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METHOD OF PREVENTING HYDRATE FORMATION IN UNDERGROUND STORAGE CAVERNS

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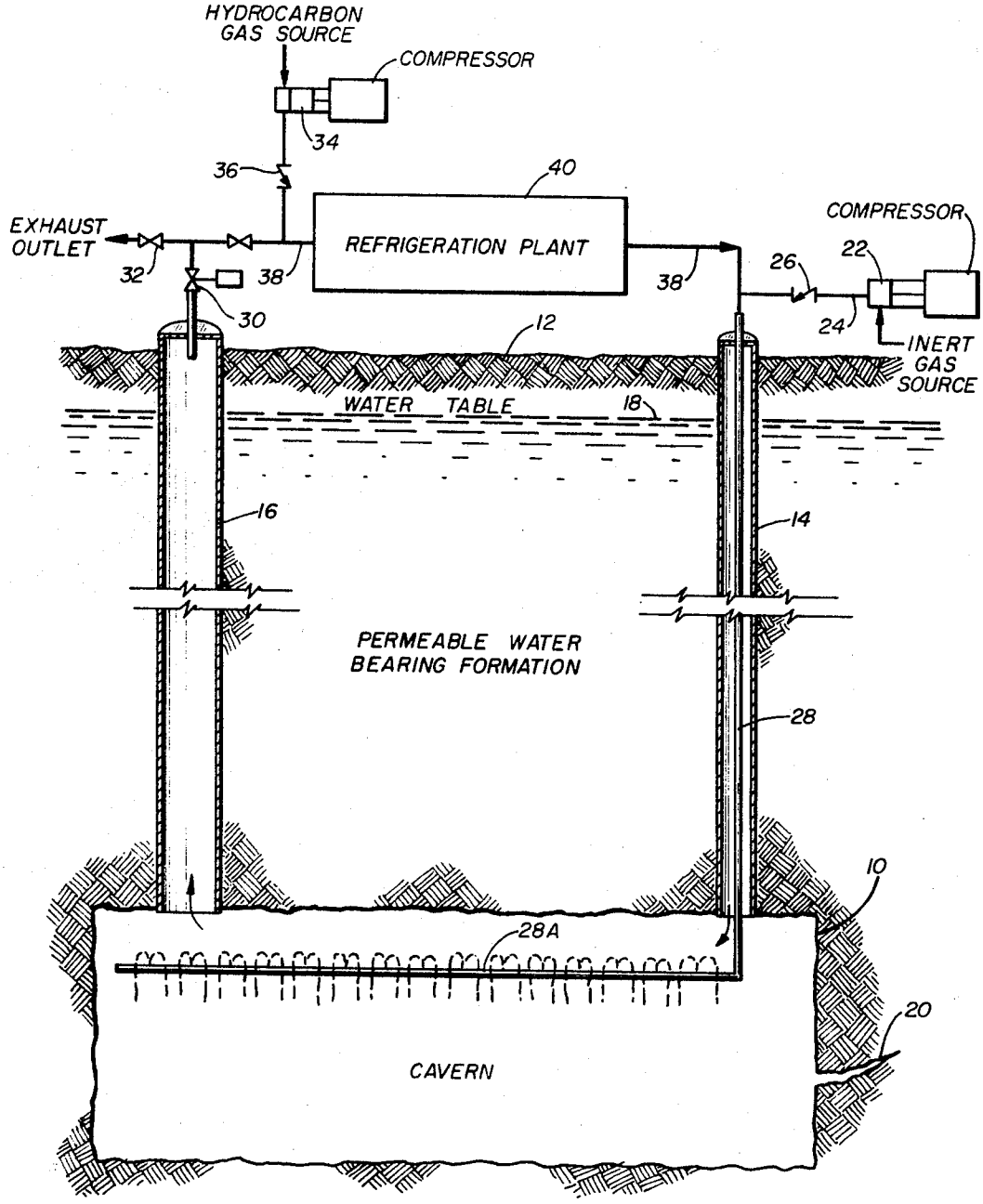

