United States Patent

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[31] 6754/68

[54] **MULTIPLE PURPOSE FLOATING CONCRETE RING**
8 Claims, 22 Drawing Figs.

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[51] **Int. Cl.** **B63b 35/02**
[50] **Field of Search** .... 114/5 R, .5 D, .5 F, 5 T, 65 A, 68, 69, 121, 125, 43.5, 74 R, 74 T, 74 A; 220/9, 13, 15, 85 A; 9/8; 61/1, 5, 46.5, 46

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Assistant Examiner—F. K. Yee
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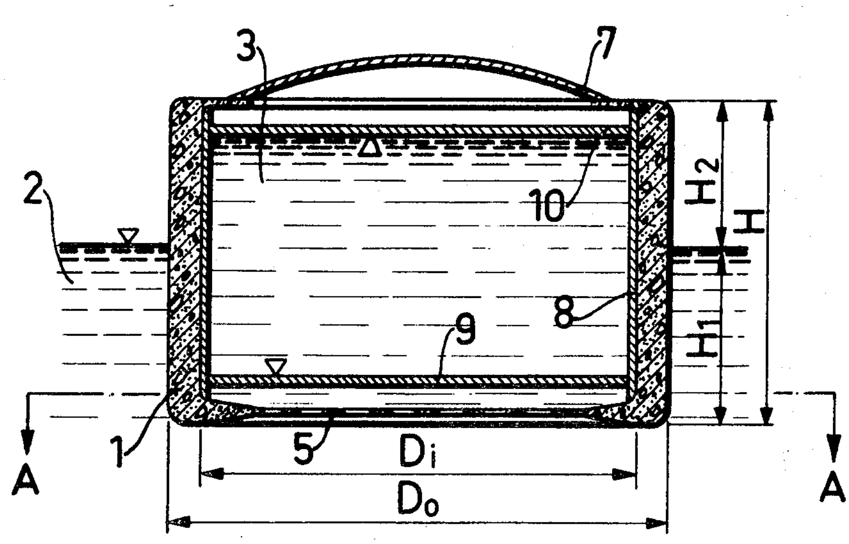
ABSTRACT: A concrete structure usable in water for a large number of various purposes, as for instance for transporting and/or storing liquids having a lower density than that of the water, for protecting a given water surface against wave motions, as a floating or bottom-fixed support foundation for other structures in the water, for mooring other structures floating in the water, etc. includes a cylindrical concrete shell, which is preferably open at both its ends and has a total displacement in the water exceeding its total deadweight and is disposed in the water with its axis of symmetry substantially vertical. The wall structure of the cylindrical concrete shell includes a large number of cells usable as ballast and trim tanks for controlling the attitude and the buoyancy of the concrete shell in the water. The concrete shell or ring can be arranged floating in the water at the water surface or submerged to rest upon the sea bottom with a force determined by the amount of ballast filled into the ballast and trim tanks. When used for transporting and/or storing a liquid having a lower density than that of water, the cargo liquid is disposed in a floating position upon the water in the space enclosed by the cylindrical concrete shell.



