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[54] **METHOD OF SUBMERGING A HOLLOW STRUCTURE**

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[58] **Field of Search**........... 61/46.5, 46, 69; 114/16, 114/16 E, 50, .5 T

[56] **References Cited**

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[57] **ABSTRACT**

A method of submerging a hollow structure in water comprising the steps of inserting in the structure floats which are substantially incompressible and have a density less than unity, progressively filling the structure with water, and then removing the floats at the end of the submersion.

20 Claims, 4 Drawing Figures

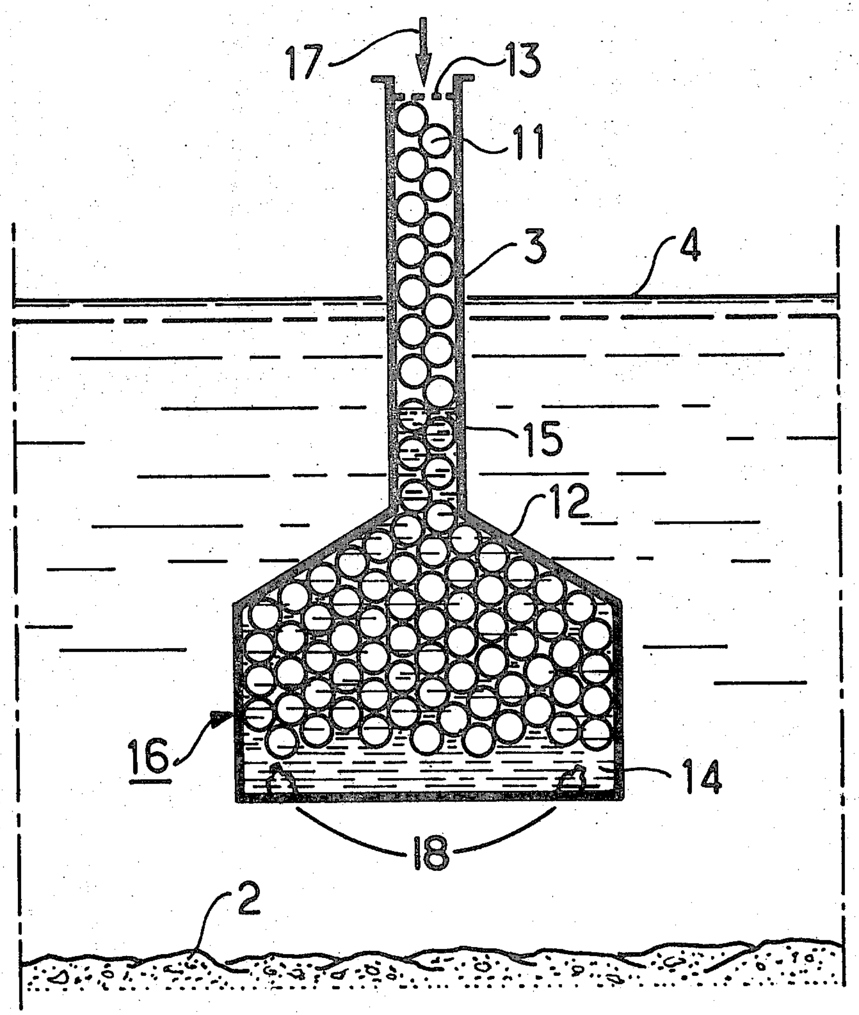


FIG. 1
PRIOR ART

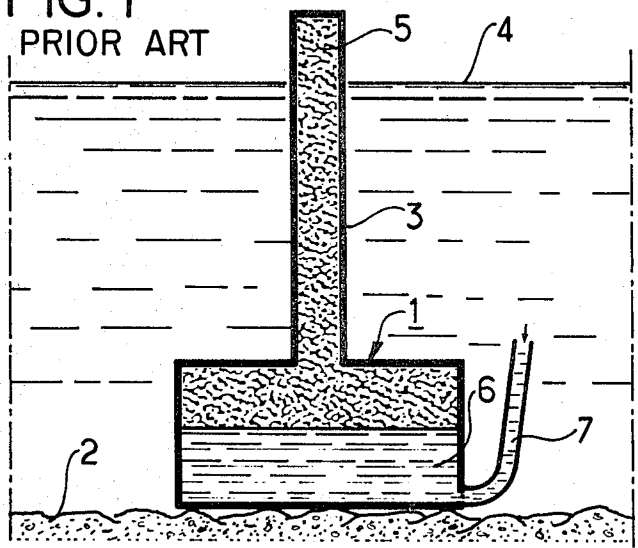


FIG. 2
PRIOR ART

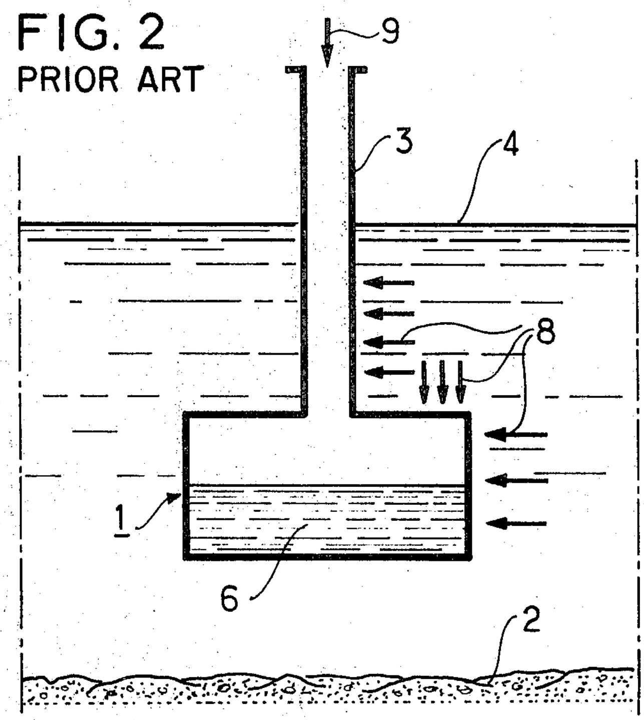


FIG. 3
PRIOR ART

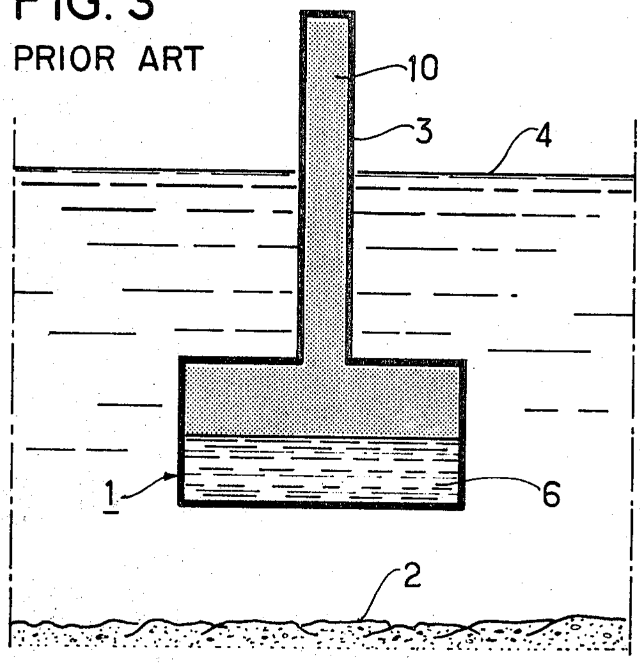
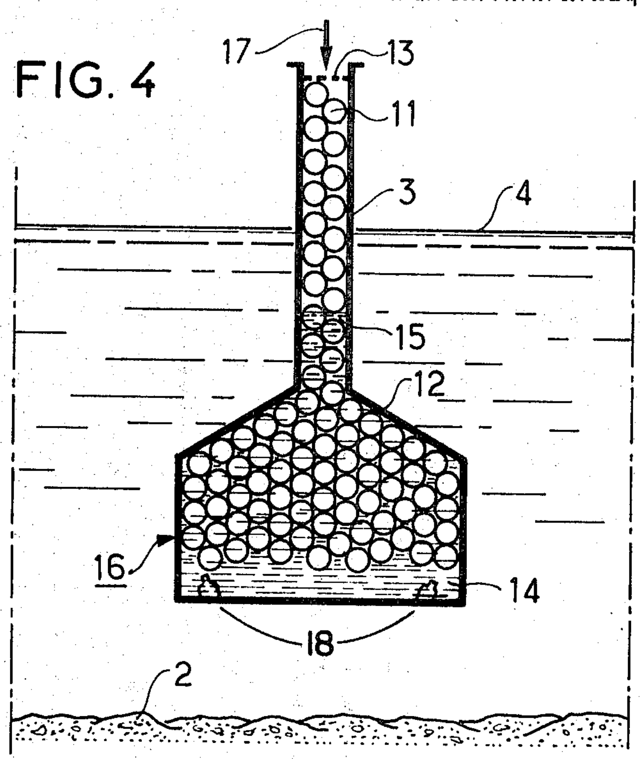


FIG. 4



METHOD OF SUBMERGING A HOLLOW STRUCTURE

The present invention concerns a method for submerging to a great depth a tank having a hollow structure with a ballasting casing whose weight is made to vary by progressively inserting water therein.

