Dec. 1, 1964 C. M. SLIEPCEVICH 3,159,006

GROUND RESERVOIR FOR THE STORAGE OF LIQUEFIED GASES

Original Filed April 20, 1960 2 Sheets-Sheet 1

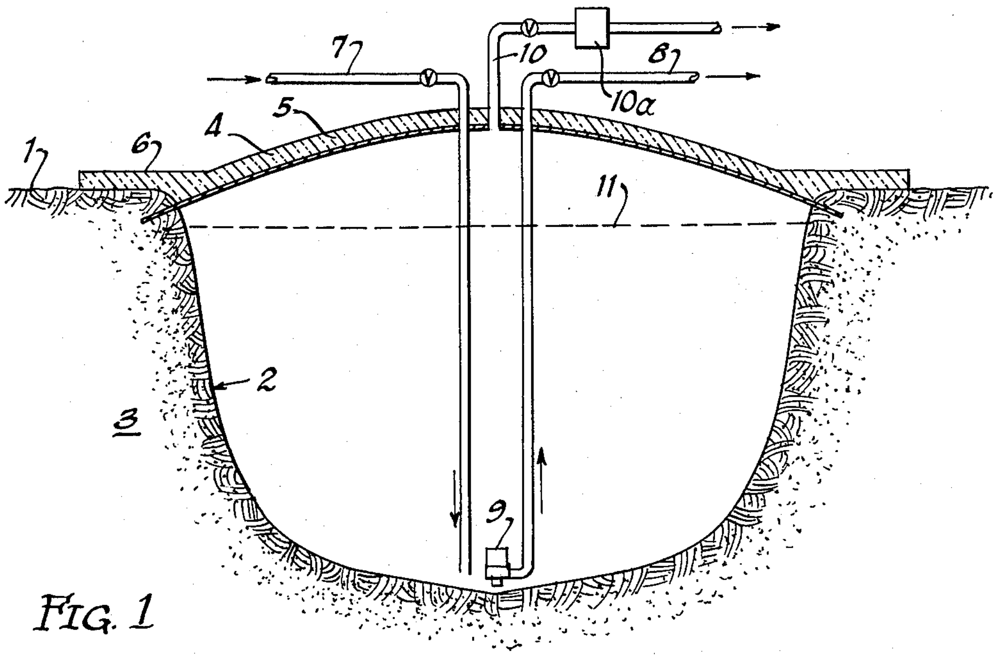

FIG. 1

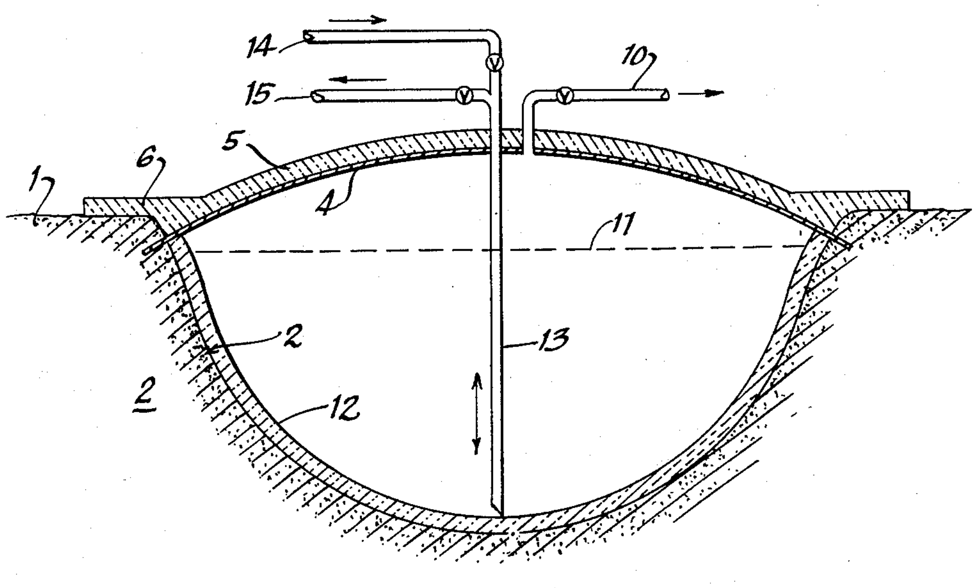

FIG. 2

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Original Filed April 20, 1960 2 Sheets-Sheet 2

