April 7, 1959 K. O. JOHNSON ET AL 2,880,593

METHOD AND EQUIPMENT FOR HANDLING VOLATILE LIQUID HYDROCARBONS

Filed Feb. 8, 1956 2 Sheets-Sheet 1

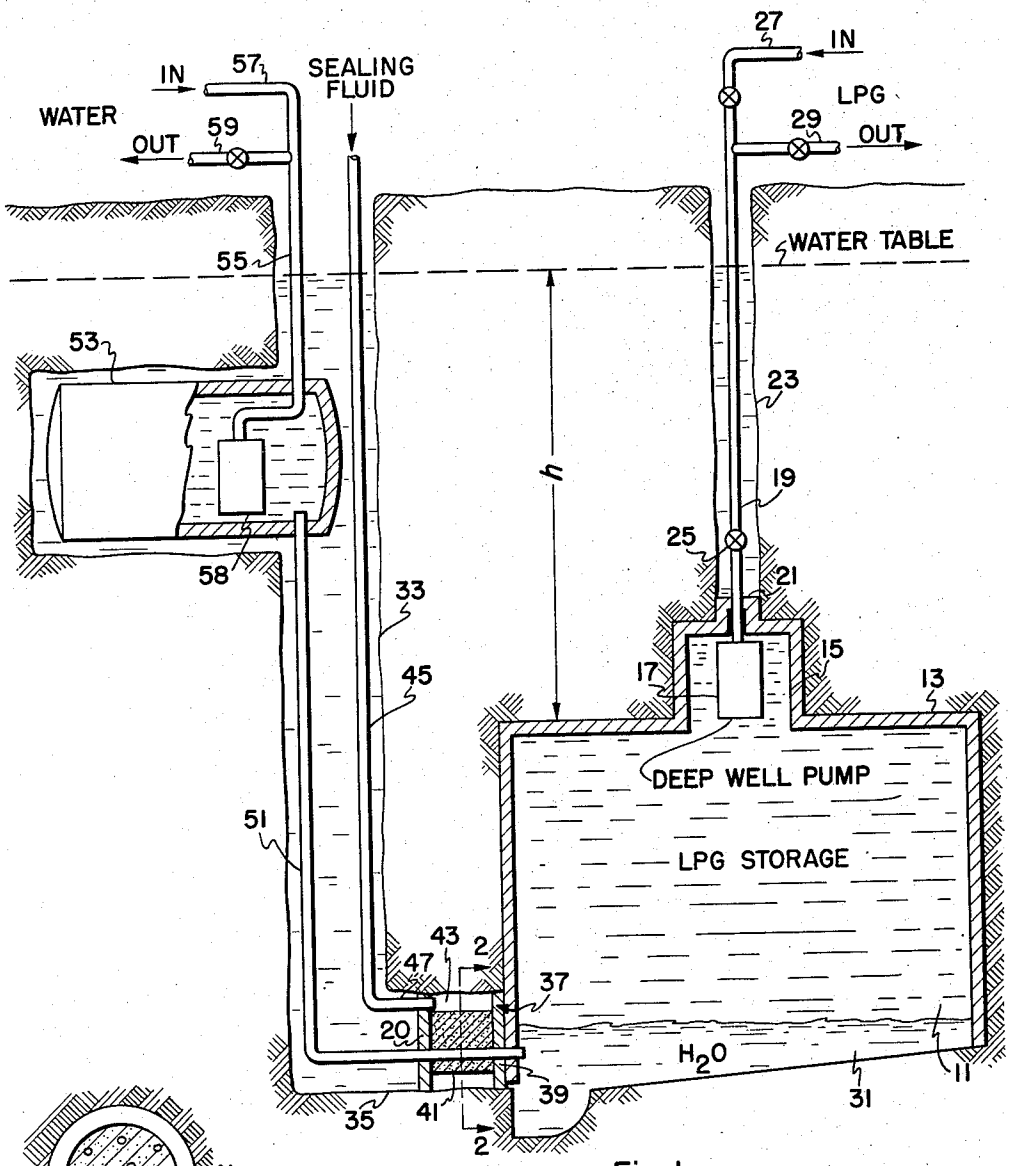

Fig. 1

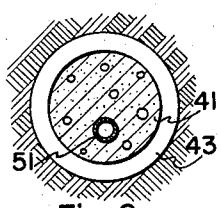

Fig. 2

Kenneth O. Johnson
Kenneth J. Nuber
Herbert H. Waddell
Robert E. Millar
Inventors

