United States Patent [19]

Turner

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[54] **BUOYANT VESSELS**

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June 21, 1971	United Kingdom	28909/71

[52] **U.S. Cl.** .... **114/74 A,** 114/65 A, 220/9 LG

[51] **Int. Cl.** **B63b 25/08**

[58] **Field of Search** .... 114/65 A, 74 A; 52/220; 219/213, 430, 439; 220/9 LG

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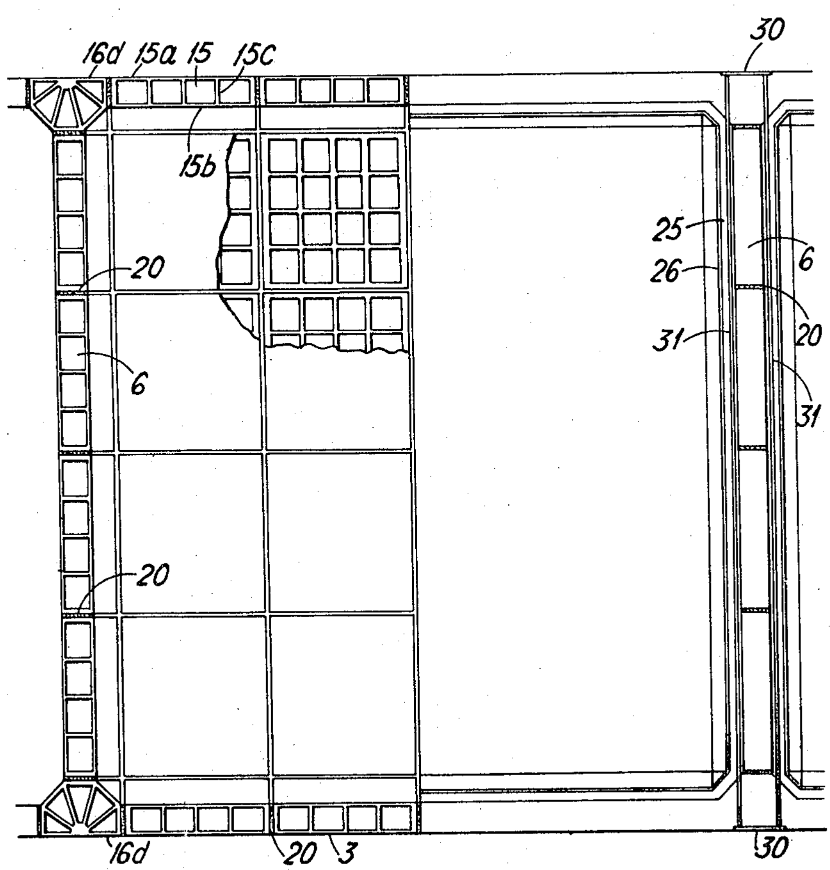
[57] **ABSTRACT**

The invention relates to buoyant vessels, which may be ships or stationary floating containers. The boundary walls of such vessels are made from prestressed concrete providing an outer layer, an inner layer, and struts between the layers. The vessel may contain a tank suitable for the containment of liquid methane or other liquid at low temperatures and the boundaries of the tank may include parts of the boundaries of the vessel.

2 Claims, 7 Drawing Figures



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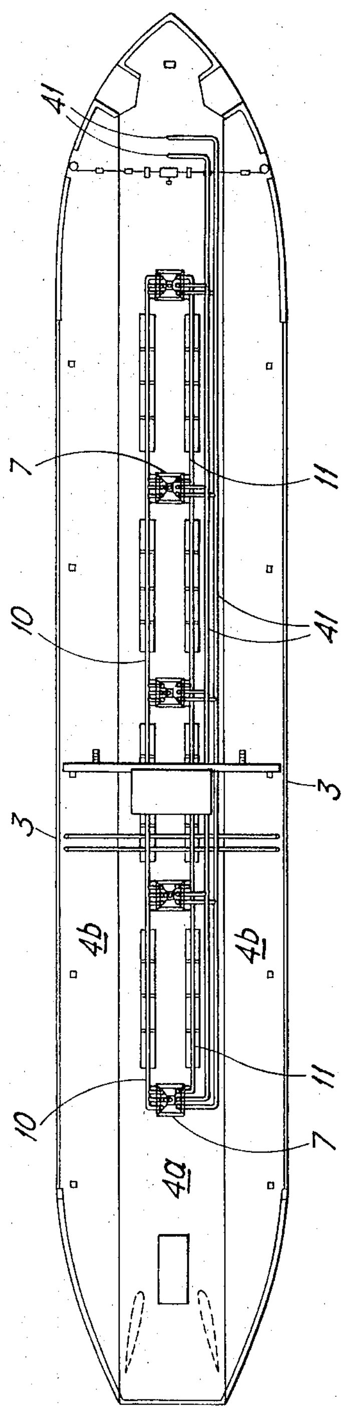

