

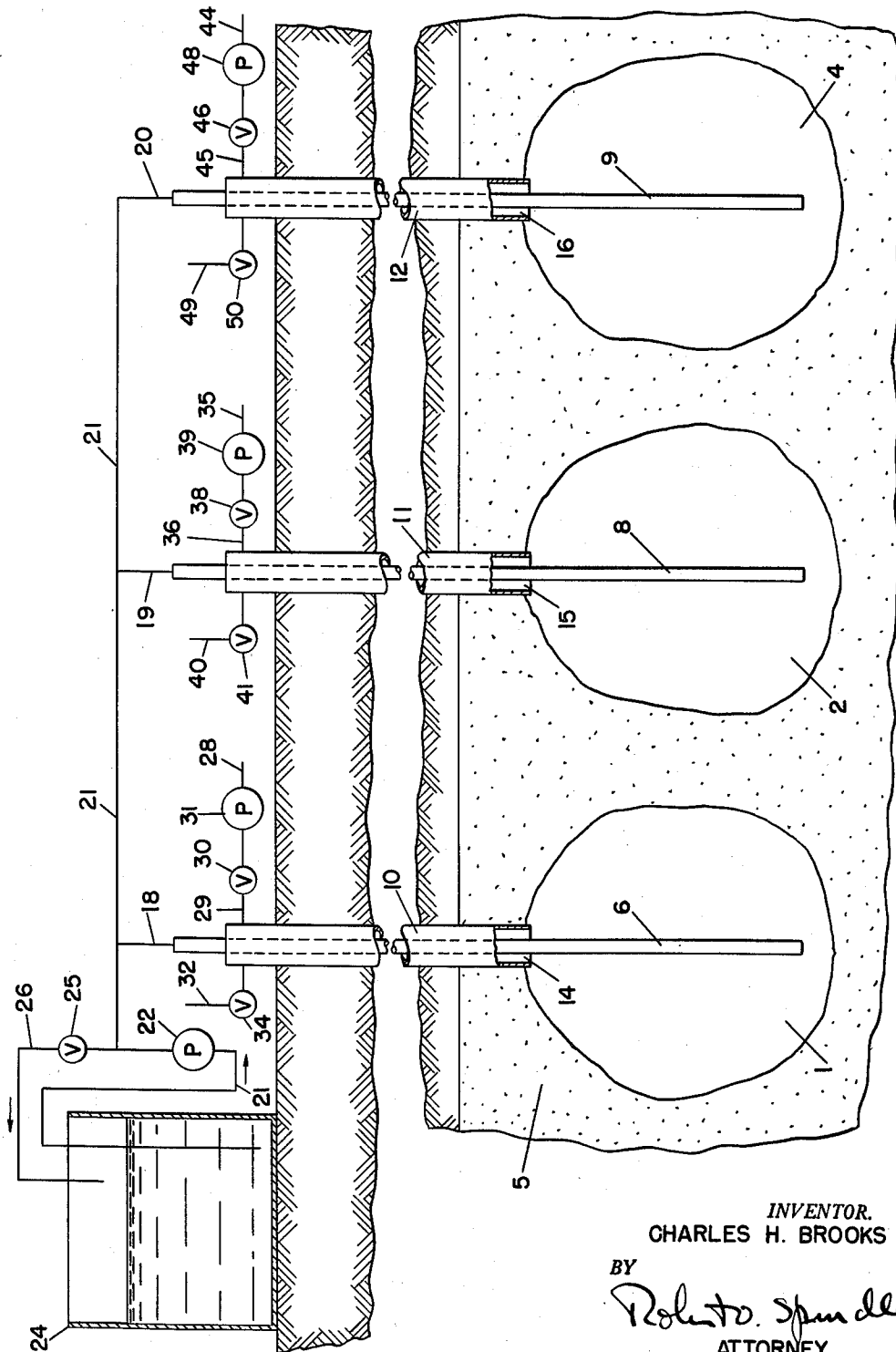
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UNDERGROUND STORAGE OF HYDROCARBONS

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UNDERGROUND STORAGE OF HYDROCARBONS

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This invention relates to the underground storage of hydrocarbons, and is particularly directed to an integrated process of storing hydrocarbons in a plurality of sub-surface salt cavities.

