METHOD FOR RECOVERING OIL FROM SUBTERRANEAN RESERVOIRS

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Field of Search ...................................... 166/272, 303

References Cited

UNITED STATES PATENTS

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3,483,924 12/1969 Blevins et al. ...................... 166/272

ABSTRACT

A method for recovering oil from a subterranean oil reservoir which has a finite water saturation and is deficient in energy so that it will not flow by natural means, whereby, first, steam is injected into the reservoir at a faster volumetric rate than production is taken from the reservoir in order to raise the pressure and temperature of the reservoir and then injection is ceased and production of the oil is commenced so that the pressure of the reservoir drops at least to the flash point of the water in the reservoir. Then continuing to produce oil from the reservoir.

9 Claims, 4 Drawing Figures
FIG. 1

FIG. 2

S = STEAM
W = WATER
SUBSCRIPTS DENOTE END OF STEP NUMBER

FIG. 3

FIG. 4

VAPOR PRESSURE OF WATER
METHOD FOR RECOVERING OIL FROM SUBTERRANEAN RESERVOIRS

BACKGROUND OF THE INVENTION

This invention pertains to the field of oil production. Specifically this invention concerns the production of oil by artificially adding energy to the reservoir with steam.

In view of the ever increasing demand for oil, the petroleum industry is continuously in search of improved methods for recovering petroleum from underground reservoirs. Particularly in demand are improved methods of secondary recovery which may be applied to depleted reservoirs or to reservoirs that lack natural gas or water drive media. A wide variety of secondary recovery techniques has been suggested or tried to date, but none of the methods have been entirely or universally applicable. It has been particularly difficult to find a method which is attractive for use in reservoirs that contain viscous crude oil.

Among the more promising methods that have been suggested or tried for the secondary recovery of oil from viscous oil reservoirs, are those methods calling for the injection of steam or hot water within the reservoirs. In such methods the hot water or steam is injected through one or more injection wells and forced through the reservoirs by means of pressure and oil is produced simultaneously from production wells.

One of the major benefits of steam flooding is the oil viscosity reduction that results from the increased temperature. The oil displacement mechanisms, however, are still by steam and hot water. As the steam contacts the cooler reservoir rock it is condensed to water. Even with the viscosity of the displacing fluid thus increased, (steam to water), the water still has a lower viscosity than oil. Also, the water is heavier than the oil. These two factors, viscosity and density, work to reduce overall recovery efficiency in prior art steam floods. The less viscous water can finger or channel through the oil and break through into the production wells before much of the oil has been swept from the reservoir.

Also, most of the more viscous oils are found in reservoirs consisting of highly permeable thick unconsolidated sands. Steam flooding of these types of reservoirs results in steam flooding of the top section and hot water flooding the bottom section of the reservoir due to gravitational segregation of the steam vapor and water.

U. S. Pat. No. 3,259,186 describes a method wherein steam is injected into an oil reservoir and allowed to remain within the formation for a period of time in order to condense most of the steam and thus heat the reservoir and reduce the viscosity of the reservoir oil. The injected steam (now hot water) and oil are then produced through the same well that was previously used for steam injection. In the method of the patent the emphasis is upon allowing the steam to condense in the formation. This results in liquid phase displacement of the oil in the formation with the resulting problems alluded to above.

Our invention solves these problems by providing a method whereby the water in the formation is vaporized in situ thus providing a vapor phase mechanism to drive the oil to production wells.

SUMMARY OF THE INVENTION

The invention is a method for recovering oil from subterranean hydrocarbon reservoirs containing a finite water saturation, wherein there is at least one input well and one output well. The method comprises injecting steam at a greater rate than oil and water are produced from the reservoir, in order to increase the pressure and temperature in the reservoir to values higher than could be obtained if injection and withdrawal rates were equivalent or if production rates were not curtailed. The steam injection is then stopped and the oil production wells are produced at a high rate so that the high pressure-high temperature water in the reservoir pore spaces is flashed to steam when the reservoir pressure is decreased as a result of reservoir fluid withdrawal. Oil production is then continued.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The method of our invention may be used in any oil reservoir which contains a finite water saturation which may be vaporized. However, it is preferred that the method of our invention be used in reservoirs which have insufficient natural energy to produce oil. The method of our invention will operate successfully with line drive floods where the steam injection wells are in a line and the injected steam drives the oil to a line of producing wells some distance away. The method of our invention is also suitable for pattern flooding where the injection and producing wells are alternated in the field such as the conventional five spot pattern. The method of our invention will work with all types of oil but will be particularly useful with the viscous oils which are not suitable for recovery by conventional means. It is here that viscosity of oil and water differ the most and where fingering of the water is the most troublesome in conventional recovery techniques.