Fig. 1

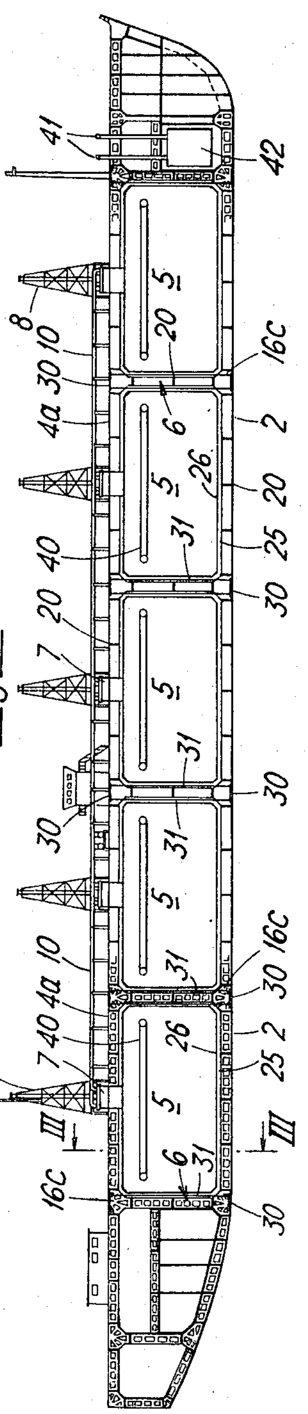

Fig. 2

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Fig. 3

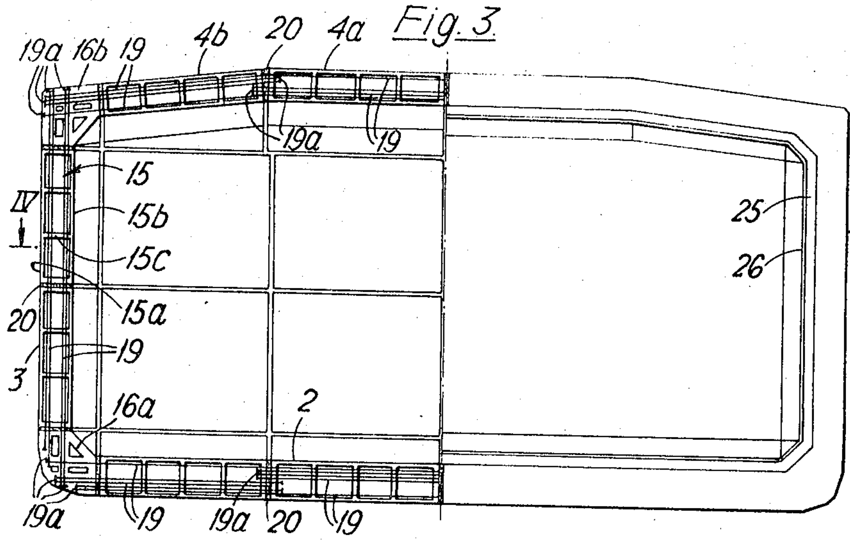


Fig. 4.

