

Oct. 20, 1959

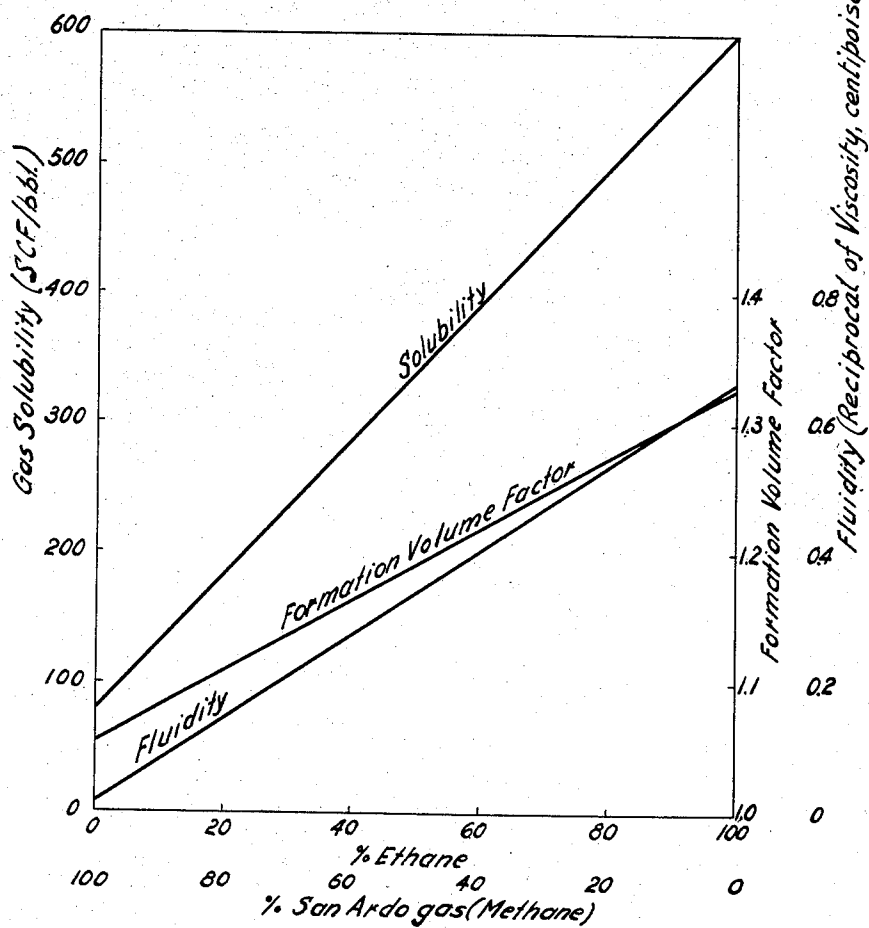
J. C. ALLEN

2,909,224

PRODUCING VISCOUS CRUDES FROM UNDERGROUND FORMATIONS

Filed March 22, 1956

*Solubilities of Methane and Ethane
in San Ardo Crude at 843psia +127°F.*



1

2,909,224

PRODUCING VISCOUS CRUDES FROM UNDERGROUND FORMATIONS**Joseph C. Allen, Bellaire, Tex., assignor to Texaco Inc., a corporation of Delaware****Application March 22, 1956, Serial No. 573,220****5 Claims. (Cl. 166—45)**

This invention relates to the recovery of viscous crudes from underground formations. More particularly, this invention relates to a method for effecting improved and increased recovery of a viscous low gravity crude from an underground producing formation containing the same.

The locations of large reserves of heavy crude oil, e.g., crude oil having a gravity in the range 9–20° A.P.I., more or less, are known. Of these, the San Ardo Field in California is perhaps the largest known commercial reserve of heavy crude. By present day commercial methods of production, however, it has been estimated only a minor portion of the in-place oil is recoverable despite the fact that the oil producing sand is relatively porous, about 30%, and possesses a relatively high average permeability, about 1300 md.

