Jan. 9, 1945. W. G. LAIRD 2,366,911

FLOATING ROOF STORAGE TANK AND METHOD OF STORING LIQUIDS

Filed June 27, 1942

Fig. 1.

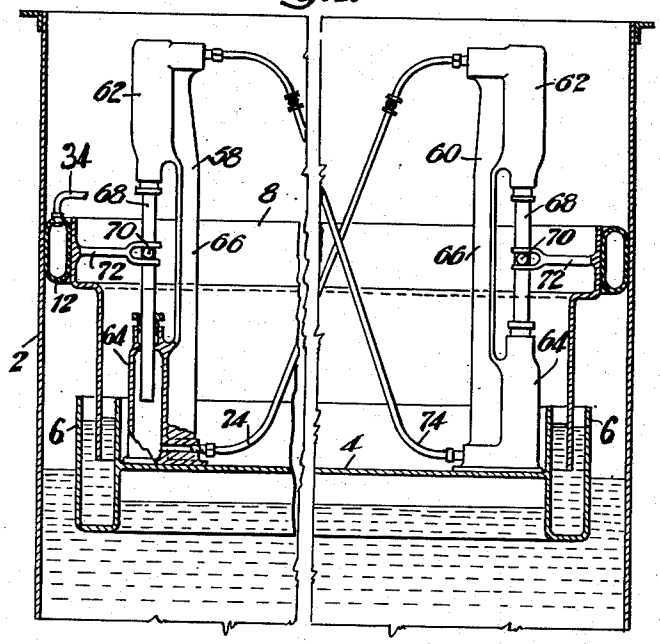


Fig. 2.

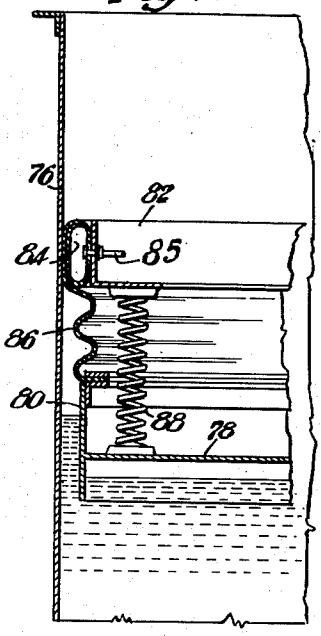


Fig. 3.

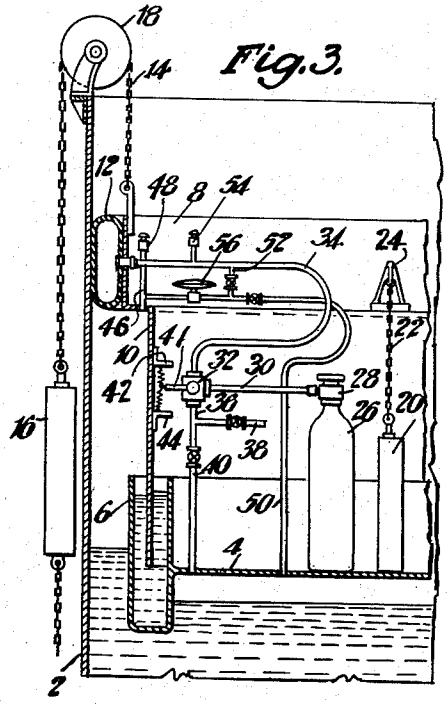


Fig. 4.

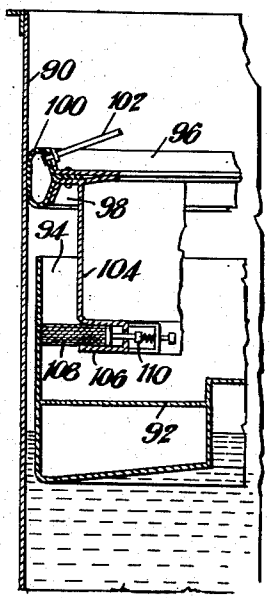
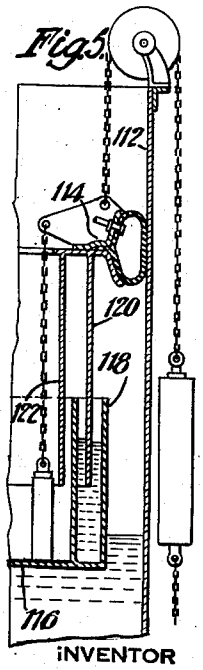


Fig. 5.



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FLOATING ROOF STORAGE TANK AND METHOD OF STORING LIQUIDS

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11 Claims. (Cl. 220—26)

This invention relates to improvements in floating roof storage tanks and more particularly to an improved floating roof and method of storing volatile liquids.

