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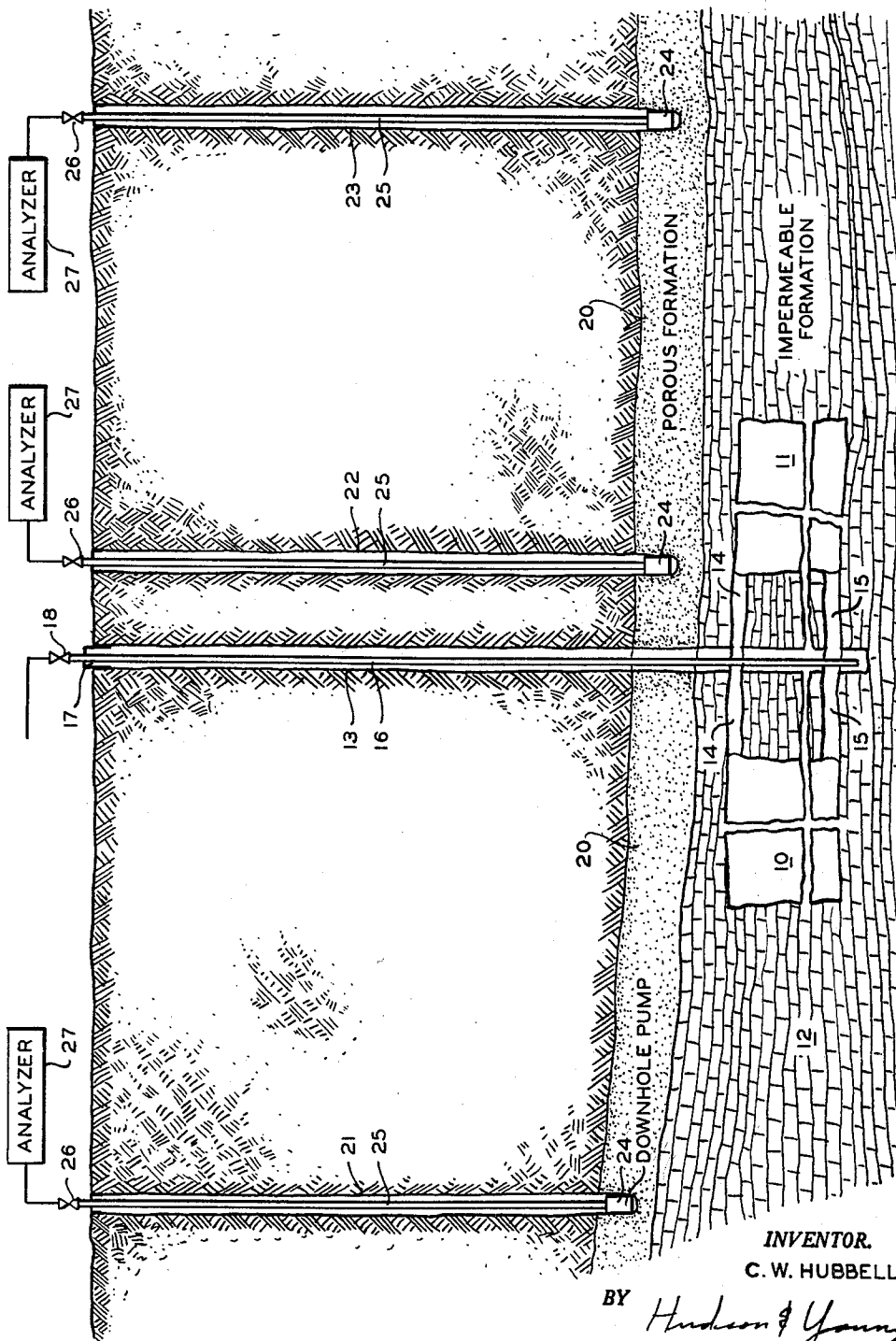
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SYSTEM AND METHOD OF DETECTING AND CONTROLLING
LEAKAGE FROM AN UNDERGROUND STORAGE CAVERN

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SYSTEM AND METHOD OF DETECTING AND CONTROLLING LEAKAGE FROM AN UNDERGROUND STORAGE CAVERN

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4 Claims. (Cl. 61—.5)

This invention relates to a method of and apparatus for determining leakage from an underground storage system. In another aspect, it relates to a method of and apparatus for localizing the flow of material leaking from an underground storage system, thereby preventing damage to life or property as a result of product leaking from the system.

