United States Patent [19]

Birdy et al.

[11] **3,886,753**

[45] **June 3, 1975**

[54] **SUBMERSIBLE STRUCTURES**

[76] Inventors: **Jal Nariman Birdy,** 61, Summit Rd., Northolt, Middlesex; **Shirley Bowers Stubbs,** 3, Birkdale Rd., Ealing, Longdon, W5, both of England

[22] Filed: **Mar. 28, 1973**

[21] Appl. No.: **345,757**

[30] **Foreign Application Priority Data**

Apr. 4, 1972 United Kingdom............... 15546/72

[52] **U.S. Cl.**....................................... **61/46.5;** 61/50

[51] **Int. Cl.**..... **E02b 17/00;** B65g 5/00; B65d 11/00

[58] **Field of Search**........... 61/46.5, 46, 50; 220/18; 114/.5 T

[56] **References Cited**

UNITED STATES PATENTS

2,938,353	5/1961	Vorenkamp	61/46.5
2,990,796	7/1961	Cole et al.	114/.5 T
3,535,884	10/1970	Chaney	61/46.5
3,592,155	7/1971	Rosenberg	114/.5 T
3,698,198	10/1972	Phelps	61/46.5
3,708,987	1/1973	Roulet	61/46
3,766,583	10/1973	Phelps	114/.5 X
3,793,842	2/1974	Lacroix	61/46.5
3,824,795	7/1974	Mo	61/46.5

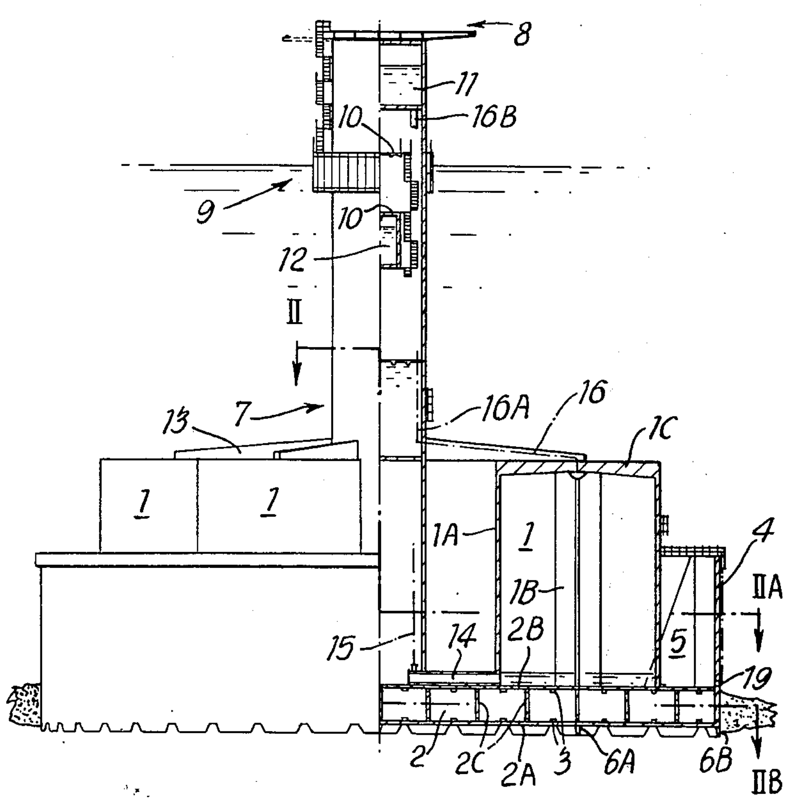
Primary Examiner—Jacob Shapiro

Attorney, Agent, or Firm—Eric H. Waters et al.

[57] **ABSTRACT**

A submersible structure floatable to a desired location and sinkable to rest on the water bed, comprising containers on a base, a perimeter wall on the base, and a column extending from the base to above water level, the containers, wall and column being formed of reinforced concrete.

