

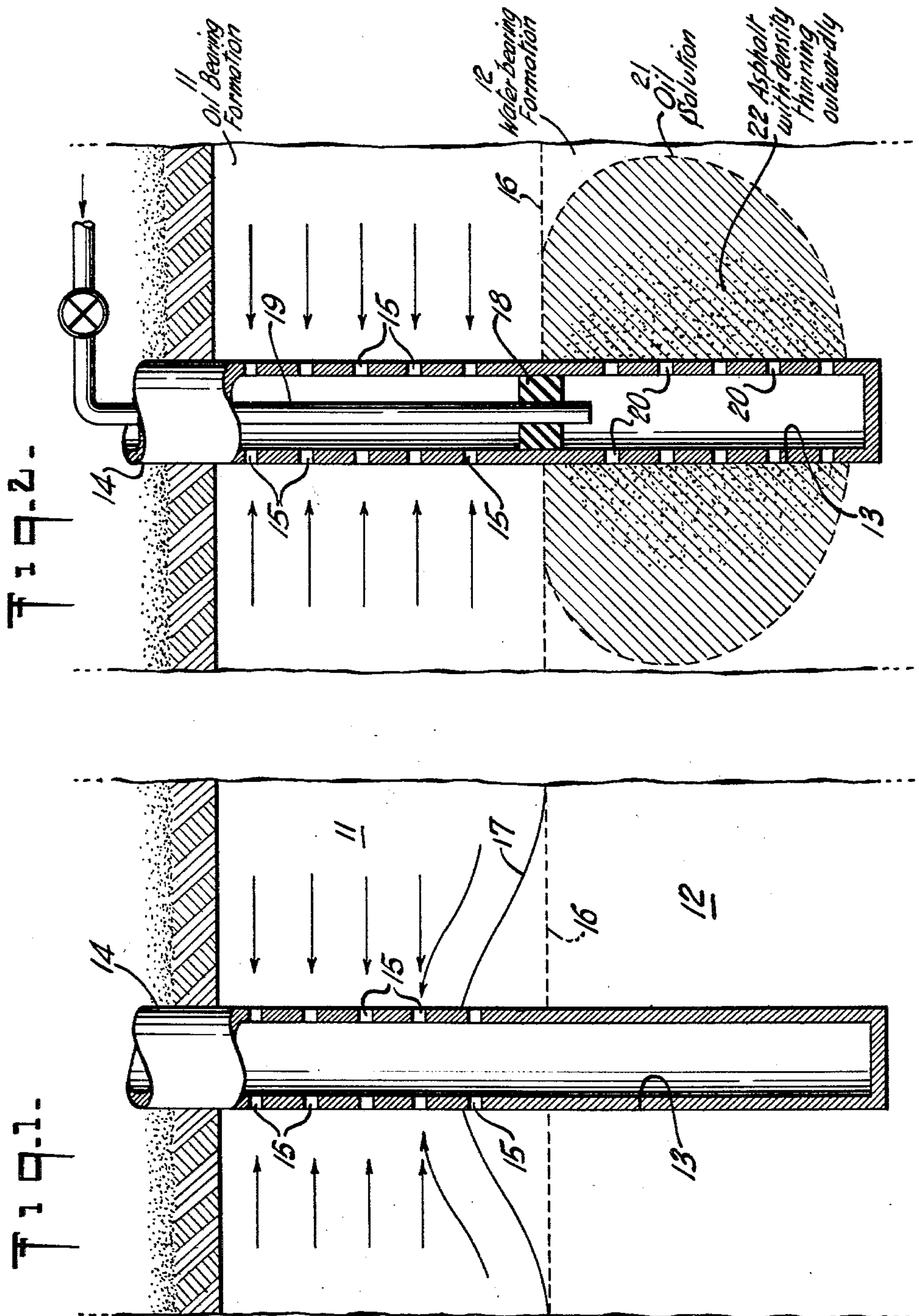
April 27, 1965

J. C. ALLEN

3,180,415

OIL WELL TREATMENT TO OVERCOME WATER CONING

Filed June 3, 1963



1

3,180,415 OIL WELL TREATMENT TO OVERCOME WATER CONING

Joseph C. Allen, Bellaire, Tex., assignor to Texaco Inc.,
New York, N.Y., a corporation of Delaware
Filed June 3, 1963, Ser. No. 284,875
11 Claims. (Cl. 166—32)

