United States Patent [19]

Lehanneur

[11] **3,835,654**

[45] **Sept. 17, 1974**

[54] **SUBMERSIBLE TANKS CONTAINING OIL OR SIMILAR LIQUIDS**

[75] Inventor: **Claude J. Lehanneur,** Le Vesinet, France

[73] Assignee: **Campenon Bernard Europe,** Paris, France

[22] Filed: **Sept. 8, 1972**

[21] Appl. No.: **287,237**

[30] **Foreign Application Priority Data**

Sept. 9, 1971 France 71.32557

[52] **U.S. Cl.** .... **61/46.5,** 114/.5 T, 220/13

[51] **Int. Cl.** **B65d 89/06,** B65g 5/00

[58] **Field of Search** .... 61/46, 46.5, .5, 1; 114/.5 T; 220/13

[56] **References Cited**

UNITED STATES PATENTS

3,113,699	12/1963	Crawford et al.	61/46.5 X
3,385,464	5/1968	Courbon	61/46.5 X
3,518,836	7/1970	Itokawa	61/46
3,570,259	3/1971	Thaxton	61/535 X
3,675,427	7/1972	Hix, Jr.	61/.5

FOREIGN PATENTS OR APPLICATIONS

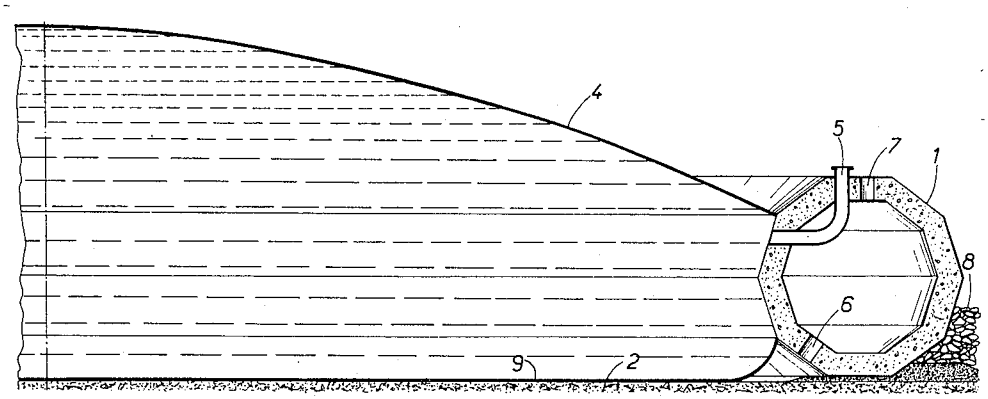
777,644	6/1957	Great Britain	61/.5

Primary Examiner—Jacob Shapiro
Attorney, Agent, or Firm—A. W. Breiner

[57] **ABSTRACT**

Tank for containing oil or a similar liquid, which is immersed in the sea. This tank comprises a ring of tore shape and hollow section, which lies on the ground, and at least one elastic membrane peripherally attached to the ring for delimiting the space where oil is introduced.

