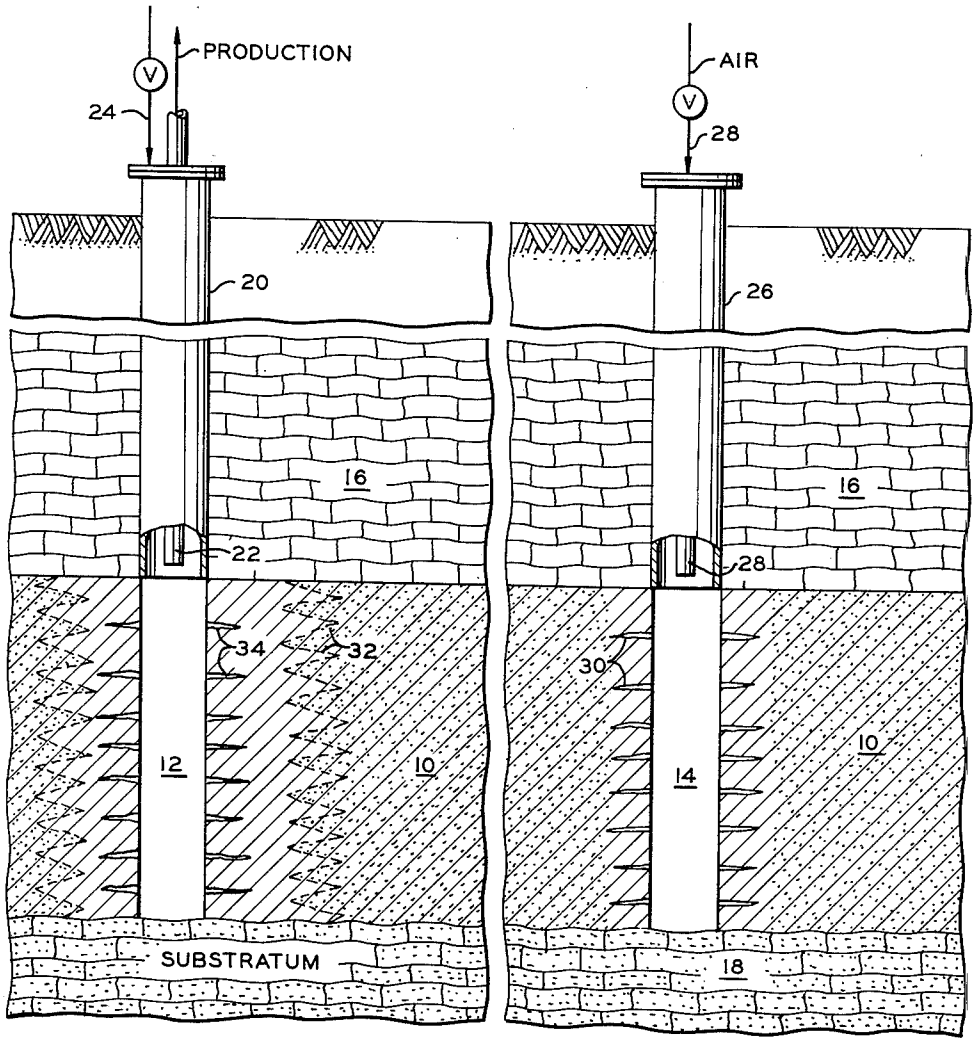
May 1, 1962 H. W. PARKER 3,032,103

INCREASING FLUID FLOW THRU AN INJECTION BOREHOLE

Filed Aug. 11, 1958



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United States Patent Office 3,032,103 Patented May 1, 1962

3,032,103

INCREASING FLUID FLOW THRU AN INJECTION BOREHOLE

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Filed Aug. 11, 1958, Ser. No. 754,275
9 Claims. (Cl. 166—11)

This invention relates to a process for producing hydrocarbons by in situ combustion. A specific aspect of the invention pertains to increasing fluid flow thru an injection borehole 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 thru 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 usually upgrades a substantial proportion of the unburned hydrocarbon material.

The ignition of carbonaceous material in a stratum around a bore hole therein followed by injection of air thru the ignition borehole and recovery of product hydrocarbons and combustion gas thru another borehole in the stratum is a direct air drive process for effecting in situ combustion and recovery of hydrocarbons from the stratum. In this type of operation the stratum usually 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.