With the increasing cost of surface storage equipment, such as steel tanks, required to contain materials, particularly volatile materials such as liquefied petroleum gas and ammonia, underground storage facilities have been proposed and built for these materials with a resultant substantial decrease in the investment per unit of product stored. Such materials, particularly liquefied petroleum gas, are stored under high pressures, liquefied petroleum gas being composed principally of the very volatile hydrocarbons propane and butane. As propane and butane are highly flammable and dangerous, it is evident that any substantial leakage of the stored material to the surface of the earth is quite hazardous and may result in damage to life and property, in addition to the loss of product from the storage facilities. Similarly, leakage of material such as ammonia can create definite hazards to life and property in addition to the loss of product.

Accordingly, it is an object of the invention to provide an improved method of an apparatus for detecting leaks of product from underground storage facilities.

It is a further object of the invention to provide a method of and apparatus for localizing the path of any material escaping from the facility to the end that loss of life and property may be avoided, and some or all the product leaking from the facility recovered.

Various other objects, advantages and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawing, in which the figure is a vertical sectional view illustrating the system of the invention.

Referring now to the drawing in detail, I have shown an underground storage facility including a plurality of underground caverns 10, 11 formed, as by mining procedures, in an impermeable formation 12, such as shale or limestone. Each of the caverns 10, 11 is connected to a central shaft 13 by an upper tunnel 14 and a lower tunnel 15. Extending downwardly through the shaft is a conduit 16 by which material can be introduced into or withdrawn from the storage zone. The conduit 16 extends through a seal, such as a well head 17, at the top of the shaft 13 and is provided, at its upper end, with a valve 18.

In commercial operation, such a cavern and its associated shaft may include a considerable amount of pumping equipment and conduits for introducing material to storage or withdrawing stored material therefrom. A complete system of this type is illustrated in the copending application of Leonard P. Meade, Serial No. 314,541,

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filed October 13, 1952, entitled "Underground Storage System," and now abandoned.

In the underground storage facility described and claimed by this application, the material is withdrawn from storage through the shaft by down hole pumps and the material is introduced to storage through drilled holes which extend to the surface from one or more of the caverns 10, 11. However, the particular construction of the cavern, or other storage facility and the method of introducing material thereinto or withdrawing material therefrom are not a primary feature of the present invention and, hence, are not described in detail herein. As will become apparent, the principles of the invention are applicable to caverns of whatever size or shape formed in impermeable formations and provided with any suitable method of introducing and withdrawing material from storage. Further, in accordance with certain broad aspects of the invention, the leak detecting and controlling system hereof is applicable to storage in other than mined caverns, as in salt caverns, abandoned railroad tunnels, and other facilities of this type which have been previously used for the underground storage of fluid materials.

In accordance with the invention, one or more wells are drilled from the surface of the earth to a porous fluid-bearing formation 20 overlying the impermeable formation 12. In some cases, satisfactory results can be obtained where the upper part of the impermeable formation is permeated by a fluid, such as water. In the embodiment illustrated by the figure, three wells 21, 22 and 23 are drilled from the surface to the formation 20, and each of these wells is provided with a down hole pump 24 at the lower end of a tubing string 25, a valve 26 being provided at the upper end of each of the tubing strings 25. Preferably, an analyzer 27 is connected at the top of each well 21, 22, and 23, the analyzer detecting the presence of any of the stored material which may leak from the caverns 10, 11. Where the material is liquefied petroleum gas or ammonia, an infra-red analyzer or explosimeter is suitable for this purpose. As shown, a separate analyzer can be provided for each of the tubing strings 25 or, alternatively, a single analyzer 27 can be used which is successively connected to streams flowing from the plurality of wells, in a cyclic manner.

