

Dec. 31, 1957

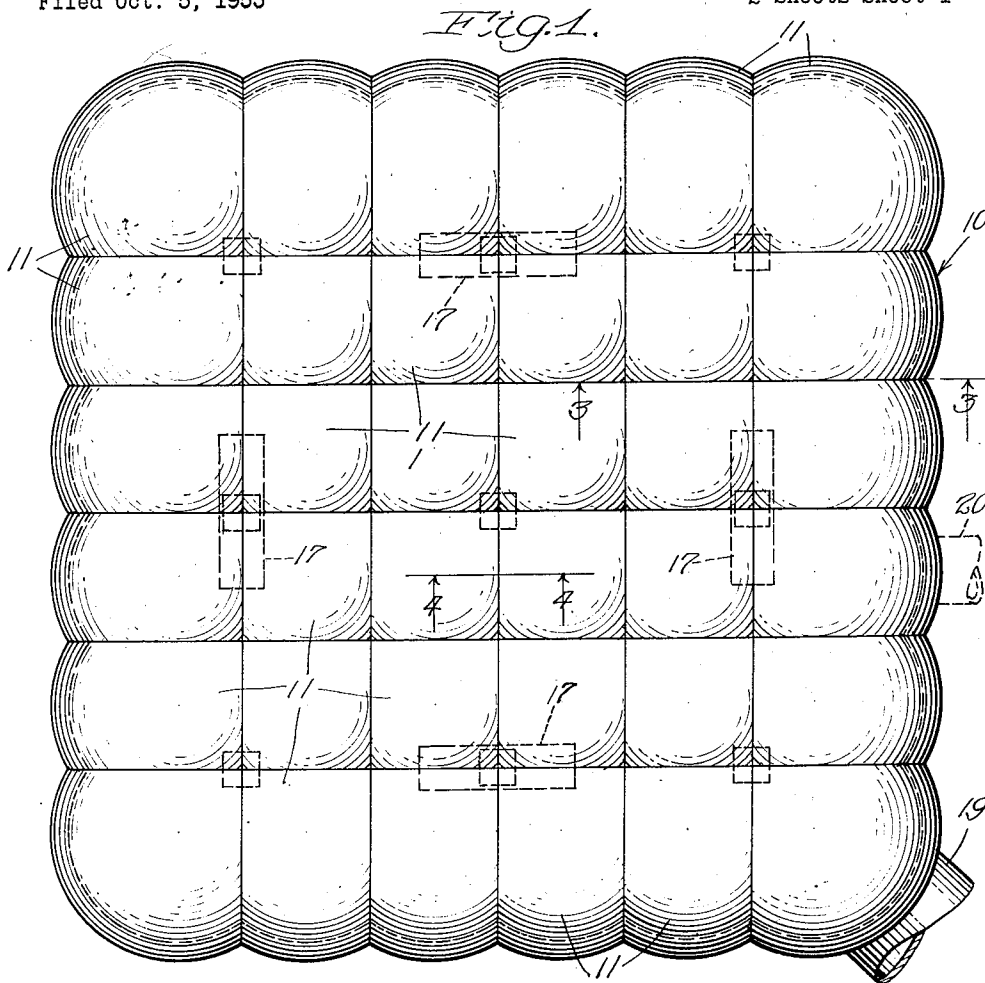
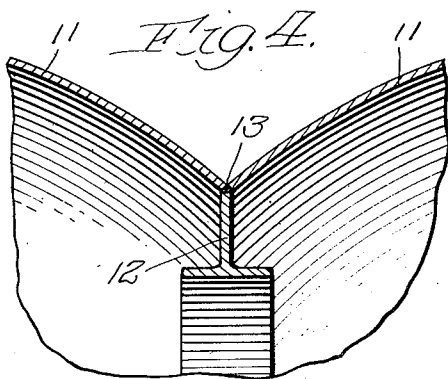
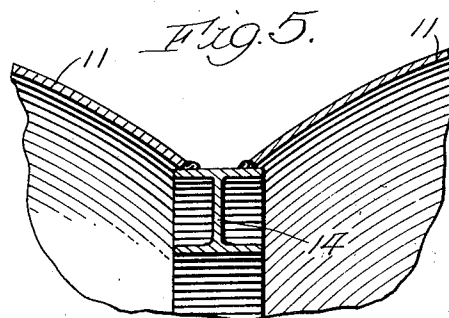
C. ARNE

2,818,191

SPHERICAL SEGMENTAL VESSEL FOR EXTERNAL PRESSURE

Filed Oct. 5, 1953

2 Sheets-Sheet 1



Inventor:
Christian Arne,
By Schroeder, Merriam,
Hagren, Brady, fltys.