It is known that for the storage on the bottom of the sea of liquids, such as raw petroleum, which are not so dense as water and when the depth exceeds a few tens of metres, tanks resting on or moored to the bottom are used. At their base, these tanks communicate with the sea, so that at the bottom of the tank the unbalanced pressure of the liquid is very slight, their walls being subject only to the hydrostatic pressure resulting from the difference in density between the liquid of the tank and the ambient medium.

The submerging of such tanks creates a difficult problem during the lowering, for the weight of the tank must be, at all instants, substantially equal to the weight of the sea water it displaces. Taking into account the great density of the walls, which are made for example, of prestressed concrete, it is then not possible to fill it completely with water; as air remains inside it, it is necessary either for that air to be compressed or for the outer wall of the tank to be strong enough to bear the difference between the external pressure of the sea water and the internal atmospheric pressure, so as to avoid the caving in of the structure.

The object of the present invention is to remove these dangers by filling the tank with elements having low density or floats before the filling of the latter with the water required for submerging it and taking up the space between the said floats. In these conditions, the quantity of air remaining during submerging is very small since the corresponding volume has been filled with slightly deformable floats which, in the case of faulty maneuvering, resist the increase in the ballast of the structure by limiting the volume of water which may enter the tank which can only be submerged slowly. It is sufficient, for that purpose, for the floats then subjected to the pressure of the water column corresponding to the level of the latter in the tank to be sufficiently strong and sufficiently incompressible to remain practically undeformable.

The essential feature of the submerging process according to the invention resides in the fact that float elements having a density less than unity and being substantially incompressible are arranged in the tank during submergence. At the end of submerging, the floats are ordinarily removed.

The design and the advantages of the invention will be better understood from the following non-limiting description, with reference to the drawing, in which:

FIG. 1 is a tank in operation;

FIG. 2 is a tank having strong walls, being submerged;

FIG. 3 is the diagram of a tank having pneumatic counter-pressure during submerging;

FIG. 4 is a tank provided with floats, during submerging, according to the process in the present invention.

In FIG. 1, a tank 1 rests on the bottom of the sea 2, a column 3 rising above it and emerging above the sea level 4. When the tank 1 is in operation, its upper part is filled with petroleum 5 whereas the portion 6 contains sea water. During operation, the petroleum 5 is drawn off by a pipe, not shown, connected to the emerging part of the closed column 3, whereas the sea water enters through the tube 7 permanently communicating with the sea so that the tank 1 remains constantly full of liquid. Conversely, for the filling of the tank 1, the raw petroleum is injected through a pipe, not shown, connecting the tank 1 to a well being worked and rises in the column 3, having a lesser density than that of sea water, whereas the water contained in the tank 1 is discharged through the tube 7 into the sea.

In FIG. 2, the tank 1, during submerging is situated between the sea level 4, from which the opening of the column 3 emerges, and the bottom of the sea 2. For submerging to be possible without caving in, the walls of both the tank and the column 3 must be determined so as to be able to withstand the hydrostatic forces 8 to which they are subjected. The necessary reinforcing of their structures has not been shown in the figure. Submerging is then effected by letting in water in the direction of the arrow 9 and on its arrival on the bottom taking into account its great weight, the tank will not be filled with water, and the wall at the level of the surface of the water inside will be subjected to a definite pressure due to the difference in the water level between the sea level 4 and the level of the surface of the water inside.

Needless to say, for great depths, this difference in levels is very great and a tank having a structure capable of withstanding it, even in prestressed concrete, would cause a prohibitive quantity of extra material. This is particularly true for depths of water greater than a hundred metres. It is, indeed, not economically feasible to reinforce a structure for the submerging operation in these circumstances, particularly since this reinforcing is superfluous for the requirements of its subsequent use.

In FIG. 3, the tank 1 being submerged is closed and compressed air is injected into the space 10 to compensate for the outside hydrostatic pressure to which it is subjected.

The submerging operation then consists in simultaneously (1) injecting water to increase the weight of the tank so as to ensure the submerging thereof until the weight of the sea water it displaces is equalized by a corresponding increase in the submerged volume and of (2) injecting compressed air to compensate for the increase in the hydrostatic pressure at the new depth reached. To obtain that result, a great quantity of equipment must be provided, including compressed air tanks connected with compressors. Moreover, while the tank is liquid-tight, gas-tight sealing is more difficult to obtain, and air leakages must be foreseen. The air replacement required by the leakages may then exceed the means available, particularly when meteorological conditions slow the submerging, and the danger of caving in of the tank resulting from a reduction in the inside pressure increases.

