Nov. 22, 1960 C. D. MILLER ET AL 2,961,118

ELEVATED STORAGE TANK

Filed Oct. 2, 1958

2 Sheets-Sheet 1

Fig. 1.

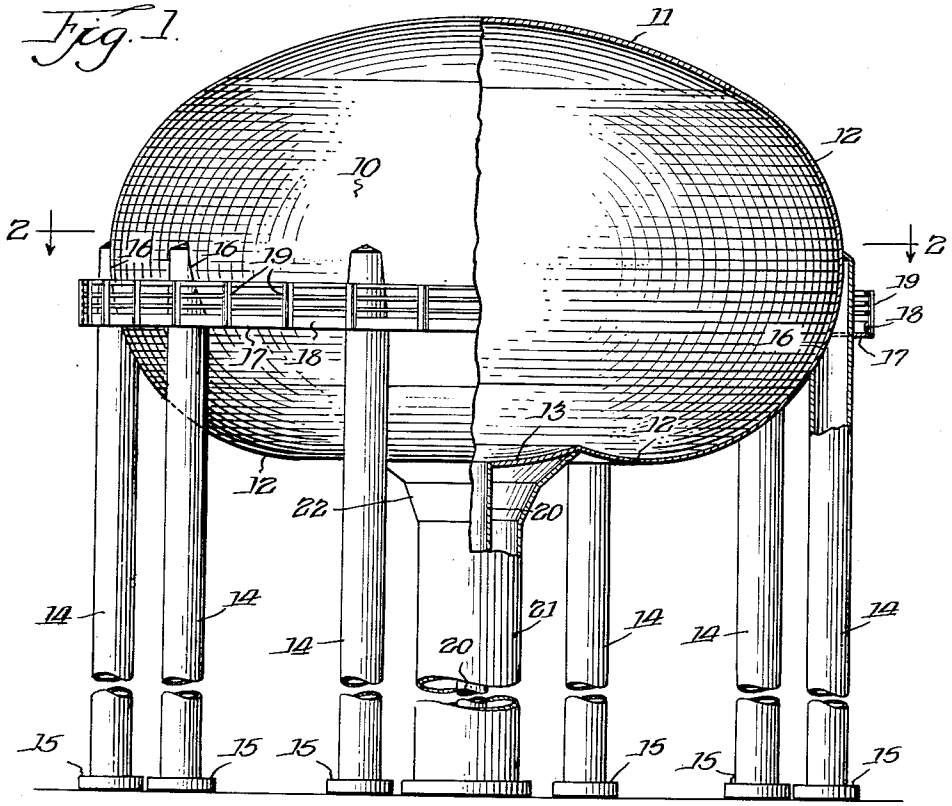


Fig. 2.

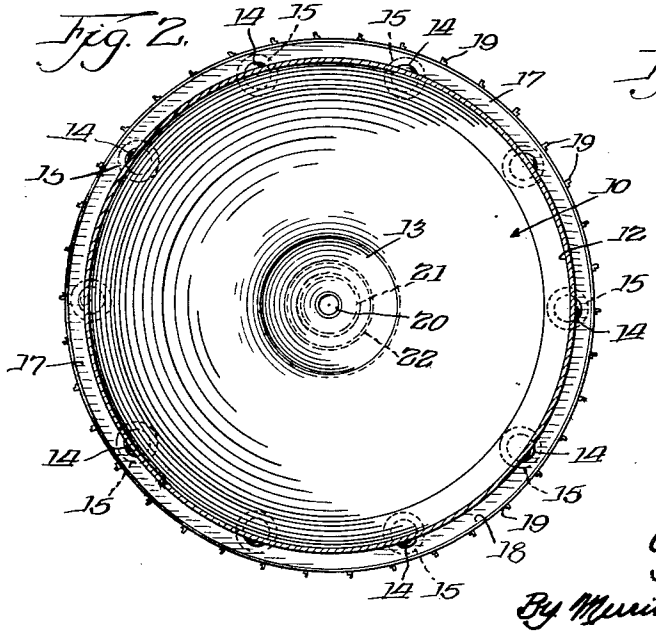
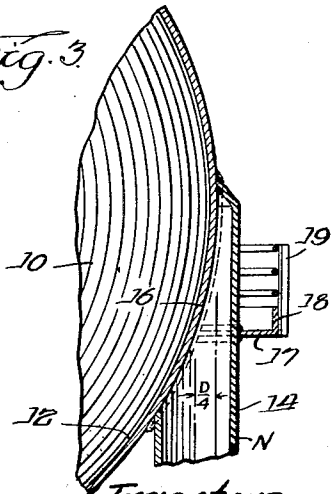


