June 22, 1965 J. MARGOT ETAL 3,189,922

VARIABLE-BUOYANCY FLOATS

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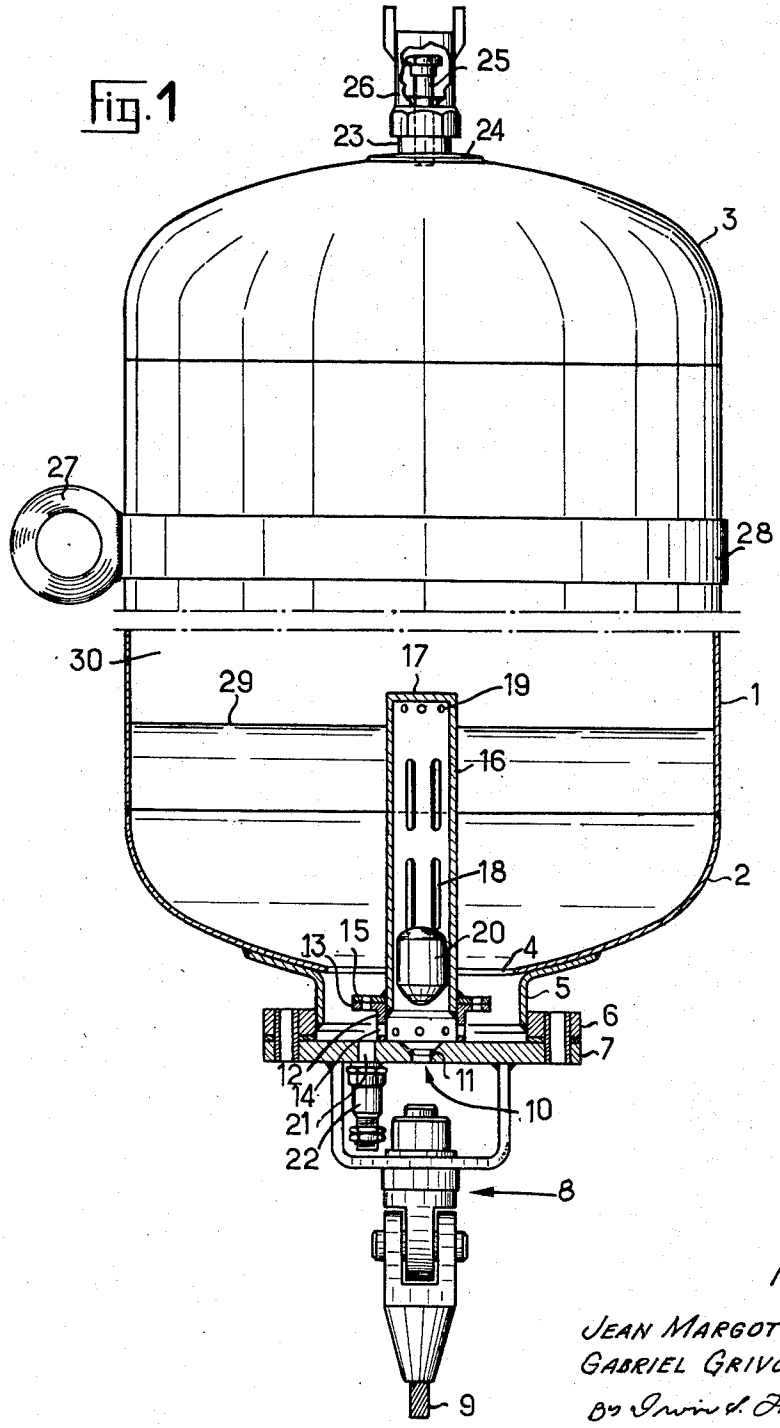
Fig. 1



INVENTORS

JEAN MARGOT

GABRIEL GRIVORY

By Irwin S. Thompson

ATTY.

