

Nov. 9, 1943.

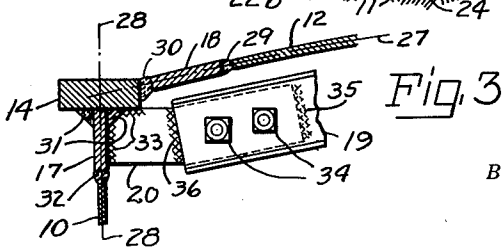
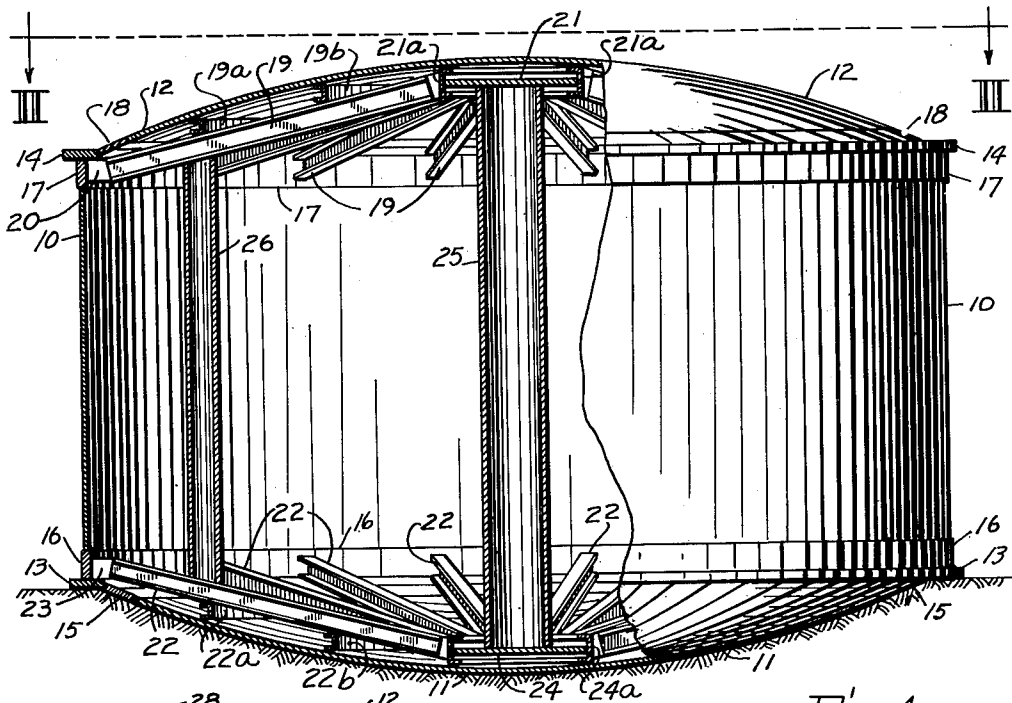
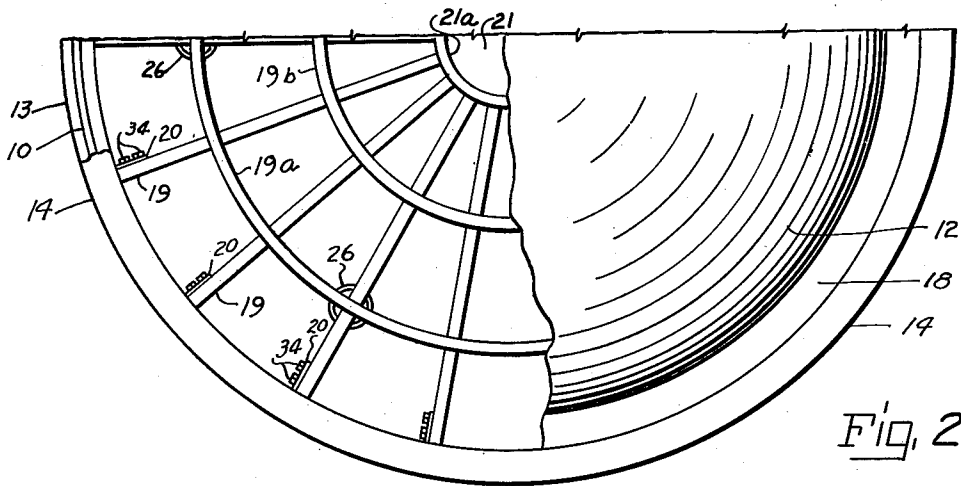
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2,333,792