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METHOD OF PREVENTING HYDRATE FORMATION IN UNDERGROUND STORAGE CAVERNS

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ABSTRACT OF THE DISCLOSURE

This invention provides a method of preventing hydrate formation in an underground storage cavern formed in a water bearing permeable formation. The method includes the steps of pressuring the cavern with an inert gas to a pressure at least equal to the hydrostatic pressure of water tending to enter the cavern to stop the flow of water into the cavern, injecting into the cavern a cooled compressed high vapor pressure petroleum product while maintaining the pressure within the cavern, and maintaining the pressure within the cavern until the walls thereof are freeze sealed.

This invention relates to a method of preventing hydrate formations in underground storage caverns. More particularly, the invention relates to a method of sealing the walls of an underground storage cavern formed in permeable water bearing formations.

In recent years the use of underground caverns has become an expedient means of storing large volumes of liquids. One of the reasons is that it has been learned that liquids, such as liquefied petroleum gas, are more economically stored in underground caverns than in aboveground vessels. A frquently used method of providing underground storage caverns is to mine the caverns in salt formations, the mining taking place either by physically removing the salt or by solution mining. Such salt formation is non-porous and after the cavern is formed, offers a substantially leakproof underground enclosure for the storage of liquids. One problem, however, is that the occurrence of large salt formations in certain geographical areas are rare so that in many instances such formations cannot be found in the places where underground storage is desired. This means that some other system is required for providing leakproof underground enclosures.

One method of providing such enclosures is that of digging caverns in porous water bearing formations and, upon completion of the caverns, freezing the water in the walls to form sealed enclosures. Whereas large salt deposits where storage caverns can be located are relatively rare, most geographical areas afford porous underground water bearing formations. In addition to leakage, a problem which has plagued the use of water bearing formations for the storage of certain high vapor pressure hydrocarbon products, or mixtures thereof, is that when these liquids are delivered into a cavern containing water, solid hydrates may be formed. The formation of hydrates causes two difficulties, that is, first, hydrate formation can materially reduce the storage capacity of the cavern, and, second hydrates can block openings to prevent the flow of fluid into or out of the caverns.

The basic object of this invention is to provide a means of preventing hydrate formations in caverns utilized to store liquefied hydrocarbons. A still more particular object of this invention is to provide a method of sealing a cavern formed in a permeable underground water bearing formation in a manner such that the formation of hydrates in the cavern is prevented.

These and other objects will be fulfilled by the methods of the invention to be now described, the description being taken with reference to the drawing which is a diagrammatic representation of a cavern formed in the earth including the mechanisms utilized to practice the method of this invention.

This invention may be described as a method of preventing hydrate formation in a cavern formed in an underground permeable water bearing formation. More particularly, but not by way of limitation, the invention may be described as a method of sealing a cavern formed in a permeable water bearing underground formation comprising the steps of introducing an inert non-hydrate forming gas into the cavern to purge air from the cavern, pressuring the cavern with the inert gas to a pressure at least equal to the hydrostatic pressure of water tending to enter the cavern to stop the flow of water into the cavern, injecting high vapor pressure hydrocarbon gas which has been cooled below the freezing point of water into the cavern to purge the inert gas therefrom and at the same time maintaining the gas pressure within the cavern at least equal to hydrostatic pressure of water tending to enter the cavern, and circulating the hydrocarbon gas through the cavern until the walls are freeze-sealed.

Referring now to the drawing, a cavern **10** is shown, the cavern having been excavated in a porous water bearing formation. The cavern is connected to the surface **12** of the earth by means of shafts **14** and **16**. The water table in the formation, the top of which is indicated by the numeral **18**, is usually below the earth's surface and is the point at which hydrostatic pressure in the earth's formation begins. The hydrostatic pressure of water table **18** tends to cause water to flow into the cavern **10**. Such water flow may take place either through the pores of the permeable formation in which the cavern has been dug or through fissures in the formation, such as indicated by the numeral **20**.

