

Feb. 4, 1964

J. M. BARRON

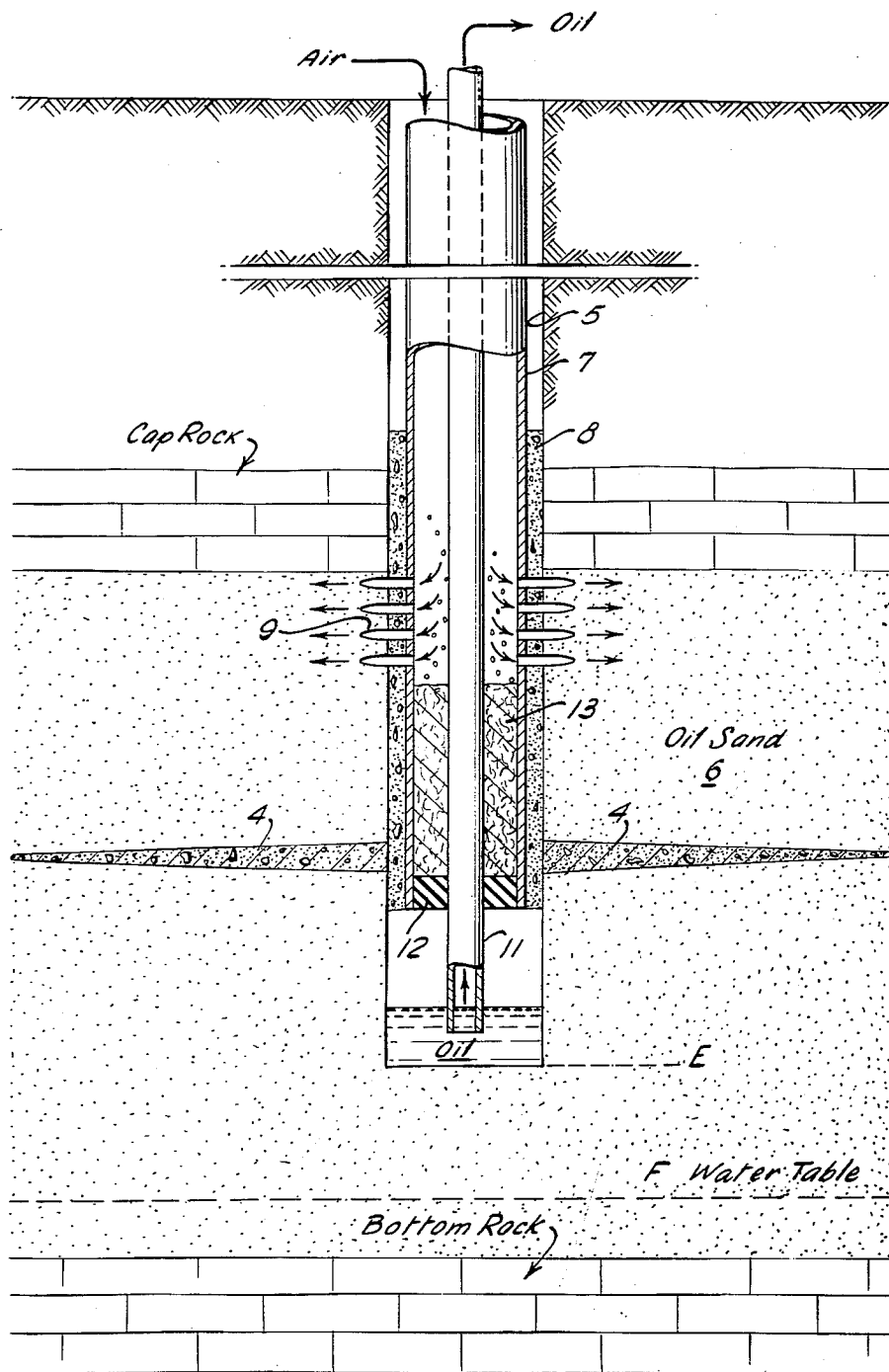
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RECOVERY OF OIL BY IN SITU COMBUSTION

Filed July 9, 1956

2 Sheets-Sheet 1

Fig. 1.



