

[54] **FLOATING ROOF HAVING
UNIFORMLY DISTRIBUTED
BUOYANCY MEANS**

[75] Inventors: Norman W. Edwards, Sewickley;
Vincent H. Derr, Coraopolis;
Richard A. Mattson, Sewickley, all
of Pa.

[73] Assignee: Pittsburgh-Des Moines Steel Com-
pany, Pittsburgh, Pa.

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[58] Field of Search220/26 R, 26 S; 9/11 R, 12;
114/123

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Primary Examiner—Lloyd L. King

Attorney—Shoemaker and Mattare

[57] **ABSTRACT**

A Floating roof for covering liquid products stored in storage tanks or the like wherein the roof has an upper surface and a lower surface, with the lower surface in substantially continuous contact with the stored product. Buoyancy means are connected to the floating roof and are substantially uniformly distributed with respect thereto to float the roof on the stored product in the event the stored product leaks onto the surface of the floating roof, and to prevent sinking thereof beyond a predetermined amount and to minimize uneven settling of the roof in the stored product.

25 Claims, 8 Drawing Figures

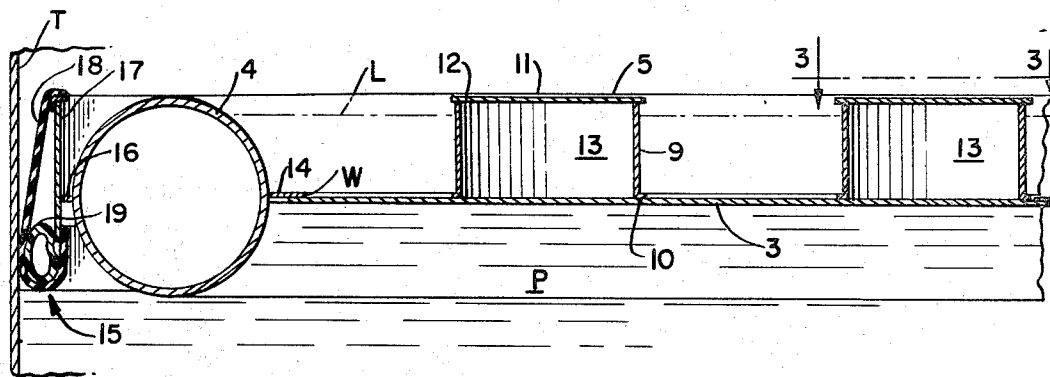


FIG. 1.

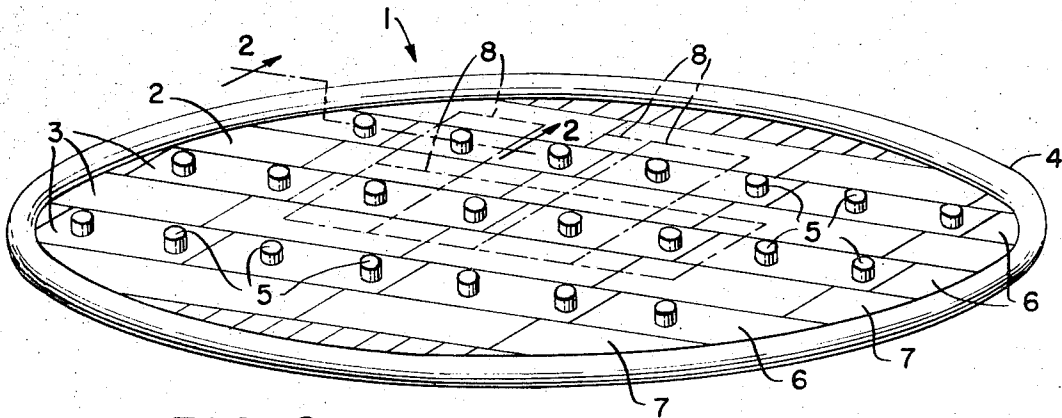


FIG. 2.

