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United States Patent

[11] 3,542,129

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[54] OIL RECOVERY OF HIGH GRAVITY CRUDES

4 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** **166/261,** 166/263, 166/274
[51] **Int. Cl.** **E21b**
[50] **Field of Search** 166/256, 261, 272, 274, 303, 251, 263

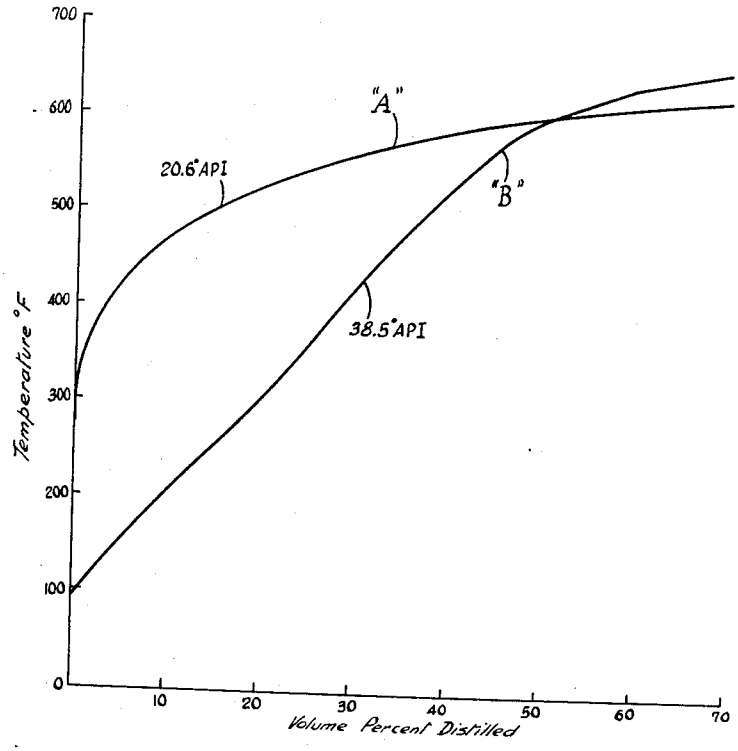
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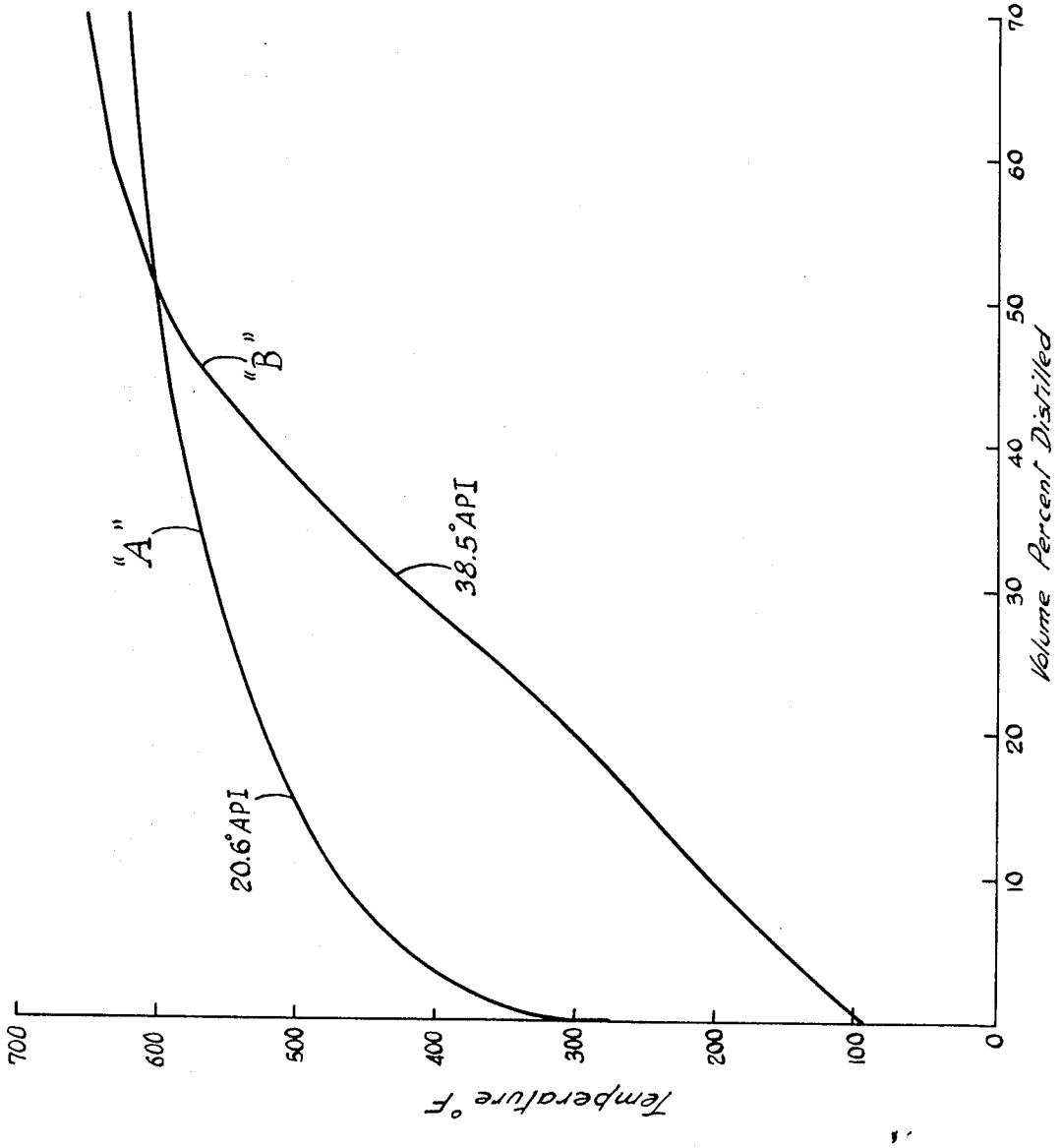
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ABSTRACT: Improved recovery of high API gravity crudes from subterranean hydrocarbon-bearing formations is effected by injecting a gas into the formation to sweep the low-boiling components of the crudes from the formation prior to the initiation of in situ combustion.