By Small, Dunham & Thomas. Attorneys

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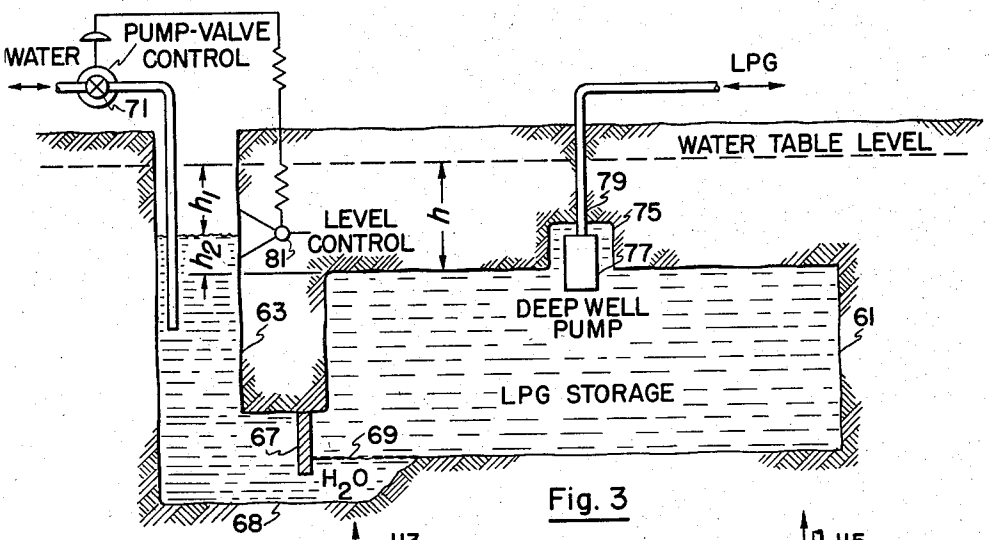

