Feb. 26, 1952 C. M. ORR ET AL 2,586,856

DOUBLE-DECK FLOATING ROOF

Filed Oct. 16, 1945 4 Sheets-Sheet 1

Fig. 1.

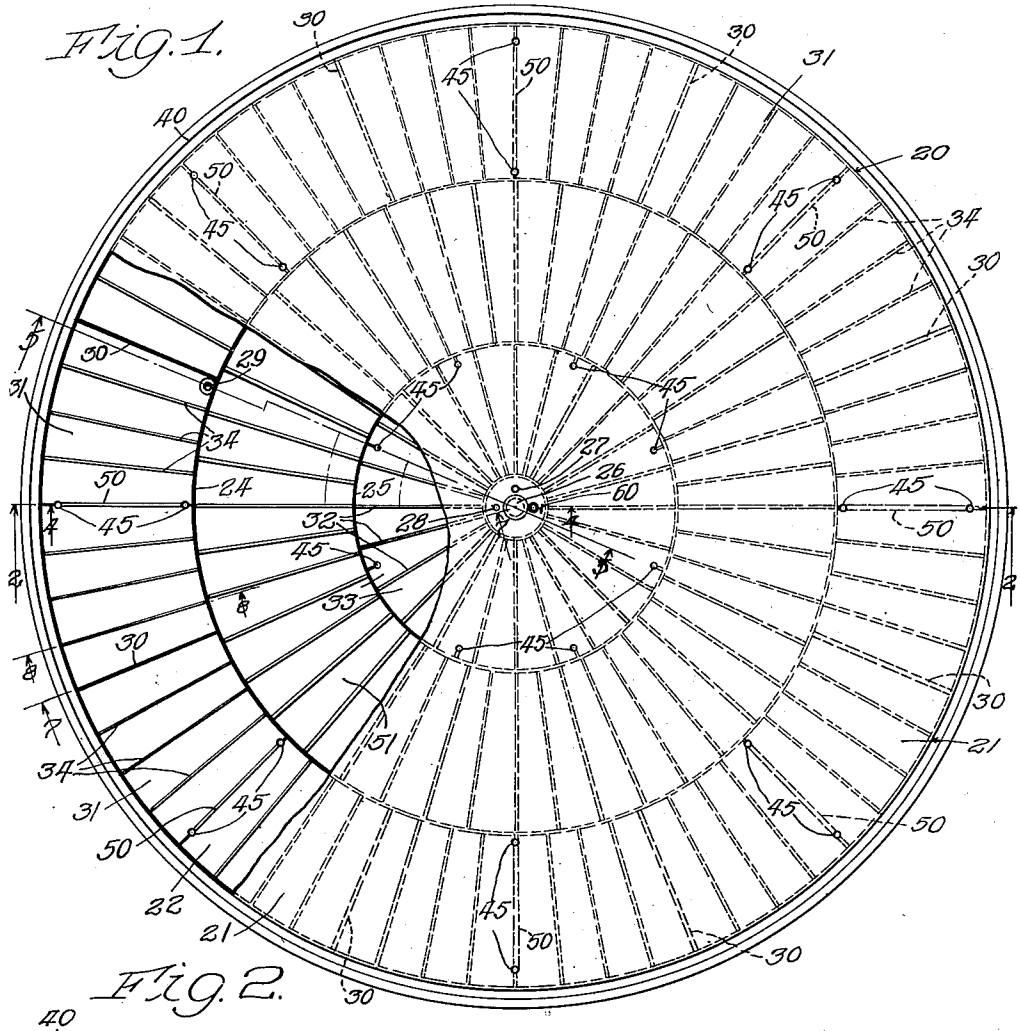
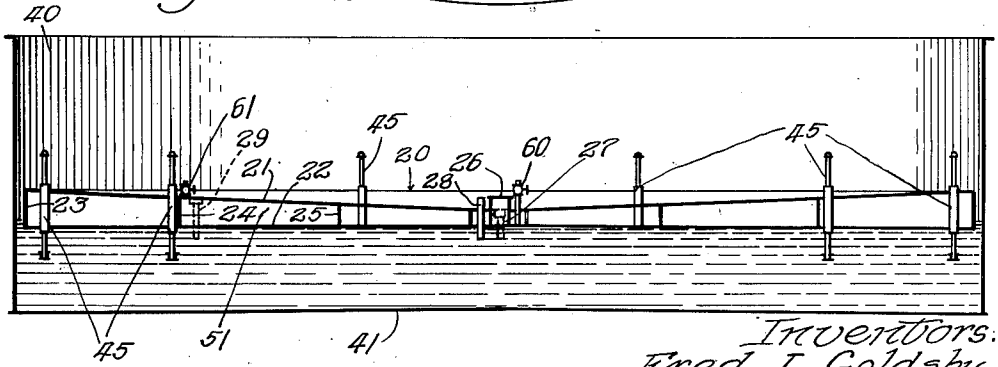