PRESSURE CONTAINER

Filed Aug. 6, 1941

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

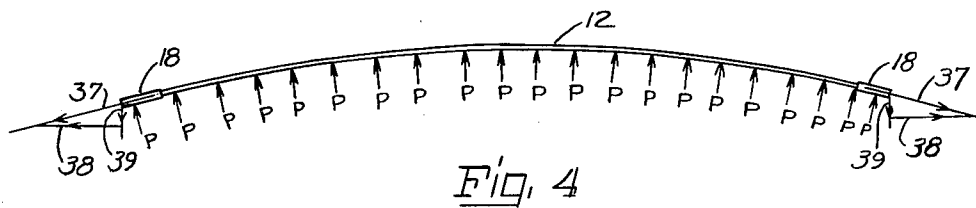


Fig. 4

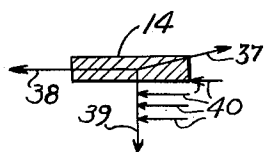


Fig. 5

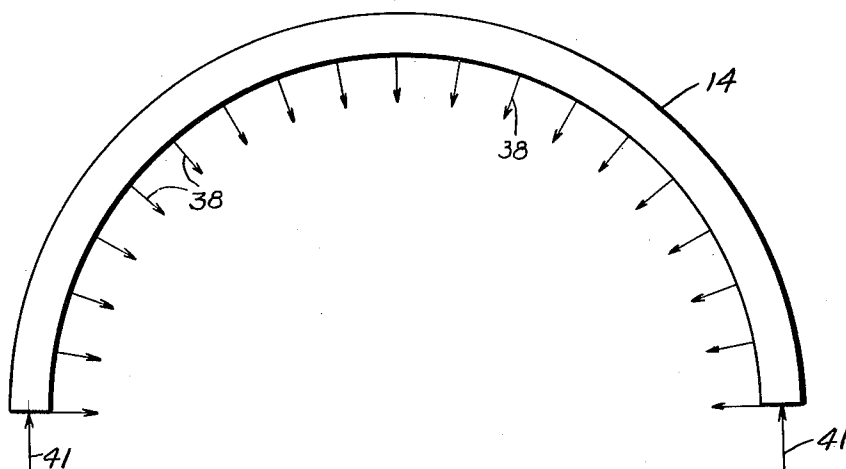


Fig. 6

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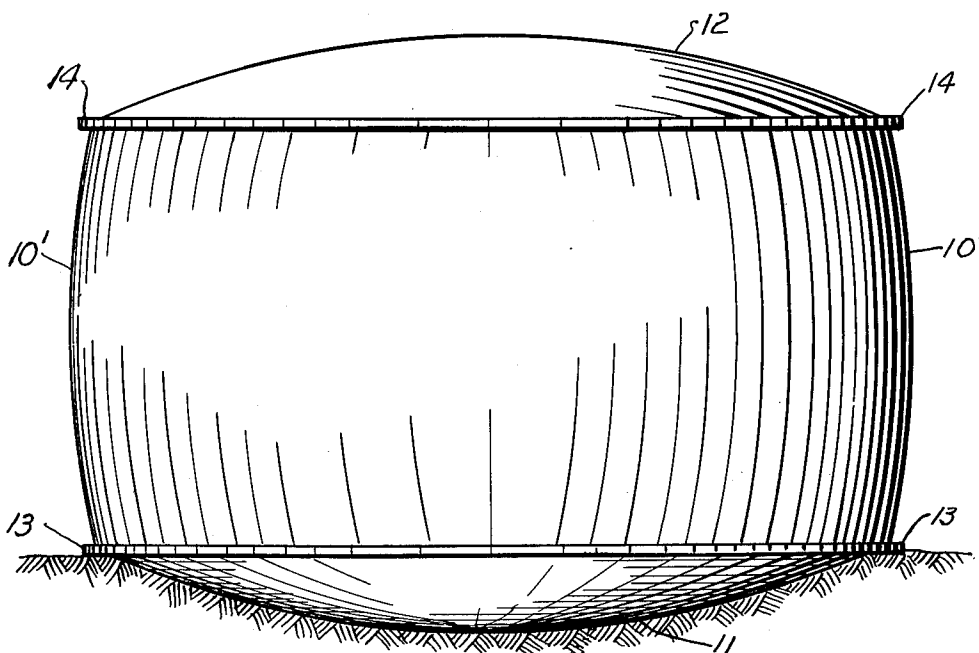