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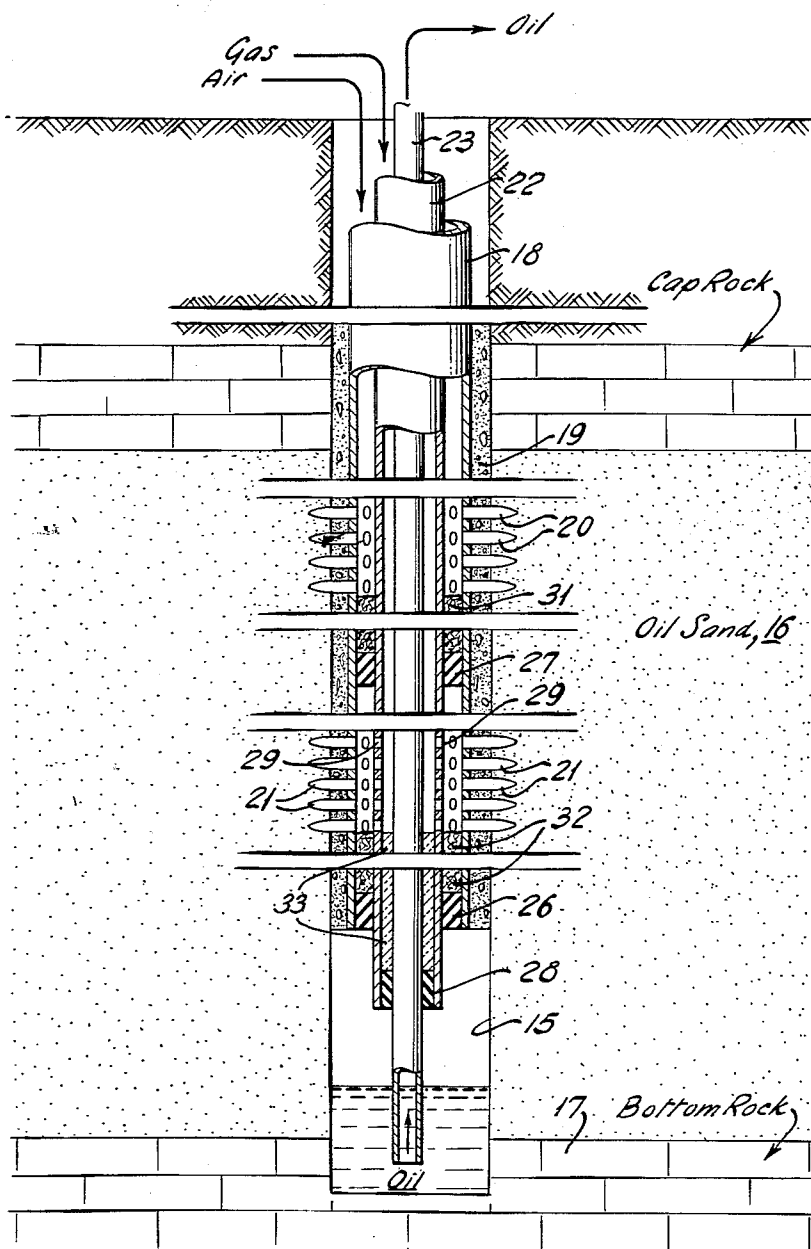
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Fig. 2.



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## RECOVERY OF OIL BY IN SITU COMBUSTION

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This invention relates to a method of recovery of hydrocarbons from an underground reservoir. In one of its specific aspects, it relates to a method for recovering low gravity crude oil from an underground oil-bearing geological formation.

In recent years there has been increased interest in the recovery of oil by heating the formation either by burning a portion of the oil in place in an underground oil reservoir or by burning a hydrocarbon as fuel in the well bore and injecting the hot gases into the formation. Burning oil in the reservoir is termed "in-situ combustion." It is estimated that only from about 2 to about 15 percent of the oil in place in the formation is consumed as fuel by in-situ combustion. Usually only the least volatile portion of the oil or the carbonaceous residue or carbon resulting from in situ distillation and cracking of the oil is consumed as fuel. Heating of the oil reservoir serves two important functions. First, the heat supplied to the reservoir greatly reduces the viscosity of the crude oil, and secondly, the hot gases physically displace oil from the formation.

The ease with which oil may be produced from a reservoir depends to a large extent upon the viscosity of the oil. The effect of temperature on viscosity of heavy oils is evidenced by the following examples. A typical 14° A.P.I. crude oil which has a viscosity of about 630 centipoises at 100° F. has a viscosity of about 67 centipoises at 175° F. A San Ardo, California crude which has a viscosity of 1700 centipoises at the formation temperature of 130° F., has a viscosity of about 717 centipoises at 150° F. and about 96 centipoises at 210° F.