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Fig. 2

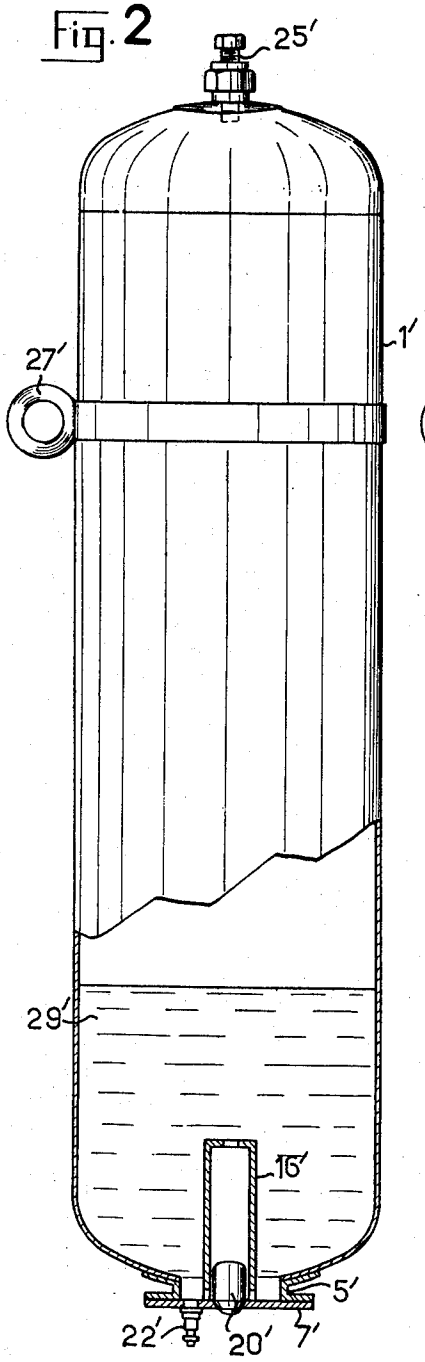
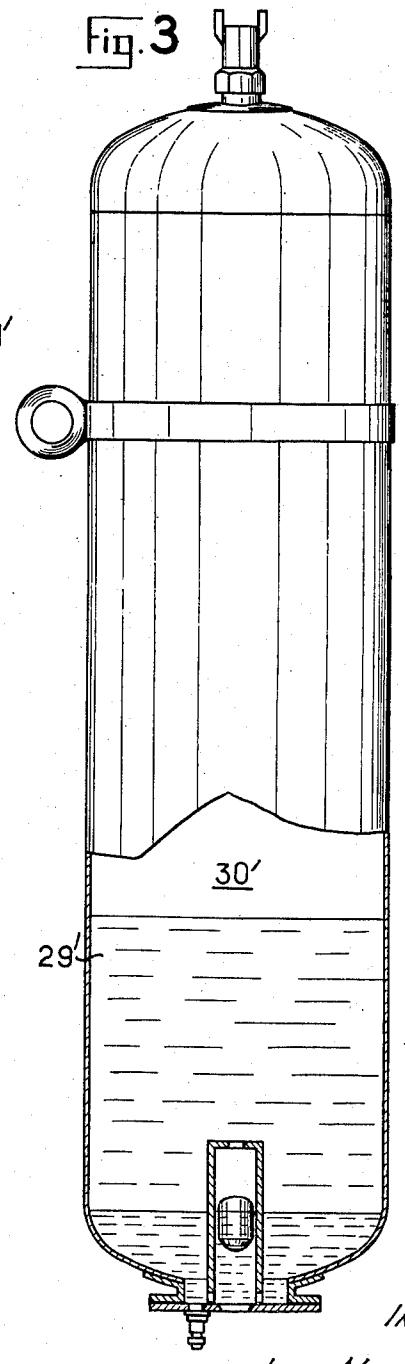


Fig. 3



INVENTORS

JEAN MARGOT

GABRIEL GRIVORY

By Irwin S. Thompson

ATTY.

