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[54] **METHOD FOR INITIATING IN-SITU COMBUSTION**

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[58] **Field of Search** 166/256, 302, 260, 166/261, 59

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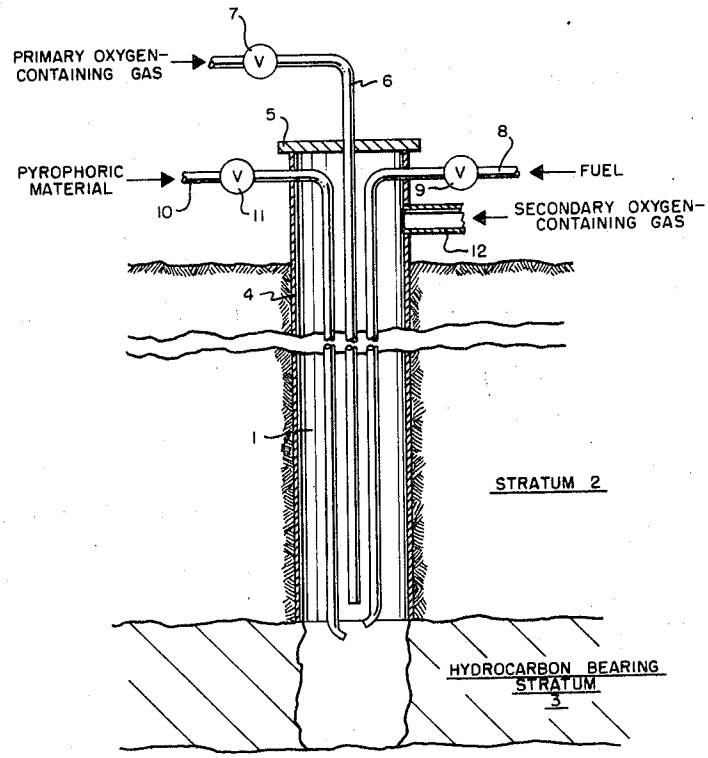
Primary Examiner—Stephen J. Novosad

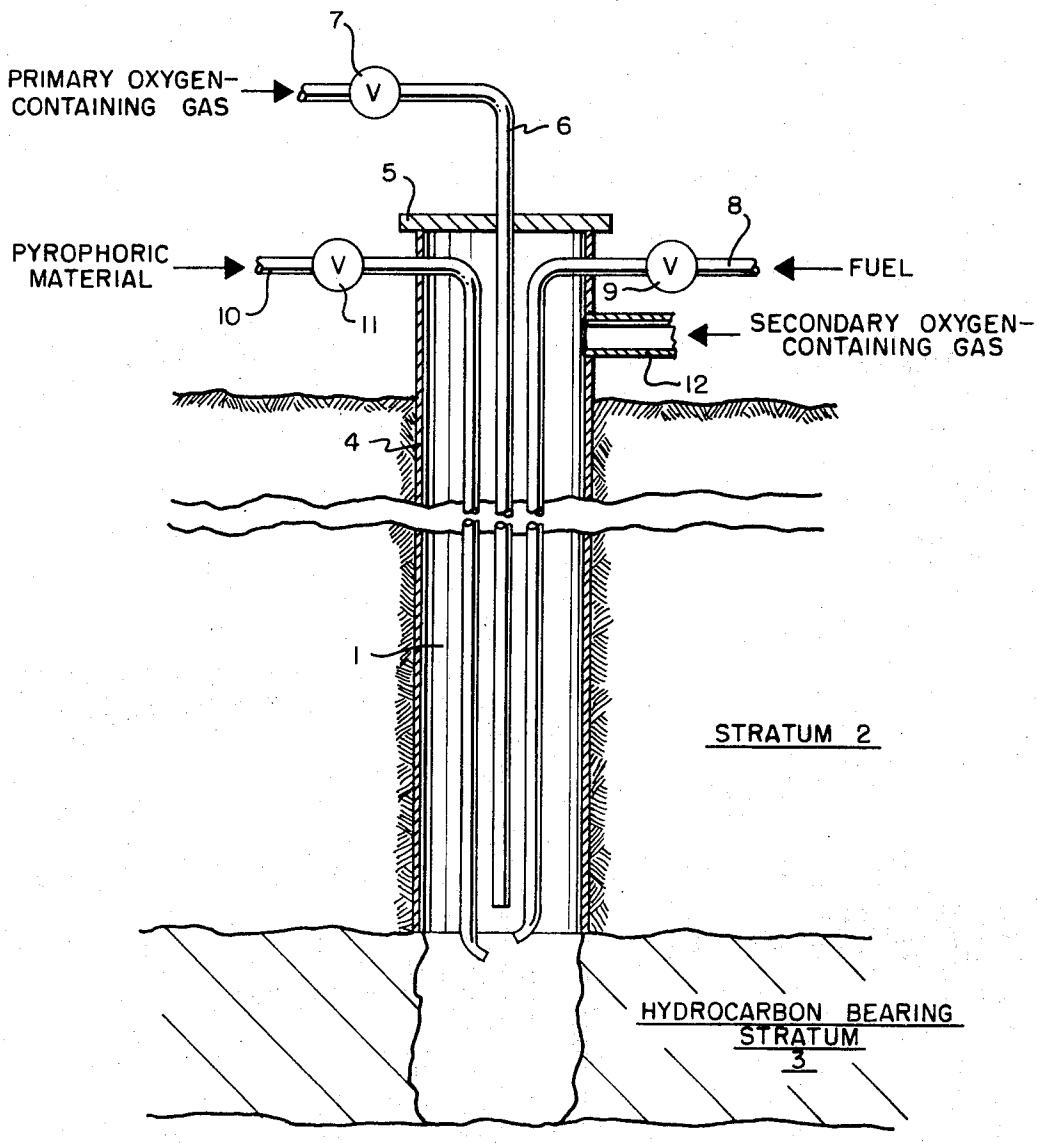
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[57] **ABSTRACT**