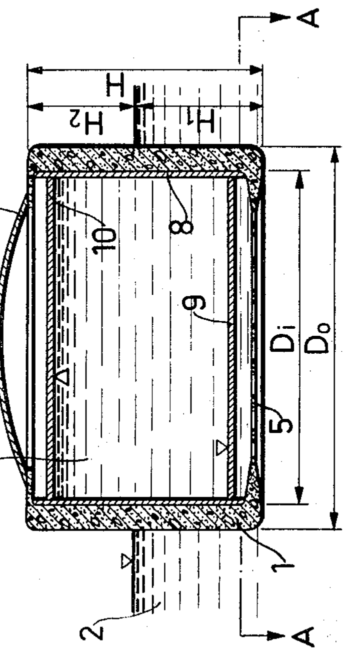


Fig.2a

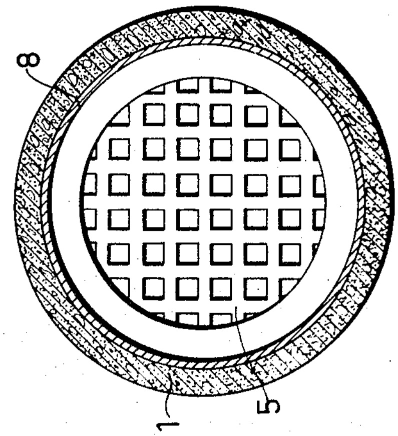


Fig.2b

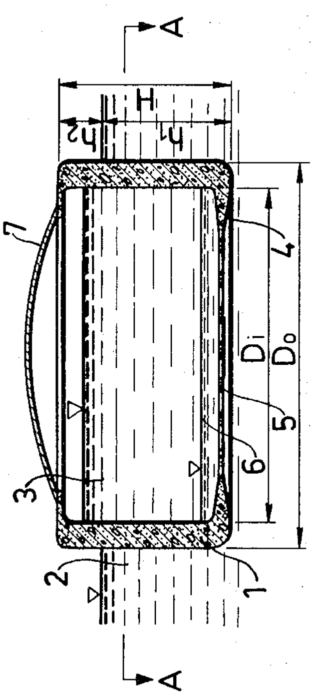


Fig.1a

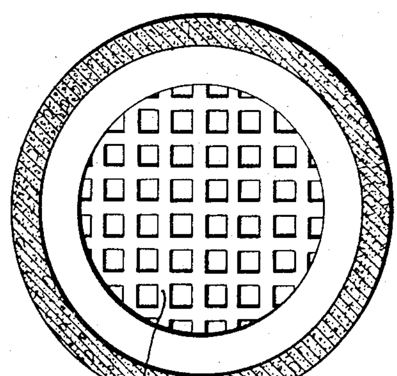


Fig.1b

Fig. 3a

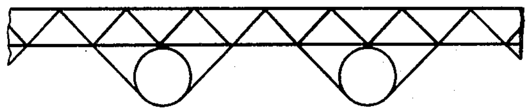


Fig. 3b

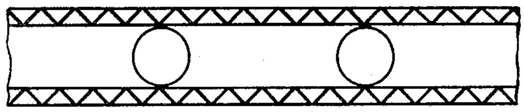


Fig. 3c

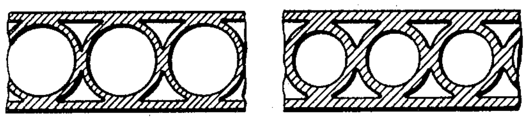


Fig. 3d

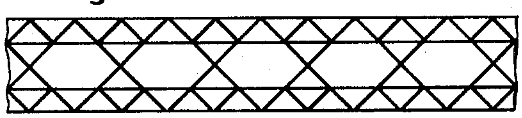


Fig. 3e

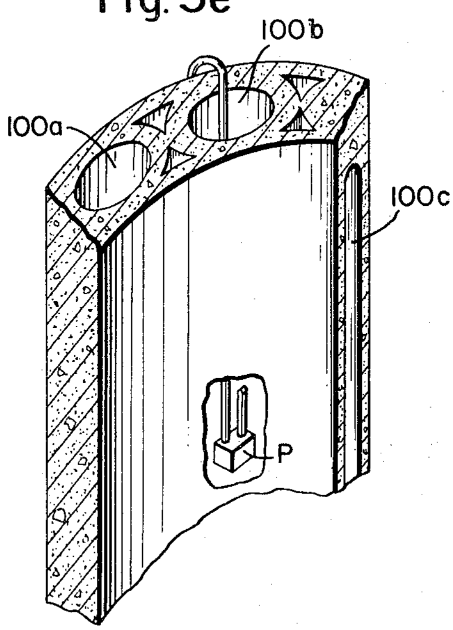


Fig. 4a

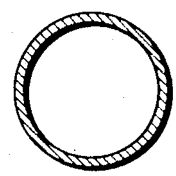


Fig. 4b

