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[54] **RECOVERY OF HYDROCARBONS FROM A SECONDARY GAS CAP BY THE INJECTION OF A LIGHT HYDROCARBON**

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[51] **Int. Cl.** **E21b 43/25**

[58] **Field of Search** ..... 166/305 R, 263, 275, 166/314, 268, 265–267, 250, 252

[56] **References Cited**

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[57] **ABSTRACT**

Recovery of residual hydrocarbons from a secondary gas cap is effected by injecting into the gas cap via one well a light hydrocarbon solvent and thereafter producing the well to recover a mixture of the hydrocarbon solvent and the immobile liquid hydrocarbons from the enriched gas produced.

13 Claims, No Drawings

RECOVERY OF HYDROCARBONS FROM A SECONDARY GAS CAP BY THE INJECTION OF A LIGHT HYDROCARBON

FIELD OF THE INVENTION

This invention relates to a method for recovery of residual or immobile liquid hydrocarbons from a secondary gas cap in a subterranean hydrocarbon-bearing formation. More particularly, this invention relates to a single well operation wherein a light hydrocarbon solvent is injected into a secondary gas cap, and thereafter the well is produced, thereby recovering a mixture of the hydrocarbon solvent and immobile liquid hydrocarbons from the enriched gas produced.

DESCRIPTION OF THE PRIOR ART

Primary production of hydrocarbons from a subterranean hydrocarbon-bearing formation normally is obtained by allowing the energy of the formation contained therein to drive the hydrocarbons from the formation to the surface through one or more producing wells. The energy of the formation may be in the form of water drive, gas cap, or solution gas drive, or combinations thereof. These various forms of energy provide the driving force necessary for the production of the hydrocarbons from the subterranean hydrocarbon bearing formation without the necessity of providing energy from an external source.

A gas drive reservoir is one in which the major source of energy being used to drive the hydrocarbons toward a producing well is associated with the gas dissolved in the liquid hydrocarbons or in a free gas zone which may exist in the formation. If there is no gas cap initially, the producing mechanism is termed a solution gas drive. As long as the pressure within the formation is sufficiently high, this gas remains in solution with the hydrocarbons. However, as the production is continued by solution gas drive, the pressure in the formation declines. When the pressure has declined to the point where bubbles of free gas commence to come out of the solution, which is known as the "bubble point," the formation develops what is referred to as a condition of free gas saturation wherein there exists in the formation, in both the major and minor flow channels, a quantity of free gas. As the free gas saturation is increased, the evolved bubbles coalesce and form a continuous gas phase. At this point, gas permeability exists and free gas flows through the formation with little or no displacement and recovery of hydrocarbons.

When this condition has occurred in a formation and a gas phase has developed, the upper portion of the formation may develop a high gas saturation, or what is known as a secondary gas cap. This development is especially likely to occur in formations that have considerable structural relief or are of the dome type. It is well known that considerable liquid hydrocarbons may be left as residual or immobile hydrocarbons in these zones of high gas saturation. There is little likelihood of further recovery of these residual or immobile hydrocarbons by continuation of the production of the formation by gas drive operations. The term "immobile hydrocarbons," within the meaning of this invention, refers to residual liquid hydrocarbons that have been rendered substantially or apparently immobile in reservoir zones of high gas saturation because of the increased viscosity of these remaining liquid hydrocarbons due to the evolution of the lighter hydrocarbons and because of the increase in the relative gas permeability.

Accordingly, it is the object of this invention to provide a method for additional recovery of the residual immobile hydrocarbons from a high gas saturation zone or a secondary gas cap that has been formed, by the injection of a light hydrocarbons solvent into the gas cap via a well that penetrates the gas cap, and thereafter producing the resultant mixture of the light hydrocarbon solvent and the immobile hydrocarbons commingled with gas, from the gas cap via the same well.

