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METHOD AND APPARATUS FOR HEATING A SUBSURFACE FORMATION

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FIG. 1

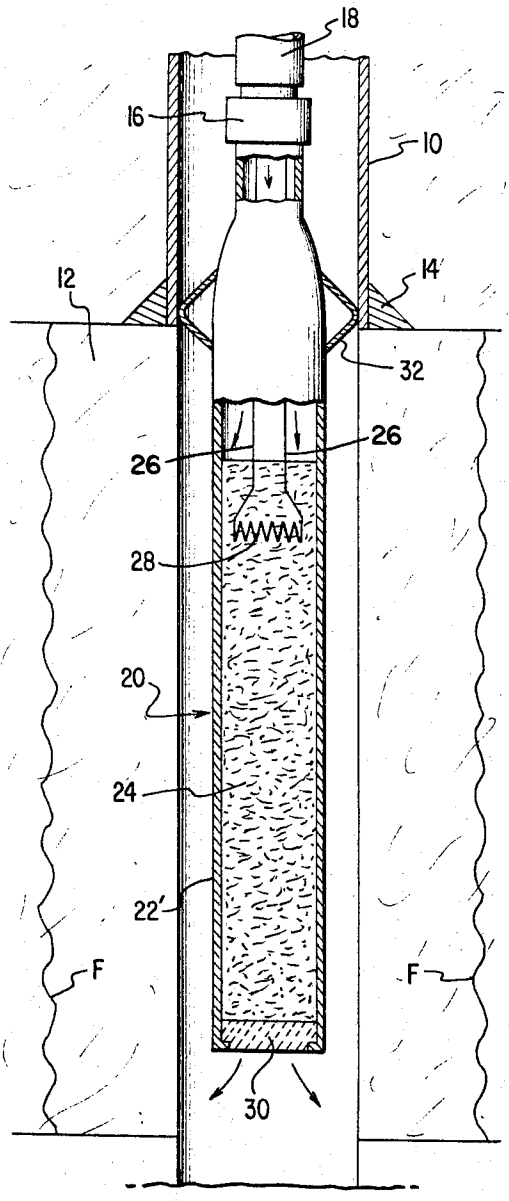
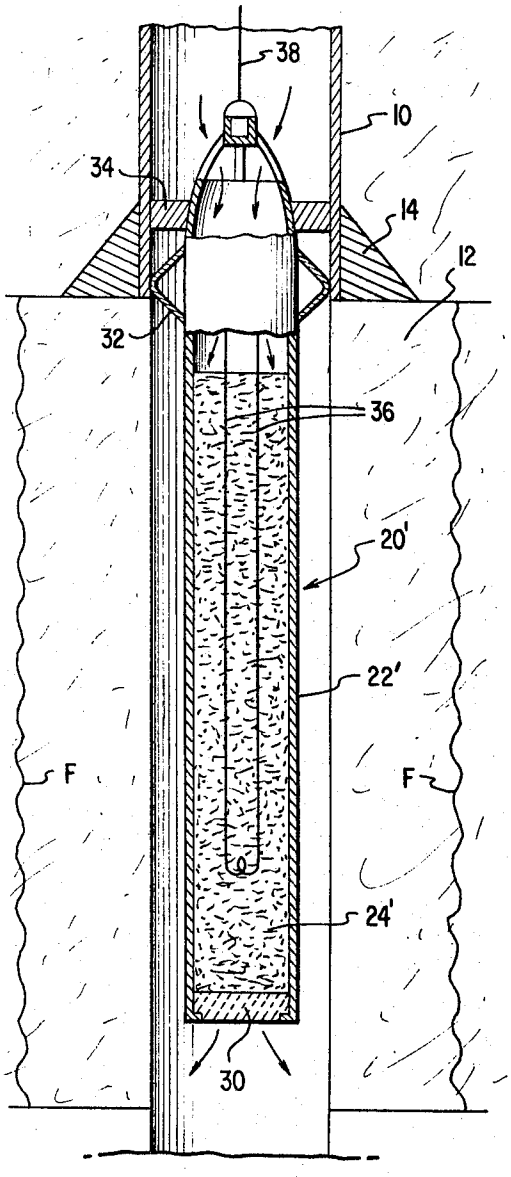


FIG. 2



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METHOD AND APPARATUS FOR HEATING A SUBSURFACE FORMATION

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ABSTRACT OF THE DISCLOSURE

A method of and an apparatus for heating a formation within a borehole. A catalytic heater is lowered to the formation, and a fuel gas and an oxidizing gas are passed therethrough. The catalytic heater is heated by an electric heater to a temperature above the temperature of oxidation of the fuel gas-oxidation gas mixture and below the temperature of oxidation of the heater. The borehole can be closed by a heat shield.

