ABSTRACT OF THE DISCLOSURE

Spontaneous ignition of crude oil in an oil stratum is prevented by injecting a slug of a liquid amine into the stratum surrounding an injection well and thereafter injecting air or other combustion supporting gas thru the injection well into the stratum to be produced by reverse in situ combustion.

This invention relates to a method or process for preventing spontaneous ignition of oil in an oil-bearing stratum during air injection into the stratum. Production of oil by in situ combustion is an accepted process in the petroleum industry. This technique involves igniting an oil-bearing stratum around a well therein to establish a combustion front and driving the combustion front by either direct or reverse drive thru the stratum to one or more surrounding wells. An inversely propagated front results from injecting air or other oxygen-containing, combustion-supporting gas thru an injection well to feed a combustion front initiated around a production well. In some oil-bearing strata, the oil is of such a nature that spontaneous combustion of the oil results from injecting the combustion-supporting gas thru an injection well into the stratum. Obviously, this results in demud ing the injected gas of O₂ so that no combustion-supporting gas reaches the combustion front around the production well and no inverse burning front is propagated. When the stratum around the injection well is ignited, a direct burning front is propagated away from the injection well. This invention is concerned with a method or process for preventing spontaneous ignition of oil in a stratum around an injection well and with a process for propagating a reverse or inverse burning front thru an oil-bearing stratum subject to spontaneous ignition.

The principal object of the invention is to provide a method or process for injecting combustion-supporting gas into an oil-bearing stratum subject to spontaneous ignition without igniting the oil in the stratum. Another object is to provide a process for conducting a reverse or inverse burning in situ combustion operation in an oil-bearing stratum subject to spontaneous combustion. A further object is to provide a method for retarding the oxidation of oil in an oil-bearing stratum around an injection well therein. 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 a section of stratum immediately surrounding an injection well penetrating an oil-bearing stratum subject to spontaneous ignition, a slug of a liquid amine oxidation retardant and thereafter injecting oxygen-containing, combustion-supporting gas, such as air, thru the injection well into the stratum, thereby avoiding spontaneous ignition of the stratum. A concentration of the amine in the range of 0.1 to about 10 volume percent based on the oil in place in the stratum into which the amine is injected is effective in retarding the oxidation of the oil. The slug of amine is sufficient to penetrate and permeate an annulus surrounding the injection well extending radially at least one foot and up to 3 or more feet from the wall of the injection well.

When injecting air or other combustion-supporting gas thru the injection well into the stratum, the highest concentration of O₂ is immediately adjacent the wall of the well and this is the area which is most subject to spontaneous combustion. As the air enters and progresses thru the stratum, the concentration of O₂ becomes less because of the increase in vertical cross section of the expanding annulus and the tendency for spontaneous ignition to take place decreases geometrically as the distance from the well wall increases.

After injecting the amine into the stratum surrounding the injection well, air is injected thru this well into the stratum and forced there thru to an offset production well where the stratum is ignited with the injected air in conventional manner as by heating up the wall of the production well to combustion-supporting temperature by burning of a fuel pack therein with the injected air whereby a combustion front moves toward the injection well. Liquid amines which may be utilized in the method or process include primary, secondary, and tertiary amines of relatively low volatility. The primary amines have the formula RNH₂ wherein R is from 4 to 12 carbon atoms. The secondary amines have the formula R₂NH wherein R is from 4 to 10 carbon atoms. The tertiary amines have the formula R₃N wherein R is from 2 to 8 carbon atoms. Mixtures of these amines may be utilized. Amines which are illustrative of those useful in the invention include butyl amine, dipropyl amine, tricetyl amine, lauryl amine, palmityl amine, stearyl amine, oleyl amine, cocoonat oil amine, tallow amine, hydrogenated tallow amine, cottonseed oil amine, soy bean oil amine, and mixtures thereof. The amine must be liquid at stratum temperature.