Fig. 2.

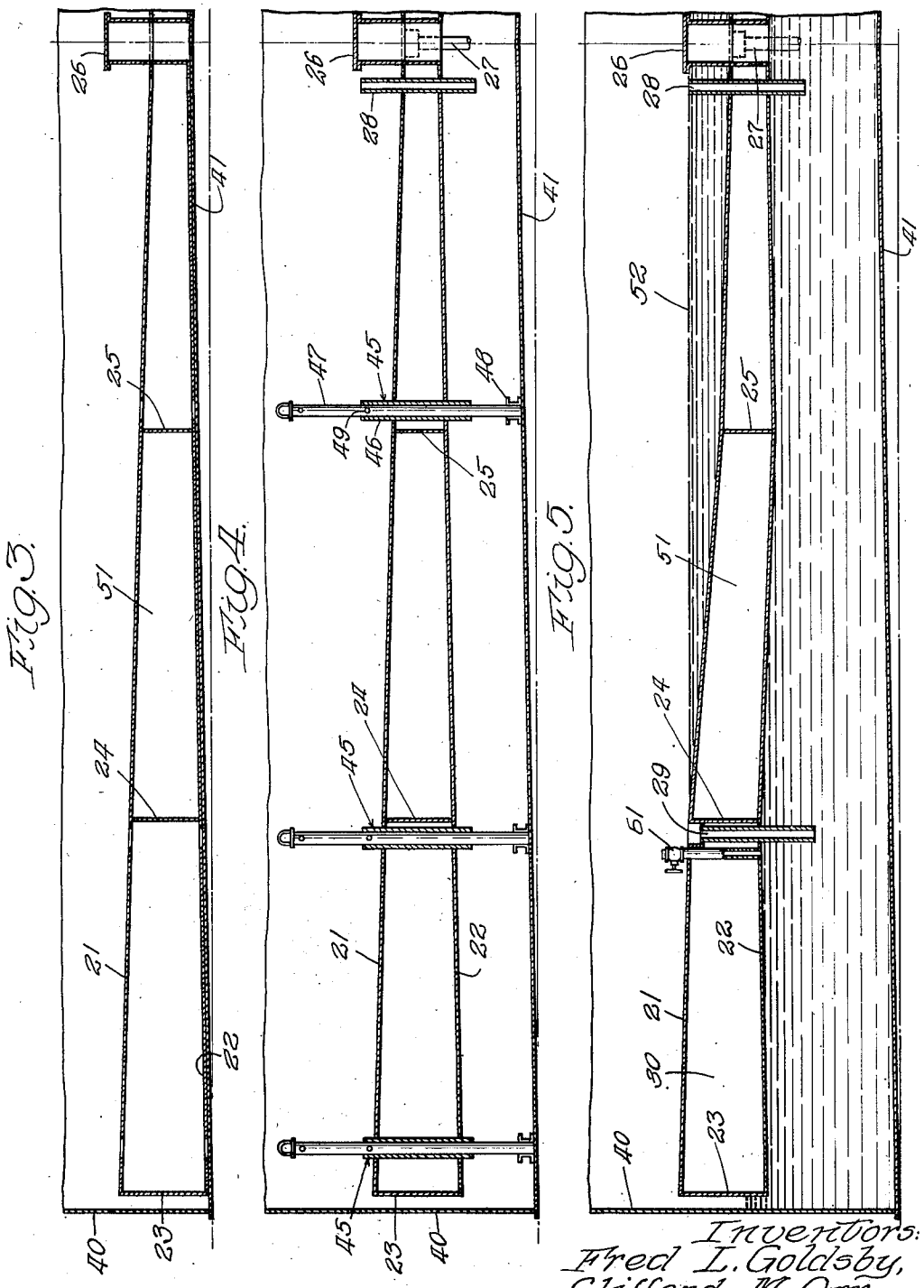


Inventors:
Fred L. Goldsby,
Clifford M. Orr,
By Christy, Wiley, Schroeder,
Merriam, Rolfsen & Tobey.

