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METHOD AND APPARATUS FOR OPERATING UNDERGROUND STORAGE CAVERNS

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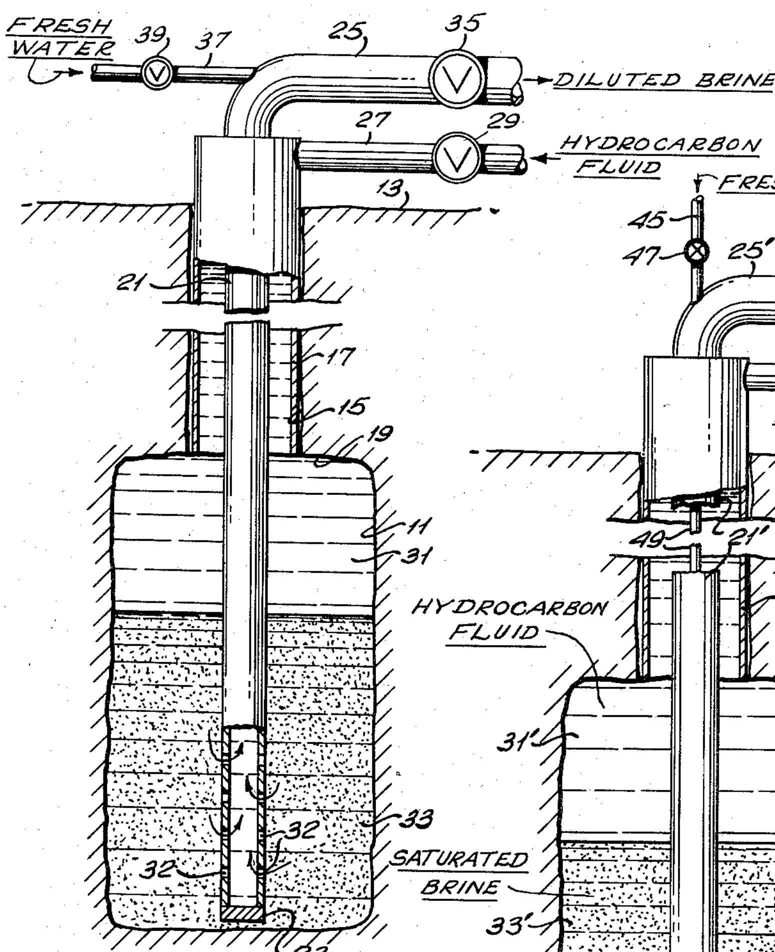

Fig.1.

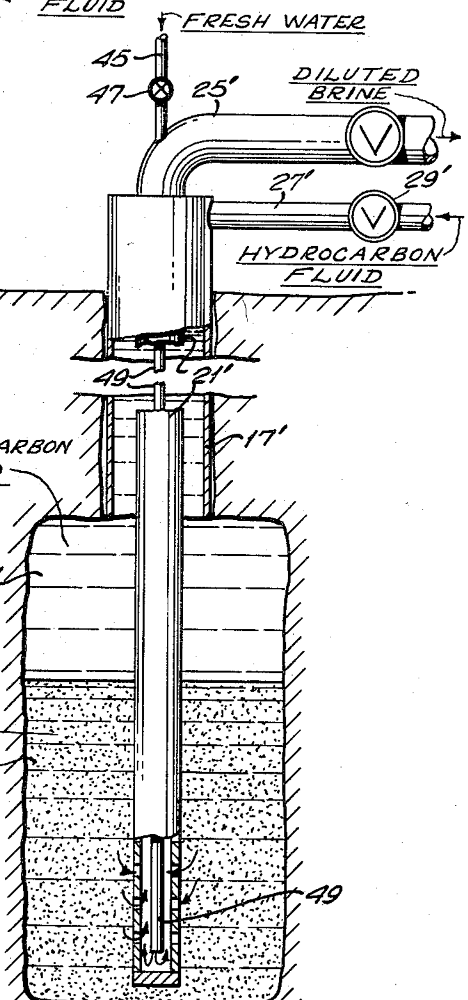

Fig.2.