In a typical application of heating an underground formation, an oxygen-containing gas or hot products of combustion are injected into the formation through an injection well and the displaced oil and gas are withdrawn from a plurality of production wells uniformly spaced about the injection well. The production wells are usually arranged to provide substantially uniform movement of fluid from the injection well radially into the formation toward the production wells.

In the process of this invention, combustion-supporting gas or products of combustion are introduced to the formation and formation fluid is withdrawn therefrom through the same well. Injection of the heating fluid and production of oil through a single well permits maximum utilization of the heat supplied to the formation. This heat is effectively utilized to heat the formation in the vicinity of the injection well reducing the viscosity of the oil contained therein and permitting increased production. This method of operation eliminates many of the problems of recovering oil by heating the formation with the usual arrangement of injection and production wells mentioned above. Numerous advantages result from the process of this invention as compared with conventional methods of oil recovery by underground or in-situ combustion.

Although the exact mechanism of in-situ combustion is not known, combustion in an oil sand probably proceeds as follows. This theory is presented for the purpose of enabling one skilled in the art to better understand the process of this invention, but the theory is not to be construed as limiting the invention in any way. Air or other oxygen-containing gas, e.g., a mixture of oxygen and recycle gas, injected into the formation burns a portion of the oil in the formation setting up a combustion wave

2

which moves outwardly into the formation from the point of injection. Combustion in the formation may be initiated in any of several known ways, e.g., by a gas-air burner in the well or by heating the oxygen-containing gas to a temperature on the order of 700° F. Once combustion is initiated in the formation, it is self-sustaining. Reportedly, an oxygen-concentration as low as 1.33 percent is capable of sustaining combustion in the formation.

The average maximum temperature reached in the formation with in-situ combustion is on the order of 1400 to 1500° F. This temperature is reached somewhere in the neighborhood of the combustion wave front or flame front. The gases resulting from combustion are pushed into the formation ahead of the flame front. These gases are eventually cooled; the cool gases displace at least a portion of the connate fluid from the formation. As the combustion wave front progresses through the formation, any oil not displaced by the cool gases is contacted with hot gases from the combustion wave front. The more volatile portion of the oil is vaporized, together with any water present, while the remainder is heated to a temperature such that cracking takes place with the formation of additional oil vapors and coke. As the oil vapors, including the cracked products, and steam advance through the formation they are cooled and condense. This region of vaporization and condensation may be considered a distillation zone. The temperature of this zone is substantially constant and is in the neighborhood of 400° F. at 250 pounds per square inch gauge and 700° F. at 3000 pounds per square inch gauge. The condensate and connate fluids are displaced by the gaseous products of combustion. Eventually, crude oil, condensate, and gaseous products of combustion reach the production well in approximately the order given. Since most of the liquid hydrocarbon is driven from the formation by the gaseous combustion products, substantially only the coke remaining in the formation is consumed as fuel by the oxygen-containing gas injected through the input well.

After the combustion wave front has progressed some distance into the formation from the input well, the oxygen-containing gas injected into the input well first contacts the portion of the formation that has been denuded of its connate fluids and heated by the combustion wave. In this region, the formation is undergoing cooling while the input gas is undergoing heating. The temperature of the input gas increases as it approaches the combustion zone. As the input gas approaches the combustion zone, it is heated to a temperature on the order of 400 to 500° F. and begins to react with residual carbonaceous fuel in the formation. As the gases move along, reaction continues until the uncombined oxygen is consumed. A maximum average temperature of about 1400 to 1500° F. is attained.

Heat transfer by conduction from the source of heat to a portion of the formation remote from the source is relatively slow, but may be very important in increasing the production of low gravity oils. It has been estimated, for example, that the temperature of the formation may be increased by as much as 75 to 100° F. for a distance of some thirty feet from the zone of combustion by conduction alone in a period of about two years.

If the fluid (e.g. a combustion-sustaining gas and its products of combustion) is injected at a point in a homogeneous permeable formation, in which the permeability and pressure are constant throughout, theoretically the fluid moves outward radially from the point of injection in the form of a sphere. If, in this same hypothetical formation, the fluid is injected at the boundary between the formation and a planar impermeable formation, the portion of the formation occupied by the injected gas theoretically will take the form of a hemisphere. Either of the foregoing cases may be approximated in a large

reservoir with relatively thick sand. In a thin oil-bearing formation with impervious formations above and below the oil sand, the paths of flow of injected fluid are essentially parallel to the formations and the front, i.e., the interface between the injected fluid and the uninvaded oil sand is essentially normal to the formations. In this instance, the portion of the sand occupied by the injected fluid is essentially a cylinder with the injection well at its axis.