In situ combustion techniques are being applied to tar sands, shale, Athabasca sand and other strata in virgin state, to coal veins by fracturing, and to strata partially depleted by primary and even secondary and tertiary recovery methods.

In injecting fluid thru an injection borehole in a carbonaceous stratum, the rate of flow with a given pressure is dependent upon the permeability of the stratum around the borehole. Because there is a limit to the amount of available pressure for forcing a fluid thru a stratum it is highly desirable and economical to increase the permeability of the stratum to obtain high flow rates with a given available pressure. In actual field operation it is necessary to feed a combustion front of substantial area from each injection borehole. Of course, the area of the borehole wall within the stratum is a factor in the injection rate, the larger the borehole the higher the rate of injection with a given pressure; however, there is an economic limit to the size of the borehole that can be provided. It is thus seen that with a given size borehole, of say, 8 to 20 inches in diameter, a substantial increase in porosity or permeability of the stratum for several feet surrounding the borehole greatly facilitates fluid injection rates with a given available pressure.

Accordingly, it is an object of the invention to provide an improved process for producing hydrocarbons by in situ combustion. Another object is to increase the permeability of the stratum adjacent an injection borehole utilized in in situ combustion and/or fluid drive to produce hydrocarbons from a carbonaceous stratum. Another object is to provide an in situ combustion process which requires lower injection pressures for a given flow rate of injected air. Other objects of the invention will become

apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises increasing the permeability of a stratum adjacent an injection borehole by applying heat to the stratum adjacent said borehole so as to drive volatile hydrocarbon material therefrom and leave void spaces or pores in the stratum which increase the permeability thereof. A preferred procedure comprises burning a fuel in the injection borehole adjacent the carbonaceous stratum so as to heat the stratum and fluidize and/or lower the viscosity of the hydrocarbons therein, whereby they are removed from the section of stratum adjacent the borehole and leave the stratum more permeable than before. One method comprises burning a mass of solid fuel such as charcoal, charcoal saturated with a heavy liquid fuel, porous refractory material (such as alumina pebbles) saturated with a liquid fuel (such as equal parts of asphalt and diesel fuel) whereby the stratum is heated to retort hydrocarbons therefrom and raise the temperature of the stratum to above its ignition point. Air or other combustion-supporting gas, alone, or admixed with a fuel gas such as propane in a concentration of about 1 to 7 volume percent of the mixture, is then fed to the heated stratum either thru the injection borehole or thru a production borehole spaced apart therefrom so as to establish in situ combustion in the stratum and drive the combustion front into the stratum a few feet. This procedure not only clears the porous stratum of a substantial proportion of its carbonaceous deposits, but also, in most cases, effects a fracturing of the stratum in the burned out area so as to greatly increase the permeability thereof.

In laboratory tests, in situ combustion of carbonaceous rock taken from a stratum increased its apparent permeability from 0.03 to 40 darcys. When carbonates are present in the sand or rock stratum, decomposition of these by heat also has the effect of increasing permeability.

After burning out the injection borehole and increasing the permeability of the stratum around the same, a fire is initiated in the stratum around a production borehole spaced from the injection borehole in conventional manner, such as by burning a charcoal pack in the production borehole and injecting a premix of oxygen-containing combustion-supporting gas (air) and fuel gas, such as natural gas or propane, in which the concentration of fuel gas is in the range of about 1 to 7 volume percent, into the stratum thru the injection borehole so that the premix passes thru the stratum to the burning charcoal thereby establishing in situ combustion in the stratum around the production borehole. This technique is more fully described in the application of H. W. Parker, J. W. Marx, and J. C. Trantham, S.N. 741,329, filed June 11, 1958. After combustion is established around the production borehole, the resulting combustion zone is advanced thru the stratum to the injection borehole by injection of combustion supporting gas therethru. The combustion supporting gas may comprise air, oxygen-enriched air, pure oxygen, or any of these gases containing a minor proportion of fuel gas.

