GROUND RESERVOIR FOR THE STORAGE OF A LIQUEFIED GAS

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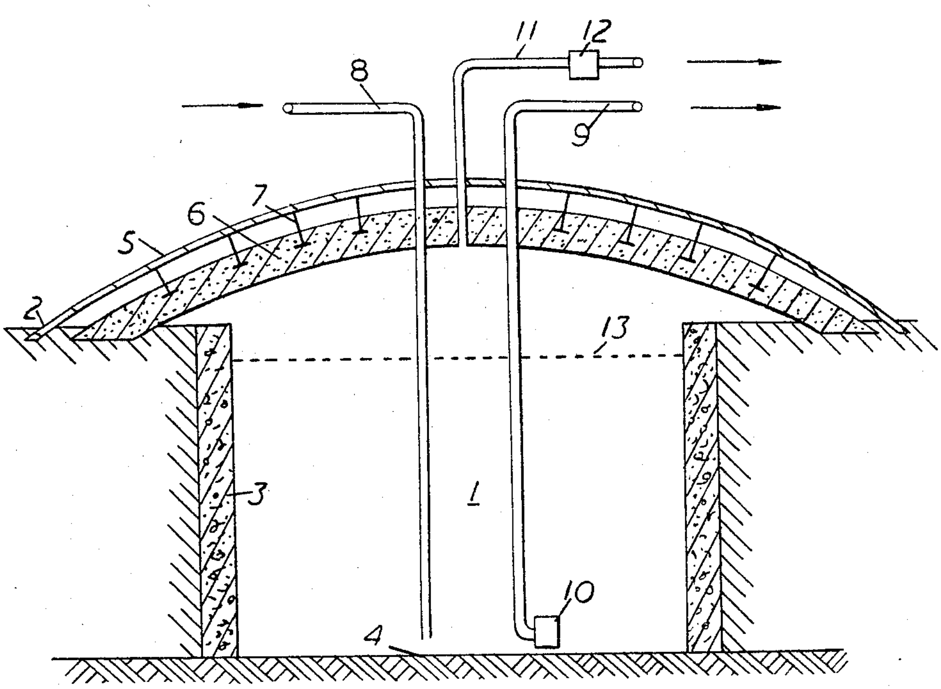
FIG. 1.



Inventor
MAURICE NACHSHEN
By
Oomo, McDougall + Hersh Attorneys

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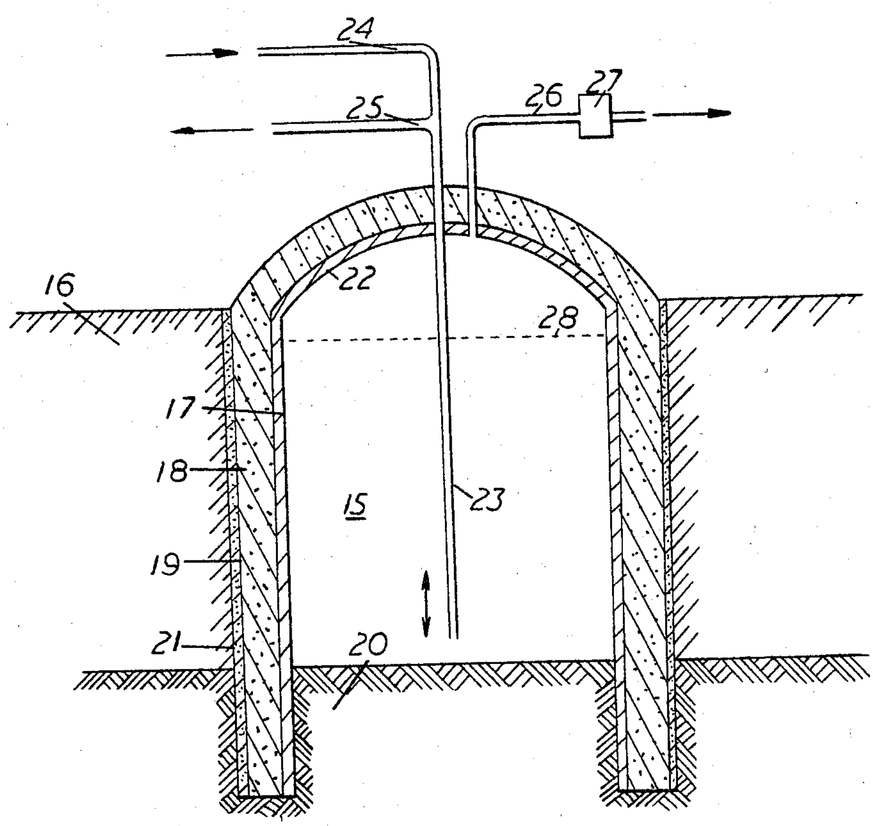
FIG. 2.



