

Aug. 20, 1957

T. B. HUDSON

2,803,114

UNDERGROUND STORAGE SYSTEM

Filed July 18, 1952

2 Sheets-Sheet 1

Fig. 1.

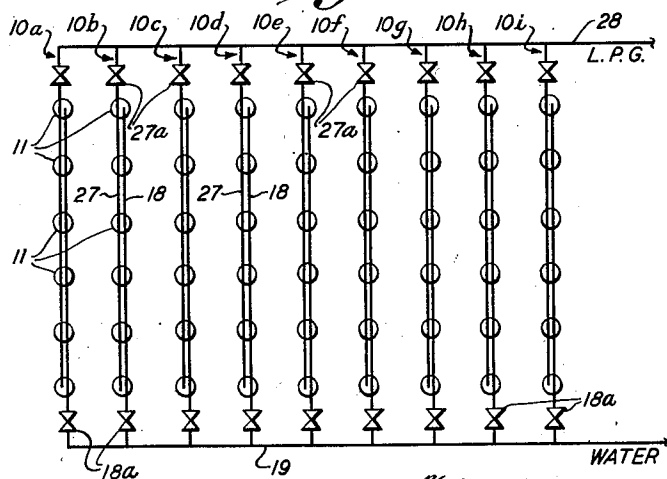


Fig. 2.

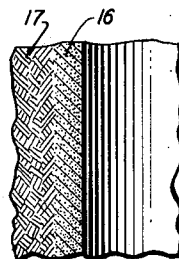
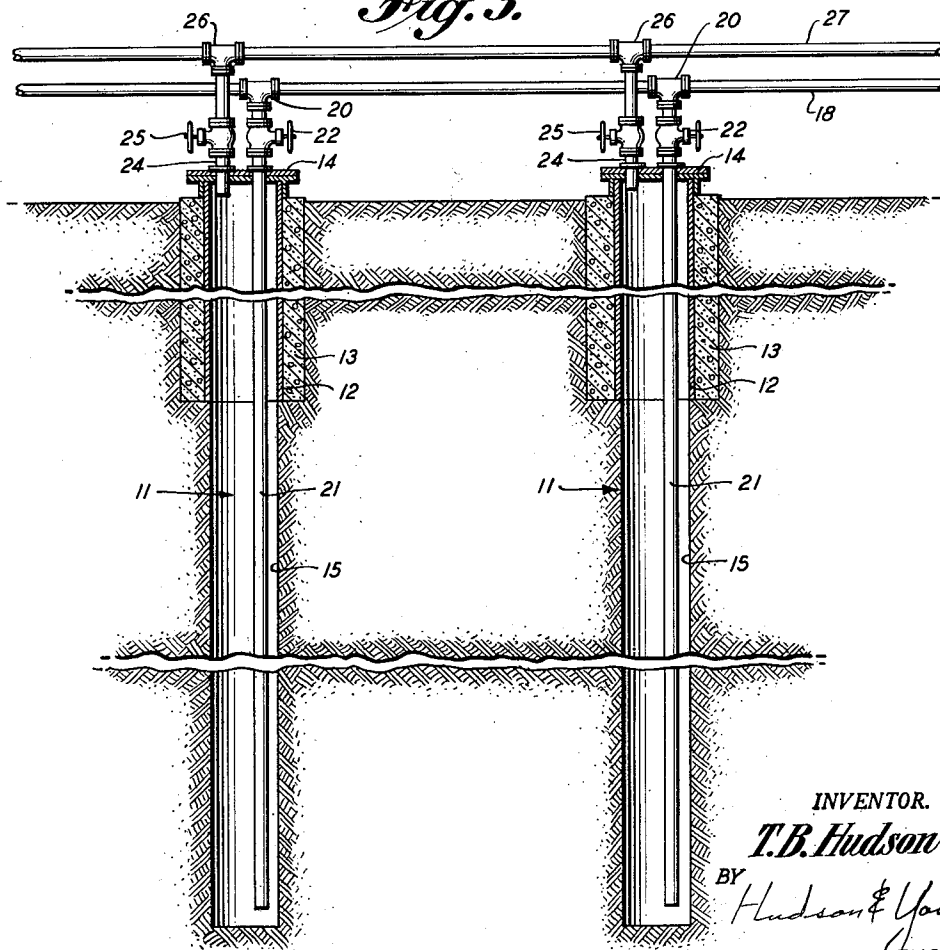


Fig. 3.