Fig. 3

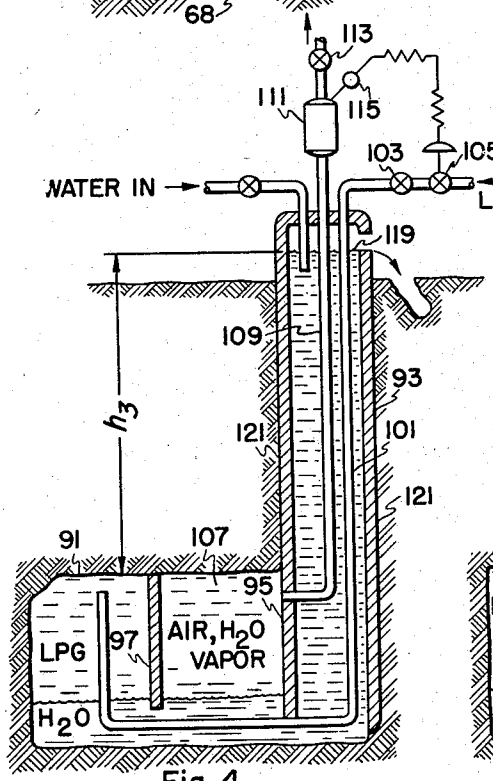

Fig. 4

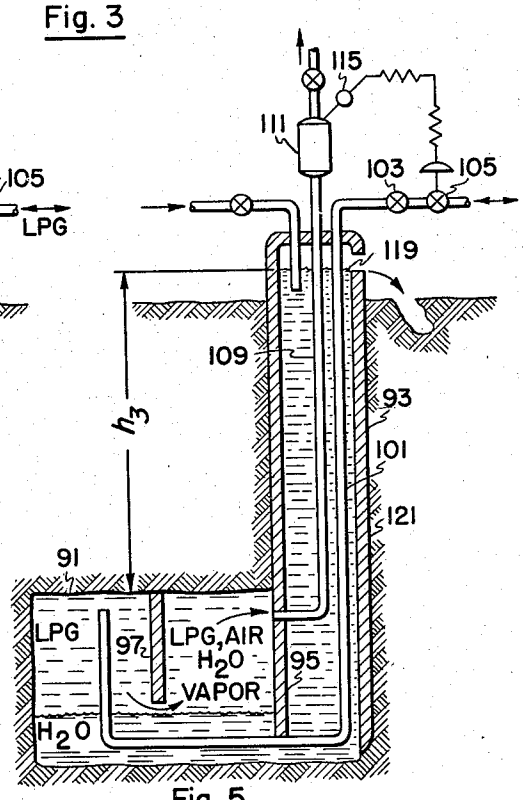

Fig. 5

Kenneth O. Johnson
Kenneth J. Nuber
Herbert H. Waddell
Robert E. Millar
Inventors

By Small, Dunham & Thomas Attorneys

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2,880,593

METHOD AND EQUIPMENT FOR HANDLING VOLATILE LIQUID HYDROCARBONS

Kenneth O. Johnson, Chatham, and Kenneth J. Nuber, Cranford, N.J., and Herbert H. Waddell and Robert E. Millar, Baltimore, Md., assignors to Esso Research and Engineering Company, a corporation of Delaware

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6 Claims. (Cl. 62—45)

The present invention relates to improvements in methods and equipment for handling liquefied volatile hydrocarbons. It relates particularly to a process and to apparatus for storing liquid pressurized gas underground to conserve it against evaporation and to facilitate its handling.

Numerous proposals have been made in the prior art for storing fluids such as hydrocarbon oils, gases and the like, in underground caverns. Thus, it has been proposed to return petroleum products to oil basins, to store them in abandoned mines, tunnels, quarries and the like. It has also been proposed to store liquid pressurized gases in underground caverns under pressure to conserve them against evaporation and to minimize the cost of pressurized vessels.

It is an object of the present invention to facilitate the handling of liquid pressurized gases such as propane, butane and the like, in underground storage by taking advantage of water pressure and water supplies which are normally available in most sections of the country.

A further object is to store liquefied hydrocarbons under water pressure in such a manner as to prevent seepage and losses of the hydrocarbons into the surrounding earth.

A further object of the invention is to maintain stable pressure conditions on normally gaseous hydrocarbons which are stored as liquids under pressure by automatic control of a water level which supplies hydrostatic pressure to the stored hydrocarbons.

Other objects will become apparent as a fuller description of the invention is given, hence reference will next be made to the accompanying drawings wherein:

Fig. 1 is a diagrammatic sectional view of an underground storage system embodying certain features of the invention;

Fig. 2 is a detailed sectional view taken substantially along the line 2—2 of Fig. 1;

Fig. 3 is another vertical sectional view of a modification of the invention showing liquid pressurized gas in storage;

Fig. 4 is another modification showing a slightly different arrangement than Fig. 3, and

Fig. 5 is another view similar to Fig. 4 showing the system in operation when there are overflow conditions.

Referring first to Fig. 1, a liquid hydrocarbon such as propane, butane, mixtures thereof and related hydrocarbons which can be liquefied by applying pressure at ordinary atmospheric temperatures, is stored in a cavern indicated at 11. This cavern preferably is at a substantial distance below the water table as indicated at *h*. The distance *h* preferably is sufficient that the water pressure will keep the hydrocarbons liquefied at prevailing temperatures. For example, a hydrocarbon requiring about 75 p.s.i.g. pressure for liquefaction should be stored at a distance of about 200 feet below the water table. With other hydrocarbons, of course, the distance may be greater or less.

