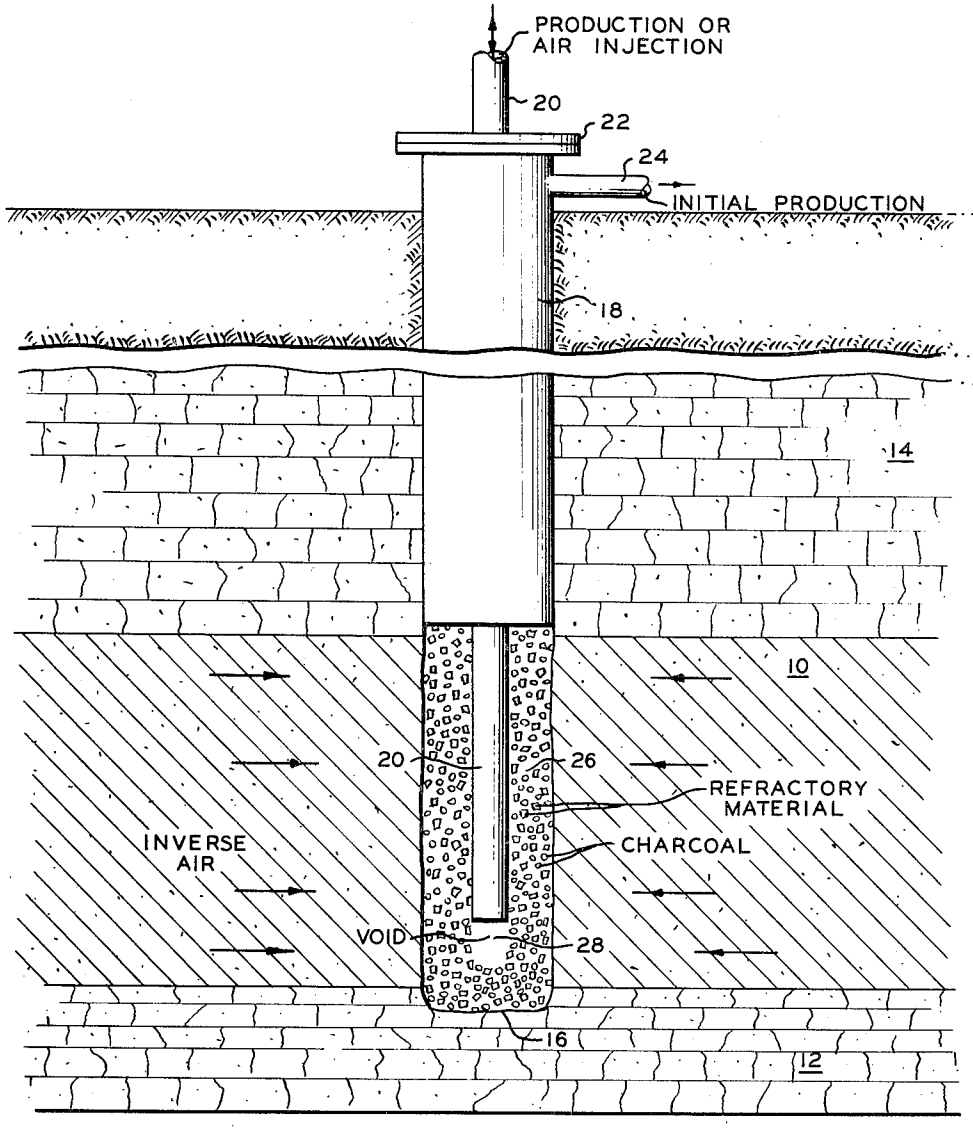
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IGNITION METHOD FOR COUNTERCURRENT IN SITU COMBUSTION

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IGNITION METHOD FOR COUNTERCURRENT IN SITU COMBUSTION

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This invention relates to an improved process for initiating inverse in situ combustion in a carbonaceous stratum. A specific aspect of the invention is concerned with a process for initiating combustion in an ignition well.

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 borehole 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, lignite, 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 the inverse air injection process upgrading of hydrocarbons by thermal and catalytic cracking is effected by driving the produced hydrocarbon material thru the hot rock or sand between the inversely traveling combustion front and the production borehole.

In field tests in a tar sand 6 feet in thickness and about 50 feet below ground level, a charcoal pack in the ignition borehole approximately the thickness of the stratum was ignited at the top by dropping a railroad fusee on top of the charcoal and passing inverse air thru the stratum from offset boreholes into the charcoal pack. It took approximately 3 hours for the flame or fire front in the charcoal to travel the 6 feet to the bottom of the pack. The reason for the slow travel of the flame front thru the pack is attributed to the countercurrent movement of the flame front relative to the air stream ascending the borehole and the charcoal pack. In inverse process the heat from the fire front is carried away from the leading face of the fire front and this leading face is continually cooled by inverse air which does not pass thru hot stratum or charcoal on its way to the combustion zone.