In FIG. 4 the floats 11 are inserted inside the tank 16 whose upper part takes the shape of inclined roofs 12. The slope of the inclined roofs 12 acts as a funnel, enabling the floats to pass easily up the column under the effect of the Archimedean thrust.

The assembly formed by the water and the elements it contains constitutes a medium which is capable of withstanding the pressure and which has a density lower than that of sea water. It then becomes unnecessary to provide walls capable of withstanding a high outside pressure or to compress the inside atmosphere. Taking equal ballasts, the water level inside the tank is high enough to compensate, to a great extent, for the outside hydrostatic pressure. This is due to the fact that only a small amount of water (that required to fill the gap between the submerged floats) is required to obtain the inside pressure which, in the absence of the floats, would only have been obtained by filling the total volume previously occupied by the floats.

The upper part of the column which rises above the tank may be open and in free communication with the outside atmosphere, covered only by a removable closing grid **13**, which allows water and air to pass in the direction **17** but retains the floats **11.** Indeed, the grid **13** may just as well be placed at an intermediate level between the base and the top of the column **3.**

The submerging process is then as follows: the tank is towed, empty or filled with the floats, to the location where it is desired to submerge it. There, the tank having been previously filled with all the floats, the filling with water of the empty space left between these latter is begun. The tank sinks progressively as the water fills it. The adjusting of the quantity of water to be brought in as a function of required depth may be effected simply, taking into account the cross-section of the column, which gives the variation in the submerged volume, and the residual compressibility of the floats, which has the effect of increasing the density of the water-and-floats mixture when the depth increases. In the state of submersion shown in FIG. **4,** the floats **11,** under the effect of the Archimedean thrust, leave free, at the bottom of the tank **16,** a volume **14** of sea water, while the gaps between the floats are filled with water up to the level **15** and the floats situated above are not yet submerged and are pushed against the grid **13** by those already submerged. The tank **16** is therefore now subject only to the hydrostatic pressure resulting from the short distance between the levels **15** and the sea level **4.**

Once the tank **16** rests on the bottom, the floats **11** may be extracted by the opening of the removable grid **13** which retains them at the upper end of the column. The Archimedean thrust is sufficient to drive them out of the tank, on condition that the slope of the latter's roof is suitable to facilitate their upward movement.

Possibly, if need be, a system of nozzles **18** under pressure may be arranged inside the tank **16** to facilitate the driving out of the floats. Since such a tank does not have to withstand high pressure, it need not contain inside compartments and separations such as are required in tanks which have to withstand the great hydrostatic pressures to which they are subjected during their submersion according to the method described in connection with FIG. **2,** and which, by their presence, would resist the driving out of the floats.

Thus, an economy is realized in the means necessary for the submerging operation. Only the floats are required, whereas in methods known up till now, the means were considerable: pneumatic means for the inflated tank method described in connection with FIG. **3** and reinforcement means for the method described in connection with FIG. **2.**

The floats **11** may be constituted by hollow convex bodies, more particularly by spheres whose geometrical shape is particularly well suited to the structure disclosed herein and to the symmetry of the hydrostatic forces to which the bodies immersed in a liquid are subjected. Such hollow spheres may have walls made of a metallic alloy which are thin and cannot be corroded by sea water, or the spheres may be protected with respect to that liquid by an appropriate treatment. The spheres may also be made of plastic, in which case they are similar to the spheres which are used for fishing nets; they may also consist of pieces of cork or of any other substance having low density, such as rigid expanded resin, more particularly, polystyrene. Finally, the hollow spheres may be filled with an appropriately selected gas.

The floats removed from a tank after it has been installed may be recuperated and used again in the case of several tanks to be submerged successively; otherwise, they may be destroyed by any mechanical, physical, or chemical means satisfying non-pollution rules for the environment. In particular, the floats may be removed from inside the tank by dissolving them in place.

Lastly, it should be said that the exemplary methods set forth above have no limiting character and that the protection sought by the present application comprises, in fact, the whole branch of modifications and variants within the scope of knowledge of the man in the art and corresponding to the general definition which has been given thereof.

Thus, that method applies to the submerging of any hollow structure, independent of its shape (for example, not provided with an emerging column) and of its function.