Fig. 3.



Inventors.
Clarence D. Miller &
John N. Pirok.
By Merriam, Lorch, & Smith.
Attys.

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Fig. 4.

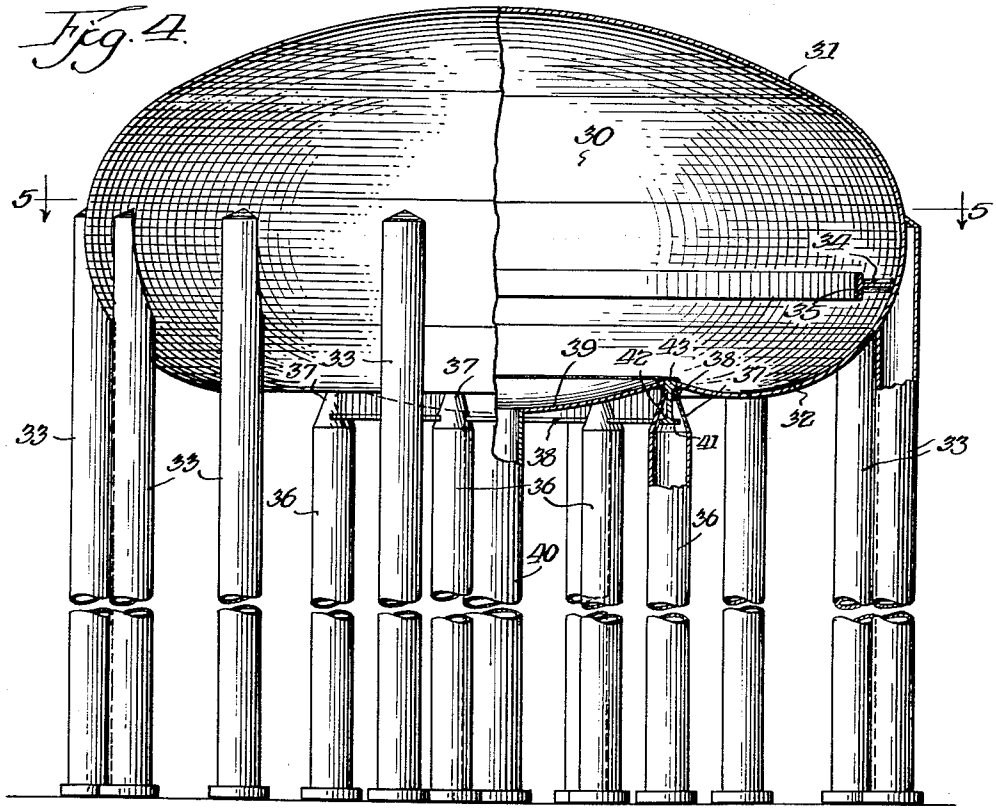


Fig. 5.