The relatively low recovery of a heavy viscous crude from a producing sand containing the same is for the most part due to the high viscosity of the in-place crude. In the San Ardo Field, for example, the viscosity of the in-place crude is in the range 25–300,000 Saybolt Universal Seconds at 80° F. Also, San Ardo crude, as produced, has a pour point of about 55° F. In a formation containing highly viscous in-place crude gas coning and water coning problems often present themselves when production of the heavy viscous crude is attempted. In order to avoid gas coning and/or water coning it has been a practice to produce a viscous crude at a level substantially removed from the gas cap and/or water table. For example, in producing crude from the San Ardo Field it has been the practice to produce from a level at least about 20 feet beneath the gas cap and from a level not closer than within 75 feet from the water table. Even at these production levels, however, and despite a producing formation thickness in some places of about 260, feet, when increased rates of production of the viscous crude are sought gas coning and/or water coning problems are experienced with the result that the recovery of the in-place viscous crude is not substantial.

Accordingly, it is an object of this invention to provide an improved method for the recovery of a viscous crude oil from an underground formation containing the same.

Still another object of this invention is to provide a method for effecting an increased recovery of a viscous, low gravity crude from an underground formation containing the same whereby the resulting produced crude possesses a reduced viscosity with respect to the crude originally in place.

Still another object of this invention is to provide a method for effecting production or recovery of a viscous, low gravity crude from an underground formation containing the same, such as in the San Ardo Field.

How these and other objects of this invention are achieved will become more apparent with reference to the accompanying disclosure and drawing wherein there is graphically illustrated the solubility of various gases in a viscous crude oil as well as the effect of the dissolved gas upon various physical properties of the resulting

2

gas-crude oil solution and the advantages obtainable and the benefits derivable from the practice of this invention. In at least one embodiment of the practice of this invention at least one of the foregoing objects will be achieved.

At one time it was thought that increased recovery of a viscous crude from an underground formation containing the same could be effected by diluting or otherwise commingling or contacting the in-place crude with a fluent, mobile fluid such as cutter stock or other low viscosity petroleum fraction. Actual tests, however, have demonstrated that the dilution or the addition of a low viscosity diluent such as a cutter stock to an underground formation containing a viscous crude for the purpose of effecting increased recovery or production of a viscous crude therefrom is ineffectual. For example, in one test a cutter stock (kerosene) was injected at one end into a sand pack containing irreducible water and a viscous oil (600 C.P.). The cutter stock was injected into the sand pack until it broke through and was produced at the opposite end. Afterwards flow was reversed by injecting viscous oil at the other end into the sand pack. The total production rate and rate of both injected fluid (cutter stock) and in-place viscous oil were measured as the function of time. There was no observable increase in the production rate of the in-place viscous oil. This failure to achieve an increase in the rate of production of the viscous oil was apparently due to the substantially complete absence of diffusion or mixing between the injected cutter stock (kerosene) and the in-place viscous oil, even despite the fact that the test cell containing the sand pack was maintained quiescent for 18 hours just prior to reversal of flow. As a result of these tests it was concluded that the displacement or recovery of a viscous crude oil from an underground formation could not satisfactorily be accomplished by means of a liquid diluent employed to effect a reduction in the viscosity of the in-place viscous crude.

In the light of the foregoing, and in accordance with the practice of this invention, there is injected into a formation containing a viscous crude a gaseous stream preferably containing a normally gaseous hydrocarbon soluble or otherwise miscible with the viscous crude. The gaseous stream thus-introduced into the formation containing the in-place viscous crude must possess a critical temperature lower than the temperature of that portion of the formation into which the gaseous stream is injected so as to insure that the injected gaseous stream will always remain in the gaseous phase and will not be liquified under the temperature and pressure conditions existing within the formation in the zone of injection. Due to the fact that the injected gaseous stream thus-introduced into the formation remains in the more mobile and fluent gaseous phase (as compared to the liquid phase) there is obtained increased opportunity and more efficient utilization of the thus-introduced normally gaseous hydrocarbon so that the thus-introduced normally gaseous hydrocarbon is readily taken up, dissolved or otherwise admixed by diffusion into the normally highly viscous in-place crude. Because of the relatively high mobility of a gaseous phase within a producing formation the rate of diffusion of the normally gaseous hydrocarbon into the viscous crude oil within that portion of the formation undergoing treatment is relatively rapid.