Floating roof storage tanks for storing volatile liquids, such as petroleum oils, have been used for many years and are in extensive use at the present time. In general, the floating roof of such tanks include a buoyant deck or cover of somewhat smaller diameter than that of the tank and a loose-fitting or flexible seal around the rim of the cover pressing against the inside wall of the tank in an attempt to cover the liquid in the space between the rim of the cover and inside wall of the tank. Such covers however do not prevent escape of gases and vapors or the access of air to the liquid in the space around the cover.

Present floating roofs prevent some losses in the storage of most petroleum products and may afford some protection from fire, but they do not prevent the losses incident to the filling of tanks with such products as crude petroleum, gasolines and other petroleum products containing volatile constituents. Many fires occur in floating roof storage tanks of the type referred to, and it appears that in many cases the fires are attributed to the presence of the floating roof. These defects or disadvantages in the present methods of storing volatile liquids appear to result from the type of roof seals employed and to the manner in which the floating roof is operated or used.

Large quantities of petroleum products are stored in tanks provided with floating roofs in which no attempt is made to save vapors, while still larger quantities of such products are stored in covered tanks without such roofs. Some closed storage is provided where there is good protection from loss by vaporization.

The present invention is directed to the object of improving and reducing the cost of tight storage by utilizing a floating roof type of tank in such a manner as to completely enclose or bottle-up the liquid at the level of the liquid in the tank. The improved method may be applied to the storage of oil and other liquids in large tanks of the field type, and is suitable for bulk storage and for underground storage at air fields and other points of use or supply.

One object of the invention is to provide an improved method of storing liquids by which the liquid in a tank is sealed-in or bottled-up at the level of the liquid regardless of the fact that different levels may be assumed at different times.

A further object of the invention is to provide an improved method of storing liquid in floating roof tanks in which the roof is permitted to move freely up and down during the filling or emptying of the tank, but in which the roof is locked to the tank wall and the liquid completely closed-in during the time the liquid is held under storage conditions.

An additional object of the invention is to provide an improved method of storing liquids in floating roof storage tanks in which the liquid is bottled-up in the storage tank and protected against contamination by the outside atmosphere, rain water, and other foreign materials.

Another object of the invention is to provide an improved apparatus for accomplishing the improved method of storing volatile liquids.

Accordingly, the present invention includes an improved floating roof tank in which a buoyant floating roof is provided with a marginal-enclosing means which is normally locked against the inside wall of the tank to form a fluid-tight joint, but which is released and moved with the floating roof upon any major change in the level of the liquid in the tank and again locked to the tank wall when the liquid level is substantially constant, the stored liquid being held under substantially sealed-in or bottle-tight conditions at any level, regardless of minor changes in the level of the liquid in the tank. In general the improved floating roof structure includes, a buoyant floating deck, a locking ring mounted above and on the deck, the ring including as a locking means preferably an inflatable hose or tire for locking the ring in fixed horizontal position with respect to the wall of the tank, means for permitting limited relative movement between the floating deck proper and the ring without uncovering the stored liquid, means for preventing the escape of vapors between the ring and the floating deck proper, means for supplying a gaseous pressure medium to the tire or hose of the ring and for releasing the pressure thereon, and means for maintaining the ring in substantially parallel relationship with respect to the floating deck proper.

It is acknowledged that various attempts have been made to enclose the space around floating roofs, for example by providing multiple liquid seals on floating roofs, as shown by the patents to Bohnbardt No. 1,666,525 and DeCastro No. 2,125,771. Inflated and uninflated tubes, tires, etc., have also been proposed as marginal "seals" for floating roofs as shown by the patents to Bown No. 1,575,033; Glass No. 1,650,340; Haupt No. 1,735,461; Patrick No. 2,014,264; and Horton

No. 2,085,752. However, in no case is there any attempt to lock such tires or tubes in place at any level.

The commercial development of the buoyant floating roof has resulted in almost universal adoption of the pontoon buoyant roof or deck which is somewhat smaller than the internal diameter of the tank, and provided with a marginal "seal" (so-called) in an attempt to cover the space between the edge of the roof and the tank wall. The space between the edge of the roof and the tank wall frequently is from six inches to a foot, to provide for the usual irregularities in the character of the tank wall, since steel tanks, such as upright cylindrical oil tanks frequently are not made and kept in the form of perfect cylinders.