15 Claims, 5 Drawing Figures



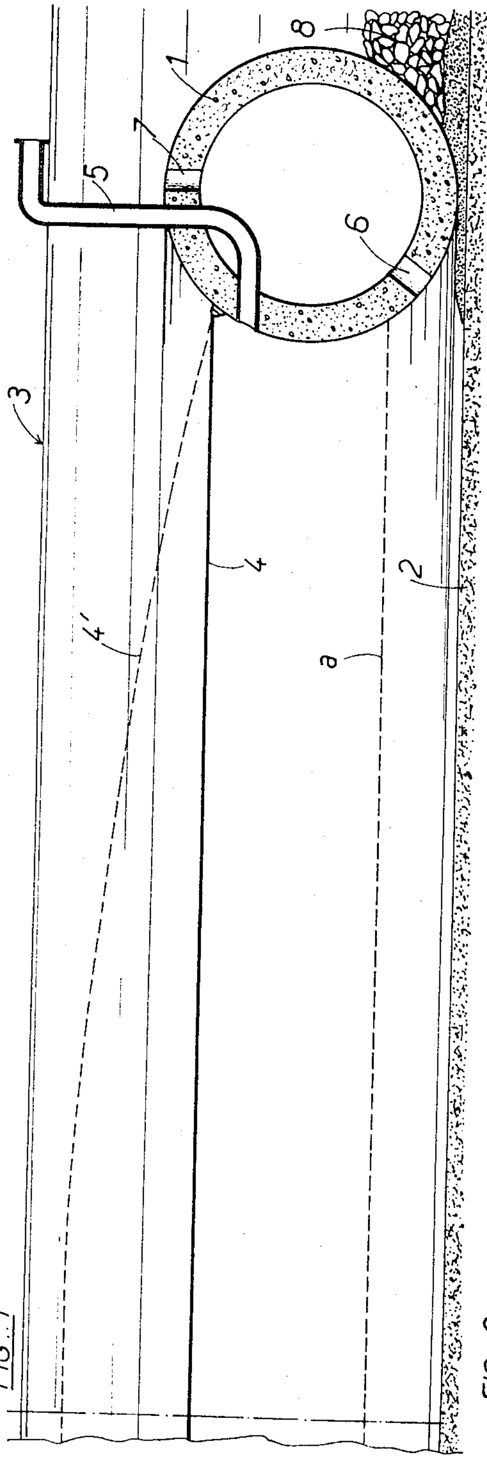


FIG. 1

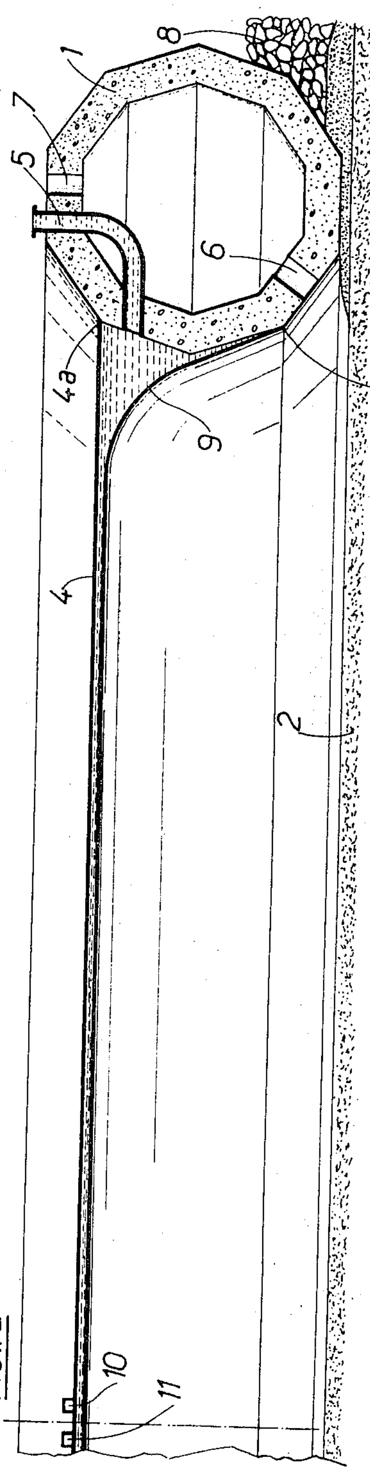


FIG. 2