In actual practice, the natural oil-bearing formations deviate considerably from the hypothetical homogenous formation considered above. Tight sedimentary layers or impermeable lenses often are present in the formation with the result that the permeability in the direction normal to the plane of the formation (generally vertically) is less than the permeability in a direction parallel to the plane of the formation (generally horizontally). In addition, the bore hole penetration of such formations disturbs the permeability in a vertical direction more than in a horizontal direction. Furthermore, there is usually a gas cap above the oil. The gas is more readily displaced by injected gas than is the oil. In reservoirs containing low gravity oil, preferential invasion of the gas cap by the injected fluid, e.g. the combustion-supporting gas and products of combustion, is particularly evidenced. In addition, the withdrawal of fluid from the formation through one or more producing wells sets up a pressure differential between the injection well and the producing well. This pressure differential favors preferential flow from the injection well in the direction of the producing well.

The process of this invention will be more readily understood by reference to the accompanying drawings.

FIG. 1 is a vertical sectional view through an oil-bearing formation and a well bore extending into the formation illustrating a means for carrying out the process of my invention.

FIG. 2 is a vertical sectional view through an oil-bearing formation and well bore illustrating another means for carrying out the process of my invention.

With reference to FIG. 1 of the drawings, a well bore 5 extends through the overlying strata into an oil-bearing stratum or formation of oil sand 6. A casing 7 extends into the oil sand and is cemented in place by cement 8. Perforations 9 through the casing and cement establish communication between the interior of casing 7 and the oil sand. These perforations may be at or near the top of the formation or some distance below the top of the formation. The formation 6 is divided, parted or isolated into an upper portion in communication with perforations 9 and a lower portion in communication with the bottom of the well bore 5 or tubing 11. One method of accomplishing the separation of formation 6 into an upper portion and a lower portion is by fracturing (hydraulically or explosively) formation 6 and cementing or otherwise filling the resulting fractures with a fluid impermeable material, such as cement, which upon setting creates an impermeable zone or barrier such as the substantially planar impermeable cement lenses 4 illustrated in FIG. 1. In this manner, the permeability in a vertical direction, which has been increased usually by the bore hole penetration, is upset, if not destroyed completely, for the lenses created by such fracturing and cementing form an impermeable zone or barrier for the purposes to be described below. When fracturing followed by cementing is employed it may be advantageous at this time also to cement casing 7 in place if this has not already been done. Other means may be employed for the creation of the impermeable zones or lenses 4 within formation 6, such as by forcing a fluid chemical or chemicals, e.g., water glass in admixture with soaps which sets per se after a period of time into a cement-like or an impermeable mass. Other methods for effectively isolating or dividing a formation in an

upper portion and a lower portion are set forth herein-after.

Tubing 11 extends through the casing into the uncased portion of the well near the bottom of the well. A packer 12 provides a seal between casing 7 and tubing 11. Packer 12 is preferably placed a sufficient distance below perforations 9 to protect it from heat of combustion. An insulating material 13 is also preferably placed above the packing to protect the packer from overheating. Oil is produced through the tubing.

In operation, a combustion-sustaining gas, for example, oxygen, air or oxygen-enriched air, optionally mixed with steam, hydrocarbon gas, or both, is supplied to the well through casing 7 and injected into the oil sand through perforations 9. Packer 12 prevents the escape of the combustion-supporting gas from the casing except through the perforations 9. The gas injection section may be at or near the top of the oil sand or some distance below the top of the sand.

