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Toyama

[11] **3,837,310**

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[54] **UNDERWATER OIL STORAGE**

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[52] **U.S. Cl.** ..... **114/.5 T**

[51] **Int. Cl.** **B63b 35/00**

[58] **Field of Search** ..... 114/.5 T

[56] **References Cited**

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[57] **ABSTRACT**

An underwater oil storage apparatus having an oil storage tank moored to the sea bottom and a buoyancy adjusting tank secured to the oil storage tank, characterized by producing a substantially constant small buoyancy for a whole oil storage equipment by introducing or draining water in the buoyancy adjusting tank according to the amount of stored oil.

1 Claim, 4 Drawing Figures

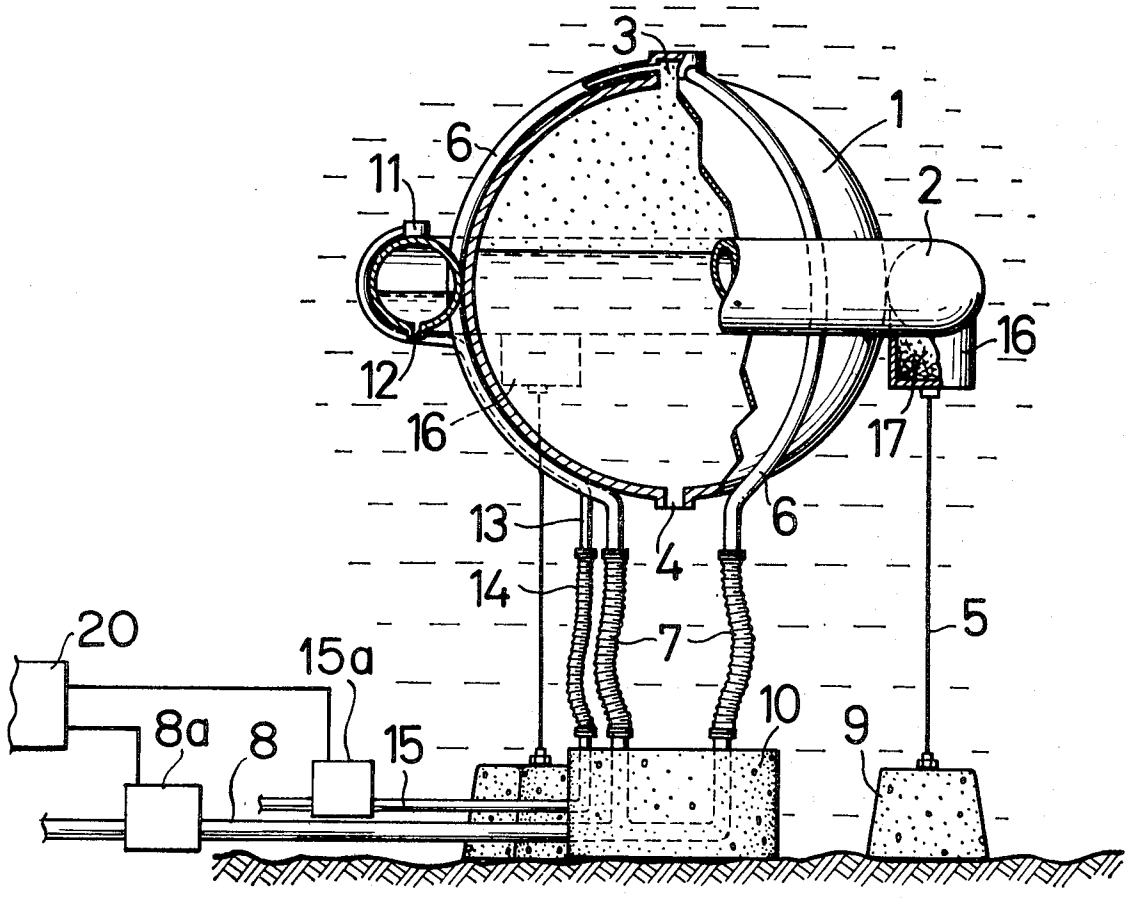


FIG. 1

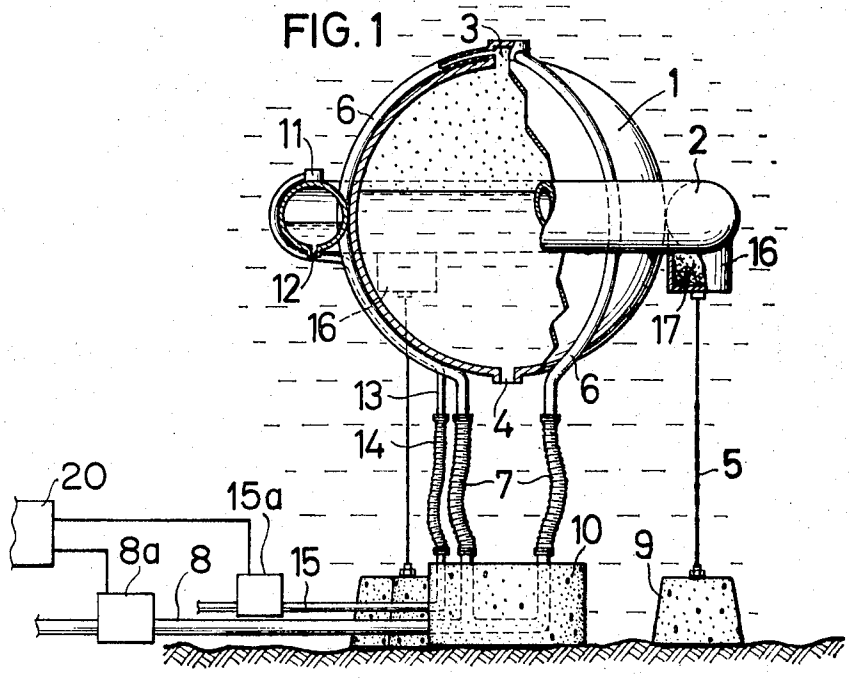

3
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FIG. 2

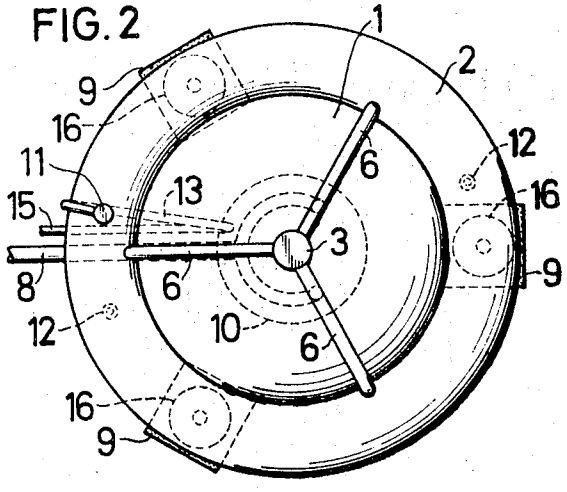

1
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FIG. 3

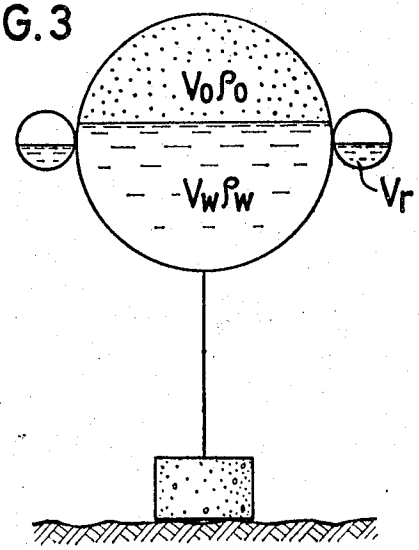
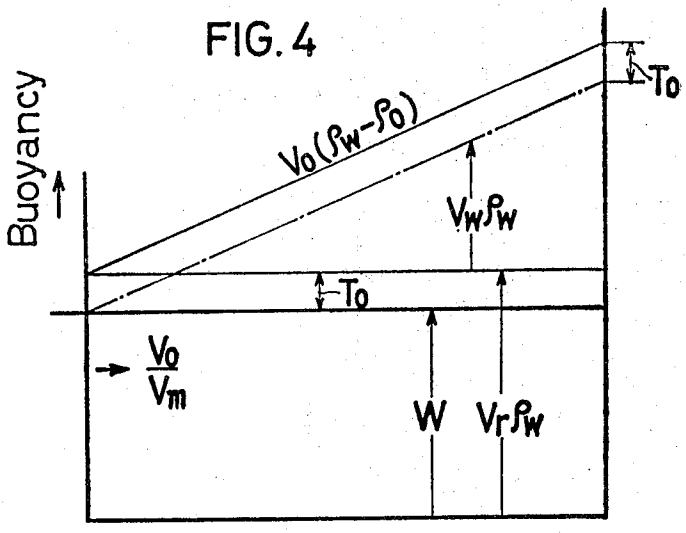

