United States Patent [19]

Hoyt

[11] **3,825,070**

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[54] **GRADIENT BARRIER IN A SECONDARY RECOVERY OPERATION TO INHIBIT WATER CONING**

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[52] **U.S. Cl.** **166/306**

[51] **Int. Cl.** **E21b 43/20**

[58] **Field of Search** ..... 166/306, 305 R, 269, 245

[56] **References Cited**

UNITED STATES PATENTS

2,607,426	8/1952	Rose	166/306
2,832,416	4/1958	Allen	166/306 X
2,886,108	5/1959	Piety	166/306
3,195,633	7/1965	Jacob	166/306
3,199,592	8/1965	Jacob	166/306
3,386,514	6/1968	Weber	166/306
3,467,191	9/1969	Van Daalen et al.	166/269
3,497,011	2/1970	Weber et al.	166/306
3,593,787	7/1971	Hoyt	166/245

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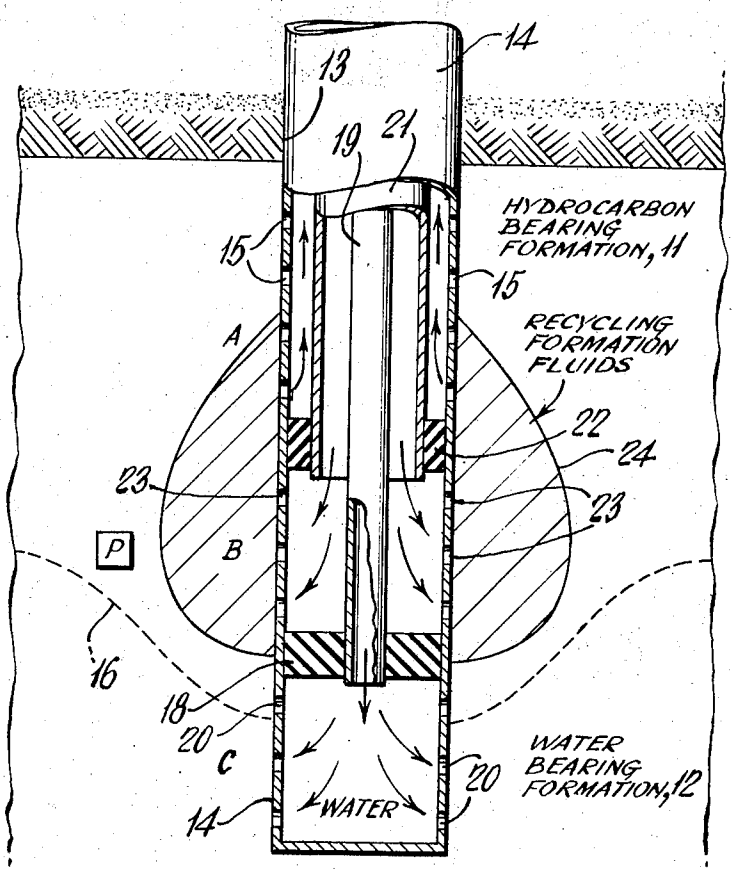
[57] **ABSTRACT**

The advance of the interface between subterranean hydrocarbon bearing formation fluids containing hydrocarbons and an underlying aquifer in a secondary recovery operation as it advances toward production perforations in a well bore to result in water coning during production is delayed by the imposition of reciculating barrier of an extraneous fluid, such as produced fluid hydrocarbons, injected into the subterranean hydrocarbon bearing formation via well perforations intermediate injection (lower) and production (upper) perforations in the well bore, the recirculation of the produced fluid hydrocarbons providing a gradient barrier.