Combustion is initiated by any suitable means, for example, by means of a squib, incendiary shell or electrical igniter, not illustrated in the drawing. Combustion proceeds within the sand and slowly moves outwardly with an ever increasing area. Because of the change in permeability in a vertical direction due to the disturbance of the formation by penetration of the bore hole, combustion proceeds more speedily along the bore hole than along the remainder of the flame front extending from the area of ignition (e.g. with combustion starting from below the cap rock disclosed in FIG. 1, the flame front would be generally hemispherical at start). Inevitably, the flame front proceeding along the bore hole would reach the bottom thereof at a time which is not the best for optimum recovery of fluid which would be driven out by in situ combustion. By insertion of an impermeable zone or barrier (such as the cement lenses 4), the flame front is prevented from short cutting from the point where in situ combustion starts to the bottom of the bore hole 5 below the casing 7. Thus, instead of having a generally hemispherical flame front, in time it will assume the shape of a cylinder extending away from the bore hole while confined between the top cap rock and the lenses 4, FIG. 1. As the combustion wave moves through the formation, hot gaseous products of combustion are pushed along ahead of the combustion front. These gases are driven into the oil sand displacing the connate fluids of the reservoir. As explained above, in a reservoir in which a gas cap is present and the gaseous products of combustion are injected into the gas cap, they will move at a more rapid rate through the gas cap than through the oil-bearing sand. Combustion of hydrocarbons within the reservoir releases heat which raises the temperature of the oil sand, the cap rock, and the fluids within the oil sand. During the injection of the combustion-supporting fluid, preferably either no production is permitted through tubing 11 or production is limited so that only oil is removed from the well. According to a preferred method of operation of the process of my invention, no oil is withdrawn through tubing 11 during the period of injection of the combustion-supporting fluid. During the period of gas injection, reservoir fluid may be withdrawn from another well in the field spaced from the injection well. Thus my process may be applied to production from several wells alternatively on injection and production cycles.

Although the operation of the process of my invention is described herein with reference to in-situ combustion, the application of my process to direct injection of hot gases, for example, by combustion of a gas-air mixture in a suitable burner within the well and injection of the resulting hot gaseous products of combustion, will be readily apparent.

The sand surrounding the well bore is heated over a sizeable section surrounding the point of gas injection, for example, a section having a 50 foot radius. The heat

stored in the oil sand is transmitted by conduction into other portions of the formation not necessarily contacted by the gas heating the oil contained in the sand and reducing its viscosity. Subsequently, oil is withdrawn from the well bore. This oil, having been previously heated, flows freely into the well permitting a greater rate of production, more complete removal of the oil from the sand, and production of the oil with less difficulty due to water or gas coning.

In some fields it may be desirable, after gas injection, to withdraw the products of combustion from the formation after they have given most of their heat to the oil sand. This may be accomplished by reversing the flow through perforations 9 and the annular space between the tubing 11 and casing 7.

Although the drawings show, for the purpose of illustration, completion of the well by cementing the casing in the oil sand and perforating the casing and the cement, for example, by means of gun perforators, other methods of completion which are known in the art may be used equally effectively. Also, the permeability of the formation at the point of fluid ingress or egress to or from the well may be increased by various known means, for example, by blasting, acidizing, or hydraulic fracturing.

As illustrated in FIG. 1, the bottom of the well bore may be, of necessity, terminated at a point (E) a sufficient distance above water table (F) to prevent coning of the water into the well bore during production. In formations having no water drive or in sections of a water-drive formation where there is no water table, the well bore may be drilled to the bottom of the producing sand. In carrying out the process of this invention, it is preferable, in the latter case, that the well bottom extend below the bottom of the sand as illustrated in FIG. 2.

In the Lombardi sand in the San Ardo, California field, it is customary to bottom the holes at least 75 feet above the water table to prevent water coning. This exceptionally large distance is considered necessary because of the unusually viscous nature of the oil. Since this particular oil sand is very thick, ranging from about 100 to about 260 feet in thickness, it is possible at present to allow a distance of 75 feet from the bottom of the hole to the water table and still permit considerable depth of penetration of the well bore into the oil sand. In a formation of lesser thickness, it may not be possible to allow such an ample distance to prevent water coning. As production continues from the San Ardo field it will be necessary eventually to drill deeper into the formation in order to recover the oil. By heating the sand and thereby reducing the viscosity of the oil, it will be possible to make a closer approach to the water table without encountering trouble from water coning. The process of the present invention, therefore, permits increased rates of production from this field and from similar fields and has the added advantage that it is not necessary to bottom the well as high above the water table as is necessary with conventional procedures in order to prevent water coning.

FIG. 2 shows an alternative arrangement for producing an oil sand in accordance with my invention. A well bore 15 extends through oil sand 16 into the bottom rock 17. In this example, it is assumed that there is no water present at the bottom of the oil sand. In this instance, three sections of the formation are in communication with separate tubes run into the well. Casing 18 is cemented in place in the oil sand by cement 19. This casing and the cement are perforated by two sets of perforations 20 and 21 through which fluid may be introduced to or withdrawn from the formation. Within casing 18 is a string of smaller diameter pipe 22 and within pipe 22 is a string of tubing 23 of still smaller diameter. Pipe 22 extends below the bottom end of casing 18 and tubing 23 extends below the bottom end of pipe 22. Packers 26 and 27 fill the annular space between casing 18 and pipe 22 at two vertically spaced points in the formation.