I claim:

1. A method of submerging a hollow structure in water comprising the steps of

1. inserting in the structure a plurality of floats which are substantially incompressible and which have a density less than unity, said plurality of floats being large enough in number so that said floats extend from a first inner wall of said structure to a second inner wall of said structure opposite to said first inner wall in contact with each other and with said walls, said floats being of a shape or shapes which leaves interconnecting volumes between said floats;
2. progressively filling the structure with water while keeping the interior of the hollow structure in communication with the outside atmosphere; and finally
3. removing the floats at the end of the submersion.

2. A method of submerging a hollow structure as claimed in claim **1** wherein the interior of the hollow structure is kept in communication with the outside atmosphere by means of a column which projects above the surface of the water even at the end of the submersion, the hollow structure is formed with a ceiling the slope of which facilitates the passing of the floats, and the column is connected to the hollow structure at the upper part of its ceiling.

3. A method of submerging a hollow structure as claimed in claim **1** wherein said floats are hollow, convex bodies having thin, fluid-tight walls.

4. A method of submerging a hollow structure as claimed in claim **3** wherein said floats are hollow spheres.

5. A method of submerging a hollow structure as claimed in claim 1 wherein said floats have walls made of metal alloy treated to prevent corrosion thereof.

6. A method of submerging a hollow structure as claimed in claim 1 wherein said floats are hollow and are filled with gas.

7. A method of submerging a hollow structure as claimed in claim 1 wherein said floats are made of expanded polystyrene.

8. A method of submerging a hollow structure as claimed in claim 1 wherein said floats are made of cork.

9. A method of submerging a hollow structure in water comprising the steps of:

1. inserting in the structure floats which are substantially incompressible and which have a density less than unity, said plurality of floats being large enough in number so that said floats extend from a first inner wall of said structure to a second inner wall of said structure opposite to said first inner wall in contact with each other and with said walls, and
2. progressively filling the structure with water while keeping the interior of the hollow structure in communication with the outside atmosphere.

10. A method of submerging a hollow structure in water comprising the steps of:

1. inserting in the structure floats which are substantially incompressible and which have a density less than unity, said plurality of floats being large enough in number so that said floats extend from a first inner wall of said structure to a second inner wall of said structure opposite to said first inner wall in contact with each other and with said walls;
2. progressively filling the structure with water while keeping the interior of the hollow structure in communication with the outside atmosphere; and
3. removing the floats from the hollow structure by means including a system of nozzles under pressure located inside the hollow structure.

11. A method of submerging a hollow structure in water comprising the steps of:

1. inserting in the structure floats which are substantially incompressible and which have a density less than unity, said plurality of floats being large enough in number so that said floats extend from a first inner wall of said structure to a second inner wall of said structure opposite to said first inner wall in contact with each other and with said walls;
2. progressively filling the structure with water while keeping the interior of the hollow structure in communication with the outside atmosphere; and
3. removing the floats from the hollow structure by dissolving them in place.

12. Submergible apparatus for storing liquids in a body of water, said apparatus comprising:

1. a hollow tank;
2. a plurality of floats located in the interior of said hollow tank, said plurality of floats being substantially incompressible and having a density less than unity, said plurality of floats furthermore being large enough in number so that said floats extend from a first inner wall of said hollow tank to a second inner wall of said hollow tank opposite to said first inner wall in contact with each other and with said walls, thereby acting as a structural support for said walls;
3. a hollow column connected to said hollow tank and in open communication therewith, said hollow column being long enough to extend from said hollow tank to the surface of the body of water in which the apparatus is intended to be submerged and having an opening on the end thereof remote from said hollow tank which, when the apparatus is in use, permits the interior of said hollow tank to be in communication with the outside atmosphere; and
4. means for removing said floats from the interior of said hollow tank.

13. Submergible apparatus as claimed in claim 12 wherein said hollow tank is formed with a ceiling sloped upward to facilitate the passing of the floats and said hollow column is connected to said hollow tank at the upper part of its ceiling.

14. Submergible apparatus as claimed in claim 12 and further comprising a system of nozzles through which fluid can be jetted to facilitate the removal of said floats.

15. Submergible apparatus as claimed in claim 12 wherein said floats are hollow, convex bodies having thin, fluid-tight walls.

16. Submergible apparatus as claimed in claim 12 wherein said floats are hollow spheres.

17. Submergible apparatus as claimed in claim 12 wherein said floats have walls made of metal alloy treated to prevent corrosion thereof.

18. Submergible apparatus as claimed in claim 12 wherein said floats are hollow and are filled with gas.

19. Submergible apparatus as claimed in claim 12 wherein said floats are made of expanded polystyrene.

20. Submergible apparatus as claimed in claim 12 wherein said floats are made of cork.

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