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VARIABLE-BUOYANCY FLOATS

Jean Margot, La Celle Saint-Cloud, and Gabriel Grivory, La Courneuve, France, assignors to Electricite de France (Service National) and Gaz de France (Service National), both of Paris, France, French National Services

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Claims priority, application France, Jan. 16, 1963, 921,557
6 Claims. (Cl. 9—8)

This invention relates to the field of floats or floatable chambers for use in underwater operations, and more specially to chambers of the variable floatability type, which may conveniently be used, in particular, in the laying of submarine pipes and conduits for the transportation of fluids or the housing of cables.

One such technique of pipe-laying consists in joining the sections of pipe together on the surface, on the bow of a pipe-laying ship, for example, and to permit the joined sections of pipe gradually to settle to the bottom as additional sections of pipe are added. In order to follow this procedure, however, it is necessary that the length of pipe nearest the ship be flexed to a certain degree so that it extends from the substantially horizontal position of the pipe already resting on the ocean floor to a substantially horizontal position on the deck of the surface vessel without forming any bends which might damage the pipe. It is also desirable that this length of pipe be supported so that it does not unduly weigh down the rear of the vessel.

One of the type curves which best satisfy the above requirements is a curve of the compound type comprised of two catenaries, one of which is concave upward from the ocean floor to a point of inflection situated between the surface and the ocean floor, and which is concave downward from the point of inflection to the surface.

In order to achieve such a curve it is necessary that the pipe be subjected to downwardly acting forces along the length of its lower, concave upward section and to upwardly acting forces along the length of its upper, concave downward section.

One of the simpleset techniques presently employed for achieving this result involves the use of "variable floatability" floats attached at regular intervals along the length of pipe just behind the pipe-laying vessel. These floats are designed to have a buoyancy which remains constant above a predetermined depth, and which decreases gradually with further increases of depth below said predetermined depth.

Many varieties of such floats have already been suggested, among them being types utilizing a deformable, gas-filled bladder whose volume is decreased in proportion to the external water pressure, and types utilizing a rigid gas-filled tank equipped with a pressure operated valve which permits the entry of sea-water whenever the external water pressure exceeds the gas pressure within the tank.

The prior art gas-filled metal tank of the latter type is so designed that entering sea water is in direct contact with the gas filling the tank so that, no matter how chemically inert the gas may be, some of it must inevitably dissolve in the sea-water and be lost when the water is expelled.

Further, since it is possible for a gas to be compressed down to practically zero volume, this type of float could

easily loose all of its buoyancy if lowered to a sufficient depth. Such a result is obviously undesirable because it would unduly complicate the problem of recovering the float after it has performed its function, i.e., after the section of pipe to which it is attached has reached the ocean bottom.

Besides, since the tank is eventually entirely filled with gas, the pressure operated valve is required to provide a tight seal against gas leakage.

The present invention contemplates overcoming these difficulties by providing a rigid gas filled tank which is adapted to eliminate the above noted objectionable features of the prior-art rigid, variable-floatability tanks.

It is therefore an object of the invention to produce a variable buoyant force which decreases for increasing water depth.

It is another object of this invention to achieve a variable buoyancy with a relatively simple apparatus.

It is still another object of the invention to prevent the gas which fills a variable-floatability tank from being dissolved in the sea water admitted into the tank.

Yet another object of this invention is to prevent the buoyancy of a variable-floatability device from ever assuming a negative value.

A further object of this invention is to prevent leakages of gas through the valve-seating.

These and other objects, advantages, and features of the present invention will become more readily apparent from the following description when taken together with the annexed drawings, of which:

FIGURE 1 is a partially cross-sectional elevation view of one preferred embodiment of the present invention;

FIGURES 2 and 3 are partially cross-sectional elevation views of the embodiment of FIGURE 1 showing the float in two different states of immersion.

