July 23, 1963 C. B. PEKOR ETAL 3,098,246

BUOY

Filed May 3, 1961 2 Sheets-Sheet 1

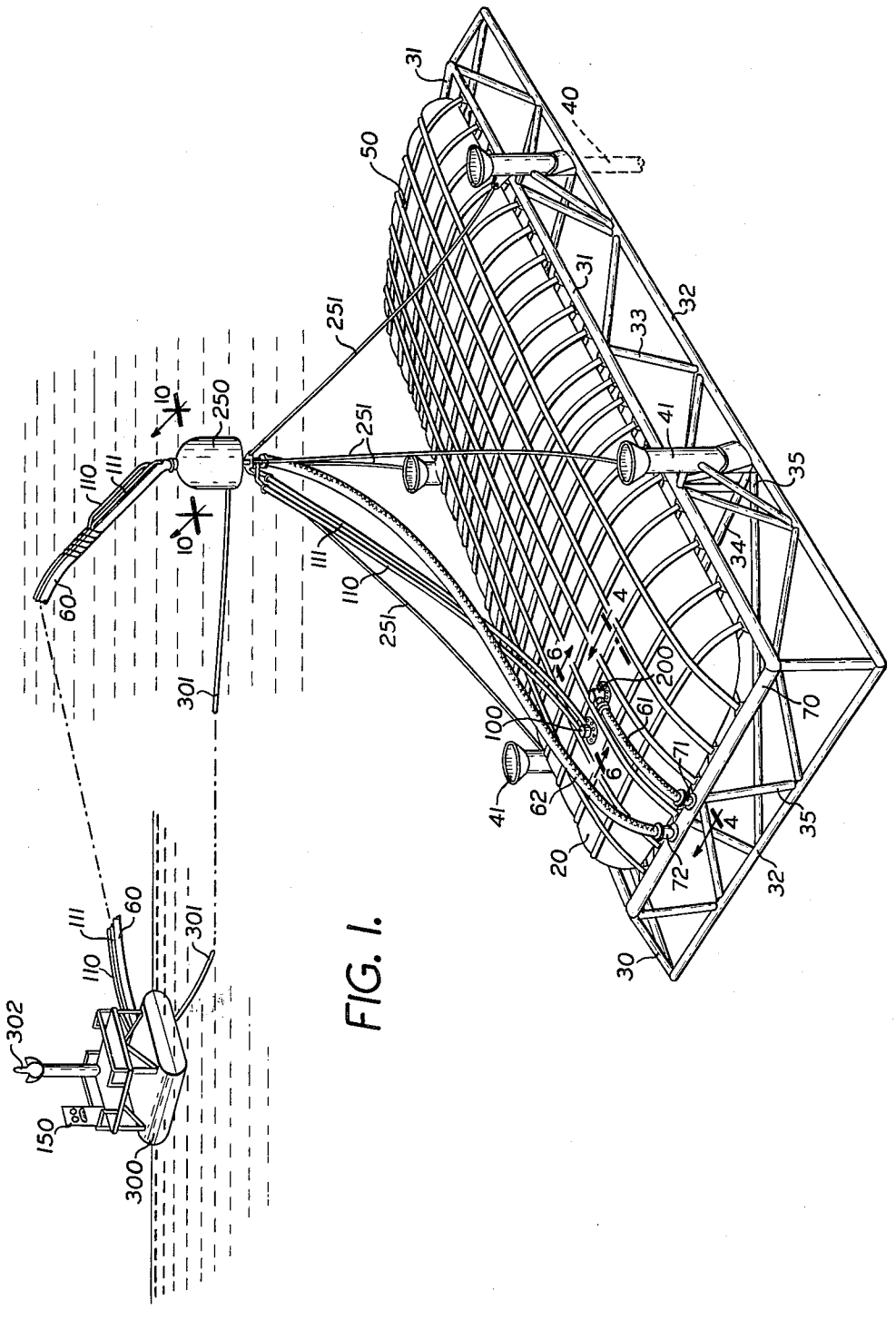



FIG. 1.