Another packer 28 closes the annular space between pipe 22 and tubing 23. Tubing 23 is in communication with the well bore at its lower end so that oil collected in the well below packers 26 and 28 may be produced through tubing 23. Perforations 29 in pipe 22 provide communication between the interior of pipe 22 and the perforated section of casing 18 intermediate packers 26 and 27. Fluid may be introduced to or withdrawn from the oil sand through pipe 22 via perforations 21 and 29. Packer 27 may be provided with a suitable heat insulator 31, e.g., a fill of bulk asbestos. Similarly, packers 26 and 28 may be provided with heat insulating fills 32 and 33.

A second gas is introduced into the formation through pipe 22, entering the formation through perforations 21 and 29. The gas injected through pipe 22 may be an inert gas, e.g., nitrogen; a hydrocarbon, e.g., recycle gas; or a combustion-supporting gas, e.g., an oxygen-containing recycle gas stream. In this example, with the first or combustion-supporting gas entering the formation through perforations 20, it is preferable to inject a non-oxidizing gas, e.g., a hydrocarbon gas, through perforations 21. The non-oxidizing gas forms a barrier between the combustion-supporting gas and the open section of the well below the bottom of casing 18. Injection of the two gas streams may be controlled to limit invasion of the formation by the combustion-supporting or oxidizing gas to the upper portion of the formation. By this method of operation, viz. injection of a non-oxidizing gas barrier, any problems arising from fracturing and cementing of a bore hole, in order to divide the formation of oil sand into upper and lower portions, is avoided, and the ultimate result of preventing the short cutting of the flame front is attained. In an alternative but generally less desirable method of operation, combustion-supporting gas is injected into the formation through pipe 22 and perforations 29 while recycle gas is injected through perforations 20 in casing 18. Oil which collects in the bottom of the well is produced through tubing 23. Oil or gas, or both, may be produced from the formation adjacent the section perforated by perforations 21 by reversing the flow in pipe 22.

As applied to a formation having a gas-bearing portion and an oil-bearing portion, in accordance with one embodiment of the present invention, the combustion-supporting gas or hot products of combustion are injected into the formation near the top of the formation so that products of combustion are displaced primarily into the gas-bearing portion of the formation. This permits heating the top of the formation with little penetration of the gases into the oil sand. After a period of time, for example, from one month to three years, during which heat from the gas-bearing portion of the formation penetrates the oil-bearing portion of the formation, heated oil of reduced viscosity may be produced from the oil-bearing portion of the formation. Movement of heated connate fluid through the formation to the point of production increases the rate of heat transmission through the formation.

In another modification, the combustion-supporting gas or hot products of combustion are injected into the oil-bearing portion of the formation below the top of the oil-bearing portion, for example, about halfway between the gas cap and the water table or bottom of the formation. In this instance, the products of combustion displace oil from the sand in the vicinity of the bore hole forcing the gas back into the formation and forming a generally spherical gas "bubble" in the oil sand. Heat is conducted away by conduction through the formation in all directions from the point of heat release or from the area of gas invasion. This heats the sand in all directions, reducing the viscosity of the oil in the formation. As the oil around the periphery of the injected gas is heated, it becomes more fluid and, under the influence of gravity, moves toward the lower part of the formation displacing the gas upward. The gas thus continues to move upward even after gas injection is interrupted. As the gas is dis-

7

placed upward by the heated oil, heat also is carried upward through the formation, heating the formation more rapidly than by conduction alone. After a period of time, for example, a period of one week to five years, the injected gas breaks through into the gas cap leaving below it a section of heated formation surrounding the well bore. The heated oil is readily produced through the well. Part or all of the injected gas may be also withdrawn from the formation, but this is generally neither necessary nor desirable.

It will be evident that by the process of my invention wherein the heat supplied to the formation is supplied through the same well from which the oil is produced, or in its immediate vicinity, it is possible to obtain the utmost advantage of the reduction of viscosity of the oil resulting from the temperature increase in the formation. It is not necessary, as in conventional practices, to produce viscous, unheated oil from a separate producing well in order to permit hot gases to penetrate the formation. In my process, as viscous oil approaches the well, from which it is subsequently produced, it encounters heated formation, its viscosity is reduced, and the flow rate through the final critical few feet of formation surrounding the producing well is greatly increased.