Dec. 31, 1957

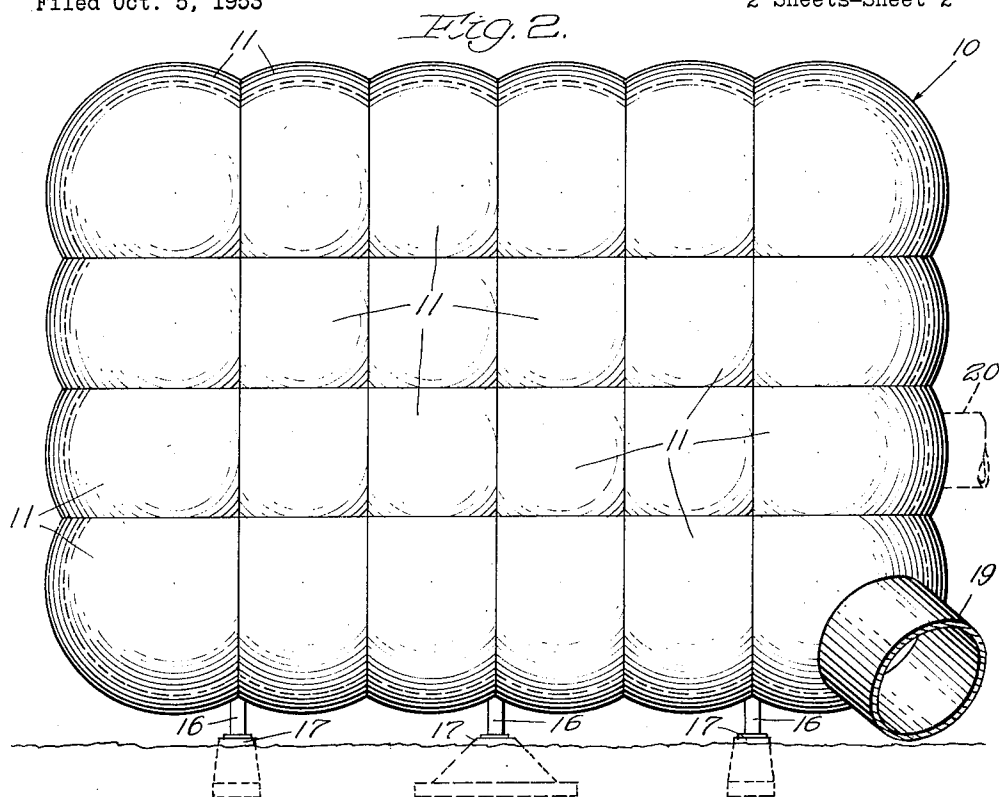
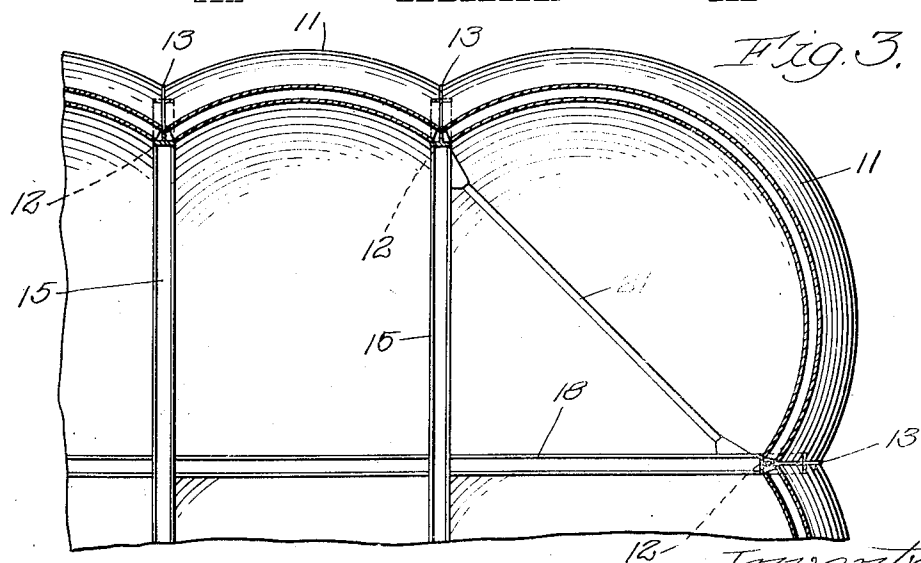
C. ARNE