SUMMARY

This invention comprises a method for the recovery of immobile hydrocarbons from a secondary gas cap by the injection of a light hydrocarbon solvent into the gas cap and thereafter producing the mixture of the light hydrocarbons and immobile formation hydrocarbons via the same well, together with free formation gas.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Results of out test work have shown that immobile liquid hydrocarbons contained in a secondary gas cap can be recovered when a light hydrocarbon solvent is injected into the gas cap via a well that penetrates the gas cap, and the well is thereafter produced. The invention has application to the increased recovery of hydrocarbons from depleted formations which have been produced and in which residual or immobile hydrocarbons in the developed gas cap are unrecoverable by primary means.

The method of the present invention employs a well that penetrates a gas cap. A light hydrocarbon solvent is injected via the well into the gas cap. Thereafter, the light hydrocarbon solvent is produced via the same well together with residual liquid hydrocarbon and free formation gas.

The light hydrocarbon solvent may be any hydrocarbon that is known to have the capability of exerting a solvent action on oil or petroleum crudes. Preferably, the solvent is a light hydrocarbon having from 2 to 6 carbon atoms per molecule or mixtures thereof. The solvent could also have present a substantial amount of methane or natural gas providing that the solvent capability is not adversely affected thereby. Additionally, the light hydrocarbon solvent could include lesser amounts of hydrocarbons having more than 6 carbon atoms per molecule. Propane or liquid petroleum gas (LPG) are preferred in view of their good solvency for oil, ease of separation from the produced oil and their moderate vapor pressure.

The liquid hydrocarbon solvent should be injected in amounts sufficient to saturate the formation in the vicinity of the well bore to exert its solvent or washing action, for example, up to distances of about 15 to 200 feet from the well bore. The amount of solvent can be determined by applying known techniques from the knowledge of the properties of the formation including the gas saturation, formation porosity and thickness of the gas cap.

For thin gas caps, such as 10 feet, the amount of the solvent injected could saturate the formation up to 50 feet away from the injection well. For thick gas caps, such as 100 feet or more, the distance invaded from the injection well bore could be affected by the density difference between the solvent and the gas. Larger vol-

umes of the reservoir could be treated by injecting the solvent near the top of the gas cap and producing, for example, only from perforations near the gas-oil contact.

After the injection of the light hydrocarbon solvent, the well is produced so as to recover a mixture of the liquid hydrocarbon solvent, the immobile hydrocarbons and the free formation gas.

The method can be applied to a plurality of wells that penetrate a gas cap or a formation that has been depleted, but is known to contain residual immobile hydrocarbons in the zones of high gas saturation. For example, the hydrocarbon solvent may be injected via one well and thereafter a mixture of the hydrocarbon solvent and immobile hydrocarbons may be recovered from the well in the method described. The hydrocarbon solvent may be separated from the recovered mixture and then reinjected into the gas cap via another well which is thereafter produced. Thus, the method can be applied to a series of wells in a sequential or cyclic manner.

In one example of the method of invention, 1,000 barrels of propane were injected into a well traversing the gas cap of a 350 foot thick formation with a 40° dip and producing a 36° API gravity crude under the effects of strong gravity drainage. The gas saturation of the gas cap prior to test was approximately 57%. After the propane had been injected, the well was immediately placed on production. Liquid samples to show changes in composition and gas measurements were made periodically. The first production consists of the propane remaining in the well tubing. The first two hours after gas broke through, a small amount of volatile, dark-colored liquid, which rapidly vaporized at atmospheric pressure, was produced. The produced liquid later became nearly clear with a slight trace of dark color. During production of the well for approximately nine days the rate of the oil recovered ranged from 0.8 BPD to 6.2 BPD (barrels per day). Thereafter, the liquid production rate increased sharply to a range between 5.2 to 29.7 BPD and the gravity increased to a range between 60.4° API and 72.6° API. A summary of the result comparing the pre-injection period with the post-injection period is shown in the following table.

TABLE

	Pre-Injection	Post-Injection Period
Average Producing GOR, $ft^3/Bbl.$	269,411	50,556
Average Stock Tank Liquid Gravity, °API	56.0	67.5
Methane Content of Well Effluent, Mol %	86.0	81.5
Propane Content of Well Effluent, Mol %	3.68	5.10
Ethane through Heptane Less Propane Content of Well Effluent, Mol %	9.97	12.12
Heptane Plus Content of Well Effluent, Mol %	0.37	1.25

The results show that the enrichment of the well effluent and the reduction of the producing GOR indicated a portion of the residual hydrocarbons in the gas cap was rendered mobile and produced. In addition, the results from the analyses of the liquid composition and the gas measurements indicated that the trend of the composition of the effluent was toward the composition of the original conditions prior to the test.

