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Allen

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[54] **METHOD FOR PREVENTING BOTTOM WATER CONING IN OIL WELLS**

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[52] **U.S. Cl.** **166/303,** 166/306

[51] **Int. Cl.** **E21b 43/24,** E21b 43/16

[58] **Field of Search** 166/303, 306, 272

[56] **References Cited**

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[57] **ABSTRACT**

Petroleum hydrocarbons are produced from a formation which is in contact and overlays a water-producing formation by a process in which water coning is inhibited. In this process a liquid hydrocarbon at a temperature of about 200° to 500° F is injected via a well bore into the lower portion of the producing formation, the liquid hydrocarbon is withdrawn via the well bore from the upper portion of the producing formation and is continuously injected and withdrawn while at the same time, petroleum hydrocarbons are produced from the upper portion of the said hydrocarbon-bearing formation. Prior to the injection of the hot hydrocarbon liquid, a slug of carbon dioxide or flue gases which can optionally contain a hydrolyzable silane, may be injected into the upper portion of the formation.

3 Claims, 2 Drawing Figures

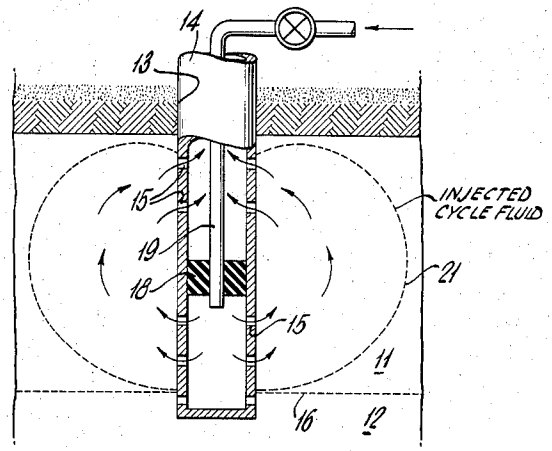


Fig. 2.

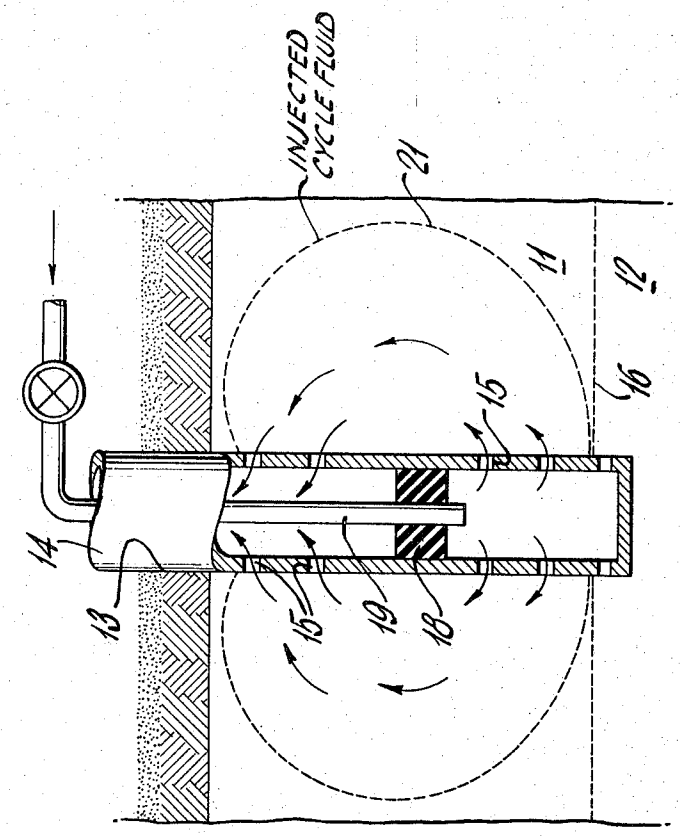
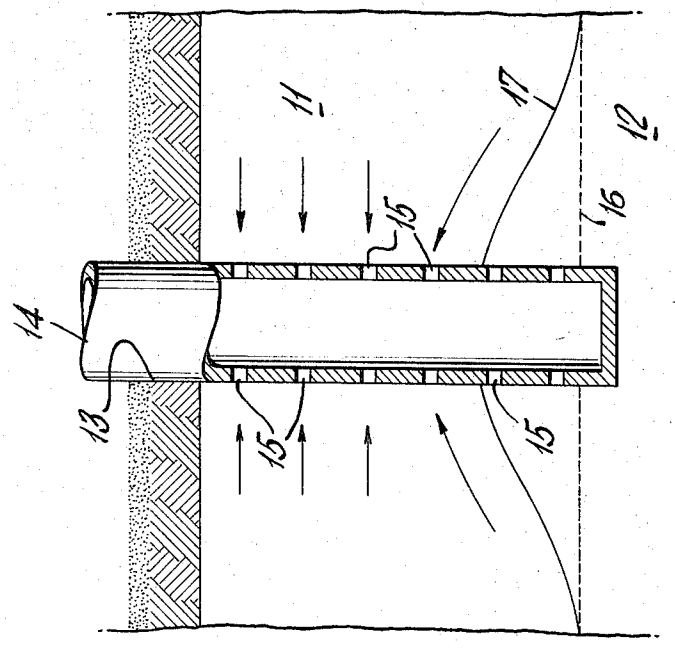