This invention relates generally to the production of petroleum hydrocarbons from a subsurface reservoir, and specifically to the production of liquid petroleum hydrocarbons from a subsurface reservoir which overlays a substantially water-saturated, water-producing formation. More particularly, this invention relates to a method for overcoming water-coning which may result during the production of petroleum hydrocarbons from a petroleum-producing formation which overlays a substantially water-saturated formation.

Water-coning is a term given to the mechanism underlying the entry of bottom waters into petroleum- or oil-producing wells. Petroleum hydrocarbons are often produced from subsurface formations which overlay a substantially water-saturated formation. Under static conditions, the water, having a greater density than the liquid petroleum, remains at the bottom of the petroleum-producing formation. At high rates of production of petroleum, however, the upper surface of the substantially water-saturated formation rises due to the increased flow of liquid petroleum into the well bore which extends into the liquid petroleum-producing formation immediately adjacent and above the substantially water-saturated formation. The rise of water into the petroleum-producing formation and into the well bore represents a dynamic effect in which the upward directed pressure gradients associated with the flow of the petroleum 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 liquid petroleum-producing formation so that higher production rates are possible without at the same time experiencing an excessive 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 liquid petroleum-producing formations are only a relatively few feet in thickness. Accordingly, reducing the well bore penetration into such a formation would restrict unduly the recovery of liquid petroleum therefrom. Other liquid petroleum formations do not have associated therewith an immediately underlying water-impermeable formation.

It is an object of this invention to provide an improved method for the recovery of petroleum hydrocarbons from subsurface petroleum-producing formations.

Another object of this invention is to provide an improved method for the recovery of liquid petroleum hydrocarbons from a liquid petroleum-producing formation which overlays a substantially water-saturated formation.

Still another object of this invention is to provide a method of preventing and/or reducing water-coning as evidenced by the production of a relatively large amount of water with respect to produced liquid petroleum during the production of liquid petroleum from a well bore extending into a liquid petroleum-producing formation and an adjacent underlying water-producing formation.

And still another object of this invention is to provide an improved method of well completion wherein the well

2

bore extends into a liquid petroleum-producing formation which overlays a water-producing formation.

These and other objects of this invention and how they are accomplished 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 initially into the water-producing formation giving rise to the water-coning phenomenon a substantial amount of a solvent liquid containing asphaltic material dissolved or suspended therein. As this solvent liquid is injected into the water-producing formation, the water filling the pores or interstices of the formation is displaced and forced back by the injected solvent liquid. The injection of solvent liquid into the water-producing formation is continued until the water has been displaced a substantial radial distance, e.g., at least about 5 feet, preferably at least about 20 feet, from the locus of injection, which is conveniently the well bore itself. Initially, the pores of the water-producing formation adjacent or in the vicinity of the well bore are usually substantially saturated with water, i.e., 100 percent occupied by water. After the injection of solvent liquid, the water saturation of the producing formation in the zone of the solvent liquid injection thereto is reduced substantially.

