United States Patent Office 3,375,871
Patented Apr. 2, 1968

3,375,871

ESTABLISHING AN INVERSE BURNING FRONT WITHOUT SPONTANEOUS IGNITION

Harry W. Parker, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

No Drawing. Filed June 15, 1966, Ser. No. 557,627
5 Claims. (Cl. 166—11)

This invention relates to a process for establishing an inverse combustion front in an oil stratum susceptible to spontaneous combustion while avoiding spontaneous combustion and the initiation of a direct burning front.

Numerous subterranean oil strata ignite spontaneously upon injection of air thereinto through an injection well. In order to establish an inverse or reverse burning combustion front in this type of stratum, it is essential to inject air thru the stratum from an injection well to the ignition or production well. When this is attempted in a spontaneously ignitable stratum, the injected air initiates combustion at the injection well and creates a direct burning combustion zone which forestalls the establishment of a combustion zone around the offset intended ignition well. The oil produced from an oil stratum by an inverse burning combustion front has a considerably higher API gravity than oil produced from the same stratum by a direct drive combustion front. It is therefore more desirable to produce oil from such a stratum by an inverse combustion drive.

This invention is concerned with a method or process for establishing an inverse burning front in an oil stratum susceptible to spontaneous combustion by injecting air thru the stratum to the ignition or production well without causing spontaneous combustion at the injection well.

Accordingly, it is an object of the invention to provide a process for establishing an inverse burning combustion zone front in an oil stratum subject to spontaneous combustion without effecting spontaneous combustion at the injection well. Another object is to provide a simple and efficient method of establishing in situ combustion around a production well in an oil stratum susceptible to spontaneous combustion by heating the stratum around the production well and injecting air into an offset injection well so as to drive the air to the heated area without casuing spontaneous combustion in the stratum around the injection well. 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 injecting into an oil stratum susceptible to spontaneous combustion in contact with air, thru an injection well therein, a gas of insufficient free oxygen concentration to cause spontaneous ignition in the stratum, continuing the injection of said gas while gradually increasing the free oxygen concentration over an extended period of at least several weeks so as to reach the oxygen concentration of air (about 20%) at the end of said period without spontaneous ignition, thereafter igniting the stratum around an offset production well thru which the injected gas has been produced by heating the stratum around said production well to ignition temperature so that the air passing from the injection well to the heated area effects ignition of the in-place oil, and continuing the injection of air thru the injection well to the ignited area to establish an inverse burning combustion front.

In order to ignite an oil stratum around a production well with air injected thru an offset injection well, it is necessary to supply air from the injection well to the ignition area around the production well with an oxygen concentration substantially that of air. In order to establish this condition, it has been found that the oxygen concentration of the initially injected gas must be below about 5 weight percent to avoid spontaneous combustion

and gradually and slowly build up the free oxygen concentration of the injected gas until the oxygen concentration of air is reached. Initially, the gas of low oxygen concentration givesu p oxygen tot he oil in the oil stratum which causes a minor amount of heating and only minor temperature rise in the stratum absorbing the oxygen. The stratum temperature does not reach spontaneous ignition temperature during the initiation phase of the injection and, as oxygen is slowly asborbed, the ignition point of the stratum rises until the oil in the stratum no longer absorbs any more oxygen. By the time this condition is reached, atmospheric air at full oxygen concentration can be injected into the stratum and passed to the production well without substantial loss of oxygen and without effecting spontaneous ignition of the stratum oil. With air of substantially full oxygen concentration available at the production well, it is feasible to heat the stratum around the production well to ignition temperature so that ignition takes place and the resulting combustion zone moves toward the injection well to establish an inverse burning combustion front, with oil produced from the process being recovered thru the production well.

The tolerance to oxygen depends upon the nature of the oil stratum being produced but an upper limit of about 5 weight percent of free oxygen in the initially injected gas is safe in substantially all known strata. It is feasible to start the injection with an inert gas such as combustion or flue gas, natural gas, nitrogen, etc., and mix air therewith after a short period of injection to provide a low oxygen concentration up to about 4 or 5 weight percent, raising the oxygen concentration not more than about 0.5 weight percent per 24-hour day until the oxygen concentration is that of air, which means that atmospheric air is finally injected without any dilution with other gases.