Fig. 7

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2,333,792

PRESSURE CONTAINER

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11 Claims. (Cl. 220—71)

This invention relates to containers and particularly to closed containers or tanks of the type suitable for storing liquids under pressure, such pressure being usually caused or created by the vapor pressure of the liquid being stored.

Such containers have in the past been built in a variety of forms such as spherical tanks which are especially suitable for moderately high pressures but which are quite costly to construct. Spheroidal tanks have also been built and may be very efficiently designed for the condition of a full tank with vapor pressure but which require considerable reinforcement or strengthening to withstand conditions of partial filling. Relatively small pressure tanks have also been built with a cylindrical shell and with dished heads or ends but such containers have been limited to the smaller sizes.

The customary large storage tank with a flat, conical or even a dome-shaped roof is very limited in its ability to withstand internal pressure. The usual type of tank is only able to withstand a few ounces of internal pressure per square inch. The vapor pressure of many liquids commonly stored in large quantities such as gasoline frequently ranges from 2 to 15 pounds per square inch at a temperature of 100° F. This conventional type of large storage tank must, therefore, be vented to prevent such excessive internal pressure but venting results in loss of vapors and, consequently, great economic waste.

An object of this invention is to provide a storage tank which through its novel design and construction will safely withstand an appreciable internal vapor pressure and which at the same time may be constructed at a cost only slightly in excess of the common type of large storage tank.

Another object of my invention is to provide a container which will withstand an appreciable vacuum in the interior of the tank which might be caused from the condensation of vapors as the tank cools, for instance, during the night.

Other and further objects and advantages of my invention reside in the various combinations, subcombinations and details hereinafter described and claimed and in such other and further matters as will be understood by those skilled in this art or pointed out hereinafter.

In the accompanying drawings, in which like numerals designate corresponding parts throughout the various views:

Fig. 1 is a side elevational view, with parts broken away to reveal the underlying structure, of a preferred embodiment of pressure tank responding to my present invention;

Fig. 2 is a half plan of the tank of Fig. 1 with parts broken away to reveal the underlying structure, Fig. 2 being taken on the plane of

line II—II of Fig. 1 in the direction of the arrows thereof;

Fig. 3 is a fragmentary section showing a corner construction of my new tank;

Figs. 4 to 6, inclusive, are more or less diagrammatic views illustrating stress characteristics involved in my new tank; and

Fig. 7 is a side elevational view of a modified form of tank.

In fabricating a tank it is usually neither necessary nor practicable to build the same to withstand either the largest possible positive internal vapor pressure or the largest possible internal vacuum which may occur during extremes of temperature variations to which the tank may be subjected. It is generally more economical and better design practice to construct the tank in such manner that a slight amount of vapor is lost or wasted under the extreme conditions of pressure and vacuum above noted since to do otherwise would require a considerable increase in the cost of the container. In this connection I wish to point out that the tank of my present invention is capable of withstanding both the extreme pressures and the extreme vacuums which may be encountered in normal usage of a tank of the present character. The accomplishment of the same is carried out by me without unduly complicating the construction of the tank and without objectionably adding to its cost.