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Fig. 4.

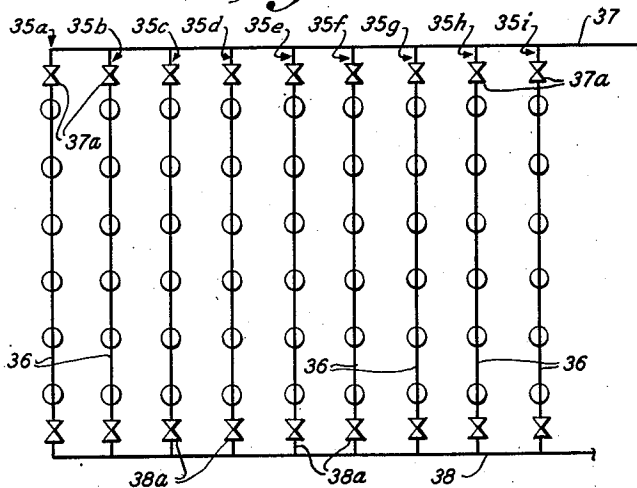


Fig. 6.

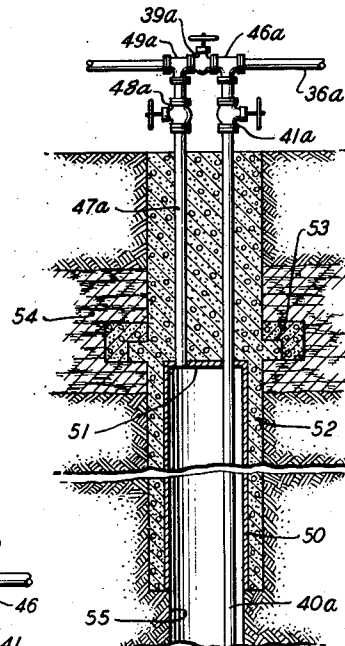
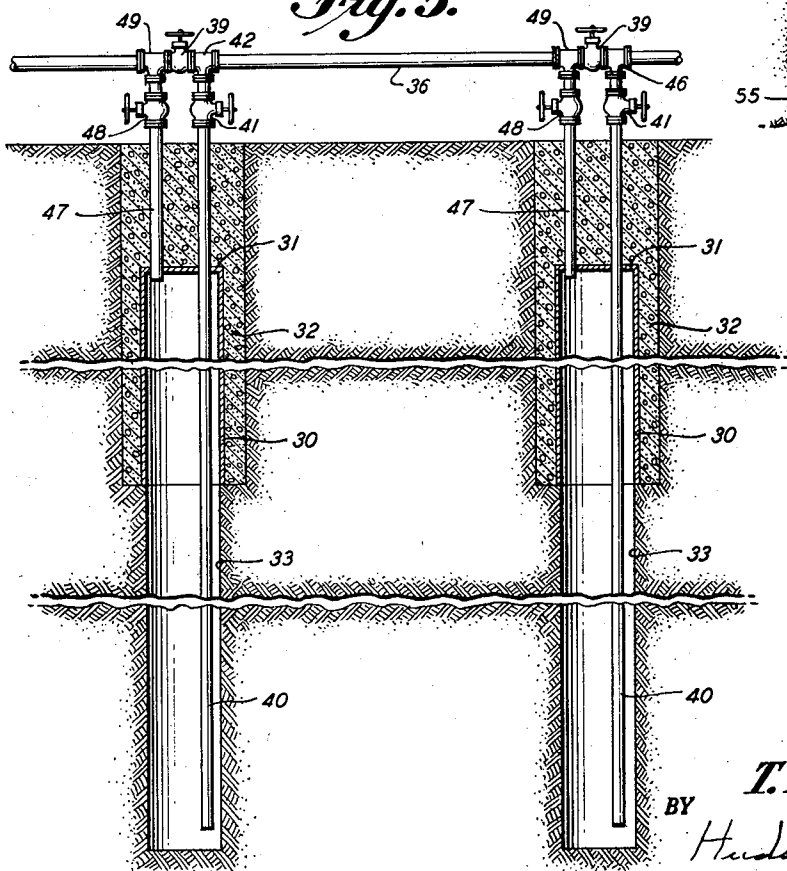


Fig. 5.



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UNDERGROUND STORAGE SYSTEM

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4 Claims. (Cl. 61—5)

This invention relates to underground storage systems particularly adapted for the storage of liquefied petroleum gas.