INJECTED CYCLE FLUID
21
11
12
16
15
14
13
15
19
18

Fig. 1.


11
17
12
16
15
14
13
15
15

METHOD FOR PREVENTING BOTTOM WATER CONING IN OIL WELLS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the production of petroleum hydrocarbon from a subsurface reservoir. More particularly, this invention relates to the production of petroleum hydrocarbons and especially to heavy hydrocarbon oils from a subsurface reservoir which is in contact with and overlays a substantially water-saturated porous formation. This invention also relates to a method for overcoming water coning which sometimes results during production of hydrocarbons from such formations.

2. Prior Art

Water coning is a term given to the mechanism underlying the entry of bottom waters into producing wells. Petroleum hydrocarbbons are often produced from porous subsurface formations which overlay a substantially water-saturated porous formation. Under static conditions the water, being of greater density than the hydrocarbons, remains beneath and at the bottom of the hydrocarbon-producing formation. At high rates of production of petroleum hydrocarbons, however, the upper boundary or surface of the substantially water-saturated formation rises due to the increased flow into the liquid petroleum-producing formation immediately adjacent and above the substantially water-saturated formation. The rise of water into the hydrocarbon-producing formation and into the well bore represents a dynamic effect in which the upward directed pressure gradients associated with the flow of the hydrocarbons into the producing well bore are able to balance the hydrostatic head of the resulting elevated water column.

Various methods have been suggested heretofore to eliminate or to reduce the water-coning phenomenon. These methods have included reducing the well penetration into the hydrocarbon-producing formation so that higher production rates are possible without at the same time experiencing a relatively increased production of water therewith. Another method which has been suggested is to bottom the producing well into a substantially water-impermeable formation. These indicated methods, however, cannot be successfully employed in all instances to eliminate or reduce water-coning. Certain underground hydrocarbon-producing formations are only a relatively few feet in thickness. Accordingly, reducing the well bore penetration into such a formation would unduly restrict the recovery of petroleum hydrocarbons therefrom. Other hydrocarbon-producing formations do not have associated therewith an immediately underlying water-impermeable formation.

BRIEF DESCRIPTION OF THE INVENTION

This invention relates to a method of producing petroleum hydrocarbons and inhibiting water coning during the production of petroleum hydrocarbons from a well bore which penetrates a surface petroleum hydrocarbon-producing formation which is in contact with and overlays an adjacent water-producing formation which comprises:

a. injecting via said well bore a liquid hydrocarbon at a temperature of about 200° to about 500° F into the lower part of said hydrocarbon-producing formation,

b. withdrawing via said well bore the injected liquid hydrocarbon from the upper portion of the hydrocarbon-producing formation, and

c. continuously injecting and withdrawing said liquid hydrocarbon while at the same time producing via said well bore petroleum hydrocarbons from the upper portion of the said hydrocarbon-bearing formation, the volume of the liquid hydrocarbon injected being less than the volume of the withdrawn liquid hydrocarbon plus the volume of the produced petroleum hydrocarbons, the volumes being expressed in reservoir or formation volumes.

