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Bremaud

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[54] **SUBMARINE RESERVOIRS**

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[52] **U.S. Cl.** .... **114/16 E,** 9/8 R, 114/52

[51] **Int. Cl.** **B63g 8/22**

[58] **Field of Search** .... 114/16 R, 16 E, 52, 68; 9/8 R; 61/69 R

[56] **References Cited**

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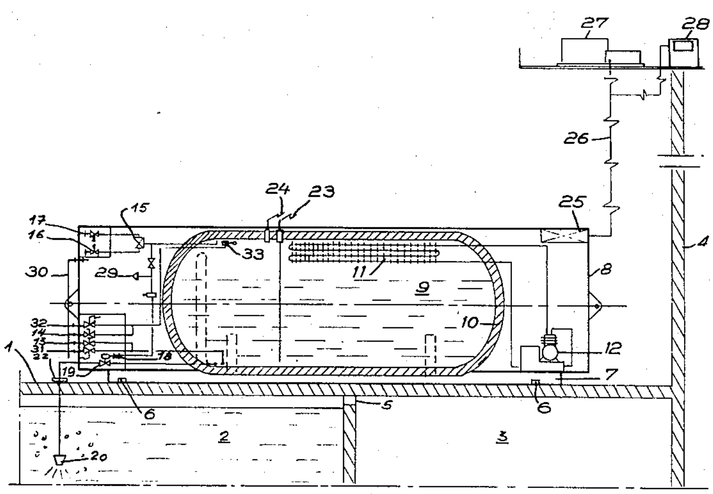
[57] **ABSTRACT**

Submarine reservoirs of large dimensions, of the type designed to be towed to the desired location for installation on the seabed, are immersed by drawing compensatory gas stored in the liquid state in an auxiliary enclosure associated with the reservoir, whereby the reservoir is submerged and when located the auxiliary enclosure can be detached from the installed submarine reservoir.