2,818,191

SPHERICAL SEGMENTAL VESSEL FOR EXTERNAL PRESSURE

Filed Oct. 5, 1953

2 Sheets-Sheet 2



Inventor:
Christian Arne,
By Schneider, Merriam,
Hofgren, Brady, & Tully.

1

2,818,191

SPHERICAL SEGMENTAL VESSEL FOR EXTERNAL PRESSURE

Christian Arne, Chicago, Ill., assignor to Chicago Bridge & Iron Company, a corporation of Illinois

Application October 5, 1953, Serial No. 384,000

1 Claim. (Cl. 220—1)

This invention relates to a closed vessel capable of withstanding external pressure.

The intended use of a vessel capable of maintaining a partial vacuum as indicated by an internal pressure of the order of 1 p. s. i. (absolute) is in conjunction with wind tunnels for simulating high altitude conditions. The vessel as presently constructed is capable of withstanding some internal pressure of the order of 15 p. s. i. g., so that it could be used for storage of some product with a varying vapor pressure. Still another use will be apparent to those skilled in the art in that the vessel can be used for storage of a product having a vapor pressure which in combination with air might produce a pressure both above and below atmospheric, depending on temperature and other conditions.

The vessel is generally of spheroidal or of spherical segmental form and is designed for relatively large capacity. The advantage of a vessel comprising a cluster of connected small spherical segments over an ordinary spherical vessel for the same capacity and pressure lies in savings of metal and cost resulting from thinner walls and the consequent lesser welding. For a sphere to withstand a predetermined pressure, the shell thickness must be increased in direct proportion to the radius of curvature. Thus, a multiple segment vessel has much thinner walls than the equivalent capacity spherical vessel.

In the past, however, all multiple segment vessels for large capacity storage at substantially superatmospheric internal pressure have been formed with diaphragms of metal plates, which diaphragms, have been designed on the same basis as shell or segmental wall plates in the vessel. This basis is the maximum permissible tensile stress. The savings in metal resulting from the use of a plurality of connected smaller spheres as against a single larger sphere of the same capacity was thereby offset by the need for installing these diaphragms between various segments. Because the diaphragms were designed to withstand the same stress as the spherical shells, approximately the same amount of metal was used in the diaphragms as was saved in changing from the single sphere to a segmental vessel. In a gas storage vessel, for example, the combined weight of the diaphragms and the segmental wall plates was the same as the weight of a single spherical vessel of the same gas capacity as the multiple segment vessel.

However, if such multiple segment vessels with internal diaphragms and designed for internal pressure were subjected to external pressure or to internal partial vacuum the diaphragms would buckle before the segmental wall plates. Therefore, in order to make the diaphragms as strong as the wall plates, they would have to be thickened or strengthened or both, thus increasing the weight.

By the use of the present invention, these diaphragms may be replaced with structural elements designed in accordance with the usual practice for non-buckling columns. These columns are essentially supported along the entire length so that the slenderness ratio need not be

2

considered as a controlling factor in the stress analysis. This permits the use of an allowable stress in the structural members of about 15,000 p. s. i. This compares with the stress of between 2,000 and 4,000 p. s. i. which would be allowable for diaphragms if they were used instead of columns in the construction of a vacuum multiple segment vessel. It is immediately apparent, therefore, that the cross sectional amount of metal used in the internal bracing structure of such multiple segment vessels can be materially decreased since the use of structural shapes instead of diaphragms permits a design which can be stressed to as much as seven times the amount of stress permitted in the diaphragms. A considerable savings in metal may thus be effected in such vessels.

Essentially the closed vessel for external pressure comprises a plurality of spherical segments wherein adjacent segments are secured to internal curved members to form a fluid-tight pressure vessel, with internal straight horizontal and vertical compression members secured at their ends to oppositely situated curved compression members to prevent pressure deformation.