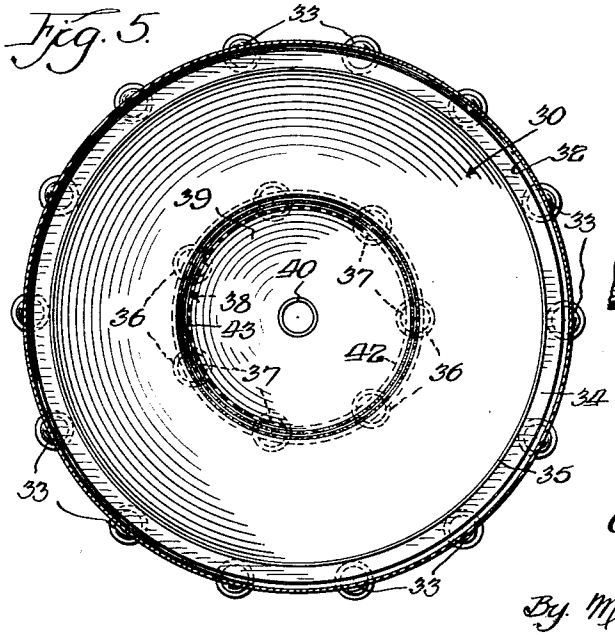
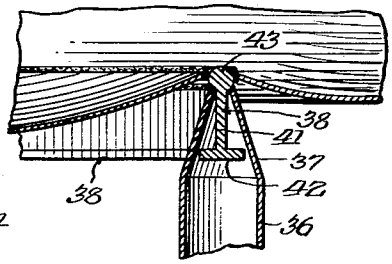


Fig. 6.



Inventors.
Clarence D. Miller, &
John N. Pirok.

By Merriam, Lorch & Smith
Attys.

United States Patent Office

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ELEVATED STORAGE TANK

Clarence D. Miller and John N. Pirok, Chicago, Ill., assignors to Chicago Bridge & Iron Company, Chicago, Ill., a corporation of Illinois

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11 Claims. (Cl. 220—18)

This invention relates to elevated storage tanks of large capacity. It is more specifically concerned with elevated water storage tanks with a relatively low range in head between the upper and lower water levels having capacities in excess of 500,000 gallons.

Water tank designs generally depend upon desired storage capacity, preferred range in head, aesthetic appearance and other factors. One widely used design for elevated water storage tanks of large capacity of 500,000 gallons or more has been the so-called radial cone design. These tanks have a series of radial girders supported at the center by a single riser of large diameter or a cluster of small columns. The outer ends of the girders are cantilevered over a ring of structural or tubular columns. The bottom plates are dished so that the portion between adjoining girders has a natural drape. With a self-supporting bottom of this nature, all of the bottom plates are in tension. Although elevated storage tanks of radial cone design have considerable advantages, cost of construction and erection of large capacity tanks of this design make the use of alternative designs necessary for competitive bidding for the installation of large capacity storage tanks.

According to this invention, there is provided a large capacity elevated storage tank having a self-supporting bottom which can be economically fabricated and erected. The storage tank in general comprises a spheroidal top portion and a noded or substantially toroidal bottom segment. The tank is installed at the desired elevation and supported in an elevated position by means of tubular or structural supports which are joined to the tank shell at its outermost periphery and cooperate with a load carrying member for counteracting the horizontal stresses which occur at the juncture between the shell of the tank and the terminal end of the support affixed thereto. In order to construct a suitable tank having the above described configuration, it is necessary to provide a reinforcing compression member whose neutral axis intersects with the neutral axis of the support cooperating therewith to intersect at the shell of the tank and laterally depend therefrom. The compression member has sufficient strength to counteract the inward thrust generated by the horizontal components of the force pattern produced at the juncture interface of the support columns and tank shell. In addition, the compression member must have sufficient resistance to bending to withstand point loading in the region of the column attachment. In other words the reinforcing compression member must have sufficient resistance to withstand the bending and direct stresses produced by the inward thrusts generated by the horizontal components of the force pattern produced at the juncture interface of the support columns and tank shell in tank installations of the instant invention wherein the neutral axis of the reinforcing compression member passes through the points where the neutral axes of the supporting columns intersect the tank shell within the outermost diameter of the tank.

Figure 1 illustrates one embodiment of an elevated storage tank employing a compression ring which also functions as a balcony circumscribing the tank shell adjacent the top of the support columns.