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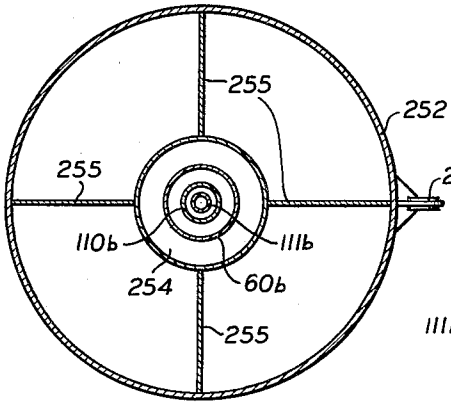



FIG. 3

FIG. 2

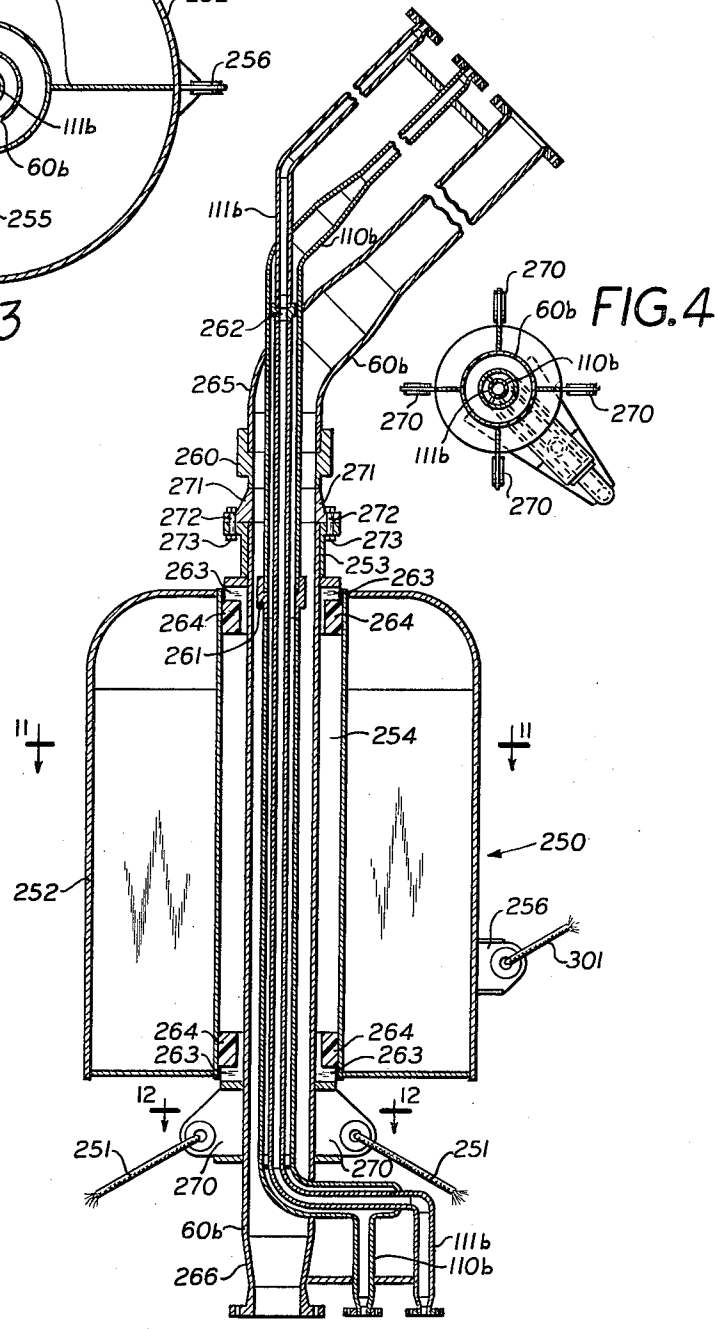



FIG. 4

United States Patent Office 3,098,246 Patented July 23, 1963



3,098,246

# BUOY

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This invention relates to an underwater liquid storage system and, more particularly, to such a storage system utilizing rubber-like collapsible containers.