DETAILED DESCRIPTION OF THE INVENTION

The operation of this invention will become apparent with reference to the accompanying drawing wherein:

FIG. 1 schematically illustrates the water-coning phenomenon; and

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

In accordance with this invention water coning is overcome by injecting into the hydrocarbon-producing formation in the zone experiencing the water-coning phenomenon a substantial amount of a liquid hydrocarbon heated to a temperature of about 200° to about 500° F. As the fluid is injected into that portion of the hydrocarbon-producing formation experiencing water coning, the water filling the pores or interstices of the formation is displaced and forced back by the injected liquid. The injection of the hot liquid hydrocarbon is continued until the water has been displaced a substantial radial distance, e.g., at least about 5 feet, preferably at least 20 feet, from the point of liquid hydrocarbon injection, which is conveniently the well bore itself. Initially, the pores of this zone of the hydrocarbon-producing formation may be substantially saturated with water, i.e., 70–90 percent occupied by water, particularly if the well produces almost 100 percent water. It is preferred in the practice of this invention to reduce the water content of the pores of the formation to the irreducible minimum for a substantial extent in the area surrounding the location of fluid injection. Depending upon the geometrical configuration of the pores or interstices of the formation the irreducible minimum water content is usually in the range of 2–50 percent of the pore range.

Prior to injecting the hot hydrocarbon oil into the formation one may inject a slug of the hot hydrocarbon oil containing carbon dioxide, flue gases or other gases soluble in oil, up to the saturation amount dissolved therein into the lower part of the formation. The effect of this is to increase the mobility of the in-place oil in the formation. In another embodiment of this invention the water content or saturation of the formation into which the hot hydrocarbon fluid is to be injected is first reduced below the so-called irreducible minimum by mere volumetric displacement by injection into the lower part of the formation a slug of hot carbon dioxide or hot combustion gases at a temperature of about **200°** to about 1,000° F, so as to substantially dry the formation into which the gas is injected. In another embodiment of this invention the injected hot carbon dioxide or flue gases may contain a small amount (i.e., from

about 200 to 5,000 parts per million) of a vaporized alkyl or alkyl-aryl halo silane which on hydrolysis deposits within the formation in the zone of the gas injection a film which is preferentially wettable by oil, e.g., a hydrophobic film. Suitable silanes include compounds of the formula:

$$R\,R'Si\,X,$$

wherein R and R' are independently selected from the group consisting of alkyl of from 1 to 6 inclusive carbon atoms and aryl of not more than 8 carbon atoms and X is selected from the group consisting of chlorine, bromine and iodine, as exemplified by: methyldiethylchlorosilane, dimethyldichlorosilane, methyltrichlorosilane, dimethyldibromosilane, diethyldiiodosilane, dipropyldichlorosilane, dipropyldibromosilane, butyltrichlorosilane, phenyltribromosilane, diphenyldichlorosilane, tolyltribromosilane, methylphenyldichlorosilane, etc. If desired, prior to injecting the hot hydrocarbon oil into the formation, a slug of the hydrocarbon oil containing dissolved therein one or more of the previously mentioned alkyl, aryl or alkyl-aryl halo silanes in an amount of from about **200** to 5,000 parts per million or more can be injected into the lower part of the formation.

Suitable hydrocarbon liquids which may be employed in the practice of this invention include crude oil substantiallly as produced fro the well undergoing treatment, stock tank oil, normally liquid petroleum distillate fractions, such as a gas oil or lubricating oil fraction, e.g., initial boiling point not less than 300° F, preferably not less than 400° F. The injection of a petroleum liquid is preferred in the practice of this invention since better displacement of the water is thereby obtained and there is less likelihood of channeling of the injected hot liquid into the water-bearing or producing formation taking place.