Referring to Figs. 1 to 3, inclusive, it will be observed that my new tank is provided with an upright central cylindrical portion 10, a dished sheet-metal bottom 11 and an oppositely dished sheet-metal top or roof 12. Members 11 and 12 have the form of a section of a spherical surface and, as will hereinafter be more fully apparent, are constructed on a large radius. The cylindrical portion 10 is provided on its upper edge with an annular upstanding band-like connecting member 17 which is firmly secured to member 10 as by welding 32. The center lines of members 10 and 17 are in alignment but member 17 is of a heavier or thicker section as will be apparent. A bar-like horizontal ring 14 is mounted on the upper edge of member 17 in the position shown best in Fig. 3 and the two members are securely united at right angles to one another as by means of the welds 31.

An annular connecting member 18, which is frusto-conical in character, is secured, as shown, to member 14 as by means of welding 30. Member 18 is positioned so as to intersect member 14 at or adjacent the upper edge thereof and so that its center line will, when projected, pass through the center of symmetry of member 14, an intersection at this point occurring with the vertical center lines through members 10 and 17, as will be clearly apparent from Fig. 3. The

roof portion 12 of the tank is of less radius than the cylindrical portion 10 and, as shown in Fig. 3, is joined securely to the connecting member 18 as by means of the circular weld 29. Members 12 and 18 are so related that the center line of top 12 is a substantially smooth continuation of the same line of member 18. This condition is illustrated by the curved broken line of Fig. 3. Member 18 is shown as composed of a number of welded arc-shaped pieces but may also be made unitary if desired.

A short bar-like member 20 is firmly secured as by welds 33 in the interior angle formed between members 17 and 14. The radially outer end of a radial beam 19 is secured to member 20. As shown in Fig. 3, this is accomplished both by means of bolts 34 passing through the said members and also by the welds 35 and 36. This provides a strong construction which is simply and readily produced without objectionably adding to the expense of the tank and it is to be understood that members 19 and 20 are preferably pre-united at the plant or factory prior to shipment or delivery. It will be understood that a plurality of members 20 is disposed around the tank and that one such member is provided for each radial beam 19, a typical spacing and relationship being illustrated in Fig. 2. The number and size of radial beams depends, of course, upon the particular tank and its intended service.

The radially inner ends of beams 19 are secured, preferably by welding, to the outer surface of the web of the annular channel 21a which has a U-shaped cross-section and a relatively small diameter, as shown. It is to be understood that a satisfactory connection between beams 19 and member 21a may also be made by bolts or in other suitable fashion. A sheet metal disc-shaped member 21 is welded or bolted to member 21a interiorly thereof, i. e. on the opposite surface of the web from beams 19. From the underside of disc 21 a column 25 depends. The upper end of column 25 is suitably secured to the underside of said disc 21 and this assembly forms a support for the inner ends of the beams 19.

The construction of the bottom portion of the tank is identical with that already described in connection with the top. In other words, cylindrical portion 10 of the tank rests upon member 16 corresponding to the member 17 above described and is secured thereto as by welding. Member 16 rests upon a horizontal member 13 corresponding to member 14 already described and it is to be understood that the relationship of members 16 and 13 is obtained and maintained in the manner described in connection with Fig. 3. Similarly, members 23 are provided corresponding to the members 20 previously described. To each member 23 a radial beam 22 is secured in a manner which will now be understood. The inner ends of the beams are secured to a structure which includes the disc 24 to which the lower end of column 25 is secured and the circular channel 24a, the construction and arrangement being the same as that already described in connection with members 21 and 21a. Member 15 responds to and is similarly formed and mounted as member 18 already referred to.

Depending upon circumstances, the size of the tank and the load which the same must withstand, I may provide additional columns, designated as 26, which are arranged in ring formation and which extend vertically between the radial beams 19 and 22. Circular girder-like

members 19a and 19b may also be provided intermediate the center and periphery of the tank and these members are disposed upon the beams 19, which are of channel-shaped section as is apparent from Fig. 1. Similarly, girder-like members 22a and 22b are provided between beams 22 and the bottom 11 of the tank. The circular girders 19a, 19b, 22a and 22b may be suitably secured to the radial beams as by welding or bolting.