Inventor
MAURICE NACHSHEN
By
Ooms, McDougall & Hersh
Attorneys

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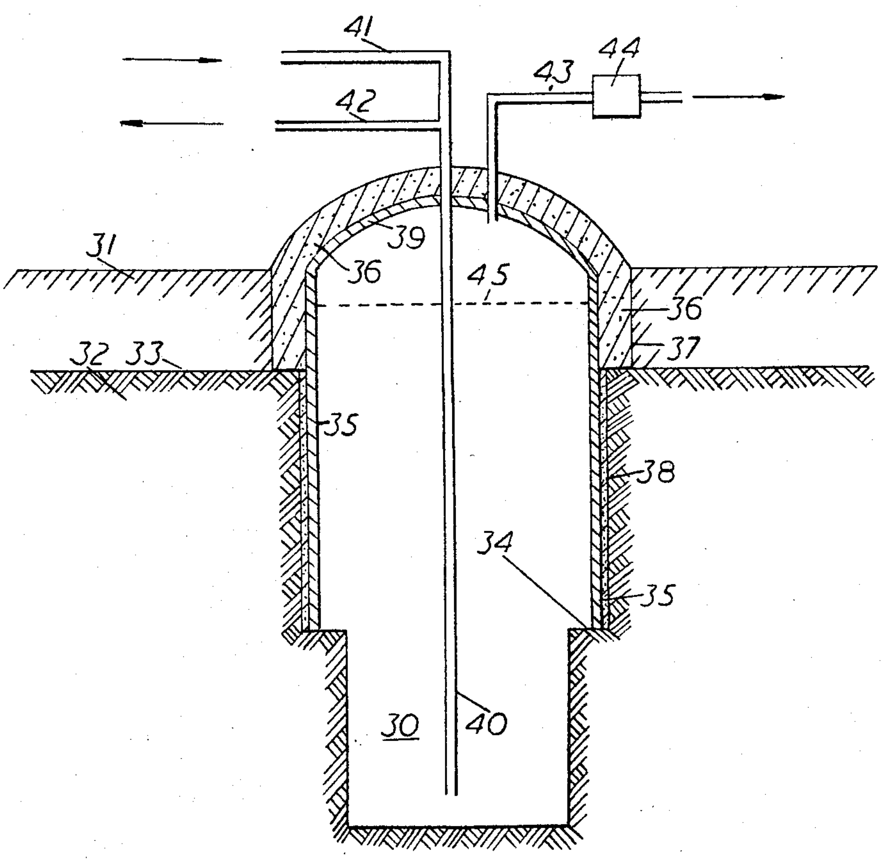
FIG. 3



Inventor
MAURICE NACHSHEN
By
Ooms, McDougall & Hersh
Attorneys

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GROUND RESERVOIR FOR THE STORAGE OF A LIQUEFIED GAS

Maurice Nachshen, London, England, assignor to Conch International Methane Limited, Nassau, Bahamas, a company of the Bahamas

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This invention concerns a reservoir for the storage of a liquefied gas in which the gas is kept in a hole in the surface of the earth which has been adapted for this purpose.

In this specification, the expression "liquefied gas" means liquid that boils at atmospheric pressure at a temperature below the ambient temperature, for example liquefied natural gas, methane, ethane, propane, oxygen or nitrogen.

According to the invention, a reservoir for the storage of a liquefied gas comprises a hole in the surface of the earth having an impervious lining to its side walls and a bottom consituted by an impervious ground layer; a thermally insulated roof completely covering the hole; a gas vent; and conduit means for charging or discharging the reservoir.

The invention enables advantage to be taken of widely available types of geological structure, namely pervious ground layers with impervious ground layers underneath. The impervious ground layer can be any impervious ground layer, namely an impervious clay or rock. A dried up river bed having a layer of gravel over a layer of rock is an example of a formation where a reservoir according to the invention could be constructed. A reservoir according to the invention can be rectangular or square, but it is preferably cylindrical, and it can be very large, for example, 200 feet wide and 100 feet deep.

