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H. O. DIXON

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PREVENTION OF WELL BORE CAVING DURING IN SITU COMBUSTION

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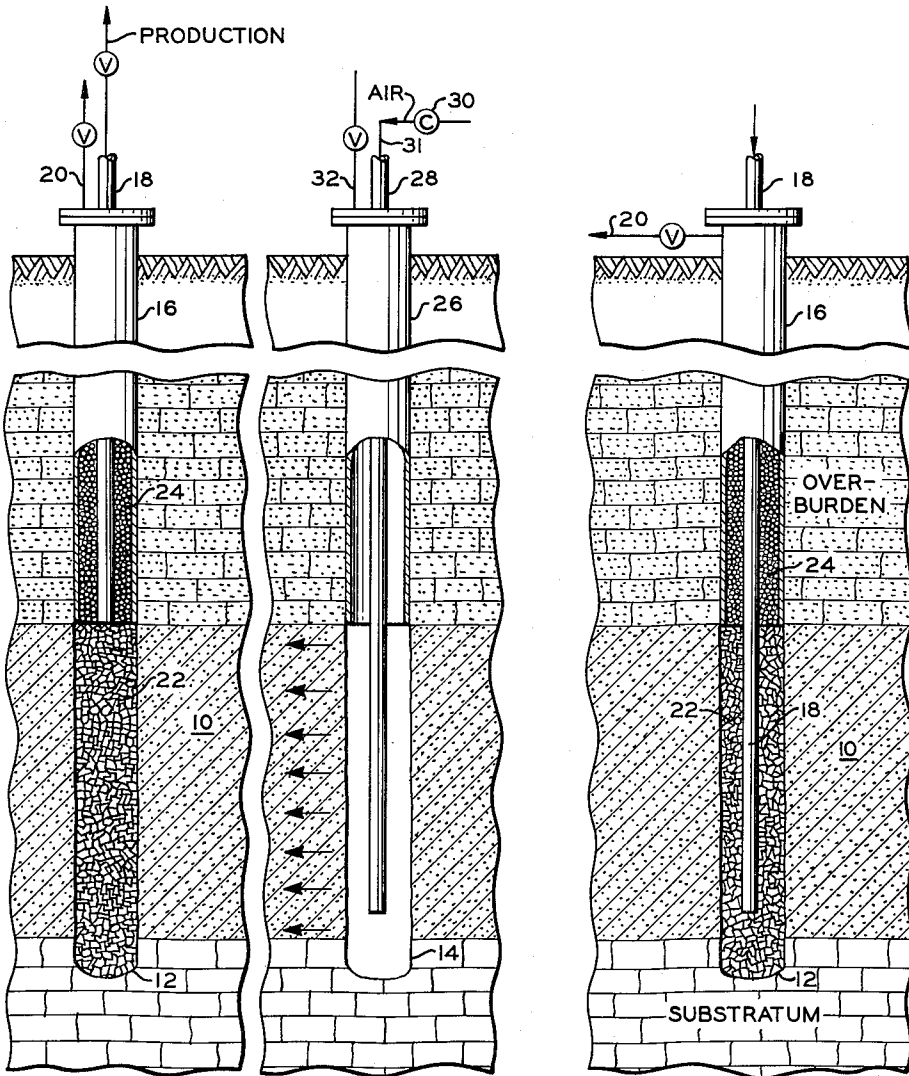


FIG. 1

FIG. 2

INVENTOR.
H. O. DIXON

BY

Hudson & Young

ATTORNEYS

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PREVENTION OF WELL BORE CAVING DURING IN SITU COMBUSTION

Henry O. Dixon, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

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This invention relates to a process and apparatus for initiating in situ combustion in a carbonaceous stratum.