Any suitable injection pressure for the introduction of the gaseous stream containing a normally gaseous hydrocarbon may be employed in the practice of this invention to effect increased recovery of a highly viscous crude oil from an underground formation containing the same provided the injection pressure is sufficient to effect actual introduction or admission of the normally gaseous hydrocarbon into the formation into contact with the in-place viscous crude. Usually an injection pressure of

about 50 p.s.i.g. is sufficient, although desirably an injection pressure in the retrograde region or an injection pressure wherein retrograde phenomenon becomes significant or apparent, e.g., an injection pressure of at least about 800 p.s.i.g., preferably in the range 1000-3000 p.s.i.g., more or less, and higher is desirable.

Any suitable normally gaseous hydrocarbon or stream comprising an admixture of normally gaseous hydrocarbons may be employed in the practice of this invention provided the normally gaseous hydrocarbon or stream containing said normally gaseous hydrocarbon possesses a critical temperature sufficiently low such that the critical temperature of the hydrocarbon is lower than the temperature of that portion of the formation containing the viscous oil and undergoing treatment and into which the gaseous hydrocarbon is injected. Suitable normally gaseous hydrocarbons, either alone or in admixture, which may be employed in the practice of this invention include methane (critical temperature -116° F.), ethane (critical temperature 89.6° F.), propane (critical temperature 206° F.), n-butane (critical temperature 307° F.), isobutane (critical temperature 273° F.), ethylene (critical temperature 50° F.), propylene (critical temperature 196° F.), isobutylene (critical temperature 293° F.), i-butene (critical temperature 320° F.) and 2-butene (critical temperature 311° F.).

Ethane, alone or in admixture with methane and/or propane, is the normally gaseous hydrocarbon preferred in the practice of this invention. More specifically, as the gaseous stream introduced into contact with an in-place viscous crude it is preferred to employ a gaseous stream comprising a major amount of ethane, preferably comprised predominantly (at least about 75% by vol.) of ethane, or even substantially pure ethane.

The advantages of employing ethane in the practice of this invention are apparent in the light of the following test which involved investigations of various normally gaseous hydrocarbons together with attendant changes in the physical property of a viscous stock tank oil as produced from the Lombardi zone of the San Ardo Field, California. The solution gas in place in the Lombardi zone of the San Ardo Field and dissolved in the in-place viscous crude is substantially pure methane. The solubility of this gas under formation conditions of pressure (843 p.s.i.a.) and temperature (127° F.) amounts to 78 standard cubic feet (s.c.f.) per barrel of crude. However, under these same conditions of temperature and pressure this highly viscous crude dissolves 600 s.c.f. of ethane.

Referring now to the accompanying drawing there is graphically illustrated a comparison of the properties between San Ardo crude when saturated with its native solution gas (methane) and the same crude when saturated with ethane. The connecting lines in the graphical illustration have been drawn assuming the applicability of the ideal gas and solution laws. Referring to the drawing, consider the injection of ethane into a formation containing a viscous crude, such as the Lombardi zone of the San Ardo Field. At the end of the ethane injection period there would be established within the formation an ethane composition gradient in decreasing amounts of ethane extending radially outwardly from the injection well bore to the farthest point of ethane penetration. Consider now a volume at a radius from the well bore in which the overall composition would be such that the composition of the gas phase therein would be 50% methane and 50% ethane. From the accompanying drawing 340 cu. ft. of a gas of this composition would be soluble in one barrel of viscous crude. However, since the in-place oil contains only 78 cu. ft. methane and since only an equivalent amount of ethane would be required to make a 50-50 solution gas composition, actually only 156 cu. ft. of gas should be dissolved. This means, as the drawing clearly indicates, that the ethane injection actually causes an increase in

solubility of the oil for methane. This increase in methane solubility is due to the fact that distribution coefficients or equilibrium "constants" are not true constants but vary with the overall composition of the system. For example, it is well known that a high concentration of intermediate hydrocarbons in a system will drastically reduce both bubble point and dew point pressures. The accompanying drawing also graphically illustrates the marked increase in formation volume factor (swelling) and in-place oil fluidity as ethane diffuses into a viscous oil containing a methane gas in solution. Both increased swelling and increased fluidity lead to increased production rates and increased recovery of crude.