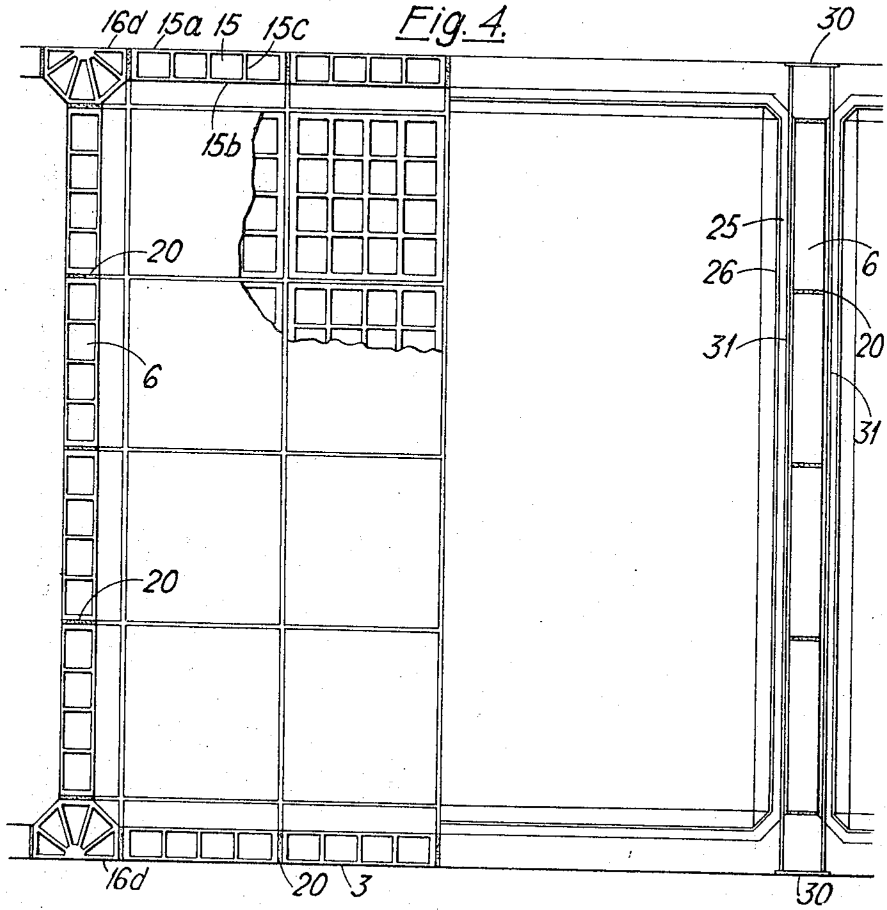


Fig. 5.

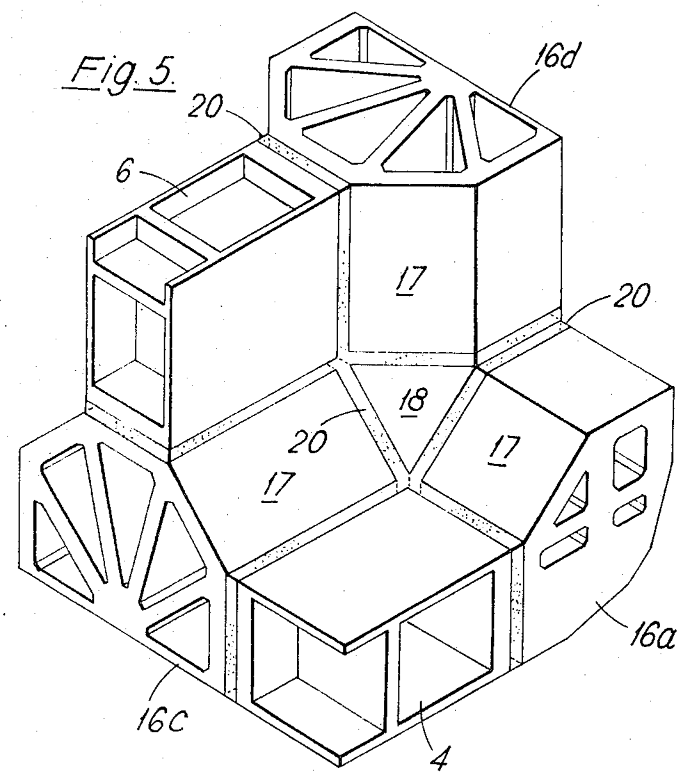


Fig. 7.