Some strata being considered for production by inverse in situ combustion have a thickness up to 240 feet or more. In the application of a charcoal pack in initiating combustion in such a stratum it would take approximately 120 hours for the fire front at the top of the charcoal pack to travel the 240 feet of depth to reach the bottom of the stratum.

This invention is concerned with an improved process or method of igniting a charcoal pack in an ignition borehole which greatly reduces the time of establishing combustion throughout the fuel pack.

Accordingly, it is an object of the invention to provide an improved process for igniting a fuel pack in an ignition well or bore hole. Another object is to provide an improved process for initiating in situ combustion in a carbonaceous stratum utilizing inverse air injection without driving fluidized hydrocarbon material into the stratum around the ignition borehole. A further object is to reduce the time required in initiating combustion of a carbonaceous stratum around an ignition borehole therein. Another object is to prevent borehole caving, plugging and entrainment of particles of sand and rock from the stratum around an ignition borehole during an in situ combustion process.

Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises introducing a combustible fuel pack of coarse particulate solids into an ignition well, igniting the fuel pack in the bottom section thereof, and passing combustion-supporting gas upwardly thru the resulting combustion zone so as to drive the same by direct drive to the top of the fuel pack. In this manner simultaneous combustion throughout the fuel pack is quickly effected in only a fraction of the time required for moving a combustion front the length of the fuel pack by inverse drive.

The fuel pack may be ignited near the bottom in any suitable manner. One method comprises inserting production tubing to the bottom area of the borehole before introducing the fuel pack thereto so that after the fuel pack is positioned an incendiary device such as a railroad fusee or similar means capable of self-sustaining combustion is dropped down the tubing into the charcoal thereby igniting a substantial area in the bottom of the fuel pack. In order to facilitate the initial phase of the ignition a void space may be provided at the end of the tubing by any suitable means such as by raising the tubing a short distance after the fuel pack is in place and just before dropping the ignitor so that the burning ignitor is outside the tubing. Other methods of igniting the charcoal may be utilized such as by positioning at the bottom of the borehole and fuel pack an electrical heating element or an incendiary device with a fuse running to ground level or even to the top of the pack where it can be ignited by dropping a burning material onto the top of the pack.

When utilizing the production tubing extending to the bottom section of the fuel pack, it is preferable to inject air thru the tubing into the bottom of the pack to feed the combustion and drive the same upwardly thru the pack by direct drive. This procedure may be supplemented by injecting air thru one or more offset wells and driving the same thru the stratum to the ignition well. Upon entering the ignition well the inverse air thus injected assists in the combustion occurring in the fuel pack. It is also within scope of the invention to utilize

the inverse air as the sole air supply for the burning of the fuel pack but when operating in this manner the effluent gas from the fuel pack should be withdrawn from the annulus surrounding the production tubing unless the production tubing is withdrawn so that its lower end is above the fuel pack or at least in the upper portion thereof. By leaving the production tubing extending to the bottom of the fuel pack and taking off the combustion gas thru the tubing the combustion can be progagated thru the fuel pack only by inverse drive which is, of course, to be avoided in this process.

In another embodiment of the invention the production tubing is extended to an area adjacent the top of the fuel pack and the produced combustion gases are removed thru the production tubing. In this type of operation the bottom section of the fuel pack is ignited first by igniting an incendiary device by means of a fuse extending to the device at the bottom of the pack or by an electrical heating element positioned therein and energized from above ground; or as indicated heretofore, the tubing may be utilized to introduce the ignitor to the bottom of the pack after which it may be withdrawn to the area adjacent the top of the pack.

Charcoal in coarse particulate form is a suitable material for the fuel pack and has been successfully used on numerous occasions. The charcoal may be dry or saturated with a liquid hydrocarbon fuel which extends the burning life of the fuel pack. It is also feasible to admix coarse porous aggregates of ceramic refractory material such as broken fire brick with the charcoal so as to provide a residual solid bed in the borehole after completion of the ignition of the surrounding stratum which then functions to reduce or prevent borehole caving and spalling. The porous ceramic aggregates may be soaked with liquid fuel either before or after introduction to the fuel pack. It is also feasible to use the porous ceramic aggregates soaked with liquid fuel as the fuel pack without admixing charcoal therewith.

Suitable liquid fuels comprise heavy liquid hydrocarbons, preferably, of wide boiling range and containing a substantial proportion of material boiling below about 500° F. and, also, a substantial proportion boiling above 500° F. One highly effective fuel for use in the fuel pack, either when using charcoal or porous refractory material comprises a mixture of diesel oil and asphalt preferably in the range of about ⅓ to ⅔ diesel fuel, the balance being asphalt.