The constantly expanding production of liquefied petroleum gas has created a definite problem in providing suitable storage facilities for this material. Due to the high vapor pressure of liquefied petroleum gas, particularly propane, the cost of storage in surface equipment, such as steel tanks, becomes excessive due to the massive construction required to withstand the vapor pressure of the stored material in a safe manner. This problem becomes extremely acute where it is necessary to store large quantities of such materials during the off-season. In addition to the expense involved, the use of steel tanks is limited by shortages in production.

In order to overcome these difficulties, it has been proposed to store liquefied petroleum gas in porous water bearing formations, in mine cavities formed in impermeable shale or limestone formations, and in water leached caverns in salt formations. Further, underground concrete storage tanks and buried sections of pipe have been used to a limited extent in the storage of liquefied petroleum gas.

In accordance with this invention, an underground storage system for liquefied petroleum gas is provided which requires a minimum of excavation and which can be carried out to a large extent with readily available equipment and material.

It is an object of the invention to provide an underground storage system of novel construction and arrangement which is of low cost, as compared to storage in steel tanks.

It is a further object to provide an underground storage system which can be constructed with readily available equipment and material.

It is a still further object to provide an underground storage system capable of use in the storage of diversified materials, particularly liquefied petroleum gas.

Various other objects, advantages and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic top view of an underground storage system constructed in accordance with the invention;

Figure 2 is a fragmentary view of one of the earth cavities;

Figure 3 is an enlarged vertical sectional view of a portion of the system of Figure 1;

Figure 4 is a diagrammatic top view of a modified underground storage system;

Figure 5 is an enlarged vertical sectional view of a portion of the system shown by Figure 4; and

Figure 6 is a vertical sectional view of a modified type of cavity construction.

Referring now to the drawings in detail, and particularly to Figures 1 to 3, inclusive, the underground storage system of this invention includes a plurality of series 10a

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to 10i of earth cavities 11 which are preferably arranged in rows as indicated by Figure 1. Preferably and advantageously, each earth cavity 11 is a vertical drilled hole in the earth, which can be conveniently formed by a rotary drilling rig, such as is used in drilling oil wells. In the drilling operation, a large hole having a diameter of, for example, thirty six inches is drilled to a depth of about one hundred feet. A tubular liner 12 is positioned within the hole and anchored in place by a mass 13 of cement. The liner 12 is preferably a section of steel pipe of the type used in pipe line construction, and can be referred to as a tubular casing positioned at the upper region of the well. In some instances, the liner 12 can be formed from a plastic impregnated material. For example, liner 12 can be a fiberglass pipe impregnated with a polyester plastic.

In the construction shown by Figure 3, the upper end of the liner protrudes a short distance above the surface of the earth and this protruding end is closed off by a cap or well head 14. The casing 12, cement 13, and well head 14, therefore, constitute collectively pressure-resistant anchoring and sealing means at the top of the hole 11, the construction being such as to prevent blowout as the result of the vapor pressure of a volatile fluid, such as propane, within the hole. It will be understood that this vapor pressure will ordinarily be in the neighborhood of 150 pounds per square inch.

After the casing 12 has been cemented in place, and before the attachment of the well head 14, the hole is further drilled using a bit just small enough to pass through the casing. The final depth of the hole can be, for example, five hundred feet so that the lower portion 15 of the hole below the casing 12 is approximately four hundred feet long. Where the hole is formed in impermeable shale or limestone formations, it is not necessary to further treat or seal the lower part of the hole. However, where permeable formations are encountered, the lower part of the hole is ordinarily sufficiently sealed by the coating of drilling mud applied to the walls of the lower portion of the hole during the rotary drilling operation. Such a coating is indicated by reference numeral 16 in Figure 2 as being deposited over a relatively porous formation 17. If necessary, a drilling mud having enhanced wall building properties can be used if relatively permeable formations are encountered. Where improved wall building characteristics are required in a water base mud, a substantial proportion of bentonite should be used in the drilling mud and the use of kaolin should be avoided. A drilling mud having good wall building characteristics can be made by using a mixture of about eighteen to thirty seven pounds of bentonite per barrel of water. Further, wall building properties can be improved by the addition of carboxymethylcellulose or a mixture of carboxymethylcellulose and starch to the drilling mud, or alternatively, various fibrous or flaky materials can be added to the mud.