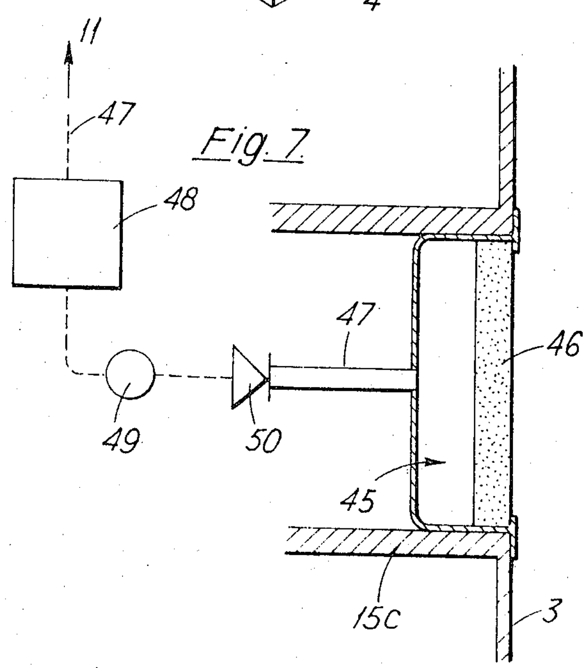
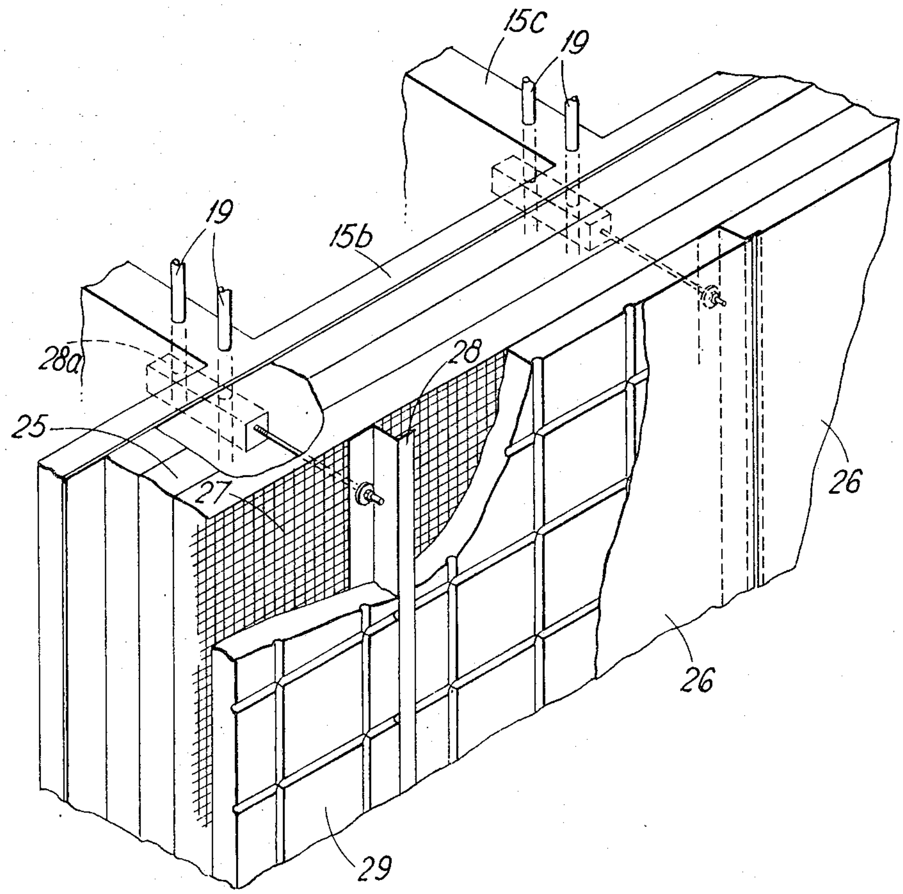


Fig. 6.



