

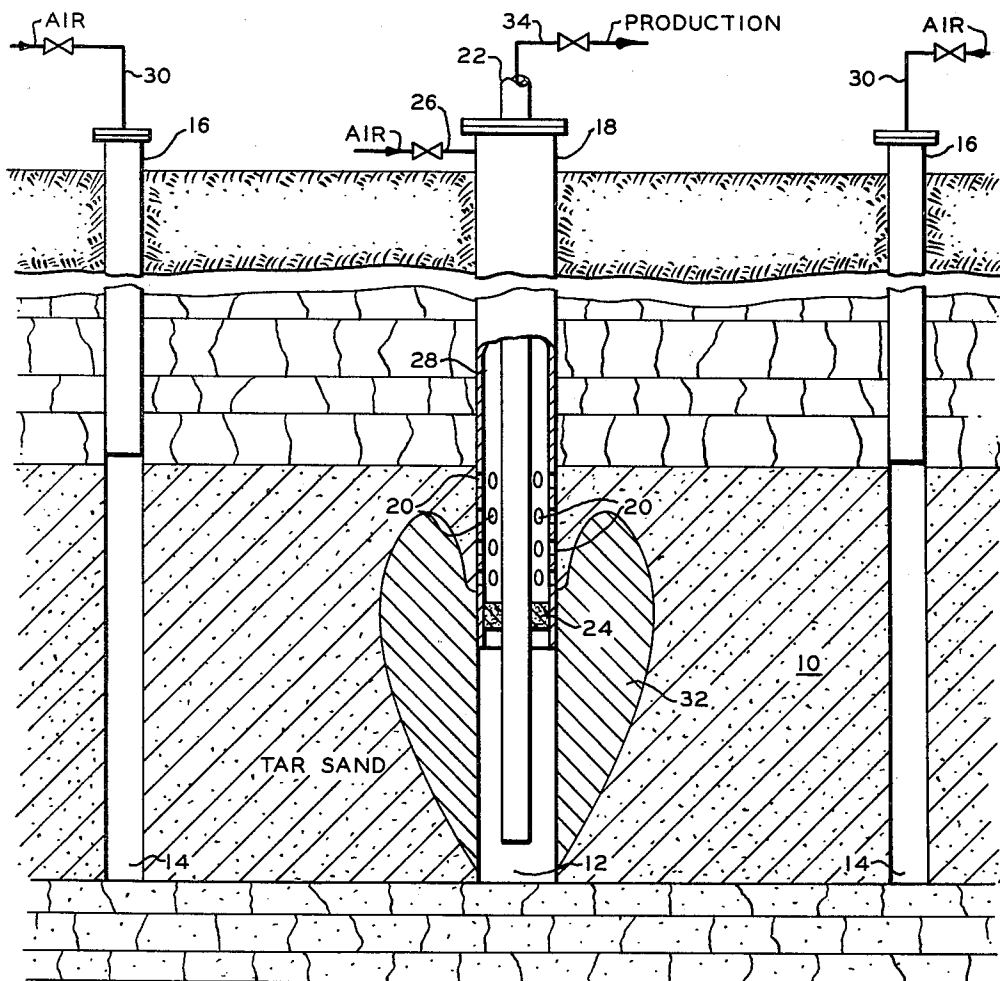
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PRODUCTION OF UNCONSOLIDATED SANDS BY IN SITU COMBUSTION

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PRODUCTION OF UNCONSOLIDATED SANDS BY IN SITU COMBUSTION

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This invention relates to a process for producing unconsolidated sands containing combustible carbonaceous material while preventing borehole caving around a production well therein.

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.

In producing unconsolidated or poorly consolidated sands, such as Athabasca tar sand, borehole caving takes place as soon as the carbonaceous material is burned out of the sand. One method of preventing caving of the sand into a well around which the hydrocarbons have been removed by burning, comprises packing the well bore within the stratum with solid refractory aggregates, such as pebbles, crushed fire brick, etc. A perforated liner, such as a well casing having holes therein, has also been used for this purpose. This invention is concerned with preventing borehole caving in producing the hydrocarbons around a well in a poorly consolidated sand by a simple and inexpensive method.

Accordingly, it is an object of the invention to provide a method of producing a poorly consolidated sand containing combustible hydrocarbon material by in situ combustion which avoids caving of the sand into the production well. Another object of the invention is to provide a simple and inexpensive method of preventing borehole caving around a production well in a poorly consolidated tar sand and producing the sand by inverse in situ combustion. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises burning an annulus around a well bore in a poorly consolidated sand, containing combustible hydrocarbons, along the well bore by inverse air injection so as to produce a hard carbon-

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ized residue in the sand, which consolidates the sand and prevents borehole caving. In order to burn the sand along the borehole by inverse air injection, a packer is positioned in the well, preferably in an upper section of the sand stratum with tubing string extending thru the packer and perforations in the casing between the packer and the top level of the sand. The sand is ignited around the well near the lower level thereof and air or other combustion-supporting gas is injected thru the annulus into the sand above the packer from which it flows around the packer and thru the sand to the combustion zone, thereby advancing the combustion zone upwardly along the well bore to the air injection area of the sand. In this manner, a pear shaped carbonized area around the well is produced which consolidates the sand around the well and prevents caving thereof into the well.

It is also feasible to pack off a lower section of the well within the sand and ignite the sand at an upper level followed by injection of air thru the tubing below the packer whereby the injected air passes thru the sand bypassing the packer and feeding the combustion zone so as to move a combustion front downwardly along the borehole with the consolidating of the sand in an annulus around the well. In either instance, the sand around the production well is consolidated so that the pay zone may be produced by in situ combustion with production thru the consolidated zone by inverse air injection thru offset wells.