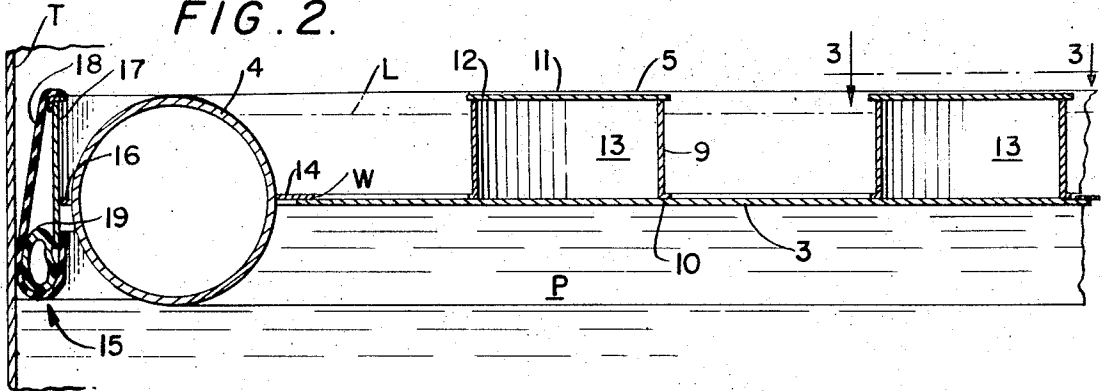


FIG. 3.