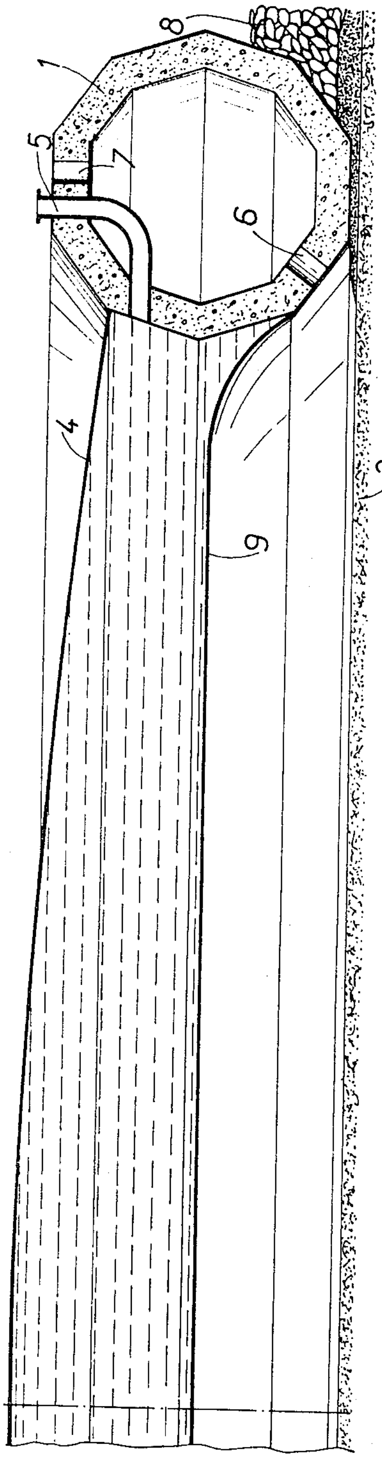


FIG.3

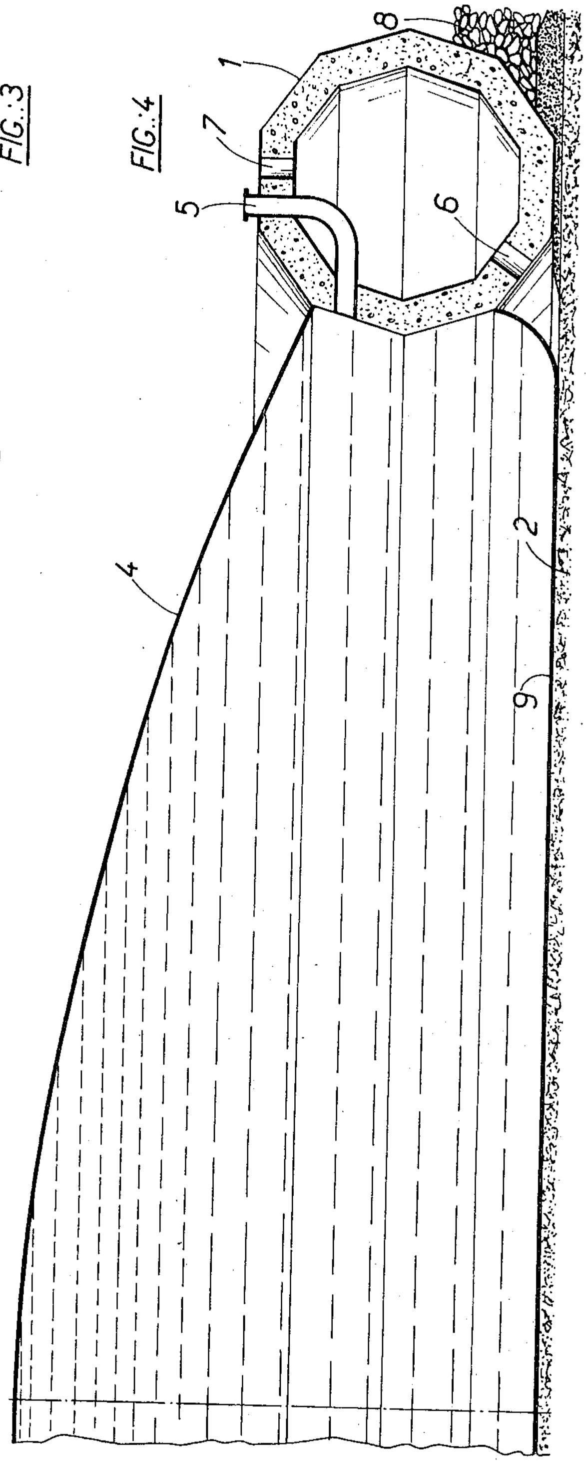
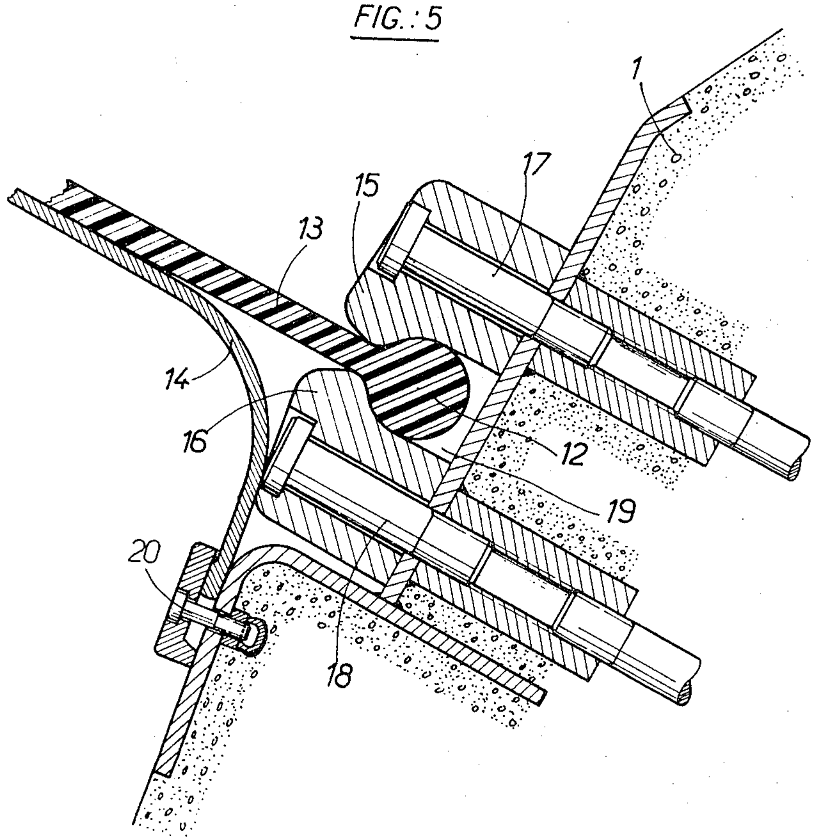