In situ combustion in the recovery of hydrocarbons from underground strata containing carbonaceous material is becoming more prevalent in the petroleum industry. In this technique of production, combustion is initiated in the carbonaceous stratum and the resulting combustion zone is caused to move through the stratum by either inverse or direct air drive whereby the heat of combustion of a substantial proportion of the hydrocarbon in the stratum drives out and, in the case of inverse drive, upgrades a substantial proportion of the unburned hydrocarbon material. The hydrocarbon material is upgraded by thermal and catalytic cracking in contact with the hot rock or sand in the formation as it passes thru the burned out stratum behind the combustion front.

The ignition of carbonaceous material in a stratum around a borehole therein, followed by injection of air through the ignition borehole in the stratum, constitutes a direct air drive process for effecting in situ combustion and recovery of hydrocarbons from the stratum. In this type of operation the stratum frequently plugs in front of the combustion zone because a heavy viscous liquid bank of hydrocarbon collects in the stratum in advance of the combustion zone which prevents movement of air to the combustion process. To overcome this difficulty and to permit the continued progress of the combustion zone thru the stratum, inverse air injection has been resorted to. By this technique, a combustion zone is established around an ignition borehole by any suitable means and air is fed thru the stratum to the combustion zone from one or more surrounding boreholes. Most of the techniques utilized are also being applied to the gasification of coal veins.

In field operation in the production of hydrocarbons from tar sands and the like, by in situ combustion, heating of the well bore to ignite the tar sand, particularly when utilizing charcoal, coal, or coke, has caused borehole caving, as well as sloughing off of sand therein after ignition. This invention is concerned with a method or process for eliminating borehole caving and minimizing the production of sand with produced hydrocarbons after ignition.

Accordingly, it is an object of the invention to provide a process and apparatus for igniting a carbonaceous stratum and establishing in situ combustion therein which prevents borehole caving. Another object is to minimize the production of sand with produced hydrocarbons after ignition is effected. A further object is to provide a process and apparatus which minimizes the possibility of explosion in the well bore and helps control well bore fires. Another object is to provide a process and apparatus for production of hydrocarbons by in situ combustion which upgrades the produced hydrocarbons. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises raising the heat of a carbonaceous stratum around a borehole therein

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to ignition temperature by burning a bed of particulate solid carbon in the borehole within said stratum, which bed initially extends from the bottom of the stratum at least to the top thereof, whereby the top of said bed progressively descends the bore; continually filling with particulate refractory material the void left by the receding bed until the bed is completely burned and the borehole within said stratum is filled with said material; and contacting the hot stratum adjacent the borehole with O₂ so as to ignite said stratum and establish in situ combustion therein. It is preferred to utilize charcoal as the bed of carbon and the preferred form of charcoal comprises briquettes; however, particulate coal, coke, and other solid carbonaceous materials may be utilized, but other particulate carbonaceous solids are to be considered operable. The discussion herein will be limited to charcoal.

The particulate refractory material utilized to fill the void left by the receding bed comprises crushed firebrick, stone, coarse sand, metal balls, ceramic pebble heater pebbles, Raschig rings, etc. The preferred refractory filler comprises ceramic pebble heater pebbles, many of which are capable of withstanding temperatures well over 3,000° F. A common pebble heater pebble consists principally of alumina with minor amounts of mullite and other materials which are considered impurities or are added to the alumina to increase the strength and breakage resistance of the pebbles. Any particulate solid refractory material which withstands the temperature in the borehole without fusing or disintegrating is suitable for use in the process; however, the preferred refractory material comprises ceramic pebble heater pebbles which are small spheres of a size within the range of about 1/4 to 1" in diameter. Small spheres of this character readily fill the void left by the receding charcoal and do not bridge the borehole.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which Figure 1 is an elevation in partial section of an arrangement of apparatus in a carbonaceous stratum for effecting the invention, and Figure 2 is a similar elevation showing a modified arrangement of apparatus.