Obviously, many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

This application is a continuation-in-part of my co-pending patent application Serial No. 459,393 filed September 30, 1954, now abandoned.

I claim:

1. In a method for the recovery of oil from an underground oil bearing formation via a single well bore having tubing and packer means associated therewith therein and penetrating into said formation which includes dividing said formation into an upper oil-bearing portion and a lower oil-bearing portion separated from each other with respect to said well bore by formation adjacent said packer means of a relatively horizontal barrier extending outwardly therefrom, said tubing and the wall of said well bore defining an annulus above said packer means, the steps of introducing via one of said annulus and tubing into one of the oil-bearing portions of said formation a heating fluid thereby heating that portion of the formation into which said heating fluid is introduced, permitting the heat thus introduced within the said that portion of said formation to be transferred as by conduction around said barrier to the other portion of said oil-bearing formation, and producing oil via the other of said annulus and tubing from said other portion of said oil-bearing formation.

2. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing with associated packer means therein and penetrating into said formation which includes fracturing said oil-bearing formation adjacent said packer means to provide a fracture therein oriented in a relatively horizontal direction to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion with respect to said well bore, and cementing said fracture thereby providing a relatively horizontal barrier extending outwardly from said well bore, the steps of introducing via said well bore into said upper oil-bearing portion a heated fluid thereby heating said upper oil-bearing portion, permitting the heat thus introduced within said upper oil-bearing portion to be transferred as by conduction around said barrier to said lower oil-bearing portion of said formation and producing via said tubing in said well bore oil from said lower oil-bearing portion of said formation.

3. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing with associated packer means therein and pene-

8

trating into said formation which includes fracturing in a relatively horizontal direction said oil-bearing formation adjacent said packer means to provide a fracture therein extending outwardly from said well bore to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal barrier, the steps of introducing via said well bore into said upper oil-bearing portion a heating fluid to heat said upper oil-bearing portion, permitting the heat thus introduced within said upper oil-bearing portion to be transferred as by conduction around said barrier to said lower oil-bearing portion, discontinuing the introduction of said heating fluid, and producing oil via said tubing in said well bore from said lower oil-bearing portion of said formation.

4. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing with associated packer means therein and penetrating into said formation which includes fracturing said oil-bearing formation adjacent said packer means to provide a fracture therein extending in a relatively horizontal direction outwardly from said well bore to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal barrier with respect to said well bore, the steps of providing via said well bore a combustion supporting fluid for subjecting said upper oil-bearing portion to in situ combustion thereby generating a substantial amount of heat therein, permitting the heat thus created within said upper oil-bearing portion to be transferred as by conduction around said barrier to said lower oil-bearing portion, and producing oil via said tubing in said well bore from said lower oil-bearing portion of said formation.

5. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing with associated packer means therein and penetrating into said formation which includes fracturing said oil-bearing formation adjacent said packer means to provide a fracture therein in a relatively horizontal direction with respect to said well bore to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal impermeable barrier extending outwardly from said well bore, the steps of subjecting said upper oil-bearing portion to in situ combustion by providing a combustion supporting fluid thereto via said well bore thereby generating a substantial amount of heat therein, permitting the heat thus created within said upper oil-bearing portion to be transferred as by conduction around said barrier to said lower oil-bearing portion, discontinuing in situ combustion within said upper oil-bearing portion by terminating the providing of a combustion supporting fluid and producing oil via said tubing in said well bore from said lower oil-bearing portion of said formation.

6. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing with associated packer means therein and penetrating into said formation which includes fracturing said formation adjacent said packer means to provide a fracture therein extending outwardly from said well bore in a relatively horizontal direction to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal impermeable barrier, said tubing and the wall of said well bore defining an annulus above said associated packer means, the steps of introducing via one of said annulus and tubing into one of said oil-bearing portions of said formation a heating fluid thereby heating that portion of the formation into which said heating fluid is introduced, permitting the heat thus introduced within the said that portion of said formation to be transferred as by conduction around said barrier to the other portion of said oil-bearing formation,

and producing oil via the other of said annulus and tubing from said other portion of said oil-bearing formation.