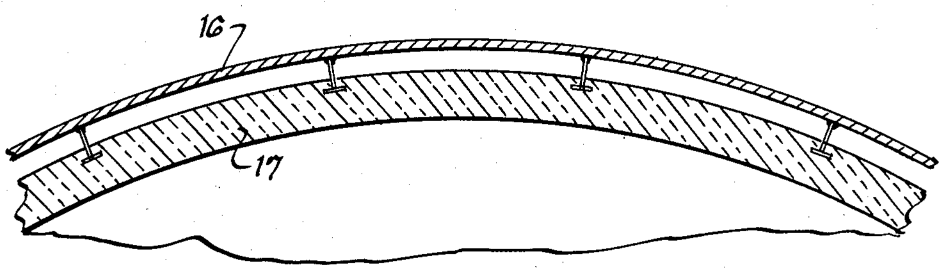

FIG. 3

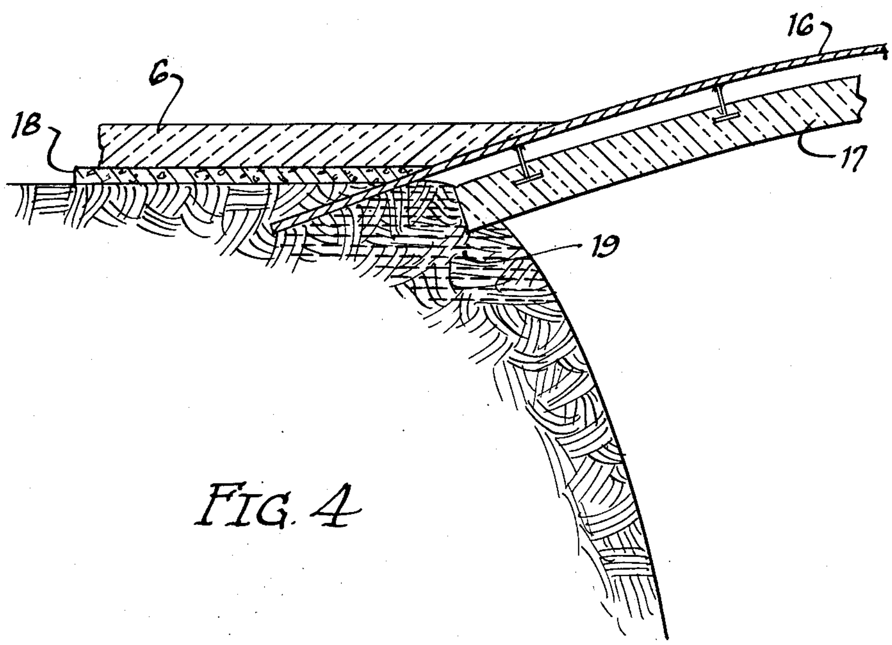

FIG. 4

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3,159,006

GROUND RESERVOIR FOR THE STORAGE OF LIQUEFIED GASES

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Continuation of abandoned application Ser. No. 23,439, Apr. 20, 1960. This application Oct. 4, 1963, Ser. No. 314,040

6 Claims. (Cl. 62—45)

This application is a continuation of application Serial No. 23,439, of Cedomir M. Sliepcevich, filed April 20, 1960, now abandoned, for Ground Reservoir for the Storage of Liquefied Gases.

This invention relates to the storage of liquefied gases, particularly liquefied natural gas or methane and liquefied petroleum gases such as ethane, propane and butane.

It is an object of this invention to produce an inexpensive, efficient and safe storage space for liquefied gases and it is a related object to produce an underground storage for cold liquefied gases which is simple in construction, efficient and safe in operation and which provides for low heat loss into the storage space thereby to minimize loss of liquid content material.

These and other objects and advantages of this invention will hereinafter appear and for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawings, in which:

FIG. 1 is a schematic sectional elevational view of a storage space embodying the features of this invention;

FIG. 2 is a schematic sectional view similar to that of FIG. 1 showing a modification in the construction of the storage space;

FIG. 3 is a sectional elevational view of a section of the roof employed in the construction of this invention; and

FIG. 4 is a sectional elevational view of a corner section of a reservoir showing the portion wherein the roof comes into engagement with the ground.

In this specification the expression "liquefied gas" means liquid which boils at atmospheric pressure at a temperature below the ambient temperature.

In this specification the expression "a hole in the surface of the earth" means a hollow place in the surface of the earth which has a substantial area in the plane of the surface in relation to its capacity, i.e. it is not intended to include narrow shafts or wells. A "compact hole" means a hole having a small surface in relation to its bulk or volume. This is important in storing cold liquids because the rate of heat loss is a minimum when the container has length, breadth and depth of the same order of magnitude so that the hole should approximate a sphere, cube or a cylinder having a depth of the same order of magnitude as its diameter. In general, the shape should be such as to present a small area for a given bulk.