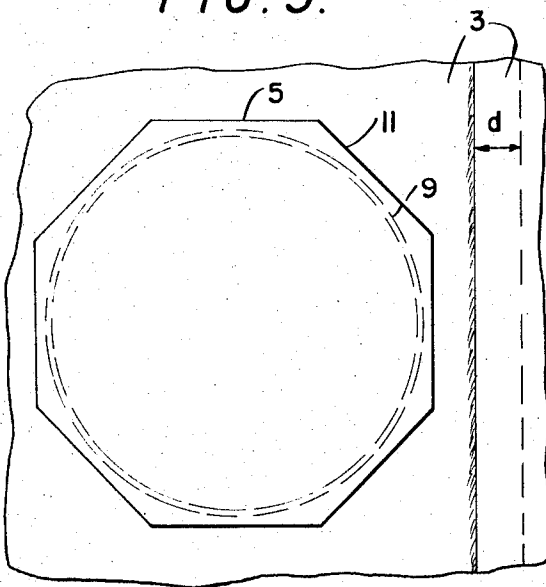
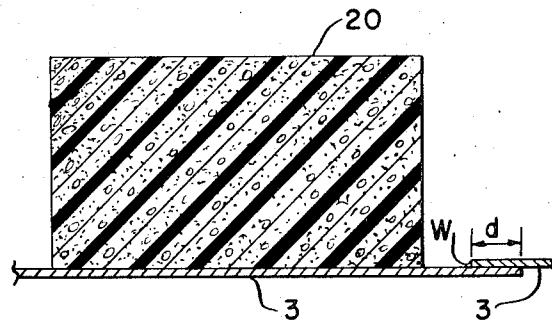
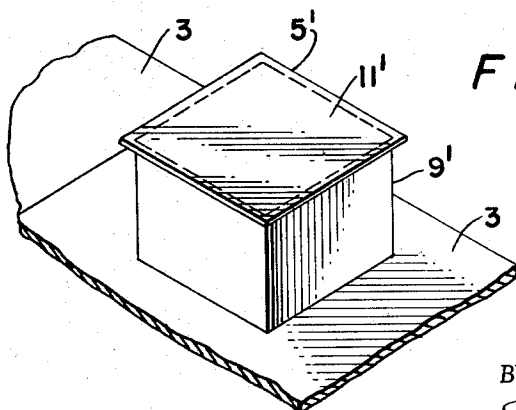
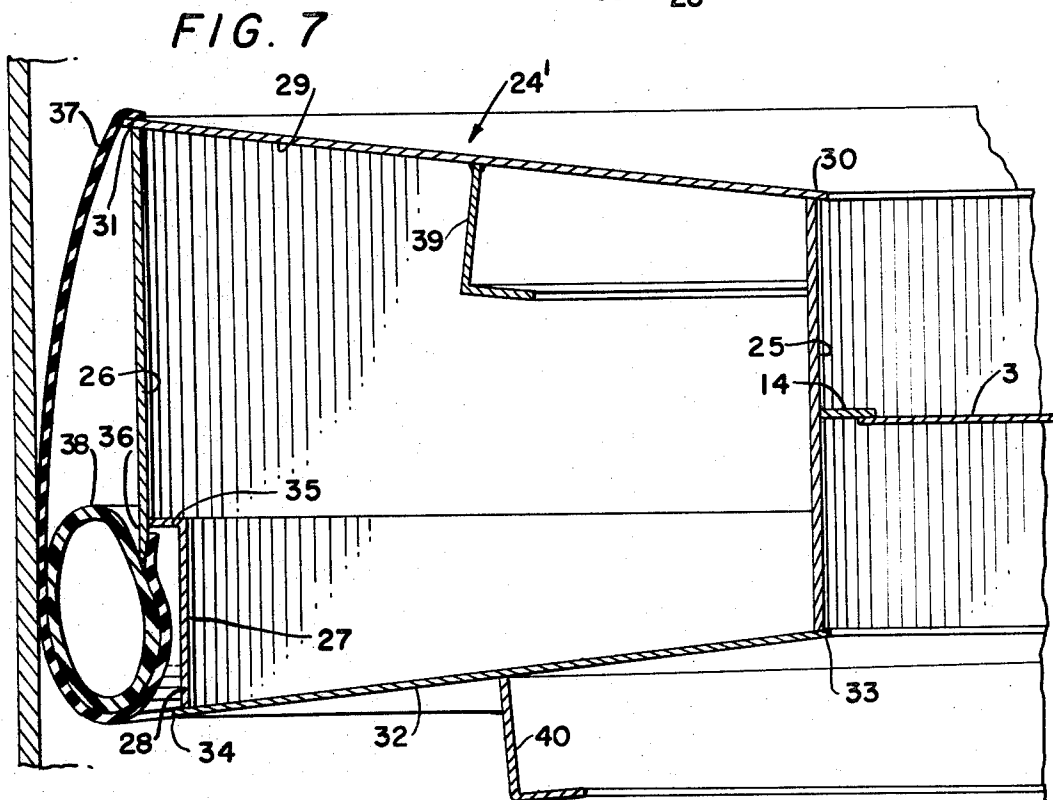
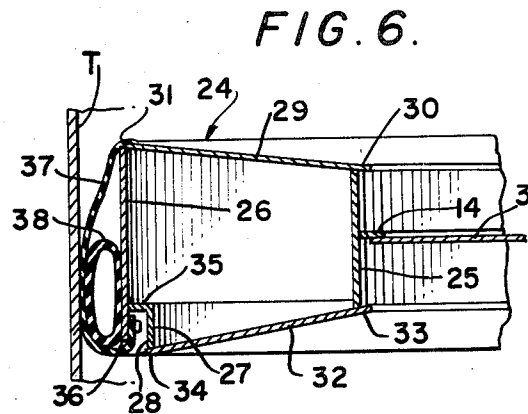
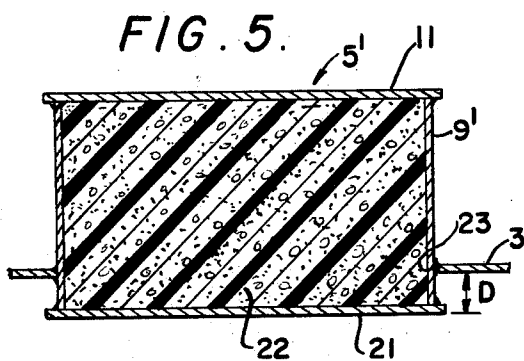


FIG. 4.