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DOUBLE-DECK FLOATING ROOF

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Inventors:
Fred I. Goldsby,
Clifford M. Orr,
By Christon, Wiles & Schroeder,
Merriam, Rogers & Flobbys.

Feb. 26, 1952 C. M. ORR ET AL 2,586,856

DOUBLE-DECK FLOATING ROOF

Filed Oct. 16, 1945 4 Sheets-Sheet 3

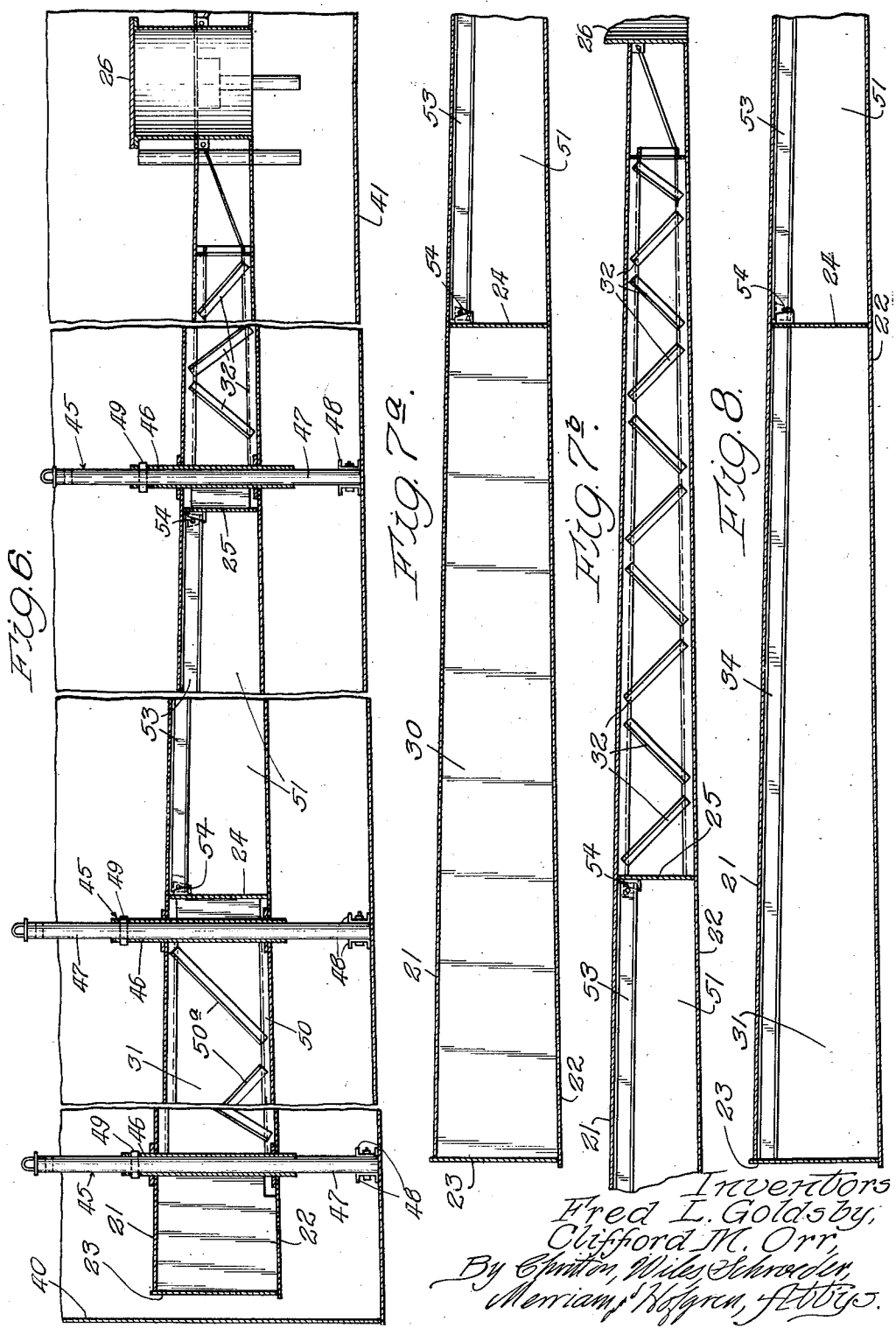


Fig. 6.

Fig. 7a.