The hole in the surface of the earth can be a naturally occurring hole or it can be made artificially by any of various methods, for example by either excavating the hole as such or excavating a perimetric trench having a bottom constituted by an impervious ground layer, placing in the trench the lining for the side walls of the hole, and excavating earth enclosed by the lining. If desired, the hole may not merely reach but can extend into the impervious ground layer, and the extension of the hole or a lower part thereof can be narrower than the part of the hole above the impervious ground layer, so as to provide a step to support the lining and into which the lining can be caulked and grouted when necessary, for example when the lining is made from metal.

The impervious lining can be jointless or consist of sections joined together at air and liquid tight joints, and it can be of any thickness appropriate to the surrounding ground layer or layers. Preferred impervious linings are made from concrete or a suitable metal such as aluminum or steel. If desired, the lining can extend to a depth below the bottom of the hole. The lining can have on its inside or outside or both a layer of thermal insulation (for example, fibre glass, foam plastic for instance polystyrene or polyurethane foam, paper honeycomb or perlite), which can have a seal coat of, for example, mastic. The insulation can extend partly or wholly over the respective surfaces; for example, thermal insulation on the outside of the lining can extend from the top of the lining to the beginning of the impervious ground layer. As described later the thermally insulated roof can be integral with the lining and of the same material.

When the lining is made from metal, it is desirable that the bottom of the lining be caulked and grouted into the impervious ground layer. Any space between the lining or the insulation, if present on the outside of the lining, and the side walls of the hole should be kept as small as possible, and is for example filled up with concrete or liquid cement grout.

When the lining is made from concrete, it can be made by any of various methods, for example by a trenching method. One such method, method A, comprises excavating a perimetric trench having a bottom constituted by an impervious ground layer, pumping out any water present in the trench, supporting the sides of the trench if necessary, and filling up the trench with concrete and allowing it to harden into a monolithic structure; supports (for example, concrete or timber) used to support the sides of the trench can be removed as the concrete is added or they can be left in place. A second suitable method, method B, is similar to method A, but, instead of using supports to support the sides of the trench, the trench is kept full with a heavy mud (for example, drilling mud), and concrete is injected into the trench, thereby displacing the heavy mud. Whatever method is used, reinforcements can be embedded in the concrete during construction of the lining.

The lining can also be made of a metal, suitable metals are for example stainless steel or steel. A possible method for its construction comprises excavating the hole in the surface of the earth as such, pumping out any water present in the hole, supporting the sides of the hole if necessary, and fabricating the lining in situ. When a metal lining is used it will in most cases be necessary to reinforce it by suitable webs fixed to the inside or the outside of the lining.

The thermally insulated roof can be jointless or consist of sections joined together at air or liquid tight joints, and it can be of any appropriate thickness. The thermally insulated roofs can be made from concrete or from metal (for example, aluminum or steel). The roof can have on its inside or outside or both a layer of thermal insulation (for example, fibre glass, foam plastic for instance polystyrene or polyurethane foam, paper honeycomb or perlite), which can have a seal coat of, for example, mastic. If desired, the insulation on the inside of the roof can be suspended therefrom by brackets, the space between the roof and the insulation adding to the insulation properties of the roof as a whole. The roof can be integral with the impervious lining and of the same material, thereby avoiding problems of the anchorage of the roof. The roof can be joined to the impervious lining in situ, if desired.

The gas vent leads gas produced in the reservoir to a disposal point or recovery plant, and is preferably fitted with a pressure control device for controlling the pressure of gas in the reservoir. It is conveniently fitted in the roof.

The conduit means can be of any suitable type; for example, a single conduit leading to the bottom of the hole in the surface of the earth can be used for charging or discharging the reservoir. Discharge of the reservoir can be effected by any suitable pumping system for example by a gas lift system, or by a submerged pump connected to an outlet conduit. The conduit means can pass through the roof, preferably through a trunk, or they can pass through tunnels in the sides of the hole up to the surface of the earth.

The invention will now be further described with reference to the accompanying drawings, in which FIGURES 1, 2 and 3 are vertical sections of different cylindrical reservoirs according to the invention.