Subsequent to the injection of solvent liquid into the water-producing formation, a gas is introduced into the thus-treated formation, whereupon deposition of asphaltic material within the water-producing formation in the immediate vicinity of the well bore occurs. The precipitation of asphaltic material from the solvent liquid containing the same is effected by vaporization of the solvent into the gas-treated portion of the water-producing formation and/or by a deasphalting effect of the subsequently injected gas upon the previously injected solvent liquid asphalt-containing solution. Thereafter, as necessary, additional solvent liquid and gas are introduced in turn into the formation to redissolve and/or disperse the thus-precipitated asphaltic material outwardly into the water-producing formation to effect a plugging in depth in that portion of the formation in the vicinity of the well bore due to extended deposition or reprecipitation of asphaltic material within the thus-treated portion of the water-producing formation for a substantial distance outwardly from the well bore. As a result of the dispersion and/or reprecipitation of the initially precipitated asphaltic material, the porosity of the thus-treated portion of the water-producing formation is substantially reduced. Also, as a result of this plugging action or reduction in porosity, the water permeability of the formation is substantially reduced. Subsequently, petroleum production is resumed from the overlying petroleum-producing formation via the well bore. Since the underlying water-producing formation from which the water-coning originates is now substantially plugged and evidences a substantially reduced water permeability for a considerable distance surrounding the well bore, the production of petroleum from the overlying petroleum-producing formation can be carried out at relatively high rates of production without undue danger of water-coning or excessive production of water with the produced petroleum. Since the deposited asphaltic materials are water insoluble, the above-indicated treatment of the water-producing formation to eliminate and/or inhibit water-coning is permanent in nature.

The term "asphaltic material" as used herein means resinous, asphaltic, carbenic hydrocarbons or asphalts, pitches and tars of plastic or solid nature, found in crude petroleum and the like or petroleum fractions, and effec-

tive to plug the interstitial voids of the water-producing formation.

Any suitable liquid solvent for asphaltic material may be employed in the practice of this invention. Particularly suitable for use in the practice of this invention are asphaltic crudes or crude oil or fractions thereof, such as may be recovered from the petroleum-producing formation overlying the water-producing formation undergoing treatment in accordance with this invention, containing asphaltic material dissolved therein. Other liquid asphaltic solvents or carriers useful in the practice of this invention include carbon tetrachloride, aromatic hydrocarbons such as benzene, xylene and the like, gas oils, kerosenes and higher boiling distillate fractions, etc. In general, the liquid solvent or carrier for asphaltic material employed in the practice of this invention may comprise any liquid having substantial solubility or solvent power for asphaltic material and which, desirably, is also compatible with the liquid petroleum in the overlying petroleum-producing formation.

Various gases may be employed in the practice of this invention. Suitable gases include natural gas, usually associated with and dissolved in the liquid petroleum-producing formation and which is recovered therefrom by suitable means, such as a gas-liquid separator at the surface. It is preferred that the injected natural gas be dry, i.e., having had its natural gasoline content stripped therefrom. Another gas which may be employed in the practice of this invention is air. Still another gas which is suitable in the practice of this invention is a gaseous mixture of combustion products such as a flue gas and the like, usually containing nitrogen, carbon dioxide and other gases in varying amounts. Normally gaseous hydrocarbons such as methane, ethane, propane, n-butane and/or isobutane, or mixtures thereof, are particularly useful in the practice of this invention, since these normally gaseous hydrocarbons exhibit a deasphalting effect upon liquid asphalt-containing oils and crudes in contact therewith.

Referring now to FIG. 1 of the drawing which schematically illustrates the water-coning phenomenon, a subsurface liquid petroleum-producing formation is indicated at 11. An immediately underlying, saturated, water-producing formation is indicated at 12. A well bore 13 extends into the liquid petroleum-producing formation 11 and 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 liquid petroleum production from the liquid petroleum formation 11, the upper surface of the water-producing formation is located at about the position indicated by the dashed line 16. At relatively high rates of production, however, because of the upward directed pressure gradients associated with the flow of liquid 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, to the area of production of liquid petroleum hydrocarbons, water is produced through the lowermost perforations 15 of casing 14. At still greater rates of production of liquid petroleum from formation 11, the water table continues to rise and there results a greater production of water relative to the amount of produced liquid hydrocarbons. 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 are employed in both FIGS. 1 and 2 for reasons of clarity and ease of understanding. As indicated in FIG. 2 well bore 13 provided with casing 14 extends into liquid petroleum-producing formation 11 which overlays water-producing formation 12. In order to prevent and/or reduce water-

coning when the production of liquid petroleum is commenced through perforations 15 of casing 14 within the petroleum-producing formation 11, packing 18 is inserted within casing 14 at about the normal interface of the formations 11 and 12, as indicated by dashed line 16. After the packing 18 has been installed, a solvent liquid, e.g., an oil containing asphaltic material dissolved or suspended therein is injected via conduit 19 into the formation 12 via perforations 20 in casing 14. The injection of this solvent liquid into formation 12 is continued until the water has been displaced within formation 12 for a substantial radial distance surrounding that portion of well bore 13 within formation 12, to the extent indicated by dashed line 21.