7 Claims, 3 Drawing Figures



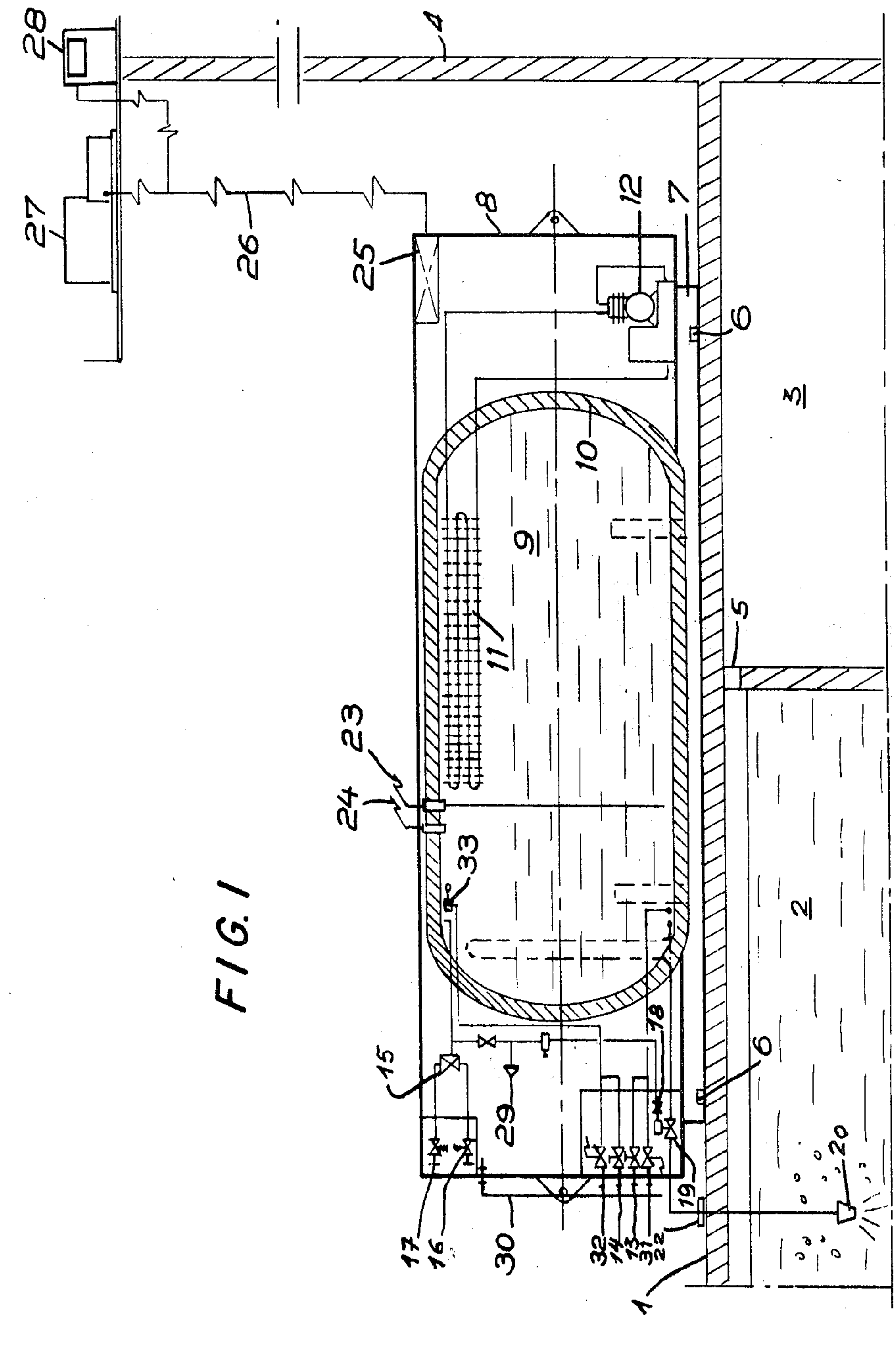

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FIG. 1

FIG. 2

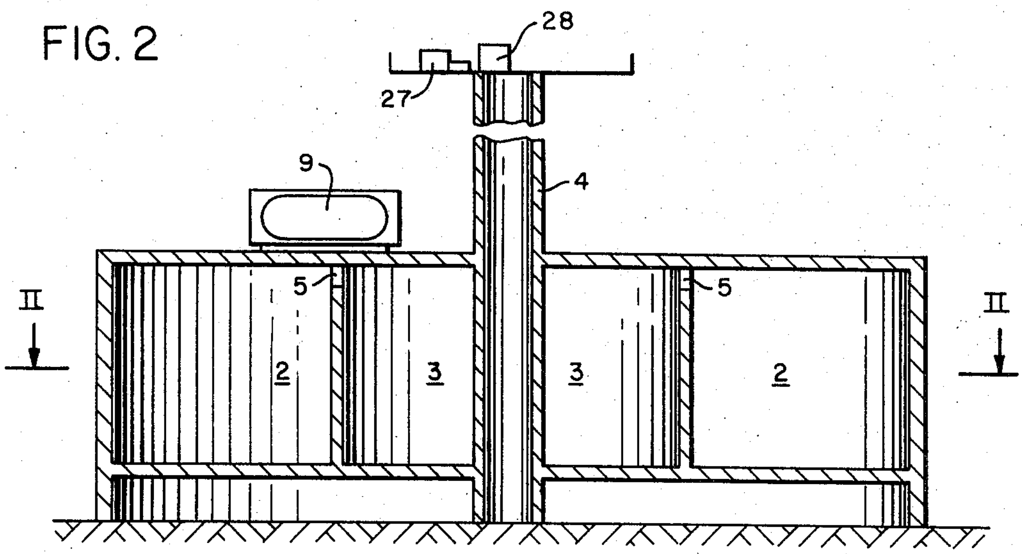
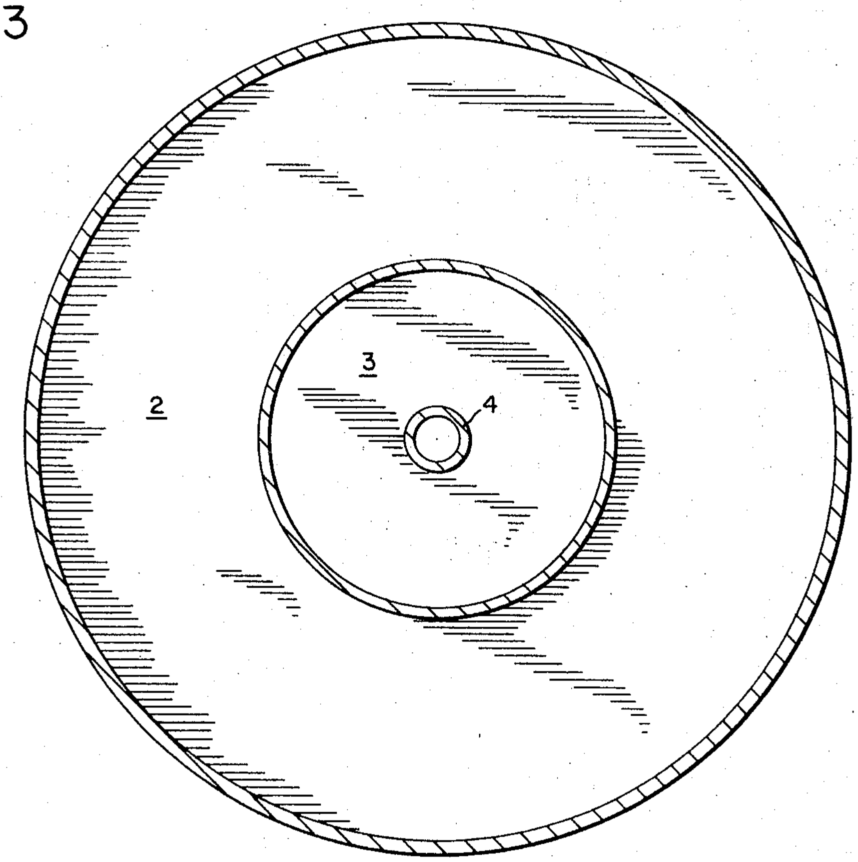