The so-called "seals" used on floating roofs are not seals in the technical sense because, almost, if not all of them are made and used in such a way as to allow the escape of gases and vapors around the edge of the roof. Furthermore, it is generally held in the art that provision must be made for the escape of gases and vapors around a floating roof. One of the most common "seals" used on floating roofs is an elaborate heavy structure including a ring of spaced vertical steel shoes (which slide along the wall of the tank), connected together with strips of water-proof fabric, the ring of shoes being supported by spaced pivoted supports from the roof so that the weight of the ring of shoes (or springs) causes them to bear against the tank wall. The space between the edge of the roof and the ring of shoes is closed with an annular piece of water-proof fabric, one edge of which is secured to the roof and the other of which is secured to the ring of shoes.

This so-called "seal" provides a metal-to-metal rubbing contact in which the shoes grind along the tank wall as the roof moves up and down in the tank with corresponding changes in liquid level. Gases and vapors formed from the liquid in the tank escape freely around the shoes along the tank wall and rain water and other foreign matter enter the liquid along the tank wall in addition to the scale and rust ground off the tank wall by the steel shoes.

The marginal "seal" used with floating roofs or decks is never, as far as known, a seal at all, but merely a kind of flexible loose cover for the space between the edge of the roof and the tank wall. (Horizontal flexibility is important because of tank wall irregularities.) These "seals" are never intended to function like the marginal "packing" of a dry gasholder, in which a gas-tight job is essential. Such gas holders, of course, are constructed with precision, so that they are smooth and of uniform shape and size throughout, whereas steel storage tanks are not. Furthermore dry gasholder packings and the shell walls thereof are thoroughly lubricated by a fluid lubricant applied under pressure to provide slip, to make the packing an effective seal against gas, and to prevent corrosion of the holder wall. It is of course possible to construct an oil storage tank on a suitable foundation and with the precision necessary for the use of a packed floating roof, but the cost has always been and is likely always to be prohibitive. The structural materials and foundation used for dry gasholders would obviously be inadequate to withstand the deforming, settling and other effects which would be produced by a substantial column of liquid. Moreover, a "packed" piston put in an oil tank as a buoyant roof, if the tank shell were constructed to take one, would simply convert the "tank" into a combination oil tank and "dry" gasholder in which the piston might never float on the liquid because of the presence of vapor and gas above the oil. Pontoons, of course, would not keep a packed piston "roof" horizontal on gas and vapor.

Oil, such as crude oil, stored in tank farms and around refineries, may not be moved for long periods of time, sometimes for months or a year or more. The same is true for oil products in bulk storage stations and other storage depots. Oil stored for such periods in ordinary tanks, water displacement storage, and tanks provided with present type floating pontoon roofs is subjected to many hazards which can be avoided by the use of the present invention. Oil products in floating roof tanks are obviously contaminated with steel corrosion products, water and other foreign matter deposited in the tank from wind storms and other agencies. Rain water, dust, dirt and tank scale enter such tanks around the roof "seal" because it is merely a loose affair, and because the roof moves up and down with all of the changes in level of liquid in the tank, even with the changes of a few inches caused by the normal thermal expansion and contraction of the oil.

In most cases oil products which are contaminated in storage must be refined before use. For example, fuel oils of the bunker C type may emulsify with rain water to such an extent as to fail to conform to specifications. Finished gasolines and other products may require additional treatment or new supplies of inhibitor, etc., after being contaminated in storage.

The present invention provides an effective and inexpensive method and apparatus by which oils and oil products may be stored under bottle-tight conditions for any desired period of time and be safe from contamination and fire hazards. The invention will be described in conjunction with the accompanying drawing forming a part of this application in which:

Fig. 1 is a broken vertical sectional view of the improved floating roof apparatus illustrating certain features of the invention.

Fig. 2 is a broken sectional view similar to that of Fig. 1 showing a variation in the structure.

Fig. 3 is a vertical sectional view of the improved floating roof and locking ring illustrating the invention in connection with means for supplying gas to the tire and means for stabilizing the ring with respect to the deck.

Fig. 4 is a view similar to that of Fig. 2 showing a modified form of apparatus.

Fig. 5 is a view similar to that of Fig. 1 showing a further modification of the improved floating roof.

Referring to the drawing, the invention will first be described in connection with the showing in Fig. 3 in which the tank for storing volatile liquids such as gasoline and crude petroleum is shown only in part at 2 which is the upper part of the shell of the tank. This tank is provided with a floating roof or deck which includes plate 4 substantially covering the area in the tank and which is surrounded by a deep liquid seal 6 in the form of a channel attached to and extending below and above the plate 4, as shown. The deck plate 4 may be of the usual type used in pan type decks while the portion of the liquid seal 6 extending above the plate will comprise an annular rim to prevent the entry of stored liquid onto the plate. The portion of the seal 6 extending

below the plate 4 will serve to trap a layer of gas or vapors under the deck plate and thereby provide a layer of insulation which will prevent direct transfer of heat from the deck plate to the liquid. The deck including the annular liquid seal 6 is slightly smaller than the tank to provide for irregularities in the tank wall.