A method of initiating in-situ combustion in a subterranean hydrocarbon-bearing formation by igniting a hydrocarbon fuel-air mixture in an input well by contacting the air with a pyrophoric material to give a spontaneous combustion reaction which thereafter initiates combustion of the hydrocarbon fuel and air.

10 Claims, 1 Drawing Figure




7
PRIMARY OXYGEN-CONTAINING GAS
V
6
5
8
PYROPHORIC MATERIAL
V
V
FUEL
9
10
11
SECONDARY OXYGEN-CONTAINING GAS
12
4
1
STRATUM 2
HYDROCARBON BEARING STRATUM 3

METHOD FOR INITIATING IN-SITU COMBUSTION

BACKGROUND OF THE INVENTION

This invention relates generally to the initiation of in-situ combustion of a subterranean hydrocarbon-bearing formation and more particularly to a method for ignition of a free oxygen-containing gas and a hydrocarbon fuel adjacent the stratum to be ignited by the use of a pyrophoric material.

In modern day production of hydrocarbons from subterranean formations it is common practice to apply secondary recovery techniques to recover additional quantities of hydrocarbon. One of the more common secondary recovery techniques employed is that of in-situ combustion. In this method of producing hydrocarbons, combustion is initiated in the hydrocarbon-bearing formation or stratum by means of an ignitor positioned in a wellbore adjacent thereto. Once the stratum has been successfully ignited, a combustion supporting fluid, e.g., a free oxygen-containing gas, such as compressed air, is injected into the wellbore to support the combustion front and move it thru the hydrocarbon-bearing stratum towards a production well.

In order to accomplish successful in-situ combustion, it is necessary that ignition of the formation be sufficient to subsequently sustain the necessary high temperatures to establish and propagate a combustion front. Among the techniques for initiating in-situ combustion included in the prior art are various types of ignitors including downhole gas heaters, electrical heating devices, chemical compounds and other combustibles placed in the wellbore.

In the use of a downhole gas heater for an in-situ combustion process a hydrocarbon fuel such as methane or natural gas is combusted with a free-oxygen containing gas, e.g., air, in an input wellbore to a temperature greater than about 400° F., for example 600°–1200° F., to establish the combustion. Generally, the downhole heater, which is lowered into the wellbore and positioned adjacent the stratum desired to be ignited, consists of an apparatus which satisfactorily mixes and burns the hydrocarbon fuel and the free oxygen-containing gas, hereafter referred to as air, in the wellbore for initiating combustion in the stratum. Streams of the hydrocarbon fuel and the air are provided via separate tubes extending down the wellbore to the desired depth at which combustion is to be initiated. A sparking device or an electrical ignition system is employed as a means for igniting the hydrocarbon fuel-air stream.