The method of our invention may be illustrated by the following description and the attached figures.

FIG. 1 is a plat showing an arrangement of injection and producing wells completed in a thick permeable formation containing a heavy oil. Rows 1, 5, and 9 are used for steam injection and the remaining wells are producers. Steam is injected into the injection wells and all producing wells are produced at maximum capacity. Whenever live steam breaks into the adjacent producing wells these wells are shut in.

FIG. 2 is a cross-section of the formation between an injection well and a producing well two locations away. The section of the formation invaded by steam and water at steam break through into row number 6 wells is designated by S, and W, respectively embounded by the solid lines. The balance of the reservoir is large and there has not been sufficient time for the unswept sections to be heated by the injected steam and hot water.

Prior to steam injection the reservoir has been produced by some natural mechanism such as solution gas drive, gas cap or water drive, for example. The pressure has declined to a low value and the recovery has been less than 10 percent, the low recovery being due to the low mobility of the highly viscous oil.

During the initial stages just described, it is highly desirable to over inject (injected volumes exceeding withdrawal volumes) for the purpose of repressuring the reservoir. However, the degree of repressuring may be small due to the need for maximum production rates for early payout of the cost of the project.

FIG. 3 is a pressure profile of the section between rows 5 and 7. At the end of this initial phase the pres-
3,796,262.

The average pressure is near and slightly above the pressure prior to steam injection. The next (second) phase begins after steam breaks through into wells in rows 2, 4, 6, and 8. These wells are shut in and steam injection is continued into rows 1, 5, and 9. Injection exceeds withdrawal for the purpose of increasing reservoir pressure. Increasing reservoir pressure is the most important single feature of this improvement in steam flooding because the temperature of saturated steam increases as pressure increases.

FIG. 4 is the vapor pressure of water. As an example, if the reservoir pressure at the beginning of steam injection is about 50 psia and the pressure never significantly elevates during steam injection the reservoir temperature could never be raised above 287°F. However, if one repressures the formation to 1,000 psia by steam injection it is possible to heat the reservoir to 540°F.

This phase terminates when steam breaks into the second row of producers from the injection rows, namely rows 3 and 7 of FIG. 1. At this time steam and water have invaded more of the vertical interval as shown by the dashed boundary lines of FIG. 2 and designated as S2 and W2. The vertical conformance of the injected fluids is still very poor.

Since producing wells adjacent to injection (rows 2, 4, 6, and 8) have been shut in during the second phase, the reservoir pressure is increased as shown by the pressure profile 2 of FIG. 3. The reservoir temperature is simultaneously increased with pressure according to the relations of FIG. 4. During the entire injection periods steam of good quality such as 80 percent is used for injection. As the injection pressure increases with reservoir pressure increased the steam generator conditions are adjusted to maintain high quality steam output. The third phase begins as injection into wells of rows 1, 5, and 9 and production from wells in rows 3–7 is continued. Over injection is stepped up by adding more steam generator capacity and/or curtailing production.

The reservoir pressure is increased to a very high value such as the original pressure or near that value such as shown by profile 3 of FIG. 3. This phase further increases the reservoir temperature.

At the end of this period the injected fluids have not invaded the entire vertical interval. The zone invaded by steam has not increased appreciably over that zone at the end of the second phase (S2 of FIG. 2). The zone invaded by water has increased as shown by the dotted boundary denoted by W3 (FIG. 2). Considerable more energy has been added to the formation in the form of heat and pressure. The last (fourth) phase of the method of our invention comes when the pressure in the reservoir has reached the desired level. At this time one would blow down the reservoir by stopping steam injection and producing all wells at maximum capacity. Having a very large quantity of heat in the formation at high pressure, this procedure would move oil at extremely high rates and expel the majority of the oil through producing wells to the surface. Sufficient energy would have been retained in the reservoir rock for flashing all or most of the water in the formation to steam. This would include not only injected water as water of condensation from the steam, but also all of the virgin connate water from the surfaces of the rock. Flashing the connate water that wets the rocks surfaces would move oil from the pendular ring sections of the formation to producing well bores. Oil from these sections of the formation cannot be displaced and moved to producing well bores by any other mechanism.