INVENTORS
NORMAN W. EDWARDS
VINCENT H. DERR &
RICHARD A. MATTSON

BY *Norman W. Edwards and Vincent H. Derr*
ATTORNEYS



INVENTORS

NORMAN W. EDWARDS
VINCENT H. DERR &
RICHARD A. MATTSON

BY

Shoemaker and Mattare

ATTORNEYS

FLOATING ROOF HAVING UNIFORMLY DISTRIBUTED BUOYANCY MEANS

BACKGROUND OF THE INVENTION

This invention relates to floating roof or cover structures for covering liquid products such as hydrocarbons and the like stored in large storage tanks or the like. The floating roof has an upper surface and a lower surface, and the lower surface is in substantially continuous contact with the stored product so as to prevent contamination of the stored product, or accumulation of vapors, for example, which would create a hazardous situation if a volatile product is stored and the vapors are allowed to accumulate. Buoyancy means are connected to the roof and are substantially uniformly distributed with respect thereto to provide a substantially uniformly distributed buoyant force to float the roof on the stored product in the event stored product leaks onto the surface thereof.

With the present invention, the buoyancy means does not provide any buoyant force so long as the roof or cover means is leak tight, and the roof floats as a pan roof or as a shallow dish floating on the stored product, with the roof simply displacing sufficient stored product until the buoyant force equals its weight. When a rupture occurs in the roof, the stored product leaks onto the surface thereof and the whole roof settles in the stored product. The mode of floatation of the roof then changes and the buoyancy means provide substantially uniform support of the roof, with the displaced volume then equaling the volume occupied by the buoyancy means and the additional volume occupied by the pontoon. This prevents sinking of the roof beyond a predetermined amount, minimizes uneven settling of the roof in the stored produce, and insures continuous contact between the roof and stored product.

Conventional floating roof structures comprise a relatively thin cover or deck made of a plurality of secured together plates with a large pontoon or buoyancy means secured thereto around the outer periphery thereof. During normal operation, the cover as well as the pontoon float on the stored product. In the event of a rupture occurring in the cover and leakage of stored product onto the surface thereof, the pontoon provides support for the cover to prevent it from sinking in the stored product. The pontoon must have sufficient buoyancy to float itself and the deck or cover. Further, the pontoon must have sufficient structural rigidity and strength to resist the loads applied thereto from the weight of the cover, which would include both horizontal and vertical force components acting on the pontoon. The horizontal or radial components produce compressive stresses in the pontoon and the pontoon must therefore be designed as a ring subjected to an axisymmetric radial load. The magnitude of the radial load increases with the diameter of the roof and such roofs have diameters up to 300 feet or more. Since the pontoon is usually fabricated of relatively thin material, as for example, materials having a thickness in the range of three-sixteenths of an inch to five-sixteenths of an inch, and since the stress is compressive, not all of the pontoon cross-section is effective in resisting the applied loads for the size of the roof for which the pontoon would be used.

As the pontoon width is increased in order to provide more buoyancy to float the cover, the cross-sectional area of the pontoon effective to resist the compressive stresses and the effective moment of inertia of the pontoon remains essentially unchanged. For the larger tanks, say for example, those having a diameter of 300 feet, the effective cross-sectional area of the pontoon is not sufficient to satisfy the structural requirements. Accordingly, additional stiffening means is added to the pontoon in conventional structures. This is satisfactory for tanks whose diameters are greater than about 200 feet, but is an expensive solution and also may not be practical for tanks having a diameter in excess of 300 feet.

With conventional cover or floating roof structures, the roof sags in the center thereof when product spills onto the top thereof as when a rupture occurs in the roof, the roof being supported about its periphery by the pontoon. The amount of sag or deflection of the roof for larger tanks often exceeds 40 inches. As a result, the cover of a conventional floating roof is often permanently distorted when a rupture occurs and the stored product leaks onto the surface thereof causing deflection of the cover.

The present invention provides a floating roof having substantially uniformly distributed buoyancy means connected thereto to provide substantially uniform floating support of the roof in the event of a rupture in the roof and leakage of stored product onto the surface thereof. Accordingly, since the weight to be supported is substantially uniformly distributed, uniform distribution of the buoyancy means for supporting the roof in the event of leakage of stored product onto the surface thereof results in even distribution of stresses throughout the roof structure and eliminates the need for a large buoyancy ring or pontoon around the periphery of the roof.