Referring now to FIG. **1** of the drawing which schematically illustrates the water-coning phenomenon, a subsurface gaseous and/or liquid petroleum hydrocabon-producing formation is indicated at **11.** An immediately underlying, substantially water saturated water-producing formation is indicated at **12.** A well bore **13** extends into the petroleum-producing formation **11** and is bottomed in the water-producing formation **12.** A production casing **14** is provided with perforations **15** within the petroleum-producing formation **11.** Under static conditions, or at a relatively low rate of petroleum production from the petroleum formation **11,** the upper surface of the water-producing formation is located at about he position indicated by the dashed line **16.** At relatively high rates of production, and/or because of the upward directed pressure gradients associated with the flow of petroleum into perforations **15,** the water table rises to the extent it is balanced by these upward directed pressure gradients. As the water table rises, as indicated by solid line **17,** into the zone of production of liquid petroleum hydrocarbons, water is produced by the lowermost perforations **15** of casing **14.** At still greater rates of production from formation **11,** the water table continues to rise and there results a greater production of water relative to the amount of produced petroleum. 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 reasons of clarity and ease of understanding. As indicated in FIG. **2,** well bore **13** provided with casing **14** extends into petroleum-producing formation **11** which overlays water-producing formation **12.** In order to prevent and/or reduce water coning when the production of petroleum is commenced or to purge the petroleum-producing formation of water which has invaded the petroleum-producing formation **11** because of water coning, the casing **14** is perforated within the petroleum-producing formation **11** near the top or upper surface thereof and near the bottom and/or in the upper part of the water-producing formation **12,** as illustrated. Packing **18** is then inserted within casing **14** intermediate the upper and lower perforations **15.** Dashed line **16** indicates the normal interface of formations **11** and **12.** After the packing **18** has been installed, a hot fluid such as stock tank oil, a high boiling petroleum distillate fraction, at a temperature of about 400° F is injected via conduit **19** into the formation **11** via the lower perforations **15** in the casing **14** and removed from formation **11** via upper perforations **15** for recycle back into conduit **19** back to the surface between conduit **19** and casing **14.** The injection of the hot hydrocarbon into formation **11** is continued until the water has been displaced within formation **11** for a substantial radial distance surrounding that portion of well bore **13** within formation **11,** to the extent indicated by dashed line **21.** After a sufficient amount of fluid has been injected to displace the water from around the well bore **13** immediately adjacent the liquid petroleum-producing formation **11,** the injection of fluid is decreased and the production of petroleum from formation **11** is commenced. As the liquid petroleum flows through perforations **15** into production casing **14,** upward-directed pressure gradients are created which tend to lift the water table into the petroleum formation **11** in the area of the well bore **13.** Accordingly, the water present within the water-producing formation **12** tends to fill the spaces or pores of formation **11** from which it was displaced by the injected fluid. However, the flow of water thereinto is resisted because of the reduced permeability of this localized portion of formation **11** due to the presence of a substantial amount of injected fluid present in the interstitial voids thereof. Due to the reduced permeability of this zone considerable resistance to the flow of water therethrough is experienced with the result that the rate of petroleum production through perforations it can be greatly increased without experiencing an undue amount of produced water due to water coning.

The practice of this invention is applicable not only to newly drilled wells but is also applicable to previously drilled wells which are producing a considerable amount of water due to the phenomon of water coning. In accordance with one preferred embodiment of this invention particularly applicable to previously drilled producing wells which exhibit an unduly large amount of water production due to the phenomenon of water coning, the producing well is shut in for a period of time necessary to approach or establish equilibrium conditions in the subsurface producing formations. This period of time, depending upon various circumstances may be three hours to a month. Thereafter a hot liquid petroleum fraction is injected into and cycled within the hydrocarbon-producing formation as de-

scribed hereinabove. After a sufficient amount of liquid petroleum has been injected and cycled to force the water in the petroleum-producing formation a substantial radial distance outwardly from the well bore the injection of liquid petroleum is continued and petroleum production commenced. This technique drastically changes the normal pressure gradients set up around the well bore and prevents premature invasion or coning of water into the petroleum-producing formation. Obviously the injection rate of the recycled petroleum liquid would have to be less than the petroleum (oil and/or gas) production rate, as measured at the well head, the volumes being expressed in reservoir volumes, so that there is a net production of petroleum from the formation.