In operation, however, difficulties often arise due to the fact that the operator is at least several hundred feet above the level of the burning, making control of the combustion difficult. Other difficulties arise concerning stringing of the electrical conductors, sizing of the wires and thermal insulation. In addition, these electrical systems are prone to burn out because of the excessive temperatures generated in the wellbore, thus making it impossible to re-ignite the stratum if the initial attempt was unsuccessful unless the inoperative heater is pulled and placed in a working condition again.

Thus, it is an object of this invention to overcome these difficulties and also to provide for control of ignition of the formation. It is a further object of this invention to provide for reignition of the formation without

the necessity of retrieving the heater in order to repair electric failure and thereafter repositioning the heater.

SUMMARY OF THE INVENTION

The invention herein disclosed provides an improved method of initiating an in-situ combustion by igniting a hydrocarbon fuel-air mixture in an input wellbore by contacting the air with a pyrophoric material to give a spontaneous combustion reaction which thereafter initiates combustion of the hydrocarbon fuel and air.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE of the drawing is a diagrammatic vertical cross-section of a wellbore having positioned therein a downhole gas heater apparatus and an ignition pilot tube.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The method of the present invention can be best described by reference to the single FIGURE drawing showing a diagrammatic sketch of a wellbore equipped with a downhole gas heater arrangement and an ignition pilot tube for the introduction of the pyrophoric material.

The FIGURE shows a wellbore **1** traversing a subterranean stratum **2** and a subterranean hydrocarbon-bearing stratum **3.** A casing **4** that extends down to the hydrocarbon-bearing stratum **3** is cemented in place. The casing is capped with a wellhead **5** located at the surface. Inside the casing is placed a first tubing **6** with suitable valving **7.** The first tubing extends thru the wellhead and almost to the top of the hydrocarbon-bearing stratum **3.** A second tubing **8** containing valve **9** is inserted into the wellbore just below the wellhead **5** and also extends about the top of the hydrocarbon-bearing stratum **3** with its lower end suitably positioned with respect to the lower end of tubing **6,** to provide for satisfactory contacting of the fuel and the air stream. Tubing **6,** at the surface, is connected to a source for a primary oxygen-containing gas such as air. Likewise, tubing **8,** at the surface, is connected to a hydrocarbon fuel source, preferably natural gas or methane.

A third tubing **10** containing valve **11** is inserted into the wellbore just below the wellhead and also extends to the outlet ends of tubings **6** and **8.** Tubing **10** is connected to a source of the pyrophoric material, and provides means for the introduction of the pyrophoric material into the wellbore, and discharge adjacent to the outlet of tubing **6,** which provides the primary air. Means for displacing the pyrophoric material from tubing **10** (not shown) may be provided by suitable means using a displacing agent such as the hydrocarbon fuel. A fourth tubing **12,** entering the wellbore below the wellhead, provides means for supplying a secondary oxygen-containing gas such as air to the wellbore.

In operation, the primary air and secondary air are started in lines **7** and **12** respectively. Valve **11** is then opened in line **10** to admit the pyrophoric material which is displaced into the formation by suitable means. Upon contact with the primary air at the lower end of tubing **7,** spontaneous reaction occurs and the pyrophoric material is combusted. Valve **9** of line **8** is then opened to permit injection of a fluid hydrocarbon fuel. This combustion of the pyrophoric material, in turn, initiates burning of substantially all of the hydrocarbon fuel with the primary air. Further combustion

can be obtained by the secondary air stream whereby any unburned fuel is combusted upon contacting the secondary air. When combustion of the hydrocarbon fuel-air mixture is established, valve **11** is closed and no further pyrophoric material is injected.

In the method of invention the heating of the hydrocarbon-bearing stratum can be continued as long as desired. Preferably, the procedure will usually be continued until the hydrocarbon-bearing formation around the wellbore is undergoing in-situ combustion up to about 2 feet from the wellbore (i.e., the temperature in this part of the formation is in the range of 400°–1200° F.). Thereafter, the valves **7** and **9** are closed. Secondary air is continued to be injected to sustain combustion of the hydrocarbon in the hydrocarbon-bearing stratum.