The required buoyancy is provided by leaktight buoys or buoy units arranged on top of the roof and evenly spaced on a repeating regular arrangement. The ring around the periphery of the roof serves primarily as a small structural member to keep the roof round and to provide means for attachment of the roof seal. The ring does impart some buoyancy to the roof, however, but the roof is not supported entirely by the annular buoyancy ring or pontoon when product leaks onto the surface thereof as in the conventional constructions. Accordingly, when a leak occurs with a floating roof according to the present invention, and the stored product leaks onto the surface thereof, the roof will settle uniformly in the product to a predetermined depth depending on the buoyancy imparted to the cover by the buoyancy means distributed thereover. When the leak or rupture in the cover is repaired, the floating roof will look and function the same as when it was new and there will be no distortion of the roof as in the conventional constructions. A floating roof structure in accordance with the invention is thus exceptionally reliable and is simple and economical in construction.

Specifically, the buoyancy means for supporting the floating roof according to the present invention comprise a plurality of separate and independent buoyant modules or units attached to the top surface of the floating roof and evenly spaced on the roof in a regular arrangement in a manner such that each buoy unit

floats or supports a predetermined portion of the floating roof, with adjacent buoys supporting adjacent areas of the roof and all of the buoys together providing sufficient buoyancy to float the entire roof. The buoys may be made of any suitable metallic or non-metallic, organic or non-organic material having any suitable shape. For example, the buoys can be made as hollow vessels of aluminum, steel or fiberglass or the like, or they may comprise blocks of foam or like buoyant material. It is only necessary that the buoys and the roof be chemically compatible with the stored product. Preferably, the buoys are attached to the top side of the roof, but they may extend through the roof and down into the stored product a slight amount, if desired, so long as the roof remains in continuous contact with the stored product.

The roof itself may be made of steel or aluminum or any other material such as fiberglass or the like so long as it is compatible with the stored product and has sufficient strength to be suspended between adjacent buoys in the event of a leak occurring in the roof.

OBJECTS OF THE INVENTION

It is an object of this invention to provide a floating roof structure for covering products stored in large storage tanks or the like wherein the roof is in substantially continuous contact with the stored product.

Another object of this invention is to provide a floating roof structure wherein buoyancy means are substantially uniformly distributed and fixed to the floating roof for floating the roof on the stored product in the event of stored product leaking onto the surface of the floating roof.

An even further object of this invention is to provide a floating roof having buoyancy means for floating the roof on stored product when the stored product leaks onto the surface thereof wherein the buoyancy means is attached to the top side of the floating roof.

A more specific object is to provide a floating roof structure wherein buoyancy means are provided for floating the roof on stored product in the event that stored product leaks onto the surface thereof, said buoyancy means being evenly spaced and distributed over the roof structure and attached to the top side thereof, said buoyancy means comprising a plurality of independent buoys each of which floats or supports a predetermined portion of said cover structure when product leaks onto the surface thereof and said roof settles in the stored product, with the buoyancy means distributed in a repeating regular arrangement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top schematic perspective view of a roof in accordance with the present invention showing the arrangement of buoys thereon.

FIG. 2 is a sectional view taken along line 2—2 in FIG. 1.

FIG. 3 is a top plan view of one form of buoy means.

FIG. 4 is a view in section of a modified buoy means.

FIG. 5 is a sectional view of another modified form of buoy means, wherein the buoy means extends through the roof.

FIG. 6 is a sectional view similar to FIG. 2 showing a modified form of annular ring or pontoon and seal means around the periphery of the roof.

FIG. 7 is an enlarged sectional view similar to FIG. 6 showing a further form of annular ring and seal means.

FIG. 8 is a top perspective view of a third form of buoy means.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, wherein like reference numerals indicate like parts throughout the several views, a floating roof structure in accordance with the invention is indicated generally at 1 in FIG. 1. The floating roof comprises a cover 2 made up of a plurality of individual rectangular plates 3 welded or otherwise suitably secured together along adjacent edges. An annular tubular ring or pontoon 4 is secured about the outer periphery of the cover 2. As seen in FIG. 1, the plates 3 are staggered or offset longitudinally relative to one another so that the joints between adjacent plates are not in alignment with one another. The annular ring 4 imparts a certain amount of buoyancy to the cover and provides support for the peripheral portion thereof, and in addition it maintains the cover in a round shape and provides a means for attachment of a seal means.