In either event, when fluid leaks from either of the cavern 10 or 11, the fluid permeating the porous formation 20 will take up a small proportion of the stored material, which can be readily detected by the analyzer 27. It is, of course, advantageous to have one or more wells located immediately above the stored facility, the well 22 being located at such position in the figure. It is also advantageous to have one or more wells such as wells 21, 23 enter the porous formation 20 a substantial lateral distance from the underground storage facility. In this event, should leakage be detected at well 22, it can be readily determined whether or not the leakage is spreading laterally, with respect to the storage facility, or whether it is confined to the central region of stratum 20 overlying the storage facility. Such information is of substantial value in correcting the factors producing the leak of stored material should such be detected.

It is a further feature of the invention that, should a small leakage occur, the undesirable effects thereof can be largely alleviated by pumping fluid at a rapid rate from well 22, thus withdrawing substantially all the leaking product through this well. Substantially complete recovery of the leaking product will be obtained where the rate of fluid withdrawal from the well is approximately equal to the amount of fluid which can be

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potentially produced by the porous formation 20. Where this method of recovery is practiced, withdrawal of samples from wells 21, 23 indicates whether or not the leakage of stored material is spreading laterally from the storage area.

In some instances, it is permissible to analyze the fluid withdrawn from formation 20 only at intermittent intervals. However, when this is done, an analyzer can be continuously connected to the interspace between the tubing 25 and the wall of one or more of the wells 21, 22 or 23, preferably well 22. It will be understood that each well is provided, at the top thereof, with a sealing plate or cap, as shown, and an analyzer so connected will permit the presence of gas resulting from vaporization of the stored material to be detected if it should penetrate the interspace between the tubing 25 and the wall of the bore hole. Of course, should there be an indication of product leakage, the pump 24 would be actuated, and some of the fluid from formation 20 withdrawn and analyzed.

It will be apparent that I have achieved the objects of my invention in providing a safe, inexpensive, and practical way of detecting the leakage of stored material from underground storage facilities of whatever configuration or structure. It will be further evident that I have provided a method of localizing the flow of any material which may leak from an underground storage cavern, thereby preventing the material from issuing at the surface of the earth with possible damage to life or property. Further, in this manner, a large proportion of any material which may leak from the cavern can be recovered.

While the invention has been described in connection with a present, preferred embodiment thereof, it is to be understood that this description is illustrative only and is not intended to limit the invention.

I claim:

1. A system for detecting leakage of material from an underground storage cavern formed in a substantially impermeable formation, said formation having a porous water-bearing formation above it which comprises, in combination, means for introducing material to be stored to said cavern and withdrawing stored material therefrom, a well drilled from the surface of the earth to a portion of said porous formation overlying said cavern, means for withdrawing water from said porous formation and lifting it and any stored material contained therein to the surface, and an analyzer at the surface cooperating with said lifting means, said analyzer indicating the presence or absence of stored material in the water withdrawn from said porous formation.

2. In an underground storage system, in combination, an underground storage cavern formed in a substantially impermeable formation, a porous water-bearing formation overlying said substantially impermeable formation, means for introducing material to be stored to said

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cavern and withdrawing stored material therefrom, a plurality of wells drilled from the surface of the earth and extending downwardly to said porous formation, one of said wells being positioned so as to directly overlie a portion of said cavern, and another of said wells entering a region of said porous formation which is laterally spaced from said cavern, means for lifting water and any stored material contained therein from said porous formation to the surface, and an analyzer connected to said lifting means to analyze said water, thereby determining the presence or absence of stored material therein.

3. The method of detecting leakage of highly volatile stored material from a subterranean cavern formed in a substantially impermeable formation which is located beneath a porous water-bearing formation which comprises withdrawing water and any highly volatile stored material which may have leaked therein from said cavern from the porous water-bearing formation at a rate sufficient to prevent lateral flow of the water through said water-bearing formation in a direction away from the zone of water withdrawal, and continuously lifting the thus withdrawn water and any highly volatile stored material contained therein to the surface, whereby material leaking from the cavern is withdrawn to the surface through the porous formation at the zone where the water is withdrawn.

4. The method of detecting leakage of highly volatile stored material from an underground storage cavern formed in a substantially impermeable formation which is located beneath a porous water-bearing formation which comprises drilling a well from the surface of the earth downwardly to said water-bearing formation, withdrawing water and any highly volatile stored material which may have leaked from the cavern to the surface of the earth through said well, and analyzing the water withdrawn to the surface to detect the presence or absence of stored material therein.

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