

Oct. 17, 1961

J. W. MARX ET AL

3,004,597

INITIATING IN SITU COMBUSTION IN A CARBONACEOUS STRATUM

Filed May 19, 1958

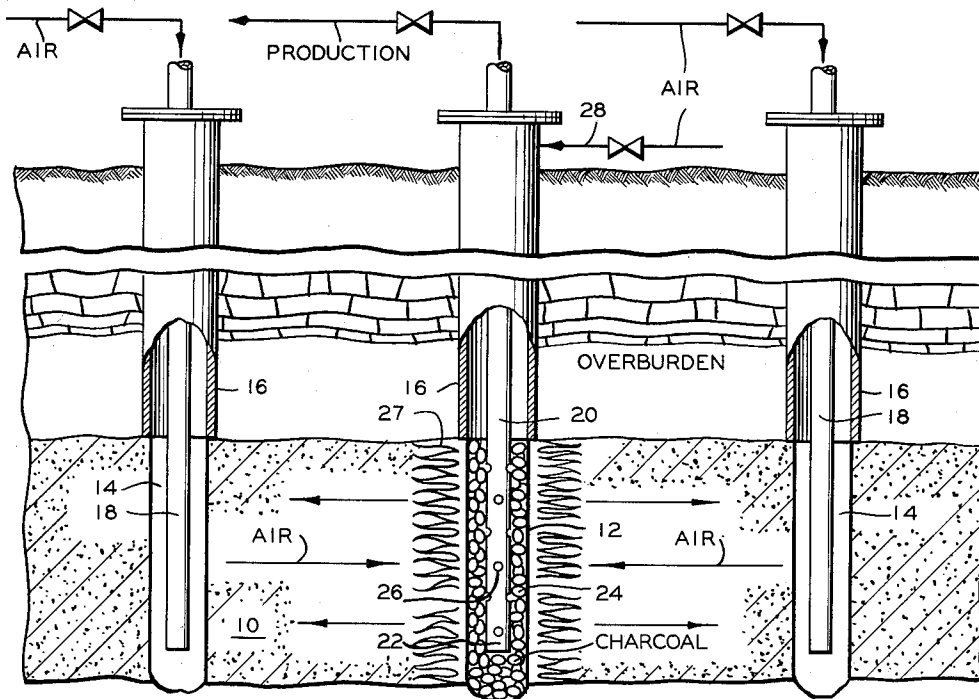


FIG. 1

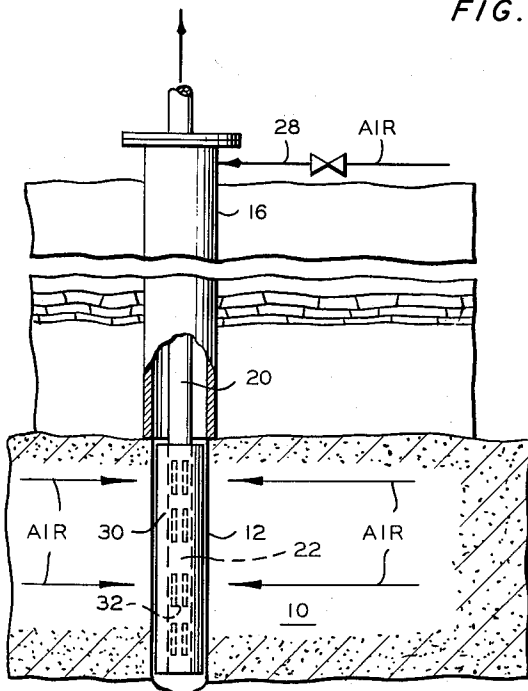


FIG. 2

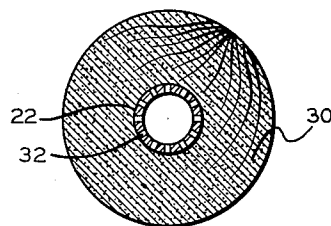


FIG. 3

INVENTORS
J.W. MARX
J.C. TRANHAM
H.W. PARKER

BY

Hudson & Young

ATTORNEYS

1

3,004,597

INITIATING IN SITU COMBUSTION IN A CARBONACEOUS STRATUM

John W. Marx, Joseph C. Trantham, and Harry W. Parker, Bartlesville, Okla., assignors to Phillips Petroleum Company, a corporation of Delaware
Filed May 19, 1958, Ser. No. 736,340
11 Claims. (Cl. 166-11)

This invention relates to a process for igniting and establishing in situ combustion in a permeable 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 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 through 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 through the stratum to the combustion zone from one or more surrounding boreholes.