When excavation of cavern **12** is completed and before the method of this invention is undertaken to seal the cavern wall, all water in the cavern is pumped out through either shaft **14** or **16**; the equipment utilized for such pumping purposes is not shown since such forms no part of this invention.

After the excess water has ben removed the first step of this invention is to purge the air within the cavern **10** to reduce the oxygen content thereof so that subsequent introduction of hydrocarbon gases will not create an explosive mixture. Such inert gas is pressured by compressor **22**, the pressured gas flowing through line **24** and valve **26**, through shaft **14** and into the cavern. To facilitate distribution of gas into the cavern, shaft **14** may contain a string of tubing **28**. Tubing **28** bends within the cavern to extend horizontally through the length of the cavern, the extending portion **28A** being provided with numerous perforations. The use of the tubing **28** and particularly the perforated extending horizontal portion **28A** is by way of example only and is illustrative only, the use of such tubing is not essential to the basic methods of the invention.

The inert gas from compressor **22** fills the cavern **10** and forces air trapped in the cavern up through shaft **16**, past control valve **30** and exhaust valve **32** to the atmosphere. When the oxygen content of the air, forced

out the exhaust outlet, falls below the point wherein danger of explosion may occur, the control valve **30** and the exhaust valve **32** are closed. Inert gas is continued to be injected into the cavern **10** until the pressure thereof rises to the point equal to the hydrostatic pressure of water tending to enter the cavern.

The hydrosatic pressure of water tending to enter the cavern is usually directly related to the height of the water table **18** above the cavern. The flow of water into the cavern is directly related to the difference between the hydrostatic pressure of the water and the pressure in the cavern. As the pressure in the cavern increases the flow diminishes and when the hydrostatic pressure in the cavern exactly equals the hydrostatic pressure of water tending to enter the cavern the water flow stops. If the hydrostatic pressure in the cavern exceeds the hydrostatic pressure of water tending to enter the cavern then water would be forced away from the cavern walls. In the method of this invention it is desirable that the hydrostatic pressure of the gas in the cavern be as near as possible to the hydrostatic pressure of the water tending to enter the cavern so that all water flow into the cavern ceases, but, at the same time, the water is not forced from the walls. This balanced force maintains the walls as near as possible in saturated condition. The pressure of gas necessary within the cavern to equalize the hydrostatic presure of water is best determined before the steps of the method of this invention are undertaken. If the height of the water table is known, such hydrostatic pressure can usually be accurately and simply computed.

As previously stated, inert gas is forced from compressor **22**, through line **24** and shaft **14** into the cavern to raise the hydrostatic pressure to that preventing the flow of water into the cavern. This can be accomplished relatively quickly, the time depending upon the capacity of the compressor **22**. In any event, the raising of the pressure in the cavern to equal the hydrostatic pressure of the water tending to enter the cavern can be accomplished relatively quickly thereby reducing the total water in the cavern.

When the pressure balance of the inert gas with the water tending to enter the cavern is achieved the next step is to quickly freeze the walls of the cavern. It is well known that running water is very difficult to freeze whereas still water is easily frozen by lowering the temperature. The next basic step of this invention is to quickly freeze the water in the porous formations forming the wall of the cavern. This is accomplished by injecting a high vapor pressure hydrocarbon gas, such as natural gas, into the cavern. This is achieved by compressor **34** forcing the gas through check valve **36** and line **38**, down shaft **14** and into the cavern **10**. As previously indicated, in the preferred arrangement, line **38**, as did line **24**, connects with a tubing **28** having a horizontally extending perforated portion **28A**. The hydrocarbon gas purges the inert gas contained in the cavern. The inert gas is permitted to escape out of the cavern through control valve **30** and exhaust valve **32**. Control valve **30** is of the type which maintains a back pressure within the cavern at the preselected hydrostatic pressure to prevent water flow into the cavern. The hydrocarbon gas is cooled below the freezing point of water by refrigeration plant **40** before it enters into the cavern **10**. Thus the hydrocarbon gas entering the cavern causes the water in the porous walls of the cavern to freeze, sealing the cavern. If necessary, the hydrocarbon gas can be continuously recirculated through the refrigeration plant **40** as long as necessary to completely freeze the walls of cavern **10**, at the same time maintaining the pressure within the cavern equal to the preselected hydrostatic pressure to prevent water flow into the cavern.

