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HUFF AND PUFF FIRE FLOOD PROCESS

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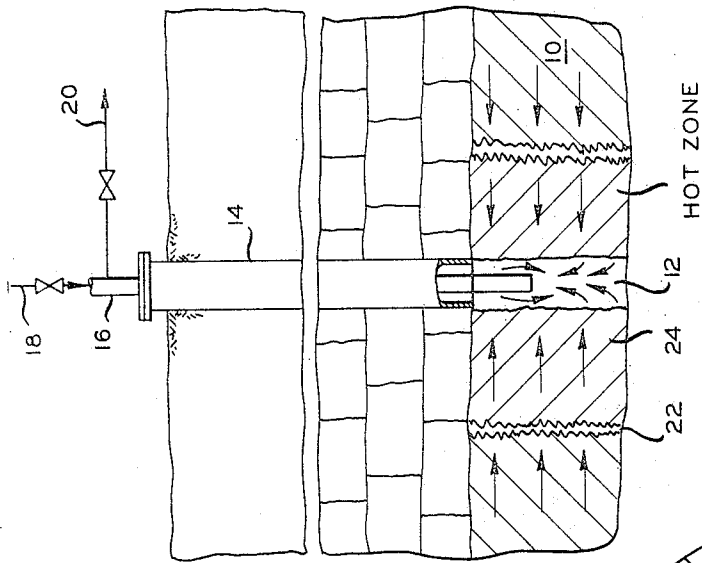


FIG. 2

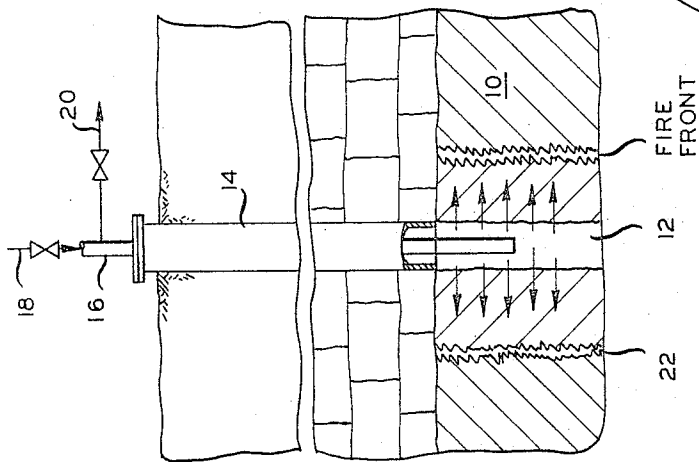


FIG. 1

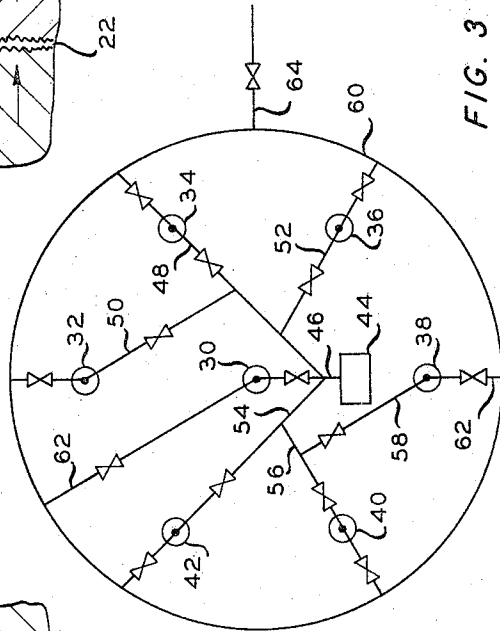


FIG. 3

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HUFF AND PUFF FIRE FLOOD PROCESS

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This invention relates to a process for producing relatively heavy viscous crude oil from a subterranean stratum containing same by the use of in situ combustion.

Production of underground oil by in situ combustion is a conventional production method in the oil industry. In conventional direct drive or forward underground in situ combustion, when applied to certain oil-bearing strata, particularly those containing a heavy viscous crude oil, it becomes impossible to continue to support an expanding combustion zone because of the formation of a viscous liquid bank of oil in advance of the combustion zone. This viscous liquid bank, formed by heating and driving the crude oil deeper into the stratum from the air injection well where the viscous oil cools in the relatively cool stratum and becomes more viscous and even congeals in the pores of the stratum, substantially completely plugs the stratum and forestalls continued injection of air to feed the combustion zone.