The cavern or excavation 11 is preferably lined with a material 13 which is impervious to the hydrocarbon to be stored in the cavern. While this is desirable, it is not absolutely necessary inasmuch as the inward pressure of water from the water table should normally exceed the hydrocarbon pressure within the storage zone. Under such conditions, of course, the only leakage or seepage that occurs is seepage of water into the cavern. This prevents the escape of hydrocarbons into the soil. Nevertheless, since water tables may sometimes vary quite widely and the flow of water through certain strata may be very slow in abnormal times or with some soil conditions, it is preferable to have the cavern lined with a fluid-tight and substantially hydrocarbon-tight lining.

It is also desirable, although not always necessary, to provide a dome 15 in the upper part of the cavern, into which a pump 17, preferably of the deep well type, may extend. A conduit 19 extends upwardly from the pump 17 through a gas-tight seal 21 in the vertical shaft 23. A cut-off valve 25, controllable from the surface, is preferably provided in the lower part of the conduit, although this is not always necessary. The pump 17 may be placed above the seal 21, if desired. Means are provided for pumping the hydrocarbons to be stored into the cavern through inlet line 27, and stored products may be withdrawn through outlet line 29, both connected to the conduit 19.

Means are provided for maintaining a supply of water in the lower part of the storage cavern, as indicated at 31. In the case of Figure 1, an upwardly extending shaft 33 is provided near the side of the cavern 11 but spaced therefrom a suitable distance so as to maintain a distinct column or standpipe of water. This shaft 33 connects through a lateral tunnel 35 to the lower part of the storage cavern. A seal for the tunnel is provided at 37 and it includes a pair of spaced bulkheads 39 and 20 which are fitted tightly into the tunnel to prevent seepage of liquid. The space between may be filled with any suitable material such as concrete, indicated at 41. To maintain a liquid-tight seal in the bulkheads, it is preferable to provide a narrow annular space 43 between the concrete or other filler 41 and the walls of the tunnel 35. Means are provided for maintaining a pressure of a sealing fluid within this space. Such means comprise a conduit 45 connecting to the annular space through a lateral extension 47 and extending to the surfaceof the ground. The sealing fluid, such as water, may be forced through conduit 45 into the annular space 43 to maintain a tight seal against the passage of gases or liquids from or to the storage zone.

Passing through the bulkheads 39 and extending upwardly is another conduit 51. The upward end of this conduit joins a reservoir 53, such as a tank, which is mounted at a suitable distance below the surface of the ground for maintaining a desired hydrostatic head of water pressure on the storage zone. Means 55, including a water inlet 57 and outlet 59, are provided for maintaining the proper amount of water in the reservoir 53. It will be appreciated that as hydrocarbons are passed to storage, water in the bottom of the storage compartment is forced upwardly in the riser 51 into reservoir 53. If this becomes too full, water may be removed from there through line 55, for example, by operation of a deep well pump 58 mounted in the reservoir. On the other hand, when hydrocarbons are removed from storage, it is necessary to replace them with water, and water from the reservoir 53 is passed downwardly through the line 51 in the storage compartment. In general, the reservoir is located below the normal water table at such a height, however, that the hydrostatic

pressure thereof will keep the hydrocarbons in storage liquefied. Automatic means not shown in Fig. 1, may be provided for the operation of pump 58 and inlet 57 and outlet 59 so as to maintain the proper volume of water in the reservoir 53 under all operating conditions.

Referring now to Fig. 3, there is shown a somewhat similar system where, however, the necessity for the seal and bulkhead structure of Fig. 2 is eliminated. This figure also embodies the automatic level control arrangement previously mentioned. This is an important feature of the invention. By its use, water seepage seals the storage cavern, but is held to a minimum by a low differential pressure, represented by h_1 in Fig. 3.