Temperature °F
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
Volume Percent Distilled
"A"
"B"
38.5°API
20.6°API

OIL RECOVERY OF HIGH GRAVITY CRUDES

FIELD OF THE INVENTION

This invention relates to an improved method for the recovery of petroleum from hydrocarbon-bearing formations. More particularly, this invention relates to a method for the recovery of high API gravity crudes which contain minimum amounts of high-boiling fractions necessary for sustaining in situ combustion.

DESCRIPTION OF THE PRIOR ART

Recovery of hydrocarbons from subterranean hydrocarbon-bearing formations by the use of in situ combustion is one of the newer methods employed for the production of crude in situations where the reservoir characteristics and the crude oil properties are amenable to this approach.

In the conventional method of applying this method, the hydrocarbon-bearing formation is penetrated by one or more injection wells and one or more production wells. A combustion supporting gas, such as air, is injected into an injection well or wells, and combustion of the crude in the formation adjacent the well bore is initiated by any of many accepted means. Thereafter, the injection of the combustion supporting gas is continued to sustain a combustion zone which is formed and which is driven out radially toward the production well or wells, leaving behind a zone of clean matrix, from which, ideally, all fluids have been displaced.

In the conventional concurrent in situ combustion, after the combustion zone has been established, various contiguous zones are built up ahead of the combustion zone which are moved outwardly radially toward the production well or wells and which drive the reservoir crude ahead to the production well or wells. Generally, these zones consist of a distillation and cracking zone immediately ahead of the combustion zone, a condensation zone, and a virgin or unaltered zone.

