Dec. 15, 1959

S. S. PRENTISS

RECOVERY OF HYDROCARBON FROM OIL SHALE ADJOINING A PERMEABLE OIL-BEARING STRATUM

Filed March 8, 1957

FIG. 1

FIG. 2
RECOVERY OF HYDROCARBON FROM OIL SHALE ADJOINING A PERMEABLE OIL-BEARING STRATUM

Spencer S. Prentiss, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Application March 8, 1957, Serial No. 644,764

2 Claims. (Cl. 262—3)

This invention relates to a process for recovering hydrocarbons from an underlying formation including an oil shale stratum lying adjacent a permeable or porous oil-bearing formation.

Large deposits of oil in the form of oil shale are found in various sections of the United States and, particularly, in Colorado and surrounding States. Various methods of recovery of oil from these shale deposits have been proposed and the principal difficulty with these methods is the high cost which renders the recovered oil too expensive to compete with petroleum crudes recovered by more conventional methods. The in situ retorting of oil shale to recover the oil contained therein is made difficult because of the nonpermeable nature of the oil shale and the difficulty of applying heat thereto without extensive mining or drilling operations. The mining and removal of the oil shale for retorting of the shale in furnaces outside the formation is commercially uneconomical in most cases.

Accordingly, it is an object of the invention to provide a process for recovery of hydrocarbon from an oil shale stratum lying adjacent a permeable or oil-bearing stratum. Another object is to provide a process for in situ retorting of oil shale utilizing the heat of combustion of oil in an adjacent permeable stratum as the heat for the retorting step. A further object of the invention is to provide an economical and efficient process for recovery of hydrocarbon from oil shale deposits. Other objects of the invention will become apparent from a consideration of the accompanying disclosure.

The broadest aspect of the invention comprises establishing and maintaining a combustion zone in an oil-bearing porous or permeable stratum lying adjacent an oil-bearing shale so as to retort the shale and distill valuable hydrocarbon therefrom by means of the heat of combustion of hydrocarbon in the permeable stratum thus heat transfer from the permeable hot stratum to the adjacent shale. In one embodiment of the invention, the shale stratum is fractured in a generally horizontal plane parallel to the permeable oil-bearing stratum and is propped by conventional means so as to maintain the resulting fractures in an open position. This facilitates retorting and recovery of hydrocarbons from the shale thru perforations in the casing of the borehole thru which the combustion is established. It is also feasible to fracture the permeable oil-bearing stratum at one or more levels so as to facilitate the in situ combustion and to the formation in this formation as well as recovery of oil therefrom.

A more complete understanding of the invention may be had from a consideration of the accompanying schematic drawing of which Figure 1 is an elevation, partially in section, of an underground formation in which the invention is applicable and Figure 2 is a plan view of a 5-spot well pattern suitable for oil recovery from the formation shown in Figure 1.

Referring to Figure 1, oil-bearing shale formations or strata 8 and 9 overlay and underlie permeable and porous oil-bearing stratum or formation 10. Numeral 11 designates fractures formed in the various strata. The strata are penetrated by boreholes 12 and 14 which are usually protected by casing 15. A tubing 16 in borehole 12 is provided with a burner 18 or other means for initiating combustion in the oil bearing formation surrounding the borehole. Well 14 is provided with tubing 20 which may be utilized for injecting air or for the recovery of fluid hydrocarbons or both during different phases of the process. Valved conduits 22 and 24 are connected with the well head (only 1st casing 15) to provide means for introducing and withdrawing fluids to and from the boreholes. Additional conduits 23 and 25 may also be used for the purpose of introducing and withdrawing fluids to and from the boreholes. Perforations 21 in the casings are made in conventional manner to facilitate injection and withdrawal of fluids to and from the producing strata.

In operation of the process utilizing the arrangement shown in Figure 1, combustion is initiated in the formation adjacent gas burner 18 in borehole 12 by burning a gas such as propane in said burner so as to bring the temperature of the formation up to combustion supporting temperature and injecting air into the heated area thru line 22 or 23 leading into borehole 12. Of course, other means may be utilized for establishing combustion in the permeable oil bearing formation around borehole 12. The temperature of the air may be elevated before injection so as to facilitate the heating of the formation as an aid in combustion, or cooled to control the temperature in the formation where such is necessary.

In formations which are not susceptible to plugging during direct injection of air and advancing of the combustion front, this technique may be followed to drive the combustion front to one or more surrounding wells 14. In most formations direct injection of air and advancement of the combustion front build up a wall of high viscosity hydrocarbon in front of the advancing combustion front and it is necessary to utilize inverse air injection thru wells 14 in order to avoid plugging of the permeable sand or stratum thru which the fluids must pass. If inverse air injection is to be utilized, a substantial combustion zone 26 is established and the injection of air is then transferred from borehole 12 to borehole 14 so as to advance the combustion front thru the injection well countercurrently to the flow of air. At an intermediate stage of the process, the combustion front is in the vicinity of 28.