Referring to Figure 1, a carbonaceous stratum 10 is penetrated by an ignition borehole 12 and an injection borehole 14. Borehole 12 is provided with a casing 16, extending from the well head to the top of stratum 10, and with a tubing string 18, extending to about the same level. A line 20 connects thru the well head with the casing tubing annulus. The borehole 12 within stratum 10 is packed with a bed of charcoal briquettes 22 on top of which is positioned a bed of refractory pebbles 24, which will fill borehole 12 to the level of the top of stratum 10, upon consumption of bed 22 by combustion. Borehole 14 is provided with a casing 26 and with tubing string 28. A compressor or other air injection device 30 is provided in line 31 which leads to tubing 28. Line 32 connects thru the well head with the casing-tubing annulus.

Figure 2 shows an arrangement in the ignition borehole similar to that of Figure 1 but, here, tubing string 18 extends substantially to the bottom of the stratum.

In operating with the arrangement shown in Figure 1, charcoal bed 22 is ignited by conventional means, as by setting off a self-sustaining charge such as a fusee, a railroad flare, or squib therein and injecting air into the charcoal so as to effect combustion thereof. Another method comprises injecting a suitable fuel gas, such as natural gas or propane, thru tubing 18 and air thru the annulus and igniting the mixture at the lower end of tubing 18 by means of an electric heater or spark plug (not shown). A preferred method comprises dropping a charge of burning charcoal or a lighted railroad flare down onto the bed

of charcoal before pebbles 24 are introduced and immediately injecting air or other combustion-supporting gas such as diluted air (with nitrogen, CO₂, combustion gas, etc.), oxygen-enriched air, or pure oxygen into the charcoal bed thru either tubing 18 or line 20 and, thereafter, introducing pebbles 24 to the casing-tubing annulus on top of bed 22. This may be done thru a suitable inlet in the well head (as thru line 20) by a process known as "lubricating" the pebbles in on top of the charcoal. It is also feasible to lower the required amount of pebbles in a wire basket on a cable to a position just above the charcoal bed and trip the bottom of the basket so as to release the contents onto the burning charcoal. During the charcoal burning phase of the operation, air may be supplied thru borehole 12 whereby the hot gases pass thru the stratum to borehole 14 and other surrounding boreholes, not shown, or the required oxygen for burning the charcoal may be supplied thru stratum 10 by injecting air thru a ring of surrounding boreholes 14, only one of which is shown. By feeding the combustion in borehole 12 thru the stratum, an inverse in situ combustion process is automatically initiated when the wall of bore hole 12 reaches ignition temperature. Continued injection of air causes the combustion zone around borehole 12 to move thru the stratum toward the injection boreholes and production is recovered thru tubing string 18.

During the combustion of the charcoal the top of the bed 22 recedes to the bottom of the borehole and, as it does, the bed of pebbles 24 fills the void left by the charcoal thereby preventing caving and spalling on the wall of the borehole within stratum 10. When the charcoal is completely consumed the bed of ceramic material 24 occupies the position in the borehole originally occupied by charcoal bed 22.

The bed of pebbles in the well bore not only prevents caving and sloughing off of sand, but it also reduces the danger of explosion in the well bore. Another advantage lies in the upgrading effect of the ceramic material, such as alumina, on the hot hydrocarbon material driven out of the stratum thru the production borehole, wherein the pebbles function as a catalyst on the hot hydrocarbons. During the field tests in tar sands there have been substantial amounts of tar produced as heavy liquid hydrocarbon and with alumina pebbles in the well bore at the temperature of the effluent gases, this material is substantially upgraded thereby contributing materially to the process of the invention.