FIG.4

FIG.: 5



SUBMERSIBLE TANKS CONTAINING OIL OR SIMILAR LIQUIDS

This invention, which concerns the storage of liquids, relates more particularly to submersible tanks containing oil or similar liquids. As is known, the construction of such tanks has already been envisaged and put into practice (see, for example, R. S. Chamberlain's article published in the August 1970 issue of "Civil Engineering," pages 57–60).

It should be recalled that the need to construct submersible oil tanks stems from the following facts. Firstly, there now exist offshore oil deposits which are being exploited, and secondly the tendency is to use ever larger "giant" oil tankers which are consequently compelled to remain at a certain distance from the coast.

It is current practice to store oil in tanks located mostly on land. In the case of offshore oil deposits, this operation requires laying long pipelines on the sea-bed to convey the oil to the coast, and in cases where an oil tanker can berth it is necessary to have very large pipes which will enable the ship to be loaded or unloaded in a reasonably short time.

It has therefore been envisaged to provide, in proximity both to the oil extraction point and to the berthing place, one or more submersible oil tanks to serve as intermediate storage facilities. In the former case (location near the extraction point) the oil is continuously extracted and feeds the tank or tanks in succession until they are filled. When an oil tanker arrives it receives its load of oil in a short space of time and, when it reaches its destination, it unloads its cargo of oil into a submerged tank equally rapidly, and this oil is subsequently moved onto land at a comparatively slow rate through small pipes.

The advantage of this method will be manifest. However, the construction of submersible tanks raises many difficulties. In the first place, it must be realized that, for them to be in keeping with the size of modern oil tankers, such tanks, even when several are used together, must have a large capacity of the order of 100,000 to 200,000 m^3, say, which implies a diameter of approximately 100 meters.

It has been proposed to construct such tanks with concrete exclusively, for instance in the form of cylindrical towers.

This concrete must be prestressed and reinforced to be able to withstand the loads produced by currents, swell, storms, etc. The resulting structure, which is built on land entirely, then becomes very heavy and cannot readily be placed in position because its walls of large expanse will not withstand the hydrostatic pressure and prevent a low and constant apparent weight from being imparted to the tank.

An alternative known solution is one of the kind described in the article mentioned in the preamble. It consists in employing a concrete base topped by a metal cap. While this ensures a lighter structure, it is nevertheless necessary to embody stiffening members in the cap since the latter is exposed to pressure variations for the reasons already mentioned and also because of variations in the degree of filling, thereby offsetting the gain in weight to some extent. Here again the walls will not withstand the hydrostatic pressure, and the submerging of such a tank involves costly procedures. Further, special precautions must be taken to

prevent the cap metal from being attacked by sea water.