The means for closing-in the annular space surrounding the deck proper (the space between the shell 2 and the liquid seal 6), includes a horizontal ring 8 preferably of steel and which may be in any desired form such as a channel iron or an angle iron adapted to keep its shape. This ring 8 is provided with a lower horizontal flange as shown, to which is secured a relatively wide vertical annular plate 10 extending into the liquid in the seal 6 in the manner shown so that any vapor escaping from the liquid between the tank shell and the seal 6 cannot escape except between the shell and the ring 8. In accordance with an important feature of the present invention, means is provided between the ring 8 and the shell 2 for closing-in this space and for locking the ring onto the tank wall, so that it will not move substantially with respect to the shell except under certain conditions. This means in the present showing comprises an annular fluid-tight tire 12 which may be inflated and deflated and which is preferably cemented or otherwise fastened to or gripped against the ring 8 so that upon being inflated sufficiently it will engage and grip the shell 2 very firmly. The tire 12 may be made like a bicycle or automobile tire and may or may not include an inner tube. The tire 12 may include any type of tread adapted to increase its grip on the tank wall.

Since it is desirable to support the weight of the ring 8 and the elements 10 and 12 independently of the deck proper but permit the apron 10 to seal in the liquid in the liquid seal 6, one means for accomplishing this result as shown in Fig. 3 includes a plurality of chains 14 and weights 16, the chains being run over sheaves 18 mounted at the top of the tank shell as illustrated. A sufficient number of the weights 16 are distributed around the circumference of the tank and the ring 8 to more than support the ring 8 and the attachments referred to. But the weights 16 are prevented from pulling the ring 8 entirely away from the deck 4 by providing another series of smaller weights 20 attached to the ring 8 by means of short chains 22 which are attached to brackets 24 on the ring 8. Now assuming that the ring 8 is not locked onto the shell 2 in the position shown, and that the deck 4 is lowered, the relationship of the weights 16 and 20 is such that the weights 20 will pull the ring 8 downward until they again rest or continue to rest on the deck 4. In other words, the normal position of the ring 8 with respect to the deck 4 (when unlocked) is achieved when a part of the mass of the weights 20 is supported by the deck 4.

It will be apparent that when the ring 8 is locked in substantially fixed horizontal position with respect to the shell 2 by inflating the tire 12, that the deck 4 is free to rise or fall in the tank as for example when liquid is introduced or withdrawn, or when the liquid expands or contracts. An arrangement is provided, however, for permitting this movement only to a limited extent in either direction. As soon as the limit is reached the pressure is released in the tire 12 so that the ring 8, together with its attachments, may be brought to its normal position with respect to the deck by either the weights 16 or the weights 20, depending on whether or not the deck proper has been raised or lowered in the tank with respect to the locked ring. This arrangement, including means for inflating the tire 12, may include a source of gas at high pressure, as for example, bottled nitrogen, propane, butane or ethane or other gas contained in a bottle or cylinder 26, from which gas is passed through a pressure reducing valve 28, a line 30, a three-way spring trip valve 32, and a line including a suitable length of hose 34, which connects into the tire 12, as shown. The valve 32 is provided with an outlet pipe 36 which may be vented to the atmosphere through a valved line 38 or into the vapor space under the deck plate 4 through a valved pipe 40. The valve 32 is also provided with a trip lever 41 which is attached to lugs 42 and 44 by short spring sections as shown. The lugs 42 and 44 are fixed to the plate 10.

Assuming that the tire 12 is inflated and that the ring 8 is locked with respect to the shell of the tank, it will be apparent that if sufficient oil is introduced into the tank, the deck 4 will be elevated and the trip lever 41 on the valve 32 will eventually be brought in contact with the lug 42. This, in conjunction with the spring sections attached to the trip lever, will automatically throw the valve 32, cut off the gas supply through the line 30, and release the pressure in the tire 12 by permitting the gas to discharge through the connecting hose 34, valve 32, and the lines 36 and 38. As the tire 12 is deflated and released from its grip on the shell 2, the weights 16 will elevate the ring 8 and its attachments until the chains 22 are taut. If the deck proper is lowered instead of being raised with the tire 12 inflated, the lever 41 will be brought in engagement with the lug 44 and substantially the same action will be repeated, except that the weights 20 will be left entirely supported by the chains 22 as the deck is lowered, and they will pull the ring 8 down after the tire 12 is deflated and the ring 8 is unlocked. When the ring 8 assumes its normal position with respect to the deck 4, the trip lever 41 of the spring trip valve 32 returns to the normal position shown in Fig. 3, under the action of the spring sections, thus permitting gas from the tank 26 to inflate the tire 12 and lock the tire and ring 8 onto the shell wall.