The present invention circumvents this problem of plugging and provides an improved process for the recovery of such heavy oils from a single well and from a group of wells in any suitable pattern.

Accordingly, it is an object of the invention to provide a process for recovering oil from a subterranean stratum containing a relatively heavy viscous crude oil. Another object is to provide a process for producing such viscous crude oils by in situ combustion which overcomes the plugging problem usually encountered in a direct or forward drive in situ combustion process. A further object is to provide a process for recovering viscous crude oil from a stratum containing same thru a plurality of wells by in situ combustion utilizing a single air compressor alternately applied in the injection of air to the several wells. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises igniting the oil in the stratum to be produced around a single well penetrating same, injecting air thru the well to expand and move the ignited area (combustion zone) into the stratum away from the well whereby a liquid bank of viscous oil builds up in the stratum beyond the combustion zone so as to substantially plug the stratum and build up substantial pressure above the stratum pressure at the time of initiation of the process, and thereafter terminating the injection of air and opening the well to production so that the fluid pressure in the stratum beyond the combustion zone forces liquid oil from the liquid bank back into the combustion zone and the hot burned-over area behind the combustion zone so as to upgrade the liquid oil by heating and cracking and force the upgraded oil into the well from which it is recovered by conventional methods. After a substantial period of production during which the pressure-build up in the stratum during the injection period forces oil in upgraded condition into the well, the stratum is again ignited adjacent the well to establish a combustion zone which feeds on the oil filling the pores of the stratum at the end of the first production phase of the process. In some cases where the hot sand or rock is at a combustion-supporting temperature, the mere injection of air into the hot stratum reignites the oil therein. In the event the stratum is below combustion-supporting temperature, the ignition is effected in conventional manner as by heating with an electric igniter, a

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charcoal pack, a gas fired heater, or similar device and injecting air into the hot stratum.

The steps of moving a combustion zone into the stratum away from the well, terminating the air injection and opening the well to production, etc., are repeated as many times as are economically feasible in the production of oil from the stratum. As long as the formation will take air at a satisfactory rate, the combustion zone is propagated radially into the stratum. As soon as the air flow under reasonable injection pressure becomes too low for effective movement of the combustion zone, the air injection is terminated and the well is produced as heretofore discussed. When the air injection is terminated the burning in the combustion zone also terminates, leaving a hot partially burned out zone intermediate the combustion zone and the well. Upon opening the injection well, the heavy oil beyond the combustion zone moves toward the well bore but is heated by the hot rock or sand and undergoes cracking and viscosity reduction so that high velocities are attained in the vicinity of the well bore without high pressure gradients. During the production phase of the process, the stratum between the combustion zone and the well becomes resaturated so that adequate fuel is provided for a new cycle of burning and production.

One aspect of the invention comprises continuing the in situ combustion and recovery process in several wells successively so that the compression facilities are maintained in constant use. A plurality of wells are operated in the manner described one after another from the same compressor which is connected with the second well after the first well of the well pattern is on the production phase of the cycle, and the third well is put on the injection and burning phase of the cycle after the second well is on production, and so on. Each well is burned and then produced and the process repeated until linking between the wells occurs so that fluids can be injected from one well to another in the pattern without effecting plugging of the stratum. The stratum is then in condition for either a forward or reverse in situ combustion burning process which is then radially effected to completely produce the intervening stratum.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation thru a well in a stratum illustrating the burning phase of the process; FIGURE 2 is a similar view of the well of FIGURE 1 illustrating the production phase of the process; and FIGURE 3 is a plan view of a ring well pattern and arrangement of equipment for producing the wells in the pattern.

Referring to FIGURE 1, a stratum 10 is penetrated by a well 12 which is provided with a casing 14 and a tubing string 16. An air line 18 connects tubing string 16 with a compressor not shown. Production line 20 connects with tubing string 16 at the well head. At the stage of operation illustrated, the fire front or combustion zone, designated 22, has been advanced a substantial distance radially from well 12.