Figure 2 is a cross sectional view through line 2—2 of the elevated tank shown in Figure 1.

Figure 3 is a fragmentary view of the attachment employed for connecting the support column and compression ring to the shell of the storage tank.

Figure 4 is an illustration of another embodiment of the instant invention illustrating the installation of the compression ring in the tank interior.

Figure 5 is a cross sectional view of the elevated tank shown in Figure 4 through line 5—5.

Figure 6 is a fragmentary view of the support means utilized by the inner cluster of support columns.

Referring to the drawings, it will be seen that the elevated tanks employed in this invention comprise a hollow tank body 10 having a spheroidal top segment 11 and a toroidal bottom segment 12 having a cusped vertical cross section. The area within the inner marginal edge of toroidal segment 12 is enclosed by dished central, bottom head 13. Tank body 10 is supported at a super elevation by means of a plurality of support columns 14 peripherally affixed to the shell of the tank at its outermost diameter. Support columns 14 are mounted on suitable footings 15 which hold the elevated tank in bearing. Support columns 14 are provided with cut out sections 16 at the upper end of the column which conforms with the configuration of the tank shell adjacent the area in which the columns are attached. In securing the supporting columns to the tank shell as shown in Figure 3, the neutral axis N of the supporting column is positioned along a line spaced within the distance $D/2$, and preferably at about $D/4$, from the vertical tangent of the outermost surface of the tank shell where D equals the width of the support column. At the juncture of the supporting columns to such an elevated storage tank there exists a stress pattern (when the tank is in storage service) which includes, inter alia, horizontal stresses which, if uncompensated for, would result in an inward thrust causing the supporting columns to be forced inwardly and resulting in a tank failure. These stresses are in addition to the membrane stresses which occur in the shell of the tank due to normal liquid loading. To compensate for and counteract the horizontal stresses described above resulting from the tank construction, a compression ring 17 is provided. This ring is joined by welding to the tank shell at the intersection of the neutral axis of the supporting column and the shell of the tank. In the illustrative embodiment of this invention shown in Figure 1, the compression ring has a dual function, serving to counteract the horizontal stresses produced at the juncture as well as a balcony which is not only decorative in nature but is used as a platform for routine tank maintenance and inspection. To provide the required strength, a laterally extending flange 18 is preferably joined to the compression member. This flange can consist of an upstanding leg, as shown, or can be joined to the web of compression ring 17 to form a T section. For safety reasons, it is preferred that hand rail 19 be attached to compression member 17 to provide a partially enclosed balcony.

To remove the water from the interior of tank 10, outlet pipe 20 which enters the interior of tank body 10 through bottom segment 13 is provided inside support riser 21. The top of the riser is joined to the inner marginal edge of toroidal bottom segment 12 to form a cusp by means of conical transition section 22. This type of connection is preferred and is utilized in all tank constructions with which a frustro-conical transition section can conveniently be employed. In the illustrative embodiment, a two section transition element is employed in order to minimize the distance between the top of

riser **21** and the juncture with bottom section **12**, and also to provide a more graceful appearance. Water left in the noded bottom segment below the top of the riser can be removed by pumps, siphons, or the like, if desired. Where the distance between riser **21** and the juncture with the adjacent marginal edge of toroidal bottom segment **12** becomes too great, so as to require a large number of transition sections to provide a flared riser top of reasonable slope, no transition section is employed and the riser is connected directly to the dished, central bottom head as shown in the illustrative embodiment in Figure 4. In this embodiment, tank **30** consists of a spheroidal top segment **31** and a bottom section **32**, comprising an outer toroidal segment and a concentric dished central bottom head. The tank is maintained in an elevated position by means of outer support columns **33** which are affixed to the tank shell as hereinbefore described.