This invention relates to a downhole burner for use in heating a bore hole, igniting a hydrocarbon-containing subterranean formation to provide combustion in the subterranean formation, and other similar applications.

Hydrocarbon materials can be recovered from a hydrocarbon-containing subterranean formation by a method which involves combustion of a portion of the hydrocarbons within the formation. In this method, a combustion supporting gas such as air is injected into the formation through an input well and combustion of hydrocarbon within the formation is initiated by suitable means. The formation is, for example, provided with a single output well, or more, if desired, e.g. four output wells each spaced 90° from each other on a circle having an input well at its center, and, as the flow of combustion supporting gas to the formation is continued, a flame front migrates from the input well to the output well or output wells. Combustion gases, oil, and distillation and cracked products of the hydrocarbons migrate in advance of the flame front to the output well or wells from which they are removed to be treated for recovery of the desired valuable hydrocarbon materials or other constituents. The heat of the fluids migrating in advance of the flame front strips the hydrocarbon-containing formation of water and the greater portion of the hydrocarbon, leaving behind a carbonaceous deposit which is essentially the fuel consumed in the process. The flame front migrates from the input well to the output well or wells in the zone of combustion progressively moving through the carbonaceous deposit.

Heated zones are also used in conjunction with small diameter cemented well tubing which has been used for water injection and which has become sludged or clogged with foreign agents. These agents may consist of bacterial organisms, insoluble carbonates, or heavy waxy hydrocarbons, and are of such a nature that they are either consumed at the point of clogging or disintegrated thereby to a powdery form by heat or fire. After this treatment, they can be blown from the well by air or flushed to the surface by water.

In carrying out these recovery methods, it is necessary to heat the formation at the desired location, e.g. ignite the hyrodcarbon in the formation at the input well in order to, for example, initiate recovery of the hydrocarbon at the output well, or wells, and in some instances heating at the output well is desirable. A number of methods and apparatus which have been successful, but difficult to operate, are known for ignition and heating a bore hole to initiate a thermal oil recovery process. Such ignition means have included downhole burners supplied

with primary and secondary air, hot fluid injection, and chemical reaction heating. Electric heaters are also common. This invention is directed to a method and apparatus which simplifies the ignition or heating of the hydrocarbon in a well bore.

The present invention comprises a method of and an apparatus for heating a location within a well bore. An elongated tubular casing closed on its lower end by a porous plate and substantially filled by a porous matrix is lowered to the location, and a fuel gas and an oxidizing gas are passed through the matrix, resulting in oxidation of the mixed gases. If the gas mixture does not oxidize at the temperature of the matrix, which can include an oxidation catalyst, the matrix can be heated by a heater imbedded in its upper portion. The well bore above the matrix can be closed by a heat shield to assure that the combustion gases travel in the desired direction.

In general, the burner of this invention comprises a bed of particulate solids, in a tube which is run on the end of tubing to just above the desired location for heating, e.g. the top of the hydrocarbon-containing reservoir. In one embodiment the tube contains a small heater to which electrical contact is made through the tubing which heats the bed to ignition temperature, e.g. approximately 1200° F. The time for the heater to heat the top of the porous matrix, i.e. the bed, may be determined experimentally or calculated. An air and fuel mixture below the combustible limit at the burner temperature is then injected down the tubing whereby the mixture is heated to the desired temperature for oxidation of the fuel in the porous matrix and to increase the temperature of the gases which pass into the formation to ignite the hydrocarbons in the formation. For example, methane with a lower-combustion-limit of about 4–5 percent CH_4 in air can be used in a typical mixture of 2.7 percent methane in air which would give about 27 B.t.u./s.c.f. with a burning temperature of 1400° F. The entire porous matrix will first reach this temperature and finally the hot gases will heat the reservoir rock to ignite the reservoir.

