SINGLE WELL BACKFLOW IN SITU COMBUSTION PROCESS

5 Claims, No Drawings

SANCTIONS: A method is disclosed for producing petroleum by igniting a reservoir containing a pressurized combustion-supporting gas previously placed in said reservoir by introduction through a production well and recovering petroleum from the well. Also a method is disclosed for repeating the production method by self-ignition of the reservoir through the subsequent introduction of an additional quantity of combustion-supporting gas.
SINGLE WELL BACKFLOW IN SITU COMBUSTION PROCESS

This invention relates to the production of petroleum by introducing a pressurized combustion-supporting gas into a reservoir through a production well, terminating the introduction of gas, igniting the reservoir, and then recovering petroleum through the production well. In another aspect this invention relates to repeating the above production method by self-ignition of the reservoir through subsequent introduction of additional quantities of combustion-supporting gas.

It is known that in many petroleum-bearing reservoirs only a small portion of the petroleum is recovered by primary recovery techniques which depend on natural gas or water pressure and/or gravity in the reservoir system to flow the petroleum into the borehole. When the pressure drops because of the removal of some of the petroleum or the petroleum is too viscous to be removed by these natural pressures in the reservoir system, primary recovery is not possible. Since there are still substantial quantities of petroleum remaining in the reservoir, supplemental recovery techniques are often employed to recover additional petroleum for the reservoir.

These supplemental techniques are sometimes referred to as "secondary recovery methods" and a useful dichotomy of these secondary methods are those involving "drives," such as waterfloods, and those involving backflow where the injection and recovery are accomplished from the said individual borehole. In the case of drives, spaced wells are used and the petroleum is driven by injecting fluid into the reservoir at one location to create a pressure differential that causes fluid in the reservoir to move into a spaced recovery location. In backflow techniques, after fluid has been injected into the reservoir, the injected fluid and the petroleum is backflowed into the same well at the same location that was used for the injection of the fluid.

Each of the backflow and drive techniques has certain advantages over the other. The drive techniques have been determined to be more efficient in many instances in that the fluid is continually moved in the direction of the gradient that is first established within the reservoir; whereas, in the backflow techniques, the injected fluid must first bypass the oil and then displace the oil back into the opening through which the fluid was injected. The principal disadvantage of drives are the expense of drilling of additional wells, and locating such wells so that they encounter the same reservoir and the space between the wells is free of discontinuities caused by impermeable streaks, faulting and the like which would render the drives inoperable. While the backflow techniques avoid the above-mentioned disadvantages of the drives, in many instances the conventional backflow techniques have not been effective enough to offset the additional oil recovery obtained by drives. Thus, this invention is superior over the prior art in that an extremely effective and efficient single well backflow technique is provided.

In summary, one embodiment of this invention comprises introducing pressurized combustion-supporting gas into a reservoir, terminating the introduction of the gas, then igniting the reservoir so as to form an expanding combustion zone and then reducing the well pressure so that the pressurized combustion-supporting gas moves toward and supports combustion of the fire front of the expanding combustion zone and finally recovering petroleum from the well. Another embodiment of this invention comprises performing the above steps and, in addition, introducing, while the combustion zone remains in self-igniting condition, the additional quantity of pressurized combustion-supporting gas into the reservoir so as to initiate additional combustion, then terminating the introduction of gas and finally recovering petroleum from the well. In still one further embodiment of the invention, the combustion-supporting gas is introduced at sufficient pressure to fracture at least a portion of the reservoir when the reservoir is composed at least partially of impermeable materials.

Accordingly, it is an object of this invention to recover petroleum. Additionally, it is an object of this invention to reduce production of combustion-supporting gas by more efficient secondary recovery through a single well. Additionally, it is an object of this invention to recover petroleum from impermeable reservoirs containing petroleum. Other objects, advantages, and features of this invention will be readily apparent to those skilled in the art from the following description, drawings, and appended claims.

One embodiment of this invention can be practiced in any reservoir containing petroleum where the reservoir is not in an initial self-igniting condition. Thus, the temperature of the reservoir should be sufficient low to permit very little, if any, oxidation during the introduction of combustion-supporting gas. In other words, in order to carry out the process of this embodiment of my invention, forward combustion during gas introduction should not occur. The maximum temperature that can be tolerated without the occurrence of forward combustion to an objectionable degree will vary with many factors, the most significant being the type of hydrocarbons present. In general, however, reservoir temperatures of the order of 200° F. or even higher can be tolerated without appreciable adverse effects.