9 Claims, 2 Drawing Figures



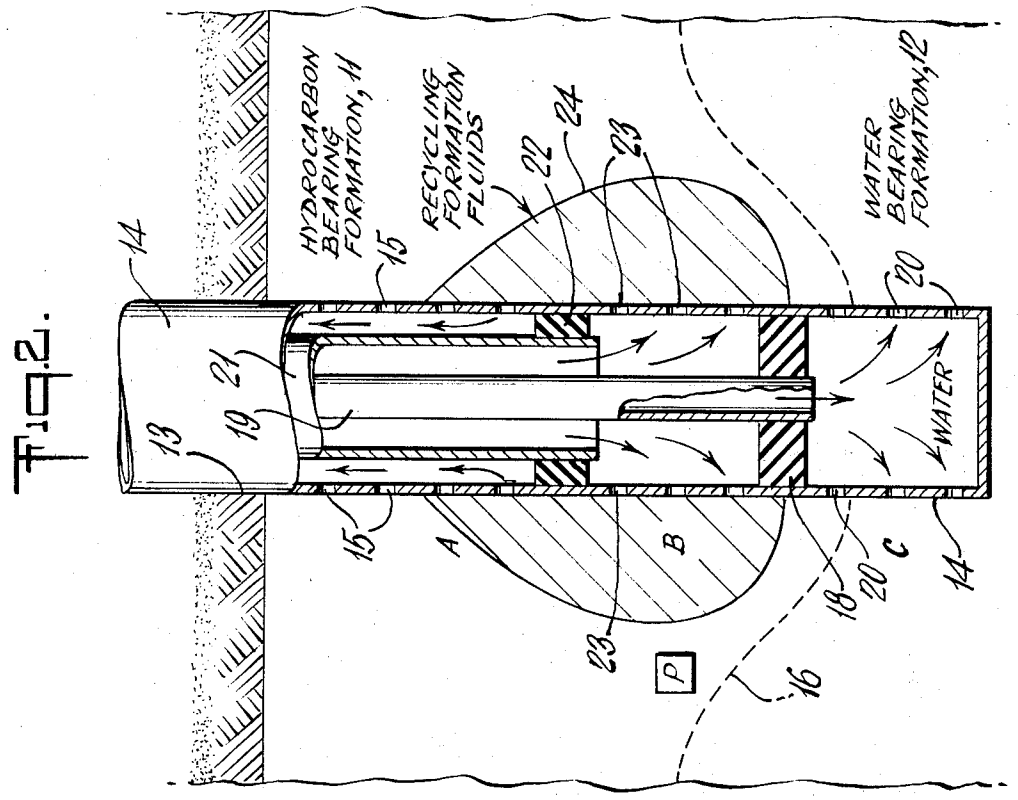

HYDROCARBON BEARING FORMATION, 11
RECYCLING FORMATION FLUIDS
WATER BEARING FORMATION, 12
WATER
A
B
C
P

Fig. 2.

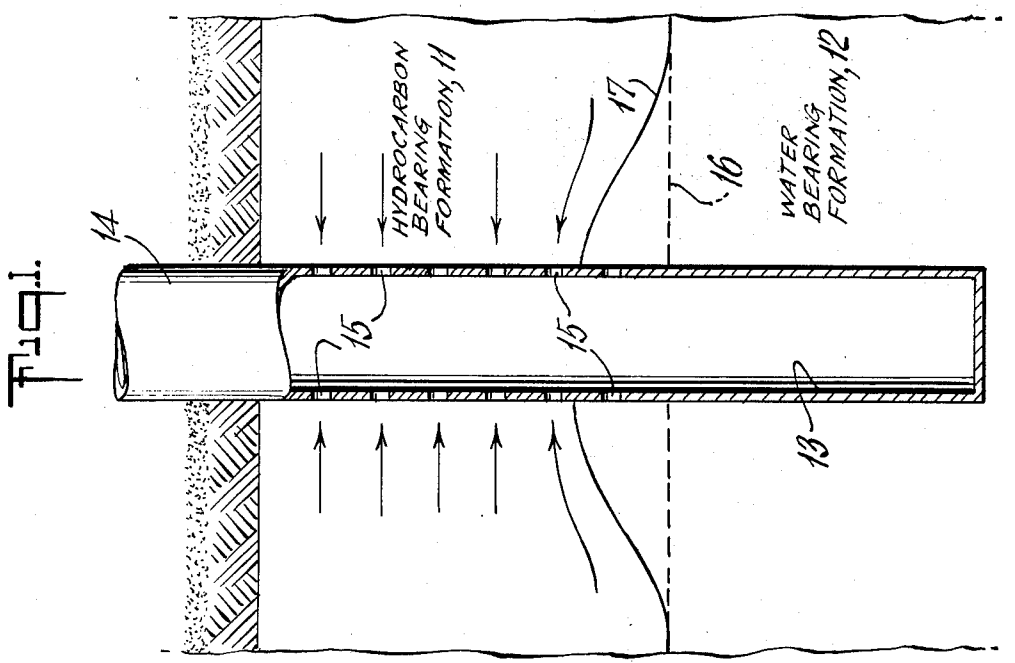

HYDROCARBON BEARING FORMATION, 11
WATER BEARING FORMATION, 12

Fig. 1.