In this embodiment, the inward thrust of the columns generated by the horizontal components along the juncture of the tank shell and the supporting column is counteracted by compression ring **34** which is installed on the interior of tank **30** in a position such that the neutral axis of the compression member and the neutral axis of the supporting column intersect at the tank shell. Compression member **34** is also provided with a flange member **35** which enhances the efficiency of compression member **34**. In order to support the tank bottom, an inner cluster of supporting columns **36** is provided at the cusp at the intersection between the outer toroidal segment and the central dished bottom head. The upper end of support column **36** is provided with a tapered terminal end **37** which serves to position support girder **38** in place at the intersection between the toroidal bottom segment and the inner dished bottom segment **39** which is provided as a bottom head for interconnecting inlet-outlet riser **40** with the toroidal bottom segment **32** of tank **30**. Support girder **38** has a web **41** and flange **42** portion which are supported within the conical terminal end **37**. The sides of conical terminal end **37** terminate at upper flange **43** which forms a part of support girder **38**. The connection between inner dished bottom segment **39** and toroidal bottom segment **32** is made by affixing the marginal edges of the respective bottom segments to flange **43** by welding or other suitable fastening means. By providing a supporting girder **38** resting on support columns **36** in the illustrated manner, a favorable stress pattern is provided at the seam joining the inner dished bottom segment **39** and toroidal bottom segment **32**.

The elevated tanks constructed in accordance with this invention can be fabricated from conventional materials of construction. The tubular riser can be employed as the inlet-outlet means such as shown in the embodiment illustrated in Figure 4 or a support and housing for a separate inlet-outlet conduit such as shown in Figure 1. The supporting columns preferably are cylindrical tubes. It is to be understood that "cylindrical" is used in its broadest connotation and includes tubular supports having rectangular, circular, elliptical, or the like transverse cross sections. In assembling the storage tank, the shell is constructed such that the entire length of the attachment between the outer supporting columns and the tank shell is within one horizontal plate course. Although in the preferred embodiments the supporting columns are placed in a vertical position, the instant invention also has application in the erection of elevated storage tanks which are supported on battered columns. The columns are joined to the tank shell such that the neutral axis of the supporting column intersects the tank shell within the outermost diameter of the tank at a point spaced within $D/2$, and preferably at about $D/4$ from the vertical tangent at the outermost diameter where D equals the width of the support column. In the preferred embodiment, the spacing is $D/4$.

The compression member is peripherally affixed to the tank shell in a plane normal to the vertical axis of the tank. This member counteracts the inward thrust of the support columns generated by the horizontal components of the supporting forces carried by the support columns and has sufficient resistance to bending to withstand point loading in the region of the support columns. The material of construction employed in the fabrication of the compression ring is preferably steel. For example, in a 1,000,000 gallon tank with a diameter of 76 feet having the configuration shown in Figure 1, an externally mounted steel compression ring is utilized having a web portion 36" x 5/16" thick and an upstanding flange 9" x 3/8" to provide an L section. Although a flange section having a rectangular cross section is preferably employed, the additional required support can be obtained by employing a flange member which is circular in cross sectional areas. Although the compression member illustrated in the drawings either laterally depends entirely within the shell or outside the tank shell, compression member designs can be utilized wherein the web portion of the compression member is mounted partly inside and partly outside the shell. In all instances, however, the compression member is affixed to the tank shell such that the radial transverse section of said compression member has a moment of inertia about its vertical axis substantially greater than about its horizontal axis and the horizontal neutral axis of the compression member intersects the neutral axis of the supporting column and the centroid of forces acting within the tank shell in the region of the column attachment.