In FIGURE 1, hole 1 of the reservoir has been constructed in surface of the earth 2 by constructing a concrete lining 3 according to method B described above, and excavating earth enclosed by the lining. The bottom of the hole is constituted by impervious clay 4. The hole is completely covered by a steel roof 5 with a layer of polystyrene foam **6** suspended therefrom by brackets **7**. The space between the roof and the foam adds to the insulation properties of the roof as a whole. The roof and the insulation are built a small way into the surface of the earth. Through the roof, pass a charge conduit **8** and a discharge conduit **9**, both extending almost to the bottom of the hole. The discharge conduit is fitted with a pump **10**. A gas vent **11** in the roof allows exit of gas produced in the reservoir, and is fitted with a pressure control device **12** for controlling the pressure of gas in the reservoir. The optimum liquid level is shown at **13**.

In FIGURE 2, hole **15** of the reservoir has been constructed by direct excavation in surface of the earth **16**. The side walls of the hole have a steel lining **17** provided on its outside with a layer of polyurethane foam **18** having a seal coat of mastic **19**. The lining extends into rock **20**, and its lower part is caulked and grouted into the rock, which constitutes the bottom of hole **15**. The narrow space between the side walls and the foam is filled up with concrete **21** or liquid cement grout. Integral with the lining is a steel roof **22**. The lining **17** and the roof **22** are made from steel plates welded together. The layer of polyurethane foam on the otuside of the lining is continued over the outside of the roof. Passing through the roof is a single conduit **23**, which can be used either for charging the reservoir through branch **24** or for discharging the reservoir through branch **25**, discharge being effected by a gas lift system. A gas vent **26** in the roof allows exit of gas produced in the reservoir, and is fitted with a pressure control device **27** for controlling the pressure of gas in the reservoir. The optimum liquid level is shown at **28**.

In FIGURE 3, hole **30** of the reservoir has been constructed by direct excavation in surface of the earth **31**, and it not merely reaches but extends into rock **32**. The rock line is shown at **33**. The lower part of the extension of the hole is of reduced diameter, so as to provide a step into which the lower part of a steel lining **35** is caulked and grouted. The steel lining **35** partly lines the side walls of the hole, and is provided on the upper part of its outside with a layer of polystyrene foam **36** having a seal coat of mastic **37**. The space between the side walls and the foam and the lining, where not covered by foam, is filled up with concrete **38**. Integral with the lining is a steel roof **39**. The lining **35** and the roof **39** are made from steel plates welded together. The layer **36** of polystyrene foam on the outside of the lining **35** is continued over the outside of the roof **39**. Passing through the roof is a single conduit **40**, which can be used either for charging the reservoir through branch **41** or for discharging the reservoir through branch **42**, discharge being effected by a gas lift system. A gas vent **43** in the roof allows exit of gas produced in the reservoir, and is fitted with a pressure control device **44** for controlling the pressure of gas in the reservoir. The optimum liquid level is shown at **45**.

I claim:

1. A reservoir for the storage of liquefied gas, at a temperature far below ambient temperature, comprising a fluid-impervious fabricated enclosure wall which is structurally rigid at all ambient temperatures completely lining the sides of a hole in the ground and extending down substantially from the surface of the ground into fluid-tight sealing engagement with a fluid-impervious natural ground stratum, constituting the bottom of the reservoir for direct retaining and supporting engagement with liquid gas to be stored in said reservoir; said wall defining with said stratum a fluid-impervious, water-free storage reservoir; a fluid-and-vapor tight roof, substantially at the surface of the earth, completely covering the storage reservoir and sealing the interior thereof from the ambient atmosphere, a gas vent in fluid communication with said storage reservoir having a pressure control device therein for controlling the vapor pressure within the storage reservoir, and conduit means in fluid communication with said storage reservoir for charging into and discharging from the storage reservoir a liquefied gas.

2. A reservoir as claimed in claim **1**, in which the wall is made of concrete.

3. A reservoir as claimed in claim **1**, in which the storage reservoir extends into the impervious ground stratum.

4. A reservoir as claimed in claim **3**, in which at least the lower part of the extension of the storage reservoir into the impervious ground stratum is deepened below the wall to define further storage capacity which is narrower than the part of the storage reservoir above the impervious ground stratum, so as to provide a step for the bottom of the wall.

5. A reservoir as claimed in claim **3** in which the wall is made of steel.

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EARL J. WITMER, *Primary Examiner.*