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 tar sand showing an arrangement of wells for producing the sand in accordance with the invention.

Referring to the drawing, a tar sand 10 is penetrated by a production well 12 and air injection wells 14 spaced from well 12 a distance usually in the range of 20 to several hundred feet. Wells 14 represent a ring of wells in a 5, 7, or 9 spot well pattern around central well 12; or wells 14 may represent parallel rows of in-line wells on either side of a line of production wells 12 for line drive in situ combustion.

Wells 14 are provided with casing 16 terminating above the sand and well 12 is provided with casing 18 extending down into the tar sand and perforated at 20. A tubing string 22 extends thru the well head of well 12 and thru a packer 24 to a lower level of the well. An air line 26 connects with casing 18 to supply air to the annulus 28 around tubing 22. Air lines 30 extend thru the well heads of wells 14 for inverse air injection during production of the tar sand. Numeral 32 designates the coked partially burned out annulus around well 12 during a later stage of the consolidating step.

The drawing illustrates that phase of the operation in which a combustion zone is initiated in the lower section of well 12 by any suitable means conventional in the art, one of which is to burn a bed of charcoal therein and supply air thereto so as to heat and ignite the adjacent sand. After ignition of the sand, air is injected thru line 26 and annulus 28, passing thru holes 20 into the sand above packer 24 from which it travels to the combustion zone previously established. The combustion zone thus moves upwardly thru the sand along the borehole and eventually reaches the uppermost holes 20 in the casing adjacent the top of the sand. During this time the produced hydrocarbons are recovered thru the tubing and production line 34. Including fuel gas in the injected air in a concentration in the range of about 1 to 4 volume per cent facilitates the movement of the combustion front thru the sand.

After the initial burning phase which consolidates the sand around the production well, and while the sand is still at ignition temperature, air, preferably including a small concentration of fuel gas such as normally gaseous

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hydrocarbons or natural gas, is injected thru lines 30 into wells 14 so that the combustion-supporting gas passes laterally thru the sand to the hot area around well 12, thereby re-igniting the sand and moving the resulting combustion front thru the sand toward wells 14. Produced hydrocarbons are recovered thru well 12 and tubing 22. After the consolidation step, packer 24 is preferably removed from well 12 and tubing 22 is withdrawn to about the level of the top of the sand.

The primary burning step which consolidates the sand must be effected by inverse drive in order to leave sufficient hard carbon residue in the sand to consolidate same. If direct drive burning is utilized, the sand is burned clean and is left unconsolidated.

While the use of the casing within the production borehole is shown, it is feasible to extend the casing only to the upper level of the sand and to pack off the borehole directly against the sand wall in which case holes 20 are not utilized and the injected air passes directly from the annulus 28 into the permeable sand above the packer.

In some applications, depending upon the character of the sand and the hydrocarbon material therein, consolidated area 32 is of low permeability has a hindering effect upon production of the surrounding sand by inverse in situ combustion. In such applications, it has been found that fracturing of the coke in the consolidated area at one or more levels greatly increases the permeability of the consolidated sand to the flow of combustion gases during the inverse burning production phase of the process. It is also feasible to shoot holes thru the consolidated sand by conventional means. However, in most applications consolidated area 32 is sufficiently permeable to make it feasible to produce the surrounding sand by inverse in situ combustion.

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 an unconsolidated sand containing producible hydrocarbons which comprises packing off an ignition well between the top and bottom levels of said sand with a packer set around a tubing string; igniting said sand on one side of said packer; feeding combustion-supporting gas from said well thru one of said tubing string and the surrounding annulus into the sand on the opposite side of said packer and around said packer to the resulting combustion zone and withdrawing combustion products from said well thru the other of said tubing string and the surrounding annulus so as to move said zone thru said sand along said well to the area on said one side of said packer, thereby leaving a carbonized residue in the sand trav-

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ersed by said combustion zone to consolidate said sand; thereafter injecting combustion-supporting gas thru at least one offset well into said sand and forcing said gas to the hot area around said ignition well to move a combustion front thru said sand toward said offset well; and recovering hydrocarbons produced by the combustion thru said ignition well.

2. The process of claim 1 wherein said gas comprises air containing 1 to 4 volume percent of fuel gas.

3. The process of claim 1 wherein the combustion gas injected thru said offset well comprises air containing fuel gas in a concentration in the range of 1 to 4 volume percent.

4. The process of claim 1 wherein said combustion-supporting gas is injected thru a ring of wells surrounding said ignition well.

5. The process of claim 1 wherein said sand is ignited adjacent the bottom level and the resulting combustion zone is driven to a level adjacent the top of said sand.

6. The process of claim 1 wherein said sand is ignited adjacent the top level and the resulting combustion zone is driven to a level adjacent the bottom of said sand.

7. A process for producing hydrocarbons from a unconsolidated sand containing producible hydrocarbons which comprises establishing a combustion zone in said sand around a production well at one of the uppermost and lowermost levels therein by heating said sand to ignition temperature at the selected level and contacting same with combustion-supporting gas; injecting combustion-supporting gas by way of said production well thru said sand along said well from the other level so as to feed said combustion zone and cause same to move thru an annulus of sand to said other level and venting combustion products thru said production well, thereby leaving a carbonized residue in said sand traversed by said combustion zone so as to consolidate the sand in the wall of said well; thereafter, while said residue is at ignition temperature, injecting combustion-supporting gas thru at least one offset well into said sand so as to force said gas thru said sand to the hot residue so as to reestablish combustion and move the resulting combustion zone thru said sand toward said offset well; and recovering produced hydrocarbons thru said production well.

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