The gas or vapor above the liquid around the seal 6 and the plate 10 will be compressed if the deck rises when the ring 8 is locked, but any excess pressure may be relieved by venting gas through a line 46 and a safety valve 48. Gas may be permitted to pass through a valved line 50 (a part of which is flexible) into the space under the deck plate 4. A valved line 52 is provided between the line 34 and the line 50 so that the tire 12 may be vented under the deck and deflated by hand if desired. The gas pressure under the deck may never be greater than a few inches of water while that in the tire 12 when inflated will be sufficient to cause the tire to firmly grip the tank wall. The proper pressure can be decided upon and governed so that the tank wall will not be over-strained, the pressure being sufficiently high to lock the ring 8 onto the tank wall.

The gas supply and vent line 34 is provided with a safety or relief valve 54 which can be operated by hand to deflate the tire 12 during the filling of the tank or during the withdrawal of liquid therefrom. A hose line for venting purposes may lead from the line 34 or the line 50 to a point outside the tank 2 for venting the tire 12

and unlocking the ring 8. Valve 28, of course, should be closed in these cases. Means may be connected to the lever 41 and lead to a point outside the tank 2 for throwing the valve 32 and venting the tire 12. The hand release or other direct release of the ring 8 during filling and emptying operations may be found particularly desirable, although either of these operations would eventually cause the automatic functioning of the valve 32 as explained above.

A regulator 56 is provided on the line 50 between line 52 and safety valve 48, for maintaining a slight pressure above atmospheric in the space above the liquid around the seal 6. Gas for this purpose may be drawn from tank 26 through line 52 from line 34 with the valve in line 50 closed, or gas or vapor may be taken from below the deck plate 4 (if gas is there) through the line 50 with the valve in line 52 closed. If desired the space may be vented to the atmosphere by opening valve 48 and closing the valves in lines 50 and 52. The tire may be vented through lines 52 and 50 into the space referred to, if desired.

Fig. 1 of the drawing shows a deck and locking ring arrangement similar to that of Fig. 3 but illustrates a different means for regulating the relative movement between the sealing ring and the deck proper. In general this alternative arrangement consists in the use of a plurality of sets of cross connected shock absorber cylinders and plungers. In Fig. 1 the ring 8 is illustrated in connection with a pair of these shock absorbers 58 and 60. Each of these elements includes an upper and lower cylinder 62 and 64 of the same size mounted in vertical alignment and in fixed position with respect to each other by means of a solid frame 66. Each is also provided with a plunger 68 which extends into the cylinders 62 and 64, through packing glands, the plunger being provided with a central lug or lugs 70 held within the yoke of a rod 72 rigidly fixed to the ring 8 and extending horizontally therefrom in the manner shown. The shock absorbers 58 and 60 are fixed to the deck plate 4. The lower cylinder 64 of each pair of shock absorbers or control mechanism is connected through a line 74, provided with a throttle valve, to the opposite upper cylinder 62.

The cylinders 62 and 64, which are provided with plungers of equal displacement, are all filled with oil or some other suitable pressure transmitting fluid when the ring 8 is parallel to the deck 4. It will be apparent that when the ring 8 is locked to the shell 2 by inflating the hose 12, and the deck 4 is raised in the tank, the plungers 68 will be forced into the lower cylinders 64, causing oil to be forced through the lines 74 into opposite cylinders 62. The opposite plungers 68 have the same diameter and displacement so that the quantity of pressure medium forced from the left cylinder 64 into the right cylinder 62 will be the same as that forced from the right cylinder 64 into the left cylinder 62. The arrangement therefore keeps the deck and sealing ring parallel to each other and provides a limiting and cushioning means for controlling the relative movement of the deck and sealing ring.

The functioning of the cylinder and plunger arrangement shown in Fig. 1 may be further explained by assuming that the ring 8 is in locked position and that the deck is moved downward to the point of ring release (by the operation of vent valve 32, Fig. 3). When the ring 8 is released from the tank wall, its weight is transferred to the plungers 68, distributed around the ring, and they force oil from each lower cylinder into a connected upper cylinder on the opposite side of the tank. By restricting the rate of oil flow through the throttle valves in lines 74, the rate of fall can be governed to anything desired.

The cylinders and plungers have another function, which is to keep the ring 8 parallel to the floating deck. Two or more pairs of these units distributed around the deck insure parallel motion because no plungers can move unless the plunger of the opposite connected unit moves to the same extent and in the same direction.