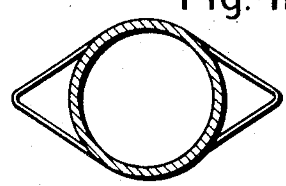


Fig. 4c

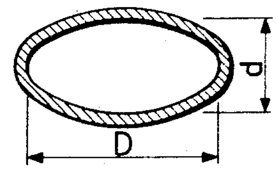


Fig. 4d

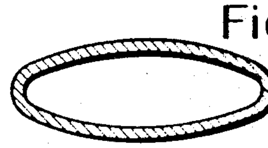


Fig. 5

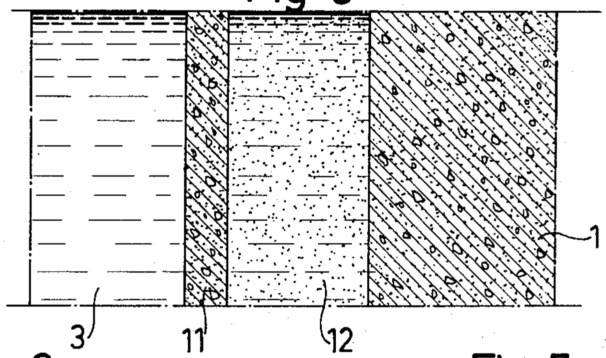


Fig. 6

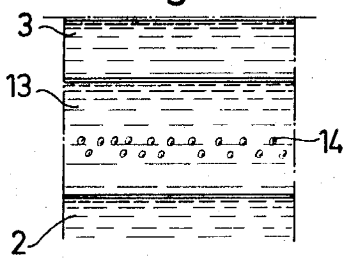


Fig. 7

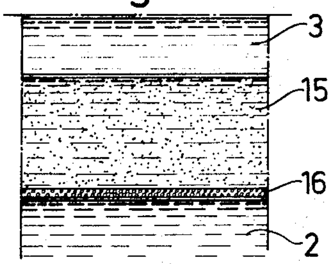


Fig. 8

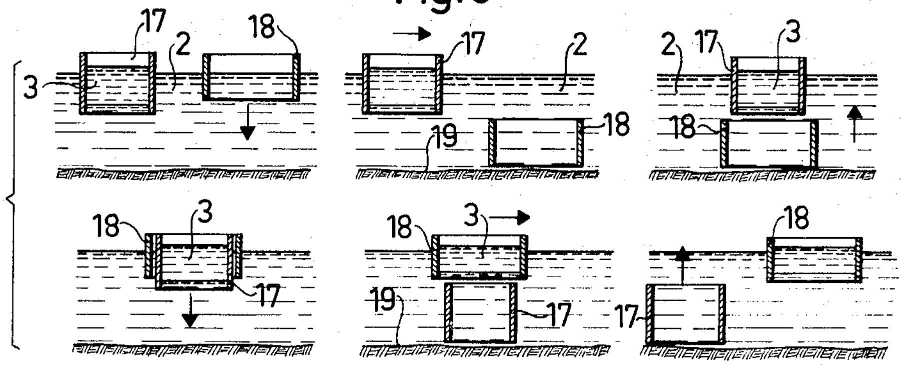


Fig. 9

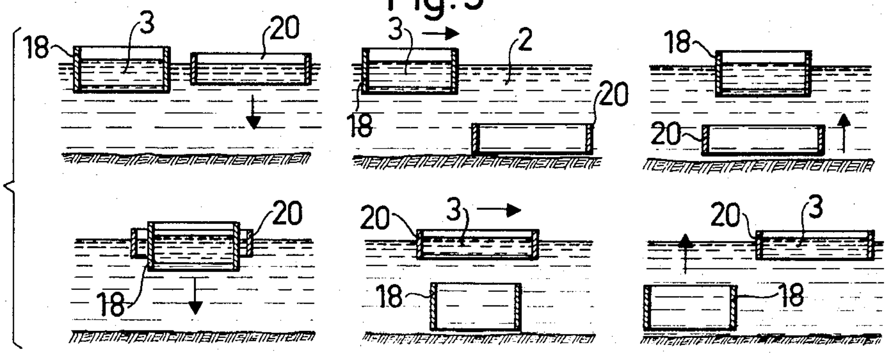


Fig.10

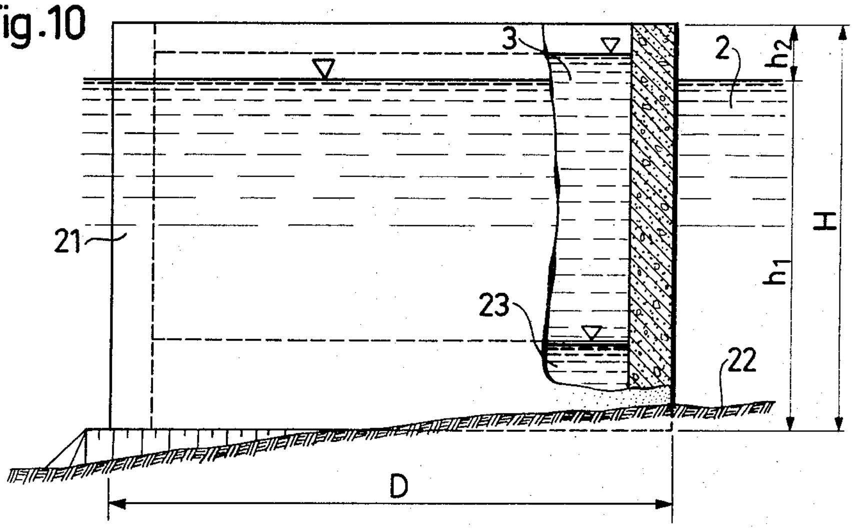


Fig.11

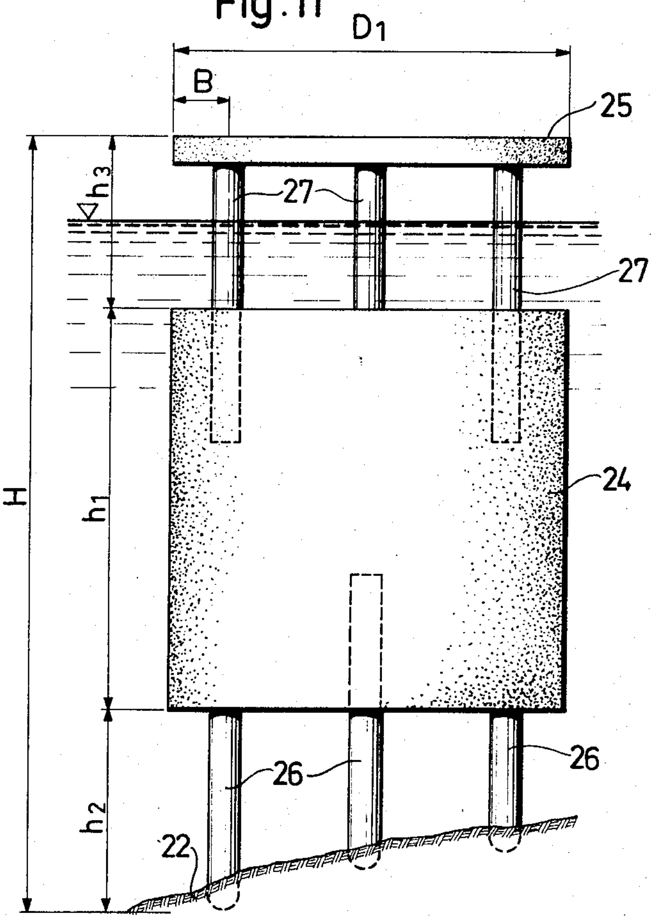


Fig. 12

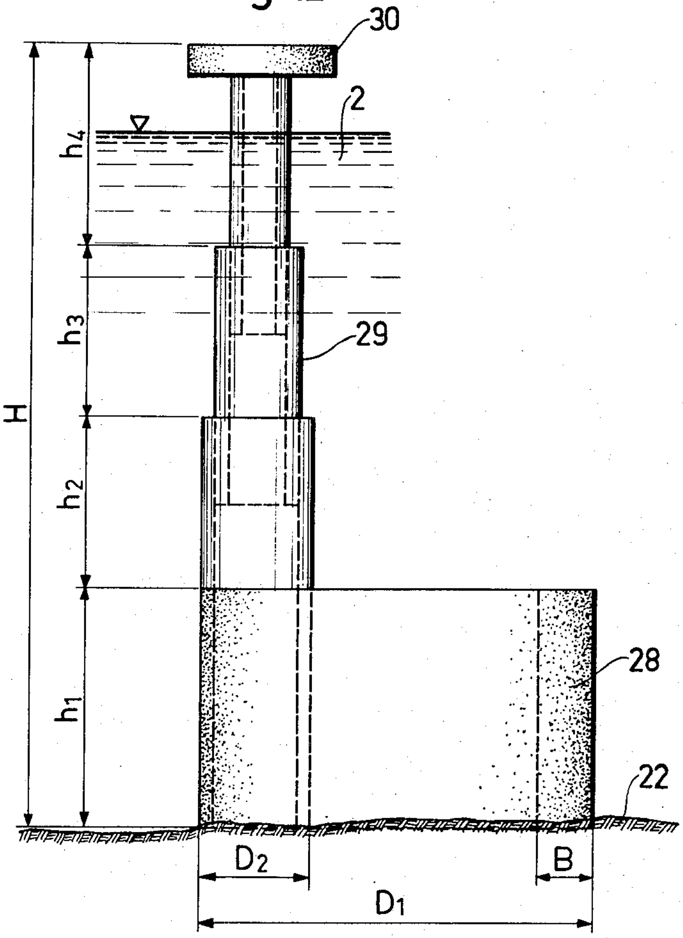
