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HIGH-PRESSURE STEAM DRIVE OIL PRODUCTION PROCESS

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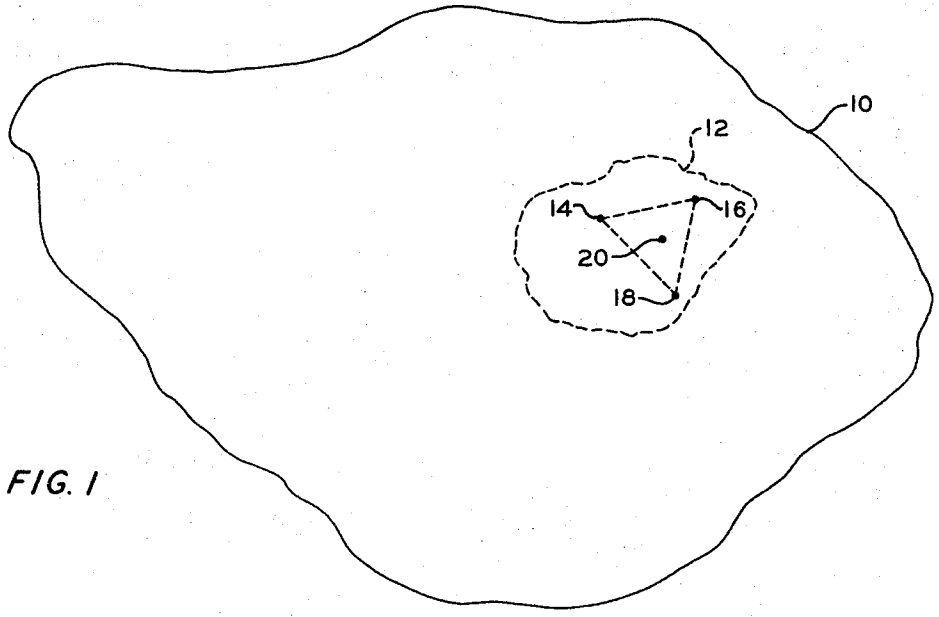


FIG. 1

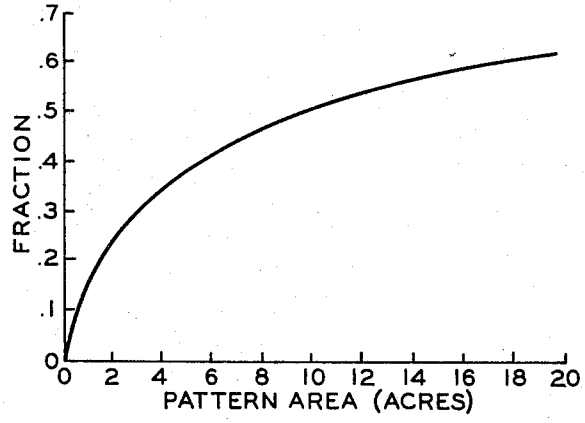


FIG. 2

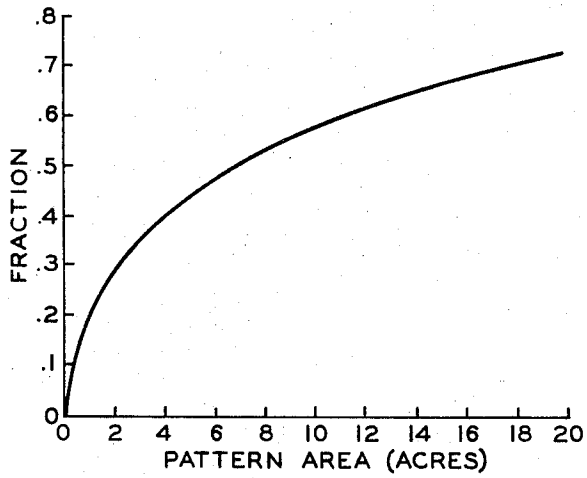


FIG. 3

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HIGH-PRESSURE STEAM DRIVE OIL PRODUCTION PROCESS

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This invention relates to a process for producing oil from a partially depleted reservoir by the injection of high pressure steam into the reservoir.

One of the unsolved problems in the production of oil from oil reservoirs is the recovery of substantially all of the oil from any given reservoir. To illustrate, the Burbank Field in Oklahoma has been continuously produced for approximately 40 years and some sections of the field contain substantially as much as has been produced therefrom. To be specific, a substantial section of the Burbank Field which has a porosity of 21 percent has an oil saturation at the present time of 46 percent. Primary production in this field terminated several years ago and gas drive followed by water drive have been applied as secondary recovery methods. While substantial quantities of oil have been produced from the Burbank Field by these secondary recovery methods, it still remains that the oil saturation throughout the field is appreciable, amounting to 46 percent saturation in a substantial section thereof, which challenges oil production workers in the art and renders solution of the production problem significantly remunerative.