This invention can be practiced in a petroleum-containing reservoir regardless of its initial permeability. If the reservoir is below the desired permeability, then the pressure of the introduced combustion-supporting gas is increased to a sufficient level to cause sufficient fracturing within the reservoir to produce the desired permeability. If the desired reservoir contains sufficient permeability for the practice of this invention, then, of course, no fracturing is necessary.

The combustion-supporting gas of this invention can comprise any gas capable of supporting combustion. Specifically, an oxygen-containing gas such as air is satisfactory.

The pressurized combustion-supporting gas introduced into the reservoir through the production well can be introduced by any conventional means desired. Either a single compressor or a bank of compressors can be utilized depending, of course, upon the size of the reservoir, the permeability of the reservoir, the pressure of the reservoir, the use of fracturing or nonfracturing pressure, and the like. According to this invention the combustion-supporting gas must be introduced into the oil well at a sufficient pressure to flow into the reservoir, or, stated another way, the gas pressure must be substantially higher than the pressure of the reservoir.

After the pressurized combustion-supporting gas has been introduced into the reservoir at sufficient pressure to permeate the reservoir, the introduction of the gas is terminated and pressure is maintained on the well and consequently on the reservoir. Typically, the gas introduction step may be continued until pressures in the range of 300 to 3000 p.s.i.g. exist in the reservoir although higher or lower pressures are sometimes satisfactory.

Thereafter the reservoir is ignited from within the production well to form a combustion zone with a fire front expanding from the production well into the reservoir. Ignition can be accomplished in any manner known in the art, specifically, by a chemical, electrical, or gas fired bottom hole igniter.

After the reservoir containing the combustible hydrocarbons and pressurized combustion-supporting gas is ignited and expanding fire front established, the pressure within the well is reduced to less than formation pressure so that the pressurized combustion-supporting gas moves toward the well. As the gas moves toward the well, it supports combustion of the combustible hydrocarbons in the reservoir and the flow of gas causes the fire front to expand into the reservoir thus creating an expanding combustion zone. Thus, the production of the well is increased by driving petroleum into the heated burned-over region of the combustion zone and into the well bore where the petroleum is subsequently recovered.

Eventually, of course, with the passage of time and the consumption of the combustion-supporting gas the pressure in the
burned-out combustion zone will become so small that the rate of petroleum recovery diminishes significantly. Thus, another embodiment of the invention providing for the repeated or cyclic practice of the invention can be initiated.

This embodiment of the invention broadly comprises repeating the above cycle one or more times. According to this embodiment, the steps beginning with the initial introduction of the combustion-supporting gas and ending with the recovery of petroleum are repeated. In order to practice this embodiment of the invention the recovery of produced petroleum is then terminated from the well upon an indication that the pressure in the reservoir has become so low as to substantially reduce the efficiency of recovering petroleum.

Next, an additional quantity of combustion-supporting gas is introduced into the reservoir via the well; however, in this embodiment the reservoir must be in a self-igniting condition. The self-igniting condition results from the fact that the initial combustion heated the reservoir to a temperature which will spontaneously ignite hydrocarbon material in the presence of additional combustion-supporting gas. Although the temperature at which this ignition will occur varies widely depending upon such factors as the specific composition of the combustion-supporting gas the composition of the hydrocarbons in the reservoir, generally the reservoir temperature as should be above 200°F.

Thus, according to this embodiment of the invention the combustion-supporting gas introduced in the reservoir for the second or any subsequent time proceeds through the burned-out region of the combustion zone and past the fire front of the combustion zone and into the unburned portion of the reservoir. Thus, the gas must be introduced at a pressure substantially higher than exists in the unburned portion of the reservoir beyond the expanding combustion zone. The gas must proceed through the burned-out region and through the fire front in order to prevent excessive forward burning. The velocity that is necessary, of course, depends on many factors such as the composition of the hydrocarbons in the reservoir, the composition of the combustion-supporting gas, the permeability of the reservoir, and the like. Generally, velocities of combustion-supporting gas from 20×10² to 20×10⁴ standard cubic feet per hour per foot of formation are required and pressure causes these gas velocities to flow through the fire front without substantial forward burning. Stated another way, according to this invention the gas pressure must be so high that it goes through the fire front of the combustion zone at a much faster rate than it can be consumed by the combustion occurring at the fire front.