The temperature of the combustion zone is about 1100°F., dependent upon the thermal losses and the cooling effects of the combustion supporting gas. The heat generated in this zone is transferred to the distillation and cracking zone where the crude undergoes distillation and cracking. In this zone, a sharp thermal gradient exists wherein the temperature drops from about 1100°F. to about 450°F. The reduced ends and cokelike materials which are formed, are deposited on the matrix and are the potential fuel for the progressive combustion. The amount of material which can be deposited is a critical factor in propagating the combustion front through the formation.

The light ends, consisting of the low-boiling components of the crude, and vapors are driven ahead and as they advance through the formation, they are cooled and condensed in the condensation zone, where there exists a thermal plateau whose temperature level may range from about 200°F. up to about 450°F., depending upon the distillation characteristics of the fluids therein.

Ahead of the condensation zone is an unaltered zone, in which the composition of the crude initially is that of the virgin crude. However, as the in situ combustion progresses, and crude is driven ahead of the advancing zones, the fluid saturation in the unaltered zone increases. This initially unaltered zone becomes a zone of high oil saturation containing not only reservoir crude, but also condensate and gaseous products of combustion which eventually reach the production well or wells whence they are produced.

One of the difficulties in utilizing in situ combustion is its application to hydrocarbon-bearing formations containing high API gravity crudes. The process cannot be successfully propagated because of the inability to deposit adequate potential fuel, which is obtained principally from the low-boiling components and reduced ends of the crude. It is believed that the condensation zone, which forms ahead of the combustion front, increases in size as the combustion front progresses and

becomes increasingly more effective in driving the more immobile fractions of the crude ahead by a "solvent" action, thereby depriving the combustion front of potential fuel. If the crude contains too high a fraction of the low-boiling components or light ends, there results a dynamic displacement of the heavy ends or high-boiling components prior to their being able to undergo thermal degradation or cracking, which is necessary to establish the fuel for sustaining the process.

Accordingly, it is an object of the present invention to overcome the limitations of the prior art by providing a recovery method whereby high API gravity crudes may be recovered by a more effective process.

SUMMARY

The invention comprises subjecting a subterranean hydrocarbon-bearing formation to a preliminary gas sweep followed by in situ combustion.

BRIEF DESCRIPTION OF THE DRAWING

The FIG. indicates typical distillation curves for two crudes.

DESCRIPTION OF THE PREFERRED EMBODIMENT

More specifically, it has been found that the combination of a preliminary gas sweep followed by a conventional in situ combustion results in a successful propagation of the in situ combustion in hydrocarbon-bearing formations containing high API gravity crudes.

A preliminary gas sweep is instrumental in altering the distillation characteristics of the crude so there is fractionally a greater percent of the high-boiling components ahead of the combustion front. The preliminary gas sweep strips the light ends of the crude from the hydrocarbon-bearing formation, thereby reducing the amount of light ends or low-boiling components which in the conventional in situ combustion are capable of rendering the heavier ends more mobile. Thus, the preliminary gas sweep reduces the means whereby the heavier ends would be dynamically displaced by light ends in conventional in situ combustion. The result is the deposition of adequate fuel in the distillation and cracking zone necessary for the propagation of the process.

Typically, for a high gravity crude (38.5° API), about 27 percent of the crude may be distilled below 400°F. and approximately 50 percent below 600°F. This characteristic indicates there is minimum potential fuel for sustaining in situ combustion because of the high percent of the light ends or the low-boiling components present.

Referring to the drawing in which typical distillation curves for crudes are shown, a crude which is a promising candidate for successful in situ combustion is represented by the distillation curve A. On the other hand, a high API gravity crude, one not amenable to in situ combustion, is represented by crude B. In accordance with the present invention, a crude of type B may be altered by subjecting the reservoir to a period of air sweep or gas sweep prior to the initiation of in situ combustion so that the lighter ends are swept ahead to the producing wells and the composition of the crude with regard to its distillation characteristics is thereby tailored to approach the more desirable distillation characteristics as represented by crude A.