It is postulated that upon injection of the light hydrocarbon solvent into the gas cap the solvent was forced radially into the formation about the well bore and into contact with the interior surfaces of the porous formation containing the immobile hydrocarbons. The additional recovery of the immobile hydrocarbons is believed to have resulted from the ability of the solvent to flush the interstices of the formation and the solvent's affinity for the immobile hydrocarbons. When production of the well was resumed, the propane and the contacted hydrocarbon liquids near the well were produced together with free formation gas.

A suggested procedure for the application of this invention to the recovery of immobile hydrocarbons from a secondary gas cap penetrated by one or more wells would comprise the following steps:

a. Obtain a sample of the fluid effluent from the secondary gas cap and determine its composition.

b. Inject a quantity of light hydrocarbon solvent into the secondary gas cap of the hydrocarbon-bearing formation via a well penetrating the secondary gas cap. The quantity of injected solvent should be sufficient to saturate the gas cap matrix in the vicinity of the well bore with the solvent. Known characteristics of the formation can be used to calculate the amount of solvent to be injected.

c. Upon completion of the injection of the light hydrocarbon solvent, immediately place the well on production and continue production until the composition of the well effluent has approached the composition of the fluid in the gas cap prior to the solvent injection.

d. Separate the light hydrocarbon solvent from the produced hydrocarbon mixture in the well effluent and thereafter recycle the hydrocarbon solvent to the well or to another well that penetrates the gas cap.

e. Thereafter produce the well or the other well as described above.

We claim:

1. A method for recovering immobile hydrocarbons from a subterranean hydrocarbon-bearing formation having a secondary gas cap and containing residual immobile hydrocarbons and free formation gas, said secondary gas cap being penetrated by at least one well, comprising the steps of:

a. obtaining a sample of said formation gas from said gas cap,

b. determining the composition of said sample of said gas,

c. injecting into said gas cap via said well a light hydrocarbon solvent thereby contacting said solvent with said immobile liquid hydrocarbons contained therein,

d. producing said well to recover a mixture of said injected hydrocarbon solvent and said immobile hydrocarbon, and said formation gas,

e. continuing production of said well until the composition of said mixture has approached the composition of said sample obtained prior to said injection of said light hydrocarbon solvent.

2. The method of claim **1**, wherein said produced mixture is separated into said solvent and said immobile liquid hydrocarbons, and thereafter said hydrocarbon solvent is reinjected into said gas cap.

3. The method of claim **1** wherein said light hydrocarbon solvent is composed of hydrocarbon consisting

essentially of hydrocarbon having from 2 to 6 carbon atoms per molecule.

4. The method of claim **3** wherein said solvent is propane.

5. The method of claim **3** wherein said solvent is liquid petroleum gas.

6. The method of claim **3** wherein said solvent contains methane.

7. The method of claim **1** wherein said formation contains a gas-oil contact and said solvent is injected via said well near the top of said gas cap and production of said well is near said gas-oil contact.

8. The method for recovery of residual immobile hydrocarbons from a secondary gas cap, said gas cap being penetrated by at least a first gas cap well comprising the injection of a light hydrocarbon solvent into said gas cap via said first gas cap well and thereafter producing said well, thereby recovering said solvent and said residual hydrocarbons.

9. The method of claim **8** wherein said light hydrocarbon solvent is composed of hydrocarbons consisting essentially of light hydrocarbons having from 2 to 6 carbon atoms per molecule.

10. The method of claim **8** wherein said solvent is propane.

11. The method of claim **8** wherein said solvent is liquid petroleum gas.

12. The method of claim **8** wherein said solvent contains methane.

13. The method of claim **8** wherein said gas cap is penetrated by a plurality of wells including the additional steps of separating a light hydrocarbon fraction from said recovered solvent and residual hydrocarbons and injecting said light hydrocarbon fraction into said gas cap via a second gas cap well.

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