In Fig. 4 I have illustrated a section through the tank roof 12 and the contiguous connecting member 18 apart from the balance of the tank structure in order to illustrate the effect of internal pressure (indicated by the arrows marked P) acting upon the concave side of the roof 12. As there shown the exteriorly acting force 37 necessary to produce equilibrium can be resolved into an outwardly acting horizontal component 38 and a downwardly acting vertical component 39.

The forces acting on member 14 are indicated on the cross-section of that member illustrated in Fig. 5. As there shown, force 37 is counteracted by forces 38, 39 and 40. Force 38 arises from the ring compression of ring member 14 in a horizontal direction. Forces 40 represent the stress of members 19 through connecting member 20. Downwardly acting force 39 represents the vertical tensional force between member 14 and member 17 caused by the internal pressure.

In Fig. 7, the modified form of tank there shown is provided with a central portion 10' which has a surface generated by the revolution of a curve around the central axis of the tank. Otherwise, this form of tank may be identical with or similar to that of Figs. 1 to 3, inclusive. The particular virtue of the tank of Fig. 7 is that the thickness of member 10' may be less than that of member 10 without sacrifice of strength or, for the same thickness, member 10' has appreciably greater strength than 10. This form of tank is, however, best employed for tanks of very large diameter.

An important feature of my invention resides in the corner structure of Fig. 3 wherein member 14 cooperates with members 19 in permitting me to form the sheet metal top 12 as a spherical section of relatively large radius. For example, in a tank 40 feet in diameter I find it is economical for the storage of gasoline with a vapor pressure of 10 pounds per square inch to form a roof 12 of sheet steel to a spherical surface having a radius of approximately 66 feet, which requires, for the unit stresses I prefer to use, a thickness of approximately $\frac{3}{8}$ inch. Member 12 is, therefore, quite flat and intersects the cylindrical shell 10 and 17 at an angle only a little greater than 90°. It is known that a spherical shell subjected to internal pressure is stressed in tension, which tension is equal in all directions in a plane tangent to the shell at any point. In the case of a segment of a spherical shell the tensional stress in the shell is numerically equal to the internal pressure expressed in pounds per square inch multiplied by the radius of curvature expressed in inches and divided by two. In order that the segment of the spherical shell be in equilibrium it is obviously necessary to apply a force around its extreme circumference, such as 37 in Fig. 4, equal to the internal stress in the shell. This force being inclined at a slight angle with the horizontal may readily be resolved into a horizontal and vertical component 38 and 39, respec-

tively. If structure is provided to properly resist forces 38 and 39 it is apparent that the roof will successfully withstand the internal pressure and that no failure will result. Force 39 is numerically equal to the total upward internal pressure acting on the roof divided by the circumference of the roof at its largest diameter. I have found that if the shell 10 is proportioned to withstand the internal pressure of the liquid and vapor that it will usually also safely withstand forces 39 without any additional increase in thickness. Force 38 which is the horizontal component of force 37 imposes upon the continuous circular ring 14 a radial inward force completely around its circumference as shown in Fig. 6 which for horizontal equilibrium must be balanced by two forces 41 which must necessarily be equal from considerations of symmetry. Forces 38, therefore, cause a ring compression in member 14 and if force 38 is expressed in pounds per lineal inch of circumference, force 41 is numerically equal to force 38 times the radius to the center line of members 14. The total compression in the ring 14 for tanks of usual sizes is considerable and would require a section of considerable cross-sectional area. I have found that the weight and cost of ring 14 may be considerably reduced by the use of beam-like members 19 so connected that they assist in opposing the inward force 37, illustrated in Fig. 5, caused by the tension in top member 12. I have found that theoretically if all of the inward force 37 could be resisted by radial members 19 the total theoretical weight of such members would be exactly one-half of the total weight of member 14 if no radial members 19 were used. However, from practical considerations it is not desirable to assume the entire inward load 37 by members 19 for the reason that it becomes expensive to develop the inward compressive load through member 21 if an excessive number of members 19 are used, for due to the relatively small circumference of members 21 and the fact that members 19 are converging toward the center of the tank it becomes increasingly difficult to develop the compressive resistance to force 37 across successive diameters of the tank where it is equalized and cancelled by forces 37 acting in the opposite direction on the opposite side of the tank. I have found, however, that a minimum cost for tanks of usual sizes is obtained if members 19 are designed so as to resist from about $\frac{1}{4}$ to about $\frac{1}{2}$ of the total value of forces 37.

