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R. C. ULM

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FLOATING ROOF

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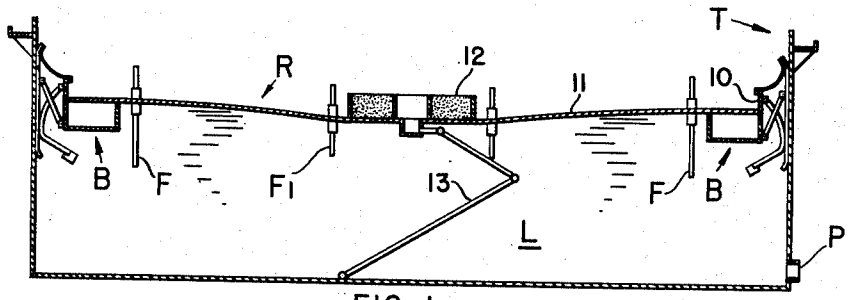


FIG. 1

FIG. 2

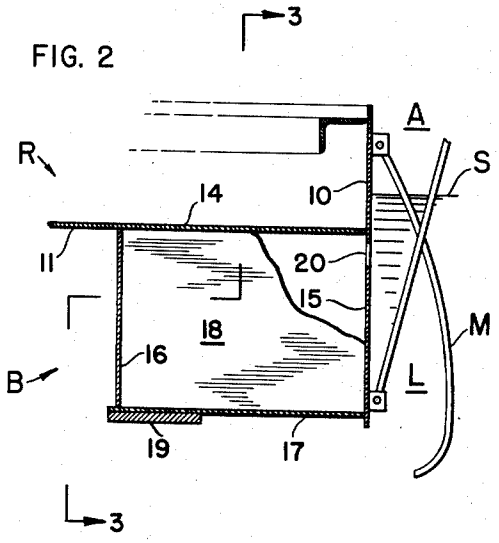
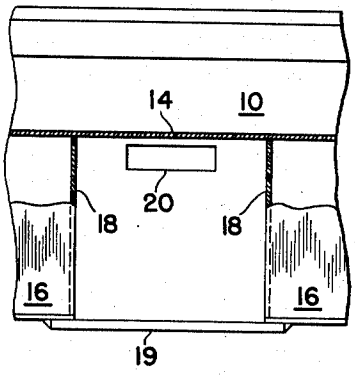


FIG. 3



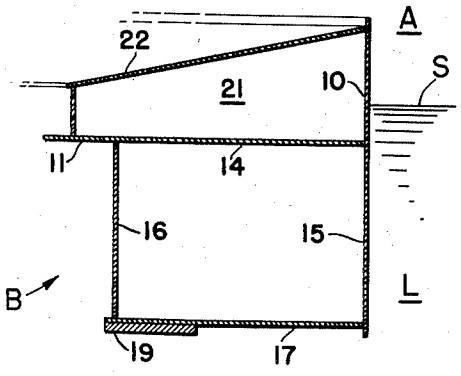


FIG. 4

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FLOATING ROOF

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5 Claims. (Cl. 220—26)

1

This invention relates to floating roofs as used in liquid storage tanks. It has particular reference to flexible, centrally weighted, single deck floating roofs of the liquid-contacting type, mainly when the tanks and roofs are very large, having diameters in excess of about 100 or 120 feet.

Flexible, centrally weighted floating roofs of the liquid-contacting type have a deck which, in vertical cross-section, has a contour curve rising from the weighted center to a peripheral upstanding rim, due to the interaction of the various forces acting upon the deck. This contour curve is relatively steep in the central parts and relatively flat in the outer parts of the deck, thereby creating a problem of rain water drainage and gas or vapor removal, in said outer parts. This problem is most pronounced in large floating roofs of this type, that is, in floating roofs with a diameter greater than about 100 or 120 feet. In floating roofs of such a size the required inward-downward slope, for instance a pitch of about 1:50 in the outer parts, tends to produce a contour curve with rather excesive pitch in the central parts. This in turn leads to very deep immersion of the central weight, to high central forces of buoyancy, to the need for a very heavy central weight, to the imposition of very high stresses upon the flexible deck, and thus to a relatively expensive construction. This follows from known facts about said contour curve as disclosed in Patent No. 2,497,047 granted to F. D. Prager and myself on February 7, 1950, and in my further applications filed October 21, 1949, and February 23, 1950, under Ser. Nos. 122,639 and 146,503, now issued as Patents 2,531,897 and 2,531,898.

My present application covers a further improvement, using a shape as previously disclosed and providing a special means to maintain such shape. It also reduces the total weight and cost of the floating roof. The shape is maintained against forces which tend to destroy it. The total weight and cost are reduced by means of a further development, utilizing the shape-maintaining members for the required reenforcement of the rim around the deck.

