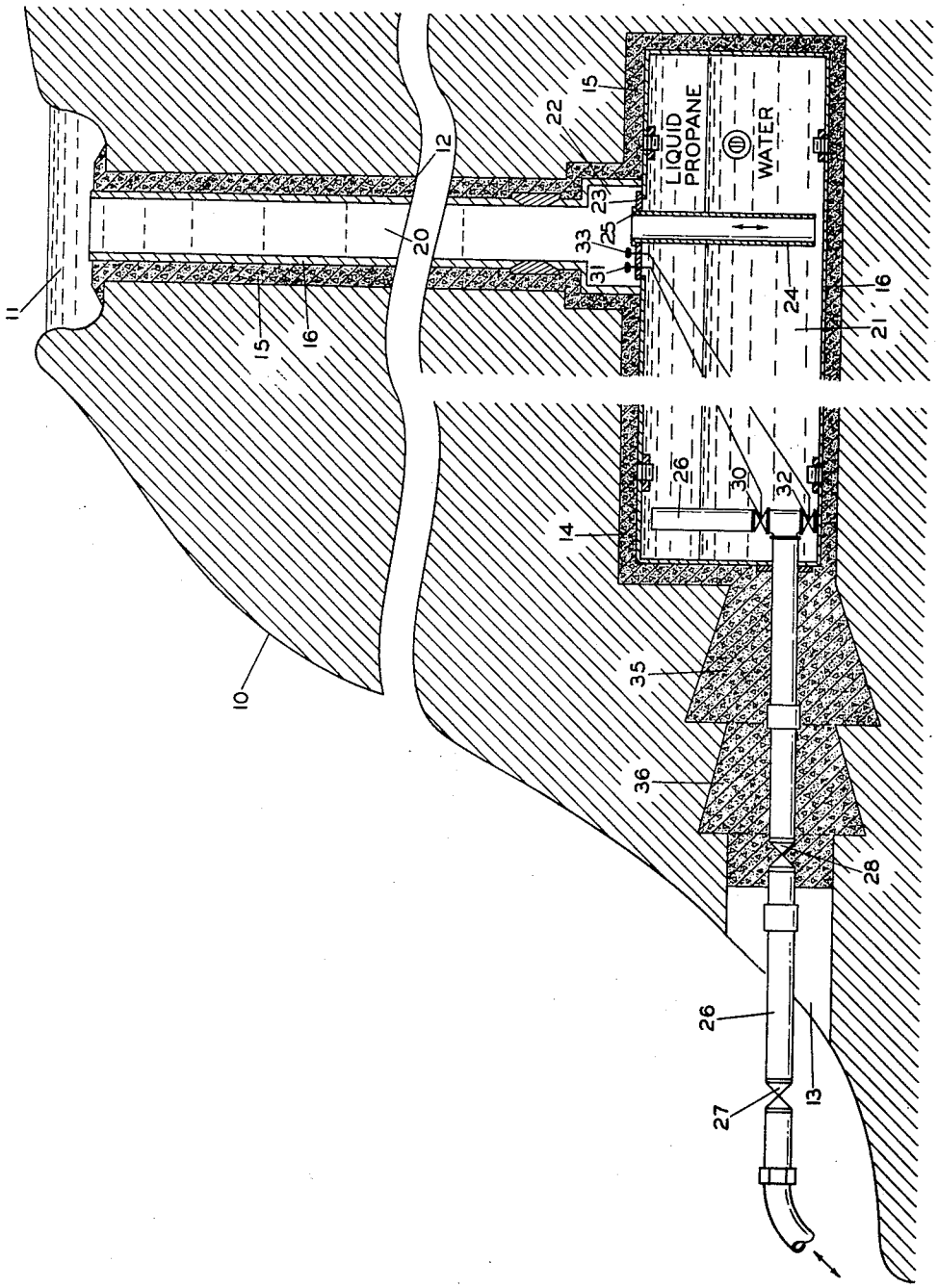
Jan. 18, 1949. A. N. KERR 2,459,227

UNDERGROUND RESERVOIR FOR THE STORAGE OF LIQUEFIED GASES

Filed Aug. 6, 1946



INVENTOR.
A. N. KERR

BY Hudson & Young

ATTORNEYS

Patented Jan. 18, 1949 2,459,227

UNITED STATES PATENT OFFICE

2,459,227

UNDERGROUND RESERVOIR FOR THE STORAGE OF LIQUEFIED GASES

Arthur N. Kerr, Los Angeles, Calif., assignor to Phillips Petroleum Company, a corporation of Delaware