When a sufficient amount of this solvent liquid has been injected to displace the water from around the well bore 13 immediately adjacent the liquid petroleum-producing formation 11, the injection of solvent liquid is stopped, after which there is introduced into water-producing formation 12 via tubing 19 and perforations 20 a gas, such as natural gas, e.g., methane or propane. Upon the introduction of gas into the thus solvent liquid-treated portion of the water-producing formation 12, deasphalting or precipitation of asphaltic material occurs in the immediate vicinity of the well bore, as indicated at 22, extending outwardly with diminishing density. To increase the amount of asphaltic material thus deposited within formation 12 in the immediate vicinity of the well bore and also to enlarge the extent of the so-treated formation, additional oil or asphaltic solvent is introduced into the formation to redissolve the thus-precipitated asphaltic material and to disperse and reprecipitate the asphaltic material outwardly into formation 12 for a substantial distance outwardly from the well bore, after which gas is again injected behind the solvent liquid, and again deasphalting or precipitation occurs as the gas makes contact with the solvent liquid. As a result of this repeat operation, the formation is thus treated in depth for a substantial distance outwardly from the well bore. Subsequently, production of petroleum is resumed from petroleum-producing formation 11 via perforations 15. Since the underlying portion of formation 12 is now substantially plugged with the asphaltic material so that the water permeability thereof is reduced substantially, the production of petroleum from petroleum-producing formation 11 can be resumed at substantial rates of production without undue danger of water-coning.

In the above-indicated embodiment of this invention wherein an oil or hydrocarbon solution or suspension of asphaltic material is employed, the asphaltic material is deposited within the interstitial non-wetting or funicular space of the thus-treated water-producing formation, i.e., that portion of the formation which would normally be occupied by oil or the non-wetting phase.

In accordance with another embodiment of the practice of this invention, the treating solution comprising asphaltic material dissolved therein is an oil-in-water suspension or emulsion wherein the oil contains the asphaltic material dissolved or suspended therein. In the practice of this latter embodiment of the invention since the treating solution is an oil-in-water suspension, the treating solution would occupy that portion of the formation normally occupied by the water or wetting phase. Accordingly, following the injection of the treating solution containing asphaltic oil-in-water emulsion, deasphalting or precipitation of the asphaltic material due to contact with the following injected gas would occur in the water phase immediately adjacent the rock matrix and in the most minute interstitial voids of the formation. Upon resumption of petroleum production from the overlying petroleum-producing formation, these asphaltic solids would tend to move toward the well bore and asphaltic agglomerates would build up within the interstitial wetting phase rather than in the non-wetting phase.

or funicular interstitial space of the formation. The formation of asphaltic agglomerates in the wetting phase and region of the formation leads to more efficient plugging and in some instances to actual cementation of the thus-deposited asphaltic material to the formation itself, thereby effecting a more effective plugging and reduction in water permeability.

Further explanatory of the practice of this invention, by appropriate choice of solvent and solute, a solution can be made to have a considerably higher viscosity than that of water, so that a comparatively high solution saturation in the formation would result because of the more efficient displacement of water therefrom, so that a large fraction of the pore volume would be filled with the solution adjacent to the well bore. The subsequent injection of gas would result in an inefficient displacement of the solution with attendant good mixing. This operation would precipitate more of the solute and would occupy a larger fraction of the pore volume near the well bore and so result in a greater reduction of permeability.

The practice of this invention is applicable not only to newly-drilled wells but is applicable also to previously drilled wells which are producing a considerable amount of water due to the phenomenon of water-coning. In previously drilled producing wells which exhibit an unduly large amount of water production due to water-coning, the practice of this invention may be as follows.