Oil base or emulsion muds, such as oil-in-water or more preferably water-in-oil muds, can also be used. Such muds can contain any of the well known fluid loss reducing additives such as soaps, blown asphalt, sulfuric acid, bentonite, sodium carboxymethylcellulose and others. An emulsion of water-in-oil can be stabilized by a multivalent metal salt of resins, such as calcium resinate, and an oil-in-water emulsion mud can be stabilized by a monovalent metal resin soap. The emulsion or oil base muds contain water loss additives which are slightly soluble or insoluble in the oil. Such materials are not appreciably displaced by solution in the presence of another hydrocarbon liquid, such as propane.

In some cases, it is desirable that the coating 16 defining the walls of the lower portion of the well be formed from a plastic material such as a phenol formaldehyde

resin, a urea formaldehyde resin, rubber latex, neoprene, cement, plaster of Paris, or sodium silicate. If excessively permeable formations are encountered, it may be necessary to line the lower portions of the hole with a thin wall metal or plastic pipe.

After the hole has been drilled to the desired depth and the desired coating, if any, applied to the walls, the well head or cap 14 is applied and valve conduits are connected to the hole in such fashion that the material to be stored can be readily introduced into the hole or removed therefrom. Referring again to Figures 1 and 3, I have provided a number of heavy liquid conduits 18, each conduit overlying all of the holes in one series 10 of earth cavities. All of the conduits 18 communicate with a common liquid supply header 19.

Referring to Figure 3, it will be noted that each conduit 18 is provided with a T 20 overlying each hole in the series fed by the conduit, and a line 21 extends from the bottom or lower region of each hole 11 through a valve 22 to the T 20. Communicating with the upper or top portion of each hole 11 is a light fluid pipe 24 which is connected through a valve 25 to a T 26 in an adjacent light fluid conduit 27. It will be noted in Figure 1 that each series 10 of holes is provided with a separate light fluid conduit 27 overlying all the holes in the series and communicating with the top or upper portion of the hole through the respective valves 25. Each of the conduits 27 is connected to a common light fluid header 28.

Where the system is utilized for underground storage of liquefied petroleum gas, such as propane, the material is introduced through fluid header 28 to the drilled holes 11, it being understood that the valves 22, 25 of each hole in which it is desired that the material be stored, are open during this period. Any desired hole can, of course, be closed off from the system at any time by closing the adjacent valves 22 and 25. When it is desired to remove the propane from storage, a heavy liquid, such as water, is introduced into header 19 and through conduits 18 and valves 22 to the bottom portions of the holes. The water displaces the propane which passes upwardly through pipe 24 and valve 25, and thence, through the adjacent conduit 27 to header 28. Thus, propane can be placed in storage at any time by introducing this material through header 28, any displaced water being removed through header 19. When it is desired to withdraw the propane from storage, water is introduced through header 19 and the propane is withdrawn through header 28. By the provision of the valves 22 and 25 any desired hole can be closed off at any time and, by selectively closing off certain of the holes, it is possible to store a plurality of materials in the system. Such a procedure can be facilitated by providing valves 18a, 27a in the respective conduits 18 and 27 adjacent the zone of communication of the conduit with the header 19 or 28.

The mass 13 of cement, the casing 12, and well head 14, collectively anchor and seal the top portion of each hole against the pressure of the propane, and the drilling mud or other coating at the bottom of each hole prevents leakage of propane therefrom.

In Figures 4 and 5, I have shown a modified underground storage system constructed in accordance with the invention. Referring to Figure 5, it will be noted that a tubular liner 30 is positioned within the hole a substantial distance below the surface of the earth, the upper end of the liner being closed by a cap or well head 31. Disposed exteriorly of the liner 30 is a mass 32 of cement which also fills the region of the hole above the well head 31. In this manner, the weight of the cement above the well head is effective in resisting the upwardly directed pressure of the liquefied petroleum gas stored within the hole, thereby providing an increased and more efficient pressure-resisting action. It will be understood that the liner can be a section of steel casing or a plastic impregnated pipe, and that the lower portion of the hole can be provided with a coating 33 of drilling mud or other suit-

able material, as described in connection with Figures 2 and 3.