Lastly — and this applies equally to both solutions — such tanks with non-deformable walls are filled with oil by driving out the sea water contained in the tank and by accepting the existence of a contact surface between the two liquids, which liquids mix to some extent and thus cause pollution of the sea.

It is the object of the present invention to overcome the above drawbacks by providing a new structure for submersible tanks.

Accordingly, in a submersible tank according to this invention, intended for containing oil or a similar liquid and comprising a rigid ring, made of concrete for example, set down horizontally on the sea-bed either directly or indirectly, the upper boundary wall and/or the lower boundary wall of the tank are formed by a fluidtight, flexible and deformable membrane made of an elastic material, sealingly attached along its entire perimeter to said ring. There is thus provided two disc-shaped membranes of low apparent weight, stretched inside the horizontal ring and sealingly attached peripherally thereto and forming the roof and bottom of the tank respectively. The ring, which may be made of concrete, for example, is designed to be set down horizontally in proximity to the sea-bed. It forms the peripheral wall of the tank, its weight balances the vertical component of the tension in the membranes, and its resistance to compression balances, by the arch effect, the horizontal component of the tension in the membrane. It accordingly performs the function of a wall, ballast and frame for the membranes.

It is accordingly possible to obtain a number of advantages, and the following in particular :

— If it is formed by a membrane, the roof of the tank is no longer subjected to the bending moments or compression stresses of conventional roofs but only to tensile forces (due mainly to the buoyancy of the oil); these forces can be withstood by synthetic fibres of low apparent weight and high tensile strength; associated to a conventional fixed bottom, such a deformable roof makes it possible to provide a tank of variable volume functioning by displacement of liquid, without polluting the sea.

— If it is formed by a membrane, the bottom of the tank will allow filling to be effected by displacement of sea water without contact between the oil and the water, hence without pollution; such a tank bottom can be associated to a conventional roof or to a membrane roof according to the invention.

— As in the case of conventional tanks, the ring is heavy and its perimeter large; in contrast, its section is of modest dimension; all the weighty material of the tank is concentrated there, and this material (concrete or metal) stands up well to compression; this means that the ring walls are capable of withstanding the hydrostatic pressure and that a ring filled with air will result in a tank of very low apparent weight, making for an easy submerging operation using the usual facilities; once set down on the sea-bed, the annular space can be filled with water (or sand or concrete) to impart the necessary apparent weight to the system required to oppose the buoyancy of the oil and ensure stability of the tank under the forces exerted by the sea.

The description which follows of three non-limitative exemplary embodiments of the invention, given with reference to the accompanying drawings, will give a clear understanding of how the invention can be carried into practice.

In the drawings :

FIG. **1** is an axial half-sectional view of a first embodiment of a tank according to the invention;

FIG. **2** is an axial half-sectional view of a second possible embodiment of the invention, the tank being empty of oil;

FIGS. **3** and **4** correspondingly depict the same tank as that in FIG. **2**, shown half full and completely full, respectively; and

FIG. **5** shows in radial section a method of fastening the membrane to the base ring of the tank according to the invention.

Reference is first had to FIG. **1** for an illustration of the construction principle of a tank according to the invention. This tank comprises a toroidal ring **1**, made of concrete and resting on the sea-bed **2**, the sea level being shown at **3** above the tank. Attached to the top of the ring is a membrane **4** forming the roof of the tank, which membrane is attached to the entire perimeter of the ring. When the tank is empty, the membrane is stretched as shown in solid lines. The tank further includes a pipe **5** for discharging oil into it, and ports **6** and **7** to facilitate displacement of the sea water.

The ring, complete with its membrane and forming the tank, is towed over the surface of the water to the point where the tank is to be submerged, this being accomplished with the help of buoyancy means, the ports **6** and **7** being sealed off and the ring filled with air. The walls of the ring, which are able to withstand the hydrostatic pressure, permit submersion with a low apparent weight with the help of conventional handling means. The position of the base ring on the sea-bed **2** is consolidated by a circular dyke made of pebbles or by driving piles into the sea-bed to form anchorage points. Once the plugging rods have been removed from the ports **6** and **7**, the tank regains its full weight on the sea-bed.

