

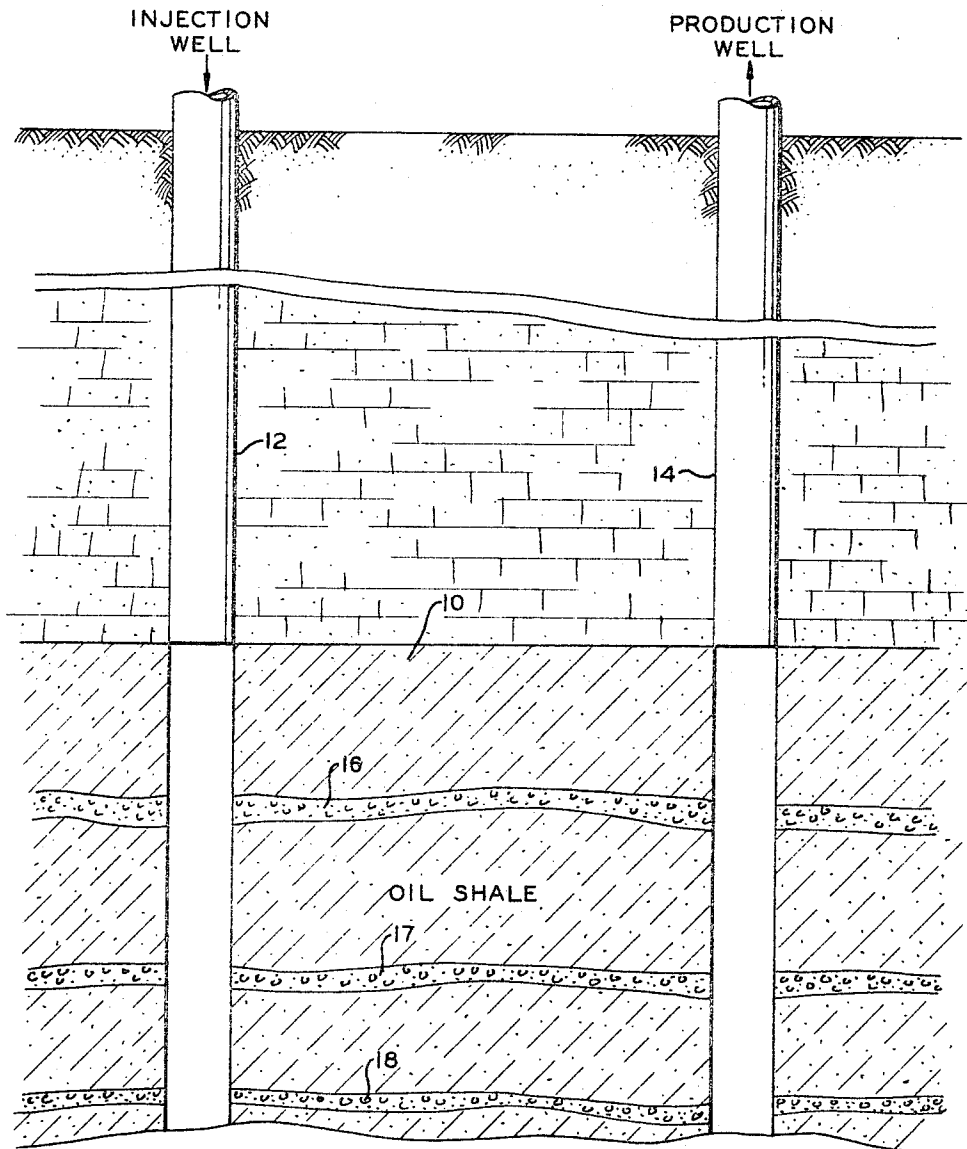
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IGNITION AND COMBUSTION OF CARBONACEOUS STRATA

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IGNITION AND COMBUSTION OF
CARBONACEOUS STRATA

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This invention relates to a process for igniting a carbonaceous subterranean stratum. A specific aspect of the invention is concerned with the ignition and production of an oil-bearing stratum by in situ combustion.

Various types of carbonaceous strata have been produced by in situ combustion which involves igniting the stratum to be produced and moving a combustion zone therethru by feeding a combustion-supporting gas, such as air, thereto. Most oil-bearing strata are sufficiently permeable to permit flow of air therethru during the in situ combustion operation. Oil shales and strata containing highly viscous crude are often not readily susceptible to in situ combustion in the usual manner.

This invention is directed to novel method of igniting a carbonaceous stratum and is particularly adapted to igniting a shale or a stratum containing highly viscous crude.