The embodiment of Figures 4 and 5 also incorporates a modified supply and withdrawal system. Referring to Figure 4, it will be noted that there are a plurality of series of 35a to 35i of earth cavities, preferably arranged in rows, and that a conduit 36 overlies each series of cavities, one end of each conduit being connected to a common header 37 and the other end of each conduit being connected to a common header 38. In Figure 5, it will be noted that conduit 36 has a bypass valve 39 disposed above each hole. A line 40 extends from the bottom or lower region of each hole through the well head 31, cement 32, and a valve 41 to a T 42 at one side of the adjacent bypass valve 39. A pipe 47 extends from the upper or top region of each hole through well head 31, cement 32, and a valve 48 to a T 49 disposed at the other side of the adjacent bypass valve 39. Thus, with all the valves 39 in a series closed and the valves 41, 48 open, the upper region of each hole in the series, with the exception of the last hole, is connected to the lower region of the next succeeding hole in the series, the upper region of the last hole communicating through conduit 36 with the header 37.

When it is desired to introduce material, such as liquefied petroleum gas, into storage, the material is introduced into header 37 and flows through the conduits 36 into the storage holes. It will be understood that any desired hole or group of holes can be closed off during filling operation by opening the associated bypass valve 39 and closing valves 41 and 48. Furthermore, any desired series of holes can be closed off by manipulation of valves 37a, 38a in conduits 36 adjacent the respective headers 37 and 38.

When it is desired to remove the liquefied petroleum gas from storage, water is introduced through header 38 and conduit 36 into the storage hole, the water displacing the liquefied petroleum gas which thereupon flows out through header 37. Due to the described series connection of each group of holes, each such group effectively constitutes a single storage chamber, the hole nearest header 37 being the first one to become filled with liquefied petroleum gas as the material is admitted to storage, and thereafter the next adjacent and succeeding holes becoming filled as additional material is fed through header 37. When water is fed through header 38, the liquefied petroleum gas is displaced and flows through header 37. It will be noted that the described arrangement permits a reduction in the amount of pipe required to control the storage and dispensing operation.

In Figure 6, I have shown a storage hole wherein the cement overlying the liner is reinforced. It will be noted that the hole is provided with a liner 50, the upper end of which is disposed a substantial distance below the surface of the earth, a well head 51 being provided at the top of the liner. A mass 52 of cement is disposed exteriorly of the liner 50 and fills the region above the well head 51. The cement mass has an undercut portion 53 which extends into a relatively hard formation 54 to lend additional strength to the pressure-resistant structure. It will be understood that the liner 50 can be formed from the materials described in connection with Figures 2 and 3, and that the lower portion of the hole can have a coating 55 of drilling mud or other suitable material. Storage holes of the type illustrated in Figure 6 can be provided with a line 40a, valve 41a, T 46a, conduit 36a, bypass valve 39a, pipe 47a, valve 48a, and T 49a corresponding to the similarly numbered parts of Figure 5, and the conduit 36a associated with each series of drilled holes can be connected to common headers in the manner shown by Figure 4. Alternatively, the conduit and header arrangement illustrated in Figures 1 and 3 can be used with drilled storage holes of the types illustrated in Figures 5 and 6.

It will be evident that I have achieved the objects of my invention in providing underground storage cavities for materials such as liquefied petroleum gas at a cost

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far less than that required for steel tanks of large capacity. Furthermore, I have provided substantial and safe pressure-resistant sealing and anchoring means for each drilled hole and a header and conduit arrangement permitting flexible handling of the materials introduced into and removed from storage.

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

I claim:

1. In an underground storage system, in combination, a plurality of series of underground cavities, a conduit for each series of cavities overlying all of the cavities in such series, a bypass valve in each conduit above each cavity, a valved line extending from a lower region of each cavity to a junction with the adjacent conduit at one side of the adjacent bypass valve, a valved pipe extending from an upper region of each cavity to a junction with the adjacent conduit at the other side of the adjacent bypass valve, a first header communicating with one end of each conduit, and a second header communicating with the other end of each conduit.

2. In an underground storage system, in combination, a plurality of series of drilled vertical holes in the earth, a liner at the top of each hole, a well head closing the top of each liner, means for anchoring said liner and said well head at the top of the hole, a conduit for each series of holes overlying all of the holes in such series, a bypass valve in each conduit above each hole, a valved line extending from a lower region of each hole to a junction with the adjacent conduit at one side of the adjacent bypass valve, a valved pipe extending from an upper region of each cavity to a junction with the adjacent conduit at the other side of the adjacent bypass valve, a

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first header communicating with one end of each conduit, and a second header communicating with the other end of each conduit.

3. A system constructed in accordance with claim 2 in which the liners are sections of steel casing.

4. A system constructed in accordance with claim 2 in which valves are inserted in each conduit adjacent the respective junctions of the conduit with said headers.

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