Another feature of my design, and one which also determines to some extent the angular spacing of members 19, is the fact that these members also act to resist the forces tending to collapse the roof either from external pressure or the weight of the roof itself or such loads as are caused by wind or snow acting upon it. Since the roof 12 is relatively thin and has a relatively large radius it would not have very much resistance against external pressure or loads. Members 19 are connected at their inner ends to column-like member 25 through members 21 and 21a and are connected on their outer ends to the tank shell 10 through connecting members 20. Curved rings 19a and 19b are constructed so as to fit the curvature of the inside of roof 12 and are spaced so as to properly support roof 12 and to assume from it any external loads or pressures without permitting undue distortion. The disposition of rings 19a and 19b is such that the distortion of roof 12 caused by external pressure is in the form of a series of concentric waves

which greatly increase the resistance of the roof 12 to external pressure and which effectively transfers such pressure through members 19a and 19b to the beam-like members 19 and thereby to the foundation through the tank shell 10 and the column member 25 or if a similar pressure is simultaneously being exerted on the tank bottom member 11 the pressures from members 11 and members 12 act against each other through members 10 and 25 and are counterbalanced.

In tanks of larger diameter it is desirable to use one or more concentric rings of intermediate column members 26 to shorten the span of members 19 and 22. In such cases it is sometimes advantageous to provide lateral or radial bracing for additional members 26 to increase their column effectiveness and shorten their slenderness ratio. Such modifications are deemed to form a definite part of this invention.

The roof 12 and the bottom 11 are not attached to any of the interior supporting members but are left free to expand with increasing internal pressure without causing high concentrations of stress on the internal supporting framework or upon the members 11 and 12 themselves.

Fig. 6 is a loading diagram showing in plan one-half of ring member 14 loaded with radial loads 38 on the inside. In proportioning the size of member 14 I consider these radial loads 38 to act on member 14 at its centroid, such loads causing a ring compression and the total compressive force acting on the cross-section of member 14 being the magnitude of the inward forces 38 expressed, for example, in pounds per lineal inch along the centroid of member 14 multiplied by the radius of the centroid of member 14 also expressed in inches. This product is the total compressive force in the member and I usually determine the cross-sectional area on the basis of an allowable compressive fiber stress of about 25,000 pounds per square inch. Since the thickness and the width of member 14 may be varied, a particular thickness and width may be found which will provide the desired cross-sectional area and which will also permit the proper intersection of forces 37 and 40 at the centroid of member 14.

In actual practice I have constructed a 20 foot pressure container to scale which was designed in the manner hereindescribed for an internal pressure of five pounds per square inch. The container was filled with water and tested by admitting water under pressure to the interior thereof, the pressure on the interior being indicated by means of a pressure gauge on the roof communicating with the tank interior. Strain gauge readings taken during the progress of the test corroborate the above rather closely and at a pressure of $7\frac{1}{2}$ pounds per square inch, which represented a stress about equal to the yield point of the steel in member 13, strain gauge readings indicated that yielding was taking place and mill scale began cracking off. The internal pressure was increased until finally at a pressure of 42 pounds per square inch several breaks occurred in member 10 causing a sufficient loss of water to prevent a further increase of pressure. At the conclusion of the test it was found that member 14 had decreased approximately $5\frac{1}{2}$ inches in circumference and member 13 had decreased $6\frac{1}{8}$ inches in circumference, indicating the extent of the yielding and also clearly demonstrating that no elastic instability exists in member 14 but that it has a large excess strength when designed in the manner I have described.