12 Claims, 9 Drawing Figures



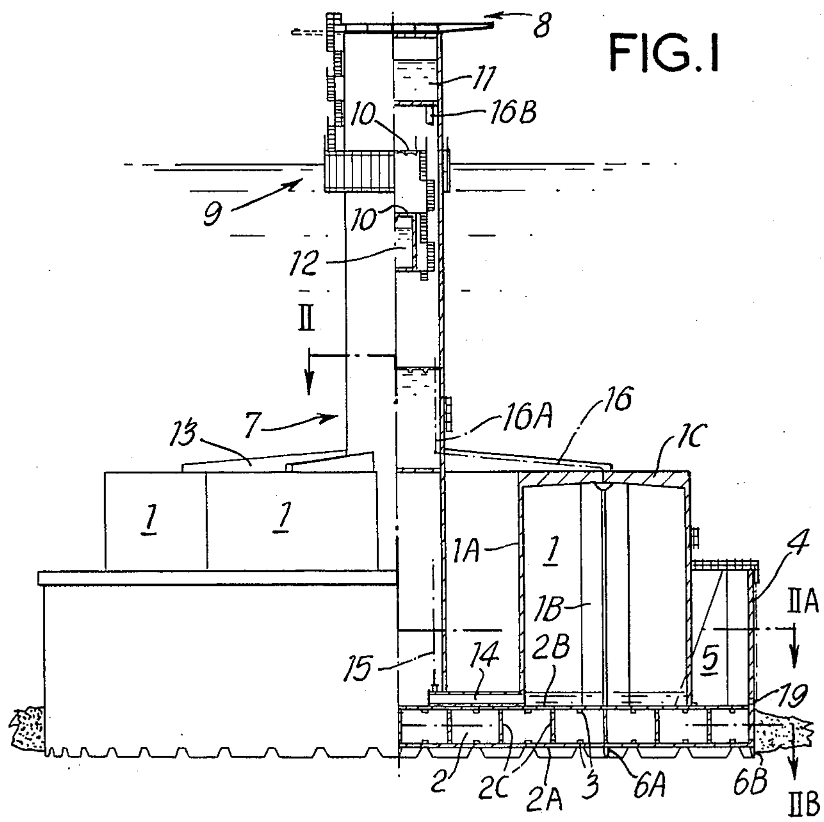

8
11
16B
10
10
9
12
II
7
13
16A
16
1C
1
1
1A
1
1B
4
IIA
5
15
14
2B
19
2
2C
2A
3
6A
6B
IIB

FIG.1

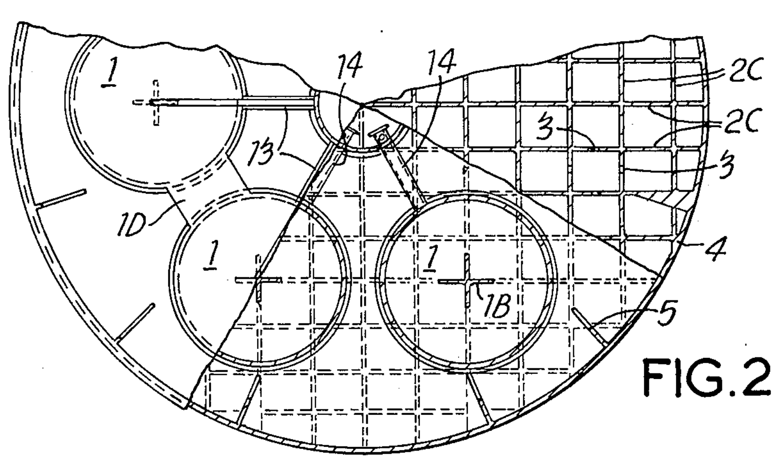

1
14
14
2C
2C
3
3
13
1D
1
1
1B
4
5

FIG.2

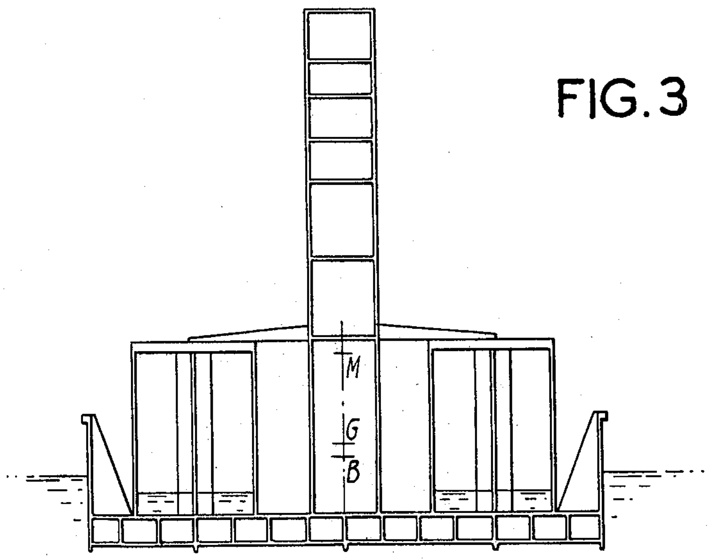


FIG. 3

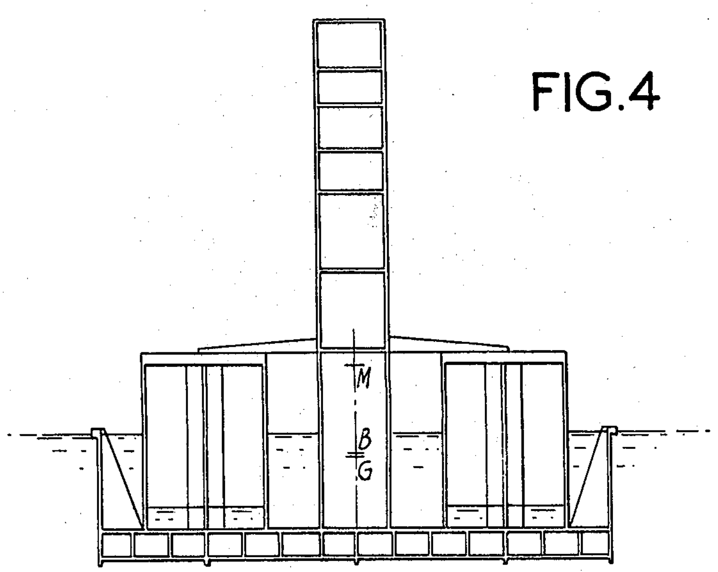


FIG. 4

FIG.5

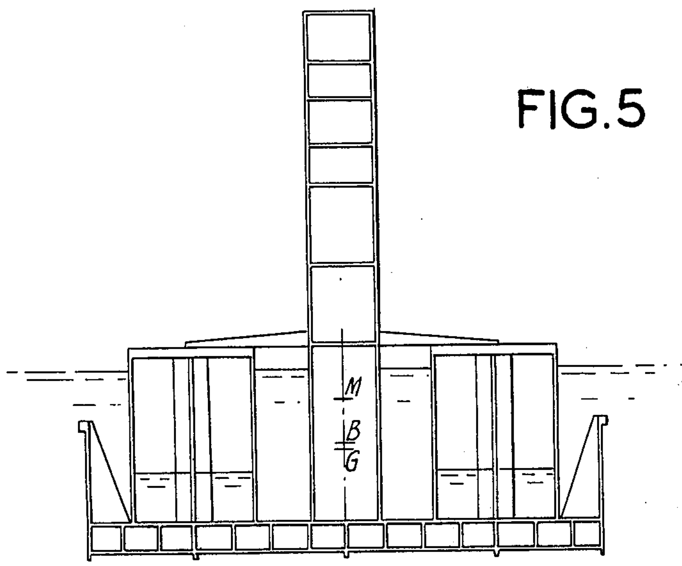


FIG.6

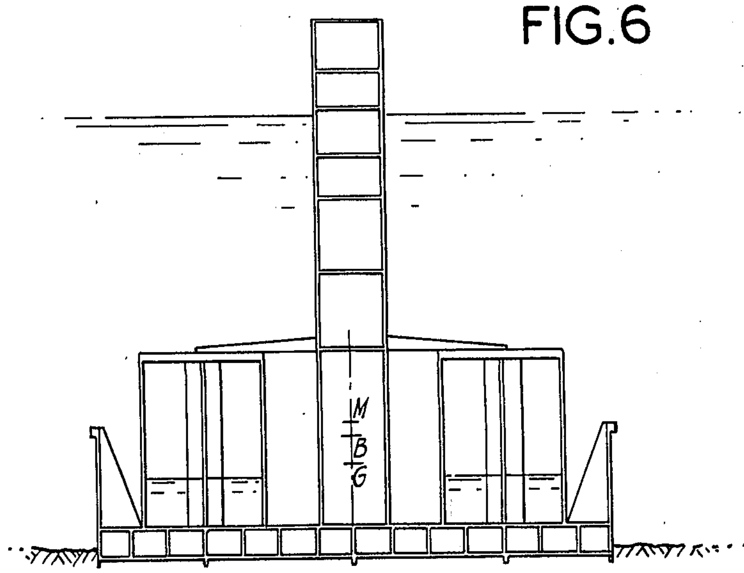


FIG. 7

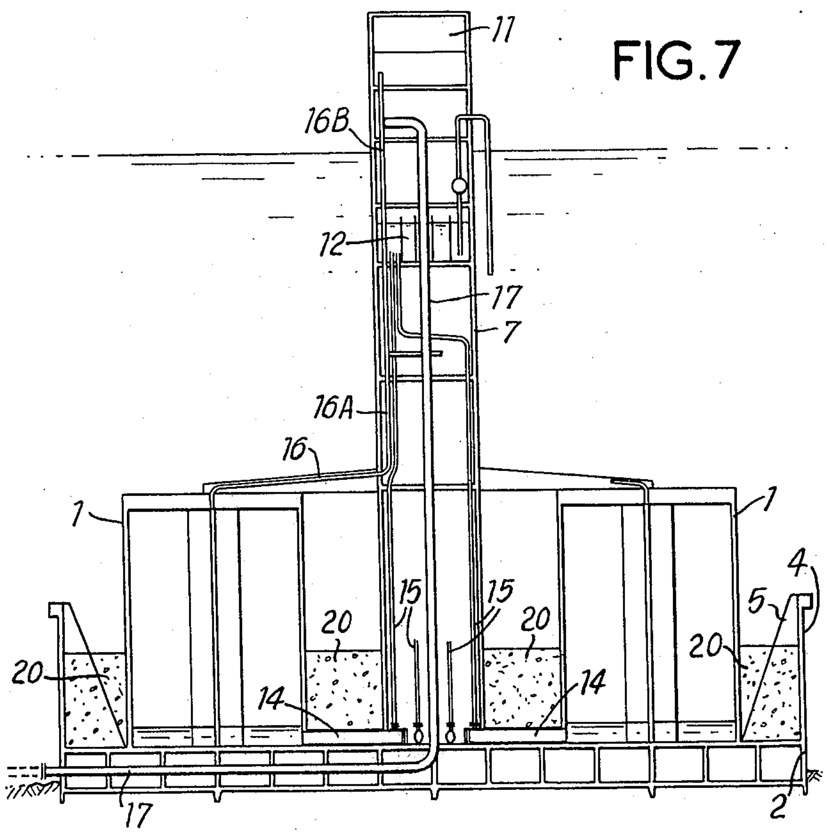


FIG. 8

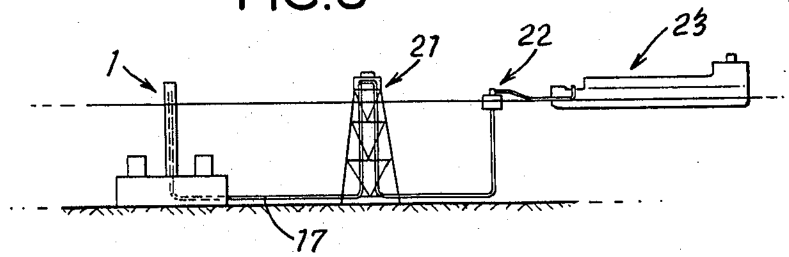
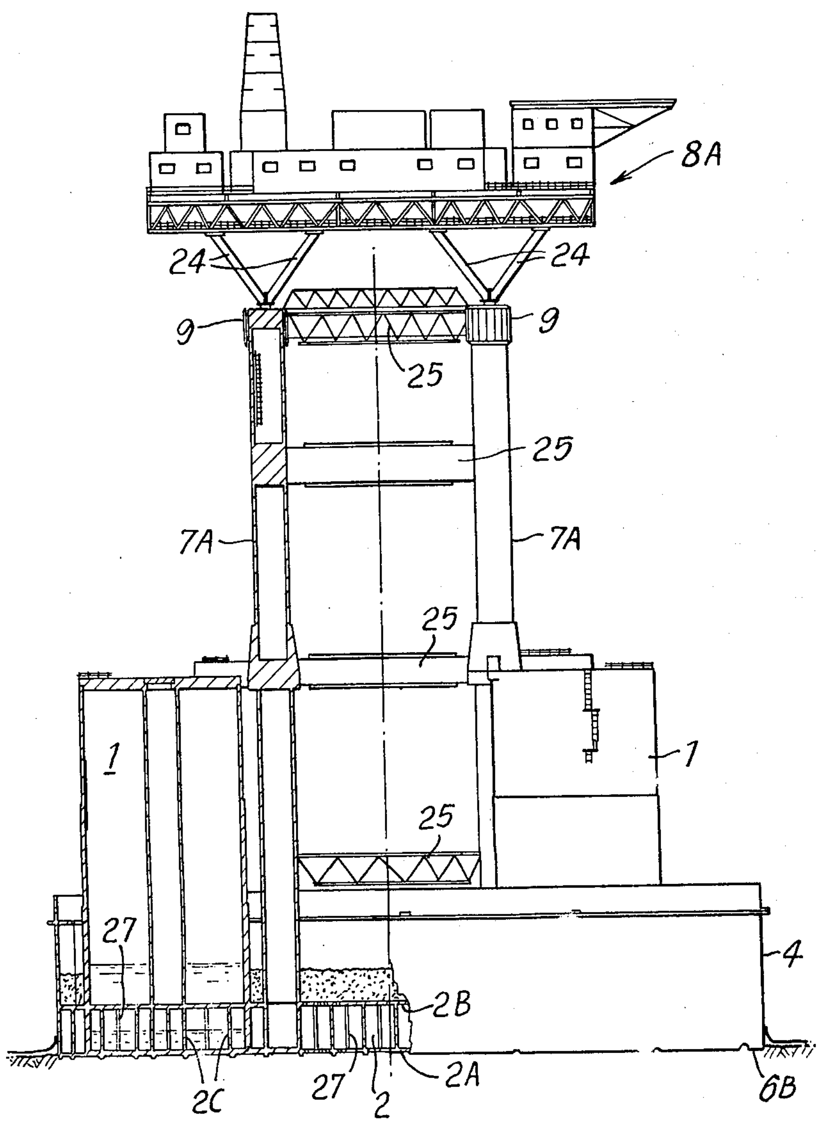


FIG.9



SUBMERSIBLE STRUCTURES