GRADIENT BARRIER IN A SECONDARY RECOVERY OPERATION TO INHIBIT WATER CONING

FIELD OF THE INVENTION

This invention relates generally to the production of hydrocarbons from a subterranean hydrocarbon bearing formation, and more particularly, to a method for overcoming water coning, which may result during the exploitation of a hydrocarbon bearing formation which overlays a water bearing formation, i.e. an aquifer.

DESCRIPTION OF THE INVENTION

Water coning is a term given to the phenomenon of the entry of bottom waters into a production well. Under static conditions, water, having a greater density than formation hydrocarbon fluids, remains at the bottom of the production well. At high rates of production, however, the interface between the formation fluids including hydrocarbons and the underlying aquifer rises toward the production perforations due to the pressure gradients, and may extend into the well bore, because the upwardly directed pressure gradients associated with the flow of formation fluids into the production perforations are able to balance the hydrostatic head of the resulting elevated water column.

Various methods have been proposed to eliminate or to reduce the water coning phenomenon. These methods have included reducing the depth of the well penetration into the hydrocarbon bearing formation, so that higher production rates are possible, without, at the same time, experiencing an excessive production of water therewith.

In the commonly assigned U.S. Pat. No. 3,593,787, a gradient barrier is used in a horizontal sense, without the application of gravity, for controlling the advance of the interface in a secondary recovery program, by changing the function of control wells at strategic times.

SUMMARY OF THE INVENTION

It is an overall object of this invention to provide a method of preventing and/or reducing water coning, manifested by the production of a relatively large amount of water with respect to produced formation fluids including hydrocarbons, during the production thereof via a well bore extending through a hydrocarbon bearing formation and into an adjacent, underlying water bearing formation.

Injecting water via the lower perforations in the well bore to create a bottom water drive, and producing via the upper perforations in the well bore to achieve efficient upward vertical displacement, with reinjection of part of the produced formation fluids intermediate such perforations, all at controlled rates, will provide a gradient barrier in the form of a stable cycling envelope to suppress bottom water coning.

Other objects, advantages and features of this invention will become apparent from a consideration of the specification with reference to the figures of the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates the water coning phenomenon; and

FIG. 2 schematically illustrates a method in accordance with this invention for overcoming water coning.

Referring now to FIG. 1 of the drawing which schematically illustrates the water coning phenomenon, a subterranean hydrocarbon bearing formation is indicated at **11**, and an immediately underlying, water bearing formation is indicated at **12**. A well bore **13** extends through the hydrocarbon bearing formation **11** and into the water bearing formation **12**. A production casing **14** is provided with perforations **15** within the hydrocarbon bearing formation **11**. Under static conditions, or at a relatively low rate of hydrocarbon production from the formation **11**, the upper surface of the water bearing formation, i.e., the interface therebetween, is located at about the position indicated by the dashed line **16**. At relatively high rates of production, however, because of the upwardly directed pressure gradients associated with the flow of formation hydrocarbon fluids into perforations **15**, the water table rises to the extent that it is balanced by these upwardly directed pressure gradients. As the water table rises further, as indicated by solid line **17**, to the area of production of formation hydrocarbon fluids, water is produced by the lowermost perforations **15** of casing **14**. At still higher rates of production of hydrocarbon fluids from formation **11**, the water table continues to rise, as indicated by the wavy arrows, and there results a larger production of water relative to the amount of produced hydrocarbon fluids. The above-described phenomenon is commonly known as water coning.

Referring now to FIG. 2 of the drawing, there is schematically illustrated therein a method according to this invention for preventing and/or reducing water coning. The same reference numerals have been employed in FIG. 2 as were employed in FIG. 1 for the same or similar elements, for reasons of clarity and ease of understanding. As indicated in FIG. 2, well bore **13** is provided with an outer casing **14** and extends through hydrocarbon bearing formation **11**, and into underlying water bearing formation **12**.

In order to apply the method of this invention to prevent and/or reduce water coning when the secondary recovery operation production of formation hydrocarbon fluids is commenced via upper perforations **15** of outer casing **14** within the hydrocarbon bearing formation **11**, packer **18** is inserted between outer casing **14** and inner conduit **19**, above the lower perforations **20** in casing **14**. Eventually, the interface of the fluids in formations **11** and **12** will be located below this packer, as indicated by dashed line **16**. After the packer **18** has been installed, injection of water to create a bottom water drive is possible via inner conduit **19** into the formation **12** through lower perforations **20** in casing **14**.