The length of the porous matrix, i.e. bed of particulate material, is such as to essentially completely oxidize the fuel before exiting to the formation and is dependent upon the gas, the gas rate, the temperature of the bed (and thus the B.t.u. content of the gas) and the characteristics of the porous media. The porous matrix can be an inert material, e.g. glass beads, or the matrix can be an oxidation-promoter, catalyst material which will require a shorter tube length than an inert material. Suitable oxidation catalysts include platinum, palladium, vanadium, iron, titanium, tungsten, copper, chromium, cobalt, aluminum, nickel, manganese, cerium, silicon, silver, molybdenum, tin, tungsten, zirconium, rhodium, combinations of these materials, alone or supported on various porous materials. A suitable matrix of this type is illustrated in U.S. Patent 2,742,437.

Suitable fuels for use in this invention include those fuel gases which will oxidize at the desired temperature, e.g., 500 to 2000° F., or more, depending upon the fusion temperature of the formation rock, such as light hydrocarbon gases, e.g., the lower alkanes, including methane, propane, etc. The particular fuel will, however, depend upon the type of porous media and may include such fuels as methanol, hydrogen etc. With certain fuel gas and catalyst combinations oxidation is rapid and starts at low temperatures, e.g., temperatures as low or lower than the formation temperature. A combination of catalyst and easily oxidized fuel is manganese dioxide-cupric oxide catalyst with carbon monoxide fuel. Thus, with such combinations no electric heater would be required.

The ignition apparatus and method of this invention

requires no added power, as electrical power (except in the case where the small starting heater which requires a small amount of power is used for a very short time). The burner can be put on a wire line with one string of tubing which can be easily run into and out of the well bore. It can be desirable to pack the casing above the burner to prevent bypassing of the gas up the bore hole. This burner also permits full and simple automation of the burning and ignition procedures. Thus labor of attending the ignition period is eliminated. Furthermore, the burner is safe as no mixtures of fuel-air need be in the bore hole which will burn free in air. The burner also is not sensitive to pressure surges. Pressure changes are particularly troublesome when burning propane in some types of burners. A slightly lower pressure in the bore hole can vaporize substantial amounts of propane whereby the fuel-air ratio becomes too high resulting in excessive temperatures, melting of the burner and fusing of the formation to glass or molten rock.

This invention will now be described more particularly with reference to the accompanying drawing wherein FIGURES 1 and 2 are sectional views of two embodiments of the bottom hole burner of this invention.

Referring to FIGURE 1, the burner, generally designated **20**, comprises an elongated cylindrical member **22** which is adapted at its upper end to be connected by coupling **16** to a string of hollow tubing which is lowered into the subterranean passage illustrated by casing **10**. Member **22** contains a porous matrix bed **24** of particulate material such as described above. Tubing **18** is open at its lower end and has projecting from this end electrical leads **26** which terminate in an electrical heater **28**. The member **22** is closed at its lower end by porous plate **30**.

In operation, bottom hole burner **20** is attached to the end of a string of well tubing and lowered into the passage, formed by well casing **10**. As it is lowered, electrical leads **26** are extended so that their upper ends are at the earth's surface. The outside diameter of burner **20**, defined by the protective sheath or member **22**, is such that a space is left between it and the passage bore, its casing or tubing as the case may be. Thus, the outside diameter of the protective sheath must be smaller than the internal diameter of casing **10** into which it is being lowered to permit lowering and, possibly, passage of air to help support combustion.

After appropriate surface connections have been made for tubing **18**, air, or any oxygen-rich gas, and fuel are introduced through tubing **18** into member **22** and passed through the porous media **24** situated in the lower end of member **22** which projects beyond tubing **18**. Before the air and fuel are started, porous matrix **24** is heated by electrical heater **28** to a temperature sufficient to oxidize the fuel. A thermocouple can be used as shown in FIGURE 2, if desired, to indicate the temperature of the matrix. Fuel and air are fed through tubing **18** and the oxidation of the fuel and heating of the air is continued until a sufficient heating in the bore hole is accomplished or until combustion is initiated in the formation by the air and gases of oxidation passing into the formation through porous plate **30** (see arrows). Once the media reaches the oxidation temperature of the fuel, the electrical heat input is discontinued. A spring-loaded heat shield **32** mounted at the upper end of member **22** may be used to force the hot gases and oxygen into the formation by closing the well casing **10**. Air to support combustion in the formation can pass inside of tubing **18** or outside of the tubing through casing **10** or can take both courses. Following ignition of the material in the formation **12**, the area of combustion will spread outwardly of the well along a front F. The temperature in the well is regulated by adjusting the air-fuel ratio and can vary, depending upon the results to be accomplished, e.g., removal of clogging material from tubing, ignition of oil sands, etc.