Sub-surface salt cavities have heretofore been used for storing petroleum products, such as propane, butane, and the like. Generally such storage has been performed by maintaining the stored hydrocarbons over brine; the hydrocarbon to be stored is introduced into the cavity under a pressure sufficient to displace a quantity of brine therefrom. To recover stored hydrocarbons, brine is introduced into the cavity to displace the desired quantity of hydrocarbons therefrom. As generally heretofore operated, each well requires a separate brine system, including for example separate brine supply conduits, pumps, valves, and the like. Also, the introduction or removal of hydrocarbons requires activation of the separate pumps involved, together with the appropriate valves and the like. For the foregoing and other reasons, operation of a plurality of salt cavities has heretofore required expensive and complicated equipment and techniques.

An object of the present invention is to provide an efficient, integrated process of operating a plurality of salt cavities for hydrocarbon storage wherein the above and other difficulties are obviated. A further object is to provide an apparatus for performing the process of the invention. Another object is to provide a process for operating a plurality of sub-surface salt cavities as an integral part of a refinery. Other objects will appear hereinafter.

It has now been found that storage of hydrocarbons in a plurality of sub-surface salt cavities can be accomplished economically as an efficient, integrated process by maintaining a manifold as a brine supply conduit communicating between a brine storage reservoir and a plurality of sub-surface salt cavities, the manifold having means for continuously supplying brine to the cavities, such as by continuously pumping brine from storage into the brine conduit. Brine is introduced into and removed from each cavity through a conduit terminating near the bottom of the cavity, and hydrocarbons are introduced into and removed from each cavity, as separate streams, through a conduit terminating near the top of the cavity, as hereinafter described. If the brine introduced into the manifold is not needed to displace hydrocarbons from a cavity, so that the continuous brine supply causes an increase of pressure in the manifold, it is returned to brine storage. This may be done automatically by means of a pressure relief valve that is actuated to permit brine to flow from the supply conduit to storage when the pressure in the supply conduit reaches a predetermined value, or by equivalent means.

Separate means for introducing hydrocarbons, as individual streams, into the cavities are provided. When hydrocarbons are introduced into a cavity for storage, the pressure used must be sufficient to displace brine from the cavity into the brine supply conduit, i.e., must be

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sufficient to overcome the relatively low pressure in the brine conduit and the pressure resulting from the head of brine as compared to the head of the lower density hydrocarbons. In practice, the pressure drop due to friction must also be taken into account. Brine displaced from the cavity into the brine manifold during hydrocarbon introduction, and the brine constantly supplied to the brine manifold from brine storage through the brine conduit, if not used to displace hydrocarbons from another cavity, are both sent back to brine storage.

To recover hydrocarbons from a sub-surface salt cavity, due to the difference in specific gravities of brine and hydrocarbons, it is only necessary to open the hydrocarbon outlet. The pressure on the hydrocarbons caused by the static brine head is sufficient to force their displacement from the cavity, and the constant brine supply through the manifold is sufficient to maintain the static brine head. In this manner the storage of hydrocarbons in a plurality of salt cavities is achieved as an integrated process, the brine being available continuously for hydrocarbon displacement, and the brine being relieved to brine storage when not required to displace hydrocarbons.

Salt cavities used in the invention should be at a distance below ground surface so that the pressure caused by the static head of brine creates a pressure above the vapor pressure of the stored hydrocarbons at the hydrocarbon outlet from the cavity. In general, the cavity will be at least about 1000 feet below ground surface. The pressure required for hydrocarbon introduction depends on the static head of brine, which varies with the distance of the cavity below ground surface, the difference in specific gravities between the brine and hydrocarbons employed, and the rate of introduction and removal of hydrocarbons, as above stated. In general, the pressure required for introducing hydrocarbons will be from about 600 to 900 p.s.i.g.

Attention is now directed to the accompanying schematic flow diagram, which illustrates the process of the invention.