In order to initiate in situ combustion in a carbonaceous stratum, such as an oil bearing sand or a porous coal vein or any petroliferous structure which is naturally porous or rendered permeable by fracturing, it is necessary to apply heat to the stratum until its temperature reaches or exceeds the ignition temperature of the combustible material in the stratum and then contact the hot stratum with O_2 . The heating may be accomplished in any of a number of ways such as by a gas fired downhole burner, an electric heater, or a mass of burning material positioned in the borehole. In these conventional methods of heating the stratum around a borehole air or other oxygen containing gas is injected thru the borehole into the stratum so as to carry heat thereto and bring the same to the required temperature for ignition. In using these methods the stratum adjacent the borehole is contaminated with combustion gases and ashes from the combustible material, when such is utilized. Another disadvantage lies in the overheating and fusing of the siliceous structure of the stratum so as to impair the permeability thereof. In some cases the overheating causes spalling and caving in the borehole within the stratum.

This invention is concerned with a method of igniting and establishing in situ combustion in a carbonaceous stratum while avoiding the disadvantages enumerated above.

It is accordingly, an object of the invention to provide an improved process for igniting a carbonaceous stratum around a borehole therein. Another object is to avoid overheating of a carbonaceous stratum during initiation of combustion therein. A further object is to provide a process for igniting a carbonaceous stratum utilizing burn-

2

ing charcoal which avoids blowing the charcoal out of the borehole. A still further object is to provide a process for igniting a stratum without contaminating the stratum with either ashes or combustion gases. Another objective of the process is to provide control of the burning rate of the charcoal. An additional object is to prevent soaking of the charcoal with formation water and maintain the charcoal in combustible condition. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises burning a porous combustible mass of fuel in a borehole in a carbonaceous stratum utilizing a supply of oxygen for the burning process passing into the borehole from the stratum. The usual source of oxygen is air, but, where the term air is utilized in this specification, it is to be understood that oxygen-enriched air, diluted air, or pure oxygen may be utilized, as long as the O_2 concentration in the gas is combustion supporting.

The combustible fuel is ignited by any suitable means and air is passed thru the stratum to the ignition borehole from at least one and preferably a plurality of air injection boreholes surrounding the ignition borehole and spaced therefrom a relatively short distance which permits injection of air into the ignition borehole without excessive injection borehole pressures. Usually a spacing in the range of several feet to 100 feet is feasible, although the injection boreholes may be closer or farther from the ignition borehole in some strata.

The preferred fuel comprises charcoal briquettes packed into the ignition borehole from the bottom level of the stratum to the top thereof. Charcoal in other forms may also be utilized so long as the charcoal mass is gas permeable. One desirable arrangement comprises a perforate section of tubing within the stratum connecting with an imperforate tubing string above the stratum, with an annular mass of charcoal briquettes or other particulate charcoal packed around the perforate tubing. The perforations in the tubing should, of course, be smaller than the particulate charcoal so as to avoid blowing the charcoal out thru the tubing when combustion supporting gas is injected into the borehole from the surrounding stratum and combustion gas is vented up the borehole.

Another desirable arrangement comprises a gas pervious mass of charcoal bonded together into a cylindrical form, slightly smaller than the borehole and casings thru which it is to be introduced to the stratum, which is supported on the lower end of a rod or tubing string. In case a tubing string is utilized to support the preformed charcoal cylinder the tubing within the charcoal may be perforate so as to permit recovery of the combustion gases thru the tubing string directly from the charcoal. In this embodiment of the invention the lower end of the charcoal mass is ignited by any suitable means such as an electric heating coil, powered from the surface, or by bottom hole batteries triggered by jarring, a vial of sodium peroxide embedded in the charcoal so that it breaks upon contact with the well bottom and ignites the charcoal, a thermite capsule, a fuse, etc.