The following table shows the volumetric expansion that one could obtain by flashing reservoir water to steam.

<table>
<thead>
<tr>
<th>Prior to Pressure Blow Down (All Water)</th>
<th>Pressure (psia)</th>
<th>Temp. (°F)</th>
<th>Specific Volume (ft³/lb)</th>
<th>Volume Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>545</td>
<td>0.0214</td>
<td></td>
<td>8.39/0.0214 = 391</td>
</tr>
</tbody>
</table>

Flashing water to steam between the two conditions noted above provides a 391 fold increase in volume. This tremendous expansion drives substantially all of the oil to producing well bores and to the surface. During most of this period of oil production it is not necessary to lift the oil because the wells flow due to the enormous expansion of water to steam. This period of pressure blow down with extremely large expansion of water by flashing to steam should be considered as boiling the oil out of the formation. A significant improvement over steam flooding is that steam vapor is in situ generated throughout the entire formation and at all matrix surfaces.

Although sufficient pressure would exist to flow the wells, another embodiment of our invention comprises using high volume bottomhole pumps in the production wells to increase the pressure differential within the formation (during the production phase) and thus increase the flashing rate.

The steam to be used in our invention is preferably of the highest quality available. The higher the steam quality the less steam required to raise the reservoir to a desired temperature. The steam may even be superheated. However, due to limitations which exist in most oil field operations the method of our invention may be performed with steam of lower quality, though at a correspondingly reduced efficiency.

The maximum pressure which may be attained during the steam injection step of our method is the overburden. This is the pressure exerted by the weight of the minerals and fluids which overlie a reservoir. If this pressure is exceeded the formation may separate or fracture causing steam to travel rapidly out in the reservoir, thus losing valuable out near the injection well. The overburden pressure of an oil reservoir is a function of the geologic peculiarities of an area. Typically it will range from as low as 0.5 pounds per square inch per foot of reservoir depth from the surface to as high as 2.0 pounds per square inch per foot of reservoir depth from the surface. It is within the capability of one skilled in the oil production art to determine the overburden pressure. The steam must, of course, be injected at a pressure at least in excess of the pressure existing in the reservoir before injection begins.

The rate of production during the production or blowdown stage of the method of our invention is only limited by the physical capabilities of the producing equipment. The faster blowdown is accomplished the faster flashing will occur in the reservoir. Also, greater volumetric increase in the reservoir will occur which will cause more efficiency of oil production.

We claim:
1. In a method of recovering oil from an oil bearing reservoir containing a finite water saturation which lacks sufficient energy to produce applicable oil by natural means, wherein there is at least one input well and one output well penetrating and in communication with said reservoir, and wherein said method includes the steps of injecting steam into the reservoir through the input wells at a rate exceeding the volumetric production from the output wells thereby increasing the temperature and pressure in substantially all of the reservoir to a point whereby the flash point of water in the reservoir is above the original pressure before injection began, stopping injection of steam and producing the output wells at maximum rate so that the pressure in the reservoir drops to the flash point of the water present in the reservoir or below and continuing to produce the output wells at any desired rate.

2. The method of claim 1 wherein the input and output wells are located so as to perform a line drive flood.

3. The method of claim 2 wherein prior to steam injection the oil bearing reservoir is depleted in energy from its original state.

4. The method of claim 2 wherein the reservoir was originally lacking in sufficient pressure to produce appreciable oil by natural means.

5. The method of claim 1 wherein the input and output wells are located so as to perform a pattern flood.

6. The method of claim 5 wherein prior to steam injection the oil bearing reservoir is depleted in energy from its original state.

7. The method of claim 5 wherein the reservoir was originally lacking in sufficient pressure to produce appreciable oil by natural forces.

8. The method of claim 1 wherein the production wells utilize bottomhole pumps to increase the rate of production during the producing stage.

9. The method of claim 1 wherein the injected steam is superheated.