Fig. 7b.

Fig. 8.

Inventors
Fred L. Goldsby,
Clifford M. Orr,
By Spriton, Wiley, Schroeder,
Merriam & Kofgren, Attys.

Feb. 26, 1952 C. M. ORR ET AL 2,586,856

DOUBLE-DECK FLOATING ROOF

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Fig. 9.

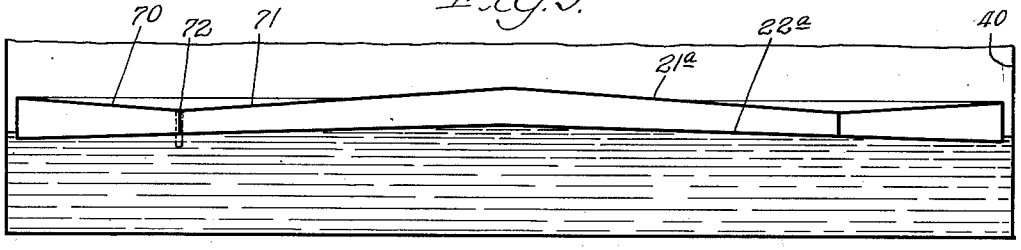


Fig. 10.

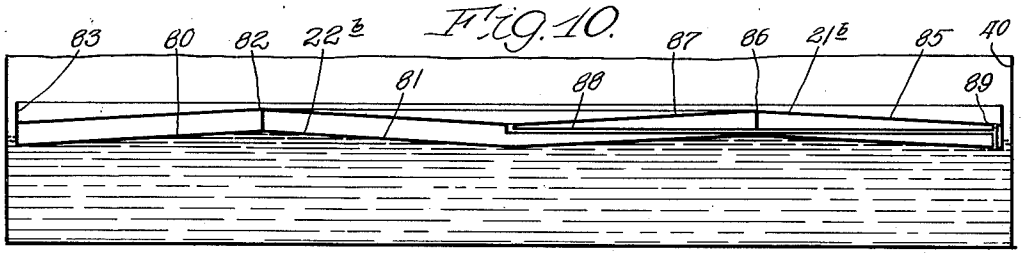


Fig. 11.

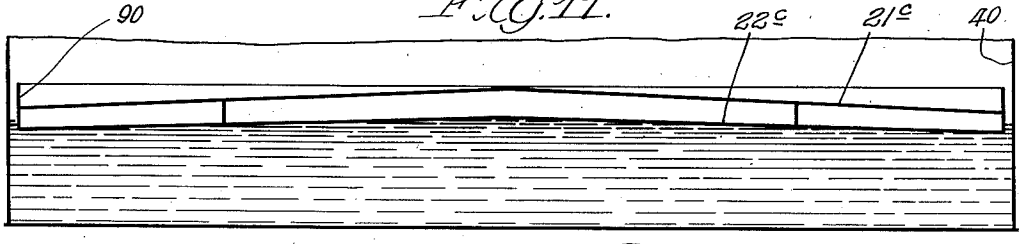


Fig. 12.