Underwater storage systems have been disclosed in a number of United States patents. (See, for example, U.S. Patent Nos. 2,383,840 and 2,487,786.) The storage systems disclosed therein, however, have all contemplated the utilization of smaller flexible storage tanks. Where a storage system is to hold quantities of liquids in the range of 1200 barrels to 25,000 barrels, additional problems arise which have not been encountered previously.

Since the flexible, collapsible container itself must not only function as an underwater storage tank, but must also serve as an expellant bag (see especially U.S. Patent No. 2,383,840), it must be designed so that the collapsing and expanding that occur during repeated filling and emptying cycles will not cause damage during the course of long periods of service. In addition, the flexible container must withstand the environmental conditions associated with extended underwater storage and must not be adversely affected by sea water and marine growth.

Additionally, the underwater storage of large quantities of liquids raises problems in anchoring the apparatus to the bottom of the body of water in which it is submerged and also problems concerning restraining and holding the containers themselves in proper position relative to the anchoring system. Where the liquid to be stored has a specific gravity less than that of water, for example, fuel oil, the assembly must be capable of withstanding large buoyant forces. It must also be able to withstand the horizontal drag forces produced by strong underwater currents and must be able to support the weight of the flexible container and attached equipment when the same is empty. If the collapsible container itself is to vary in profile from a flat envelope in the empty state to an approximately oval, elliptical or cylindrical shape in the filled state, the restraining system must not impair the ability of the container to thus change its shape.

The anchoring system must be designed with an adequate safety factor, so that failure of one component will not result in a storage container breaking loose. The safety factor must also be sufficient to compensate for corrosion and the consequent gradual deterioration which results therefrom. The anchoring system also must be suitable for use in both hard and soft bottom conditions.

A filling and emptying hose is, of course, an indispensable part of any underwater liquid storage system. Such a hose would normally abrade and/or apply other destructive forces to a rubber-like container. Thus, some form of header tank has been found necessary to absorb these forces and leave the flexible container undisturbed. The header tank would normally be anchored to the sea floor adjacent to one end of the flexible container. Where, however, the underwater storage system comprises a number of collapsible containers, a long header tank is advisable to serve as a manifold for the multiple installation, so that one set of filling and emptying hoses can serve all the flexible containers.



The large volume storage system herein contemplated requires a means of accurately measuring the quantity of liquid stored in the containers at any time. Thus, it is necessary to have a metering system to indicate the amount delivered to or withdrawn from the containers. Furthermore, since it must be assumed that no single agency or vessel will use the storage system, it is essential that this metering system comprise self-contained instrumentation equipment.

Since the basic container unit itself is, of course, constructed of flexible material, a positive means to prevent over-filling the same is also an absolute necessity. Thus, the underwater storage system herein contemplated requires a completely reliable automatic shut-off valve positioned at each individual container. The valve must be capable of preventing over-filling, which could cause total destruction and loss of contents.

In some installations it may be desirable to protect the flexible containers from contact with the filling and emptying hoses and the various anchor lines required. If so, an intermediate underwater floating swivel-type buoy can be used. The buoy would provide intermediate support for the hose and, as such, would have to be adapted to withstand those forces that would otherwise be transmitted directly to the underwater containers.

It is the object of the present invention to provide a buoy for such an underwater storage system.

Our underwater liquid storage system comprises one or more essentially fluid-impermeable, flexible collapsible storage containers. Based on the principle of water displacement, the containers will change shape whenever liquids are induced or withdrawn and thus no differential pressure will occur across the container wall notwithstanding the buoyant force of the contained liquid. The containers themselves are horizontally oriented and are disposed within a substantially rectangular, rigid frame adapted to rest on the bottom of the body of water in which they are submerged. Means are provided to anchor the collapsible containers and enclosing frame to the bottom and to restrain them from movement due to buoyant forces and wave and current forces.

