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3,482,630

IN SITU STEAM GENERATION AND
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10 Claims

ABSTRACT OF THE DISCLOSURE

A process for the recovery of oil from subterranean formations by steam flooding is described wherein the steam is generated in situ by continually injecting into the formation a combustible mixture of a hydrocarbon and an aqueous medium in the presence of an oxygen-containing material and thereafter initiating and maintaining a combustion front to produce a steam front ahead of the combustion front which effectively displaces the crude oil to outlying production wells to be recovered.

Background of the invention

This invention concerns the use of steam in the recovery of crude oil from subterranean formations. It has been shown that the residual oil saturation in a steam swept reservoir is considerably less than the residual oil saturation after a cold or hot water flood. Improved efficiency of steam flooding can be attributed, inter alia, to heat transfer from the steam to the crude oil to improve the mobility thereof, and to steam distillation of the crude oil.

Heretofore, steam flooding was effected by generating the steam on the surface, then pumping it down an injection well into the formation. This method of steam flooding is deficient in different ways. There are the tremendous heat losses during the pumping into the formation, e.g. 80% quality steam can lose about 20% of its heat content by the time it has descended 2,000 feet and, in some injection situations, it can lose all of its latent heat. Thus, the resulting injected fluid may be hot water rather than steam. Another problem is damage to the well casing due to high temperatures. This problem, of course, can be partially obviated by insulating the injection tubing, but this increases the overall cost of steam flooding. The main problem, directly attendant with heat losses, is the transferral of sufficient heat to the crude oil to facilitate displacement thereof. The deeper and larger the reservoir, the more critical are these heat losses.

These heat loss problems are inherent in traditional steam flooding techniques. They can be obviated, however, by transferring steam potential to the subterranean formation and generating the steam in situ. U.S. 3,024,841 to Willman teaches in situ combustion to move a water bank, which may alternately evaporate and condense. Applicant has discovered a novel and efficient process of generating steam in situ wherein the process can be controlled from the surface.

Description of the invention

This process is essentially a steam flooding technique, wherein steam is generated in situ. The invention involves injecting into the formation a combustible mixture of a hydrocarbon and an aqueous medium and a combustion-supporting material, i.e. an oxygen containing material. Thereafter, the injected material is ignited and position of the combustion front and the immediate outlying steam front is controlled by varying the amount and ratio of injected combustible mixture to oxygen contain-

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ing material. Oil in the formation is displaced by the steam drive toward at least one production well where the crude oil is recovered.

Heat losses in steam flooding are reduced by this invention. Also, the percent residual oil within the formation is substantially decreased by this efficient process utilizing in situ steam generation. Since the steam is generated in situ, there is no heat loss to the well bore, and heat loss due to employment of surface equipment is eliminated. Furthermore, since the well bore is not subjected to elevated temperatures, equipment failure due to thermal stresses is eliminated. The principal advantage of this invention is that the well bore heat losses (described above) are eliminated and this heat is now available to facilitate the movement of crude oil in the formation. This allows more efficient recovery of the crude oil.

Since the combustion front may be positioned at will, the steam front can be better maintained at desired temperatures as the front moves through the formation. In addition, heat losses to the overburden and underburden are reduced. This can be explained: First of all, since the high temperature steam is confined to the area ahead of the combustion front, there will be no heat losses in the area already swept; secondly, the hot underburden and overburden in the steam swept area of the formation will transfer heat to the cooler injected fluids.

Preferably, the ratio of aqueous medium to hydrocarbon is from about 7:1 to about 100:1, by weight respectively. When the ratio is higher than about 10:1, by weight respectively, then it is possible that part of the connate crude oil is combusted with the injected hydrocarbon. When the ratio is low, i.e., closer to 7:1, the combustible component is preferably the injected hydrocarbon.

In summary, the instant invention combines the advantageous portions of both the traditional steam flooding technique and the in situ combustion technique.

The hydrocarbon fuel and aqueous medium are injected either separately or as a mixture, e.g. an emulsion. They are injected preferably in a ratio which is combustible with the oxygen containing material. As previously mentioned, some of the connate crude oil can be combusted with the oxygen containing material when the ratio of injected water to hydrocarbon is higher than about 10:1, by weight respectively. The aqueous medium can be soft water or slightly brackish, but preferably is relatively soft water. The amount of aqueous medium injected will depend upon how much connate water is present in the reservoir, and how much steam is needed to efficiently sweep the reservoir of oil. Preferably from about 0.5 to about 10 and more preferably from about 1.0 to 5.0 formation pore volumes of aqueous medium are injected. The hydrocarbon fuel employed is preferably a hydrocarbon which boils in the range of from about -260° to about 700° F. and more preferably from 0° to about 450° F., but can be any crude oil or cut thereof which is combustible. Examples of useful hydrocarbon fuels include crude oil and refinements of crude oil such as light and heavy crude column overheads, straight-run gasoline, liquefied petroleum gases, and gaseous hydrocarbons such as natural gas. In addition, some of the hydrocarbon fuel can be supplied by the connate crude oil within the formation. The amount of hydrocarbon fuel to be injected is dependent upon existing physical and economic conditions. This can readily be determined by one skilled in the art. In general, it is best to inject from about 0.5 to 12 formation pore volumes of combustible mixture into the formation. Either or both of the fuel and aqueous medium can be preheated before injection into the formation.