FIG. 3



SUBMARINE RESERVOIRS

The present invention relates to a method of immersing and placing on the seabed a concrete submarine reservoir of large dimensions designed to store a considerable quantity of hydrocarbon extract below water. The invention relates more particularly to a method of regulating the pressure inside the reservoir during immersion, the reservoir containing a flotation gas, in which method an inert compensatory gas is introduced into the reservoir until the pressure present inside it is at least approximately equal to that of the surrounding medium in which the reservoir is immersed.

The invention relates equally to a concrete submarine reservoir designed to be immersed and located on the seabed.

Submarine reservoirs designed for location on the seabed are, as is known, filled with a flotation gas, generally air, so that they can float on the water and can be pulled along from the shipyard where they are constructed to the point where they are to be immersed. The immersion operation is made possible by making the reservoir almost non-buoyant, for example by introducing a suitable quantity of seawater into the reservoir, and keeping the buoyancy of the reservoir virtually at zero during immersion. For this purpose, the enclosure forming the reservoir is constructed so that it can be isolated from the exterior, for example by gates; in this way, by closing the isolation gates, it is possible to keep constant the volume occupied by the flotation gas during the whole operation of immersion of the reservoir. However, because of this isolation, the external walls of the reservoir are subject during immersion to differential pressures which increase progressively as the reservoir sinks into the water, so that the reservoir is liable to be damaged or even destroyed well before reaching the bottom of the water. It is therefore necessary to regulate constantly the internal pressure of the reservoir during its descent, by introducing an inert pressure-compensating gas into the enclosing wall of the reservoir during immersion, so that the pressure inside the enclosure is constant and at least approximately equal to the pressure of the external surrounding medium in which the reservoir is located.

According to a known method, compressed air is used as the pressure-compensating gas, the source of which is located on the surface of the water and is connected to the reservoir by a connecting pipe of variable length. Since the volume of compensatory gas necessary for immersion is usually very large, the source of compressed air must be of large dimensions and therefore expensive; furthermore, the connecting pipe comprises special equipment which is therefore expensive, not only because of the variable distance between the reservoir to be fed with compressed air and the surface of the water, but also because of the generally increased maximum value of the pressure of the compressed air which is necessary to bring about regulation of the pressure mentioned, this increased pressure being withstood by the connecting pipe.

The invention seeks to remedy these disadvantages and provides, in particular, an economical and safe method of regulating the internal pressure of the reservoir.

For a method of the type mentioned above, this is achieved in accordance with the invention in that before it is introduced into the reservoir, the compensatory gas is first stored in the liquid state in an auxiliary enclosure or chamber associated with the reservoir.

In this way, the pressure-compensating gas is stored in compact form and it is no longer necessary to connect the concrete reservoir to a source of compensatory gas located at the surface of the water; the result of these advantages is that the immersion operation is greatly simplified.

According to an advantageous and preferred feature of the invention, the compensating gas is introduced in the liquid state into an aqueous solution, i.e. an auxiliary solution, which is contained in a chamber forming part of the reservoir and constantly in communication with the space in the reservoir filled with the flotation gas. The auxiliary solution can simply be, for example, the seawater which has already been introduced to give the reservoir virtually no buoyancy. This auxiliary solution serves as a heat source and also as a thermal damping force or heat store, which can supply the heat necessary to convert into compensatory gas the liquid introduced into the auxiliary solution. This solution advantageously comprises brine which can be prepared from seawater which is introduced into the reservoir and from the addition, for example, of a suitable quantity of sea salts. An auxiliary solution is thus obtained which has a relatively low freezing point, which is lower than that of ordinary seawater.