This invention relates to submersible structures and is particularly concerned with such structures that can be utilized as containers for storing fluids, such as oil under water, or as supporting structures for platforms, buildings and/or plants.

According to the present invention there is provided a submersible structure that can be floated to a desired location and then caused to sink so as to rest on the water bed, the structure comprising a plurality of reinforced concrete hollow containers upstanding from a reinforced concrete cellular base, a reinforced concrete perimeter wall also upstanding from the base, and at least one reinforced concrete hollow column extending from the cellular base to above water level in use of the structure, there being valves and ducting extending from the interiors of the containers and the cellular base to services situated inside the column, whereby, from the floating condition, the structure can be caused to sink by supplying ballast water to the space between the containers and the outer perimeter wall, to the interior of the cellular base and to the interiors of the containers, and whereby the structure can be refloated by pumping these zones dry. The reinforced concrete structure can be wholly or partially prestressed.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

FIG. 1 is a diagrammatic side view, half in section, of a reinforced concrete submersible structure that serves as an underwater storage container that can be floated to a desired location and then caused to sink to rest on the water bed,

FIG. 2 is a part plan view showing sectors of the structure taken on the lines II–IIA and II–IIB of FIG. 1,

FIGS. 3 to 6 illustrate how the structure of FIGS. 1 and 2 is caused to sink from a floating condition to rest on the water bed,

FIG. 7 illustrates how the structure is operated whilst resting on the water bed,

FIG. 8 is a schematic illustration of an installation including the structure of FIGS. 1 to 7, and

FIG. 9 is a diagrammatic side view, partly in section, of another form of structure.

