

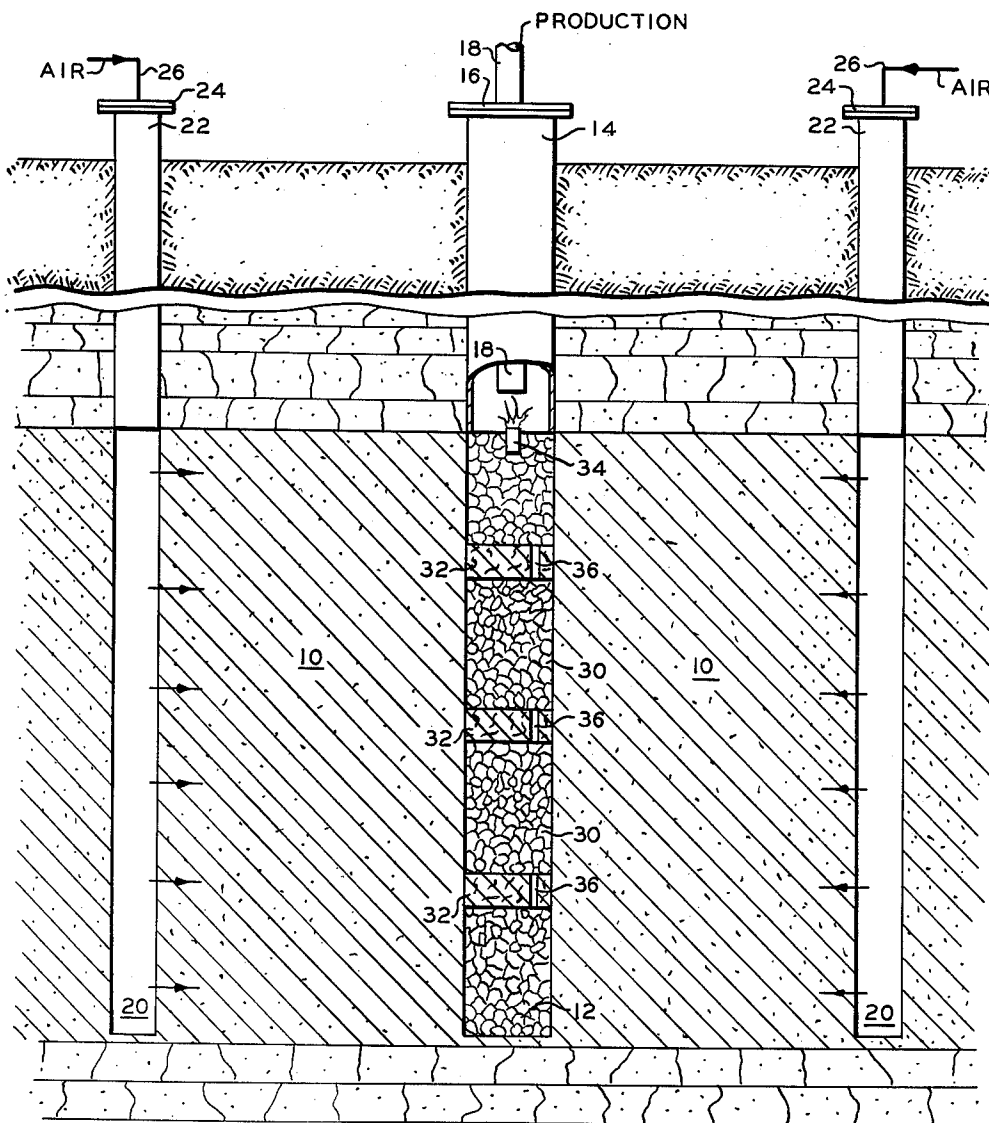
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IGNITION OF THICK STRATA FOR IN SITU COMBUSTION

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IGNITION OF THICK STRATA FOR IN SITU COMBUSTION

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This invention relates to a process for igniting a combustible carbonaceous stratum around an ignition well for recovery of hydrocarbons from the stratum in situ combustion and to a novel fuel pack in an ignition well for effecting the process.

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, 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.

A suitable method of igniting combustible carbonaceous strata for countercurrent in situ combustion comprises filling an ignition well within a stratum to be produced with a fuel pack such as charcoal in particulate form, alone, saturated with a heavy fuel oil, admixed with solid refractory aggregates, such as crushed fire brick, rock, etc., both saturated with oil, or porous ceramic material saturated with heavy fuel oil without the charcoal. The fuel pack is ignited at the top or on the end adjacent the well head and a combustion supporting gas such as air containing about 1 to 3 volume percent of fuel gas (normally gaseous hydrocarbons such as ethane, propane, and butane, or natural gas) is passed thru the stratum from one or more offset injection wells to the ignition borehole so as to burn the fuel in the pack and heat the adjacent stratum to combustion temperature whereby the stratum becomes ignited to initiate the in situ combustion process. When this technique is applied to thick strata the volume of air entering the ignition borehole is of such magnitude that the air velocity up the borehole adjacent the top of the fuel pack is so great that it entrains charcoal and carries it out of the borehole. This invention is concerned with a process and fuel pack for igniting a carbonaceous stratum which avoids this problem.