This invention is concerned with a unique method of recovering oil from a partially depleted reservoir or oil-bearing stratum which has defied ordinary secondary oil production methods such as water flooding and gas drive.

Accordingly, it is an object of the invention to provide a unique method of secondary oil production utilizing high pressure steam injection. Another object is to provide a process for secondary oil recovery which combines certain aspects of water flooding and steam injection. A further object is to provide a process for secondary oil recovery utilizing steam injection which makes efficient use of the size of the production pattern. 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 subjecting a partially depleted reservoir or oil-bearing stratum to water flooding to further partially deplete same, injecting high pressure steam into the water flooded area defined by a specific well pattern until a substantial portion but not all of the available pore space in the well pattern has been filled with steam, and thereafter driving the heat front and steam thru the well pattern to the production wells therein so as to produce the steamed-out oil from the pattern. A significant aspect of the invention comprises building up a substantial reservoir pressure during the water flooding phase of the process and maintaining this water pressure in the area of the stratum surrounding the pattern thru which steam is driven so that the oil steamed out by the steam flood is squeezed into the production wells by the combination of steam pressure and resisting water pressure surrounding the steam flood pattern. This solves the problem frequently encountered wherein the secondary recovery drive forces oil out of the well pattern and leaves pockets of oil unrecovered in the reservoir.

The injection of water after the steam injection to drive the steam and the heat in the stratum thru the well pattern has a significantly beneficial effect in that no steam is bypassed and the condensation of pockets of steam behind the driving front is avoided. This type of condensation greatly reduces the pressure in the condensation

area and sucks in oil from surrounding areas which creates oil pockets unrecovered by the drive of the steam front. The injection of water at normal reservoir temperature assures proper driving of the steam and heat front thru the production pattern and effects substantially all of the steam condensation at the interface of the water and steam, thereby avoiding later condensation of steam behind the driving front or water-steam interface.

The invention is more fully described by reference to the accompanying schematic drawing of which FIGURE 1 is a plan view of a partially depleted reservoir illustrating one well pattern particularly adapted to secondary recovery by steam injection following water flooding; FIGURE 2 is a plot of a curve showing the relationship between the pattern area in acres and the fraction of steam-out time during which steam must be injected; and FIGURE 3 is a plot of a curve showing the relationship between the pattern area in acres and the fraction of the pattern volume which must be filled with steam.

In FIGURE 1, an oil field outline is identified by the numeral **10**. A substantial section of the field indicated by numeral **12** is of higher oil concentration than the surrounding field. Water flooding has been applied to substantially the entire field **10** thru conventional well patterns not shown. Wells **14**, **16**, and **18** are wells in the primary production pattern and also in the water flooding pattern. Injection well **20** was drilled specifically for the steam injection phase of the recovery process.

During the water flooding phase of the secondary recovery program, water pressure within the field was built up to approximately 1000 p.s.i. and this pressure was substantially maintained for the steam injection and steam drive phases of the recovery process. The injection of steam thru injection well **20** in a specific embodiment of the invention is at a pressure of about 1700 p.s.i. (temperature 613° F.) at a rate of about 23,000 lbs. of steam per hour. The Burbank sand, which field **10** represents, is a consolidated sand containing natural horizontal fractures. In strata which unduly limit steam injection rates, horizontal fracturing should be applied before steam injection is attempted. The well pattern formed by wells **14**, **16**, **18**, and **20** has an area of about 4.37 acres and the triangular pattern is about 680 feet on each side. Well **20** is at substantially the geometric center of the pattern. About .43 or 43 percent of the pattern volume is flooded with steam before initiating the water drive. This value is read directly from FIGURE 3 which shows the relationship between the pattern area in acres and the fraction of the pattern volume which must be filled with steam if the steam and water are to arrive at the production wells substantially simultaneously. This represents the most efficient use of steam and water in the steam-and-water drive phases of the process. If less steam is utilized, all of the steam is condensed before the water and steam arrive at the production wells and, if more steam is injected, the steam phase reaches the production wells substantially ahead of the water front. The volume of steam injected is in the range of about 0.2 to 0.65 pore volume of the well pattern.

A fraction of the steaming-out period, i.e., the time elapsed from initial steam injection until steam arrives at the production wells, in the pattern of FIGURE 1 under the conditions set forth, is 0.37 or 37 percent of the total steam-out time. This is read from FIGURE 2 for a well pattern of 4.37 acres under the conditions set forth. The curves of FIGURES 2 and 3 were plotted using the method disclosed by J. W. Marx and R. H. Langenheim in Petroleum Transactions, AIME, volume 216, 1959, pp. 312–315.