The device of the present invention is essentially constituted by a rigid tank filled with gas and having a pressure actuated valve situated in its base. The tank is also provided with a quantity of liquid having a lower density than water. This liquid serves the double function of isolating the gas both from incoming sea water and from the valve seating and of preventing the tank from ever having a negative buoyancy. The latter advantage is produced because of the fact that the light liquid, being practically incompressable (as is true of liquids in general), prevents the sea water from ever filling the entire tank. Therefore, when the quantity and density of this liquid are properly chosen, the tank will always retain a positive buoyancy.

Turning now to FIGURE 1, there is shown a float or buoy of variable floatability constituted essentially by a rigid casing adapted to contain a substance under pressure. This casing is composed of a hollow cylindrical section 1 which has each of its ends welded to a respective dome-shaped base 2, 3. The center of base 2 comprises a circular opening 4 which opens into a hollow tubular section 5. The section 5 is welded to the base 2 and carries with it a flange 6 which is designed to connect with a cover-plate 7. This plate serves to seal off the interior of the float and to support the mooring unit 8 which is fastened to the mooring cable 9. In the center of the cover-plate 8 there is provided a small opening 10 which is provided with gasket 11 and which serves as a valve seat. The plate 7 also supports, on its internal face, a tubular section 12 comprising a flange 13 and a series of perfora-

tions 14 which permit the flow of liquid from the opening 10 to the interior of the float. A flange 15, which is rigidly fastened to a cylindrical passage 16, is fastened to flange 13 in such a way as to permit tubular section 13 and passage 16 to form a linear path. The passage 16 is closed at its upper end by base 17 and comprises a series of slits 18 and perforations 19 which constitute flow paths between the inside of the passage and the interior of the float. A valve 20, which will float in water, is disposed within the passage 16 and is so formed as to be able to slide freely therein and when seated in opening 10, to provide a fluid-tight contact with gasket 11.

The plate 7 is also provided with a second opening 21 which is associated with a safety valve 22.

At the center of the upper dome 3 there is fastened a base plate 27 attached to a tube 23. The tube 23 carries a gas-inlet valve 25 which is protected by a hollow screw-plug 26.

A band 28 is welded to the periphery of cylinder 1 and carries a reinforcing ring 22 which serves to facilitate the handling of the float.

The float thus constructed is partially filled with a liquid 29 which is lighter than water and in which valve 20 will sink. For example an appropriate variety of petroleum could be used. The remainder of the hollow volume 30 is then filled by means of valve 25 with air or nitrogen, or any other suitable gas, to a predetermined pressure.

The float is then submerged and as long as the pressure of the gas filling volume 30 is greater than that of the water surrounding the float, the valve will remain seated on gasket 11 and no water will enter the float. When the float descends to a depth where the ambient water pressure exceeds this gas pressure, this depth depending of the initial gas pressure, the water will force the valve from its seat and will enter the tank. The entering water will force the light liquid upward, thus compressing the gas until a point is reached where the gas pressure has risen to a value equal to that of the water pressure.

When this point is reached, no more water will enter the tank. As the tank continues to descend the external water pressure will continue to rise, thus permitting additional quantities of water to enter and to further compress the gas in order to maintain the equilibrium between the ambient water pressure and the gas pressure. The volume of the gas will diminish in accordance with Boyle's law, and the buoyancy of the float will consequently progressively diminish with depth until eventually reaching a point where the gas volume is very close to zero. At this point the float will be filled almost entirely with the light liquid 29 and water and if the volume and density of liquid 29 have been properly selected, it will continue to give the float a positive buoyancy. The valve 20 will, of course, remain suspended in the water away from gasket 11. It should be noted that during this entire process the gas never comes in contact with the water.

As the float returns to the surface, the process is reversed; the decreasing water pressure permits the gas to expand and drive out the water until practically all of the water is forced out and the valve 20 once again seals the opening 10 by sinking in liquid 29. At this point, the float will have regained its original buoyancy and the gas pressure will maintain valve 20 firmly in its seating.