Once the lower tip of the combustible rod or cylinder is burning, the whole assembly, including the rod and support means, may be raised or lowered so as to progressively ignite the stratum along any selected section thereof from top to bottom or vice versa. As the rod or cylinder burns away, additional rod is fed downhole. In utilizing inverse air injection thru the stratum, formation-produced air (air forced thru the stratum into the ignition borehole) is more than adequate to sustain the combustion, the excess being sufficient to initiate combustion within the stratum once the temperature has been raised to the ignition level. In this type of operation the resulting ash is blown out the production line with the exhaust gas and

3

does not contaminate the stratum. When direct injection of air thru the ignition borehole is utilized, the ash is deposited at the bottom of the borehole or on the face of the stratum. In either case, the glowing end of the rod can be made to traverse the pay thickness at any desired rate, independently of the normal attrition rate of the rod, until the combustible stratum is ignited from top to bottom thereof within the walls of the borehole. Position of the burning end of the rod may be determined by sliding thermocouples attached to the rod or to the tubing above the rod or otherwise positioned in the borehole.

In application of the invention to strata containing water, it is advantageous to soak the charcoal in a liquid which prevents water-soaking of the charcoal. Such liquids as melted paraffin, fuel oil, or other heavy hydro-carbon oil serve this purpose.

A more complete understanding of the invention may be had by reference to the accompanying drawing of which FIGURE 1 is an elevation partially in section showing an arrangement of boreholes and apparatus therein for effecting one embodiment of the invention; FIGURE 2 is an elevation in partial section of apparatus in an ignition borehole in accordance with a second embodiment of the invention; and FIGURE 3 is a transverse section of the fuel element in FIGURE 2.

Referring to FIGURE 1, a carbonaceous stratum 10 is penetrated by an ignition borehole 12 and surrounded by a number of air injection boreholes 14, two of which are shown. Each of the boreholes is provided with casing 16 and air injection tubing 18 is positioned in boreholes 14. A production tubing string 20 comprising a perforate bottom section 22 is positioned in ignition borehole 12. Charcoal in the form of briquettes forms an annular packed bed 24 between the wall of the borehole and section 22. Perforations 26 in section 22 are smaller than the briquettes and provide a passageway into the tubing string so that gases may pass between the stratum and the tubing thru the charcoal mass without blowing the charcoal into the tubing string. If desired, perforations 26 may be in the form of elongated slots extending lengthwise or circumferentially of the tubing as shown in FIGURE 2. Numeral 27 designates a fire front established in stratum 10 around borehole 12, moving outwardly toward boreholes 14. An air supply line 28 connects with casing 16 of borehole 12.

Operation utilizing the arrangement shown in FIGURE 1 comprises igniting the mass of charcoal 24 by soaking the charcoal with a highly flammable hydrocarbon fluid, such as gasoline, injected thru tubing 20 (or prior to the positioning of the charcoal in the borehole) and igniting the fluid by a spark, a squibb, or other suitable means so that the entire mass of charcoal is ignited with the aid of air injected thru the stratum from borehole 14. Air may be injected thru line 28 to effect the ignition or assist in the ignition of the charcoal. The combustion gas from the ignition is exhausted thru line 20. As combustion of the charcoal continues, the temperature of stratum 10 adjacent borehole 12 is raised until the ignition point is reached at which time the in-place carbonaceous material is ignited in the presence of free oxygen passing thru the stratum to the ignition borehole.

Since the temperature of burning charcoal under the conditions maintained in the bed of charcoal reaches the level of 2500° F. and higher, reduction in the permeability of the surrounding stratum would result with direct injection of air which carries the heat into the stratum; however, with inverse air injection the passage of air into the ignition borehole prevents excessive heating of the stratum and thereby avoids damage and loss of permeability of the surrounding stratum.