What is claimed is:

1. A method of producing petroleum hydrocarbons and inhibiting water coning during the production of petroleum hydrocarbons from a well bore which penetrates a subsurface petroleum hydrocarbon-producing formation which is in contact with and overlays an adjacent water-producing formation which comprises:

a. injecting into the lower portion of the formation a slug of liquid hydrocarbon having a material selected from the group consisting of carbon dioxide and flue gases dissolved therein in amounts up to the saturation value at the injection pressure,

b. injecting via said well bore a liquid hydrocarbon at a temperature of about 200° to about 500° F into the lower part of said hydrocarbon-producing formation,

c. withdrawing via said well bore the injected liquid hydrocarbon from the upper portion of the hydrocarbon-producing formation, and

d. continuously injecting and withdrawing said liquid hydrocarbon while at the same time producing via said well bore petroleum hydrocarbons from the upper portion of the said hydrocarbon-bearing formation, the volume of the liquid hydrocarbon injected being less than the volume of the withdrawn hydrocarbon plus the volume of the produced petroleum hydrocarbons, the volumes being expressed in reservoir or formation volumes.

2. A method of producing petroleum hydrocarbons and inhibiting water coning during the production of petroleum hydrocarbons from a well bore which penetrates a subsurface petroleum hydrocarbon-producing formation which is in contact with and overlays an adjacent water-producing formation which comprises:

a. injecting into the lower portion of the formation a slug of liquid hydrocarbon having dissolved therein from about 200 to about 5,000 ppm of a hydrolyzable silane of the formula:

$$R\,R'\,Si\,X,$$

wherein R and R′ are independently selected from the group consisting of alkyl of from 1 to 6 inclusive carbon atoms and aryl of not more than 8 carbon atoms and X is selected from the group consisting of chlorine, bromine and iodine,

b. injecting via said well bore a liquid hydrocarbon at a temperature of about 200° to about 500° F into the lower part of said hydrocarbon-producing formation,

c. withdrawing via said well bore the injected liquid hydrocarbon from the upper portion of the hydrocarbon-producing formation, and

d. continuously injecting and withdrawing said liquid hydrocarbon while at the same time producing via said well bore petroleum hydrocarbons from the upper portion of the said hydrocarbon-bearing formation, the volume of the liquid hydrocarbon injected being less than the volume of the withdrawn liquid hydrocarbon plus the volume of the produced petroleum hydrocarbons, the volumes being expressed in reservoir or formation volumes.

3. A method of producing petroleum hydrocarbons and inhibiting water coning during the production of petroleum hydrocarbons from a well bore which penetrates a subsurface petroleum hydrocarbon-producing formation which is in contact with and overlays an adjacent water-producing formation which comprises:

a. injecting into the lower portion of the formation a slug of gas selected from the group consisting of carbon dioxide and flue gases at a temperature of about 200 to about 1,000° F in an amount sufficient to reduce the water content of the formation into which the hot liquid hydrocarbon is injected to an amount below the so-called irreducible minimum, the said carbon dioxide containing from about 200 to about 5,000 ppm of a vaporized hydrolyzable silane of the formula:

$$R\,R'\,Si\,X,$$

wherein R and R′ are independently selected from the group consisting of alkyl of from **1** to **6** inclusive carbon atoms and aryl of not more than **8** carbon atoms and X is selected from the group consisting of chlorine, bromine and iodine,

b. injecting via said well bore a liquid hydrocarbon at a temperature of about 200° to about 500° F into the lower part of said hydrocarbon-producing formation,

c. withdrawing via said well bore the injected liquid hydrocarbon from the upper portion of the hydrocarbon-producing formation, and

d. continuously injecting and withdrawing said liquid hydrocarbon while at the same time producing via said well bore petroleum hydrocarbons from the upper portion of the said hydrocarbon-bearing formation, the volume of the liquid hydrocarbon injected being less than the volume of the withdrawn liquid hydrocarbon plus the volume of the produced petroleum hydrocarbons, the volumes being expressed in reservoir or formation volumes.

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