The system further comprises a plurality of straps extending in two mutually perpendicular directions and attached to the rigid frame, said straps forming a network to enclose the collapsible containers top and bottom and to restrain them from vertical movement when filled and from rubbing on the bottom when empty. The straps thus form a restraining harness and, being flexible, will not prevent the containers from changing shape when liquids are withdrawn or added. The system further comprises a header tank communicating with the individual containers. A filling and emptying hose attached at one end to the header tank and having a valve at its other end is also provided.

An underwater buoy disposed directly above the container system and adapted to provide intermediate support for the filling and emptying hose may be a part of the system. Means are provided to indicate the volume of liquid stored in the system at all times and means are also provided to prevent over-filling of the individual containers. Finally, the system comprises means to raise the

end of the filling and emptying hose adjacent the surface of the water.

The system having been broadly described, a more detailed description is given hereafter with reference to the accompanying drawings, wherein:

FIG. 1 is a perspective view of a 1200 barrel (50,000 gallon) underwater liquid storage system, having a single flexible, collapsible container, which will be used to illustrate the invention;

FIG. 2 is a sectional view taken on line 10—10 of FIG. 1, showing the details of construction of the underwater buoy;

FIG. 3 is a sectional view taken on line 11—11 of FIG. 2; and

FIG. 4 is a sectional view taken on line 12—12 of FIG. 2.

*The Overall System*

FIG. 1 illustrates a 1200 barrel (50,000 gallon) underwater liquid storage system, particularly designed for offshore storage of fuel oil. In general, the system comprises a flexible, collapsible container 20 enclosed within a substantially rectangular, rigid frame 30, which is adapted to rest on the bottom of the body of water in which the system is submerged.

The frame 30 is anchored to the bottom and restrained from lateral movement by means of four piles 40. A network of straps 50 forming a tank-restraining harness encases the container 20 top and bottom and suspends it within the rigid frame 30.

Filling and emptying of the container 20 is accomplished by means of a flexible hose 60, which extends from the surface of the body of water to a header tank 70, which is an integral part of the rigid frame 30. The header tank 70 itself communicates directly with the container 20 by means of a flexible hose 61.

The system is equipped with a metering system adapted to indicate the volume of fuel contained at all times. The metering system comprises a pressure actuated signaling device 100, pressure lines 110 and 111, and a manometer type of visual gauge 150 which is supported at the surface.

To prevent the possibility of over-filling the container, it is equipped with an automatic shut-off valve 200, which operates mechanically when the container 20 is expanded to the depth that provides the specified capacity.

To protect the container 20 from contact with the filling and emptying hose 60 and the various anchor lines required, an intermediate underwater floating swivel-type buoy 250 is provided, as shown in FIG. 1. Buoy 250 is maintained in position by four steel cables 251, as shown.

Finally, hose 60 is supported at the surface of the water by a floating buoy 300, having suitable liquid transfer control valves. Buoy 300 is maintained in position by a steel cable 301 connecting it with underwater buoy 250. Buoy 300 may desirably be provided with a navigation light 302; the buoy also furnishes support for manometer 150.

*Submerged Swivel Buoy*

FIGS. 1–4 show the intermediate underwater floating swivel-type buoy 250, which can be used to protect container 20 from contact with hose 60 and the various anchor lines required. Buoy 250 is also adapted to prevent fouling of the various lines and cables needed by the overall system. Broadly, buoy 250 comprises a buoyant chamber 252 and a pipeline section 253, which is attached to buoyant chamber 252 within a center cylindrical opening 254 therein.

As shown in FIG. 1, hose 60 and pressure lines 110 and 111 are attached to floating buoy 300 for ease in filling and emptying the storage system. As varying wind, wave and tide conditions are encountered, floating buoy 300 will shift in position relative to the underwater storage system, which action would ordinarily tend to foul lines and cables. To negate this possibility, buoy 250 is provided. The buoy permits all necessary lines to emanate from a single point, acting as an underwater swivel, and thus keeps the submerged lines free.