The circulation of the hydrocarbon gas continues until the walls are completely freeze sealed. The hydrocarbon gas may then be vented and the cavern put to use as a storage facility for liquefied petroleum gas or some other gas having similar property. The cavern will be sealed as long as the walls are kept below freezing temperature which is accomplished by previously known means, such as circulating a refrigerant therethrough, not forming a part of this invention.

In this description the expression "hydrocarbon gas" or "high vapor pressure hydrocarbon gas" means any hydrocarbon gas having a vapor pressure of butane or higher. Inert gas as used herein includes any gas which is noncombustible and nonhydrate forming, such as nitrogen or flue gas.

While in this description two shafts **14** and **16** are illustrated for purposes of simplicity it can be seen that the operation can easily be carried out by the use of a plurality of lengths of tubing located in a single shaft, the number of shafts not forming a part of the method of this invention. This invention provides a means of freeze sealing the walls of a cavern in a manner wherein it is not necessary to pump water from the cavern as the freezing process is taking place. This is an important advantage in that prior methods have encountered considerable difficulty in attempting to excavate water while hydrocarbons are being injected due to the hydrates blocking the water evacuation lines.

While this invention has been described with a certain degree of particularity it is manifest that many changes may be made in the details of construction and in the sequence of steps employed by the arrangement of components, without departing from the spirit and scope of this disclosure.

What is claimed:

1. A method of preventing hydrate formation in a cavern formed in a water bearing permeable formation comprising the steps of:

(1) pressuring the cavern with an inert gas to a pressure at least the hydrostatic pressure of water tending to enter the cavern to stop the flow of water into the cavern;

(2) injecting into the cavern a cooled compressed high vapor pressure petroleum product while maintaining the pressure within the cavern; and

(3) maintaining the pressure within the cavern until the walls thereof are freeze sealed.

2. A method of sealing a cavern formed in a permeable water bearing underground formation comprising:

introducing an inert non-hydrate forming gas into said cavern to purge air from the cavern;

pressuring the cavern with said inert non-hydrate forming gas to a pressure at least equal to the hydrostatic pressure of water tending to enter the cavern to stop the flow of water into the cavern;

injecting high vapor pressure hydrocarbon gas cooled below the freezing point of water into the cavern to purge the inert gas therefrom and at the same time maintaining the gas pressure within the cavern above the hydrostatic pressure of water tending to enter the cavern;

circulating the cooled gas through the cavern until the walls thereof are freeze sealed.

3. A method of sealing a cavern formed in a permeable water bearing underground formation comprising:

introducing an inert non-hydrate forming gas into said cavern to purge air from the cavern;

increasing the pressure of the inert gas to substantially the hydrostatic pressure of water tending to enter the cavern to stop the flow of water into the cavern;

injecting high vapor pressure hydrocarbon gas into the cavern at a pressure thereof substantially equal to the hydrostatic pressure of water tending to enter the cavern to continue to prevent the flow of water into the cavern; and

circulating cooled hydrocarbon gas through the cavern while maintaining the hydrostatic pressure therein

sufficient to prevent water flow into the cavern until the walls of the cavern are frozen.

References Cited

UNITED STATES PATENTS

2,932,170	4/1960	Patterson et al.	61—.5
2,961,841	11/1960	Giles	61—.5 X
3,062,012	11/1962	Allen	61—.5
3,205,665	9/1965	Van Horn	61—.5
3,296,805	1/1967	Graham	61—.5

FOREIGN PATENTS

111,569	3/1962	Pakistan.

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