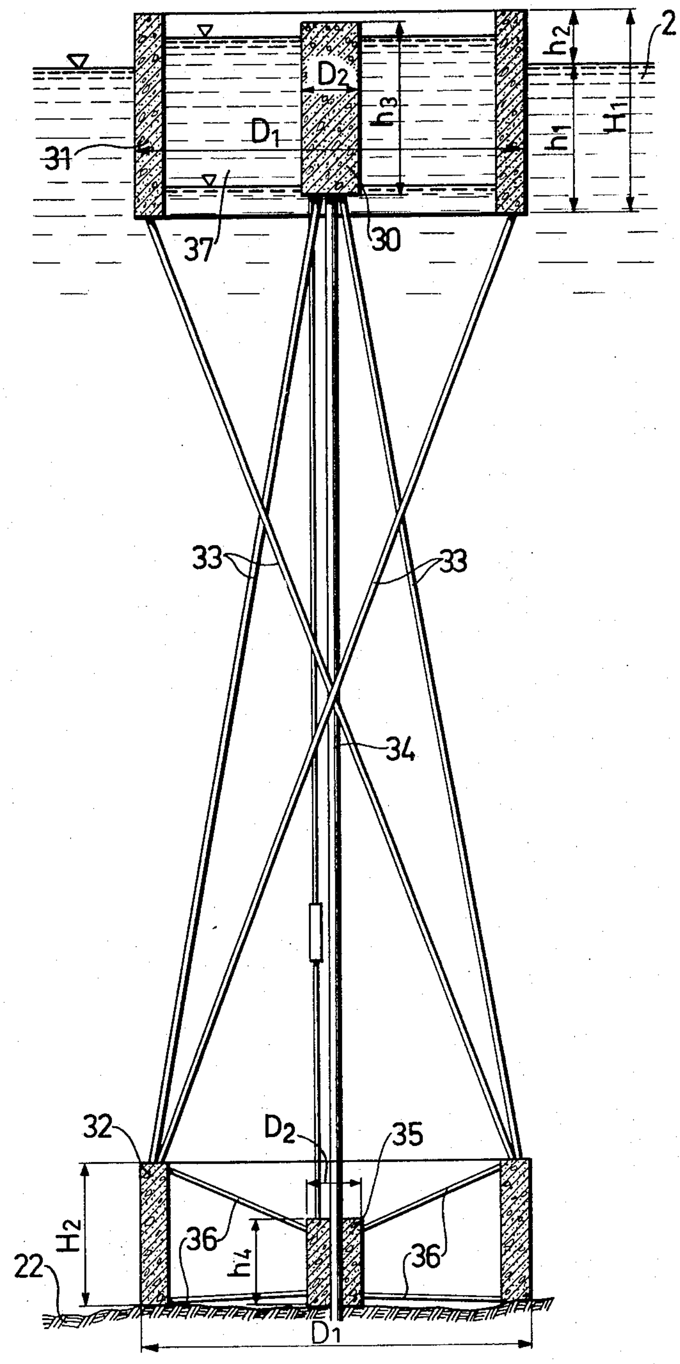


Fig. 13



MULTIPLE PURPOSE FLOATING CONCRETE RING

The present invention relates to concrete structures which may be used in water for a large number of various purposes, as for instance for storing and/or transporting a liquid having a lower density than that of the water, for protecting a water surface against wave motions or similar disturbances, as a floating or bottom-fixed support foundation for other structures in the water, for the mooring of structures floating in the water, etc.