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METHOD AND APPARATUS FOR OPERATING UNDERGROUND STORAGE CAVERNS

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7 Claims. (Cl. 61—.5)

The present invention relates to a novel method of and apparatus for operating an underground storage cavern wherein the fluid being stored is introduced into the cavern while displacing a highly concentrated water solution therefrom. The invention has particular application to operating an underground storage cavern formed in a salt bed or dome hundreds of feet beneath the surface of the earth, from which a highly concentrated sodium chloride brine is displaced as butane or other hydrocarbon liquid is forced into the cavern.

Underground storage of butane and other hydrocarbon liquids in salt caverns has recently become important in petroleum technology, and has been adopted widely. One problem encountered in this storage method has been that as the butane or other fluid to be stored displaces highly concentrated or saturated brine from the cavern to the top of the earth through a long conduit, dissolved salt has precipitated out of solution and tended to clog the conduit. Precipitation of salt is due to the reduction in both temperature and pressure as the brine rises to the surface. For example, a pool of brine in a salt cavern 1500–2000 feet below the surface of the earth may have a temperature of about 112° F. When this brine reaches the surface of the earth its temperature may be reduced to 80° F. The aqueous solubility of sodium chloride at 112° F. and a pressure of 1 atmosphere is 36.77 grams per 100 grams of water; and at 80° F. is only 36.19 grams per 100 grams of water. The solubility difference is even greater because of the higher pressure in the cavern, of the order of 400 pounds per square inch.

In accordance with the present invention when operating an underground storage cavern wherein the flow into the cavern of the fluid to be stored, such as butane, is accomplished by displacement of a stream of a highly concentrated water solution, such as sodium chloride brine, at a relatively high temperature through a discharge conduit having an inlet in the cavern and a section at a relatively lower temperature, the problem of solute precipitation in the discharge conduit is solved by introducing a flowing stream of solvent such as relatively fresh diluting water into the discharge conduit at a point between its inlet and the lower temperature section to reduce the concentration of solute and thereby substantially prevent solute from precipitating.

The invention will be described more in detail below, with reference to the accompanying drawings, wherein:

Figure 1 is a schematic vertical sectional view, parts being in side elevation, showing an underground storage cavity and its associated equipment; and

Figure 2 is a schematic vertical sectional view, parts being in side elevation, showing a similar underground storage cavity with a modified form of associated equipment.

As shown in Figure 1, an underground storage cavity **11** is located hundreds of feet beneath the surface **13** of the earth in a salt bed or salt dome. Cavity **11** is provided with an access bore **15** lined with a casing **17** which extends from the top **19** of the cavity to a position a short distance above the surface **13**. Within the casing **17** is concentrically located a long central conduit **21** having its lower end **23** located adjacent the bottom of cavity **11**, and extending at its upper end through casing **17** to a section **25** a short distance above the surface **13**.

When introducing the hydrocarbon or other fluid to be stored into the cavity **11** it is forced by a pump or by its own vapor pressure through a supply conduit **27** controlled by a valve **29** into the casing **17** and down into the cavity to form a pool **31** floating on the top of a pool **33** of highly concentrated brine. As fluid enters through conduit **27** the level of the brine **33** is forced down and displaced brine enters the central tube **21** through perforations **32** in its side wall near its lower end **23**, flows up through tube **21** into its section **25**, through a control valve **35**, and thence to a storage reservoir.

As the brine flows up through tube **21** in countercurrent heat exchange relationship with the incoming cool hydrocarbon its temperature and pressure are gradually reduced as it approaches the surface **13**, and some precipitation of salt may occur. When the brine reaches the section **25** above the surface, there is a further reduction in temperature and precipitation of salt in the conduit section **25** ordinarily may occur to such an extent as to clog the conduit. Precipitation may also be caused by the agitation imparted by valve **35**.

To eliminate salt precipitation there is provided a conduit **37** controlled by a valve **39** which opens into and supplies relatively fresh water continuously to the section **25** in such volume as to dilute the brine so that the concentration of salt is reduced below the saturation value, at which salt may precipitate out of solution. As an example, precipitation clogging has been prevented by supplying fresh water at a rate of about 2 gallons per 42 gallon barrel of saturated brine flowing.