It has already been proposed to store liquefied natural gas and liquefied petroleum gases in underground caverns either naturally formed or mined out of impermeable rock. Underground storage systems in salt formations have also been proposed. The difficulty with these proposals is that suitable formations are not generally available exactly where the storage system is desired.

It has also been proposed to store liquefied petroleum gas in an underground storage cavern located in a permeable water bearing formation in which the water in the cavern wall is frozen to render the wall impermeable to the fluids stored. This proposal suffers from the defect that if no natural cavern is available in the desired location of the storage system such a cavern has to be mined and this is an expensive operation. Furthermore, the shape of large underground caverns is inherently not

compact, both because of the way they are formed in nature and because a large cavern would tend to collapse without internal supporting columns (such as are left in coal mines for this purpose), due to the unsupported weight of the cavern roof, and these supporting columns would have to be of limited length and therefore, the cavern would have a large diameter compared with its depth and would therefore not be compact.

I have now invented a reservoir which can be constructed cheaply at any type of site.

This invention provides a reservoir for the storage of liquefied gases which comprises a compact hole in the surface of the earth, the earth formation surrounding said hole containing a liquid which will solidify when the reservoir is charged with the liquefied gas to be stored, a thermally insulated roof completely covering said hole, a gas vent in said roof and conduit and pumping means for filling and discharging liquid from said reservoir. This roof is made of solid and impermeable material, and is supported at the periphery of the hole without any substantial internal supporting columns or other solid internal support.

When such a reservoir is filled with liquefied gas, the liquid in the surrounding earth formation is solidified and the formation is sealed by the frozen liquid. Accordingly, the invention ultimately provides a reservoir containing a liquefied gas which comprises a hole in the surface of the earth, the earth formation surrounding said hole containing a frozen liquid which seals the said formation, a thermally insulated roof covering said hole, a gas vent in said roof, liquefied gas within said hole and conduit and pumping means for filling and discharging liquid from said reservoir.

The earth formation in which the hole is made must be one containing a liquid which solidifies at the boiling point of the liquefied gas. Normally, this liquid will be water, and, therefore, if the earth formation is a water bearing one, such as wet soil or sand, it can be used without further modification. If, however, the earth formation at the site where the reservoir is to be built is dry it will be necessary to impregnate the earth with water or with some other liquid which solidifies at the boiling point of the liquefied gas. Such other liquid might be a crude petroleum oil or a heavy oil fraction or residue.

The hole may be a naturally occurring one or it may be made artificially by excavation or by suitable explosion forces. When working in dry sand it may be desirable to impregnate the area in which the hole is to be made with water and freeze the water before carrying out the excavation.

The roof over the hole may be made of any suitable material such as steel, particularly carbon steel, aluminum or wood. In the case of wood it should be suitably sealed at the joints. The roof must be thermally insulated to prevent as far as possible transfer of heat from the atmosphere into the reservoir. This insulation may be on top of the roof or beneath it or both. In the case of insulation beneath the roof, it may be fixed in contact with the underside of the roof or it may be suspended a short distance from the underside. Preferably the surface of the earth in the neighborhood of the perimeter of the roof should also be insulated and this insulation may be continuous with any insulation on the top of the roof. A compact hole has a depth of the same order of magnitude as its width. Since heat loss is a major problem, a small hole in the ground will tend to lose too much heat to be practically feasible; the hole should preferably be at least 100 feet in diameter, and in any case, greater than 75 feet. In so large a hole, since supporting columns would need to be of the same order of length as the diameter, it is clear that such supporting columns would be very expensive to construct, and would also reduce the valuable storage space. I am aware of the U.S. patent to Cooper, No. 2,437,909, which uses a fill of detritus to support a roof in a ground storage system for liquefied gas, which both adds to the expense and greatly detracts from the storage capacity of the system.

Suitable thermal insulating materials for both the roof and the surface of the earth around its perimeter are perlite, fiber glass, paper honeycomb and foam plastics, such as foamed polystyrene and polyurethane foams. The surface of the earth surrounding the perimeter of the roof may also be insulated by dry shingle, sand or concrete.