The well is shut in for a period of time necessary to promote the establishment of equilibrium conditions in the subsurface producing formations. This period of time, depending upon various circumstances, may be three days to a month, more or less. Then, an asphaltic containing liquid is injected into the water-producing formation immediately adjacent the liquid petroleum-producing formation in the vicinity of the well bore. This can be done by perforating the production casing in the zone of the water-producing formation and injecting this liquid thereinto, and after a sufficient amount has been injected to force the water in the formation a substantial radial distance outwardly from the well bore at the locus of injection, liquid injection is stopped and the well treated by injection of a gas thereinto, as indicated with respect to FIG. 2 of the drawing.

Thus, there has been shown and described a more efficient method for overcoming water-coning by applying the principle of efficient displacement of water from the water-producing formation adjacent the well bore by a more viscous fluid and the subsequent inefficient displacement of the more viscous fluid by a gas to the deposition of a plugging material adjacent the well bore, specifically, using initially an asphaltic material carrying liquid to displace water adjacent the well bore, followed by a gas to cause deposition of the asphaltic material in that part of the underground formation from which the water has been displaced by the more viscous fluid.

As will be apparent to those skilled in the art, other substitutions, alterations or omissions are possible without departing from the spirit or scope of this invention.

I claim:

1. A method of treating a well to inhibit water-coning during the production of oil from an oil-producing formation adjacent an underlying water-producing formation via a well bore extending through said oil-producing formation which comprises introducing a solvent liquid containing asphaltic material dissolved therein via said well bore into said water-producing formation in an amount sufficient to force water in said water-producing formation a substantial distance outwardly from said well bore adjacent said oil-producing formation, subsequently introducing via said well bore into that portion of said water-producing formation into which said solvent liquid has been introduced a gas to effect vaporization of at least a portion of said solvent liquid and to

effect precipitation of at least a portion of said asphaltic material contained in said solvent liquid, subsequently successively introducing solvent liquid substantially free of asphaltic material dissolved therein and a gas via said well bore into the thus-treated portion of said water-producing formation to force the remaining first introduced solvent liquid outwardly further into said water-producing formation and to redissolve and then reprecipitate the aforementioned precipitated asphaltic material thereby plugging a substantial portion of the thus-treated water-producing formation outward from said well bore and substantially reducing the water permeability thereof, and subsequently resuming production of oil via said well bore from said oil-producing formation.

2. A method of treating a well bore which penetrates an oil-producing formation and into an adjacent underlying water-producing formation which comprises introducing via said well bore into said water-producing formation adjacent said oil-producing formation an oil solution containing asphaltic material dissolved therein in an amount sufficient to force water in said water-producing formation a substantial distance outwardly from said well bore, subsequently introducing via said well bore into the thus-treated portion of said water-producing formation a normally gaseous hydrocarbon in gaseous state to contact the previously introduced oil solution introduced into said water-producing formation thereby tending to precipitate at least a portion of said asphaltic material within the thus-treated portion of the water-producing formation in the zone thereof immediately surrounding said well bore, subsequently introducing via said well bore oil and gaseous hydrocarbon in turn to effect dissolution of precipitated asphaltic material and to move the redissolved asphaltic material outwardly from said well bore into the said thus-treated portion of the formation and to cause said redissolved asphaltic material to be reprecipitated therein adjacent and at a location within said water-producing formation removed from said well bore, and resuming production of petroleum via said well bore from said oil-producing formation.

3. A method of treating a well bore which penetrates an oil-producing formation and into an adjacent underlying water-producing formation which comprises introducing via said well bore into said water-producing formation adjacent said oil-producing formation an oil-in-water emulsion in an amount sufficient to force the water in said water-producing formation a substantial distance outwardly from said well bore, said oil containing dissolved therein asphaltic material, subsequently introducing via said well bore into the thus-treated zone of said water-producing formation a normally gaseous hydrocarbon in gaseous state, permitting introduced oil-in-water emulsion to remain in contact within the thus-treated portion of said formation with the subsequently introduced normally gaseous hydrocarbon to effect de-asphalting of the oil in the oil-in-water emulsion to cause asphalt to be precipitated from said emulsion within said formation and subsequently resuming production of petroleum via said well bore from said oil-producing formation.