Hydrocarbons are stored in a cavern 61 at a suitable distance h below the water table so that water pressure will keep them liquefied. A connecting and upwardly extending shaft 63 is joined to the storage zone by a tunnel 65 in which an inverted weir is placed as indicated at 67. The latter need not be of great structural strength, but it must have sufficient strength to resist pressure due to the difference in specific gravity between water and the stored hydrocarbon liquid. The arrangement is such that water level 69 never falls below the bottom of the weir. It may rise higher into the storage compartment, as will be obvious. An automatic pump with suitable control valves, is indicated at 71. It is operated in such a manner as to maintain a constant water level at a moderate distance h_1 below the normal water table, representing a very moderate differential pressure, and a distance h_2 above the storage compartment. Obviously, distance h_2 should be sufficient to keep the stored hydrocarbons liquefied. The distance h_2 is normally somewhat less than distance h in order that there may be an inward pressure of water all around the storage compartment, but the difference, h_1, should not be excessive since it is desirable to hold seepage into the cavern to a minimum. Here, as in the case of Fig. 1, the storage compartment is preferably lined with a hydrocarbon-tight lining material, although this is not absolutely necessary, since inward seepage of water substantially eliminates loss of the stored material. In case of minor leaks, however, the inward water pressure prevents loss of stored hydrocarbons into the surrounding soil.

The storage compartment is preferably provided with a dome 75 in which a deep well pump 77 is mounted. The later connects to a conduit 79 which extends to the surface. Suitable controls, not shown in Fig. 3, may be provided for feeding hydrocarbons downwardly into storage or removing them upwardly from storage.

A level controller is mounted in the side of the shaft 63 as indicated at 81. It is connected to the pump 71 through electrical means forming no part of the present invention, so that the rising of the water level in shaft 63 will actuate the pump to remove water and a fall in the water level will actuate the pump to bring in water. The walls of the shaft 63 may be sufficiently pervious that water will seep into the shaft and have a tendency always to maintain it above the desired level. In this case, the pumps may be arranged only to pump out excess water provided the seepage rate into the shaft is sufficient to compensate for the withdrawal of stored hydrocarbons at their maximum rate of flow. Otherwise, provision is made for pumping water into as well as out of the shaft 63.

Referring to Fig. 4, an arrangement is shown which is generally similar to that of Fig. 3, except that double weirs are provided. A suitable zone 91 is located a suitable distance h_3 below the overflow elements of a vertical shaft 93. The latter is connected for free flow of water into the storage zone under an outer weir 95 and an inner weir 97. The outer weir 95 extends lower than the inner weir 97. The arrangement is such that the normal storage compartment does not extend below the lower edge of the weir 97.

Means including a conduit 101 are provided for pumping liquid pressurized gas into the upper part of the storage compartment. The same line may be used for withdrawing stored liquid from the compartment. A suitable cut-off valve 103 is provided at the outlet (inlet) and an automatically controlled valve 105 is also provided for a purpose to be explained.

Ordinarily, the stored hydrocarbons are in the zone to the left of the weir 97 in Figs. 4 and 5. Under such normal conditions, the space between weirs 97 and 95 is filled with water. As hydrocarbons are pumped into the storage zone, however, it may be overfilled and caused to overflow or, more technically, to underflow at weir 97 into the next compartment designated 107. In this case, he volatile liquid will rise in vent pipe 109 because its specific gravity is less than that of water. As the hydrocarbon rises, it will vaporize when the decreasing pressure equals its vapor pressure. Vent pipe 109 is provided for carrying vapors to a suitable flare or recovery system. A drum 111 and a suitable control valve 113 are included in the line 109. An indicator 115 is provided in the drum 111 and, when the flow of gas is detected, this actuates a relay system to close the automatic valve 105. Thus, as shown in Fig. 5, the moment that the main storage compartment is filled, a slight overflow or underflow of the stored hydrocarbons under weir 97 actuates the control mechanism to cut off the further feed of hydrocarbons to storage.