A plurality of individual buoyancy means or buoys 5 are attached to the top surface of the cover 2. The buoys 5 are arranged near opposite ends of each of the plates 3 in alternate rows 6 of plates in the cover, with the intermediate rows 7 of plates 3 not having any buoys attached thereto. Each buoy 5 has sufficient size and buoyancy to float itself and a predetermined portion of the cover 2, as indicated in phantom lines at 8, and with the buoys evenly spaced over the cover in a rectangular grid arrangement so that buoyancy is imparted uniformly to the entire cover sufficient to float the cover on a stored product P in the event a leak occurs in the cover and the stored product leaks onto the surface thereof. As shown in FIG. 2, the buoyancy means impart sufficient buoyancy to the roof to prevent it from sinking beyond the level indicated in phantom line at L in the event a rupture occurs in the roof and stored product leaks onto the surface thereof.

As best seen in FIG. 2, each buoy 5 comprises a relatively short cylinder 9 welded at one end 10 to the top of the plates 3 comprising the cover 2, and a flat plate or cover 11 welded to the other or top end 12 of cylinder 9 to define a closed volume 13 filled with a buoyant material such as air or foam or the like. The opposite edges of each of the plates 3 are overlapped a predetermined amount *d*, such as for example 1 inch, and are suitably secured together such as by welding or the like. The annular ring 4 is suitably secured such as by welding or the like about the periphery of the cover 2 with the cover secured to the annular ring 4 at its mid portion by means of a short, radially extending flange 14 welded between the ring 4 and plates 3. A suitable seal means indicated generally at 15 is secured about the outer periphery of the floating roof for sealing engagement with the side wall of a tank T or the like in which the floating roof is disposed. The seal means 15 includes a relatively narrow or short annular connecting member or web 16 secured as by welding or the like to the mid-portion of tube 4 and extending radially outwardly therefrom. A vertically disposed, annular, cylindrical support wall 17 is secured intermediate its upper and lower edges to the web 16 and has a vertical

dimension approximately equal to the diameter of ring 4. A scuff band 18, formed of a suitable flexible and wear resistant material, is connected at its opposite ends to the upper and lower edges, respectively, of the support wall 17, and an annular flexible tube seal 19 is supported in the scuff band for sealing the floating roof to the tank T.

The cover 11 of buoy 5 is shown as having an octagonal shape in FIG. 3 and projects a slight amount beyond the outer periphery of the cylinder 9. The cover 11 and buoy side wall 9 could have any shape other than that shown, as desired, or the buoy could comprise a block of foam material or the like as at 20 in FIG. 4, suitably attached to the top side of the cover 2.

Referring now to FIG. 5, a slightly modified buoy means 5' is illustrated and comprises a tubular side wall 9' with a top cover 11 and a bottom cover 21 welded to opposite ends thereof. The buoy 5' is filled with a suitable buoyant material 22 such as foam or the like and extends through an opening 23 in the plate 3 and projects below the plate 3 a distance D. The distance D may be varied, so long as the buoy 5' does not extend below the plate 3 an amount sufficient to float the plate 3 above the surface of the product stored therebeneath; and for a typical tank, the distance D would be approximately 2 or 3 inches.