4. A method of inhibiting water-coning in a well wherein oil is produced from an oil-containing formation penetrated by a well bore and wherein said well bore also penetrates into an adjacent, underlying water-producing formation which comprises introducing via said well bore into said water-producing formation adjacent said oil-producing formation an oil solution containing asphaltic material dissolved therein to substantially reduce the water saturation within the water-producing formation in a zone therein immediately surrounding said well bore, introducing into said zone of said water-producing formation a normally gaseous hydrocarbon in gaseous state whereby said asphaltic material is precipitated from said solution within said formation

7

in said zone immediately adjacent said well bore, subsequently introducing in turn via said well bore into said zone of said water-producing formation oil in an amount sufficient to redissolve the previously precipitated asphaltic material from immediately adjacent said well bore and to move said asphaltic material outwardly into said zone and a gas to reprecipitate said asphaltic material thereby effecting a redistribution of precipitated asphaltic material within said zone in said water-producing formation whereby a substantial portion of said zone has its porosity reduced due to the precipitation of asphaltic material therein and subsequently resuming production of oil from said oil-producing formation via said well bore.

5. A method of reducing water-coning, as evidenced by the production of a relatively large amount of water with respect to produced liquid petroleum, which is experienced during the production of liquid petroleum from a well bore extending through a subsurface liquid petroleum-producing formation and into an adjacent underlying water-producing formation which comprises halting production of liquid petroleum from said well bore to promote the attainment of equilibrium conditions in the aforesaid subsurface formations, injecting via said well bore into said water-producing formation adjacent said petroleum producing formation surrounding said well bore a solution containing asphaltic material dissolved therein sufficient to force the water in said water-producing formation a substantial distance outwardly from said well bore, subsequently introducing into said water-producing formation into that portion thereof surrounding said well bore containing the injected solution a gas whereby asphaltic material is deposited in a zone surrounding said well bore in the thus-treated water-producing formation due to vaporization of solvent from said solution, thereupon introducing in turn additional solvent substantially free of asphaltic material via said well bore into the thus-treated portion of the water-producing formation to dissolve the precipitated asphaltic material from the zone therein immediately surrounding said well bore and to move this asphaltic material outwardly into the treated portion of said water producing formation from said well bore and a gas to re-

8

precipitate asphaltic material in the thus-treated portion and thereafter resuming production of liquid petroleum from said liquid petroleum-producing formation via said well bore.

6. A method in accordance with claim 5 wherein the gas injected into the water-producing formation to deposit and subsequently to reprecipitate asphaltic material is natural gas.

7. A method in accordance with claim 5 wherein said solution containing asphaltic material dissolved therein comprises benzene as a solvent for said asphaltic material.

8. A method in accordance with claim 5 wherein said solution containing asphaltic material contains carbon tetrachloride as the solvent for said asphaltic material.

9. A method in accordance with claim 5 wherein said solution containing asphaltic material dissolved therein consists essentially of an oil-in-water emulsion wherein the oil phase of the emulsion dispersed in the continuous water phase contains asphaltic material dissolved therein.

10. A method in accordance with claim 5 wherein the solution of asphaltic material introduced into the water-producing formation comprises an oil-in-water emulsion wherein the oil phase of the emulsion comprises a liquid hydrocarbon solvent for asphalt containing asphaltic material dissolved therein.

11. A method in accordance with claim 5 wherein said solution containing asphaltic material has a viscosity greater than water.

References Cited by the Examiner

UNITED STATES PATENTS

2,713,906	7/55	Allen	166—32
2,779,415	1/57	Howard	166—30
2,805,720	9/57	Wiegand	166—32
2,859,820	11/58	Trott	166—32 X
2,896,716	7/59	Spurlock	166—38 X
3,084,744	4/63	Dew et al.	166—32 X

CHARLES E. O'CONNELL, *Primary Examiner*.

BENJAMIN HERSH, *Examiner*.