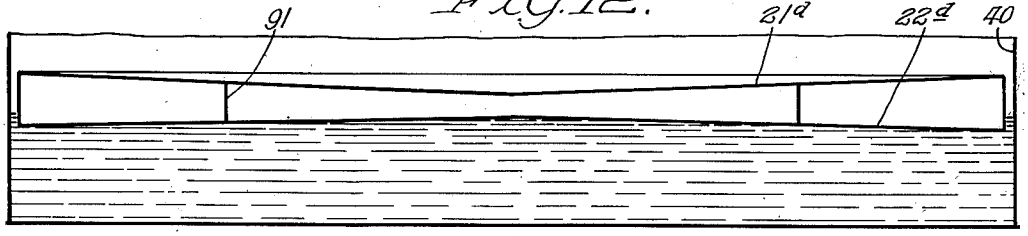
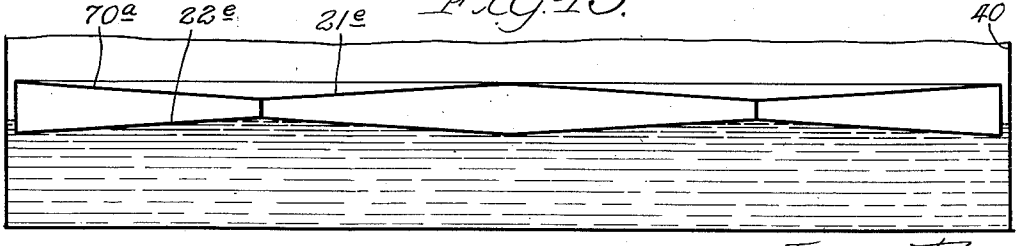


Fig. 13.



Inventors:
Fred I. Goldsby,
Clifford M. Orr,
By Chilton, Wiley, Schroeder,
Merriam & Rogers, Attys.

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UNITED STATES PATENT OFFICE

2,586,856

DOUBLE-DECK FLOATING ROOF

Clifford M. Orr and Fred L. Goldsby, Chicago, Ill., assignors to Chicago Bridge & Iron Company, a corporation of Illinois

Application October 16, 1945, Serial No. 622,566

12 Claims. (Cl. 220—26)

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This invention relates to a double deck floating roof for bulk storage vessels, and particularly for bulk storage for highly volatile liquids, such as gasoline.

While double deck structures have heretofore been employed for small storage vessels, for example, tanks up to 30' or even 40' diameter, the forms of double deck roofs heretofore available were not adapted to application to larger vessels, particularly to those of 100' diameter and upwards. Double deck roofs herein described are not only suitable for large vessels of 120' diameter or more, but also for smaller vessels and they have a number of advantages over not only the prior double deck structures, but over single deck floating roofs of all sizes.

The present double deck roof is considerably more stable than the single deck roof. It is practically unsinkable under all conditions, it provides insulation against the heat of the sun over the entire area of the roof, and is very easily assembled.

In the preferred form of the roof the bottom is very slightly coned upwardly and inwardly to the center of the deck. The amount of this coning is no more than sufficient to provide displacement such that under normal conditions, with the roof floating on liquid for which it is designed, the under deck will be in contact with the liquid. No permanent gas space is, therefore, provided by the coning of the under deck. On the other hand, if for any reason boiling should occur, or non-condensible gases should be trapped beneath the roof, they will be led by the slight slope of the underside of the deck to a central location and will thus stabilize the structure.

Because the roof is double deck, and because the center of the lower deck is normally a point of zero displacement, drains through the roof, and vents through the roof do not need to be valved in the usual manner. This is a particular advantage in the storage of gasoline or other materials which should not be brought into contact with an excessive amount of water. In these cases any emergency drain opening or other drain opening may readily be connected to an open hose leading to the bottom of the vessel.

The invention, and its other advantages are described more fully in the specification.

The various forms are illustrated in the drawings in which

Fig. 1 is a top plan view of one form of the double deck roof;

Fig. 2 is a sectional elevation taken along the the line 2—2 in Fig. 1;

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Fig. 3 is a fragmentary sectional elevation of the form of the roof shown in Figs. 1 and 2 resting upon the bottom during construction;

Fig. 4 is a section on line 4—4 in Fig. 1 illustrating the roof when supported in its normal bottom-most position;

Fig. 5 is a section on line 5—5 in Fig. 1 showing the roof floating under maximum emergency water load. Fig. 5 is purposely distorted by enlargement of the deviations in the vertical plane in order to illustrate the adaptation of the roof to a water load under emergency conditions;

Fig. 6 is a vertical elevation in fragmentary sections taken along the line 4—4 in Fig. 1;

Figs. 7*a* and 7*b* are sections taken along the line 7—7 in Fig. 1;

Fig. 8 is a section taken along the line 8—8 in Fig. 1;

Figs. 9, 10, 11, 12 and 13 are, respectively, sectional elevations of modified forms of the invention.