Tendencies to destroy the required shape, and to form an outward-downward slope in peripheral parts of the roof, are due to the inherent weight of the peripheral rim reinforced against loads due to the central ballast, and the additional weight of seal and other mechanisms supported by the rim or by the peripheral part of the deck. In order to counteract such tendencies it is desirable, mainly in large floating roofs of this type, to provide forces of buoyancy in the peripheral parts, compensating for the extra weight of those parts.

2

In certain roofs known to the art a plain, annular, peripheral pontoon has been used, for other purposes. The use of such a pontoon would have undesirable side effects in the present case since it would interfere with the removal of gases and vapors. Therefore I apply the required force of buoyancy by a discontinuous series of peripherally located buoyant members, generally provided by spaced, hollow boxes below the deck. It has further occurred to me that such boxes can be tied together to form a novel reenforcement for the rim. Thus the buoyant members both compensate and reduce the extra weight.

In the drawing Fig. 1 is a diagrammatic cross-sectional elevation of apparatus constructed in accordance herewith. Fig. 2 is an enlarged detail from Fig. 1. Fig. 3 is a section through Fig. 2 along lines 3—3. Fig. 4 shows a modified construction in a view generally similar to Fig. 3.

The floating roof R rests on the surface S of the liquid product L stored in the tank T. The roof R rises and falls with the liquid surface S, as liquid is introduced or withdrawn through piping P. The roof R is slightly smaller than the tank T, thereby leaving an annular space A between the roof and the inside of the tank T. A peripheral, annular seal mechanism diagrammatically represented by letter M bridges the annular space A. This mechanism is sufficiently elastic to adapt itself to local irregularities of the annular space, while being sufficiently sturdy to withstand the friction imposed by frequent rising and falling movements of the floating roof.

The seal mechanism M is supported by and directly from the rim plate 10 at the periphery of the floating roof R, which plate is upstanding and usually cylindrical. This rim plate 10 is one of the basic parts of the floating roof R, as is the single deck 11 lying on the liquid surface S and secured to the rim plate 10 below the upper edge of the latter. A pan 10—11 is formed in this manner, which pan is capable of floating on the liquid surface S even when the liquid L is light, like water or gasoline, and the material for the floating roof R is heavy, like steel plate or the like. An additional important part of the flexible floating roof R is the central ballast weight 12, which is heavy enough to keep the entire deck 11 inwardly and downwardly inclined in substantial accordance with the contour curve as mentioned, thereby assuring practically com-

plete removal of vapor and gas to the annular space A, and of rain water to the drain 13; said drain connecting a central part of the space above the deck with a lower space outside the tank, in manner well known to the art.

When the tank is drained of liquid product for maintenance purposes the floating roof R rests on feet or support members F, which are desirably mounted on the deck 11 so that they can be vertically adjusted from the top of the deck in well known manner. In a centrally weighted floating roof most if not all of these feet F are installed in and distributed along the peripheral part of the deck, it being undesirable to subject the body of the deck to concentrated weight loads due to such feet, which would tend to form rain water retaining and corrosion inducing pockets in the deck. Being substantially limited to the peripheral part of the roof, the series of supporting feet constitutes an addition to the inherent weight of the peripheral part itself.

Some additional support feet F' are desirably installed in locations adjacent to and surrounding the central ballast weight 12, in order to relieve the outer feet F of the high extra loads that would otherwise be imposed; it being desirable to suspend the ballast weight as well as the deck above the bottom of the drained tank, in order to allow maintenance operations on the underside. Accordingly, when the tank is drained, the feet F and F' support the roof; when the tank is in use the floating roof supports the feet and is in turn supported by the liquid product.

For the basic purpose of covering the liquid surface S it has long been known to be necessary and sufficient to form a deck 11 from steel plates about 3/16 or 1/4'' thick, which weighs about 8 or 10 lbs. per sq. ft. A pan 10—11 formed of 3/16'' steel and not centrally or peripherally weighted would tend to float about 1.54 or 1.74'' below the liquid surface S, depending on whether the liquid is water or gasoline. The provision of the central ballast weight 12, which is necessary to insure central drainage etc. increases the basic weight of the floating roof, usually by about 20% to 30%, and tends to produce said contour curve, as a result of which the center of the deck floats several inches deeper, and the avegage immersion of the roof is about 2 to 2.25''.

The upstanding and generally reenforced rim 10, the seal mechanism M and the peripheral feet F add weight to the peripheral parts of the roof. As a result there is a tendency for a reversal of the contour curve, that is, for the development of such a curve which runs outward-downward, instead of outward-upward, adjacent the rim 10. This tendency, which is objectionable since it interferes with simple methods of drainage and gas removal, is particularly outspoken in large roofs R.