7. A method in accordance with claim 6 wherein said heating fluid comprises hot gaseous products of combustion.

8. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing and packer means associated therewith therein and penetrating into said formation which includes fracturing said oil-bearing formation adjacent said packer means to provide a fracture therein extending outwardly from said well bore in a relatively horizontal direction to divide said oil-bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal impermeable barrier, said tubing and the wall of said well bore defining an annulus above said packer means, the steps of providing via one of said annulus and tubing a combustion supporting fluid for subjecting one of said oil-bearing portions of said formation to in situ combustion thereby generating a substantial amount of heat therein, permitting the heat thus created within that portion of said oil-bearing formation to be transferred as by conduction around said barrier to the other portion of said oil-bearing formation, and producing oil via the other of said annulus and tubing from said other portion of said oil-bearing formation.

9. In a method for the recovery of oil from an underground oil-bearing formation via a single well bore having tubing and packer means associated therewith therein and which penetrates into said formation which includes fracturing said oil-bearing formation adjacent said packer means to provide a fracture therein in a relatively horizontal direction extending outwardly from said well bore to divide said oil bearing formation into an upper oil-bearing portion and a lower oil-bearing portion, and cementing said fracture to provide a relatively horizontal impermeable barrier, said tubing and the wall of said well bore defining an annulus above said packer means, the steps of subjecting one portion of said oil-bearing formation to in situ combustion by providing via one of said annulus and tubing a combustion supporting fluid thereto thereby generating a substantial amount of heat therein, permitting the heat thus generated within said one portion of said oil-bearing formation to be transferred as by conduction around said barrier to the other portion of said oil-bearing formation, discontinuing in situ combustion within said one portion of said oil-bearing formation by terminating the providing of a combustion supporting fluid thereto, and producing oil via the other of said annulus and tubing from said other portion of said oil-bearing formation.

10. A process of removing viscous oil from a subsurface stratum traversed by a vertical well bore, including the steps of: (a) initiating combustion in the upper portion of the stratum around the well bore to form a flame front and (b) continuously forcing gas only into the upper portion of the stratum for feeding the flame front and forcing the flame front downwardly around the well bore, whereby the stratum is progressively heated in a downward direction and the products of combustion are forced downwardly to release oil entrained in the stratum and direct the released oil into the well bore at the lower portion of the stratum.

11. A process as defined in claim 10 characterized further by including the steps of removing the released oil from the well bore upwardly through the well bore to the surface.

12. A process as defined in claim 10 characterized

further by the fracturing of said stratum around the well bore in a relatively horizontal direction with respect to said well bore thereby dividing said stratum into upper and lower portions, and cementing the resulting fracture thereby to provide a relatively impermeable barrier extending outwardly from said well bore.

13. A process for removing viscous oil from a subsurface stratum traversed by a substantially vertical well bore and ending adjacent the lower portion thereof including the steps of: (a) placing a casing in said well bore at such a depth that the casing terminates in the lower portion thereof in said stratum, (b) cementing said casing in said well bore from the lower end of said casing throughout the major portion of the well bore traversing said stratum, (c) perforating said casing adjacent the upper portion of said stratum, (d) suspending a tubing in said casing thus forming an annulus therewith, (e) packing said tubing with respect to said casing below the perforations in said casing, (f) forcing a combustion supporting gas such as air down through said annulus formed between said tubing and said casing and outwardly through said perforations in the latter, (g) initiating combustion of said combustion supporting gas and oil in the upper portion of said stratum adjacent said perforations to form a flame front around said well bore whereby said combustion supporting gas feeds and forces said flame front progressively outwardly and downwardly from said well bore to heat said stratum and drive oil therefrom into said well bore at the lower portion of said stratum.

14. A process as defined in claim 13 characterized further by the fracturing of said stratum below said perforations in said casing in a relatively horizontal direction thereby to define separate portions with respect to said well bore, and cementing the resulting fracture extending outwardly from said well bore to provide a relatively horizontal impermeable barrier.

15. In a recovery process for recovering hydrocarbon fluid from a subterranean formation traversed by a vertical well bore, said well bore having a substantially horizontal impermeable barrier extending radially outward therefrom in a fracture formed in the formation, thereby dividing the formation into an upper and a lower section, said wellbore further having a sealing means therein positioned adjacent said barrier and dividing the well bore into an upper and a lower zone, and having a tubing string within the well bore extending from the surface thereof through the sealing means, said tubing string and the wall of said well bore defining an annulus above said sealing means, the steps of injecting a fluid under pressure through one of said annulus and tubing string into one of said sections of the formation, continuing the injection of said fluid to force hydrocarbon fluid around said barrier from said one of said sections to the other of said sections, and recovering said hydrocarbon fluid from the other of said sections of the formation through the other of said annulus and tubing string.

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