An embodiment of the present invention is shown in the accompanying drawings, in which:

Fig. 1 is a plan view of the multiple spherical segment vessel;

Fig. 2 is a side elevational view of the vessel shown in Fig. 1;

Fig. 3 is an enlarged fragmentary sectional view taken along the lines 3—3 of Fig. 1;

Fig. 4 is an enlarged fragmentary sectional view taken along the lines 4—4 of Fig. 1; and

Fig. 5 is a view similar to Fig. 4, showing a modification of the internal curved compression members.

The embodiment of the vessel as illustrated in Figs. 1 and 2 is approximately 108' square and about 77' high. From these dimensions it will be seen that the vessel is quite large and comparable in size to a building.

The vessel generally indicated 10 comprises a series of interconnecting spherical segments 11 which form the pressure shell. Each segment intersects with at least three other segments. As illustrated in Fig. 2, the end or edge segments are larger in that they extend over greater spherically curved areas than those segments internal of the ends. The segments on the corners are those having the greatest expanse of surface. Those segments which are not on the edges of the vessel have even a smaller surface expanse, although all segments in the embodiment illustrated have the same radius of curvature. The plates making up segments are welded together at their intersections.

Curved compression members 12 are shaped to conform to the arc of segmental intersection and are secured to adjacent segments. Adjacent segments may be contiguous along the intersection as shown in Fig. 4 in which case the segments may be welded to each other as well as to the curved compression member 12. The particular curved compression member 12 is shown as a T structural shape which has been curved so that the cross flange is spaced from the shell plates and the connection to the shell plates is made by welding the free end of the web in a 3-way weld at the intersection of the shell plates. This is particularly illustrated in Fig. 4 wherein the weld is designated 13.

In the embodiment shown in Fig. 3, four intersecting curved compression members 12 are joined to column 15 at their point of intersection. The connection of these five members can be made by riveting or welding. A preferred form of connection is provided in a single structural casting in which all five members extend away from the theoretical point of connection. In some applications the structural members could be made of castings

which resemble structural shapes in cross-section and when incorporated in the vessel would comprise joined arches. A casting of joined arches eliminates the difficulty in field assembling five members so that they intersect at the theoretical point of connection.

An alternative form of compression member is shown in Fig. 5 wherein an H-beam 14 is used instead of a T shape. The adjacent edges of spherical segments are welded to one of the flanges of the beam rather than to each other. Preferably the shell plates are welded to the flange independently of each other to avoid a three-way weld.

Vertical compression members or columns 15 extend between and are secured at their ends to oppositely situated curved compression members 12. Those illustrated are wide flange beams, but other structural shapes may be used. Some of the vertical compression members 15 may be extended through the bottom of the vessel, with the protruding portions 16 of said vertical columns resting on a foundation 17 to support the vessel.

Horizontal compression members 18 are secured to oppositely situated curved compression members in the same manner as are the vertical compression members. To provide further rigidity in the structure, the horizontal and vertical compression members 18 and 15 are bolted or welded at their points of intersection within the vessel. In the preferred embodiment, the ends of the horizontal and vertical compression members 18 and 15 are secured at the points of intersection of curved compression members 12.

In providing a vessel to act as a reservoir for air simulating high altitude conditions, the tendency of the vessel to collapse because atmospheric pressure is greater than the pressure within the vessel must be withstood by the shell plates and the internal bracing structure. The spherical form of the segmental shell plates provides some resistance to external pressure whereby the forces on the shell segments are transmitted to the curved compression members attached on the lines of intersection of the segments. These forces produce compression within these curved members which is in turn carried by the cross bracing members which extend between the opposite sides, both horizontally and vertically.

Connections 19 or 20 for air ducts may be made in any intermediate segment or lobe or at any corner segment. A corner connection 19 can be twice the diameter of a lobe connection 20 since the corner lobes are larger as stated above.