If the structure of the earth formation is such that a considerable amount of liquefied gas is likely to be lost when it is first charged into the reservoir, two courses are open; viz, the earth formation surrounding the hole may be frozen before any liquefied gas is put into the reservoir, or the earth formation surrounding the hole may be sealed by a thin metal membrane such as thin aluminum sheet or by a layer of thermal insulation which has the ability of holding the liquefied gas away from the earth. Suitable materials are fiber glass, very fine perlite or foam plastics, such as those mentioned above.

It should be noted that when a thermal insulation is laid within the hole it is only required to act as a temporary barrier and, therefore, need not be of robust construction. Eventually, the liquid, for example the water in the earth formation, freezes and forms a permanent barrier.

With the passage of time as the reservoir is used the temperature of the ground outward from the liquefied gas progressively decreases and as a result the heat leakage inward towards the liquefied gas decreases. Thus with time the insulation of the ground improves and after several years the heat leakage for all practical purposes becomes negligible. The heat leakage through the roof is reduced as far as possible by the use of thermal insulation, but in any case is comparatively small because because the roof is in contact only with gas and not with liquefied gas.

The hole in the ground may be of any suitable shape, for example, it may be a hollowed out basic or a cylindrical or rectangular hole.

The roof must be fitted with a gas vent which will lead the gases produced in the reservoir to some suitable disposal point or recovering plant; for example, it may lead to a flare or to a gas storage system or to a reliquefaction plant. Preferably the vent will be fitted with a pressure control device which will control the pressure of gas in the reservoir.

The conduit and pumping means for filling and discharging from the reservoir may be of any suitable type. Thus a single pipe leading to the bottom of the reservoir may be used for both filling and emptying the reservoir, the latter being accomplished by a gas lift installation. Alternatively, there may be one inlet pipe and a second outlet pipe connected with the submerged pump.

Normally the gas vent and the conduits for filling and discharging the reservoir will pass through the roof, preferably through a trunk in the roof. It is possible, however, to take the filling and discharging conduits through tunnels made in the side of the reservoir and leading up to the earth's surface.

The invention will now be described with reference to the accompanying drawings which illustrate modifications of the invention.

In FIG. 1, numeral **1** represents the surface of the earth in which a ground reservoir has been constructed. A basin **2** has been hollowed out of the earth, for example by excavation, and the surrounding formation **3** has been subjected to continuous cooling by conventional refrigeration machines so that the water in the formation is frozen. A roof **4** covers the basin **2** and is itself covered by a layer of thermal insulation **5**, for example perlite or fiber glass. This insulation is extended around the perimeter of the roof to cover the adjacent earth as at **6**.

Through the roof runs a filling conduit **7** extending almost to the bottom of the basin, and also a discharging conduit **8** fitted with a submerged pump **9**. A vent **10** through the roof allows the exit of gas produced by the heat leakage into the reservoir. In this manner, the vapor pressure in the space above the liquid gas is maintained slightly above atmospheric pressure resulting only in a small upward thrust on the roof, which may accordingly be of relatively light, self-supporting construction. It should be noted that at pressures substantially higher than atmospheric, in the case of a reservoir of such large diameter as this invention is concerned with, the weight of the roof required to safely hold the pressure soon becomes so great, as the pressure required is increased, that a fabricated roof is impractical to construct, since it must have the mechanical strength necessary to support its own great weight. For this reason, it was heretofore not considered practical to construct a large diameter surface storage reservoir of compact shape. It may, however, be possible to construct a roof capable of withstanding such higher pressures if the breadth of the hole is small in relation to the length, allowing for short spans in one direction, i.e., if the hole is not a compact one, for example as shown in the U.S. patent to Goldtrap, No. 2,961,840, but then the heat loss becomes so great that it is not feasible to store extremely cold liquids such as liquid methane.

The vent **10** is preferably fitted with a pressure control device as indicated at **10***a*. Liquefied natural gas may be stored in such a reservoir over long periods, and the longer the reservoir is in use, the more effective is the thermal insulation of the frozen area **3**. The optimum liquid level is shown at **11**.

In FIG. 2, the numerals **1, 2, 3, 4, 5, 6, 10** and **11** have the same significance as in FIG. 1. However, in this reservoir the initial basin **2** was covered with a layer of glass fiber **12** which provided a temporary insulation and barrier preventing loss of liquefied natural gas when it was first charged into the reservoir. In this type of structure, there might be no need to freeze the surrounding formation **3** prior to charging the liquid gas to the reservoir. The slow heat leak into the reservoir causes the surrounding formation to be frozen over a period of time, during which period substantial loss of liquefied gas is prevented by the glass fiber layer **12**. If desired, the glass fiber layer **12** can be covered by a thin film of, for example, paper or aluminum sheet. Instead of layers of fiber glass in the lining or in the roof insulation, use can be made of other thermal insulating materials such as balsa wood, foamed plastics and the like.