The structure shown in the Figures has a container part made up of six short hollow reinforced concrete cylindrical containers **1** which may be prestressed if required. Each of these containers has an outer cylindrical wall **1A** and a central column **1B** which in the form illustrated is of cruciform section. The column **1B** can, of course, be of other section, for example annular. The column **1B** supports a top slab **1C**. The top slabs **1C** of the containers **1** are interconnected by a horizontal ring beam **1D**.

The cylindrical containers **1** are supported on a cellular reinforced concrete or prestressed concrete raft base **2** made up of a lower slab **2A**, an upper slab **2B** and vertical walls **2C** extending at right angles to each other, these walls **2C** connecting the upper and lower slabs whereby the interior of the raft is divided into individual cells. These individual cells are interconnected by bores **3** to enable ballast water to flow from one cell to another, as required, or to allow the cells to be emptied of water by pumping, the diamter of the bores being such as to limit the flow so as to preserve adequate stability during motion at sea. Some of the walls **2C** extend below the lower slab **2A** to form keys **6A**. The lower slab **2A** may be flat on the underside or may be shaped to provide specific bearing areas in the form of pads or inverted shallow domes, depending upon the nature of the water bed.

The raft base **2** is surrounded by a reinforced concrete perimeter wall **4** partly cantilevering from the raft base and also supported at intervals by counterforts **5.** This wall **4** is also extended below the lower slab **2A** of the raft to form a key **6B** around the perimeter. The keys **6A** and **6B** may be of castellated form as illustrated, depending upon the nature of the water bed.

In the form of FIGS. **1** to **8,** a single, central, reinforced concrete or prestressed concrete hollow cylindrical column **7** extends from the top of the raft base **2** and supports a platform **8** that can serve for helicopter landings and other purposes, at a level that is above, with the structure resting on the water bed, the highest anticipated water level at which the structure is to be operated, fenders **9** (at a level to extend from below to above the anticipated greatest range of tides), platforms or decks for plant and machinery **10,** a surge tank **11** for oil, and an oil separator chamber **12.** In the form illustrated the column **7** is supported by spokes **13** radiating to the tops of the containers **1** but these can be omitted.

Ducts **14** connect the bottom of each container **1** to riser ducts **15,** within the column **7,** that connect the ducts **14** to a first manifold (not shown) connected to the separator chamber **12** by further ducts. Further ducts **16** extending through the radial spokes **13** connect the tops of the containers **1,** via further riser ducts **16A** within the column **7** and connected to a second manifold (also not shown), to the oil surge tank **11** this second manifold being connected to the tank **11** by a duct **16B.** An oil inlet pipe **17** (FIG. **7**) extending from outside the perimeter of the structure at its base to the foot of the column **7** and up the column **7** is connected to the duct **16B** above the second manifold.

The particular structure shown will stand where the highest anticipated water level is approximately 85 metres above the water bed, and has a storage capacity of 500,000 barrels of crude oil. The overall diameter of the raft base **2** is 103 metres, and the height of the cylinders **1** is 38.5 metres above the water bed. It will be appreciated that these dimensions relate to this one example only, and alternative dimensions can be selected as desired.

The structure can be conveniently constructed in two stages, or alternatively it may be constructed completely in one stage in a deeper cofferdam. The first stage of construction can be completed in a shallow dyked basin or cofferdam where the raft base **2** and part of the perimeter wall **4** are built utilizing conventional reinforced and prestressed concrete techniques. The partly-built structure can then be floated by flooding the basin with water and subsequently the partly-built structure may be towed to a sheltered deeper water site. Conventional reinforced and prestressed concrete techniques may then be used to complete the structure, save for parts such as the helicopter landing platform, working platforms and other ancillary parts, in this location whilst afloat.

The thus-completed structure is trimmed as necessary for verticality by ballasting the individual containers **1** with water as necessary to place the structure in the condition illustrated in FIG. **3**, in which Figure (and throughout FIGS. **4** to **6**) G indicates the centre of gravity of the structure, B indicates its centre of buoyancy and M its metacentre.