The problem of salt precipitation in the part of conduit **21** within the earth is not as severe as in section **25**. However, in time even this may become clogged with salt. Therefore, periodically the valve **35** is closed while the valves **29** and **39** are allowed to remain open, with the result that fresh water from conduit **37** flows down through the conduit **21** to its lower end and removes the deposited salt both by dissolving it and mechanically washing it free from the walls. Hydrocarbon at the same time flows back through conduit **27**. In one example of how the conduit **21** is flushed out, fresh water is injected in an amount equal to twice the volume of the conduit, which is then left standing full of fresh water until fluid flow into the cavern through supply conduit **27** is resumed after reopening valve **35**.

In the embodiment illustrated in Figure 2 the fluid to be stored is introduced through a conduit **27'** to a casing **17'** to form a pool **31'** floating on a pool of saturated brine **33'** as described in connection with Figure 1. As fluid enters the cavern brine is displaced up through a central conduit **21'** and thence through a section **25'** to a disposal reservoir. In this modification, relatively fresh diluting water is injected continuously through a supply conduit **45** controlled by a valve **47** and extending down through the conduit **21'** to a position **49** adjacent its lower end. Consequently, fresh water reaches the lower end of conduit **21'** adjacent the point where brine enters the conduit and dilutes the brine below the saturation value so that no precipitation of salt will occur in any part of the conduit **21'**. With this construction and mode of operation it is usually unnecessary to flush out the conduit **21'** periodically, as described in connection with Figure 1. However, any unusual deposition of salt in conduit **21'** can be removed by closing a valve 29' and continuing the flow of fresh water through conduit 45 until the deposit has been removed, after which valve 29' is reopened to resume normal operation.

Obviously, many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. In a method for operating an underground storage cavern wherein the flow into said cavern of the fluid to be stored is accompanied by the displacement of a stream of a highly concentrated solution of solute in liquid at a relatively high temperature out of said cavern through a conduit having an inlet in said cavern and a section at a relatively low temperature in which solute normally precipitates out of solution and accumulates on the walls of said conduit, the improvement which comprises introducing a flowing stream of diluting liquid into said conduit at a point between said inlet and said section to reduce the concentration of solute in said solution and thereby substantially prevent solute from precipitating out of solution at said relatively low temperature, whereby to prevent clogging of said conduit by precipitated solute.

2. In a method for operating an underground storage cavern wherein the flow into said cavern of the fluid to be stored is accompanied by the displacement of a stream of highly concentrated brine out of said cavern through a conduit having an inlet in said cavern and a section adjacent the surface of the earth in which salt normally precipitates out of solution and accumulates on the walls of said conduit, the improvement which comprises introducing a flowing stream of diluting water into said conduit between said inlet and said section in sufficient volume to reduce the concentration of salt in said brine below the value at which salt precipitates out of solution, whereby to prevent clogging of said conduit by precipitated salt.

3. In a method in accordance with claim 2, introducing said stream of diluting water into said conduit adjacent said inlet whereby the entire length thereof is kept free from precipitated salt.

4. In a method in accordance with claim 2, introducing said stream of diluting water into said conduit adjacent the surface of the earth.

5. In a method in accordance with claim 1, the additional steps of periodically stopping the flow of solution from said cavern, and flushing out with diluting water the part of said conduit between said inlet and said point to remove any precipitated solute therefrom.

6. In a method in accordance with claim 5, flushing out said conduit by forcing said diluting water to flow therein in a direction opposite to the flow of solution therethrough.

7. Apparatus for operating an underground storage cavern comprising a first conduit extending from the surface down into such a cavern for introducing therein the fluid to be stored; a second conduit extending from said cavity to the surface for conducting from said cavity a liquid control solution displaced by said fluid, said second conduit having an inlet in said cavern and a section adjacent said surface wherein the temperature of said solution is lower than in said cavern; and a third conduit opening into said second conduit near said surface for supplying diluting water to said second conduit in sufficient volume to reduce the concentration of solute in said control solution below the value at which precipitation occurs.

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