BUOYANT VESSELS

There is an increasing demand for gases, such as methane, that are liquid at low temperatures and it is usual to transport and store these fluids in a liquid condition. The present invention arose from a consideration of the problems met with in the transportation and storage of cryogenic liquids, such as methane.

According to the present invention, there is provided a buoyant vessel of which the lateral boundary walls are formed from pre-stressed concrete providing an outer layer, an inner layer, and struts extending between the layers.

According to the present invention, there is also provided a buoyant vessel in which is contained a tank in which liquid at low temperature may be stored, wherein part of the boundary walls of the tank is provided by the boundary walls of the vessel, that part is formed from pre-stressed concrete providing an outer layer, an inner layer and struts extending between the layers, and the part is provided inwardly of both layers with thermally insulating material.

By way of example, embodiments of the invention will be described with reference to the accompanying drawings, in which:

FIG. **1** shows in plan view a barge in which liquid methane may be transported and stored;

FIG. **2** is a sectional elevation through the centre line of the barge;

FIG. **3** is a somewhat schematic cross-section on the line III—III of FIG. **2**, the left-hand part showing the formation of the outer walls of the barge and the right-hand showing an inner lining of the walls;

FIG. **4** is also a somewhat schematic cross-section on the line IV—IV of FIG. **3**, the left-hand part showing the formation of the outer walls of the barge and the right-hand part showing an inner lining of the walls;

FIG. **5** is a detail, in isometric projection, of the method of construction of the barge;

FIG. **6** is a detail, in isometric projection, illustrating the way in which the inner lining is fixed; and

FIG. **7** is a detail showing a modification of the barge illustrated in FIGS. **1** to **4**.

The barge indicated generally at **1** and illustrated in FIGS. **1** to **4** has a hull that is generally flat-bottomed, **2**, and flat-sided, **3**, whilst the upper deck **4** includes a horizontal central section **4***a* extending between knuckles from which the side sections **4***b* slope down towards the sides **3**. The width of the barge is 100 feet and the height 45 feet. The major part of the space within the barge is occupied by five similar rectangular storage tanks **5** each extending across the width and height of the barge and being bounded at their ends by bulkheads **6**.

For each tank **5** there is a tank trunk **7** closing an opening in the deck **4** and a lattice mast **8** is associated with each trunk **7** to provide a hoist and carry other apparatus. By ducts passing through the trunk **7**, each tank **5** is connected to a liquid methane main **10** and a vapour methane main **11**.

The hull, decks and the bulkheads of the barge are fomed from pre-stressed concrete, the construction consisting generally of flat panels, about 5 feet thick, connected to each other edge-to-edge and to corner girders **16**. A typical panel is denoted by **15** (FIGS. **3** and **4**). This panel is included in a side wall **3**. The panel includes an outer layer or slab **15***a*, an inner layer or slab **15***b*, and struts **15***c* each extending between both layers and intersecting to form a rectangular lattice. The dimensions of the panels are such that a man could get into them for the purpose of inspection, and suitable openings, normally closed by manholes, are provided to permit such access. Pretensioning tendons, such as high tensile bars, extend both ways within the inner and outer slabs.

The panels in the side walls **3** extend between lower and upper girders **16***a* and **16***b*. The panels that are included in the bottom **2** and the deck **4** extend between girders **16***a* and **16***b* respectively, whilst the panels forming the bulkheads extend between girders **16***c* and **16***d* included in the bottom and deck, and in the side walls, respectively. The girders **16***c* and **16***d* are of essentially hollow construction, with the outer boundaries supported by radially disposed struts and the girders **16***a* and **16***b* are of rather more solid construction, relieved only by longitudinally extending bores. The cross-section of each girder **16** is such that a surface **17** at each corner of each tank **5** lies at 45° to each of the adjacent sides of the tank **5**. Where three girders converge at right angles to each other, their ends abut a solid corner piece **18** providing a flat face parallel to the adjacent end face of the girder.

The panels and girders are held together by the tendons, such as are indicated at **19**, which are provided to effect pre-stressing of the concrete. The tendons extend through the ribs **15***c* of the panels to to anchors **19***a* and access to the tendons to tension them can be had through the access openings that are provided for inspection. At each junction with a panel or girder, the joint is filled, as indicated at **20**. A suitable filler may be provided by sand mixed with either, or both, of epoxy resin and cement. A light pre-stress is applied as soon as, or before, the filler has hardened and the final pre-stress is applied subsequently, being developed in such a way that the resultant distortion that develops in the vessel is a minimum.