Accordingly it is an object of the invention to provide a novel method of igniting a combustible carbonaceous stratum. Another object is to provide an improved process for initiating in situ combustion in a carbonaceous stratum. A further object is to provide a process for producing hydrocarbons from oil-bearing strata, utilizing in situ combustion. 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 fracturing the stratum to be produced so as to extend a fracture radially outwardly (either horizontally or vertically) from a well penetrating the stratum, using a non-aqueous fracturing fluid; injecting into the fracture a mixture of a high temperature resistant propping agent in particulate form, "Thermit" pellets, and pellets of a starter material reactive with water, using a non-aqueous injection fluid; thereafter, injecting water into the fracture in contact with the injected solids so as to energize the starter material which then heats and ignites the "Thermit;" and feeding an oxygen-containing gas, such as air, into the fracture so as to ignite the carbonaceous material in the stratum. After the stratum is ignited, the injection of air is continued so that the injected air feeds the combustion in the stratum and moves a combustion zone therethru. This procedure is applicable to a single well or to any selected pattern of wells such as a 5-, 7-, or 9-spot pattern. It is also applicable to rows of in-line wells utilizing alternate rows of injection and production wells.

The preferred propping agent comprises glass beads which are highly resistant to fracturing and fusion at high temperatures. A suitable bead or pellet size is in the range of 8-12 mesh but beads up to 1/4" in diameter can be used in the process. Glass beads particularly suitable are those available from Union Carbide Corporation, 270 Park Avenue, New York 17, New York. Beads obtained from this source consisting principally of silica have a crushing strength in the range of 60 to 100,000 p.s.i., the smaller sizes having the higher and the larger sizes the lower crushing strengths.

The physical properties of the beads are set forth below:

Refractive index	1.506.
Density	2.45 to 2.48.
Hardness (mohs')	6 1/2 to 7.
Fusion point	approx. 2000° F.

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The glass beads described have been tested as propping agents in producing wells and have proved superior to other known propping agents in that oil production was increased more than with other commercially available propping agents and the rate of fall-off of production was substantially lower for these glass beads. The glass beads described have been found to be more effective in propping shale than any other type of propping agent, probably because they do not penetrate the shale.

Other propping materials include pellets or spheres or similar particulate material formed of high temperature alloys or metals or boron type glass.

"Thermit" comprises iron oxide intimately admixed with powdered aluminum compressed into pellets or beads with a suitable binding agent, such as a phenol formaldehyde resin (Bakelite), or other powdered resin. The starter beads are preferably formed of powdered aluminum mixed with either barium peroxide or sodium peroxide. The "Thermit" and starter beads may be of substantially the same size or slightly smaller than the propping pellets.

The stratum is fractured in conventional manner with a non-aqueous fracturing fluid such as oil or gas, such as air. Oil is the preferred fracturing fluid, since this material provides a readily available combustible material in the fracture. When fracturing with gas, a liquid is used for the injection of the propping agent and fire-initiating materials. When fracturing with oil, the beads of the several materials are mixed with the oil and "tailed in" after the fracturing has been affected.

Subsequently to positioning the mixture of beads or pellets in the fracture, water is pumped down the well and into the fracture system so as to contact and energize the starter material which then causes ignition of the "Thermit." By supplying air to the fracture during the burning of the "Thermit," the combustible material in the adjacent walls of the fracture is ignited and the continuing injecting of air expands the resulting combustion zone so as to drive hydrocarbon material in vapor and liquid form out of the fracture into a well with which the fracture is connected.

A more complete understanding of the invention is obtained by reference to the accompanying schematic drawing which is an elevation thru a section of stratum penetrated by a pair of wells.

Referring to the drawing, a carbonaceous stratum 10, such as an oil shale, is penetrated by an injection well 12 and a production well 14. Stratum 10 is fractured between wells as illustrated by numerals 16, 17, and 18 and the fractures are filled with pellets or beads of propping agent, "Thermit," and starting material. Water is thereafter injected thru well 12 into the several fractures where it contacts the starter material and energizes same, causing heating and combustion of the "Thermit" which heats the adjacent stratum to combustion supporting temperature. Injection of air follows immediately after injection of water so as to supply oxygen for the combustion of the carbonaceous material in the stratum. During these phases of the process, the produced fluids are recovered from well 14 by pumping or other conventional means. During combustion of the carbonaceous material in the stratum, hydrocarbons mostly in vapor form are produced thru well 14 and are readily recovered without pumping.