When the tank is supplied with oil through pipe **5**, using suitable pumping means, the oil drives out the sea water and the flexible and deformable membrane **4** stretches and assumes a shape (**4'** in dash lines) of increasingly bulging profile with increasing amounts of oil entering the tank. It is to be noted that the tensile force exerted radially at the periphery of the membrane, at the points of attachment thereof to the toroidal base ring, varies both in magnitude and direction. The vertical component of the force is balanced by the weight of the ring and the horizontal component is balanced by the arch effect of the ring.

In FIG. **1**, reference letter *a* designates for example the level of the oil filling the space from *a* to **4'**, sea water being present below *a*. The sea water driven out by the pressure of the oil escapes through the ports **6** and **7**.

The membrane is formed with a fabric web of synthetic fibres with a sealing coat of neoprene. The membrane may further embody wire gauze, and it may be made likewise of rubber or similar material. Further reference will be made to the constitution of the membrane in connection with the second form of embodiment of the invention.

As already stated, a drawback of this form of embodiment stems from the contact surface *a*, as a result of which the two liquids (water and oil) mix partly and a small quantity of oil is discharged into the sea each time the tank is filled, even though the filling operation may be monitored with an appropriate gauge. This in turn requires the provision of suitable de-polluting plant nearby.

This requirement is circumvented by providing a tank as shown in FIGS. **2** to **4**, having two membranes both attached to the base ring along their peripheries and receiving the incoming oil between them, after the fashion of a bag.

In FIGS. **2** to **4**, like parts to those in FIG. **1** are designated by like reference numerals or letters, making it unnecessary to describe these parts once more. The upper membrane **4** is attached at **4*a*** to base ring **1**, which in this case has a polygonal (specifically a decagonal), rather than a purely circular, cross-section in order to simplify the concrete coffering. A second membrane **9** is peripherally attached at **9*a*** to one of the lower points (a corner of the cross-sectional polygon) of toroidal ring **1**, as in the case of membrane **4**. This second (lower) membrane is shaped and directed so as to apply itself against the upper membrane when the tank is empty, as shown in FIG. **2**.

At the top of membrane **4**, near the centre, is provided an orifice **10** equipped with a pressure gauge **11** and means for detecting and discharging the gases released by the oil.

FIG. **3** shows the tank half full. In FIG. **4** it is shown as being completely full, with the membrane **9** applied against the seabed **2**. Sea water is discharged through the ports **6** and **7** of the base ring, and it will be appreciated that in the case of this installation the oil is not in contact with the water, thereby obviating the difficulties mentioned precedingly.

For a proper construction of a tank according to this invention, the membrane must have the required composition, structure and shape, with the latter determined primarily as a function of the peripheral attachment method.

In order to provide a 100,000 m^3 tank, it is necessary in practice to use a concrete torus the diameter of whose median circle is 105 m and the diameter of whose generating decagon is about 10.5 m. This being so, each of the two membranes will be shaped at rest as a 96 m disc formed with a peripheral attachment bulge **12** (see FIG. **5**).

Lower membrane **9** forms a flexible and elastic fluid-tight separation between the oil and the sea water, and the tensile stresses therein are negligible. It may be devised in the form of a sheet of neoprene reinforced with a synthetic-fibre cloth, with a total thickness of 8 to 10 mm.

Upper membrane **4** works to a greater extent, being subjected, on the one hand, to the thrust of the oil and, on the other, to the action of the sea (swell, waves, currents, and so on); it must therefore be fairly strong, especially under tension. It is proposed to devise it in two superimposed layers: a layer **13** forming the membrane proper, possessing the required strength and made of nylon, polyester or a like material chosen with a density close to that of sea water and an ultimate elongation of 15 to 25 percent, and another layer **14** to provide fluid-tightness.

When the tank is full, the resulting elongation in membrane **13** is only 3 percent — hence well below the ultimate elongation — and the tensile stress in the fibres is 1,200 kg/cm^2. Having regard for the necessary criss-crossing of the fibres, the required thickness for this membrane is approximately 30 mm.

Beneath membrane **13** is provided the thin (8 mm) layer **14** of fluidtight material such as neoprene.

It will be appreciated that, in any event, the manufacture of such membranes is not unduly costly, especially by comparison with the prior art metal or concrete structures.