In operation with the arrangement shown in FIGURE 1, the oil in the stratum adjacent well 12 is ignited in any suitable conventional manner as by packing the well bore with a charcoal pack soaked in heavy oil and provided with an igniter such as a fusee or by dropping a fusee onto the pack from the well head. Air is then supplied to the charcoal pack thru line 18 and tubing string 16 so as to burn the charcoal and eventually ignite the oil in the adjacent stratum. Continued injection of air moves the resulting combustion zone into the stratum to the position illustrated.

In FIGURE 2 the corresponding elements are correspondingly numbered. At the phase of the operation illu-

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strated in FIGURE 2, the valve in air line 18 is closed and the valve in line 20 is open to production so that the fluid pressure built up in the stratum, particularly the pressure beyond combustion zone 22, forces heavy oil into the combustion zone and the hot burned-over area 24 behind the combustion zone so that the oil is heated, cracked, and upgraded as it passes thru the hot zones into well 12 from which it is produced in conventional manner thru tubing string 16 and production line 20.

FIGURE 3 illustrates one arrangement of wells to which the invention is applicable. Central well 30 is surrounded by ring wells 32, 34, 36, 38, 40, and 42. A compressor 44 is connected with the tubing string of each well by a system of valved conduits 46, 48, 50, 52, 54, and 56. A production pick-up ring 60 connects with the tubing string of each well by means of valved conduits 62 and a production line 64 connects with ring 60 for delivery of the produced fluids to a refinery.

In operation with the arrangement shown in FIGURE 3, ignition is effected in a selected well in the pattern, as in well 30, while the other wells are shut-in, and air is fed from compressor 44 thru line 46 into well 30 to move a combustion zone toward the ring wells by direct or forward drive. Pressure is built up in the stratum as the combustion proceeds; and the resistance to air flow increases as liquid oil is pushed deeper into the cool stratum until it finally is no longer feasible, with available pressure from compressor 44, to sustain combustion. At this time, or even earlier, air injection thru line 46 is terminated by closing the valve in line 46 and the valve in line 62 leading from well 30 is opened to production. This allows pressure in stratum 10 to force liquid oil toward well 30 where it is upgraded and flows into well 30 as explained previously.

While well 30 is on in situ combustion, one (or more) of the ring wells, such as well 32, is prepared for ignition, as by burning a charcoal pack in the well, so that it is ready for the in situ combustion phase of the process when air is cut off from well 30. Air for the ignition is supplied by diverting a small fraction of the air from the compressor feeding the in situ combustion process. Air is switched from well 30 to well 32 by obvious manipulation of the valves in conduits 46 and 50 and the combustion phase is operated on well 32.

It may be necessary to close well 30 to production during the later stages of combustion thru well 32 to build up pressure in the stratum. During air injection thru well 32 pressure is applied on the fluids around well 30 to assist in the production phase of the process and pressure may not build up as high as when well 30 is shut in. However, during production of well 30, following the combustion phase, air injection thru well 34 or well 42 furnishes adequate stratum pressure for this purpose.

The various phases of the process cycle are operated successively on the various wells in the pattern in any selected sequence. The process is repeated in each well as many times as necessary to open up the stratum to a direct or reverse drive in situ combustion which is effected by igniting the oil around well 10 and driving the combustion zone to the ring wells, with recovery of the produced oil thru the ring wells. It is also feasible to ignite at the ring wells and drive the combustion zone to the center well, with recovery of oil thru this well.

In some cases, it will be preferred to utilize a reverse drive combustion zone, either igniting at the ring wells and injecting air thru the center well or vice versa.

The process of the invention operates most advantageously on a single well or on wells in a selected pattern which are spaced far enough apart that injection pressure applied on one well has little effect on other wells in the pattern during the early stages of the repetitive cycles. Of course, after many repetitions, the stratum between wells in the pattern become permeable to air flow and eventually permits driving a combustion front thru from well to well.