The device according to the invention consists principally of a cylindrical shell of concrete which has a total displacement in the water exceeding its total deadweight and which is disposed in the water with its axis of symmetry substantially vertical. The wall structure of the shell is impermeable and preferably designed as a framework structure with cavities or cells extending in the axial direction of the shell from the one end of the shell to its opposite end and impermeable concrete walls surrounding and separating these cavities or cells. With such a design the concrete shell or ring obtains a very high mechanical strength and resistance to pressures and other forces acting upon the outside of the shell and in spite of this the deadweight of the shell becomes comparatively low. The desired ratio between the total displacement of the shell in the water and its total deadweight so that the shell can float in the water with its axis vertical can be achieved either by designing some of the cavities or cells in the wall structure as sealed, pressuretight cavities serving as float tanks or by including in the concrete in the shell a ballast or filler material with a density lower than that of water, as for instance spheres or grains of polystyrene, or by a combination of these two steps. Preferably a number of the cavities or cells mentioned above spaced around the circumference of the shell are designed so as to be usable as ballast and trim tanks, which may be filled to a desired predetermined extent with a ballast, preferably water or some other liquid, whereby the attitude and the buoyancy of the shell in the surrounding water may be controlled.

A cylindrical or ring-shaped concrete shell of this type may be manufactured in very large dimensions in a manner satisfactory from both an economical and technological point of view by means of the process for fabricating hollow concrete bodies described in detail in the U.S. Pat. specification No. 3,537,268. When using this manufacturing method the above-mentioned cavities or cells in the wall structure of the concrete shell may be used as the ballast spaces required during the manufacturing process for the water ballasting of the concrete body during the casting thereof. In view of the very large dimensions of the cylindrical concrete shells according to the present invention a number of somewhat different embodiments or modifications of the manufacturing process described in said U.S. patent specification may be used. According to one embodiment the cylindrical shell or ring is manufactured in a number of separate sections, each having the shape of a ring sector. Each such section is manufactured by the method described in the above-mentioned U.S. patent specification in that a bottom piece of the section is manufactured on land or in a dock and subsequently launched, whereafter the section is built up vertically from this bottom piece by means of slip form casting simultaneously as the completed portion of the section is lowered in the water in that water is filled into at least some of the cavities or cells in the section. The completed sections are thereafter joined to form the complete cylindrical shell. This joining of several separately manufactured sections may, however, involve certain problems and difficulties. These can be avoided, if the ring-sector-shaped bottom pieces for the various sections of the shell are manufactured on land or in a dock and subsequently launched and thereafter assembled to a complete bottom ring, upon which the cylindrical shell is manufactured by slip form casting by the method described in the above-mentioned U.S. patent specification. The bottom ring assembled by the prefabricated bottom pieces may then be designed either to form an integrating portion of the completed cylindrical shell or to be removable from this and usable for the manufacturing of another cylindrical shell.

It is appreciated that a cylindrical concrete shell according to the invention dimensioned to have a ratio of its diameter to its axial height exceeding about 1.5 will have a very high healing resistance in a floating state in the water or a very large bottom stability if it is sunk to rest on the sea bottom. Preferably the shell is designed to be circularly cylindrical, whereby a maximum healing resistance or bottom stability is obtained independent of the direction of the forces acting upon the shell. However, the shell may also be designed with an elliptical or any similar elongated cross section.

A cylindrical concrete shell according to the invention may be used for a large number of various purposes. A very advantageous application is for instance the transporting and/or storing of liquids having a lower density than that of water, as for instance oil or liquid gas. In this case the cargo, that is the liquid to be stored or transported, is disposed floating upon the water in the space surrounded by the concrete shell so that the interface between water and transported or stored liquid is located close to the lower end of the concrete shell but sufficiently spaced above the lower ring shaped edge of the concrete shell so that no portion of the transported or stored liquid can escape from the space surrounded by the concrete shell. If the liquid is to be transported, the concrete shell and the liquid enclosed thereby may be moved either by towing or by the use of some suitable propulsion machinery attached to or mounted on the concrete shell itself.

A concrete ring according to the invention may also be used in a floating position in the water surface as a breakwater for the protection of the water surface surrounded by the concrete ring against wave motions and similar.

A concrete ring according to the invention may also be used as a floating or bottom-fixed foundation supporting other structures in the water. Upon sinking and resting on the sea bottom, a concrete ring according to the invention can preferably be used for the mooring of structures floating in the water above the ring.

In the following the invention will be further described with reference to the accompanying drawings, which show by way of example a number of embodiments and applications of a concrete ring according to the invention.