As an example of a vessel, the embodiment illustrated in Figs. 1 and 2 has six spherical segments across the width, six along the length and four in depth. If each segment has a radius of curvature of 15'-16" the vessel will have a capacity of 800,000 cubic feet. In accordance with the current A. S. M. E. code, a sphere of any radius to accommodate an external pressure of 13.5 p. s. i. may have an allowable stress of no greater than 2465 p. s. i. To meet this allowable stress requirement, the shell thickness of a 15'-6" radius sphere must be 0.51". The total weight of metal in the outer surfaces is 1,130,000 pounds. A single sphere to accommodate the same capacity and pressure would have a radius of 58' and a shell thickness of 1.91", and would weigh 3,500,000 pounds. If diaphragms were used and also stressed to 2465 p. s. i., they would weigh 2,370,000 pounds which, in combination with the 1,130,000 pounds used in the spherical segments, totals 3,500,000 pounds, the same as the single sphere. Employing the compression members disclosed in this invention, and stressing the internal straight horizontal and vertical compression members to 15,000 p. s. i. which is the maximum allowable compressive stress in laterally unsupported columns, only 900,000 pounds of compression members need be used in conjunction with the 1,130,000 pounds used in the spherical segments. Thus, including the curved compression members, the total weight of the

present vessel made in accordance with the disclosed invention is 2,030,000 pounds, or 58% of the weight of an equivalent single sphere.

In this 6 x 6 x 4 lobed spherical segment vessel capable of withstanding 13.5 p. s. i. external pressure and designed for a capacity of 800,000 cubic feet by using a radius of curvature of 15'-6" for the spherical segments, the curved compression members may be stressed also to as much as 15,000 p. s. i. and each may be a standard 7" WF weighing 59.5#/ft. formed on a circular radius of 13'-5 $\frac{1}{16}$ ". The straight horizontal and vertical members will be stressed at 15,000 p. s. i. and each is a 14" x 14 $\frac{1}{2}$ " WF weighing 111#/ft.

Although no savings in metal result in the spherical shell segments themselves over a vessel formed with diaphragms, the following two measures effect savings by allowing a higher compression stress in the shell: (1) spacing the curved compression members closer together than the wave length of an elastic buckle in the shell so that the curved members form effective stiffeners; and (2) locating the curved compression members at spaces of one wave length or greater but running intermediate stiffeners on the shell between the curved members.

As seen from Fig. 2, the portions of the shell outside the outer foundation may be supported by cantilever construction. However, it is desirable to provide intermediate framing in the form of tie rods to transfer the otherwise overhanging weight to a vertical column. This may be done by means of an intermediate member 21.

These auxiliary tie members may be secured to the ends of vertical and horizontal compression members by riveting, welding, or bolting. For convenience in riveting or bolting, gusset plates may first be affixed to the compression members. If desired, additional diagonal tie members can be connected at the ends of each horizontal compression member, or a tie member can be extended vertically between the outer ends of unsupported horizontal members.

A spherical segmental vessel constructed according to the invention herein is also capable of withstanding internal pressures greater than atmospheric so that the vessel may be used for storing liquids having a widely varying vapor pressure. Capacity to withstand internal pressure in a vessel storing volatile liquids is important to eliminate the need for venting.

The foregoing description has been given for clearness of understanding only and no unnecessary limitations should be understood therefrom.

I claim:

A closed vessel, the outer shell of which consists entirely of a plurality of external intersecting and interconnected spheroidal surface segments of equal radii of curvature, a structural compression member conforming to the arch of the segments and contiguous to each line of intersection of the connected surface segments, and formed to abut the adjacent edges of adjoining surface segments and weldably secured thereto to provide a fluid-tight vessel, and a plurality of spaced structural compression members extending between opposite walls of the vessel internally thereof, and being secured at their ends to opposite sides of the vessel surface segments at points of intersection of said arched compression members, said vessel being free of internal diaphragms, the external shell segments being proportioned for a low stress according to the nature of shells under external pressure and the internal structural members being proportioned for a high stress according to the nature of columns, the external pressure load being carried partly by the shell and partly by the compression members, whereby the vessel may be free of internal diaphragms and the distribution of load effects a saving in material over the material required for a simple sphere of equal capacity under external pressure.

2,818,191

5

References Cited in the file of this patent

UNITED STATES PATENTS

1,686,931	Russell	Oct. 9, 1928	2,408,105
1,844,854	Horton	Feb. 9, 1932	2,457,118
2,094,589	Day	Oct. 5, 1937	2,516,100
2,354,691	Lebedeff	Aug. 1, 1944	2,668,634
2,380,089	Ulm	July 10, 1945	2,673,001
			158,024

6

Starrett	Sept. 24, 1946
Boardman	Dec. 28, 1948
Boardman	July 25, 1950
Arne	Feb. 9, 1954
Ulm et al.	Mar. 23, 1954

FOREIGN PATENTS

Great Britain	Feb. 3, 1921
---------------	--------------