In the condition of FIG. **3**, the structure is stable and can be towed along a prepared channel into deeper water and thence to its intended operational location. To this end, towing pads can be provided at appropriate locations on the tops of the containers **1**. Once the intended operational location is reached, submerging can commence under control of the towing craft. The first stage in the submerging operation is to allow ballast water to enter the space above the raft base **2** between the containers **1** and the perimeter wall **4**. Alternatively, and dependent upon the design, water may be allowed to enter the base raft cells completely before being admitted to the upper tray, via holes or perforations in the upper slab. This is effected by operating valves **19** disposed at the base of the perimeter wall **4** and operable from the top of this wall. When this stage has been completed the structure is in the condition shown in FIG. **4**. It may be noted that for this example FIG. **4** has been drawn showing the water levels equal on either side of the perimeter wall. In other cases it may be more convenient to allow the water externally to overtop the wall before the water internally has risen thus far. The second stage in the submerging procedure is to allow ballast water to enter the spaces inside the cellular raft base **2**. This is effected by operating valves (not shown) in the bases of these containers and operable from the tops of the containers or elsewhere, vent lines (not shown) being provided to allow air to escape during ballasting. When this is completed the structure is in the condition illustrated in FIG. **5**. The final stage in the submerging procedure is to open valves (not shown) to allow water to enter the containers **1** (vented via the ducts **16**) to ballast the structure until the structure comes to rest on the water bed, as illustrated in FIG. **6**. Throughout the submerging operation the structure is always under control and can be brought to the surface at any time by reversing the entire process and pumping out ballast water via pumps (not shown) connected to ducting (also not shown). These pumps can be those that are installed permanently, or only temporarily whilst submerging or re-floating is being carried out.

After the structure has reached the water bed the containers **1** are entirely filled with water to give negative buoyancy to the structure and allow the raft base **2** to bite into the water bed. The central column may be maintained dry if required for suitable plant environment.

Sand ballast **20** (FIG. **7**) may then be introduced if necessary in the space above the raft base **2** between the containers **1** and the perimeter wall **4** to make the structure safe against disturbing forces caused by the environment in which it is to operate. The working platforms, helicopter landing platform and other ancillary work (not shown in FIG. **7**, in which Figure other parts have also been omitted or shown diagrammatically) are then completed and the structure made ready to receive crude oil for storage.

It will be appreciated that a detailed sea bed exploration has to be undertaken since a reasonably level area is required in order that the structure does not rest at a very large angle of tilt, although there can be provision for adjustment of the levels of the working platforms, helicopter landing platform and so on. The ground bearing pressure imposed by the structure if bedding uniformly is in the range 80 kN/m^2 to 140 kN/m^2. If the water bed is too soft or uneven, then some form of levelling may be needed, e.g. in the form of a gravel bed.

Once the structure is sited at a desired location, the pipe **17** is connected to a production platform **21** (FIG. **8**) and oil is introduced into the tops of the containers **1** via the pipe **17**, the duct **16B**, the manifold connection (not shown) with the ducts **16A**, and the ducts **16**. Surges in oil supply are accommodated by the surge tank **11**. The oil being lighter than water floats on the water in containers **1** displacing it through the ducts **14** and **15** to the separator chamber **12** from where it is pumped out to the sea by pumps on one of the plant room decks **10**. When the containers **1** contain oil to a depth of 2 metres or thereabouts above the top of the raft base, supply of oil is stopped. The containers are emptied by pumping oil from the tops of the containers via ducts **16** and **16A** and the pipe **17**, water entering the bases of the containers via the ducts **15** and **14** from the separator chamber **12**, the separator chamber being replenished with sea water by the pumps. The oil passing along the pipe **17** is pumped through meters on the production platform **21** and via a single point mooring **22** (FIG. **8**) to a tanker **23**.

During operation, the level of water in the separator chamber **12** is maintained below the level of the water outside the structure in order to reduce bursting forces on the structure due to the stored crude oil, that is the bursting force due to the storage of liquids is reduced or eliminated by the external hydrostatic pressure.

When it is desired to move the structure to another location, the stored oil is first pumped out and any emulsion removed. The sand ballast, if any, is then taken out and water ballast pumped out using the pumps previously used for submerging (reinstalled if necessary) in reverse order from the submerging operation, until the structure floats at the required draught. It may then be towed to the required new location.