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Accordingly, it is an object of the invention to provide a novel fuel pack and process for igniting a thick combustible carbonaceous stratum around an ignition well therein which avoids the entrainment of solid fuel in the vented gases and carrying the same out of the borehole. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises filling an ignition well within a combustible carbonaceous stratum with sections of solid particulate fuel separated by combustible packers, igniting the section of fuel adjacent the well head, injecting combustion-supporting gas into the stratum thru at least one offset injection well so as to feed said gas thru the stratum to the ignited fuel section and cause same to burn toward the adjacent fuel section whereby the intervening combustible packer is burned and the adjacent stratum is ignited, continuing the injection of said gas until the combustion zone passes thru the packer into the adjacent fuel section so as to ignite the stratum surrounding the adjacent fuel section, and venting the produced gases thru the ignition well. In this manner the combustible packer prevents any appreciable flow of gas from the stratum into the well below the packer during the initial phases of the ignition process so as to avoid entrainment of the fuel aggregates in the vented gas. After the upper section of the fuel pack is burned out, the gas velocity in this section of the hole does not affect the fuel pack. With only a short section of ignition well open to the stratum, sufficient air injection pressure to induce entrainment of fuel aggregates is practically impossible, while a long section of ignition well free to receive injected gas from the stratum results in such a large volume and velocity of air in the upper end of the fuel pack to blow the fuel aggregates out of the hole.

In strata upwards of 20 to 30 feet in thickness more than one packer is used so that the sections of fuel between the packers do not exceed 10 to 15 or 20 feet in length. Generally the packers are placed in the fuel pack at 3 to 20 foot intervals. The packers prevent production of air from the low portion of the well while the upper portions are being ignited and burned, but since the packers are combustible and burn out when the fire reaches them, the fire progresses thru the fuel pack so as to progressively open up more hole to air production as the fuel above is consumed. In this manner, a thick stratum is ignited in segments of convenient size in continuous manner from the top of the formation to the bottom thereof without entrainment of fuel aggregates.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing which is an elevation in partial section of an arrangement of a fuel pack in an ignition borehole in a combustible carbonaceous stratum, along with air injection wells.

Referring to the drawing, a combustible carbonaceous stratum 10 is penetrated by an ignition well 12 which is provided with a casing 14 extending to the approximate upper level of the stratum. Casing 14 is provided with a wellhead 16; and a production tubing string 18 passes thru the wellhead, extending down to some suitable level such as adjacent the lower end of the casing. A pair of air injection wells 20 are provided with casings 22 extending to the approximate upper level of the stratum. Each casing 22 is provided with a well head 24 and a line 26 for injecting combustion-supporting gas, such as air containing 1 to 3 volume percent of fuel gas. Well 12 within stratum 10 is filled with a fuel pack 30 consisting of charcoal aggregates such as briquettes or any of the solid fuel aggregates mentioned hereinbefore. Spaced at selected intervals thruout the fuel pack 30 are packers 32.

A suitable incendiary device, squibb, or fusee 34 is

shown on top of the first section of fuel in burning condition as the initial phase of the ignition process. The ignitor may be dropped down tubing string 18 in ignited condition or it may be set off by an electrical spark, thru means not shown but readily apparent to one skilled in the art. Device 34 may comprise an open charge of gun powder with a fuse leading thereto from the well head or it may be ignited by dropping burning charcoal down the tubing string on top of the ignitor. In some cases, ignition is effected without a self-combustion ignitor by dropping a large burning charge, such as 25 pounds of red hot charcoal, down the well onto the top of the fuel pack.

The packers 32 may be formed of any suitable combustible material such as rubber, wood, or plastic (polypropylene, polyethylene, etc.). Another effective packer is a plug comprising a mixture of ammonium nitrate, sawdust, and a suitable binder such as a rubbery binder utilized in forming solid propellant grains. Various types of resin binders are also satisfactory. The packer or plug may also be formed of solid propellant grain material, compositions of which are well known in the art. Another type of packer suitable in the fuel pack is an inflatable packer commonly used in sealing off boreholes, such as inflatable rubber packers or those made of other elastic impervious material.

In most cases it is also feasible to utilize as packers, plugs which do not fit the borehole tightly but which prevent passage of substantial volumes of air thru the borehole from below the packer, there being only a narrow annulus around the periphery of the plug for air leak. This prevents a blowout of the particulate material because of the low volume of air passing thru the narrow annuli and renders it impossible for the air flowing into the ignition well below the plugs to reach such velocity as to lift the plug with the mass of fuel above it. The narrow annulus between the plug and the wall of the well aids in moving the combustion zone thru the packer into the next section of fuel. Where the packer is set against the wall of the borehole, as shown in the drawing, and where the composition of the packer is not of incendiary type, such as propellant grain material, it is advantageous to provide the packer with one or more small diameter breather holes 36 to facilitate the progress of the combustion front thru the packer. It is preferred to fabricate the packer of self-combustible material, i.e., solid fuel containing an oxidizing material which does not require the presence of added combustion-supporting gas. In this manner the combustible packer burns readily, providing additional heat for the ignition process and speeding up the movement of the combustion zone thru the fuel pack.