The addition of weight due to the rim plate 10 and its required reenforcements depends largely on the size of the roof. In roofs of 100 to 160 ft. diameter this item usually adds 12 to 18 lbs. per linear foot of roof periphery; the heavier rim being required for the larger roofs. The seal mechanism M adds about 25 to 35 lbs. per linear foot; the heavier mechanisms being required when the tank is riveted, and lighter ones when it is welded. The feet F usually add about 10 lbs. per linear foot. Accordingly the peripheral parts of a large roof added to the deck have a total weight of 47 to 63 lbs. per foot of roof periphery.

It can be assumed that most of this extra weight is supported by the reenforced, peripheral, annular area of a floating roof of the type in question, which area is about 2 to 6 feet wide, depending on the diameter of the roof. It can be assumed that substantially all of this extra weight is supported by such reenforced area plus an annular area directly inside therefrom, which is about 1 foot wide. Thus the extra weight is distributed over a ring of 3 to 7 feet width, and constitutes a downward load of about 9 to 16 lbs. per sq. ft., or more usually, as I find in practice, about 11 to 14 lbs. per sq. ft. over and above the weight of the ring-shaped deck portion itself.

I install peripheral, hollow, buoyant box members B to compensate this extra weight load of 11 to 14 lbs. per sq. ft. More specifically I install a discontinuous series or plurality of separate buoyant members B, spaced along and below the peripheral part of the deck 11, with open spaces between these box members, in order to allow peripheral removal of gas or vapor.

Theoretically I could make these box members B in any one of several forms. Particularly their radial extension below the roof could be made greater or less great, so long as they underlie the said ring of 3 to 7 feet width. Practically I found it most desirable to make these box members rather flat and to give them a radial extension at least as great or sometimes greater than said ring; making them large enough to displace, when immersed slightly beyond the peripheral edge of deck 11 as shown, an amount of liquid L substantially balancing the weight of the box members B themselves plus said peripheral extra weight. Only exceptionally is it desirable to provide, additionally, pontoon means to displace an amount of liquid balancing, a temporary extra weight of rain water which may accumulate largely in central regions of the roof due to insufficient drainage facilities 13. For this added function I prefer to provide pontoon means elsewhere than in the peripheral zone; for instance to make the ring-shaped area occupied by the box members B about one-third to one-half of the total roof area, using the one-half proportion in the smaller roofs considered herein and the one-third proportion in larger ones. On the other hand this extra protection against rain can be dispensed with, in certain cases. The aforementioned load-supporting ring of 3 to 7 ft. width used in this event represents only about one quarter to one fifth of the roof area; and the area of the ring of box members can well be even somewhat smaller.

I secure these box members B rigidly to the underside of the deck 11 and the inside of the rim 10, which rim for this purpose is extended downwards below the deck. Thus the box members B are partially formed by the outer parts 14 of the deck and the lower part 15 of the rim plate. They are completed by inner walls 16 more or less parallel with the rim plate; together with bottom walls 17 and endwalls 18 running more or less radially of the roof.

I interconnect the inner or bottom walls 17 or 16 of adjacent boxes B by bottom tie plates or structures 19, spaced below the deck 11 and spaced inwardly of the rim plate 10. In the embodiment as shown in Fig. 2, tie plates 19 effectively interconnect both sets of members 16 or 17, the tie plates being secured to the joints between these members. In this manner the series of boxes B is tied together into a rigid ring, thereby dispensing with the need for the rigid

ring of reenforcements for the rim plate, heretofore used in floating roofs of this type. This in turn provides a further improvement of the drainage of rain water from the peripheral areas of the roof. At the same time the removal of vapor and gas from underneath the roof remains feasible, being allowed by suitable slots or apertures 20 in the lower part 15 of the rim plate 10, directly below the deck 11 and between pairs of boxes B.

In a number of instances it is desirable to install additional hollow boxes above the deck 11, in the peripheral part of the roof. Such an upper box 21 is shown in Fig. 4. Desirably it is formed in part by the rim plate and deck and in other part by a top plate 22 extending inward-downward from the rim plate 10 with a greater inclination than that of the outer parts of the contour curve, in order to safeguard more positive drainage of rain water from the large outer areas of the roof.

Such an upper box 21 will also prevent the rain water temporarily collected on the roof from excessively shifting the center of gravity due to wind action and the like, since it will collect the total amount of water retained in a relatively small annular area between the center weight 12 and the upper box 22.