With continued inverse air injection, combustion zone 28 advances thru the permeable formation leaving a carbonized residue therein and arriving at the injection wells 14. With continued air injection thru wells 14, the combustion front is reversed in direction and moves back thru the formation to well 12 around which combustion was initiated, feeding on the carbon residue left in the formation during the inverse air injection phase.

During the movement of the combustion front thru the permeable oil-bearing stratum between well 12 and wells 14, high temperatures are developed which heat up the formation and because of the heat differential between the permeable formation and the adjacent shale formations a tremendous amount of heat is imparted to the latter so that oil or kerogen deposited in the shale is reoriented and distilled thru the permeable formation and also into the fractures in the shale so that produced fluids are driven thru the perforations 21 into casings 15 from which they are recovered in conventional manner as by pumping, application of vacuum, etc. As the kerogen is driven from the shale, the residual structure becomes porous and eventually the shale formation is rendered permeable from the original permeable stratum to the fractures in the shale,
which facilitates distillation and heat transfer by passage of hot gases thru the formation from the combustion area. The carbonized residue deposited in the shale structure is also susceptible to combustion and the combustion zone spreads from the permeable oil-bearing stratum into the now permeable shale structure so as to drive additional hydrocarbon material from the shale structure.

It is also feasible to utilize alternate direct and inverse air injection in moving the combustion zone or front thru the permeable oil-bearing stratum. This technique comprises driving the combustion zone by direct air injection until the permeability decreases appreciably then moving the front by inverse air injection so as to establish high permeability and then reestablishing direct air injection until permeability is again substantially decreased, etc.

Figure 2 shows the relative positions of wells 12 and 14 in a 5-spot well pattern and the position of combustion zone 28 at an intermediate stage of the process.

In situ combustion recovery of hydrocarbons in accordance with the invention, the combustion supporting gas is usually air but air may be either increased or decreased in oxygen content, as by the mixing of combustion gas or oxygen therewith, where conditions warrant. While Figure 1 shows a porous oil bearing formation sandwiched in between two impermeable shale strata, it is to be understood that the invention is also applicable to the production of shale oil from strata in which shale is both overlain and underlain by a porous oil bearing stratum. In this type of structure production of oil from the porous strata by in situ combustion transfers heat into the shale formation from both above and below.

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 recovering fluid hydrocarbons from an oil-bearing impermeable shale and from an adjoining permeable oil-bearing stratum which comprises fracturing said shale horizontally in at least one level therein so that the resulting fractures connect with a production borehole therein; initiating combustion in said stratum around an ignition borehole therein and driving the resulting combustion front thru said stratum to an injection borehole therein by inverse air injection thru said injection borehole whereby heat of combustion is passed directly into the adjoining shale and kerogen therein is fluidized and driven therefrom into said production borehole, rendering said shale permeable from said stratum to said fractures; as said combustion front reaches said injection borehole, continuing the injection of air thru said injection borehole so as to drive said front back thru said stratum, feeding on the carbon residue left by the first burn thru so as to further heat said shale and cause hot gases to pass thru the permeable shale into said fractures, thereby producing additional hydrocarbons therefrom; and recovering the produced hydrocarbons from said shale and said stratum.

2. The process of claim 1 wherein the combustion zone is driven into the permeable shale, thereby producing additional hydrocarbons therefrom.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,422,204</td>
<td>Hoover et al.</td>
<td>July 11, 1922</td>
</tr>
<tr>
<td>2,584,605</td>
<td>Merriam et al.</td>
<td>Feb. 5, 1952</td>
</tr>
<tr>
<td>2,584,606</td>
<td>Merriam et al.</td>
<td>Feb. 5, 1952</td>
</tr>
<tr>
<td>2,596,845</td>
<td>Clark</td>
<td>May 15, 1952</td>
</tr>
<tr>
<td>2,718,263</td>
<td>Hellman et al.</td>
<td>Sept. 20, 1955</td>
</tr>
<tr>
<td>2,734,579</td>
<td>Elkins</td>
<td>Feb. 14, 1956</td>
</tr>
<tr>
<td>2,780,449</td>
<td>Fisher et al.</td>
<td>Feb. 5, 1957</td>
</tr>
<tr>
<td>2,793,696</td>
<td>Morse</td>
<td>May 28, 1957</td>
</tr>
<tr>
<td>2,818,118</td>
<td>Dixon</td>
<td>Dec. 31, 1957</td>
</tr>
</tbody>
</table>