In the drawings:

FIG. **1***a* is an axial section of a device according to the invention for transporting and/or storing a liquid having a lower density than that of water;

FIG. **1***b* is a section taken on line A—A in FIG. **1***a*;

FIG. **2***a* is an axial section of a similar device for low-temperature fluids, as for instance liquid gas;

FIG. **2***b* is a section taken on line A—A in FIG. **2***a*;

FIGS. **3***a*–**3***d* show schematically and in cross section a number of embodiments of the wall structure of the concrete shell;

FIG. **3***e* is a perspective view of a portion of a shell;

FIGS. **4***a*–**4***d* show schematic different possible cross sections of a concrete shell according to the invention;

FIG. **5** illustrates schematically in axial section a method of heat insulating the shell wall in a device for transporting or storing low-temperature fluids;

FIGS. **6** and **7** illustrate in axial section two different methods of separating and heat insulating the low-temperature fluid from the water;

FIG. **8** illustrates schematically a method of transferring the cargo to a transport ring for liquid according to the invention from a storing ring according to the invention;

FIG. **9** illustrates in the same way a method for unloading the cargo from a transport ring for liquid according to the invention to a storing ring according to the invention;

FIG. **10** shows schematically a bottom-fixed ring according to the invention for storing a liquid;

FIG. **11** shows a ring according to the invention used as a bottom-fixed support foundation for a so-called offshore platform;

FIG. 12 illustrates how a bottom-fixed ring according to the invention may be used as a foundation and a mooring for a tower; and

FIG. 13 shows how a bottom-fixed ring according to the invention may be used for the mooring of a structure floating in the water above the bottom-fixed ring and also how a ring according to the invention floating in the water surface may be used for the protection of the water surface surrounded by the ring wave motions.

FIGS. *1a* and *1b* illustrate schematically a device according to the invention for transporting and/or storing in water a liquid having a lower density than that of the water. The device consists substantially of a ring or a cylindrical shell **1** of concrete which is designed to have a larger total displacement in the water than its total deadweight and which is disposed in the water **2** with its axis of symmetry vertical. The wall structure of the concrete ring is designed as a framework structure, for instance with some of the cross sections shown in FIGS. *3a–3d*, including a large number of cavities or cells extending axially from one end to the opposite end of the ring and surrounded and separated by impermeable concrete walls. Preferably some of the cavities or cells in the wall structure of the concrete ring are designed as sealed, pressuretight float tanks, whereas other cavities or cells may be open so that they are automatically filled with water to the same height as the water surface outside the ring. Additionally a number of cavities or cells spaced about the circumference of the ring must be designed so as to be usable as ballast and trim tanks, in which a ballast medium, for instance water or the liquid which is stored or transported respectively in the ring, can be filled by means of pumps or the like for controlling the buoyancy and/or the attitude of the ring in the water. The ring can be manufactured from ordinary high-quality reinforced concrete, which whenever necessary may be prestressed with cables. Alternatively, the ring may be made of reinforced lightweight concrete, for instance including polystyrene spheres as a filler and ballast material, which concrete in itself can be made with a density lower than that of the water. Also in this case, however, some of the cavities or cells in the wall structure of the ring must be designed as ballast and trim tanks.

FIG. *3e* shows a portion of the wall of a ring in which cell **100*a*** is open at top and bottom and is filled with water to the same level as the water surface outside the ring. The cell **100*b*** serves as a ballast or trim tank and contains an immersion pump P which communicates with the water outside the ring to selectively adjust the level of the water in cell **100*b*** to control the buoyancy and/or altitude of the ring in the water. A portion of a sealed cell **100*c*** is also seen in FIG. *3e*.

The ring may for instance have some of the various cross section designs shown in FIG. **4**. The circular cylindrical form of the ring is preferable from the point of view of mechanical strength and stability. If the ring is to be used for transporting a liquid, an elliptical or other elongated cross section may be preferable, as they have a lower resistance to movement in the water.

As illustrated in FIG. **1**, the cylindrical concrete shell **1** is in principle open at both its ends. The liquid **3** to be transported or stored is disposed within the ring floating in the water **2**. Consequently, the cargo **3**, as for instance oil, floats on the water surface and is enclosed by the cylindrical concrete shell **1**. For the transport of the cargo **3** the ring **1** may be towed or be provided with its own propulsion machinery. The ring **1** is dimensioned so as to have a very large healing resistance and a period of self-oscillation which is relatively long as compared with the period of the wave motions that may occur in the surrounding water. The stability of the ring **1** may be further improved in that its lower end is provided with an annular internal flange **4**. The ring has such a large axial height H that only insignificant and slow vertical water movements exist at the lower edge of the ring. In order to reduce the vertical water motions at the lower end of the ring still more a thin, flexible, perforated membrane or net **5** may be arranged at the lower end of the ring **1** so as to extend across the opening of the ring. The interface between the cargo **3** and the water may also be stabilized by means of a thin, flexible, preferably resilient membrane **6**, which may be attached to the inside of the concrete shell **1** or be free from the concrete shell. In the latter case the material in this membrane must have a density between the density of the water and that of the cargo **3**. The upper opening of the ring **1** may be closed with a dome or cover **7** of any suitable design, which protects the cargo **7** of any suitable design, which protects the cargo from rain, snow, sprays from waves etc. However, when transporting oil and similar fluids, rain, snow and wave spray does not have any serious effect upon the cargo **3** as the water will sink through the cargo without causing any damage.

The following table gives the main dimensions for some liquid transport rings of various sizes according to the invention.