After a combustion zone has been established within the stratum adjacent borehole 12, continued injection of air thru the injection boreholes moves the combustion zone radially outwardly from the ignition borehole toward the injection boreholes. When the combustion zone arrives at

4

the injection boreholes these boreholes may either be closed or utilized as production boreholes with injection thru an outer ring of boreholes being commenced upon termination of the injection thru boreholes 14 so as to move the combustion zone outwardly into unburned stratum. The arrangement shown in FIGURE 1 also illustrates a borehole arrangement wherein initiation of ignition around each of a series of ignition boreholes 12 in a line of boreholes in a stratum flanked on each side by a line of injection boreholes 14, is effected, in which case the operation is similar to that described with a ring type arrangement of injection boreholes around a central ignition borehole.

When utilizing a packed porous mass of fuel, such as charcoal, in borehole 12 without axial tubing section 22, the charcoal is ignited from the top by dropping a mass of burning charcoal onto the charcoal bed or by other suitable means and the injection of air thru the stratum into borehole 12 effects burning of the charcoal downwardly from the top, thereby establishing ignition in stratum 10 around borehole 12 progressively from the top to the bottom thereof. In such an operation tubing string 29 may be utilized to withdraw combustion gases, picking up these gases at a level just above the top of stratum 10. It is also feasible to withdraw combustion gases from the casing at or above ground level. In igniting a stratum which is difficult to ignite, charcoal may be added after ignition of the mass in the borehole so as to replenish the supply of fuel. The addition may be either continuous or periodic as desired.

FIGURE 2 illustrates an embodiment of the invention wherein the charcoal fuel supply is formed in a gas-permeous mass in the form of a cylinder 30 bonded to a perforate tubing section 22. The perforations in tubing section 22 are in the form of longitudinal slots 32, providing a passageway for gases into the tubing or from the tubing into the charcoal. The charcoal cylinder is of slightly smaller diameter than borehole 12 and casing 16 to facilitate positioning of the fuel element in the borehole and to provide a narrow annulus between the charcoal and the wall of the borehole. The lower end of tubing section 22 is preferably closed so that gas passing from the stratum into the tubing must pass thru the charcoal.

The charcoal fuel element in FIGURE 2 is of a length corresponding to the thickness of stratum 10 and in this form it is ignited along its entire extent in any suitable manner as hereinafter described and thereby simultaneously ignites the stratum over its entire cross section as air is fed thru the stratum into the borehole.

In another embodiment of the invention utilizing a pre-formed fuel element such as 30 on the end of a rod or tubing string, the fuel element is prepared in a form substantially longer than the thickness of the stratum to be ignited and only the lower end of the fuel element is initially ignited. Feeding air thru the stratum into the ignition borehole then causes only the lower end of the fuel element to burn thereby producing maximum heat in the stratum adjacent the burning section of the fuel element. The burning end of the fuel element may be positioned at the bottom of the stratum whereby the element is progressively burned upwardly from the lower end and rod or tubing 20 is lowered into the borehole as the burning proceeds and as fuel element 30 becomes shorter. The rate of lowering the supporting tubing or rod is regulated so as to maintain the burning end of the fuel element at the upper edge of the combustion area in stratum 10 so that the stratum is progressively ignited along the length of the borehole therein upwardly from the bottom. In this type of operation, fuel element 30 may be solid without an axial passageway so that tubing section 22 does not interfere with lowering the burning end of the fuel element into the borehole as fuel is consumed and the fuel element becomes shorter. Tubing string 20 may, however, extend into the fuel element a substantial distance and be open on the lower end to exhaust combustion gases from the

5

burning fuel thru an axial passageway thru the fuel element. It is also feasible to ignite the lower end of fuel element 30 with the same opposite the upper surface of stratum 10 and progressively lower the burning end thereof into the stratum as ignition in the stratum is effected and the fuel rod becomes shorter, thereby igniting the stratum progressively downwardly from the upper level thereof.