The filling and discharging arrangements of FIG. 2 comprise a single conduit **13** passing through the roof which can be used either for filling through branch **14** or discharging by means of a gas lift system through branch **15**.

Although FIGS. 1 and 2 illustrate basin shape reservoirs, it will be clear that the same principle can be applied to a cylindrical or rectangular shape reservoir.

FIG. 3 illustrates a preferred roof structure for use in the reservoir of the present invention. This roof structure comprises a steel roof **16** with a layer of insulation **17** suspended therefrom by suitable brackets. The insulation is preferably impermeable to gases and may be formed, for example, of foamed plastic with disconnected pores or filled paper honeycombs. The gas space between the roof **16** and the suspended insulation **17** adds to the thermally insulating properties of the roof as a whole.

FIG. 4 illustrates a preferred method of sealing the joint between the roof and the surrounding earth formation. The roof **16** with its suspended thermal insulation **17** is built a small way into the surface of the surrounding earth **1**. A layer of cement **18** is laid on the earth surface adjacent to the perimeter of the roof and a layer of a thermally insulating material 6, such as perlite or fiber glass, is laid on the cement. The portion of the formation in the corner between the roof and the side of the basin at 19 is kept frozen if necessary by artificial means.

One of the chief advantages of the present invention is that very large quantities of liquefied gases can be stored cheaply. Reservoirs of this invention may be very large indeed, for example, they can vary from 50 feet to 200 feet in diameter. Convenient size is 100 feet in diameter. Similarly in depth they can vary from 50 feet to 200 feet, but conveniently a depth of 70 feet to 200 feet is used. Where the earth surface is insulated around the perimeter of the roof, the distance for which the insulation is required will depend on the particular liquefied gas being stored and the particular atmospheric conditions prevailing. In general, the ground surrounding the perimeter of the roof will be insulated to a distance of 15 feet to 50 feet.

It will be understood that various changes may be made in the details of construction and operation without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. A reservoir for storing liquefied gas at substantially atmospheric pressure and at a temperature below minus 40° F., which comprises a large compact, basin-like hole in the surface of the earth, the diameter of said hole at said surface being in the order of at least 75 feet; the earth formation surrounding said hole containing a frozen liquid which seals said formation at the temperature of said liquefied gas; a roof including an impervious structural roof panel which is solid at all normal ambient temperatures above 32° F. spanning the top of said hole, said roof including a layer of insulation; supporting means at the perimeter of the hole taking the full weight of the roof in the empty condition of the reservoir; said roof being in sealed relationship with the frozen earth surrounding the rim of said hole; said roof being both gas-and-liquid tight except for a controllable gas vent therein; the interior of said hole being substantially clear of any solid obstructions for retaining a maximum volume of liquefied gas, and being substantially clear of internal supporting structure for said roof, and means for conducting liquefied gas into and out of said hole and means for maintaining the vapor pressure of boiling liquefied gas in said reservoir at slightly above atmospheric pressure.

2. The invention according to the preceding claim 1, said layer of insulation being suspended below and supported by said panel.

3. A reservoir for the storage of liquefied gases which comprises a hole defined in the surface of the earth, a layer of a thermal insulating material located adjacent the surfaces defining said hole and a thin metal membrane covering said insulating layer, the earth formation surrounding said hole containing a liquid which solidifies at the boiling point of the liquefied gas to be stored, a thermally insulated roof completely covering said hole and made of a material which is solid at ambient temperatures, a gas vent, and conduit and pumping means for filling and discharging liquid from said reservoir, said thermal insulating material being glass fiber material.

4. The invention according to claim 1 said layer of insulating material being above and supported by said panel.

5. The invention according to claim 1, and a layer of liquid impervious material lining the interior surface of said compact hole.

6. The invention according to claim 5, said layer of impervious material being a thin metal membrane.

References Cited by the Examiner

UNITED STATES PATENTS

2,241,843	5/41	Buddrus et al.	62—45
2,437,909	3/48	Cooper	62—45
2,705,414	4/55	Rose	220—9
2,796,739	6/57	Meade et al.	62—54
2,911,125	11/59	Dosker	62—45
2,961,840	11/60	Goldtrap	62—45
3,092,933	6/63	Closner et al.	220—18

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