The apparatus shown in Fig. 2 of the drawing is a modified form of deck and clamping or locking ring in which springs are employed for bringing the ring to a normal (intermediate) position with respect to the deck when the ring is not locked with respect to the tank wall. In this figure, the apparatus includes a tank shell 76, and a floating deck 78 provided with a vertical plate 80 which extends both above and below the deck plate so that gas may be trapped below the deck. The plate 80 is welded or otherwise secured to the deck plate 78 in a fluid-tight manner and the projection above the deck plate gives the deck buoyancy.

An annular clamping ring 82 is mounted above the deck, comprising a vertical section and a lower horizontal stiffening flange. An inflatable and deflatable tire 84 is secured to the outside of the ring 82 and is operated in the same manner as the tire 12 described in connection with Fig. 3, the tire being inflated and deflated through a line 85. (The gas supply and other mechanism not being shown in Fig. 2.) The means for enclosing the space between the deck 78 and the tire 84 comprises a flexible gas proof sheet of fabric 86 extending entirely around the deck. One edge of this fabric, which may be coated with any gas-proofing composition, is secured to the top rim of the vertical plate 80, while the other extends around the tire 84 and is preferably cemented or otherwise secured to the upper portion of the tire as shown, or to the ring 82.

A plurality of springs 88 (one only being shown) are distributed around the upper portion of the deck 78 to support the ring 82, tire 84, and the fabric 86, and to cushion the relative movements between the deck and the ring. The springs 88 are preferably fastened to the deck plate and to the horizontal flange of the ring 82 in the manner shown. Assuming that the ring 82 is locked or clamped with respect to the shell 76, and a quantity of oil, for example, is introduced into the tank, the deck 78 will rise and compress the springs to a certain extent. If the deck continues to rise the tire 84 is automatically deflated in the manner described in connection with Fig. 3 so that the ring 82 will be unlocked with respect to the shell 76 and will be moved up from the deck 78 to its normal position by the springs 88. If the procedure is reversed, when the ring 82 is in locked position, and the deck 78 lowered, the springs 88 will expand until the ring is unlocked.

A sufficient width of fabric 86 is provided between the plate 80 and ring 82 to permit the relative movements described above without allowing escape of gas or vapors. In many cases, as for example with the normal expansion and contraction of oil in a tank due to temperature changes, the deck 78 will move up and down the distance necessary to take care of such expansion and con-

traction without causing the ring 82 to be unlocked.

The apparatus illustrated in Fig. 4 includes a tank wall or shell 90, a buoyant pontooned deck 92 provided with a marginal vertical rim plate 94 of substantial width. In this instance, the clamping and gripping ring above the pontoon deck comprises upper and lower plates 96 and 98 bolted or otherwise secured together to form an outside pocket or channel arrangement in which is mounted an inflatable and deflatable tire 100 having an integral extension rib projecting between the plates 96 and 98 as shown. Gas is supplied to and removed from the tire 100 through a line 102. This means for holding the tire on the outside of the ring is very effective since an integral part of the tire structure is assembled between the flanged members 96 and 98.

The means for flexibly connecting the ring to the pontoon deck includes a downwardly extending vertical plate 104 secured in fluid-tight manner to the flanged member 98 and provided at its lower edge with an annular horizontal channel 106 for holding an annular packing ring 108. This packing is supported directly in the horizontal channel 106 and bears against the inside of the plate 94. A spring pusher mechanism 110 is shown for keeping the packing snug against the annular plate 94. A number of these are distributed around the deck. If desired the packing ring 108 may be attached to plate 94 and bear against plate 104.

The deck and ring shown in Fig. 4 is adapted to function in substantially the same manner as that shown in the other figures of the drawing, and the apparatus will obviously include means for supplying gas to the tire 100, and automatic means for releasing the pressure therein. Other elements necessary are the weights shown in Fig. 3 or Fig. 5, the springs of Fig. 2, or equivalent means for stabilizing the locking ring and its attachments with respect to the deck and for bringing it to a normal intermediate position when the ring is not locked with respect to the shell 90.

