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REDUCTION OF COKE FORMATION DURING IN SITU COMBUSTION

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This invention relates to an improved process for producing oil from an oil-bearing stratum by in situ combustion.

The production of hydrocarbons from oil-bearing strata and other carbonaceous deposits by in situ combustion is an accepted process in the petroleum industry. In such a process, the carbonaceous material in the stratum to be produced is ignited around a well penetrating the stratum and air or other O_2-containing, combustion-supporting gas is fed to the resulting combustion zone so as to move this zone thru the stratum toward one or more offset wells. In one method of operation, the combustion-supporting gas is injected thru the ignition well so as to drive the combustion zone to the offset well(s) concurrently to the flow of gas thru the stratum. In a stratum containing highly viscous oil which tends to congeal when warmed and driven into the cold stratum by direct drive, reverse burning is usually resorted to. The reverse burning process involves igniting the stratum around a well in the usual manner and injecting the combustion-supporting gas thru one or more offset wells so as to cause the combustion zone to move countercurrently to the flow of gas, the ignition well serving as a production well. When reverse burning is utilized, a preferred procedure comprises injecting air thru the injection well(s) until air appears in the ignition well before initiating combustion around the ignition well.

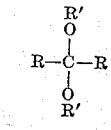
Ignition is effected in any suitable manner, as by burning a charcoal pack, soaked with a heavy oil, in the ignition well. Another method of igniting the combustible material in the stratum comprises depositing a spontaneously-ignitable fuel such as tung oil or linseed oil in the stratum around the injection well and feeding air to the fuel area so as to ignite the same and initiate combustion of the in-place hydrocarbon material. The spontaneously-ignitable fuel may be driven into the stratum a short distance, such as one to five feet, by injecting a fluid driving agent after the injection of the fuel, in order to effect ignition a spaced distance from the ignition well, thereby protecting downhole equipment from the high-temperature combustion zone. These methods of ignition are disclosed and claimed in copending applications S.N. 520,845, filed Jan. 17, 1966, and S.N. 559,804, filed June 23, 1966.

In the production of hydrocarbons by in situ combustion, a portion of the carbonaceous deposit is burned and another portion is produced as fluidized and vaporized hydrocarbon material which appears in the production well(s) in admixture with the combustion gas produced by the burning. Another portion of the carbonaceous deposit is converted to coke. In viscous oil deposits, the conversion to coke is particularly excessive unless measures are taken to reduce coke formation.

The instant invention is concerned with an improved in situ combustion process which substantially and materially minimizes coke formation in a carbonaceous deposit during in situ combustion.

Accordingly, it is an object of the invention to provide an improved in situ combustion process for the production of hydrocarbons from a carbonaceous deposit, which minimizes or materially reduces coke formation. Another object is to provide a process which produces more hydrocarbon material from a carbonaceous deposit than is normally produced. 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 depositing in the carbonaceous stratum to be produced a liquid hydrocarbon fuel containing a ketal in sufficient concentration to reduce the formation of coke during the burning of the in-place carbonaceous deposit with injected O_2-containing gas. The ketal has the formula



wherein R is a C_1 to C_{10} alkyl radical, R′ is a C_1 to C_4 alkyl radical, and the total carbons is not greater than 20.

Ketals exemplary of those within the scope of the formula include 2,2-dimethoxypropane, 6,6-di-n-butoxydodecane, 4,4-diisopropoxynonane, 3,3-diethoxy-5-ethylheptane, and 2-ethoxy-2-tertbutoxyhexane.

The ketals defined have the capacity to substantially and materially minimize coke formation during the combustion of the carbonaceous deposit. Also, the burning of the injected fuel reduces the amount of in-place carbonaceous material burned to maintain suitable combustion and production temperatures, thereby increasing the amount of hydrocarbons produced by the combustion.

Various liquid hydrocarbon fuels may be utilized ranging from propane thru kerosene or even heavier fuels. LPG is an effective fuel since injection pressures are sufficient to maintain this type of fuel in liquid form in the injection well and in the surrounding stratum. The amount of fuel injected is in the range of 0.05 to 5 percent of the pore volume (based on the sweep pattern of the combustion within the stratum to be produced). It is preferred to utilize the liquid fuel in an amount in the range of 0.1 to 3 percent of the pore volume. The ketal is incorporated in the liquid fuel in an amount in the range of 0.01 to 2.0 volume percent; however, larger amounts may be utilized but the cost involved when compared to the benefits derived therefrom is not economically justified.

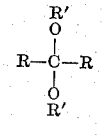
It is feasible to inject the liquid fuel-ketal mixture into the stratum to be produced so as to admix the mixture with the in-place crude oil prior to the initiation of combustion. In this manner, the auxiliary fuel is burned in admixture with the ketal in the combustion zone as the combustion zone is moved thru the stratum. Any method of depositing the fuel-ketal mixture in the stratum so that it is burned in the combustion zone is within the scope of the invention.

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 a process for producing hydrocarbons from a combustible carbonaceous stratum by in situ combustion wherein an O_2-containing, combustion-supporting gas is fed into a combustion zone in said stratum thru an injection well therein to burn a portion of the carbonaceous material with coke formation and produce a portion as hydrocarbons thru an offset production well in admixture with combustion gases, the improvement comprising:

burning in said combustion zone an injected liquid hydrocarbon fuel containing a ketal having the formula



wherein R is a C_1 to C_{10} alkyl radical, R' is a C_1 to C_4 alkyl radical, and the total carbons is not greater than 20, the concentration of said ketal in said liquid fuel being in the range of 0.01 to 2.0 volume percent and the resulting fuel mixture being in the range of 0.05 to 5 pore volume percent.

2. The process of claim 1 wherin said ketal comprises principally 2,2-dimethoxypropane.

3. The process of claim 1 wherein said ketal comprises principally 6,6-di-n-butoxydodecane.

4. The process of claim 1 wherein said ketal comprises principally 4,4-diisopropoxynonane.

5. The process of claim 1 wherein said ketal comprises principally 3,3-diethoxy-5-ethylheptane.

6. The process of claim 1 wherein said ketal comprises principally 2-ethoxy-2-tertbutoxyhexane.

7. The process of claim 1 wherein said stratum contains a viscous crude oil.

8. The process of claim 1 wherein said fuel is deposited in said stratum prior to initiation of combustion.

9. The process of claim 1 wherein said fuel is injected in admixture of air as the combustion-supporting gas.

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