The water is injected following the steam injection period at reservoir temperature and at a rate of about 5,000 bbl./day. Under these conditions the steam-out time is about 1.15 years. The oil saturation in the steam production pattern is about 46 percent with 21 percent porosity and the oil saturation after the steaming-out period is in the range of 8–12 percent.

While specific values have been given to illustrate the technique of the invention in a specific reservoir situation, these values may be varied substantially within the scope of the invention. The steam injection rate may be varied in the range of 12,000 to 50,000 lbs./hr. of steam depending upon the porosity of the stratum, the characteristics of the oil in place, and the character of the stratum immediately surrounding the injection well. For high injection rates, fracturing should be resorted to. The steam injection pressure may be varied in the range of 750 to 3000 p.s.i., the temperature depending upon the injection pressure. The size of the well pattern for most efficient utilization of steam is in the range of 1–12 acres. Larger well patterns than 12 acres may be utilized but the efficiency and heat losses indicate the use of more desirable smaller acreages. Utilizing production patterns in the range of 1–12 acres required steam injection periods in the range of 20–65 percent of the total steam-out period. Larger acreages require higher percentages of steam injection periods. The water injection rate may be varied in the range of 2500 to 15,000 bbl./day and will depend upon the pattern area being produced as well as the conditions of the stratum in which the process is being effected. Water-injection pressure in the range of about 500 to 2000 p.s.i.g. is used.

While a 4-spot well pattern is illustrated herein, other well patterns are utilizable including a 5-, 6-, 7-, 8-, or 9-spot pattern. It is also feasible to utilize a line of steam injection wells flanked on either side by parallel lines of production wells as is conventional in line drive production.

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 an oil-bearing stratum which has been produced by natural fluid drive comprising the steps of:

(a) water flooding a well pattern penetrating said stratum by injecting water under pressure into at least one injection well in said pattern to build up substantial pressure within the well pattern and in the surrounding stratum and producing fluids including oil thru at least one production well therein;

(b) following step (a), without substantial reduction of pressure, steam flooding said pattern by injecting steam at a pressure substantially above stratum pressure at the end of step (a) thru at least one injection well in said pattern and producing fluids including oil from at least one production well in said pattern, the volume of the injected steam being in the range of about 0.2 to 0.65 of the pore volume of said pattern;

(c) following step (b), terminating steam injection and driving injected steam thru said pattern with cool fluid to drive a resulting hot zone toward the production well(s) of step (b); and

(d) recovering fluids including oil from the production well(s) of step (b) produced by step (c).

2. The process of claim 1 including the step of driving fluids including oil from said pattern by a gas drive intermediate natural fluid drive and step (a).

3. The process of claim 1 wherein step (c) is effected by a water drive free of gas at an injection rate in the range of about 2500 to 15,000 bbl./day.

4. The process of claim 1 wherein said injection well in step (b) is a central well and the production wells are ring wells and including the steps of:

(e) selecting said well pattern surrounded by oil-bearing stratum;

(f) building up stratum pressure during step (a) to the range of 500 to 2000 p.s.i. by water injection;

(g) maintaining stratum pressure in the range of step (f) during steam injection of step (b) and during the drive of step (c) so as to squeeze stratum fluids toward last said production wells.

5. A process for producing oil from an oil-bearing stratum following primary production thereof comprising the steps of:

(a) waterflooding a substantial section of said stratum by injecting water under a pressure in the range of about 500 to 2000 p.s.i. thru at least one injection well and producing oil thru at least one production well and building up a pressure in said range throughout a substantial pressure area;

(b) selecting a well pattern including a central injection well and at least 3 surrounding production wells within the pressure area of (a);

(c) without substantially reducing pressure established in step (a), injecting steam thru the injection well of step (b) while substantially maintaining the stratum pressure of step (a) until a volume of steam equal to a substantial portion but less than all of the pore volume of the well pattern of (b) has been injected, said steam being injected at a pressure in substantial excess of the pressure established in step (a);

(d) driving the injected steam of step (c) and a resulting hot zone toward the production wells of step (b) with a cool driving fluid so as to produce oil therein while maintaining substantially the stratum pressure of step (a); and

(e) recovering oil from the production wells of step (b) produced by the process.

6. The process of claim 5 wherein the well pattern of step (b) covers an area in the range of about 1 to 12 acres, the steam injection pressure is in the range of about 750 to 3000 p.s.i.; and the pore volume in the well pattern filled with steam is in the range of about 0.2 to 0.65 of the pore volume in said well pattern.

7. The process of claim 6 wherein said well pattern is in an island of said stratum of higher permeability and higher oil saturation than the surrounding stratum.

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