Numbers 1, 2 and 4 indicate sub-surface salt cavities prepared in sub-surface salt formation 5. Conduits 6, 8 and 9, positioned within casings 10, 11 and 12, respectively, provide fluid communication for brine from the ground surface to the bottom of cavities 1, 2 and 4, respectively. Annuli 14, 15 and 16, formed between the said conduits and casings of cavities 1, 2 and 4, respectively, provide fluid communication for hydrocarbons between the ground surface and the top of said cavities 1, 2 and 4, respectively. Conduits represented by lines 18, 19 and 20 provide fluid communication between conduits 6, 8 and 9, respectively, and a single brine supply conduit represented by line 21. Manifold 21 is the brine supply conduit and is in fluid communication, through pump 22, with brine storage means 24, the inlet of conduit 21 being below the brine level in storage means 24. Conduit 21 also communicates with brine storage through pressure relief valve 25 and conduit 26, which conduit preferably terminates above the brine level in brine storage 24.

Cavity 1 communicates with hydrocarbon line 28 through annulus 14, line 29, valve 30 and pump 31, and with hydrocarbon line 32 through annulus 14, line 29 and valve 34. Cavity 2, in similar manner communicates with hydrocarbon line 35 through annulus 15, line 36, valve 38 and pump 39, and with hydrocarbon line 40 through annulus 15, line 36 and valve 41. Also, cavity 4 communicates with hydrocarbon line 44 through annulus 16, line 45, valve 46 and pump 48, and with hydrocarbon line 49 through annulus 16, line 45 and valve 50.

In operating the cavities for hydrocarbon storage in accordance with the invention, brine from storage 24 is

continuously supplied, by means of pump 22, to conduits 6, 8 and 9 via manifold 21 including conduits 18, 19 and 20, respectively. When brine is not needed to displace hydrocarbons from a cavity, the brine is relieved back to storage 24 from manifold 21 through valve 25 and conduit 26. Valve 25 operates as a pressure relief valve, i.e., when the pressure in conduit 21 reaches a predetermined value, valve 25 opens to permit brine to flow to storage 24 and thus relieve the pressure in the brine supply conduit.

In filling a cavity with hydrocarbons for storage, such as introducing butane into cavity 1, for example, butane is introduced through line 28, pump 31 and valve 30, valve 34 being closed. Pump 31 provides sufficient pressure to force brine from cavity 1 through conduits 6 and 18 and into manifold 21. If the pressure in manifold 21 is thereby caused to exceed a predetermined value, valve 25 is actuated and brine flows from manifold 21 to storage 24. When the desired quantity of butane has been introduced into the cavity, valve 30 is closed and the use of pump 31 discontinued. To remove butane from cavity 1, it is only necessary to open valve 34. Butane is then displaced from cavity 1 through annulus 14 and conduits 29 and 32, the pressure for displacement being provided principally by the difference in densities in the brine in conduit 6, and the butane in annulus 14, the brine flowing from conduit 6 into cavity 1 being continuously replaced by the constant brine supply source through conduit 21.

In the event hydrocarbons are being introduced into cavity 1 while being removed from cavity 2, pump 31 supplies hydrocarbons to cavity 1 as above described, displaced brine enters manifold 21 through conduits 6 and 18, and is thereby available for use in displacing hydrocarbons from cavity 2 by flowing through conduits 19 and 8, the hydrocarbons being displaced through annulus 15, conduit 36, valve 41 and conduit 40. If brine is displaced from cavity 1 at a rate faster than it is required in cavity 2, the excess entering manifold 21 will flow through valve 25 and pass through conduit 26 to storage 24. In the event brine is displaced from cavity 1 at a rate insufficient to supply the brine required by cavity 2, the additional brine is supplied to cavity 2 by means of pump 22 and manifold 21.