The tank portion, in this example, comprises a spheroidal segment top portion which has a radius of about 50 to 60 feet and forming a segment having an included angle within the range of about 50° to 70° and a toroidal segment portion preferably circular in vertical cross section and forming a circular arc having an included angle within the range of about 160° to 200°. Depending upon the head required, the toroidal segment will have a radius of 12 to 25 feet. The configuration of the top and bottom portions is such that a smooth substantially uninterrupted surface is provided at the juncture between said top and bottom portions. The tank shell is preferably constructed from steel plates which vary in thickness according to the segment of the tank on which they are used, preferably with plates in the bottom portion of the shell thicker than required for existing normal membrane stresses. For example, in a 1,000,000 gallon tank 76 feet in diameter such as that illustrated in Figure 1, the spheroidal top segment forming the top course is fabricated from 1/4" mild carbon steel plate. The second course forming the upper portion of the toroidal segment is also fabricated from 1/4" steel plate. The course forming the intermediate portion of the toroidal segment to which the supporting columns of the compression member are affixed is constructed from 1/2" steel plate. The bottom course of the toroidal segment and dished bottom head is constructed from steel plate 11/32" thick. To prepare the flared transition section interconnecting the riser with the toroidal segment, 1/2" steel plate is employed. To support a water tank of this design, ten tubular supporting columns of 5/16" steel plate having a diameter of 46" are used. These columns are equally spaced around the periphery of the tank. In order to further increase the stability of the elevated tank, suitable cross bracing can be used to interconnect the supporting columns.

Although a single toroidal segment is employed in the illustrative embodiments in order to maintain a low head range in larger capacity tanks, multiple concentric toroidal segments can be used to minimize the radius of the transition section joining the riser with the adjacent toroidal segment.

It is apparent from the foregoing detailed description of this invention that various modifications can be made

in the fabrication, construction and erection of the illustrated large capacity elevated storage tank. The elevated storage tank can be supported at various heights and can be constructed by means of a variety of designs suggested to those skilled in the art relating to the instant invention which can be used without departing from the scope of the instant invention as defined in the appended claims.

What is claimed is:

1. An elevated storage tank which comprises an enclosed tank body having a spheroidal segment top portion; a bottom portion including a peripheral toroidal segment joined at one marginal edge to said top portion and a central annular riser connection joined along its outer edge to the inner marginal edge of said toroidal segment; intermittent support means consisting of a plurality of peripherally spaced columns and a riser joined to the inner edge of said annular riser connection for supporting said tank and its contents; and a reinforcing compression ring for counteracting the horizontal forces which occur in the area of attachment of said tank body to the columns mounted on the tank periphery adjacent the circle formed by the points of vertical tangency of said bottom portion, and extending horizontally from said tank periphery within said area of attachment, the radial transverse section of said compression ring having a moment of inertia about its vertical axis substantially greater than the moment of inertia about its horizontal axis, said columns being attached directly to the tank periphery with the neutral axis of said columns being inward of said point of vertical tangency and with the centroids of horizontal forces in the areas of attachment of said tank to the columns being in apposition to the neutral axis of said compression ring.

2. An elevated storage tank which comprises an enclosed tank body having a spheroidal segment top portion; a bottom portion including a peripheral toroidal segment joined at one marginal edge to said top portion to provide a substantially uninterrupted surface between said top and bottom portions and a central annular riser connection connected along its outer edge to the inner marginal edge of said toroidal segment; a riser concentric to the vertical axis of said tank body and connected to the inner edges of said annular riser connection; a plurality of peripherally spaced columns intermittently supporting said tank body at an elevated position, each of said columns being affixed directly to said tank body immediately adjacent the outermost periphery of said body and having the neutral axis of each column pass through a point inwardly spaced from the circle formed by the points of vertical tangency of said bottom portion; and a reinforcing compression ring for counteracting the horizontal forces which occur in the area of attachment of said columns to said tank body mounted on the tank periphery adjacent said points of tangency and extending substantially horizontally from said tank periphery within the area of attachment of said columns to said tank body, the radial transverse section of said compression ring having a moment of inertia about its vertical axis substantially greater than the moment of inertia about its horizontal axis, said compression ring having sufficient resistance to withstand the bending and direct stresses produced by the inward thrust generated by the horizontal components of the force pattern produced at the juncture interface of the support columns and the tank shell, the neutral axis of said reinforcing compression member passing through the points where the neutral axes of said columns intersect the tank shell within the outermost diameter of the tank.