The compensatory gas advantageously comprises CO_2. As is known, this gas can easily be liquefied and can be stored economically at low temperatures under pressure. Furthermore, CO_2 is very soluble in water, seawater or brine. If CO_2 is used as compensatory gas, as is preferred, the auxiliary solution serving as the intermediate medium between the source of liquid CO_2 and the gas-receiving volume of the reservoir enclosure is permanently supersaturated with dissolved CO_2 and liberates gaseous CO_2 into the gas-receiving space as soon as a quantity of liquid CO_2 is introduced and dissolved in the auxiliary solution at a point located below the maximum level of the solution. In this way, the formation of carbonic frost or snow is avoided, which can occur as is known when carbon dioxide gas is released adiabatically.

The CO_2 is preferably stored at a temperature of about −20°C under a pressure of about 20 bars.

The method according to the invention is advantageously carried out by means of a concrete reservoir which comprises at least one enclosure whose volume is symmetrically or otherwise uniformly associated with the periphery of the concrete body of the reservoir and is filled with an auxiliary aqueous solution, at least one second enclosure which is arranged in a central zone of the concrete body of the reservoir which is filled with flotation gas and which is in constant communication with the first enclosure and a chamber filled with liquid CO_2, which is associated with the concrete body of the reservoir and is connected to the first enclosure by means of a valved supply pipw which enters the first enclosure at a point below the maximum level of the auxiliary solution.

Such a reservoir produces a moment of inertia around its raised centre, since the ballast material which in the present case comprises the auxiliary aqueous solution contained in the first enclosure is distributed uniformly in relation to the periphery of the reservoir, so that the latter is very stable as regards its inclination to the horizontal and can thus be kept horizontal very easily during its immersion. Furthermore, in this new reservoir, the ballast liquid also serves as the auxiliary solution receiving CO_2 in a liquid state and introducing CO_2 in a gaseous state into the second enclosure.

Other characteristics and advantages of the invention will be seen in connection with the following description of an illustrative embodiment of a submersible reservoir according to the invention, the description being given with reference to the accompanying drawings.

FIG. 1 is an axial section partially in elevation of an embodiment of the reservoir according to the invention.

FIG. 2 is vertical cross section of the apparatus

FIG. 3 is cross section taken along the line II—II of FIG. 2 showing the concentric arrangement of enclosures 2 and 3.

As can be seen from the drawing, the reservoir consists of a body of concrete which comprises a principal part in the form of a cylindrical plate **1**, in which enclosures are formed which are filled with brine **2** and which are uniformly distributed around the periphery of the reservoir and air-filled enclosures **3** which are located in the central zone of the reservoir and which are in constant communication with the enclosures **2** by means of apertures **5** in the upper part of the divisions separating the enclosures **2** and **3** from one another. The concrete body of the reservoir further comprises a chimney **4** whose height is equal to or slightly higher than the depth of the under-water site on which the reservoir is to be placed.

On the upper part of the reservoir, a frame **7** is fixed by means of explodable bolts **6**, which frame supports a caisson **8** containing the CO_2 storing unit. Horizontally arranged in the caisson **8** is a cylindrical tank **9** filled with liquid CO_2 at a pressure of 20 bars and a temperature of −20°C. The tank **9** is of steel and is covered on its exterior with an insulating coating **10** which can resist the surrounding pressure and which consists for example of a layer of foam polyurethane covered with a layer of polyester. The tank **9** is mounted on supported cradles mounted on the frame **7**.

In the tank **9** is located an evaporator **11** which is connected by means of rigid pipes equipped with gate valves, which are not illustrated, to a refrigerator unit **12** installed inside the caisson **8**. The refrigerator unit **12** serves to keep the liquid contained in the tank **9** at the temperature of −20°C during the period between filling of the tank and immersion of the reservoir. A double-inversion member, comprising a threeway electric valve **15**, safety valves **16** and pressure-rupturable discs **17**, is similarly connected to the interior of the tank **9**; these members **15, 16, 17** form a safety device which precludes an increase in pressure in the interior of the tank **9** caused by overheating of the CO_2 during storage. Filling and balancing valves **13** and **14** for the tank **9** are provided to allow liquid CO_2 to be supplied to the tank **9** from tankers which are not illustrated and which can be loaded on the reservoir when it is in the quayside.