Each tank **5** is lined internally, the lining consisting, essentially, of a layer of thermally insulating material **25** covered by an aluminum casing **26**, into contact with which the liquid methane comes. As shown in the scrap view of FIG. **6**, the insulating material **25** is formed by blocks, of Foamglas, which are held against the walls and bulkheads by screens **27** of aluminium mesh that are retained by Z-section uprights **28**. Fixing bolts pass through the uprights **28**, screen **27** and insulation **25** into blocks **28***a* embedded in struts **15***c*. The uprights **28** also support panels **29** of light weight concrete, about three inches thick, serving as a backing for the aluminium sheeting **26**. The pieces of the sheeting **26** are seam welded to the uprights **28**.

The thickness of the insulating material **25** at the sides, bottom and deck is about 1 foot 6 inches, whilst at the bulkheads **6** its thickness is about 2 feet. Since the bulkheads **6** lie between adjacent tanks containing methane, they are liable to become colder than the other boundary walls of the tanks **5**, since one side of these walls is exposed to the sea or the air. There is thus a risk that differential contraction could occur. The extra thickness of insulation will tend to counteract this, but means is also provided to conduct heat to the bulkhead from the side of the bulkhead at which the insulation is applied. For this purpose, metal plates **30** are embedded in the central lengths of the outer surfaces of the girders **16***c* and **16***d* and bars **31** of good thermal conductivity extend between them, through the thermally insulating material adjacent the bulkhead. Thus ambient heat picked up by the plates **30** will pass along the bars **31** and so prevent excessive cooling of the bulkheads **6.**

In modifications of this arrangement for protecting the bulkheads, the bars **31** may be replaced by resistance heating elements and means may be provided for heating them. They may also be replaced by ducts through which heating fluid may be passed. Such ducts may also be filled with a static body of fluid, or even ice, since such materials would conduct adequate heat from the ambience to restrict the cooling effect of the methane on the bulkheads. To minimise the risk of tensions developing, each bar **31** may be replaced by two separate shorter ones extending towards each other from opposite ends of the bulkhead and overlapping in the middle. Although such heating is provided only for the bulkheads, similar heating can be provided for any other boundary wall.

Methane is liquid at a temperature of –259°F. and it will be realised, therefore, that when the barge shown in the drawings is at sea, there will be a tendency for boil-off to occur. Such boil-off may be economically tolerable and present no pollution objections. The barge is, however, provided with means for supercooling the tanks **5.** Each tank **5** includes tubing forming a loop **40** lying close to the upright walls of the tank and just below the normal liquid level in the tank. Each loop **40** is connected by ducting **41** to a storage and refrigerating means **42** included forward of the tanks **5.** The means **42** includes a tank containing liquid nitrogen and associated with means for maintaining the nitrogen in its liquid state and for circulating it through the loops **40** and the ducting **41.** The temperature at which nitrogen boils is less than that at which methane boils, so that the circulation of the nitrogen will effectively prevent boil-off of methane. The loops **40** are near the upper ends of the normal liquid level in the tanks **5** so that the methane will be cooled by convection effects.

The barge that has been described is intended to be charged at a source of liquid methane and then towed or pushed, perhaps with one or more similar barges, by a tug to a point of discharge. It is intended that the barge should be unmanned and controlled during transit from the tug by an automatic electronic monitoring system. Energy for the operation of such an apparatus, such as bilge pumps, that need be mounted on the barge could be provided be electric storage batteries which could be recharged through a generator device by an inertia propeller or by a diesel generator. The barge may be so simply constructed that its use as a storage vessel is not uneconomic. For return of a barge to its charging port, ballast is unnecessary, since the weight of the concrete is sufficient.