The process of the invention offers good control of the burning rate of the charcoal by controlling the back pressure on the ignition well thereby regulating the supply of oxygen entering the ignition borehole. Another advantage lies in the fact that direct air injection thru the ignition borehole passes hot gases into the stratum thereby melting or rendering more fluid heavy viscous hydrocarbons in the stratum which are driven deeper into the stratum and upon cooling congeal there and shut off the supply of air by rendering the stratum impermeable. By utilizing a bonded mass of charcoal as the fuel, or by arranging the mass of fuel around a perforate tubing section in the stratum, the blowing of particles of charcoal out thru the ignition well with combustion gases and/or air is completely avoided with only the ashes from the charcoal being blown out thru the production tubing. The inverse air injection technique also permits simultaneous ignition of the entire pay stratum around the ignition borehole which is less feasible with direct injection thru the charcoal into the pay zone.

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.

We claim:

1. A process for igniting a combustible gas-permeable carbonaceous stratum comprising suspending a bonded unitary mass of solid fuel comprising charcoal in an ignition borehole adjacent said stratum; heating and igniting a lower end section of said mass of fuel; passing O₂-containing combustion-supporting gas into an offset borehole and thru said stratum into said ignition borehole to burn the ignited mass of fuel, so as to heat and ignite a section of said stratum adjacent the burning fuel; thereafter moving the burning mass of fuel along said ignition borehole while passing said gas thru said stratum so as to ignite an adjacent section of said stratum; and venting gases from said ignition borehole.

2. The process of claim 1 wherein the burning section of said mass of fuel is moved progressively up said ignition borehole from the bottom to the top of said stratum so as to ignite the entire exposed section of said stratum within said ignition borehole.

3. The process of claim 1 wherein the burning section of said mass of fuel is moved progressively down said ignition borehole from the top to the bottom of said stratum so as to ignite the entire exposed section of said stratum within said ignition borehole.

4. The process of claim 1 wherein said fuel mass is

6

supported on the end of a tubing string and combustion gases are removed thru said string.

5. The process of claim 1 wherein said stratum is ignited adjacent the bottom and the ignited area is caused to move progressively upwardly therefrom to a level adjacent its top.

6. A process for initiating in situ combustion in a permeable carbonaceous stratum comprising placing a gas-permeable mass of charcoal in a borehole within said stratum; heating said charcoal mass to ignition temperature; passing O₂ containing, combustion-supporting gas thru said stratum from an injection area into said borehole and said charcoal so as to ignite and continue combustion of said charcoal, thereby heating the adjacent stratum; continuing the passing of said gas thru said stratum so as to continue said combustion and to ignite the carbonaceous material in said stratum after said stratum reaches ignition temperature to establish in situ combustion therein; and venting from said borehole all gases produced by the combustion so as to avoid passing hot gases into said stratum and plugging thereof with heavy hydrocarbon material.

7. The process of claim 6 wherein a mass of charcoal briquettes is packed into said borehole.

8. The process of claim 7 wherein the top of said mass of briquettes is adjacent the top of said stratum and said mass is ignited at the top whereby combustion proceeds downwardly thru said mass the thickness of said stratum so as to ignite the entire wall of said borehole within said stratum.

9. The process of claim 6 wherein said charcoal is soaked with a liquid, water-repellant, combustible material prior to placement in said stratum so as to minimize absorption of formation water.

10. A process for initiating in situ combustion in a permeable carbonaceous stratum comprising positioning a gas permeable mass of fuel, provided with an axial gas passage therethru, in a borehole within said stratum; igniting said mass of fuel; burning said mass of fuel by injecting combustion-supporting gas into said stratum at a locus spaced from said borehole so as to pass said gas into said borehole and into said mass of fuel, thereby heating and igniting the carbonaceous material in said stratum adjacent said borehole; passing combustion gas from the burning fuel and said material into said axial passageway, upwardly therethru, and out of said well.

11. The process of claim 10 wherein said fuel mass is bonded together on a perforate section of tubing prior to positioning within said stratum to form said fuel and said tubing connects with a tubing leading out of said borehole.

References Cited in the file of this patent

UNITED STATES PATENTS

2,670,047	Mayes et al. -----	Feb. 23, 1954
2,901,043	Campion -----	Aug. 25, 1959