$V_o\rho_o$
$V_w\rho_w$
V_r

FIG. 4


Buoyancy
$V_o(\rho_w-\rho_o)$
T_o
$V_w\rho_w$
T_o
$\frac{V_o}{V_m}$
W
$V_r\rho_w$

UNDERWATER OIL STORAGE

The present invention relates to underwater oil storage.

The present invention has for its object to obtain an oil storage apparatus capable of storing oils in the deep sea.

The sea-bottom oil storage tank according to the present invention is so arranged that an oil storage tank made of metallic plate or ferroconcrete is provided at a considerable depth under the sea and is moored to the sea bottom by mooring lines and the buoyancy of the tank is controlled by the buoyance adjusting tanks mounted outside the tank so that excessive upward tension is not exerted on the mooring lines and the sinker weights connected to the lower ends of the mooring lines. The storage tank is filled with water before storing oil, and the sea water is substituted by oil in storing. Since the specific gravity of oil is fairly smaller than that of sea water, the tank has a buoyancy larger than the structure weight when the tank is full of oil. However, in the case of the tank full of sea water, it will sink to the sea bottom unless a buoyancy tank having a buoyancy larger than the structure weight is mounted on the storage tank. However, if the storage tank with the buoyancy tank is filled with oil, the storage tank is subjected to a buoyancy equal to difference between the specific gravities of oil and sea water, and the force exerted on the sinker weights and mooring lines amounts to about 20 percent of the capacity of tank. Hence, the sinker weights and mooring lines must be large beyond the limit of practicability.

In accordance with the present invention, water is introduced into the buoyancy tank as much as to cancel the buoyancy increase caused by oil introduced into the storage tank and, reversely, the sea water in the buoyancy tank is drained by compressed air or a pump when the oil in the storage tank is removed, thereby the buoyancy of an oil storage equipment as a whole is maintained at an approximately constant small value.

In drawings:

FIG. **1** is a partly cross-sectional front view of an embodiment of an underwater oil storage tank controlled according to the present invention;

FIG. **2** is a plan view thereof;

FIG. **3** is a schematic view explaining the relation between a storage tank storage quantity and the water supply quantity to a buoyancy adjusting tank; and

FIG. **4** is a diagram showing the relation between buoyancy and water supply quantity.

A storage tank **1** is a spherical tank made of metallic plate as steel plate or made of ferroconcrete, and at the lower end thereof is provided a port **4** so as to balance the exterior and the interior pressures.

The storage tank is moored at three points by mooring lines **5** to sinker weights **9** on the sea bed. A circular buoyancy adjusting tank **2** is secured to the storage tank at the periphery thereof.

At the top of the storage tank is mounted an oil supply or discharging ports **3**, and oil supply or discharge pipes **6** run from the oil supply and discharge ports **3** along the meridian of the storage tank to its bottom portion and are connected to flexible pipes **7**. The flexible pipes **7** are collected inside the central sinker weight **10** on the sea bottom and communicated to a sea-bottom pipe **8**. At the top of the buoyancy adjusting tank is provided a port **11** for introducing and discharging air, and at the bottom is provided a water inlet-and-outlet port **12**. From the port **11**, an air pipe **13** is led to the bottom portion of the storage tank along the meridian of the storage tank and connected to a flexible tube **14**, the lower end of which is fixed to the sinker weight **10**, and further communicated to a sea-bottom air pipe **15**. The sea-bottom oil pipe **8** and air pipe are connected to a sea berth or one-point buoy, and the oil supply pipe is connected to a tanker and the air pipe is open to the atmosphere in the case of introducing or discharging water by the pump, or connected to the compressed air source. In case the storage body is composed of steel plates, its own weight is small. Accordingly, a fixed ballast vessel **16** is provided and ballast **17** is contained therein so that the total weight of the equipment in the case the tank is full of oil may be approximately equal to the buoyancy at that time as hereinafter described.