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The pressure build-up during the combustion phase of the process depends upon the depth of the stratum but will be at least 300 or 400 p.s.i. above normal stratum pressure. Injection pressure will not exceed fracturing pressure. Ordinarily, pressures up to 1500 to 2000 p.s.i. are used, depending upon stratum depth and available compressor capacity.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A process for producing oil from a subterranean stratum bearing a relatively viscous crude oil and penetrated by a production well and a plurality of offset wells which comprises the steps of:

- (a) injecting air thru said production well into said stratum at substantially higher pressure than the pressure therein adjacent said production well;
- (b) igniting said stratum within said production well to establish a combustion zone around said production well;
- (c) thereafter, continuing air injection as in step (a) so as to move the combustion zone of step (b) into said stratum until plugging said stratum by mobile viscous oil from the heated area of the stratum is effected and substantial pressure is built up therein;
- (d) thereafter, discontinuing the air injection of step (c) and opening said production well to production so that compressed gases within the stratum radially remote from said production well and beyond the plugged area expand and flow toward said production well, thereby driving fluid oil into the hot burned-over area between the plugged area and said production well wherein said fluid oil is substantially heated and upgraded and resulting upgraded oil is forced into said production well;
- (e) maintaining said offset wells shut in during steps (a) through (d) to assist pressure build-up and oil production in said production well; and
- (f) recovering oil of step (d) from said well.

2. The process of claim 1 including repeating steps (a) thru (e) after the pressure within said stratum has been reduced substantially in driving oil toward said well, so as to produce and recover additional oil; and thereafter moving a combustion zone thru said stratum from said well to at least one of said offset wells.

3. A process for producing upgraded oil from a subterranean stratum bearing relatively viscous crude oil penetrated by a production well and a plurality of offset wells which comprises the steps of:

- (a) igniting oil in said stratum adjacent said production well so as to establish a combustion zone therein;
- (b) injecting air thru said production well into said combustion zone to continue the combustion of oil in said stratum and move said zone away from said production well toward said offset wells, whereby a portion of said viscous oil is heated, rendered more fluid, driven more remote from said production well, cooled, and causes plugging of said stratum, and the pressure in said stratum is built up substantially;
- (c) thereafter, terminating the air injection of step (b) and opening said production well to production so as to allow fluid pressure within said stratum to force liquid oil from the plugged area into the hot burned-over area nearer said production well, thereby heating, upgrading, and driving the upgraded oil solely into said production well;
- (d) maintaining said offset wells shut in during steps (b) and (c); and
- (e) recovering upgraded oil from said well.

4. The process of claim 3 including repeating steps (a) thru (d) thru each of said wells to recover additional oil from said stratum.

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5. The process of claim 3 wherein the pressure built up during step (b) is in the range of 300 to 2000 p.s.i but below fracturing pressure.

6. A process for producing oil from a subterranean stratum bearing relatively viscous oil and penetrated by a plurality of wells which comprises the steps of:

- (e) applying steps (a) thru (d) of claim 4 to said stratum thru each of said wells and repeating the steps thru each well so as to open up the stratum between said wells to flow of fluid;
- (f) thereafter moving a combustion zone thru the stratum between wells; and
- (g) recovering oil produced by step (f).

7. The process of claim 6 wherein said wells are in a ring pattern including a central well and step (f) is effected by reverse combustion drive.

8. The process of claim 6 wherein said wells are in a ring pattern including a central well and step (f) is effected by direct combustion drive.

9. A process for producing upgraded oil from a subterranean stratum bearing relatively viscous crude oil, penetrated by a plurality of wells, which comprises the steps of:

- (a) igniting oil in said stratum adjacent one of said wells so as to establish a combustion zone therein;
- (b) injecting air thru said one well into said combustion zone to continue the combustion of oil in said stratum and move said zone away from said well toward the other of said wells, whereby a portion of said viscous oil is heated, rendered more fluid, driven

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more remote from said well, cooled, and effects plugging of said stratum, and the pressure in said stratum is built up substantially;

- (c) thereafter, terminating the air injection of step (b) and opening said well to production so as to allow fluid pressure within said stratum to force liquid oil from the plugged area into the hot burned-over area nearer said well, thereby heating, upgrading, and driving the upgraded oil into said well;
- (d) recovering the upgraded oil from said well;
- (e) applying steps (a) thru (d) to said stratum successively thru the others of said wells; and
- (f) using a common compressor for supplying air for step (b) in producing each well so that when the first of said wells is in the phase of steps (c) and (d), the second of said wells is in the phase of step (b), and so on.

References Cited

UNITED STATES PATENTS

2,862,557	12/1958	Baron van Utenhove	-- 166--11
2,906,340	9/1959	Herzog	----- 166--39
2,958,380	11/1960	Schild	----- 166--11
3,136,359	6/1964	Graham	----- 166--40 X
3,171,482	3/1965	Simm	----- 166--39

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