Considering next the peripheral attachment of membrane **13,** this is accomplished, as shown in FIG. **5,** by means of metal clips **15, 16** which are secured to ring **1** through the agency of turnbuckles **17** and **18** and in each of which is formed a cavity **19** for restraining the bulge **12** on membrane **13.** On the other hand, the sealing layer **14,** which has virtually no loads to withstand, is merely gripped beneath a clamp secured to the ring by bolts **20.**

Recourse may also be had to a third alternative embodiment which has not been illustrated in the drawings since it can be deduced from the previously described embodiments. This would comprise a tank having a conventional, possibly metallic roof and a bottom membrane similar to the membrane **9** in the second form of embodiment hereinbefore described, for providing flexible and fluidtight separation means between the water and the oil that obviate the pollution mentioned precedingly. Since the tension in the bottom membrane is low, both the ring and the attachment means thereto would need to be far less substantial.

It goes without saying that the invention is by no means limited to the specific embodiments hereinbefore described, but that many changes and substitutions may be made without departing from the scope of the invention.

I claim:

1. Tank for containing oil or a similar liquid to be stored, said tank comprising a toroidal hollow ring of rigid, heavy and resistant material such as concrete, which is adapted to lie on the ground when said tank is immersed within a water environment of sufficient depth; an upper limitation means for retaining the liquid to be stored, said means consisting of a membrane of fluidtight, elastic and deformable material in combination with attachment means for sealingly attaching said membrane around its entire perimeter to said ring and stretching it so as to form a flat disk; and means for introducing said liquid under pressure under said membrane, thereby deforming the same elastically with a bulged form.

2. Tank as claimed in claim **1,** wherein said ring is shaped as a tore having a hollow generating section with a sufficient thickness for sustaining hydrostatic pressure at the location where the tank will be immersed.

3. Tank as claimed in claim **1,** wherein said ring is shaped as a tore having a hollow generating section with a sufficient thickness for sustaining hydrostatic pressure at the location where the tank will be immersed, the interior volume of the hollow tore-shaped ring being also so dimensioned that the apparent weight of the tank is substantially nil when said volume is filled with air.

4. Tank as claimed in claim **2,** wherein the generating section is a polygon.

5. Tank as claimed in claim **2,** wherein the generating section is a decagon.

6. Tank as claimed in claim **1,** wherein said ring has apertures for circulation of water therethrough associated with means for closing said apertures.

7. Tank for containing oil or a similar liquid to be stored, said tank comprising a ring of rigid, heavy and resistant material such as concrete, which is adapted to lie on the ground when said tank is immersed within a water environment of sufficient depth; a first and upper limitation means for retaining the liquid to be stored, said means consisting of a membrane of fluidtight, elastic and deformable material in combination with attachment means for sealingly attaching said membrane around its entire perimeter to said ring and stretching it so as to form a flat disk; a second and lower limitation means for retaining the liquid to be stored and cooperating therefor with said first limitation means and said ring for enclosing the storage space of the tank; and means for introducing said liquid under pressure into said space, thereby deforming the membrane elastically with a bulged form.

8. Tank as claimed in claim **7,** wherein said second limitation means is the ground.

9. Tank as claimed in claim **7,** wherein said second limitation means is a rigid wall.

10. Tank as claimed in claim **7,** wherein said second limitation means has the same structure as the first limitation means.

11. Tank as claimed in claim **7,** wherein said tank comprises a duct for feeding said liquid, said duct passing through said ring and opening under said membrane and above said second limitation means.

12. Tank as claimed in claim **1,** wherein said membrane is formed with a peripheral attachment bulge and wherein said ring comprises conjugate attachment means for retaining said bulge formed at the upper interior side of the ring.

13. Tank as claimed in claim **1,** wherein said membrane includes at least two superimposed sheets, one of which is tension resistive and the other one ensures fluidtightness.

14. Tank as claimed in claim **1,** wherein said membrane includes at least two superimposed sheets, i.e., one in nylon or polyester which is tension resistive and the other in neoprene which is fluidtight.

15. Tank as claimed in claim **7,** wherein said second limitation means is also a membrane, which is made of a neoprene sheet reinforced with a texture of synthetic fibres.

* * * * *