The lining of the tanks is such that the concrete will not normally be cooled to the temperature of the methane. The aluminum lining of the tanks **5** is well able to resist the conditions established by the methane, but even were a fault to develop so that the liquid methane reached the concrete, the latter, too, would be well able to resist these conditions. The effect of liquid methane on the mild steel from which the hulls of ships are usually made would be destructive is that it made the steel brittle. The worst effect on the pre-stressed construction that has been described is likely to be to cause a crack that would, in effect, be self-healing. Thus, the effect of either leakage developing from within the methane tank or of the vessel being involved in a collision is likely to be far less drastic than would be the case if the hull were made of mild steel.

When boil-off is likely to occur, and if the discharge of the vapour directly to atmosphere is unacceptable, suitable provision must be made.

One such provision is illustrated in FIG. 7 which shows one of two similar devices mounted on opposite sides of the ship, forward of the storage tanks **5.** Each device includes a flat nozzle **45** let into the side wall **3** of the barge below the water line. The nozzle is formed mainly of metal or plastic sheeting, although the outer boundary **46** is a panel of porous bronze **46.** The nozzle **45** is connected through a duct **47** to the vapour methane main **11,** the duct containing a reservoir **48,** a pump **49** and a one-way valve **50.** Should boil-off occur, the methane vapour will flow into the main **11** and thence into the tank **48.** The pump **49** is arranged to operate automatically when the pressure in the tank reaches a predetermined value and will then operate to send the vapour through the valve **50** into the nozzle **45** from which it will discharge through the diffuser plate **46** into a fine dispersion in the water. The valve **50** will prevent sea water from entering beyond that point, although an obturating device may be included to cover the plate when it is not required to operate. A valve, not shown, may also be included upstream of the reservoir **48** to prevent vapour from flowing into the reservoir during normal unloading of the methane.

Alternatively, and this is especially suitable for dealing with boil-off when the barge is berthed, it may be associated with a tender carrying a refrigerating plant. The tender is moored alongside the barge and a detachable coupling connected between the vapour main **11** and the refrigerating plant and a further detachable coupling connected between the liquid main **10** and the refrigerating plant. Thus vapour boiling off from the tanks **5** can be re-liquified and recirculated to the tanks **5.** The tender may also carry plant for withdrawing liquid methane from the barge and vaporizing it; most of the vaporized gas would be supplied to a point of use but some would be returned to the tank to compensate for the falling liquid level and ensure that air, which might create an explosive mixture, does not enter the tank. The tender can be connected to, or disconnected from, successive barges and be used as required to deliver, or recirculate, vapour.

Although the tender is envisaged to be in the form of a ship, it might be a land vehicle and either a tracked or a free-running vehicle.

Where no special provision is made to deal with boil-off, then the loops **40** provided to suppress it, may be dispensed with.

Although what has been shown in the drawings is a sea going barge, providing a plurality of storage tanks, it is envisaged that static, floating storage vessels having a similar cellular construction may also be formed within the scope of the present invention. Such vessels need not be in the form of a ship and each may constitute simply a single storage tank. It is also envisaged that while a ship may be built with a hull of the cellular construction shown, it may contain methane tanks of which no part of the walls is included in the hull. In such a case, insulation may be disposed between the tanks and the hull.

Many of the details of the specific embodiment shown in FIGS. **1** to **6** may be modified. The casing **26** may, alternatively, be formed of stainless steel, Invar steel, pre-stressed concrete, or glass fibre reinforced plastic. Other materials suitable for use as the insulating material **25** include polyurethane and balsa wood whilst the screen **27** may be made from a mesh of stainless steel. Whilst the part of the casing **26** that appears in FIG. **6** is plane, it may be appropriate to provide it with flutes, bosses or dimples to facilitate its accommodation of thermally induced contractions.

What we claim is:

1. A buoyant vessel in which cryogenic liquid may be contained comprising outer walls and at least one bulkhead that divides the space defined by the outer walls into compartments, said walls and bulkhead being formed from prestressed concrete providing boundary layers between which struts exist, insulating material internally lining each said compartment and heating means by which said bulkhead may be heated positioned on opposite sides of said bulkhead in said insulating material.

2. A buoyant vessel as claimed in claim **1** in which said heating means comprises thermal conductors embedded in the insulating material and connected thermally to plates lying at the boundaries of the vessel.

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