Generally, the amount of hydrocarbon fuel supply will be such that its mixture with all of the air available will have a heat of combustion of less than 40 BTU per cu. ft. Accordingly, when using air and a hydrocarbon gas of 1,000 BTU per cu. ft., the hydrocarbon fuel excess is preferably not greater than about 4 volume percent of the total air provided. With lower BTU fuels, increased volumes of the fuel can be used to maintain about 15 to 40 BTU per cu. ft. of the total fuel and air mixture. The quantity of secondary air supplied will depend on the desired temperature of the final gas mixture.

Any pyrophoric material may be used. However, a gaseous pyrophoric material such as a hydride of silicon or phosphorus, i.e., silane (SiH_4), disilane (Si_2H_6) or phosphine (PH_3) is preferred. The pyrophoric material may be introduced in either substantially pure form or diluted in a carrier gas such as hydrogen or an inert gas, e.g., nitrogen, argon or helium. In either form the pyrophoric material may be displaced into the wellbore by a displacing agent such as methane or natural gas.

In ignition tests using silane to ignite a natural gas-air mixture, silane injections were made using two lengths 0.25-inch diameter (0.19 inch I.D.) of tubing **10** and 30 feet. The tubes were partially or totally filled with silane which was then displaced into the atmosphere by natural gas. Ignition of the pyrophoric material occurred upon contact with air. At 80° F., at least 65 percent of the tube volume was required to be filled with silane to give ignition. At temperatures of about 200°–300° F. the required volume of silane in the tube was about 40 percent. When 100 percent of the tube volume was occupied by silane, the silane ignited in the presence of air and burned as a pilot until the natural gas started to burn.

Additional ignition tests were made in which 15 volume percent silane in hydrogen gas was found to ignite spontaneously in air. In these tests, the silane-hydrogen mixture was injected through a tube and burned as a pilot upon contact with air. Natural gas was then introduced behind the pyrophoric material until it reached the tube exit and also began to burn.

We claim:

1. A method for initiating and continuing combustion in a subterranean hydrocarbon-bearing formation penetrated by a wellbore comprising:

a. introducing into said wellbore a stream of free oxygen-containing gas,

b. simultaneously introducing into said wellbore a stream of a hydride of silicon,

c. contacting said hydride with said free oxygen-containing gas to produce a spontaneously combustible reaction in the vicinity of said subterranean hydrocarbon-bearing formation,

d. thereafter introducing into said wellbore a stream of fluid hydrocarbon fuel while continuing injection of said free oxygen-containing gas and said hydride for a time sufficient to insure combustion of said hydrocarbon fuel,

e. terminating injecting said hydride material,

f. continuing injection of said hydrocarbon fuel and said free oxygen-containing gas to continue the combustion reaction to establish combustion of said hydrocarbon-bearing formation,

g. terminating injection of said hydrocarbon fuel,

h. continuing injection of said free oxygen-containing gas to support combustion of said hydrocarbon-bearing formation.

2. The method of claim **1** wherein said hydride of silicon is silane, disilane and mixtures thereof.

3. The method of claim **1** wherein said hydride of silicon is admixed with hydrogen gas prior to introduction into said wellbore.

4. The method of claim **3** wherein said hydride of silicon is admixed with said hydrogen gas in at least 15 volume percent of total hydride and hydrogen gas.

5. The method of claim **1** wherein said hydride of silicon is admixed with inert gas prior to introduction into said wellbore.

6. The method of claim **1** wherein said hydride of silicon is introduced into said wellbore by displacement with natural gas, methane and mixtures thereof.

7. The method of claim **1** wherein said hydrocarbon fuel is selected from the group consisting of methane and natural gas.

8. The method of claim **1** wherein said free oxygen-containing gas is air.

9. A method for initiating combustion of hydrocarbon fuel in a wellbore penetrating a subterranean hydrocarbon-bearing formation which comprises separately introducing into said wellbore in the vicinity of said hydrocarbon-bearing formation a hydrocarbon fuel, a free oxygen-containing gas and a hydride of silicon capable of reacting spontaneously with said oxygen-containing gas into admixture with one another, effecting spontaneous reaction of said oxygen-containing gas and said hydride of silicon and thereby initiating combustion of said hydrocarbon fuel in said free oxygen-containing gas.

10. The method of claim **9** wherein said hydride of silicon is admixed with hydrogen gas prior to introduction into said wellbore.

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