The enclosures **2** of the concrete reservoir are each connected to the interior of the liquid CO_2 tank **9** by means of supply pipes on which are placed pneumatic valves **19** which are controlled by electric gate valves **18** and by explosive cutter devices **22**.

The ends of the supply pipes each connected to an enclosure **2** are equipped with injection nozzles **20** which are entirely submerged in the brine solution. Furthermore, the tank **9** is equipped with a level tester **23** and a pressure senser **24**.

An electric junction box **25** is similarly provided in the caisson **8**, which, by means of a supply and operating cable **26**, connects the electrical equipment of the CO_2 unit to a generator **27** and to a control station **28**. The generator **27** and the control station **28** are placed on a platform located at the top of the chimney **4** of the reservoir. This platform is placed at a level which is above the sea after immersion of the reservoir. In order to ensure recovery of the CO_2 unit by flotation, the caisson **8** comprises air spaces on either side of the tank **9**. In these are installed the valves **13** to **19**, the refrigerating unit **12** and the electric equipment **25**. A constant flow of CO_2 gas through the nozzle **29** and an external purge line **30** whose outlet opening is placed at the level of the lower part of the caisson **8** allows the pressure to be kept equal between the interior of the caisson **8** and the surrounding medium. After emptying the tank **9** of liquid CO_2, filling of the tank with seawater is effected by a pyrotechnic valve **31** and the drainage of air is effected by way of a pyrotechnic valve **32** mounted on a pipe which terminates in the tank **9** at a float valve **33**.

The method of using the reservoir illustrated in the drawing takes place in the following manner:

The reservoir is lowered in stages in the direction of the under-water site on which it is to be placed. When the pressure in the interior of the tank **9** has been reduced to **18** bars, the electric supply cable is disconnected from the refrigerator unit **12**.

At each stage of descent of the reservoir, a suitable quantity of liquid CO_2 is injected into the brine contained in the enclosures **2** using the electric valves **18**, so that the pressure inside the reservoir is reduced to only slightly higher than that in the surrounding medium in which the reservoir in submerged.

When the reservoir has reached the bottom of the water, the tank **9** is filled with seawater after it has been emptied of CO_2 and the caisson **8** of the reservoir **1** is released by using the explosive cutters **22** and by detonating the bolts **6**. The caisson **8** rises, the purge device **30** ensuring during this ascent that the internal and external pressures acting on the walls of the caisson **8** are kept equal.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A concrete reservoir of large dimensions for immersion in the sea and location on the seabed, comprising at least one enclosure distributed uniformly around the periphery of the concrete body of the reservoir, for receiving an auxiliary aqueous solution, at least one secondary enclosure located centrally of the concrete body of the reservoir, for receiving a flotation gas, the second enclosure being in constant communication with the first enclosure, and a chamber containing liquid CO_2 attached to the concrete body of the reservoir and connected to the first enclosure by way of a CO_2 supply pipe, which is connected to the first enclosure at a point below the maximum level of the auxiliary solution.

2. A reservoir according to claim **1**, wherein the liquid CO_2 chamber is removably attached to the reservoir body by means of explodable bolts, the supply pipe is associated with an explosive cutter device and the

CO_2 chamber is provided with a variable buoyancy flotation device.

3. A reservoir according to claim **2,** wherein a control valve in the CO_2 supply pipe, the flotation device and the explodable bolts and cutter devices are associated with electromagnetic control members connected by a cable to a single control station located above the level of the sea.

4. A method of immersing a buoyant reservoir into a body of liquid and controlling the pressure in the interior of the reservoir, which comprises introducing an aqueous solution into a first enclosure within said reservoir, in amount sufficient to counteract the initial buoyancy thereof, introducing a liquefied gas into an auxiliary enclosure detachably attached to said reservoir, lowering the reservoir in stages into the body of liquid, injecting said liquefied gas in stages into said first enclosure, said reservoir containing a third enclosure containing a flotation gas, said third enclosure being in communication with said first enclosure, said liquefied gas being soluble in said aqueous solution, the injection of said liquefied gas into said aqueous solution being regulated to maintain the pressure within the reservoir slightly higher than the surrounding medium, and when the reservoir has reached the bed of said body of liquid, removing said auxiliary enclosure from the reservoir.

5. A method according to claim **4,** wherein the auxiliary solution comprises seawater or brine.

6. A method according to claim **4,** wherein the compensatory gas is CO_2.

7. A method according to claim **6,** wherein the CO_2 is stored at a temperature of about −20°C and under pressure of about 20 bars.

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