Buoyant chamber 252 is preferably cylindrical in shape and, as above mentioned, contains a cylindrical opening 254 passing vertically through its center. Chamber 252 is further divided into four sub-chambers by bulkheads 255, thus to lessen the chance of buoyant failure. (See FIG. 3.) Positioned on the outer surface of chamber 252 is a lug 256, to which cable 301 is attached. (See FIG. 2.) Cable 301 maintains floating buoy 300 in position, as above mentioned.

Pipeline section 253 is positioned within buoyant chamber 252, as above mentioned, in such a manner that chamber 252 can rotate thereabout. Section 253 furnishes continuity for hose 60 and pressure lines 110 and 111.

As shown in FIG. 2, section 253 is adapted to transmit the fuel oil that passes through hose 60 and pressure lines 110 and 111 through separate pipelines therein, which pipelines are located one within the other. The pipelines are respectively designated 60*b*, 110*b* and 111*b*. Line 60*b* furnishes continuity to hose 60; line 110*b* furnishes continuity to pressure line 110; and line 111*b* furnishes continuity to pressure line 111. Pressure line 110 connects lower chamber 105 of signaling device 100 to manometer 150; pressure line 111 connects upper chamber 106 of signaling device 100 to manometer 150; all as previously described.

As shown in FIGS. 2 and 3, line 111*b* is disposed within line 110*b*; line 110*b* is itself disposed within line 60*b*. This construction permits buoy 250 to rotate freely about its vertical axis.

Line 60*b* is provided with a swivel joint 260, as, for example, a standard 8 inch swivel joint of galvanized metal, which permits rotation about the vertical axis. Line 110*b* is provided with a swivel joint 261, as, for example, a standard 3 inch swivel joint of stainless steel, which permits rotation about its vertical axis. Finally, line 111*b* is provided with a swivel joint 262, as, for example, a standard 1 inch swivel joint of stainless steel, which permits it to rotate about its vertical axis. Thus, lines 60*b*, 110*b* and 111*b* can be swiveled about the vertical axis of the entire buoy 250 as a single unit, although none of the three lines can itself swivel independently of the other two.

Line 60*b* is provided with flanged fittings 263 adapted to contact bearings 264, which are themselves attached to chamber 252. Bearings 264 may conveniently be made of "Teflon" brand of plastic bearing material. This construction permits chamber 252 to rotate with respect to section 253, as above described.

It will be noted that, in general, the upper section 265 of section 253 swivels in much the same manner as buoyant chamber 252, as each is attached to floating buoy 300. The lower section 266 of section 253 will, in general, remain stationary relative to container 20, as this section is attached thereto.

Lower section 266 is provided with four radial lugs 270 (see FIGS. 2 and 4), to which are attached the four steel cables 251, above mentioned.

If desired, means for connecting line 60*b*, should the latter be desired to be constructed in two parts, may be positioned immediately below swivel joint 260. Such means comprise flanged fittings 271, which may be attached together by means of bolts 272 and nuts 273.

Thus, buoy 250 is seen to be well suited to the type of underwater storage system herein disclosed. Buoy 250 not only protects container 20 from contact with hose 60 and the various anchor lines required, but its swivel action also prevents fouling of the various lines and cables.

Having thus described our invention, what we claim and desire to protect by Letters Patent is:

A buoy for underwater liquid storage systems, comprising a buoyant chamber having a central vertical cylin-

drical opening therein; a bearing disposed in said opening and directly attached to the vertical walls thereof; and a plurality of varying diameter pipeline sections rotatably supported in said opening by said bearing, each of said pipeline sections comprising an upper and a lower part, said pipeline sections being disposed one within the other; each pipeline section further comprising a swivel joint connecting its upper and lower parts; said swivel joints, said pipeline sections, said opening in said buoyant chamber and said bearing all having a common



axis therethrough, whereby said upper and lower parts of each of said pipeline sections can rotate about said common axis with respect to each other and with respect to said buoyant chamber.

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