When utilizing the arrangement illustrated in Figure 2, after initiating combustion of the charcoal at the top of the bed and placing thereon a bed of pebbles, combustion is continued by either injecting air thru tubing 18 and withdrawing combustion gases thru line 20, or vice versa. In the first instance, the combustion area at the top of bed is moved downwardly therethru countercurrently to the upwardly moving air, while in the second instance, the combustion area is moved thru the stratum concurrently to the injected air. It is also feasible to initiate combustion in the entire charcoal bed by injecting a combustible mixture of fuel gas and air thru either line 20 or tubing 18 and igniting same by suitable means within the charcoal bed, thereafter injecting air into the charcoal or air containing a small amount of fuel gas such as 1 to 3 volume percent of propane. A preferred method comprises igniting the entire charcoal mass as aforesaid and feeding a portion of the required oxygen thru either line 20 or tubing 18 and another portion of the oxygen thru stratum 10 from a ring of surrounding boreholes. The flow air thru the stratum should be relatively slow so as not to effect too much cooling of the stratum being heated by the burning charcoal. It is desirable to initiate the injection of air thru the stratum at a slow rate during the last stages of heating, just before ignition temperature is reached, so that as ignition temperature is produced in the stratum the ignition of the carbonaceous material by the air passing thru the stratum is automatic or inherent.

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 method of preventing caving in a borehole during initiating of in situ combustion in a carbonaceous stratum around said borehole comprising placing a bed of particulate solid carbon in said borehole, filling the same at least to the upper level of said stratum; placing on top of said bed a bed of particulate refractory solids at least equal in volume to said borehole up to the top of said stratum; burning said carbon bed so as to raise the temperature of the carbonaceous stratum around said borehole to ignition temperature, whereby said refractory solids descend said borehole as carbon is consumed and occupy the borehole up to the top of said stratum, thereby preventing caving and spalling of the wall of said borehole; and contacting the hot stratum with O₂ so as to ignite same and establish in situ combustion therein.

2. The process of claim 1 wherein said carbon comprises charcoal.

3. The process of claim 2 wherein said charcoal is in the form of briquettes.

4. The process of claim 1 wherein said carbon is in the form of charcoal briquettes and said refractory solids comprise ceramic pebbles.

5. The process of claim 4 wherein said ceramic pebbles comprise alumina.

6. A process for initiating in situ combustion in a carbonaceous stratum around a borehole therein which comprises raising said stratum to combustion temperature by burning a bed of charcoal in said borehole within said stratum, which bed initially extends at least to the top of said stratum, whereby the top of said bed progressively descends said borehole; continually filling with particulate refractory material the void left by the receding charcoal bed until said bed is completely burned and the entire borehole within said stratum is filled with said material, thereby preventing caving and spalling of the wall of said borehole; and contacting the hot stratum adjacent said borehole with O₂ containing, combustion-supporting gas so as to ignite same and establish in situ combustion therein.

7. The process of claim 6 wherein said material comprises alumina pebbles.

8. The process of claim 6 wherein a bed of pebbles of a volume at least equal to the volume of said borehole within said stratum is positioned on top of said charcoal during the burning step.

9. The process of claim 6 wherein said O₂-containing, combustion-supporting gas is passed thru said stratum from an offset well to said borehole.

10. Apparatus for initiating in situ combustion in a carbonaceous stratum around an ignition borehole therein which comprises a casing in said borehole above said stratum terminating in a well head; a gas permeable bed of particulate carbon in said borehole sufficient to heat a section of stratum around said borehole at least to ignition temperature, said bed of carbon filling said borehole at least to the top of said stratum; a bed of particulate refractory material on top of the bed of carbon, said bed of refractory material having a volume sufficient to fill said borehole at least to the top of said stratum; means for feeding air to said bed of carbon; and means for withdrawing combustion gases from said borehole.

11. The apparatus of claim 10 wherein said carbon comprises charcoal briquettes.

12. The apparatus of claim 11 wherein said refractory material comprises ceramic pebbles.

13. The apparatus of claim 11 wherein said refractory material comprises alumina pebbles.

14. The apparatus of claim 10 wherein said means for feeding air to said bed of carbon comprises at least one

air injection borehole in said stratum spaced close to said ignition borehole and air injection means connected therewith.

15. The apparatus of claim 14 including an axial conduit extending into a lower section of said bed of carbon thru said well head. 5

References Cited in the file of this patent**UNITED STATES PATENTS**

2,670,047	Mayes	Feb. 23, 1954
2,793,696	Morse	May 28, 1957
2,880,803	Parker	Apr. 7, 1959