Application August 6, 1946, Serial No. 688,761

4 Claims. (Cl. 62—1)

1

This invention relates to the storage of hydrocarbons. In one general modification this invention relates to the storage of hydrocarbons as liquids under a substantial superatmospheric pressure. In a preferred embodiment the invention relates to the storage of a liquefiable normally gaseous hydrocarbon, such as propane.

Liquefiable normally gaseous hydrocarbons, particularly propane and/or butanes, are used in large quantities as fuels for domestic and industrial purposes, being generally referred to under the term "liquefied petroleum gas." These materials are generally used in large quantities during the winter months and in much smaller quantities during the summer months. However, the supply of these materials is relatively constant throughout the year. As a result there is a great over-supply from about the middle of March until about September or October. By about the middle or last of December the demand has greatly exceeded the current supply and there is often a pronounced shortage.

Although spherical tanks of substantial capacities are now available commercially in which butanes will be stored as liquids, it is often necessary to employ large numbers of such tanks, since the size of any one tank is limited to about 10,000 barrels. Because propane has a much higher vapor pressure at ordinary atmospheric temperatures, it is possible to store this material only in relatively small, heavy, and therefore, expensive, tanks. Large bulk storage of propane is therefore not possible economically.

It is an object of this invention to provide bulk storage of liquid hydrocarbons.

Another object of this invention is to store normally gaseous hydrocarbons in large quantities as liquids.

Still another object of this invention is to store propane as a liquid in large quantities without constructing numerous high-pressure tanks.

Further objects and advantages of my invention will become apparent, to one skilled in the art, from the accompanying disclosure and discussion.

I have now found that it is possible to store a liquid hydrocarbon material under a substantial superatmospheric pressure in a single large storage zone by excavating a large storage zone deep in the earth, lining this storage zone with a relatively thin lining which is impervious to the liquid hydrocarbon being stored, and which is also impervious to water, and maintaining a hydrostatic head of water on the hydrocarbon being stored greater than the vapor pressure of

2

the hydrocarbon material at the temperature of the surrounding earth. My invention will be more particularly discussed and described in connection with the accompanying drawing, which is a diagrammatic cross-sectional view, not drawn to scale, of one modification of my invention.

Referring now to the drawing, a suitable hill, or mountain side, 10 is located. At an elevated portion of this hill a water reservoir 11 is established. This may be either a natural or artificial reservoir. From a low point at the bottom of this reservoir a shaft 12 is sunk to a substantial depth. If it is desired to store propane as a liquid this shaft should be at least about 225 feet deep. From the side of the hill at an elevation of about, or slightly more than, 225 feet lower than the elevation of the reservoir 11, a horizontal tunnel 13 is driven into the earth to a point which meets or closely approaches the bottom of the shaft 12. At the point where the shaft and the tunnel approach or meet each other a large excavation is made, somewhat larger than the planned volume for the final storage. Such an excavation, for example, may be roughly cylindrical in shape with a diameter of approximately 300 feet and a height of about 10 to 20 feet. The shaft 12 and the excavation 14 are suitably lined, as with a layer of concrete 15 and a relatively thin inner layer of corrosion-resistant steel 16. As will be readily appreciated, neither of the linings 15 or 16, either jointly or individually, needs to be strong enough to withstand the vapor pressure of liquid propane, since they are mutually supported by the surrounding earth which will be sufficiently strong to withstand the pressure.