I have described the form of my invention which I consider the most suitable for tanks of common sizes and pressures but it is to be understood that the same is illustrative, not limitative. Other and further additions, omissions, substitutions and variations may be resorted to and all such are deemed to form a part hereof. Rather the invention is that defined by the appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A tank for the storage of large quantities of liquid having a substantial vapor pressure at the temperature of storage and undergoing considerable variations in pressure in response to changing atmospheric conditions, which comprises an upright relatively thin cylindrical shell, a thicker annular band-like connecting member of rectangular section welded in position on the upper and lower edges of said shell with the center line of each in alignment with the center line of said shell, a bar-like ring member welded to the distal end of each of said band-like connecting members and extending at right angles thereto, an annular connecting member of frusto-conical configuration welded to the inner edge of each bar-like ring member and in such relationship thereto that the projection of the exterior surface of each annular connecting member passes through the center of symmetry of the adjacent bar-like ring member, and an outwardly convex member of spherical section welded in position within each of said annular frusto-conical connecting members and forming a substantially uninterrupted extension thereof.

2. A tank of the construction set forth in claim 1 in which an axial columnar support extends vertically between said outwardly convex members which intersect said shell at an angle only slightly in excess of 90° and in which radial bracing members extend in a substantially horizontal plane between said band-like connecting members and said columnar support.

3. A tank of the construction set forth in claim 1 in which each band-like connecting member is provided with a plurality of circumferentially spaced inwardly projecting radial bar-like connecting members disposed in the interior angle between each of said band-like connecting members and its contiguous bar-like ring adapted to be connected to the outer ends of radial bracing members extending between said band-like connecting members and the central portion of said tank.

4. A tank of the construction set forth in claim 1 in which means is provided for preventing movement of said band-like connecting members in response to changing pressure conditions internally and externally of said tank and in which means is also provided for supporting said roof and bottom in predetermined spaced relationship in such manner as to prevent deformation due to changing pressure conditions, said means together including an axial column terminating at each end in a cap-like disk, an annular channel surrounding each such disk and to which such disk is secured, a plurality of spaced bar-like connections extending radially inward from each of said band-like connecting members and secured thereto and radial bracing members extending between and rigidly secured to said annular channels and said bar-like connections.

5. A tank of the construction set forth in claim 1, in which an axial column-like support extends vertically between said outwardly convex members and in which radial bracing members extend in a substantially horizontal plane between each of said band-like connecting members and said column-like support.

6. A tank of the construction set forth in claim 1, in which the outwardly convex members intersect the cylindrical shell at an angle only slightly in excess of ninety degrees.

7. In a storage tank, an upright substantially cylindrical sheet metal shell provided with relatively thicker top and bottom band-like portions having their side surfaces equally spaced from the side surfaces of the thinner portion, a continuous bar-like metal ring weld united to the distal end of each band-like portion and extending at right angles thereto, an annular frusto-conical member weld united to the inner edge of each bar-like metal ring and a circular outwardly convex sheet metal member of spherical section having its outer edge weld united to the inner edge of each such annular frusto-conical member.

8. A storage tank of the construction set forth in claim 7, in which a column-like support extends vertically between the centers of said outwardly convex members, and radial beam-like members extend between each band-like member and said column-like support.

9. A storage tank of the construction set forth in claim 7, in which a column-like support extends vertically between the centers of said outwardly convex members, in which radial beam-like members extend between said band-like members and such column-like support and in which annular beam-like members are positioned between such radial beam-like members and said outwardly convex members.

10. In a storage tank, an upright substantially cylindrical metal shell, relatively thicker band-like members welded to the upper and lower edges of such shell and having their side surfaces equally spaced from the side surfaces of the shell, a continuous bar-like metal ring welded to the distal end of each band-like member and extending at right angles thereto, an annular frusto-conical member having its outer edge welded to the inner edge of each bar-like metal ring, a circular outwardly convex member of spherical section welded to the inner edge of each annular frusto-conical member, upper and lower groups of radially extending beam-like members, one group located immediately below the upper outwardly convex member and the other immediately above the lower convex member, means adjacent the vertical axis of the tank to which the inner ends of the beam-like members of each group are connected, and means connecting the outer ends of each group to the band-like members and to said bar-like metal rings.

11. A storage tank of the construction set forth in claim 10, in which annular beam-like members are positioned between each group of radially extending beam-like members and the adjacent outwardly convex member, and in which a column-like member extends vertically at the center of the tank and terminates within the means to which the inner ends of each group of radially extending beam-like members is connected.

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