Another embodiment of the invention comprises packing charcoal in the ignition borehole to a level substantially above the top of the stratum to be ignited and introducing a layer of coarse refractory aggregates such as pebble heater pebbles or broken fire brick on top of the charcoal pack so as to prevent entrainment of the charcoal from the top of the pack by the effluent gases and to fill the borehole opposite the stratum as the charcoal is consumed in the ignition step. Coarse aggregates in the range of about ¼ or ½ inch to an inch or more in diameter are suitable as coarse material for the fuel pack or for the bed of refractory material over the fuel pack utilized to prevent entrainment of the charcoal and to fill the void left by the burned up fuel when charcoal is utilized.

A more complete understanding of the invention may be had by reference to the drawing which is an elevation thru a stratum showing an initial arrangement of tubing in a well for initiating combustion of a fuel pack therein. Referring to the drawing, carbonaceous stratum **10** is underlain by substratum **12** and is overlain by overburden **14**. Borehole **16** is provided with a casing **18** which extends to a level adjacent the top of stratum **10**. A tubing string **20** extends from about well head **22** down to the bottom section of the borehole. Conduit **24** is utilized for the purpose of taking off initially produced gases during the time in which air is injected thru tubing **20** to drive the combustion or fire front upwardly

thru the fuel pack. Fuel pack **26** comprises both refractory material and charcoal in the embodiment illustrated in the drawing. A void space **28** is shown at the lower end of tubing **20** to provide space for the introduction of an incendiary device thru tubing **20** when this method of ignition is to be utilized. However, as indicated hereinbefore any other method of igniting the charcoal in the area of the void space shown is feasible.

After ignition of the charcoal or other fuel in the bottom section of the fuel pack, it is preferred to inject air thru the tubing string **20** so as to drive the combustion front upwardly thru the borehole. It is also desirable to commence the injection of inverse air from a ring of offset boreholes so that the inverse air arrives at the fuel pack and assists in the combustion step as the combustion zone moves up the fuel pack thru the borehole. By injecting inverse air during this phase of the process, the driving of fluidized hydrocarbon from the wall of borehole **16** into the stratum is avoided and, also, as the wall of the bore hole reaches combustion supporting temperature the inverse combustion process is commenced with the combustion zone being propagated into the stratum radially outwardly from the borehole.

In some strata it is difficult to propagate a combustion front from an ignition borehole inversely to the flow of air thereto without the use of fuel gas in the inverse air. In such cases it is desirable to incorporate in the inverse air fuel gas such as propane or liquefied petroleum gases in the range of about 1 to 3 or 4 percent, preferably about 2 percent. Introduction of fuel gas with the inverse air also has the effect of increasing the rate of movement of the inverse burning fire front and also increases the amount of hydrocarbons produced by the combustion process.

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 initiating combustion in an ignition well within a carbonaceous stratum which comprises introducing into said well an elongated upright combustible fuel pack comprising coarse particulate solids containing combustible material; igniting said fuel pack in the bottom section thereof; and passing combustion-supporting gas upwardly thru the resulting combustion zone so as to drive same rapidly by direct drive to the top of the pack and effect simultaneous combustion throughout the pack.

2. The process of claim 1 wherein said fuel pack comprises charcoal aggregates.

3. The process of claim 1 wherein said fuel pack comprises porous refractory aggregates impregnated with fuel.

4. The process of claim 3 wherein said fuel comprises a heavy hydrocarbon oil.

5. The process of claim 1 wherein a tubing passes from ground level down thru said fuel pack, an igniting device is dropped thru said tubing into the charcoal, air is injected into the ignited area thru said tubing, and effluent gases from the combustion are withdrawn thru the annulus around said tubing.

6. The process of calim 5 wherein air is injected into said stratum thru at least one offset well and is passed thru said stratum to the burning charcoal so as to propagate the combustion zone from said charcoal into said stratum.

7. The process of claim 6 wherein fuel gas in a concentration in the range of about 1 to 3 volume percent is incorporated in the air injected thru said stratum.

8. The process of claim 5 wherein said tubing is withdrawn from said charcoal pack to a level adjacent the upper level of said stratum after ignition throughout said fuel pack is substantially complete and combustion in said fuel pack is supported by air injected thru said stratum from at least one offset well therein.

9. The process of claim 1 wherein said combustion-supporting gas is supplied thru said stratum from at least one offset well therein.

10. The process of claim 1 wherein said fuel pack comprises charcoal extending to a level substantially above the upper level of said stratum so as to compensate for shrinkage of said pack during combustion thereof, and a mass of coarse solid refractory aggregates is positioned on the top of the charcoal bed.

11. The process of claim 1 wherein said pack comprises a mixture of porous refractory material and charcoal.

12. The process of claim 11 wherein said pack is soaked with liquid hydrocarbon fuel.

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