In operating the process, valve 25 is actuated at a predetermined pressure. It is preferred to have valve 25 actuated at a pressure of about 10 p.s.i.g. Thus, the pressure in manifold 21 will vary within the limits of about 10 p.s.i.. If desired, manifold 21 can be operated under smaller or larger pressure variations by adjusting valve 25 to be actuated at pressures of from about 5 to 15 p.s.i.g. and variations within this range are considered to meet the term "substantially constant pressure" and terms of similar import when used with reference to the brine pressure in conduit 21. Still higher operating pressures can be used if desired, but at high pressures care should be taken that the total pressure within the cavity does not cause a fracture of the cavity. It is preferable to install check valve in manifold 21 immediately at the discharge side of the pump 22 to prevent brine from passing, in reverse, through pump 22 before valve 25 opens due to increased pressure in the conduit. Other valves, meters, pressure indicators, regulators and the like can be employed where necessary or desirable, the use thereof, in light of the teachings of the present specification, being within the scope of those skilled in the art.

The preparation of underground salt cavities for use in the present invention can be accomplished by methods heretofore known. The usual method is to drill to a point within a salt stratum or salt dome, and to dissolve salt therefrom by circulating water into and out of the borehole. The circulation of water is continued until the cavity has the desired size.

Hydrocarbons that can be stored in accordance with

the invention are those which are normally gaseous or liquid, and which are preferably liquid when stored under the conditions of the process of the invention. Such hydrocarbons include, for example, propane, butane, pentane, olefins corresponding thereto, and mixtures of said hydrocarbons; hexanes, heptanes, octanes, olefins corresponding thereto and mixtures thereof; and gasoline and other distillate fuels such as gas oil. Crude oil can also be stored in accordance with the invention with good results. Hydrocarbons that are gases under the conditions of storage, such as methane and ethane, can be stored in accordance with the invention, and brine displacement thereof from the cavity assists in maintaining the pressure thereof at a desired elevated level.

Brine used in the invention is preferably substantially saturated. Aqueous sodium chloride solutions having a specific gravity of above about 1.1 give good results. The use of a substantially saturated brine which has a specific gravity about 1.2 prevents dissolution of additional quantities of salt from the sub-surface cavities when the brine is in contact therewith. However, brine solutions having a lower salt concentration, and even water, can be employed if desired, it being understood that such use will cause dissolution of brine from the sub-surface salt cavity surfaces. The use of substantially saturated brine is preferred, as above described, and also for the further reason that the relatively high density thereof assists in maintaining a sharply defined interface between the brine and the stored hydrocarbons. This prevents mixing of hydrocarbons and brine within the cavity, and permits the introduction or removal of hydrocarbons at a faster rate than otherwise would be permissible. A difference in specific gravities between the brine and stored hydrocarbons should be at least 0.25 to obtain good results.

The following descriptions of operations illustrate the integrated storage of hydrocarbons in salt cavities, and such use of salt cavities as integrated with refinery operations, in accordance with the invention:

Three sub-surface salt cavities were prepared in salt strata as follows: Cavity A at a depth of 2300 feet below ground surface with a capacity of 30,000 barrels; cavity B at a depth of 2300 feet below ground surface with a capacity of 45,000 barrels; cavity C at a depth of 2600 feet below ground surface with a capacity of 50,000 barrels. The three wells were in fluid communication through a manifold serving as the single brine supply conduit, the brine from the supply conduit being introduced into the cavities through conduits with outlets near the cavity bottoms. Brine storage of a capacity approximately equal to the total capacity of the three cavities was connected with the brine supply conduit. Brine storage was provided by a concrete lined pit. A pump adapted to force brine from the brine storage into the brine manifold was provided. A pressure relief valve provided communication between the brine manifold and brine storage. The pump was designed to supply brine to the manifold at a pressure of up to about 25 p.s.i.g. A check valve at the outlet side of the pump was set to close at a pressure of about 25 p.s.i.g. to prevent reverse flow of brine through the pump when the pressure in the manifold exceeded this value. The pressure relief valve was set to open at about 35 p.s.i.g. to permit brine to flow from the manifold to brine storage. Individual means for introducing hydrocarbons into the several cavities was provided, together with the necessary valves for introducing and withdrawing hydrocarbons, substantially as shown by the accompanying diagram.