The movement of the combustion zone thru the stratum countercurrently to the flow of air produces a substantial amount of hydrocarbons from the stratum which are collected along with the combustion gas thru the production borehole and the hydrocarbons are recovered from the collected effluent in conventional manner.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing which is an elevation in partial section thru a carbonaceous stratum penetrated by production and injection boreholes.

Referring to the drawing, a production borehole 12 and an injection borehole 14 penetrate a carbonaceous

stratum **10** lying between an overburden **16** and a substratum **18**. Production borehole **12** is provided with a casing **20** extending approximately to the upper level of the stratum. Production tubing **22** extends to the lower end of casing **20** in borehole **12** and an injection line **24** is also connected with the well head on casing **20**. Injection borehole **14** is provided with casing **26** and with injection tubing **28**. The drawing shows fractures **30** around borehole **14** which have been induced by burning the stratum around this borehole as heretofore described. At the stage of operation shown, a fire front has been established around production borehole **12** and this has been advanced thru the stratum as indicated at **32** by injection of air thru tubing **28** which passes thru the more permeable area around borehole **14** and moves thru the stratum to the combustion front thereby moving the same toward the injection borehole.

It is to be understood that production borehole **12** may be either a central borehole in a 5, 7, or 9-spot well pattern, surrounded by a ring of injection boreholes **14**, or it may be one of a line of production boreholes with a parallel line of injection boreholes **14** on each side of the line of production boreholes. Numeral **34** designates fractures formed around production borehole **12** as the fire front passes into the stratum from this borehole.

While the increasing of the permeability of the injection borehole has been described in connection with in situ combustion, it is also feasible to utilize this procedure when injecting any fluid into a stratum thru an injection borehole to drive hydrocarbons from the stratum as in gas drive or in water flooding.

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 producing hydrocarbons from a carbonaceous stratum penetrated by an injection borehole and a production borehole which comprises heating said stratum adjacent said injection borehole so as to drive volatile hydrocarbons therefrom thereby increasing the permeability of the stratum adjacent said injection borehole; terminating the heating of said stratum around said injection borehole; thereafter, igniting said stratum around said production borehole; injecting an O_2-containing combustion-supporting gas into said stratum thru said injection borehole so as to pass same to the ignited stratum and cause the combustion to move toward said injection borehole; and recovering produced hydrocarbons thru said production borehole.

2. A process for producing hydrocarbons from a carbonaceous stratum penetrated by an injection borehole and a production borehole which comprises heating said stratum adjacent said injection borehole so as to drive volatile hydrocarbons therefrom and form fractures extending into said stratum from said borehole, thereby increasing the permeability of the stratum adjacent said injection borehole; thereafter, terminating the aforesaid heating and igniting said stratum around said production borehole; injecting an O_2-containing combustion-supporting gas into said stratum thru said injection borehole so as to pass same to the ignited stratum and cause the combustion to move toward said injection borehole; and recovering produced hydrocarbons thru said production borehole.

3. The process of claim 2 wherein said heating is effected by initiating combustion in said stratum around said injection borehole.

4. The process of claim 2 wherein a mass of fuel is packed into said injection borehole and burned therein to fracture said stratum.

5. The process of claim 4 wherein said fuel is charcoal, and air is injected into said injection borehole to burn said charcoal and drive the combustion into the stratum around said borehole.

6. The process of claim 2 wherein said O_2-containing gas comprises air admixed with a minor proportion of fuel gas up to about 7 volume percent.

7. The process of claim 2 wherein fuel is ignited in said injection borehole and air containing fuel gas in the range of about 1 to 7 volume percent is injected thru said production borehole so as to pass same to said injection borehole to burn said fuel and cause the combustion to move into said stratum a few feet.

8. The process of claim 7 wherein said fuel comprises a charcoal pack.

9. A process for producing a permeable combustible carbonaceous stratum which comprises igniting said stratum adjacent a first borehole therein; feeding combustion-supporting gas to the resulting combustion zone so as to move same out from said borehole thereby burning out carbonaceous material from an annulus around said first borehole; thereafter terminating said burning; igniting said stratum adjacent a second borehole therein offset from said first borehole; injecting combustion-supporting gas thru said first borehole so as to feed same to the resulting combustion zone around said second borehole and to cause said zone to move toward said first borehole; and recovering produced fluids thru said second borehole.

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