The following is exemplary of the practice of this invention. From a well bore penetrating an underground formation containing a viscous low gravity crude, such as is present in the Lombardi zone of the San Ardo Field, there is introduced into the upper portion of the producing formation a gaseous stream comprised predominantly of ethane at a pressure of about 900 p.s.i.g. to effect penetration of gaseous ethane into the upper part of the producing formation which is at a temperature substantially higher, at least 10 degrees Fahrenheit, than the critical temperature of the injected gaseous stream. The injection of the gaseous ethane stream is continued for a substantial period of time, such as a period of time in the range 1-60 days, more or less, so as to effect penetration of the thus-injected ethane into the producing formation for a substantial distance, at least about 15 feet, preferably in the range 25-250 feet, more or less, into the formation. Since the critical temperature of ethane is about 90° F. and since the formation temperature of the Lombardi zone into which the ethane is injected is actually about 127° F., a temperature substantially higher (by about 37 degrees Fahrenheit) than the critical temperature of ethane, the ethane thus-introduced into the formation under the temperature and pressure conditions existing therein will be substantially completely maintained in the gaseous phase. After a suitable amount of ethane has been injected into the formation and after a suitable period of time has expired to permit commingling or dissolution of the injected ethane into the in-place viscous crude (period of time in the range from 2 days to 10 months) the production of the in-place crude is resumed via the well bore from the thus-treated formation. Advantageously the formation is produced from the lower portion of the production zone although, if desired, crude oil may be produced from the formation through the zone of gas injection.

In accordance with still another feature of this invention, the produced crude containing ethane dissolved therein is produced and recovered at the surface by means of suitable equipment at a pressure sufficiently high to maintain and keep substantially all the gas (native solution gas together with the extraneously-introduced ethane) in solution in the produced and recovered crude. For example, a mixture of San Ardo crude recovered from the Lombardi zone containing 340 cu. ft. of 50-50 mixture methane-ethane has a bubble point pressure of only about 200 p.s.i.g. at 80° F. The recovered crude substantially saturated with a gas of this composition can readily be kept in the liquid phase without any evolution of dissolved gas and pumped by pipeline to a refinery. The resulting produced crude containing dissolved gas will have a markedly reduced viscosity as compared with conventionally produced crude containing substantially no methane or ethane or substantially depleted of its native methane solution gas. At the refinery the produced crude is fractionated by pressure release and distillation to produce a normally gaseous fraction comprising substantially all of the solution gas, the gaseous fraction then separated from the produced fractionated crude and the ethane portion extracted from the gaseous fraction and returned to the field by pipeline for rein-

jection for the purpose of recovering additional heavy crude.

Although emphasis in this disclosure has been placed on a one well system wherein the same well bore is employed to effect gas injection and recovery of produced crude containing injected gas dissolved therein, it will be apparent to those skilled in the art in the light of this disclosure that the practice of this invention is readily adaptable to a multiple well system employing an injection well and a production well, the injection well being employed to introduce a normally gaseous hydrocarbon having the desired properties into the formation containing a viscous oil to be recovered and a production well being employed to recover crude oil containing dissolved extraneous gas.

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

I claim:

1. A method of treating an underground formation containing a viscous heavy crude so as to increase the productivity of said crude from said formation via a well bore penetrating said formation which comprises introducing into said formation via said well bore a gaseous stream consisting essentially of substantially pure ethane, that portion of said formation surrounding said well bore and into which said gaseous stream is introduced being at a temperature substantially greater than 90° F. the critical temperature of ethane, maintaining said gaseous stream introduced into said portion of said formation at a temperature substantially greater than 90° F. and in the gaseous state without liquefaction and in contact with the viscous crude in that portion of said formation for at least about two days to dissolve a substantial amount of said gaseous stream in said crude and subsequently producing crude oil from said formation via said well bore, said crude oil now containing a substantial amount of ethane dissolved therein.