		Ring I	Ring III	Ring V
H	m.	50	100	100
h_t loaded	m.	30	75	75
h_t empty	m.	20	50	40
D_o	m.	100	200	400
D_i	m.	90	180	370
Shell thickness	m.	5	10	15
Total displ. of shell	$10^6 m.^3$	0.19	1.9	8.1
Cargo volume	$10^6 m.^3$	0.2	2.0	8.5
Deadweight of shell	10^6 kg 30		300	700

FIGS. *2a* and *2b* show a device according to the invention for transporting liquid gas, so-called low-temperature fluid. In general this device is substantially identical to the device shown in FIGS. *1a* and *1b*. In view of the low temperature of the cargo **3**, however, some form of heat insulation is necessary. Thus, in the device shown in FIG. *2a* the inside of the cylindrical concrete shell **1** is provided with a heat-insulating layer, for instance of lightweight concrete. This insulating layer is preferably designed and mounted on the concrete shell **1** so as to be somewhat movable relative to the shell, whereby distortions in the insulating layer **8** caused by temperature variations will not cause mechanical stresses in the concrete shell **1**. For the heat insulation of the cargo **3** relative to the water **2** a disc or plate **9** of heat-insulating material is provided. This heat-insulating plate **9** is axially movable relative to the concrete shell **1** and covers substantially the entire opening of the shell. This heat-insulating plate **9** has a density between the densities of the water and the low-temperature fluid **3**. The disc **9** may for instance consist of lightweight concrete or foam glass. For the heat insulation of the upper surface of the cargo **3** a similar disc **10** is provided of a heat-insulating material having a density lower than that of the low-temperature fluid **3**.

FIG. **5** illustrates schematically another suitable type of heat insulation for the inner surface of the cylindrical concrete shell **1**. In this case a vertical wall **11**, preferably consisting of a cylindrical concrete shell, is arranged within the outer cylindrical concrete shell **1** somewhat spaced from its inner surface so that an annular space is formed between the outer concrete ring **1** and the inner concrete shell **11**, which may be homogeneous and consist of ordinary high-quality concrete. This annular space is open at its lower end so that it is filled with water up to the level of the water surface outside the concrete ring. When the low-temperature fluid **3** is loaded into the device, the water in the annular space **12** freezes and forms an ice layer which acts as a heat insulation. Preferably the inner concrete shell **11** is suspended in the outer concrete ring **1** at the upper edge thereof so that no forces are transferred from the shell **11** directly to the concrete ring **1**. Due to the temperature fall when the cargo is loaded the ring **11** shrinks but at the same time the ice layer in the space **12** expands so that a desired pressure is maintained against the outer side of the shell **11** and the inner side of the concrete ring **1**.

Other types of heat insulation between the cargo **3** and the water are illustrated in FIGS. **6** and **7**. In FIG. **6** the heat insulation consists of an oil layer **13**, the heat-insulating capacity of which is increased by small air bubbles **14**, which have been blown into the oil layer during the loading of the low-temperature fluid **3**, As the viscosity of the oil layer **13** changes due to the temperature fall, the air bubbles **14** eventually become stationary in the oil layer. In FIG. **7** the heat insulation consists of an ice layer **15** between the cargo **3** and the water **2**. This ice layer **15** is separated from the water **2** by a layer **16** of polystyrene spheres or grains.

FIG. **8** illustrates how a transport ring for liquid according to the invention, designed for instance as described in the foregoing, can be loaded from a concrete ring according to the invention used for storing the liquid. In the first step illustrated in the drawing the storage ring **17** is filled with the cargo liquid **3**, whereas the transport ring **18** is empty. Both rings are floating at the surface of the water **2**. At first the trim tanks and ballast tank of the transport ring **18** are filled so that the transport ring is sunk down to the sea bottom **19**, and the storage ring **17** is moved transversely to a position directly above the transport ring **18**, which has a larger diameter than the storage ring **17**. Thereafter the transport ring **18** is raised again to the water surface so that it will enclose the storage ring **17**, which is subsequently sunk to the sea bottom **19** by water filling of its trim and ballast tanks. In this way the cargo **3** has been transferred from the storage ring **17** to the transport ring **18**, which can be used for removing the cargo **3**.

FIG. **9** illustrates in a similar way how the same technique can be used for unloading the liquid cargo **3** of a transport ring **18** into a storage ring **20**. In this case the storage ring **20** must have a larger diameter than the transport ring **18**.

However, it is appreciated that a transport or storage device according to the invention of course can be filled and emptied in any ordinary way by means of pumps or similar device.

FIG. **10** shows schematically by way of example a bottom-fixed device according to the invention for storing a liquid having a lower density than that of water, as for instance oil. The device consists of a concrete ring **21** designed substantially as described in the foregoing. The ballast tanks of the ring are filled, however, to such an extent that the ring **2** rests on the sea bottom **22** with a pressure sufficient for the mooring of the ring **21**. The oil **3** to be stored is enclosed within the ring **21** and floats on a water layer **23** in the bottom of the ring. Also the cells or ballast tanks in the cylindrical concrete shell **21** may in this case be used for storing oil or some other liquid. The standing cylindrical shell **21** may consist of several separate but joined concrete rings, which gives a larger flexibility for the storage plant. The dimensions of a storage plant of this type may for instance be: D=150 m., H=100 m., h_1=75 m., and h_2=25 m.