Fig. 5 shows an apparatus arrangement similar to that shown in Fig. 3 except that the deck is of the pan type which does not permit the accumulation of gas thereunder. The apparatus shown in this figure includes a tank 112, an annular clamping ring 114 of the general type of that shown in Fig. 4, and a deck 116 provided with a deep marginal liquid seal 118. The space between the deck and the ring 114 is enclosed and sealed-in by means of a vertical annular plate 120 secured to the ring 114 and dipping into the liquid in seal 118. The weights shown in Fig. 5 function in exactly the same manner as those shown in Fig. 3. An additional feature shown in Fig. 5 is an enclosing curtain wall 122 secured to the ring 114 and extending down over the liquid seal 118. This curtain prevents dust, water and other foreign material from entering the liquid seal 118. It is to be understood that the clamping ring 114 and its tire grip will be operated and will function in the manner described in connection with Figs. 3 and 4. The floating roof or deck shown in any of the views may be provided with marginal pontoons if desired. The decks of Figs. 1 to 3 can be provided with marginal pontoons under the deck plate so that gas will collect and maintain a layer within the area surrounded by the pontoons. The use of pontoons with these decks will tend to keep them level. Other means for keeping the decks level may be used in connection with the apparatus of the present invention.

The apparatus of the present invention is well suited for underground storage in which the tank may be of steel or of concrete. Water for displacement is not necessary. The floating deck effectively isolates the oil and keeps the oil more free from contamination than a water displacement system would.

The process and apparatus of the present invention are particularly useful in connection with the long time storage of petroleum oil products such as for example in field storage tanks. Under such conditions, it will be apparent that the bottling-up of the oil will have substantially the same effect as if the oil were "canned" or stored in drums, since the oil will be kept free from contamination and substantial loss. The locking-up of the oil in the manner described prevents the escape of the small amount of vapors which normally might be formed and therefore maintains a definite vapor pressure above the liquid which in turn retards or suppresses the formation of additional quantities of vapor. In present floating roof tanks the vapor is always free to diffuse out around the so-called seals and air is breathed in. Oil stored under the conditions described in connection with the present invention, however, cannot go through the breathing operations which take place in connection with oil stored in the usual floating roof tank.

The tire used for bottling-up the oil may include any type of tread adapted to increase the effectiveness of its grip on the tank wall consistent with the formation of a substantially fluid-tight joint. The tire furthermore may be fastened to the outside of the annular ring in any suitable manner so long as it is firmly secured thereto in a fluid-tight manner when inflated. The inflation of the tire when merely set in an annular channel of the ring, effects a tight joint with the ring as well as with the tank wall. While a tire type gripping and locking means is preferred, it is to be understood that other suitable means may be employed to accomplish the same results.

It will be apparent from the foregoing description of the invention, and the various modifications thereof, that a tank provided with a freely floating deck and a relatively movable clamping ring, may be provided with any type of flexible enclosing arrangement between the clamping ring and deck, with any type of stabilizing means for bringing the ring to a normal intermediate position with respect to the deck when the ring is unlocked, and that any suitable means may be employed for keeping the deck and clamping ring parallel with respect to each other. The ring and its attachments is preferably supported substantially free of the deck, as in Fig. 3, but may be partly or entirely supported thereby.

It is to be understood that the liquid seals of the apparatus shown in Figs. 1 and 3 may be provided with a protecting apron or curtain such as the curtain 122 shown in Fig. 5, for preventing water, dirt, dust, etc., from entering these seals. A protecting eave of any kind such as a heavy tarpaulin, which will deflect rain water from running down the inside wall of the tank and direct it onto the floating roof, may be used. Any of the floating roofs may be provided with the usual water drainage lines, not shown.

It is furthermore to be understood that while a specific means is shown for supplying gas to the inflatable and deflatable tire for gripping the tank wall, that other equivalent means may be

provided, and that the source may be outside the tank.

It will be apparent to those skilled in the art that various modifications may be made in the apparatus and in the improved method. Such changes are to be included within the scope of the present invention, as defined by the claims.

Having described the invention in its preferred form, what is claimed as new is:

1. In a cylindrical floating roof storage tank for liquids including an upright cylindrical shell and a buoyant vertically movable roof in the shell, of slightly smaller diameter than the inside diameter of the shell, an improved means for enclosing and locking-up the annular space between the roof and the shell comprising a rigid annular ring mounted above the floating roof and spaced slightly from the shell wall, said roof and ring being vertically movable with respect to each other within an appreciable predetermined range, a clamping and gripping means attached to the ring between the ring and shell wall for locking the ring onto the wall in a fluid-tight manner, means for operating said clamping and gripping means, an expansible and contractible fluid-tight closure means between the ring and the outer portion of the roof, whereby gas and vapors are retained in the annular space between the shell and buoyant roof and said roof is free to move vertically with respect to said ring within said predetermined range when said ring is locked onto said shell wall.

2. In a storage tank as defined by claim 1 in which said clamping means is permanently secured to the outside of said ring and in which automatic means is provided for locking and unlocking said clamping means with respect to said shell, said clamping means being unlocked with respect to said shell in response to a predetermined rise or fall of said roof with respect to said ring.