As will be readily appreciated the hill should be so chosen that it is not far removed either from a source of supply for the propane to be stored, such as a refinery or a natural gasoline plant, or so that it will be not too far from a suitable distribution point. It will also be desirable to choose a hill which has a relatively soft layer or stratum of rock at the point where it is desired to establish the storage zone. Such a soft rock can be easily and relatively cheaply excavated but will still have sufficient structural strength to back up, and support, the relatively thin lining for the storage zone. Such a soft stratum may be chalk or soft sand stone.

In a preferred modification of my invention the shaft 12 has a sufficient diameter that the interior 20, after the lining is in place, will be large enough to enable a man to pass through it. At the point where the shaft enters the storage

zone 21, it may be enlarged somewhat to form a small room 22. The steel inner lining 16 has a hole in it at this point which is normally covered with a cover 23. This cover will serve as a partition between storage zone 21 and the interior of shaft 20. Since this point will be at least about 225 feet below the surface of the water in the reservoir 11 when storing liquid propane, the shell 16 and the cover 23 need not be stronger that is sufficient to withstand about 5 to 10 pounds per square inch differential pressure. Through this cover 23 extends a relatively large conduit 24 down to the bottom of storage zone 21. This conduit 24 will be attached to the cover 23 by a flange 25 so that it may be readily removed, leaving a man hole through which storage zone 21 may be entered for purposes of inspection and/or repair. As will be readily appreciated, a separate man hole may be employed for this purpose, with the conduit 24 being more permanently attached to the shell 16, or to cover 23.

A conduit 26 extends from the top of the storage zone 21 out through tunnel 13. The liquid propane is introduced and withdrawn through this conduit as desired. Flow through the conduit is controlled by valve 27. The conduit is preferably also equipped with an excess-flow valve 28, to prevent uncontrolled discharge from the tank in the event any of the external connections are broken. If desired, conduit 26 may be also equipped with an internal valve 30 which can be controlled from the bottom of the shaft 20, as by a control wheel 31. It is generally desirable also to have a conduit extending to the bottom of storage zone 21 so that the entire storage zone may be drained of liquid material. This latter conduit may comprise a valved extension 32 from conduit 26, controlled also from the bottom of shaft 20 by control wheel 33. As will be readily appreciated, the propane conduit and the drainage conduit may be entirely separate conduits extending to the outside through the tunnel 13, in which case internal valves 30 and 32 may be unnecessary.

It is preferred that after the construction and lining of storage zone 21 has been completed, and the desired conduits installed, the tunnel 13 be completely sealed, as by being plugged with concrete. Such concrete plugs 35 and 36 may be firmly anchored to the surrounding earth, in any suitable manner, so that they furnish a sufficiently strong backing to the lining 16 of the storage zone 21.

When the entire installation is complete, storage zone 21, reservoir 11, and the connecting conduit comprising shaft 20 and conduit pipe 24, may be filled with water. Liquid propane can then be pumped in through conduit 26 in any desired amount up to that which will just fail to bring the water level down to the bottom of the conduit pipe 24. As the amount of liquid propane in storage varies, water will be supplied to or withdrawn from reservoir 11 through the connecting conduit. While it will be preferable in many instances for reservoir 11 to have a volume at least equal to the maximum volume of liquid propane to be stored in storage zone 21, this is not absolutely necessary if there is available a sufficient water supply to keep the reservoir water level at the necessary height when large quantities of propane are withdrawn and if there is suitable overflow to remove excessive water when large quantities of propane are stored. It may be desirable to provide a suitable screen, or electrical barrier, to keep fish from going into shaft 20 and the bottom of storage zone 21, as they may be killed by the small amount of hydrocarbons dissolved in the water, and also to prevent solid matter from accumulating on the bottom of the storage zone.

If at any time it becomes necessary to inspect the interior of storage zone 21, or to repair it, all the propane is withdrawn and then all the water is withdrawn. In such a case it is not always necessary to empty reservoir 11, as a coffer dam may be built around the upper portion of shaft 20, or a suitable extension may be attached which rises above the surface of the water. It is, of course, necessary that shaft 20 and storage zone 21 be emptied of water. In the modification shown final removal of water, after shaft 20 has been emptied, may be readily effected by closing valve 30 and opening valve 32.