2. A method of treating an underground formation containing a viscous heavy crude having a gravity in the range 9-20° A.P.I. and a viscosity in the range 6,000-400,000 Saybolt Universal seconds at 80° F. which comprises introducing via a well bore into that portion of said formation surrounding said well bore a gaseous stream of substantially pure ethane, that portion of said formation surrounding said well bore and into which said stream of ethane is introduced being at a temperature substantially greater than 90° F., and above the critical temperature of said gaseous stream, maintaining the thus-introduced stream of ethane at said temperature in the gaseous state without liquefaction in contact with the heavy viscous crude within said portion of said formation for a substantial period of time to dissolve a substantial amount of ethane in said crude and subsequently producing said crude now containing a substantial amount of ethane dissolved therein from said formation via said well bore.

3. A method of producing a viscous heavy crude from an underground formation containing the same, said crude having a gravity in the range 9-20° A.P.I. and a viscosity in the range 6,000-400,000 SUS at 80° F. which comprises introducing via a well bore into that portion of said formation surrounding said well bore into contact with said crude for dissolution therein a gaseous stream containing at least about 75% by volume of ethane, that portion of said formation surrounding said well bore and containing said crude and into which said gaseous stream is introduced being at a temperature substantially greater than 90° F. and greater than the critical temperature of said gaseous stream, maintaining the thus-introduced

stream of ethane at said temperature in the gaseous state without liquefaction and in contact with the viscous crude within that portion of said formation for a substantial period of time to dissolve a substantial amount of said gaseous stream in said crude, subsequently producing via said well bore said crude containing a substantial amount of ethane dissolved therein from said formation recovering the resulting produced crude at the surface, the aforesaid recovery operation being carried out such that the recovered crude is maintained under a pressure substantially greater than the bubble point pressure of the recovered crude to avoid any substantial evolution of dissolved ethane from the recovered crude, subjecting the recovered crude to fractionation under a relatively reduced pressure to produce a gaseous fraction comprising ethane, recovering from said gaseous fraction a gaseous stream comprising a major amount of ethane and introducing said stream into said formation via said well bore to contact additional viscous crude.

4. A method of producing a viscous crude oil from an underground formation containing the same which comprises introducing into said formation into contact with said crude oil via a well bore a gaseous stream comprising at least about 75% by volume ethane, said stream having a critical temperature lower than the temperature of that portion of said formation containing said crude oil and surrounding said well bore into which said stream is injected, maintaining said gaseous stream within said portion of said formation at a temperature above the critical temperature of said gaseous stream and in the gaseous state without liquefaction and in contact with the viscous crude within said portion of said formation for a period of time sufficient to dissolve a substantial amount of said gaseous stream in said crude, subsequently producing from said formation via said well bore crude oil containing the thus introduced gaseous ethane dissolved therein, maintaining a pressure on the produced crude oil to prevent the evolution of the dissolved ethane therefrom, fractionating said produced crude oil under a relatively reduced pressure to separate a gaseous fraction containing said ethane previously dissolved in said crude oil, recovering ethane from said gaseous fraction and reintroducing the recovered gaseous ethane via said well bore into said formation to contact additional crude oil therein.

5. A method of treating an underground formation containing a viscous heavy crude so as to increase the productivity of said crude from said formation via a well bore penetrating said formation which comprises introducing into said formation via said well bore a gaseous mixture consisting essentially of methane and ethane, said ethane comprising a major amount of said mixture, that portion of said formation surrounding said well bore and into which said gaseous mixture is introduced being at a temperature substantially greater than the critical temperature of said gaseous mixture, and maintaining the thus-introduced gaseous mixture of ethane and methane in the gaseous state without liquefaction and in contact with the viscous crude within said portion of said formation for a substantial period of time to dissolve a substantial amount of said gaseous mixture in said crude and subsequently producing said crude now containing a substantial amount of said gaseous mixture dissolved therein from said formation via said well bore.

References Cited in the file of this patent

UNITED STATES PATENTS

2,217,749	Hewitt	Oct. 15, 1940
2,412,765	Buddrus et al.	Dec. 17, 1946
2,699,832	Allen	Jan. 18, 1955