Of course an upper box of this type adds to the total weight of the roof while not contributing to its buoyancy. It also adds to the rigidity of the peripheral part of the roof, thereby allowing the use of lighter and more economical members 10, 16, 17 and 19.

It will be obvious to persons skilled in the art that a number of further modifications are possible. I claim:

1. A floating roof for a liquid storage tank, comprising a single deck; a rim surrounding an annular, peripheral part of the deck and extending above and below the same; drain means connecting central parts of the space above the deck with a lower space outside the tank; vent means connecting outer parts of the space below the deck with a space unconfined by the deck; ballast weight means secured to and supported by a central part of the deck and heavy enough to maintain a contour curve, in any vertical cross-section of the deck, upon immersion of the deck in the stored liquid, which curve rises relatively steeply from the central part of the deck connected to the ballast weight while being relatively flat in outer parts of the deck; and a pontoon ring formed in part by a lower portion of the rim, said pontoon ring being located at least in part below the peripheral part of the deck, being secured to said peripheral part, and displacing, when immersed slightly beyond the elevation of said peripheral part, an amount of stored liquid which substantially balances the weight of the rim and pontoon ring plus that of any equipment secured to the rim and pontoon ring; whereby upon immersion of the floating roof in the stored liquid no outward-downward slope is formed even in the outer and peripheral parts of the deck, while the ballast weight means and the entire floating roof can be relatively light.

2. A floating roof for a liquid storage tank, comprising a single deck; a rim secured to the periphery of the deck and extending above and below the same; drain means connecting central parts of the space above the deck with a lower space outside the tank; ballast weight means secured to and supported by a central part of the deck and heavy enough to maintain an outwardly rising contour curve in any vertical cross-section of the deck, upon immersion of the deck in the stored liquid, at least the top of the deck being entirely unobstructed from the ballast weight means to the periphery of the deck and floating roof; and a ring of pontoons below the deck, the pontoons being separated by open vent spaces and the ring being formed in part by a lower portion of the rim and in part by tie members spanning the open vent spaces, whereby reenforcement of the rim against loads due to the ballast weight means need not be effected by reenforcement members secured to the top of the deck and obstructing the same, the lower part of the rim being apertured at the end of each vent space, and the ring of pontoons displacing, when immersed slightly beyond the elevation of said peripheral part, an amount of the stored liquid which substantially balances the weight of the rim and pontoon ring plus equipment secured thereto.

3. A floating roof for a liquid storage tank, comprising a single deck; a rim surrounding an annular, peripheral part of the deck and extending above and below the same; drain means connecting central parts of the space above the deck with a lower space outside the tank; vent means connecting outer parts of the space below the deck with a space unconfined by the deck; ballast weight means secured to and supported by a central part of the deck and heavy enough to maintain a contour curve in any vertical cross-section of the deck, upon immersion of the deck in the stored liquid, which curve rises relatively steeply from the central part of the deck connected to the ballast weight while being relatively flat in outer parts of the deck; and a pontoon ring formed in part by a lower portion of the rim, said pontoon ring comprising hollow chambers above and below the peripheral part of the deck, being secured to said peripheral part, being large enough above the deck to confine any rain water falling on the roof within a relatively small, inner space, and displacing, when immersed slightly beyond the elevation of said peripheral part, an amount of the stored liquid which substantially balances the weight of the rim and pontoon ring plus that of any equipment installed on the rim and pontoon ring.

4. A floating roof for a liquid storage tank comprising a single deck; a drain means connecting central parts of the space above the deck with a lower space outside the tank; vent means connecting outer parts of the space below the deck with a space unconfined by the deck; ballast weight means secured to and supported by a central part of the deck and heavy enough to maintain a contour curve in vertical cross sections of the deck upon immersion of the deck in the stored liquid which curve rises relatively steeply from said central part of the deck while being relatively flat in outer parts of the deck; and a hollow rim secured to an annular, peripheral part of the deck, extending above and below the same and displacing when immersed in the stored liquid to an elevation between said peripheral part and the top of the hollow rim, a volume of the stored liquid the weight of which substantially equals that of the hollow rim plus any equipment installed thereon.

5. A floating roof for a liquid storage tank comprising a single deck; a drain means connecting central parts of the space above the

deck with a lower space; vent means connecting outer parts of the space below the deck with a space unconfined by the deck; ballast weight means secured to and supported by a central part of the deck and heavy enough to maintain a contour curve in vertical cross sections of the deck upon immersion of the deck in the stored liquid which curve rises relatively steeply from said central part of the deck while being relatively flat in outer parts of the deck; and a hollow pontoon ring structure secured to an annular, peripheral part of the deck and extending above and below the same in order to support its own weight and that of any equipment installed thereon.

REIGN C. ULM.

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