As shown in the drawings a double deck floating roof 20 comprises an upper sheet metal deck 21 and a lower sheet metal deck 22. Each of these decks is made up of plates, preferably steel, suitably fabricated and joined together preferably by welding. The upper deck 21 will sometimes be referred to as the top deck or top of the structure, and the lower deck 22 will sometimes be referred to as the bottom deck or the bottom of the structure.

As will best be observed from Fig. 3 the bottom 22 is in the form of a cone. The slope of this cone is correlated to the size of the deck, the weight of the deck, and the density of the liquid upon which the roof is to be used so that the center of the bottom will normally have zero buoyancy or displacement. Deviations from this normal buoyancy, which may be expected in smaller vessels, such as those below 60' diameter for example, are preferably in the direction of buoyancy below zero at the center—that is, so that there is no permanent gas space under the bottom of the deck.

The purpose of that degree of slope is to have the bottom plates of the deck normally wetted by the liquid. If any permanent gas space is left below the deck corrosion will occur much more rapidly when storing many types of commercial materials.

Those skilled in the art will have no difficulty in calculating the proper slope. For a tank 120' in diameter in which the roof itself will be about 119' in diameter, and of normal weight, and for use in a liquid of 45 pounds per

cubic feet density, the bottom may be pitched 6" from the outside to the center. On smaller roofs the pitch is about the same, but increases somewhat. On a 60' diameter roof it should be about 8". For most large roofs, on gasoline, it may be considered that the pitch may be 1" for 10' of radius.

The top 21 is pitched in the opposite direction in the form shown in Figs. 1 to 5 inclusive, so that water will drain to the center of the roof. The degree of pitch employed is such as to take care of proper drainage, and also to provide capacity for such emergency water load as desired. A preferable pitch for a 120' diameter tank is approximately 15", or 2½" for 10' of radius.

The figures given for both bottom and top are based upon the shape of the roof when resting on the bottom of the tank. Under conditions of operation there will normally be very slight deviations from these conditions, and under emergency water load there will be noticeable deviations as will be hereinafter explained, the structure being built so as to permit such deviations.

One of the basic values of the roof is insulation against the sun and, therefore, the minimum thickness of the double deck roof is of importance. Normally, a minimum depth of about 15" at the center is preferred. The thickness at the center, plus the respective pitches of the top and bottom determine the height of the vertical rim 23 which completes the double deck closure. Concentric rings 24 and 25 may likewise be employed to divide the double deck into annular sections. In the form shown in Figs. 1 to 5 inclusive, three rims are indicated, but this number may be altered to suit the size and purpose of the particular floating roof.

The roof is provided with a customary manhole 26. It is also provided with a drain 27 of usual form, and preferably situated at the lowermost point on the top deck.

Emergency drains of suitable number are likewise provided. Such drains are indicated centrally at 28 and also adjacent the ring 24 at 29.

The double deck is also suitably stiffened to make the structure as a whole substantially rigid.

As indicated in the drawings, the outer annulus between rings 23 and 24 is divided by bulkheads 30 into radial segments 31. The inner circle within ring 25 is similarly divided by trusses 32 into segments 33. The entire top is supported by rafters 34 which are preferably staggered as between the various ring portions.

One of the advantages of the preferred form of the deck is the ease with which it may be constructed in a conventional tank. The normal storage vessel 40, as indicated in Fig. 3, is provided with an upwardly and inwardly sloping bottom 41, and in the preferred vessel we provide a pitch on this bottom corresponding to the pitch of the bottom 22 of the deck. In assembling the floating roof, the bottom plates may be placed in position on the bottom of the tank and joined together while so positioned. The rings, trusses, rafters and top plates may then be assembled while the structure is still resting on the bottom of the tank.

The roof is then raised from the bottom and adjustable supports 45 inserted, as indicated in Fig. 4. These supports comprise sleeves 46, extending through the double deck, rod members 47 which are flanged at the bottom as indicated at 48, and pins 49 which extend through openings in the sleeve and rod. Trusses 50 are provided between pairs of these supports, as indicated in Fig. 1.