A modified annular buoyancy ring or pontoon 24 is shown in FIG. 6, and has a generally trapezoidal cross-sectional shape and comprises an inner, annular cylindrical wall 25 welded or otherwise suitably secured intermediate its upper and lower edges to a short, radially extending flange 14, which is secured to the periphery of cover 2, and a radially outwardly spaced annular cylindrical wall 26 of greater vertical dimension than wall 25 and having a radially inwardly offset portion 27 at the lower marginal edge thereof defining a clearance recess or notch 28. An upper, slightly inclined annular wall or plate 29 is welded or otherwise suitably secured to the top marginal edges of walls 25 and 26 and extends slightly beyond the plates of walls 25 and 26 at its inner and outer peripheral edges 30 and 31, respectively. A similar slightly inclined annular wall or plate 32 is welded or otherwise suitably secured to the bottom marginal edges of the radially offset wall 27 and wall 25 and extends slightly beyond the planes of walls 27 and 25 at its inner and outer peripheral edges 33 and 34, respectively. A relatively narrow, radially extending wall 35 joins the upper marginal edge of wall 27 and wall 26 spaced upwardly from the bottom marginal edge thereof to define a downwardly extending, annular bolting flange 36. A scuff band 37 of a suitable flexible and wear resistant material is connected as by bolts or the like (not shown) at its upper marginal edge to the outer peripheral edge 31 of plate 29 and is connected at its bottom marginal edge to bolting flange 36 as by bolts or the like (not shown). A suitable, annular, tubular, expandable seal ring 38 is enclosed within and supported by the scuff band 37 for effecting a sliding seal between the floating roof and the side wall of tank T. The construction shown in FIG. 6 could be used, for example, on tanks having a diameter of up to about 300 feet.

In FIG. 7, a slightly modified form of pontoon 24' is shown and is substantially identical with the pontoon shown in FIG. 6 except that annular, circumferentially

extending stiffening angles 39 and 40 are welded or otherwise suitably secured approximately medially of the top and bottom annular plates 29 and 32 to impart additional stiffening thereto. This embodiment of pontoon could be used for example on tanks having a diameter of about 300 feet or less.

In FIG. 8, a further form of buoy 5' is shown and rather than being circular with an octagonal cover 11 thereon as shown in FIG. 3, the buoy 5' is rectangular in cross-section with substantially flat, rectangular side walls 9' and with a square or rectangular cover 11' welded or otherwise suitably secured over the top thereof. The buoy 5' is attached to the top surface of plate 3 as in the FIGS. 2 and 3 embodiment, but could extend through the plate as in the FIG. 5 embodiment, if desired.

In a typical tank constructed in accordance with the present invention, the plates 3 would be approximately 30 feet long, 7 1/2 feet wide and 3/16 to 5/16 of an inch thick. Adjacent plates would be welded together with their adjacent edges overlapped approximately 1 inch, and on a tank having a diameter of about 280 feet, approximately 241 buoys would be used, with the buoys attached to the top surface of the plates 3 and equally spaced approximately 15 feet apart in a rectangular grid arrangement. The annular buoyancy ring or pontoon would be approximately 3 feet wide and each buoy would be approximately 3 feet high and 5 feet wide. For a tank having a diameter of about 340 feet, approximately 365 buoys would be used in the cover.

Obviously, either the pontoon as shown in FIG. 2 or as shown in FIGS. 6 and 7 could be used on the floating roof or any other suitable pontoon could be used. Further, the buoys could have any suitable shape and size and any suitable material could be used, and the buoys could be arranged in any regular manner relative to the roof so long as the buoyancy means for floating the roof is evenly distributed with respect thereto and provide uniform support of the roof in the event the roof ruptures and stored product leaks onto the surface thereof. For example, buoys of different sizes may be placed in lines extending radially from the center of the roof. The individual buoys are fabricated, welded or otherwise suitably secured to the plates 3, and leak tested in the shop prior to shipment to the field, thus minimizing the amount of field work and substantially reducing the cost of the floating roof.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive, since the scope of the invention is defined by the appended claims rather than by the description preceding them, all changes that fall within the metes and bounds of the claims or that form their functional as well as conjointly cooperative equivalents, are therefore intended to be embraced by those claims.

We claim:

1. A floating roof for covering liquid stored in storage tanks or the like wherein the roof floats on the stored liquid, said roof having an upper surface and a lower surface, said lower surface in continuous contact with the stored liquid to prevent the formation and accumulation of vapor therebeneath and/or to prevent contamination of the stored liquid, a plurality of

buoyancy means connected to the floating roof only on the upper surface thereof uniformly distributed with respect thereto to provide uniform floating support of the floating roof and to prevent sinking of the roof beyond a predetermined amount and to minimize uneven settling of the roof in the stored liquid in the event of a rupture in the roof and leakage of the stored liquid onto the surface thereof.