Illustrative of this invention, a series of experiments was performed using a 38.5° API gravity crude which had been premixed with a clean, unconsolidated silica-type sand in amounts so as to obtain an initial oil saturation of approximately 27 percent of the pore volume. The mixture was packed into a stainless steel reactor, approximately 56 inches long and 3 7/8 inches in diameter. New sand-oil packs were used for each experiment. Combustion was initiated electrically and conducted at essentially adiabatic conditions using an air flux of 50 SCF/ft²-hr.

The experiments are described below and the results are shown in the following table.

TABLE

Conditions of Experiment, Using 38.5° API crude	Vol. percent oil produced by air sweep	S.C.F. air/pound fuel burned
Conventional in situ combustion		279
Conventional in situ combustion using reduced ends of crude topped at 300° F		257
Conventional in situ combustion using reduced ends of crude topped at 400° F		256
Preliminary air sweep—24 hrs. at ambient temperature (~85° F.), followed by conventional in situ combustion	3.6	236
Preliminary air sweep—24 hrs. at 150° F., followed by conventional in situ combustion	9.3	221
Preliminary air sweep—4 hours at 150° F., followed by 8 hrs. at 300° F., followed by conventional in situ combustion	10.4	235

The results are expressed in terms of the air requirement, which is the standard cubic feet of air injected per pound of fuel burned (SCF/lb). Air requirement is a measure of the efficiency of combustion and the ability of the crude to undergo successful in situ combustion. An efficient in situ combustion is obtained when the air requirement is in the neighborhood of 200 to 250 SCF/lb. As the in situ combustion process becomes less efficient, the air requirement number will increase. Again referring to the drawing, crude A which sustained an efficient in situ combustion, had an air requirement of 220 SCF/lb.

In the first experiment using a 38.5° API crude, a conventional concurrent in situ combustion run was performed. An air requirement of 279 SCF/lb. was obtained, indicative that an efficient combustion was not sustained throughout the length of the run.

Since it has been theorized that the zone of low-boiling components, which formed ahead of the combustion front, is a controlling factor in the deposition of potential fuel necessary for sustaining the combustion, a sample of the 38.5° API gravity crude was first topped at 300°F., and the higher boiling reduced ends were used as the "crude" in an in situ combustion experiment. Using the same in situ combustion procedure, an air requirement of 257 SCF/lb. was obtained. In yet another run, in which the reduced ends from the crude topped at 400°F. were used in the initial sand-oil pack, an air requirement of 256 SCF/lb. was obtained.

To test the effectiveness of a preliminary gas sweep, three runs were made in which air sweeps were carried out on the packed tube at different conditions of time and temperature and prior to the initiation of the forward in situ combustion. In all runs, the combustion efficiency, as shown by the air requirements, was improved.

For example, after an air sweep of a 38.5° API crude for 24 hours at ambient temperature (**85°F.), the subsequent in situ combustion experiment had an air requirement of 236 SCF/lb. In the second experiment, after an air sweep at 150°F. for 24 hours, the subsequent in situ combustion experiment had the air requirement of 221 SCF/lb. In yet another experiment, after a 4 hour air sweep at 150°F., followed by an air sweep at 300°F. for 8 hours, a subsequent in situ combustion experiment had an air requirement of 236 SCF/lb.

The results of these experiments, as shown in the table, have demonstrated that a preliminary gas sweep will materially improve the efficiency of a subsequent in situ combustion as indicated by the air requirements. Further, the test demonstrates the feasibility of initiating and sustaining in situ combustion in an oil sand containing a high API gravity crude. Removal of low-boiling components by a preliminary gas sweep improves the subsequent in situ combustion.

As will become apparent, the present invention is particularly applicable to the recovery of high API gravity crudes from hydrocarbon-bearing formations in which they occur. Briefly stated, it is the general object of the present invention to effect modification of the crude in a hydrocarbon-bearing formation so as to sustain in situ combustion which is carried out in accordance with an optimum program determined by knowledge of the crude and formation characteristics.