It will be noted that the central section 51 between the rings 24 and 25 is, in the preferred form of the invention, not stiffened by trusses. This feature permits bending as shown in Fig. 5 under emergency water or other loads. Under normal conditions all water falling on the top of the floating roof will be drained through the central opening. On rare occasions, however, the central drain may become clogged, either by ice or debris, or some other agent. While these occasions are rare, the roof must be designed to accommodate any load under such circumstances, and if the roof is provided with sufficient metal to be completely rigid under such extraordinary load conditions it would be considerably heavier than the present design. We have, therefore, purposely formed the central section of the deck in the form of an annulus, and left it unbraced so that slight bending thereof may occur under such extraordinary water loads. As illustrated in Fig. 5, water 52 has collected to the depth of about 10" up to a point where it will drain through the emergency drain 29. At the same time the center of the deck has moved downwardly a very slight distance, which is normally about 5". The emergency drain 28 normally has an opening about 5" higher, or slightly less, than the drain 29, but the movement of the deck brings this drain to the same level, or slightly below that of the drain 29.

The slight bending in section 51 may be facilitated by pivoting of the beams 53 at the pivotal point 54. The roof does not have any appreciable tendency to flex in an upward direction or in a downward direction under normal conditions. There is no appreciable change in the relative positions of the center of the deck and the outside edge under all conditions from full displacement with the bottom of the deck entirely wet to no displacement when the bottom of the deck is completely resting on gas under pressure. Section 51 is, therefore, structurally rigid, except under conditions of extraordinary and emergency water load, or other similar load on the top of the deck.

The interior construction of the double deck roof is best shown in Figs. 6 to 8 inclusive. Fig. 6 is taken along the line which shows the trusses 50 and 32 which brace the outer and inner sections of the roof. It also illustrates the method of mounting the rafters 53 and the pivots 54 on which they are supported.

Fig. 7*a* is taken through a bulkhead 30; Fig. 7*b* is taken through the center section trusses 32; while Fig. 8 is taken to show the rafters 34.

As shown in Figs. 1 and 2, a valved air vent 60 is provided near the center of the deck. A supplementary vent 61 may be provided at the inner edge of the outer section, if desired, so that air may be vented when the roof is in the position shown in Fig. 5. When the tank is originally floated the air valve 60 is open and any air entrapped under the deck is allowed to vent. The valve may then be closed. This operation may be repeated each time the roof is floated after the tank has been emptied.

The roof may be operated as a floating lifter roof by keeping the valve closed after the roof has been floated. Any boiling which occurs under the roof, or any permanent gas entrained in the product which is pumped into it collects at the center and the roof will rise supported partly by liquid displacement and partly by gas. If the

amount of gas is great enough the roof may be supported entirely by gas. At night the vapors may recondense in part or in toto and thus reduce evaporation loss.

It will also be noted that in the form of invention shown in Figs. 1 to 8 inclusive, a different drain load will be supported, depending upon whether the roof is floating or resting upon the bottom supports. Inasmuch as the supports and the roof may carry a greater rain load when the roof is floating than when it is on the supports, the present structure is of particular value in this respect. For example on a 120' tank roof, a structure made as described in Figs. 1 to 8 inclusive, is designed to hold 1½'' of rainfall with the drain clogged and the tank supported on the bottom supports. More rain than this will drain through the emergency drains. When the roof is supported on the bottom the center drain is higher than the outer emergency drains and, therefore, will not function. The total weight of water is thus limited to a predetermined amount for which the supports are designed.

When floating, however, the roof will collect the rain from about 2¾'' of rainfall before the water starts to drain through the center emergency drain which has been lowered relatively to the others by the bending of the roof.

In the structure shown in Fig. 9 the floating roof comprises a bottom **22***a* sloped in the same manner as those shown in Figs. 1 to 8 inclusive. The top **21***a* is, however, pitched downwardly and inwardly from the edge to provide an inwardly sloping section **70**, and is sloped downwardly and outwardly from the center to provide an outwardly sloping section **71**. Water drainage is thus to an annular portion having its low point in ring **72**, in which area a drain is provided.