However, to inhibit water coning, an intermediate conduit **21**, located in the annulus between casing **14** and inner conduit **19**, with packer **22** between itself and casing **14**, is installed to provide a flow of an extraneous fluid, compatible with the formation fluids, when injected into the formation via the intermediate perforations **23**.

In time, the extraneous fluid injected through the perforations **23** in the zone B will form a stable cycling envelope, as indicated at **24**, while water injection via the lower perforations **20** in the zone C is continued and production via the upper perforations **15** in zone

A is maintained. This results when the water, injected in the zone C, has to travel a longer flow path around the envelope, as indicated by the depressed interface **16,** FIG. **2.** Thus, when a unit volume of water reaches point P, its distance from the upper production perforations is such that the gravitational force acting downwardly is greater than the upward components due to injection and production gradients. The balance point depends on injection and production rates, densities of fluids, and geometry. Fluid flow from zone B should have flow rates adjusted to prevent a direct flow to zone A.

When required, the intermediate perforations **23,** may be moved up the well bore, after the water level has risen, to maintain blockage of water from the upper production perforations. Usually, the intermediate perforations are approximately halfway between injection and production perforations, and the fluids injected via the intermediate perforations **23** in zone C are in the range of about **10%** to about **50%** of the produced formation fluids via the upper perforations in zone A.

The choice of barrier fluid is a matter of economics and availability. Recovered formation hydrocarbon fluids from produced formation fluids are a readily available supply source and can be recovered with little extra expense. Other extraneous fluids may include such recovered production fluids treated with thickeners, butane and propane, all being miscible with formation fluids, for ease in ultimate recovery of the gradient barrier.

Thus, there has been shown and described the manner in which water coning is inhibited after the creation of a bottom water drive, by injecting an extraneous fluid into a hydrocarbon bearing formation via perforations intermediate the lower injection perforations and the upper production perforations to create a gradient barrier.

As will be apparent to those skilled in the art in the light of the accompanying disclosure, other changes and alterations are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A method of producing formation fluids including hydrocarbons from a subterranean hydrocarbon bearing formation under the influence of an aquifer which comprises penetrating a well bore through said formation and into said aquifer, providing upper and lower perforations in said well bore respectively for communication with said formation and with said aquifer, producing said formation fluids including hydrocarbons from said formation while injecting water into said aquifer to create a bottom water drive, providing perforations in said well bore intermediate said upper and lower perforations and thereafter injecting an extraneous fluid into said formation to provide a gradient barrier adjacent said well bore between said hydrocarbon bearing formation and said aquifer while maintaining producing said formation fluids including hydrocarbons from said formation and injecting water into said aquifer.

2. In the method as defined in claim **1,** said extraneous fluid injected via the intermediate perforations being selected from the group consisting of butane, propane and produced hydrocarbon fluids.

3. In the method as defined in claim **1,** recovering formation fluid hydrocarbons from produced formation fluids, and then injecting a portion of the recovered fluid hydrocarbons into said formation via said intermediate perforations.

4. In the method as defined in claim **3,** said portion being in the range of about 10 percent to about 50 percent of the recovered fluid hydrocarbons.

5. In the method as defined in claim **3,** said portion of recovered fluid hydrocarbons injected via said intermediate perforations being treated with thickeners.

6. A method of inhibiting water coning wherein fluid hydrocarbons are produced from a hydrocarbon bearing formation overlying a water bearing formation and being penetrated by a well bore extending into said last mentioned formation which comprises introducing sufficient water into said last mentioned formation to create a bottom water drive and producing formation hydrocarbon fluids from said hydrocarbon bearing formation while injecting an extraneous fluid into the formation below the level at which said formation fluids are produced from the formation and above the level at which water is being introduced into the formation so that the extraneous fluid forms a stable cycling envelope.

7. In the method as defined in claim **6,** said extraneous fluid being selected from the group consisting of butane, propane and produced hydrocarbon fluids.

8. In the method as defined in claim **7,** the amount of said extraneous fluid comprising produced hydrocarbon fluids in the range of about 10 percent to about 50 percent of the total of produced formation fluids.

9. A method as defined in claim **6** wherein said water and said extraneous fluid are introduced into said formation via the same well as is used for production of hydrocarbons from the formation.

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