To illustrate a typical integrated operation, a mixture of butane and butene from a hydrocarbon pipeline, which was contaminated with other hydrocarbons from a previous use of the pipeline was introduced into cavity A at the rate of 13,000 bbl./day. The purpose of introducing this hydrocarbon mixture into the cavity was to

provide storage therefor, until subsequent processing involving the removal of contaminating hydrocarbons and separation of the saturated from the unsaturated hydrocarbons could be undertaken. While introducing hydrocarbons into cavity A, butane, which had previously been introduced into and stored in cavity B, was removed therefrom at a rate of 7,000 bbl./day. The butane was passed to a refinery operation where it was blended with gasoline to obtain an optimum vapor pressure for the final product. While adding hydrocarbons to cavity A and removing hydrocarbons from cavity B, a mixture of light hydrocarbons, from methane through pentane, was introduced into cavity C at the rate of 3,000 bbl./day, cavity C being used for utility storage of light hydrocarbons.

For the introduction of hydrocarbons into cavity A and cavity C, pumps supplying the hydrocarbons to the respective cavities at relatively high pressures were employed, the actual pressure being about 860 p.s.i.g. for introducing the hydrocarbons into cavity C and about 765 p.s.i.g. for introducing the hydrocarbons into cavity A. These pressures were sufficient to overcome the static heads of brine, the relatively low pressure supplied by the pump in the brine conduit, and the pressure drops in the conduits due to friction.

For the removal of butane from cavity B, it was only necessary to open the butane outlet from the cavity; brine from the brine supply conduit flowed into the cavity to displace the butane, the pressure developed by the static head of brine, as compared to the static head of butane, being sufficient for the removal at the rate stated.

When the input of hydrocarbons to the cavities was greater than the output thereof from the cavities, the pressure within the brine manifold exceeded the value of 35 p.s.i. required to actuate the pressure relief valve, and hence the brine not employed for displacing butane from cavity C was returned to storage. However, the pump employed for supplying brine remained in continuous operation to insure an adequate brine supply at all times.

To further illustrate the invention, a refinery operation required the removal of butane-butene from cavity A at the rate of about 1200 bbl./day while simultaneously introducing butane into cavity B at the rate of about 1000 bbl./day. Storage of light hydrocarbons in cavity C remained unchanged, i.e. hydrocarbons were neither introduced nor removed from cavity C during this operation. Operation was as before, with the brine displaced from cavity A flowing into the manifold and thence, at least in part, into cavity B for displacement of butane. The remaining brine required for butane displacement was supplied from storage through the pump in the manifold.

In all of the foregoing operations, the pressure within the common brine conduit remained within the range of from about 25 to 35 p.s.i., and the pump supplying brine from storage to the brine manifold operated continuously

so that brine was always available for displacing hydrocarbons as needed.

The invention claimed is:

1. In the storage of hydrocarbons over brine in a plurality of underground salt cavities wherein the hydrocarbons are pumped therein at relatively high pressure to displace brine and subsequently are removed therefrom by returning brine to the cavities, the process which comprises continuously supplying, from a brine storage source, brine at relatively low pressure into a manifold communicating with each of said cavities through a conduit extending to a lower part thereof, and cycling brine from said manifold to said brine storage source when the pressure in said manifold exceeds the brine supply pressure, whereby hydrocarbons may be pumped independently to the cavities as individual streams resulting in a corresponding displacement of brine from the cavities into said manifold and whereby hydrocarbons may be independently displaced from said cavities by brine fed from said manifold while utilizing as the motivating force for such displacement the weight of the column of brine in each of said conduits.

2. In a process for storing hydrocarbons in sub-surface salt cavities wherein the hydrocarbons are stored over brine, in which process brine is displaced from the cavity by hydrocarbons introduced therein for storage and subsequently stored hydrocarbons are recovered from the cavity by brine introduced therein to displace from the cavity the stored hydrocarbons, the improvement that comprises: (A) continuously supplying brine to a supply conduit communicating between brine storage and a plurality of sub-surface salt cavities, (B) returning brine from the supply conduit to brine storage when the pressure of brine in said supply conduit exceeds the brine supply pressure, (C) introducing hydrocarbons to be stored into a salt cavity under a pressure sufficient to displace brine from the cavity into the brine supply conduit, and (D) removing stored hydrocarbons from the cavity by displacement thereof with brine from the brine supply conduit.

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