The structure of FIG. **9** is, in many respects, similar to that described above and parts differing only in details are identified by the reference numerals already used and will not be again described. In this form the single central column **7** of the form of FIGS. **1** to **8** is replaced by four columns **7A** disposed at the corners of a square just inboard of the containers **1**, of which there are, in this form, only four also disposed at the four corners of a square. The columns **7A** contain ducting and piping (not shown) similar to that already described and support, at their upper ends, a platform or deck **8A** mounted on the column **7A** through support beams **24** and having plant and pump rooms and crew living quarters and the like thereon. Braces **25** extend between the columns **7A** at intervals along the length thereof, there being a foot bridge across at least one of the uppermost braces **25**. A further difference is that in this particular example there is in each of the individual cells of the base **2** central upright strut **27**. The construction and manner of operation of the structure of FIG. **9** is otherwise similar to that of the structure of FIGS. **1** to **8**.

In other applications than as already described, structures such as described above can be utilized merely as platform supporting structures, from which a wide variety of operatiions can be carried out.

It will be appreciated that since the structures described above are almost entirely of concrete, they have the inherent advantage of adequate weight. This obviates the need for anchoring the structures to the water bed with piles, since the large uplift forces, due to the oil stored and waves, can be safely resisted by the deadweight of the structure. This can be particularly useful in location where the water bed is of soft materials.

Facilities for single-point mooring of tankers can be incorporated if required.

Although the structure of the FIGS. has been described in connection with the storage of oil, it will be appreciated that such a structure can be used for the underwater storage of any fluids that are lighter than water.

We claim:

1. A submersible structure that can be floated to a desired location and then caused to sink so as to rest on the water bed, the structure comprising a reinforced concrete cellular base, a plurality of reinforced concrete hollow containers upstanding from said reinforced concrete cellular base, a solid reinforced concrete perimeter wall also upstanding from the base and completely encircling said containers to form an upwardly open interior space which is capable of holding water, at least one reinforced concrete hollow column extending from the cellular base to above water level in use of the structure, valves and ducting extending from the interiors of the containers and the cellular base to services situated inside the column, whereby, from the floating condition, the structure can be caused to sink by supplying ballast water to said interior space between the containers and the outer perimeter wall, to the interior of the cellular base and to the interiors of the containers, and whereby the structure can be refloated by pumping these zones dry and a separator chamber in said column connected by said ducting to said containers, said separator chamber being at a level in said column to be below the water level in the submerged condition of the structure to reduce by external hydrostatic pressure, the bursting forces due to the storage of liquid in said containers.

2. A structure as claimed in claim 1, wherein the cellular base consists of a lower slab, an upper slab and upright walls connecting the slabs together so as to divide the base into individual cells.

3. A structure as claimed in claim 2, wherein said individual cells are interconnected by bores to enable limited flow of said ballast water from cell to cell.

4. A structure as claimed in claim 2, wherein some of said upright walls extend below the lower slab to form keys.

5. A structure as claimed in claim 2, wherein the lower slab is shaped to form bearing areas disposed to suit the conditions of the water bed.

6. A structure as claimed in claim 2, wherein said perimeter wall extends below said lower slab to form a key around the perimeter of the base.

7. A structure as claimed in claim 4, wherein the keys are of castellated form.

8. A structure as claimed in claim 1, wherein there is only one reinforced concrete column which is disposed centrally of the hollow containers.

9. A structure as claimed in claim 1, wherein the concrete containers serve as buoyancy chambers during towing and submergence, supports for said column, and provide for the storage of liquids.

10. A structure as claimed in claim 1, wherein there is a plurality of spaced-apart reinforced concrete columns.

11. A structure as claimed in claim 1, wherein the upper end of the reinforced concrete column serves as a platform support.

12. A structure as claimed in claim 1 further comprising a surge tank in said column, said separator chamber and surge tank being disposed above the level of said hollow containers, said ducting including a first duct means connecting said separator chamber to said containers at the bottom thereof and a second duct means connecting said surge tank to said containers at the top thereof; and means connected to said surge tank for supplying thereto or removing therefrom a liquid which can be stored in the containers above the level of water therein.

* * * * *