In the form shown in Fig. 10 the bottom **22***b* is sloped upwardly and inwardly from the edge to provide an upwardly facing section **80**, but is also sloped upwardly and outwardly from the center to provide an upwardly facing section **81**. Gas is thus trapped in an annular portion having its apex at **82**. In this form of roof the slope is such as to provide a point of zero displacement at **82**. In the form here shown the upper deck **21***b* is sloped upwardly and inwardly from the edges to provide an upwardly facing section **85** having an apex at **86**, and is then provided with a circular section sloping downwardly and inwardly from **86** to the center of the deck to form an upwardly concave section **87**.

Water drainage in this form occurs to the center and to the rim. The drain **88** may be provided leading from the center to a connection **89** at the rim. This form of drain is the shortest drain of the various forms shown. On this form an upstanding flange **83** is provided at the rim for additional displacement, and also to catch the water flowing to the edge.

The form shown in Fig. 11 has a bottom **22***c* like that shown in Figs. 1 to 8, inclusive, and the top **21***c* which is substantially parallel therewith. This provides an advantage in trussing, inasmuch as all the trusses may be made alike. In this form a flanged rim **90** is provided for additional displacement and also to catch the water flowing to the edge.

In the form shown in Fig. 12 the bottom **22***d* and the top **21***d* are sloped similarly to the forms shown in Figs. 1 to 8 inclusive. The floating roof shown in this figure, however, is braced by the ring **91** which divides it into two sections as distinguished from the three sections in Figs. 1 to 8 inclusive.

Fig. 13 illustrates a form in which the bottom **22***e* has the same shape as that shown in Fig. 10, whereas the slope **21***e* has substantially the same shape as that shown in Fig. 9. It will be noted, however, that the upwardly facing outer section **70***a* is somewhat wider than the form shown in Fig. 9.

On any of the forms, a depending rim may be employed, if desired, to increase vapor capacity.

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

What we claim as new, and desire to secure by letters patent, is:

1. A floating roof for a liquid storage vessel comprising: a double deck float, said double deck comprising a top and a bottom closure of sheet metal joined by an upstanding rim, said roof being structurally rigid under all normal floating stresses and said roof being bendable only at an annular portion intermediate the center and outer edge of the roof under extraordinary loading and comprising adjoining ring-like sections, one of the outermost of said sections being trussed and at least one of the intermediate sections being untrussed, there being bracing means to provide radial rigidity in the untrussed section, the bracing means being connected to provide for the bending under extraordinary loading.

2. A roof as set forth in claim 1 in which the bottom closure slopes upwardly and inwardly from the rim.

3. A roof as set forth in claim 1 in which the slope of the bottom closure is such as to provide substantially zero displacement at the center of the bottom closure.

4. A roof as set forth in claim 1 in which the slope of the bottom closure is equivalent to approximately 1'' for 10' of radius on a liquid having a density of approximately 45 pounds per cubic foot.

5. A roof as set forth in claim 1 in which the top closure slopes downwardly and inwardly.

6. A roof as set forth in claim 1 in which the bottom closure slopes upwardly and inwardly from the rim to the center.

7. A roof as set forth in claim 1 in which the sections are at least three in number and the untrussed section is an intermediate section between two trussed sections.

8. A roof as set forth in claim 1 in which the untrussed section includes a plurality of substantially radial supporting girders which are pivotally connected at their ends to adjoining trussed sections.

9. A floating roof as set forth in claim 1 having a plurality of emergency drains through the roof at different distances from the center thereof, the centermost drain having a drain opening normally at a height substantially above the opening of the outermost drain.

10. A floating roof as set forth in claim 1 in which the top closure slopes inwardly and downwardly, and then inwardly and upwardly to provide an annular drainage section.

11. A floating roof as set forth in claim 1 in which the top closure slopes inwardly and upwardly, and then inwardly and downwardly to provide a central drainage section and a rim drainage section.

12. A floating roof as set forth in claim 1 in which the bottom closure slopes upwardly and

inwardly from the rim, and then downwardly and inwardly from the rim to the center to provide an annular gas collecting zone intermediate the center and the rim.

CLIFFORD M. ORR.
FRED L. GOLDSBY.

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