Concurrently with the injection of fuel and aqueous medium an oxygen containing material is injected into

the formation. The material can be liquid, or gas, and is preferably air. Although not necessarily desirable, the material may be preheated before injection into the well bore.

The hydrocarbon fuel and oxygen containing material in the formation can be ignited by any means known in the art. For example, a squib, incendiary shell, gas heater, an electrical igniter, or a chemical reaction may be used to obtain combustion temperatures. Also, the oxygen-containing material may be preheated to a temperature such that when pumped down into the formation it will initiate combustion upon contact with fuel within the formation. Concurrent injection of fuel and oxygen containing material can commence after ignition has occurred and the combustion region is a safe distance from the injection point.

The importance for incorporating the fuel and aqueous medium in the present invention is essential. The hydrocarbon fuel serves at least two purposes: Control of the combustion front and control of the amount of heat provided to the formation. In the traditional in situ combustion process, it is frequently not possible to sustain combustion in the formation. This is due to either an insufficient amount of fuel deposition by the in situ crude oil, or to excessive heat losses to the overburden and underburden for the amount of fuel available to be burned. In these circumstances, additional fuel must be provided in order to sustain in situ combustion, as is taught by the present invention. Also, in the present invention, the combustion front location may be regulated by the amount of injected fuel. For instance, if the combustion front is moving at an undesirable rate, the amount of injected fuel can be varied to cause combustion to either subside, or become stationary, or even reverse. That is, the less fuel injected, the more connate oil is burned, thus the faster the combustion front will move toward the production point(s). In summary then, by injecting fuel one can effectively control the position and velocity of the combustion front and hence the rate of heat transferred to the formation. During combustion, the injected aqueous medium is converted into steam. This steam advances ahead of the combustion zone to form an effectively large zone in which the hot steam comes directly in contact with and gives up heat to the crude oil in place. Such lowers the crude oil's viscosity and causes distillation of "light" portions in the crude oil, the result being to facilitate movement of the crude oil to a production well.

This invention is preferably applied to either secondary or tertiary-type recovery processes. It is useful to recover crude oil of 8–45° API range and preferably in the range of about 18–40° API. The higher the °API gravity, the larger the percentage of easily distillable components are present and, therefore, the more efficient the distillation of the oil in place by the hot steam front—thus less residual oil is left in place.

It should be understood that the invention is capable of a variety of modifications and variations which will be made apparent to those skilled in the art. Such is to be included within the scope of this invention.

What is claimed is:

1. A process of generating steam in situ in an oil-bearing subterranean formation to facilitate the recovery of crude oil therefrom, the formation containing at least one injection well in fluid communication with at least

one production well, the process comprising: (a) continually injecting substantially liquid hydrocarbon boiling in the range of 0° to about 450° F. and aqueous medium into the formation, (b) continually injecting a sufficient amount of an oxygen-containing material to support combustion of the hydrocarbon, in the formation and (c) initiating and controlling combustion of the hydrocarbon and the oxygen-containing material through the formation to facilitate recovery of crude oil at the production well.

2. The process of claim 1 wherein the hydrocarbon and aqueous medium are injected as a mixture, the mixture being a combustible mixture with the oxygen-containing material.

3. The process of claim 1 wherein the aqueous medium is relatively soft water.

4. The process of claim 1 wherein the oxygen-containing material is air.

5. The process of claim 1 wherein the amount of aqueous medium injected is from about 0.5 to about 10 formation pore volumes of the subterranean formation.

6. The process of claim 1 wherein the ratio of aqueous medium to hydrocarbon is from about 7:1 to about 100:1 by weight, respectively.

7. The process of claim 6 wherein part of the connate crude oil is combusted with the injected hydrocarbon when the weight ratio of aqueous medium to hydrocarbon is greater than about 10:1 by weight, respectively.

8. A process of generating steam in situ in an oil-bearing subterranean formation to facilitate the recovery of crude oil therefrom, the formation containing at least one injection well in fluid communication with at least one production well, the process comprising: (a) continually injecting a combustible mixture of a substantially liquid hydrocarbon boiling in the range of 0° to 450° F. and water into the formation, (b) continually injecting a sufficient amount of air to support combustion of said combustible mixture, and (c) initiating and controlling combustion of said combustible mixture and air through the formation to generate steam in situ to facilitate recovery of said crude oil at the production well.

9. The process of claim 8 wherein from about 0.5 to about 12 formation pore volumes of the combustion mixture is injected into the formation.

10. The process of claim 8 wherein the ratio of aqueous medium to hydrocarbon is from about 7:1 to about 100:1 by weight, respectively.

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