FIGURE 2 illustrates a second embodiment of this invention. In this embodiment oxygen and fuel pass through casing **10** and a packer **34** of conventional construction is arranged in the well bore to force the gases through member **22'** (see arrows) and the porous matrix **24'** which, in this instance, is a catalytic material capable of oxidizing the fuel at formation temperature, i.e., 0.05" diameter pellets of alpha Al_2O_3. Thermocouple **36** can be used to measure the temperature of the porous media and determine the desired fuel:oxygen ratio, etc. The igniter **20'** is supported on cable **38** and casing **22'** is open at the top. The fuel is hydrogen and at about 1000° F. methane is used.

Thus it is seen that this invention provides a compact, efficient, rapid and inexpensive means for initiating and maintaining combustion in subterranean passages.

What is claimed is:

1. A method for supply heat to a location in an underground formation which has well bore piercing the same at said location comprising locating in said bore at said formation a tube containing a porous matrix adapted to have gases flow therethrough, injecting a fuel gas and an oxidizing gas mixture into said tube, heating said porous matrix to a temperature above the temperature of oxidation for the fuel gas-oxidizing gas mixture and below the temperature of oxidation of said matrix, oxidizing said fuel gas in said matrix, said fuel gas having an exit temperature from said matrix of from about 500° F. up to the fusion temperature of said formation, said fuel gas-oxidizing gas mixture having a concentration of the one in the other below the combustible limits therefor at the temperature prevailing in said bore, and passing the hot gases of oxidation into said formation to heat said formation.

2. The method of claim **1** wherein said heating is discontinued after said oxidation begins.

3. The method of claim **1** wherein the length of said porous matrix is sufficient for essentially complete oxidation of the fuel gas.

4. A method for supplying heat to a location in an underground formation which has a well bore piercing the same at said location comprising locating in said bore at said formation a tube containing a porous matrix adapted to have gases flow therethrough and consisting of manganese dioxide-cupric chloride catalyst, injecting carbon monoxide and an oxidizing gas mixture into said tube, oxidizing said carbon monoxide in said matrix, said carbon monoxide having an exit temperature from the matrix of from about 500° F. up to the fusion temperature of said formation, said carbon monoxide-oxidizing gas mixture having a concentration of the one in the other below the combustible limits therefor at the temperature prevailing in said bore, and passing the hot gases of oxidation into said formation to heat said formation.

5. A downhole burner for use in well bores consisting essentially of an elongated tubular casing adapted to slide within said well bore, means for lowering said casing into said bore, a porous plate closing one end of said casing, a porous matrix substantially filling said casing, an electrical heater in the upper portion of said matrix, and means for passing fuel gas and oxidizing gas through said casing.

6. A downhole burner for use in well bores consisting essentially of an elongated tubular casing adapted to slide within said well bore, means for lowering said casing into said bore, a porous plate closing one end of said casing, a porous matrix substantially filling said casing, means for passing fuel gas and oxidizing gas thorugh said casing, and heat shield means for closing the bore above said burner and directing the hot gases exiting from said casing through said plate into the formation.

7. A downhole burner for use in well bores consisting essentially of an elongated tubular casing adapted to slide within said well bore, cable means for lowering said casing into said bore, a porous plate closing one end of said

casing, a porous matrix substantially filling said casing, means for passing fuel gas and oxidizing gas through said casing, and means for sealing the bore between said casing and the said well of said bore, said means for passing fuel gas and oxidizing gas through said casing being formed by at least one opening in the wall thereof above said means for sealing and said matrix for the introduction thereinto of gases passing down through the well bore.

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