Tests were run with distilled cocoonat oil primary amine and with triethyl amine as oxidation retardants using boiled linseed oil as the spontaneously ignitable oil. The distilled coco primary amine used in the test was Alamine 21D supplied by General Mills. Oillinseed oil was mixed with the linseed oil at a weight ratio of 9 sand to 1 of oil and the mix was packed into an adiabatic tube 2" in diameter to form a 2" long section in the central portion of the tube. The tube and sand were preheated to a temperature of 150°F with nitrogen flowing thru the sand. The flow of nitrogen was terminated and O₂ was passed thru the sand at a rate of 5 s.c.f./hr./ft.². The temperature of the sand during O₂ flow was sensed and recorded.

Similar runs were made in the apparatus utilizing linseed oil containing 0.9 and 9.0 volume percent distilled coco primary amine and 9 volume percent triethyl amine.

Untreated linseed oil under the conditions of the test exhibited a temperature increase of 75°F in 40 minutes. In the run using only 0.9 volume percent distilled coco primary amine, there was only a 24°F rise in 60 minutes while with 9 volume percent of triethyl amine a rise of 28°F in 80 minutes was recorded. With a concentration of 9 volume percent of the distilled coco primary amine in the oil, the temperature increased only 19°F in 240 minutes of O₂ flow. The test is rather severe since linseed oil is a particularly easily ignitable substance under the test conditions.

In actual practice the amount of amine required depends upon the nature of the formation crude, but should rarely exceed 5 volume percent of the oil-in-place volume in the immediate (1 to 3') vicinity of the injection well. The tests show that smaller quantities of higher amines are effective as larger amounts of lower amines but that both are useful. The appropriate choice depends upon the nature of the deposit, the price, and the availability of the amine additives.

The propagation of a reverse burning in situ combustion front in accordance with the invention is effected in
any type of well pattern. The conventional 5-, 7-, or 9-spot pattern is suitable, either the center well or the ring wells being used as production wells with the amine slug being injected thru the injected well(s). The process may also be effected using parallel lines of wells, preferably, a line of injection wells intermediate parallel lines of production wells.

The oxidation retarding effect of the amine is unexpected because this class of compounds is combustible and even has been recommended as igniters for in situ combustion. However, the amine suppresses the oxidative reaction of more readily flammable oils and prevent the temperature rise which leads to self-propagating ignition. The effect is not simply one of dilution since even a concentration of 0.1 percent of these amines is effective.

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.

We claim:

1. A method of preventing ignition of an oil-bearing stratum subject to spontaneous ignition when injecting combustion-supporting, O₂-containing gas into same thru an injection well wherein, which comprises the steps of:

   (1) depositing in the annular 1 to 3 foot wide section of stratum immediately surrounding said well a continuous liquid phase slug of a liquid amine oxidation retardant of at least 4 carbon atoms which remains liquid at stratum temperature to provide a concentration of liquid amine in the range of 0.1 to 10 volume percent of the oil in place in said section; and

   (2) following step (1), injecting said combustion-supporting gas free of oxidation retardant into said stratum thru said well, thereby avoiding spontaneous ignition of said stratum.

2. The method of claim 1 wherein said amine is distilled coco primary amine.

3. The method of claim 1 wherein said amine is triethylamine.

4. A process for initiating and propagating an inverse burning combustion front in an oil-bearing stratum penetrated by an injection well and a production well and containing oil which is subject to spontaneous ignition which comprises the steps of:

   (1) injecting into said stratum thru said injection well a liquid slug of a liquid amine in continuous liquid phase which remains liquid at stratum temperature as an oxidation retardant so as to effect a concentration of said amine in an annulus of at least 1 foot and up to 3 foot radius adjacent said well in the range of 0.1 to 10 volume percent of the oil in place;

   (2) injecting O₂-containing, combustion-supporting gas free of oxidation retardant thru said injection well and producing same thru said production well;

   (3) thereafter, igniting said stratum adjacent said production well with the gas of step (2);

   (4) continuing the injection of gas in step (2) so as to propagate a combustion front thru said stratum toward said injection well; and

   (5) recovering produced oil thru said production well.

5. The process of claim 4 wherein said gas is air.

6. The process of claim 5 wherein said amine is distilled primary coco amine.

7. The process of claim 5 wherein said amine is triethylamine.

References Cited

UNITED STATES PATENTS

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OTHER REFERENCES


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