive spheroids and the adjoining zones have their cross-sectional diameter reduced, whereby the wall thickness at said points of intersection is increased, and whereby the completed spheroids are caused to substantially retain the wall thickness of the original cylindrical blank.

4. Method as defined in claim 3, characterized in that use is made of a cylindrical blank having a wall thickness which is approximately only one-half of that required of a cylinder which is to be subjected to the same unit stress and which has the same internal diameter.

5. Method as defined in claim 3, characterized in that the step of reducing the cross-sectional diameter of the points of intersection of the spheroids is combined with an upsetting operation, whereby the wall thickness of the container at the points of intersection is substantially increased.

6. Method as defined in claim 3, characterized in that the constriction of the hollow cylindrical blank takes place when the blank is in a heated condition.

7. A method of producing containers from cylindrical blanks which comprises heating properly spaced peripheral portions of a cylindrical blank to a forging or upsetting temperature, enlarging the wall thickness of the heated peripheral portions by exerting pressure at the ends of the cylinder in a substantially axial direction, and spherically expanding the portions of the cylinder intermediate said enlarged portions by subjecting them to internal pressure.

8. Method as defined in claim 7 characterized in that peripheral sections of the cylinder whose wall thickness is to be enlarged are heated by one or more suitably arranged burners.

9. Method as defined in claim 7 in which the peripheral sections whose wall thickness is to be enlarged are heated and simultaneously subjected to the effect of an axial pressure exerted at the ends of the cylinder.

10. Method as defined in claim 7 in which the cylindrical blank is subjected to a pressure sufficient to substantially double the wall thickness of the necks or peripheral sections intermediate the spherical sections, whereby said portions of increased wall thickness are caused to be better adapted to withstand the effect of pressures, shocks and vibrations.

11. Method as defined in claim 7 in which the volume of the spherical zones between the sections of enlarged wall thickness is enlarged until the diameter of said zones is greater by about

$$\sqrt{2}$$

times that of the original cylinder.

12. A method of producing spheroidal pressure vessels from a cylindrical blank, which comprises heating properly spaced peripheral sections of said blank to a swaging or upsetting temperature, increasing the wall thickness of the heated sections by exerting pressure at the ends of the cylinder in a substantially axial direction, and gradually reducing the diameter of the heated peripheral sections by a suitable mechanical operation.

13. In the method of forming a pressure vessel having a plurality of interconnected and intercommunicating hollow spheroids, the steps comprising applying pressure radially inward against a plurality of spaced annular zones of a cylinder wall to form constricted zones uniting adjoining spheroids, and compressing the cylinder axially to increase the wall thickness of the constricted zones.

14. The method of producing hollow vessels for compressed fluids comprising expanding a hollow cylindrical blank at intervals to form interconnected and intercommunicating spheroidal zones, reducing the portions intermediate the spheroidal zones to a diameter less than the diameter of the original blank, and increasing the wall thickness of the portions connecting the spheroidal zones.

15. In the method of forming a pressure vessel having a plurality of interconnected and intercommunicating hollow spheroids, the steps comprising applying pressure radially inward against a plurality of spaced annular zones of a cylindrical tube to thereby form interconnected and intercommunicating hollow spheroids connected by constricted hollow zones uniting adjacent spheroids, and increasing the wall thickness of the constricted zones inversely as the diameter of said constricted zones.

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