A preferred ignition technique, particularly around a production well which is provided with downhole equipment for pumping, etc., comprises that disclosed in the copending U.S. application of F. A. Klein and M. R. Dean, Ser. No. 559,804, filed June 23, 1966, wherein an autoignitable fuel, such as tung oil, linseed oil, red oil, castor oil, turpentine, tall oil, tall oil fatty acids, oleic acid, linseed oil fatty acids, or mixtures thereof, is injected into an annulus around the ignition well and contacted with air. Preferably, the autoignitable fuel is driven into the stratum away from the wall of the production well a short distance by injecting a non-oxidizing gas and/or a liquid hydrocarbon fuel having an ignition temperature substantially above the ignition temperature of the autoignitable fuel. When the production well contains a ceramic liner, it is desirable to inject the hydrocarbon fuel following the autoignitable fuel to clear the ceramic liner of the autoignitable fuel and then inject non-oxidizing gas to impregnate an annulus of the stratum spaced from the production well with the fuel or fuel mixture. When the injection of air thru the offset injection well is resumed after deposition of the fuel in the annulus of the stratum around the production well, the autoignitable fuel is burned to establish a self-propagating combustion zone which moves toward the injection well (or wells, in case a ring of offset wells is utilized). It is also feasible to utilize a fuel composition comprising the autoignitable fuel, a liquid oxidation catalyst (such as cobalt naphthenate) in a concentration in the range of 0.025 to 1.0 weight percent of the fuel, and the liquid hydrocarbon fuel as the injected fuel and follow the injection thereof with a non-oxidizing gas to drive the fuel away from the immediate vicinity of the production well.

Any other suitable ignition method may be utilized once the flow of air to the production wall from the injection well at substantially full oxygen concentration has been

established. It is feasible to burn a charcoal pack soaked with diesel fuel or the like in the production well in the event downhole equipment is not present. Another method of ignition comprises heating the wall of the wellbore within the oil stratum to at least ignition temperature by means of a downhole heater (gas, electric, or chemical) so that the air passing thru the stratum to the production well causes ignition of the surrounding heated area.

It is also feasible to inject air thru the well used as a production well during the phase of the process in which oxygen concentration is raised to that of air and ignite around the well originally utilized as the gas injection well. However, it is more practical to inject air thru the original injection and ignite around the production well.

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 an inverse burning front in an oil stratum susceptible to spontaneous combustion in contact with air, said stratum being penetrated by an injection well and a production well, which comprises the steps of:

(a) injecting into said stratum thru said injection well a gas of insufficient free O_2 concentration to cause spontaneous ignition in said stratum and producing fluids from said production well driven into same by said gas;

(b) continuing step (a) while gradually increasing the O_2 concentration over a period of at least several weeks so as to reach the O_2 concentration of air at the end of said period without spontaneous ignition;

(c) thereafter, igniting said stratum around said production well by heating same to ignition temperature and passing air from said injection well to the heated area; and

(d) continuing the passing of air from said injection well to the ignited area to establish an inverse burning combustion front.

2. The process of claim 1 wherein the initial O_2 concentration of said gas in step (a) is not more than 5 weight percent and the rate of increase in step (b) is not more than about 0.5 percent per day.

3. The process of claim 2 wherein said gas is a mixture of air and flue gas.

4. The process of claim 2 wherein ignition in step (c) is effected by depositing an autoignitable fuel in an annulus around said production well, driving said fuel into said stratum a relatively short distance by injecting an oil of substantially higher ignition point than said fuel, and contacting said autoignitable fuel with air injected thru said injection well.

5. The process of claim 4 wherein natural gas is injected thru said production well behind said oil to drive said oil a short distance into said stratum so that ignition is effected in an area spaced a few feet from said production well to protect downhole eqnuipment therein.

References Cited

UNITED STATES PATENTS

2,917,112	12/1959	Trantham et al.	166—11
3,007,521	11/1961	Trantham et al.	166—39 X
3,019,837	2/1962	Marx et al.	166—11
3,180,412	4/1965	Bednarski et al.	166—11
3,209,825	10/1965	Alexander et al.	166—11
3,221,809	12/1965	Walton	166—11 X
3,221,812	12/1965	Prats	166—11
3,314,476	4/1967	Staples	166—39 X

STEPHEN J. NOVOSAD, *Primary Examiner.*