The subject disclosure could use any sweep gas, as, for example, a combustion supporting gas, such as air, or natural gas, combustion flue gas, nitrogen, carbon dioxide, methane, steam, or mixtures thereof. The temperature of the injected sweep gas should be in the range of about 70°F. to about 750°F.

The selection of the sweep gas depends principally upon its availability and the equilibrium partial pressures of the fluids in the formation. The economics and availability of air, for example, would suggest its use as the sweep gas, particularly because of its prospective use for the subsequent in situ combustion.

In another embodiment, conceivably, combustion flue gas from producing wells of an in situ combustion process, could be used as the sweep gas by means of a suitable recycle operation.

A suggested procedure for the application of this invention would comprise the following steps:

a. Inject a gas at ambient temperatures or above into an injection well or wells, while producing fluids from a production well or wells, to accomplish stripping and removing of the low-boiling components of the said crude. The period and quantity of gas injection should be sufficient to convert the in-place oil from a high API gravity crude to a lower API gravity crude, such as from 30°—45°to 20°—25°. Crude oil distillation analyzes, reservoir pressures and temperatures could be utilized for calculating the amount of gas injected. Monitor wells could be used to determine the quantity of low-boiling components which would be removed by measuring the composition and quantity of light hydrocarbons in the produced fluids.

b. Continue gas injection until the production of low-boiling components or light ends at the production well or wells shows that the distillation characteristics and the API gravity of the crude are more amenable to the application of in situ combustion.

c. Initiate an in situ combustion at the injection well or wells by any of the conventional methods known for initiation, such as electric heaters, downhole burners, or spontaneous ignition chemicals. Alternatively, in situ combustion could be initiated at the production well or wells.

d. Inject a combustion supporting gas such as air into the hydrocarbon-bearing formation through the injection well or wells to sustain the in situ combustion.

e. Continue air injection until the combustion front has been propagated to the production well or wells.

It will be apparent from the foregoing description that the method is subject to numerous modifications without departing from the scope of the invention as defined in the following claims.

In summary, application of the in situ combustion process may be extended to hydrocarbon-bearing formation reservoirs containing high API gravity crudes by the use of the method disclosed, whereas without it the presence of the low-boiling components would render the process ineffective and uneconomical.

I claim:

1. A method for recovering hydrocarbons from a subterranean hydrocarbon-bearing formation in which they naturally occur said hydrocarbons originally in place having an API gravity in the range from about 25° API to about 45° API, said formation penetrated by at least one injection well and at least one production well, comprising the steps of:

a. injecting gas into said formation through said injection well wherein the temperature of said gas is between about 70°F. and 450°F. in amounts sufficient to strip and sweep in-place low-boiling components of said formation hydrocarbons contained therein to said production well;

b. producing said gas and said low-boiling components of said formation hydrocarbons from said production well thereby decreasing the API gravity of in-place hydrocarbons in said formation; and

c. thereafter injecting into said formation through one of said wells a combustion supporting gas and effecting in

situ combustion of stripped hydrocarbons in said formation and recovery of hydrocarbons from said formation.

2. The method of claim 1 wherein the injected gas contains at least one member selected from the group consisting of combustion supporting gas, natural gas, combustion flue gas, nitrogen, carbon dioxide, methane, steam or mixtures thereof.

3. The method of claim 1 wherein said combustion is advanced from said injection well to said production well by injecting said combustion supporting gas into said injection well thereby causing said hydrocarbons to be produced from said production well.

4. The method of claim 1 wherein said combustion is advanced from said injection well to said production well by injecting said combustion supporting gas into said production well and producing said hydrocarbons from said injection well.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,542,129 Dated November 24, 1970

Inventor(s) Charles L. Bauer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the specification:
Col. 3, line 52, change "(**85°F.)" to --(~85°F.)--

Col. 4, line 27, change "analyzes" to --analyses--
Col. 4, line 6, change "750°F." to --450°F.--

Signed and sealed this 3rd day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR
Commissioner of Patents