3. In a cylindrical floating roof storage tank for liquids including an upright cylindrical shell and a buoyant vertically movable roof in the shell, of slightly smaller diameter than the inside diameter of the shell, an improved means for enclosing and locking-up the annular space between the roof and the shell comprising a rigid annular ring mounted above the floating roof and spaced slightly from the shell wall, said roof and ring being vertically movable with respect to each other to a substantial predetermined extent, means for maintaining said ring substantially parallel to the roof, a clamping and gripping means attached to the outside of the ring between it and the shell wall, means for operating said clamping and gripping means to lock it onto said wall, and an expansible and contractible fluid-tight closure means between the ring and the outer portion of the roof.

4. In a cylindrical floating roof storage tank for liquids having an upright cylindrical shell, the combination with a buoyant vertically movable roof in the shell which is of somewhat smaller diameter than that of the shell, of a rigid annular ring mounted near but spaced from the shell wall and above the said roof, said roof and ring being vertically movable with respect to each other to a substantial predetermined degree, an inflatable and deflatable tire mounted on the outside of said ring adjacent the shell wall, means for locking said tire to said wall including means for supplying gas under sufficient pressure to said tire, and a flexible fluid-tight annular closure between the ring and the outer portion of said roof.

5. In a cylindrical floating roof storage tank for liquids which includes an upright cylindrical shell and a buoyant floating roof therein of slightly smaller diameter than that of the inside of the shell, improved means for preventing contamination of the stored liquid by the entry of foreign materials around the edge of the floating roof and for enclosing the space between the roof and the shell, comprising a vertically movable horizontal annular ring spaced above the roof and from the shell, an inflatable and deflatable tire having a peripheral surface grip for closing the space between the ring and shell, the tire being mounted on the periphery of the ring in the annular space between the ring and the shell, said tire being connected to the ring in a fluid-tight manner, said roof and ring being vertically movable with respect to each other to a substantial degree, a vertically expansible and contractible fluid-tight closure between the ring and the margin of the roof, means for locking said tire on said shell including means for inflating said tire, and means responsive to predetermined changes in the volume of the liquid under the roof for deflating said tire and unlocking the ring from the shell.

6. In a cylindrical floating roof storage tank for liquids which includes an upright cylindrical shell and a buoyant floating roof therein of slightly smaller diameter than that of the inside of the shell, improved means for preventing contamination of the stored liquid by the entry of foreign materials around the edge of the floating roof comprising an annular ring substantially parallel to and substantially above the margin of the roof near the tank wall, said roof and ring being vertically movable with respect to each other to a substantial extent, a clamping and gripping means secured to the periphery of the ring in a fluid-tight manner, said clamping and gripping means being adapted to completely close the space between the ring and shell of the tank when expanded, means for expanding said clamping and gripping means including means for locking the ring with respect to the shell to prevent vertical movement thereof, and vertically expansible and contractible means for closing the space between the ring and the margin of the roof.

7. In a floating roof storage tank for liquids having an upright cylindrical shell and a buoyant roof in the shell of slightly smaller diameter and adapted to move up and down in the shell as the volume of liquid therein changes, the combination therewith of a rigid annular ring mounted near but spaced from the shell wall and parallel to and substantially above the roof, said roof and ring being vertically movable with respect to each other to a substantial predetermined extent, an annular locking means mounted between said ring and the shell for locking said ring to the shell, a vertically expansible and contractible fluid-tight annular closure between said ring and the outer portion of said roof, and means responsive to the vertical movement of said roof for unlocking said ring from said shell when the roof moves up or down with respect to said ring to a predetermined maximum extent.

8. In a storage tank for liquids including an upright cylindrical shell, the combination with a floating roof therein of a sealing means for the space between the roof and the shell wall, comprising a rigid ring above the roof having an

external annular locking seal adapted to act on said shell wall, a supporting means for said ring and seal, said ring and roof being movable vertically to an appreciable extent with respect to each other, expansible and contractible means attached to said ring and to said roof to form a closure for the space at the peripheral edge of the roof, thus forming an annular vapor space between said closure and the tank wall, and means for operating said annular locking seal to force said seal outward against said shell wall in locking engagement therewith.

9. In a storage tank as defined by claim 8, in which said supportng means is flexible to permit the relative movement of said ring and roof, and in which said means for operating said locking seal includes means operable by the movement of said roof with respect to said ring for unlocking said seal from the shell wall.

10. In a storage tank as defined by claim 8, in which said locking seal is normally locked to the shell wall, and which includes means operable by the vertical movement of the roof with respect to the locked seal for unlocking the seal from the shell wall.

11. In a storage tank as defined by claim 8, in which automatic means is provided for locking and unlocking said locking seal with respect to said shell wall.

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