As will be readily appreciated the location of storage zone 21 should be so chosen that the temperature of the surrounding earth is not abnormally high, as it might be in the region of volcanic activity or near hot springs. A difference of elevation between the bottom of shaft 20 and the surface of the water in reservoir 11 should be at least about 225 feet when propane is stored as a liquid, and with normal subterranean temperatures. If one or more of the butanes is being stored as a liquid, or is present in substantial proportions in the propane, the vapor pressure of the liquid will be correspondingly lower and the difference in elevation may be correspondingly less. While it is possible to store ethane as a liquid in such a storage zone, with the difference in elevation being at least about 1750 feet, this will generally be not practicable. However, it will often be desired to store a liquid hydrocarbon material containing a substantial quantity of ethane, in which instance the difference in elevation will need to be proportionally greater. In any event, it is necessary that the difference in elevation be sufficiently great to provide a hydrostatic head at least equivalent to the vapor pressure of the hydrocarbon material being stored at the highest prevailing temperature of the earth surrounding storage zone 21. As will be appreciated propylene, or butylenes, may also be contained in the hydrocarbon material being stored.

Various modifications of my invention may be practiced by one skilled in the art without departing from the spirit, or scope, of the accompanying disclosure and without departing from the scope of the claims.

I claim:

1. Means for storing as a liquid a normally gaseous hydrocarbon material liquefiable under pressure at normal earth temperatures which comprises, in combination, a totally enclosed subterranean storage zone, a reservoir of water the surface of which is sufficiently higher than said storage zone as to provide a hydrostatic head at least equal to the vapor pressure of said hydrocarbon material at the highest prevailing temperature of the earth surrounding said storage zone, a vertical shaft connecting said reservoir and said storage zone, a partition at the bottom of said shaft, a conduit extending through said partition to the bottom of said storage zone whereby water can freely flow between said reservoir and said storage zone, a man hole in said partition which is normally closed, a conduit leading from the top of said storage zone for introduction and removal of liquid hydrocarbon material and a conduit extending into the bottom of

said storage zone for emptying of said storage zone, a valve in each of the last said two conduits, and means connected with each said valve and operable from the bottom of said shaft for opening and closing said valves.

2. Means for storing as a liquid a normally gaseous hydrocarbon material liquefiable under pressure at normal earth temperatures which comprises, in combination, a totally enclosed subterranean storage zone, a reservoir of water the surface of which is sufficiently higher than said storage zone as to provide a hydrostatic head at least equal to the vapor pressure of said hydrocarbon material at the highest prevailing temperature of the earth surrounding said zone, a vertical shaft connecting said reservoir and said storage zone, a partition at the bottom of said shaft, a conduit extending through said partition to the bottom of said storage zone whereby water can freely flow between said reservoir and said storage zone, a man hole in said partition which is normally closed, a conduit leading from the top of said storage zone for introduction and removal of liquid hydrocarbon material and a conduit extending into the bottom of said storage zone for emptying of said storage zone.

3. Means for storing liquid propane which comprises, in combination, a storage zone, a water reservoir directly above said storage zone at an

elevation such that the water level is at least about 225 feet above the top of said storage zone, a vertical conduit directly joining said reservoir and the bottom of said storage zone and permitting free flow of water therebetween, and a horizontal conduit directly connecting with the top of said storage zone for induction and eduction of propane.

4. Means for storing liquid C_3 hydrocarbons which comprises, in combination, a totally enclosed, subterranean storage zone, a reservoir of water the surface of which is at least about 225 feet higher than the highest point of said storage zone, a conduit connecting said reservoir and the bottom of said storage zone so constructed as to permit free flow of water therebetween, and conduit means connecting with the top of said storage zone for introduction and withdrawal of liquid C_3 hydrocarbons.

ARTHUR N. KERR.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,006,912	Cook	Oct. 24, 1911
1,008,830	Lamb et al.	Nov. 14, 1911