According to this embodiment of the invention the second or subsequent introduction of combustion-supporting gas is then terminated and pressure retained on the well. Subsequently, pressure is relieved and petroleum produced by backflow. Thus, the gas that has been forced through the burned-out region and through the fire front and into the reservoir then flows back toward the well and supports combustion at the fire front of the self-igniting combustion zone. Consequently, the fire front continues to expand as a result of combustion being supported by the second introduction of combustion-supporting gas and the entire combustion zone expands farther into the reservoir, thus permitting additional petroleum to be recovered.

Of course, it is fully within the scope of this invention to repeat this embodiment of the invention as many times as may be practical in the particular reservoir or as many times as may be desired by one practicing this invention. The frequency and relative length of the "on-off" periods of introduction of combustion-supporting gas are variable and their optimum value depends on many variables such as the characteristics of the hydrocarbons in the reservoir, the rate of introduction of gas, the composition of the gas, and the like. Quite often, from weeks, or months may lapse between periods of gas introduction without the reservoir rock temperatures falling below the critical self-ignition temperature level. Ordinarily, the introduction of combustion-supporting gas can take several weeks and since the major portion of the recovery of petroleum usually takes place within a few weeks after the reservoir is ignited, in a typical operation about equal on and off periods are used, each of which is several weeks in duration.

As noted, reservoir permeability is not a limitation in this invention because the invention does not contain sufficient permeability to practice the invention, the permeability may be increased by fracturing at least a portion of the formation by increasing the pressure of the introduced gas. As noted, the gas must go through the self-igniting combustion zone fairly rapidly in the recycle embodiment of the invention, and as explained, very little forward burning must occur when the combustion-supporting gas proceeds through the fire front. Thus, sufficient permeability is required in order to permit the gas to move through the fire front at the required velocity. Generally, the invention can be practiced in reservoirs that contain a permeability from about 5 to about 10 millidarcys. However, in some instances, this permeability may be insufficient and the permeability can be increased by fracturing at least a portion of the formation.

The amount of fracture can vary over a wide range and, generally, any fracture that will produce sufficient permeability to practice the invention is satisfactory. Specifically, a minor portion of the reservoir or a substantial portion of the reservoir can be fractured and, more specifically, uncontrolled fracture may be necessary in some reservoirs consisting of impermeable material such as oil shale.

Of course, it is fully within the scope of this invention to utilize the fracturing embodiment of this invention either with the single sequence of steps disclosed in one embodiment or the repeated cyclic sequence of steps disclosed in another embodiment. Thus, this invention is broadly applicable to the recovery of petroleum from a reservoir.

Various modifications of this invention can be made in view of the foregoing disclosure and the appended claims without departing from the spirit or scope thereof.

I claim:

1. In a subterranean reservoir containing petroleum which is penetrated by at least one production well, a method of recovering petroleum from said reservoir through a single production well comprising the steps of:

a. introducing combustion-supporting gas through said single production well into the reservoir at substantially higher pressures than the pressure of the reservoir in the region of said single production well;

b. terminating the introduction of combustion-supporting gas through said single production well;

c. thereafter igniting said reservoir from within said single production well to from a combustion zone, said ignition being effected in the substantial absence of introduction into the reservoir in the region of said single production well of additional combustion-supporting gas from offset wells;

d. reducing the pressure within said single production well to less than formation pressure so as to allow petroleum and the previously introduced combustion-supporting gas to flow toward said single production well in the substantial absence of introduction into the reservoir in the region of said single production well of additional combustion-supporting gas from offset wells; and

e. recovering petroleum from the reservoir through said single production well.

2. The method of claim 1 wherein said combustion-supporting gas is introduced through the production well into the reservoir at a sufficient pressure to fracture at least a portion of said reservoir.

3. A method of recovering petroleum from a subterranean reservoir penetrated by a production well comprising the steps of:

a. introducing combustion-supporting gas through the production well into the reservoir at substantially higher
5. said combustion-supporting gas to flow through the fire front at a rate faster than it can be consumed by combustion at said fire front;

6. terminating the introduction of combustion-supporting gas through the production well;

4. The method of claim 3 wherein said combustion-supporting gas is introduced through the production well into the reservoir at a sufficient pressure to fracture at least a portion of said reservoir.

5. The method of claim 3 wherein said gas velocity is in the range of 20×10¹ to 20×10⁴ standard cubic feet per hour per foot of formation.