Thus, it will be seen that automatic means are provided for controlling the storage of the gases. Moreover, the height of the shaft 93 to its overflow point 119 is such as to maintain the desired pressure on the stored hydrocarbons. It will be noted that the overflow 119 may be made adjustable in height where desired to apply the proper hydrostatic head to different hydrocarbons or hydrocarbon mixtures according to pressure requirements. In the arrangements shown in Figs. 4 and 5, the water table is not indicated. This system is particularly suitable for storage of hydrocarbons in areas where there is no stable water table or where the compartments or the earth structure are such that water cannot permeate to any substantial extent. The vertical shaft 93 is shown as being lined with a liquid-proof liner 121 to prevent the escape of water into the surrounding earth. Obviously, if water seeps from the earth into the standpipe (which could only occur if the overflow were below ground level and water table level), the overflow would take care of such seepage.

It will be noted that in cases of Figs. 3, 4 and 5, a substantially uniform hydrostatic as well as dynamic pressure head of water is maintained in free flowing communication with the storage zone. In the arrangement of Fig. 1, the flow is through the conduit 51 rather than under an inverted weir, but the principles are essentially the same. A special storage zone or reservoir 53 is provided in Fig. 1, whereas the height of a column of water in an open shaft is used for control in the other modifications.

It will be appreciated that numerous variations may be made in the system described but not departing from the spirit of the invention. It is intended to cover such modifications so far as the appended claims and the state of the prior art permit.

What is claimed is:

1. An apparatus for storing liquefied gases which includes a substantially impermeable subterranean storage zone for maintaining a supply of liquefied normally gaseous hydrocarbons under liquefying pressures, an inverted weir in the form of a wall extending to near the bottom of said storage zone to permit flow of liquid thereunder and forming a boundary wall of said storage zone, a vertical column of water in free communication with said storage zone by liquid flow under said weir, means for supplying water to said column to maintain the desired height thereof whereby the water pressure in said storage zone is maintained so as to keep the hydrocarbons liquefied, a second weir in the form of a

wall spaced from said first weir and extending down closer to the bottom of said storage zone than said first weir but still permitting flow of liquid thereunder, the space between said weirs forming a safety zone to receive hydrocarbons when they overflow from said storage zone.

2. An apparatus according to claim 1 wherein means are included for passing liquefied hydrocarbons under pressure to said storage zone, said safety zone acting as an overflow zone to receive hydrocarbons from said storage zone in case of overfilling, means for disposing of said overflowed hydrocarbons and means responsive to the overflow of the hydrocarbons to shut off said passing means automatically.

3. An apparatus according to claim 1 wherein separate vent means are provided for withdrawing overflow hydrocarbons from said safety zone, and automatic control means associated with said vent means for cutting off supply of hydrocarbons to said storage zone when overflow under said first weir occurs.

4. A process of handling liquefied hydrocarbons which ordinarily are gaseous at normal temperatures and pressures which comprises passing said liquefied hydrocarbons to storage in a subterranean storage zone behind an inverted weir having its lower end normally submerged in water in said zone, the wall portions at least above said weir of said zone being impervious to said hydrocarbons; forcing water past said weir to displace or accommodate hydrocarbons withdrawn from or supplied to said storage zone; maintaining a vertical column of water arranged laterally of said storage zone

and in open communication with said storage zone at such height as to keep said hydrocarbons liquefied by the pressure of said water column; maintaining the height of said water column at a selected level to obtain the desired pressure; overflowing liquefied hydrocarbons supplied in excess to said storage zone below said weir into a safety zone adjacent said storage zone preferentially to overflowing said excess hydrocarbons into said vertical column of water.

5. A process according to claim 4 including the step of venting liquefied hydrocarbons supplied in excess from said safety zone.

6. A process according to claim 5 including the step of using hydrocarbons vented from said safety zone to control apparatus regulating the passing of liquefied hydrocarbons to said storage zone.

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