The operation of this equipment will now be described. In the condition that the present equipment is built up underwater, the storage tank **1** is filled with sea water and the buoyancy adjusting tank is empty and filled with air equal in pressure to the outside sea pressure or occupied by air communicating the atmosphere by closing the sea water inlet **12**, where the buoyancy acting on the whole equipment is slightly larger than the weight of the equipment excluding the weight of the sinker weight. The sinker weight **9** is determined to have weight enough to hold that buoyancy, and therefore a small amount of tension acts on the mooring lines **5** so that the equipment is floated in the sea. When oil is introduced into the storage tank, for example by operating a pump **8***a*, buoyancy increases due to the difference of specific gravity from water. In order to cancel the increase of buoyancy, water is introduced into the buoyancy adjusting tank **2** in the predetermined amount by quantity of oil to be introduced and the specific gravity, so that the buoyancy is controlled not to deviate from the initially adjusted value. This control is performed by exhausting the compressed air from the tank **2**, for example by operating a pump **15***a*, or opening the valve for introducing water. Reversely, in case of discharging oil, buoyancy is adjusted by discharging water in the buoyancy adjusting tank. Discharging of water is performed by supplying compressed air or by an under water pump mounted on the under face of the buoyancy adjusting tank. A suitable controller for performing these controls is shown diagrammatically at **20** in FIG. **1**.

The relationship between amounts of oil in the storage tank and of the water supplied to the buoyancy adjusting tank will now be described.

In FIGS. **3** and **4**, the designation is made as follows:

Vm	:	Volume of the storage tank	m^3
Vr	:	Volume of the buoyancy adjusting tank	m^3
Vo	:	Amount of storage oil	m^3
Vw	:	Amount of water in the buoyancy adjusting tank	m^3
W	:	Weight of structure (in water)	ton
ρo	:	Specific gravity of oil	ton/m^3
ρw	:	Specific gravity of water	ton/m^3
To	:	Tension acting on mooring line	ton

The minimum necessary capacity of a buoyancy adjusting tank is determined by the following formula.

$$Vr\rho w - W = To \tag{1}$$

where To is a value so determined that the equipment may not be inclined by tidal current or other factors.

Buoyancy B increasing in the storage tank when oil is loaded is represented by the formula (2).

$$B = Vo\ (\rho w - \rho o) \tag{2}$$

When full loaded:

$$Bmax = Vm\ (\rho w - \rho o) \tag{3}$$

The amount Vw of supply water to the buoyancy adjusting tank necessary for maintaining the buoyancy acting on the mooring line equal to To, is given by the following equation.

$$Vo(\rho w - \rho o) = Vw\ \rho w \tag{4}$$

This relationship is shown in graph as in FIG. 4. The minimum specific gravity of oil loadable in case Vm and Vr are determined is given by the following:

$$Vm\ (\rho w - \rho o) - Vr\ \rho w - To = 0$$

and rewritten as follows

$$\rho w = \rho w\ (1 - Vr/Vm) - To/Vm$$

Since To/Vm is negligibly small,

$$\rho o \approx \rho w\ (1 - Vr/Vm)$$

When Vr = 0.2 Vm and the outside is sea water of

1.025 in specific gravity,

$$\rho o = 1.025 \times 0.8 \approx 0.82$$

Accordingly, all kinds of crude oil may be fully loaded.

In accordance with the present invention, an oil storage tank of great volume may be moored to the sea bottom of 100 to 150 meters depth as not obstructing the navigation of ships and not affected by waves under stormy weather, and the size of mooring line and the weight of sinker weight is prevented from growing too large by buoyancy adjusting device. It will be understood that the sinker weights may be substituted by anchor bolts.

What is claimed is:

1. A method of controlling the buoyancy of an underwater oil storage apparatus comprising an oil storage tank, a buoyancy adjusting tank secured to the oil storage tank, means for mooring the oil storage tank to the sea bottom, a port provided in the oil storage tank for oil, a port provided in the oil storage tank for water, a port provided in the buoyancy adjusting tank for water, and a port provided in the buoyancy adjusting tank for air, comprising the steps of charging and discharging oil and water into or from the oil storage tank in displacing relation, charging and discharging air and water into or from the buoyancy adjusting tank in displacing relation, and controlling said charging and discharging of the storage tank and the discharging and charging of thebuoyancy tank together to charge water into said oil storage tank concurrently with discharge of water from said buoyancy adjusting tank and vice versa, whereby the floating oil storage apparatus is controlled to have a relatively small buoyancy at all times.

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