3. An elevated storage tank in accordance with claim 2 in which said riser has its upper end terminating below the other marginal edge of said toroidal segment and said annular riser connection is connected along its inner edge to and being supported by said riser to provide a flared riser connection.

4. An elevated storage tank in accordance with claim 2 in which a circular diaphragm is suspended between the marginal edge of said toroidal segment within said annular riser connection, said diaphragm being provided with means for filling and emptying said storage tank.

5. An elevated storage tank in accordance with claim 2 in which each of said columns has a circular transverse cross section with each of said columns being affixed to said tank body immediately adjacent the outermost periphery of said body and having the neutral axis of each column pass through a point inwardly spaced from said point of vertical tangency not more than $D/2$ horizontally from said outermost periphery, where D equals the width of said column.

6. An elevated storage tank in accordance with claim 2 in which said tank body is fabricated from a plurality of horizontal courses of metal plate, such that the attachment of said columns to said tank body is effected within one course.

7. An elevated storage tank in accordance with claim 2 in which there is provided a second plurality of columns spaced around the juncture of said toroidal segment.

8. An elevated storage tank which comprises an enclosed tank body having a spheroidal segment top portion; a bottom portion including a peripheral toroidal segment joined at one marginal edge to said top portion and a central annular riser connection joined along its outer edge to the inner marginal edge of said toroidal segment; intermittent support means consisting of a plurality of columns and a riser joined to the inner edge of said annular riser connection for supporting the tank and its contents; a compression ring for counteracting the horizontal forces which occur in the area of attachment of said columns to said tank body mounted on the tank periphery adjacent the circle formed by the points of vertical tangency of said bottom portion and extending substantially horizontally from said tank periphery within the area of attachment of said columns to said tank body, the radial transverse section of said compression ring having a moment of inertia about its vertical axis substantially greater than the moment of inertia about its horizontal axis, said compression ring comprising an annular web portion having one marginal edge affixed to and outwardly extending horizontally from said tank body and a flanged member affixed to the other marginal edge of said web, said columns being attached directly to the tank periphery with the neutral axis of said columns being inward of said points of vertical tangency and with the centroids of horizontal forces in the areas of attachment of said tank to the columns being in apposition to the neutral axis of said compression ring.

9. An elevated tank in accordance with claim 8 in which an upstanding guard rail is affixed to the flanged member on said compression ring.

10. An elevated storage tank which comprises an enclosed tank body having a spheroidal segment top portion, a bottom portion including a peripheral toroidal segment joined at one marginal edge to said top portion and a central annular element joined along its outer edge to the inner marginal edge of said toroidal segment, intermittent support means consisting of a plurality of columns having a circular transverse cross section and a riser concentric to the vertical axis of said tank body having its upper end terminating below the said inner marginal edge of said toroidal segment, said annular element comprising at least one inverted frusto-conical section and being connected along its inner edge to and being supported by said riser and joining the upper terminal edge thereof with the inner marginal edge of said peripheral toroidal segment for supporting the tank and its contents; and a reinforcing compression ring for counteracting the horizontal forces which occur in the area of attachment of said columns to said tank body comprising an annular web portion having one marginal edge affixed to and outwardly extending horizontally from said tank body adjacent the circle formed by the points

of vertical tangency of said bottom portion and within the area of attachment of said columns, the radial transverse section of said compression ring having a moment of inertia about its vertical axis substantially greater than the moment of inertia about its horizontal axis, said columns being attached directly to the tank periphery with the neutral axis of said columns being spaced horizontally inward of said point of vertical tangency not more than $D/2$, where D equals the diameter of said columns, and with the centroids of horizontal forces in the areas of attachment of said tank to the columns being in apposition to the neutral axis of said compression ring.

11. An elevated storage tank in accordance with claim 10 in which said tank body is fabricated from a plurality of horizontal courses of metal plate such that the attachment of said columns to said tank body is effected within one course.

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