Packer 36 may be formed in situ on the top of any section of the fuel pack by introducing a plastic, semi-fluid mass of a plastic or propellant grain material which sets to a solid mass upon standing. Various types of resins and glues which have this function may be utilized. The fluidity or plasticity of the mass of packer material should be such that the mass settles by gravity, before setting, to form a pancake-type layer on the top of the fuel section. After a short setting period, additional fuel may be added in the desired quantity to fill an extended section of the borehole and another packer may then be set on this section of fuel in similar manner and the process may be repeated until the entire borehole co-extensive with the stratum is filled with the fuel pack.

The ignition process is effected by igniting the top of the fuel pack as heretofore described and injecting combustion-supporting gas thru injection wells 20 so that the gas enters borehole 12 above the upper packer. With a small concentration of fuel gas in the injected combustion-supporting gas, as heretofore indicated, the combustion zone progresses rapidly thru the upper section of the fuel pack and ignites the surrounding stratum. As the combustion zone reaches the first packer the same is ignited and burns rapidly, particularly if incendiary material is used in its fabrication, and the combustion zone

moves into the next section of fuel. As the second section of fuel is burned, the surrounding stratum is also ignited and the combustion front therein is fed by the injected gas. Additional packers and fuel sections are progressively ignited and burned in the same manner until the entire cross section of stratum is ignited. During the ignition process, produced gases, including combustion gases and hydrocarbons driven from the stratum as the combustion front moves out from the ignition borehole, are recovered thru the ignition well in gaseous form thru tubing string 18. Ignition well 12 may be a central well in a 5, 7, or 9-spot ring pattern with wells 20 being two of the ring wells; or ignition well 12 may represent one of a line of ignition wells with injection wells 20 representing parallel lines of injecting wells for effecting an in-line inverse in situ 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. In combination with an ignition well in a subterranean carbonaceous stratum, a solid particulate fuel pack in said well within said stratum and at least one solid impervious combustible packer across said well intermediate the ends of said fuel pack and intermediate the top and bottom of said stratum, said packer substantially impeding the flow of gas in said borehole from the section of said fuel pack below said packer to the section above said packer.

2. The combination of claim 1 wherein said packer is provided with a small gas passageway therethru from one adjacent section to the other.

3. The combination of claim 1 wherein said packer is an inflatable packer.

4. The combination of claim 1 wherein said packer comprises a self-burning material.

5. The combination of claim 4 wherein said self-burning material comprises a solid propellant grain.

6. The combination of claim 1 wherein said packer comprises a mixture of sawdust, ammonium nitrate, and a solid combustible binder.

7. The combination of claim 1 including several packers spaced apart in said fuel pack intermediate the top and bottom of said stratum.

8. The combination of claim 1 wherein said fuel pack comprises charcoal and including an ignitor in the top section of said packer.

9. The combination of claim 1 including means forming a small passageway for minor flow of gas between the section of fuel pack below said packer and the section above same.

10. A process for igniting a combustible carbonaceous stratum around an ignition well therein which comprises filling said well within said stratum with sections of solid particulate fuel separated by a combustible packer, positioned intermediate the top and bottom of said stratum which substantially impedes flow of gas between said sections; igniting the section of fuel adjacent the well head; injecting combustion-supporting gas into said stratum thru at least one offset injection well so as to feed said gas thru the stratum to the ignited fuel section and cause same to burn toward the adjacent fuel section whereby the intervening combustible packer is burned and the stratum surrounding the initially burned fuel section is ignited; continuing the injection of said gas until the combustion zone passes thru the packer into the adjacent fuel section so as to ignite the stratum surrounding said adjacent fuel section; and venting produced gases thru said ignition well.

11. The process of claim 10 wherein said combustion-supporting gas comprises air containing fuel gas in a concentration of 1 to 3 volume percent.

12. The process of claim 10 wherein said fuel comprises charcoal.

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13. The process of claim 12 wherein said packer comprises a self-burning material.

14. A process for placing in an ignition well in a combustible carbonaceous stratum a fuel pack of solid fuel aggregates which comprises introducing to said well within said stratum a mass of said aggregates to form an elongated section of fuel therein; positioning on top of said section a self-setting plastic flowable mass of combustible material so as to form a packer across said well which prevents any appreciable flow of gas from the subjacent section of fuel upwardly thru the well; and adding another section of said fuel aggregates on top of said packer.

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15. The process of claim 14 wherein said combustible material comprises a self-oxidizing fuel.

16. The process of claim 15 wherein said material comprises propellant grain.

17. The process of claim 15 wherein additional sections of fuel separated by combustible packers are added to said fuel pack.

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