When necessary the ring **21** may be additionally moored in the sea bottom **22** by means of piles driven into the sea bottom through the cavities in the wall structure of the concrete shell **21**.

FIG. **11** shows a concrete ring **24** according to the invention serving as a support foundation for a so-called offshore platform **25**. The ring **24** rests on the sea bottom **22** with a number of fixed or hydraulic pillars **26** and in the same way the platform **25** is supported from the ring **24** through a number of fixed or hydraulic pillars **27**. The concrete ring **24** is so heavily ballasted that it provides the required mooring pressure for the pillars **26** against the bottom **22**. As the construction has small dimensions at the water surface and adjacent thereto, the forces on the construction caused by wave motions are small. The dimensions of a construction of this type may for instance be: H=150 m., h_1=70 m., h_2=40 m., h_3=40 m., D_1=70 m., and B=10 m.

FIG. **12** illustrates schematically how a large concrete ring **28** according to the invention resting on the sea bottom can be used as a foundation and a bottom anchor for a tower **29**, which in the illustrated embodiment is of a hydraulic type and has an operating or working platform **30** at its upper end. The ring **28** is so heavily ballasted that it rests on the sea bottom **22** with the required mooring pressure. If necessary the bottom ring **28** may be additionally moored by means of piles in the manner described in the foregoing. The tower **29** is cast together with the bottom ring **28** so that the forces acting upon the tower **29** are transferred to the bottom ring **28**. The dimensions of a construction of this type may for instance be: H=130 m., H_1=40 m., h_2=30 m., h_3=30 m., h_4=30 m., D_1=70 m., D_2=20 m., and B=10 m.

FIG. **13** illustrates a plant for oil drilling in the sea bottom, which is constructed by the aid of devices according to the present invention. The drilling platform as such consists of a concrete cylinder **30**, which floats in the water surface and is provided with ballast tanks and trim tanks for controlling the buoyancy of the cylinder and its height above the water surface. This drilling platform is protected against wave motions, currents and wind by a surrounding concrete ring **31** according to the invention floating in the water surface. The drilling platform **30** as well as the protection ring **31** are moored to a concrete ring **32** according to the invention standing on the sea bottom **22**. The ballast tanks of this bottom ring **32** are so heavily ballasted that the ring rests with the required mooring pressure upon the sea bottom **22**. The mooring cables **33** may be prestressed, in that the buoyancy of the ring **31** and the drilling platform **30** is adjusted by the aid of the trim tanks. For the guidance of the drill **34** and for connection, sealing and inspection of the drill hole a bottom cylinder **35** is provided, which is maintained in position by cables **36** connected to the bottom ring **32**. When used for oil well, the oil produced from the well may as indicated in the drawing be temporarily stored in the space **37** inside the ring **31** substantially as described in the foregoing.

The dimensions of a plant of this type may for instance be: D_1=140–250 m., H_1=70–40 m., h_1=50 m., h_2=20 m., D_2=20 m., H_2=50 m., h_3=50 m., and h_4=30 m.

It is obvious that a large number of other embodiments and applications of a device according to the invention are possible.

What is claimed is:

1. A concrete structure for storing and/or transporting in a body of water a liquid having a lower density than said water, for sheltering a restricted area of the surface of a body of water, for serving as a floating or bottom-fixed support foundation in a body of water, or for mooring another structure floating in a body of water respectively, said structure comprising a cylindrical ring of concrete disposed in said body of water with its axis of symmetry substantially vertical, said concrete ring having open opposite axial ends, said ring including a wall structure having a plurality of peripherally spaced, sealed, pressuretight cells extending in the axial direction of the ring between said opposite axial ends thereof, the volume of said cells being such relative to the volume of concrete in said ring that the ring has a maximum displacement in said body of water substantially exceeding the total deadweight of the ring, said ring having at least one further cell extending in the axial direction between the opposite ends serving as ballast and trim tanks with means for filling such cell with water to a variable extent for controlling the attitude, and/or the buoyancy of the concrete ring when floating in the body of water or its pressure against the bottom of the body of water when resting thereon.

2. A concrete structure as claimed in claim **1** comprising a filler material in said concrete ring constituted as spheres and grains of polystyrene having a lower density than that of water.

3. A concrete structure as claimed in claim **1** wherein said cylindrical concrete ring is a right cylinder.

4. A concrete structure as claimed in claim **1** wherein said cylindrical concrete ring has an elliptical cross section.

5. A concrete structure as claimed in claim **1** wherein said concrete ring is floatable in water and includes an annular internal flange at its lower axial end.

6. A concrete structure as claimed in claim **1** wherein said concrete ring is floatable and includes a flexible, perforated membrane attached to the lower axial end of said concrete ring and covering the inner opening thereof.

7. A concrete structure as claimed in claim 1 wherein said concrete ring is floatable and comprises a first disc of heat-insulating material disposed inside said concrete ring so as to be axially movable therein and substantially covering the inner opening of the ring, said first disc having a density lower than that of water and higher than that of said low-temperature fluid, and a second disc of heat-insulating material disposed

inside said concrete ring above said first disc so as to be axially movable therein and substantially covering the inner opening of the ring, said second disc having a density lower than that of said low-temperature fluid.

8. A concrete structure as claimed in claim 7 comprising a heat-insulating layer covering the inside of said concrete ring.

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