2. A floating roof as in claim 1, wherein said buoyancy means comprises a plurality of individual and separate buoys attached to said roof in a regular arrangement, each of said buoys having a size and buoyancy such as to float a predetermined portion of said roof and all of said buoys together providing sufficient buoyancy to uniformly float the entire roof.

3. A floating roof as in claim 2, wherein the lower surface of said floating roof is substantially flat and planar.

4. A floating roof as in claim 3, wherein said buoys are tubular, one end of each of said tubular buoys attached to the upper surface of said roof and a substantially flat planar top closing the other end of said buoys to define an enclosed buoyant volume within each of said buoys.

5. A floating roof as in claim 4, wherein each of said buoys is filled with a foam material.

6. A floating roof as in claim 2, wherein said buoys comprise blocks of foam material.

7. A floating roof as in claim 25, wherein said buoys extend through openings in said floating roof and project a slight amount below the roof.

8. A floating roof as in claim 7, wherein said buoys are tubular, with the opposite ends thereof closed by substantially flat plates or covers to define a closed buoyant volume.

9. A floating roof as in claim 8, wherein said buoys are filled with a foam material.

10. A floating roof as in claim 3, wherein said buoys are cylindrical.

11. A floating roof as in claim 11, wherein one end of each of said buoys is attached to said roof and a substantially flat cover closes the other end of said buoys, said cover having a polygonal shape.

12. A floating roof as in claim 3, wherein said buoys are rectangular in cross-section.

13. A floating roof as in claim 2, wherein an annular pontoon is connected to said floating roof around the periphery thereof.

14. A floating roof as in claim 13, wherein said pontoon is circular in cross-section.

15. A floating roof as in claim 13, wherein said pontoon has a substantially trapezoidal cross-section.

16. A floating roof as in claim 15, wherein said pon-

toon comprises a substantially vertically disposed cylindrical inner wall and a radially outwardly spaced substantially vertically disposed cylindrical wall, said outer wall having a greater vertical dimension than said inner wall, and slightly inclined annular top and bottom walls attached to the top and bottom edges of said inner and outer walls, respectively, said inner wall being secured intermediate its top and bottom edges to the periphery of said roof.

17. A floating roof as in claim 16, wherein circumferentially extending stiffeners are secured to each of said top and bottom annular walls for stiffening and reinforcing the pontoon.

18. A floating roof as in claim 2, wherein said roof comprises a plurality of substantially rectangular plates welded or otherwise suitably secured together along adjacent edges thereof.

19. A floating roof as in claim 18, wherein said plates are overlapped at adjacent edges.

20. A floating roof as in claim 19, wherein said plates are longitudinally offset relative to one another so that joints between adjacent plates are not aligned.

21. A floating roof as in claim 13, wherein seal means is connected to said floating roof about the periphery thereof.

22. A floating roof as in claim 21, wherein said seal means comprises a scuff band connected to the top and bottom edges respectively of a support means on said pontoon, and an annular flexible tube seal is supported in said scuff band for effecting a sliding seal between the wall of said tank and said floating roof.

23. A floating roof as in claim 20, wherein said plates are arranged in rows, and said buoys are attached to alternate rows of plates.

24. A floating roof as in claim 23, wherein said buoys are attached to said plates in said alternate rows in evenly spaced relationship to one another, with two buoys attached to each plate in said alternate rows.

25. A floating roof for covering liquid stored in storage tanks or the like wherein the roof floats on the stored liquid, said roof having an upper surface and a lower surface, said lower surface in substantially continuous contact with the stored liquid, a plurality of buoyancy means connected to the floating roof with at least a major portion of each buoyancy means positioned above the lower surface of the roof, said buoyancy means substantially uniformly distributed with respect to the floating roof to provide uniform floating support of the floating roof and to prevent sinking of the roof beyond a predetermined amount and to minimize uneven settling of the roof in the stored liquid in the event of a rupture in the roof and leakage of the stored liquid onto the surface thereof.

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