Continuing combustion in and adjacent fractures 16, 17, and 18 not only produces vaporous hydrocarbons by combustion and heating but also greatly reduces the viscosity of oil in areas of the stratum remote from the fractures, thereby causing liquid oil to flow into the fractures. This liquid oil is driven into the production well and is recovered by pumping whereas the hydrocarbons in gaseous form are recovered from the well head without pumping. After a substantial period of in situ com-

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bustion in and adjacent the fractures, the intervening stratum becomes sufficiently permeable to permit air flow therethru. It is then feasible to terminate injection of air thru fractures 16 and 18 and inject only thru fracture 17 so as to drive a combustion zone thru the formation substantially vertically to upper fracture 16 and lower fracture 18. Another method of operation comprises terminating injection into fracture 17 and producing thru this fracture with an injection of air continuing thru fractures 16 and 18. The conduit and packing system required in the wells for this type of operation is well known in the art and is not shown.

In application of the invention to permeable strata, production around a single well is readily effected by igniting in a single fracture in accordance with the invention and packing off the well either above or below the fracture, followed by driving the produced fluids during combustion to the well on the opposite side of the packer. It is also feasible to provide a second fracture in the stratum spaced from the ignition fracture and drive the produced fluids to the second fracture from which same flow to the injection well and are produced thru a separate conduit therefrom.

The proportions of the 3 kinds of beads injected into the fractures may vary over a wide range. On a weight percent basis, the glass beads vary from 70 to 20 percent, the "Thermit" beads from 15 to 50 percent, and the starter beads from 15 to 30 percent. Usually the fracture is filled with the mixture of beads but this is not essential to the operation of the process, it being necessary to incorporate sufficient glass beads to adequately effect propping and maintaining the fracture open during subsequent operation with sufficient "Thermit" and starter incorporated to effect the required heating for ignition of the stratum.

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 igniting a carbonaceous stratum penetrated by a well which comprises the steps of:

- (a) fracturing said stratum to extend a fracture radially outwardly from said well using a non-aqueous fracturing fluid;
- (b) injecting into said fracture a mixture of a high temperature resistant propping agent in particulate form, "Thermit" pellets, and pellets of a starter material reactive with water, using a non-aqueous injection fluid;
- (c) following step (b) injecting water into said fracture so as to energize said starter material which then heats and ignites the "Thermit" pellets; and
- (d) feeding O_2 -containing gas into said fracture so as to ignite the carbonaceous material in said stratum.

2. The process of claim 1 wherein said starter material comprises a mixture of aluminum particles with particles of a member of the group consisting of berium peroxide and sodium peroxide.

3. The process of claim 1 wherein said propping agent comprises glass beads capable of withstanding high temperatures and pressures.

4. A process for igniting a carbonaceous stratum penetrated by a pair of wells which comprises the steps of:

- (a) fracturing said stratum so as to form a fracture

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system providing communication between said wells, using a non-aqueous fracturing fluid;

- (b) injecting into said fracture system a non-aqueous fluid containing a suspension of a mixture of pellets comprising a propping agent, an igniter comprising "Thermit," and a starter material reactive with water;
- (c) subsequently, contacting the pellets in said fracture system with water so as to energize said starter material thereby supplying heat to ignite the "Thermit"; and
- (d) passing air into said fracture system during burning of said "Thermit" so as to ignite said stratum adjacent said fracture system.

5. The process of claim 4 wherein said propping agent comprises glass beads capable of withstanding high temperatures and pressures, and said starter material comprises aluminum particles admixed with particles of at least one member of the group consisting of barium peroxide and sodium peroxide.

6. A process for producing oil from an oil bearing stratum which comprises the steps of:

- (a) igniting said stratum by the process of claim 4;
- (b) continuing the injection of air to the ignited stratum to expand the burning area and produce hydrocarbons therefrom; and
- (c) recovering produced hydrocarbons from one of said wells.

7. A process for producing hydrocarbons from an oil shale stratum which comprises the steps of:

- (a) fracturing and igniting said stratum at a plurality of spaced-apart levels therein by the process of claim 4;
- (b) continuing the injection of air to the ignited areas adjacent said fractures so as to produce hydrocarbons therefrom and render the stratum between fractures permeable;
- (c) thereafter, injecting air thru alternate fractures and producing hydrocarbons thru remaining fracture(s); and
- (d) recovering produced hydrocarbons thru one of said wells.

8. A process for producing hydrocarbons from a permeable oil-bearing stratum which comprises the steps of:

- (a) fracturing said stratum at spaced-apart upper and lower levels;
- (b) igniting said stratum adjacent one of said levels by the process of claim 4;
- (c) subsequently to step (b), injecting air thru one of the fractures formed in step (a) so as to move a combustion zone thru the stratum between fractures and produce hydrocarbons therefrom; and
- (d) recovering the produced hydrocarbons from the other fracture.

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