FIGURES 2 and 3 illustrate two states of immersion of the float of FIGURE 1. The primed numbers indicate elements similar to those having the same reference numbers unprimed in FIGURE 1. The float 1' contains a quantity of liquid 29' having a light density. The remainder of the float chamber is filled with air or nitrogen or any other convenient gas through valve 25', under a pressure which is adjusted to control the submersion depth at which water will begin to enter the chamber. The quantity of liquid 29' is so chosen that when the chamber is completely filled by this liquid and water, the former will still give the entire unit a positive buoyancy. The liquid 29' also serves to isolate the gas from the entering water and thus prevents loss of gas through dissolution in the water. Some gas may dissolve in liquid 29', but since this liquid remains permanently in the chamber such dissolution will be terminated by the saturation of the liquid. Further, since the rate of transfer of dissolved gas from one liquid to another is very small almost no dissolved gas will be lost to the sea water passing into and out of the chamber.

During the course of the immersion of the float a point will be reached where the ambient water pressure becomes greater than the gas pressure within the chamber. The water will then force the float away from its seat and will enter the tank (see FIGURE 3), the amount of water entering the chamber being proportional to depth, driving the liquid 29' upward and compressing the gas 30' until a point is eventually reached when the volume occupied by the latter is practically zero. At that point, no more water will enter the tank and its buoyancy will remain constant during the remainder of its descent. When the float begins its return to the surface, it will reach a point where the gas pressure inside the chamber becomes greater than the ambient water pressure and the gas will begin to expand, forcing the liquid 29' downward and expelling the sea water. When all or nearly all, of the sea water has been expelled the float valve will return to its seat, once again sealing the chamber.

The float thus constituted is able to undergo many submersions without losing any of its original quantity of gas or lighter than water liquid.

In addition to the previously described advantages possessed by the float of the present invention, the float of the present invention offers a further improvement over prior art floats due to the fact that leakage of gas is entirely eliminated by the presence of the light liquid; the prior art devices, containing only gas, could not provide such an effective seal.

There has thus been described a sturdy variable buoyancy float possessing many improvements over the prior art. It should be obvious that many modifications can be made to the embodiment shown and described herein without departing from the spirit and scope of the present invention. For example, the tank could be filled with any suitable types of gas and light liquid, the tank could be given an infinite variety of shapes, and the float valve could be given any convenient configuration. It should therefore be recognized that the scope of this invention should be limited only by its spirit and by the breadth of the appended claims.

What we claim is:

1. A variable-buoyancy float comprising:
   (a) a closed hollow rigid tank comprising a filling valve disposed on its surface and a water orifice formed with a valve-seating and disposed in the lowest portion of its surface;
   (b) a quantity of lighter than water liquid filling the lower part of the hollow interior of said tank;
   (c) a quantity of gas filling the remainder of the hollow interior of said tank; and
   (d) a valve for controlling the opening and closing of said water orifice so as to permit external water to enter said tank when the pressure of said external water exceeds that of said gas.

2. A device as recited in claim 1 wherein the quantity of said lighter than water liquid in said tank is sufficient to preserve the floatability of said tank when the pressure produced by water entering said tank has compressed said gas to a practically negligible volume.

3. A device as recited in claim 1, wherein the body of said tank is in the form of a surface of revolution and said water orifice is aligned with the longitudinal axis thereof.

4. A device as recited in claim 1, wherein the valve is lighter than its equivalent volume of water and heavier than its equivalent volume of said lighter than water liquid, and is dipsosed within said hollow tank in communication with said water orifice, so as to rise clear of said

seating for opening said orifice when immersed in water, and to sink back on its seating for closing said orifice when immersed in said lighter than water liquid.

5. A device as recited in claim 4 further comprising a guiding cage for said valve, said cage being fastened to the interior surface of said tank, surrounding said valve and being positioned coaxial with said water orifice.

6. A device as recited in claim 5, wherein said cage comprises an upper stop end for preventing said valve from rising above the confines of said cage.

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FERGUS S. MIDDLETON, *Primary Examiner.*