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METHOD FOR INITIATING UNDERGROUND COMBUSTION

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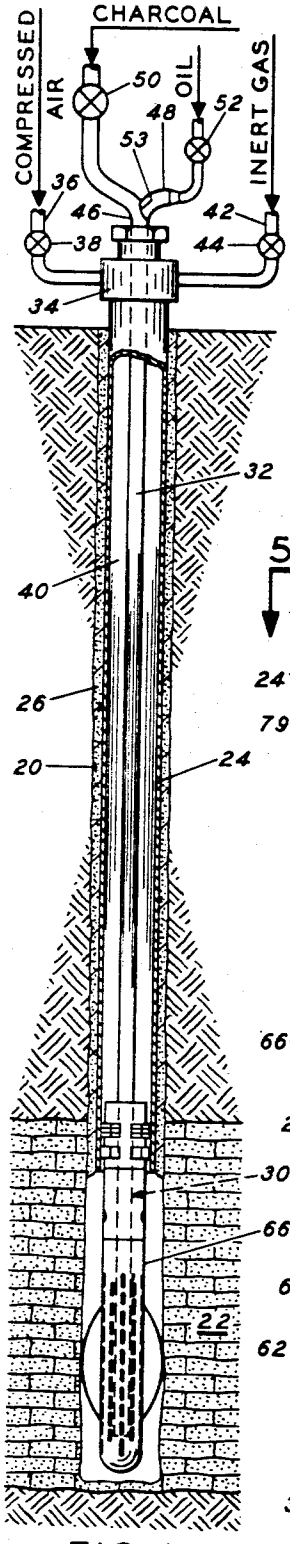


FIG. 1

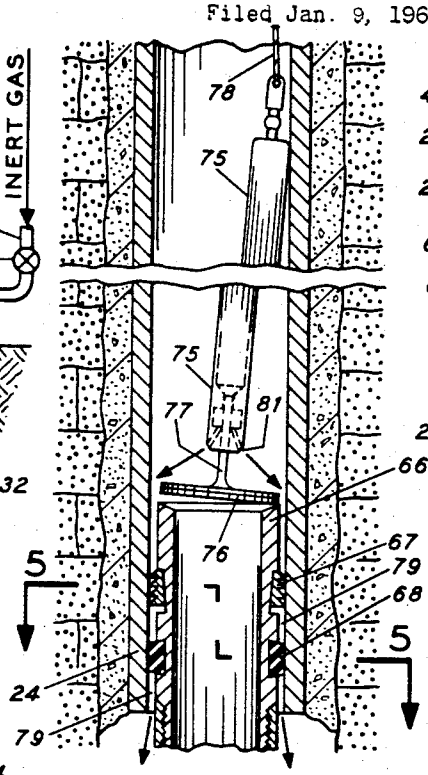


FIG. 4

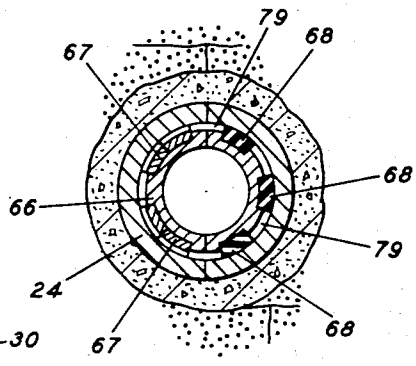


FIG. 5

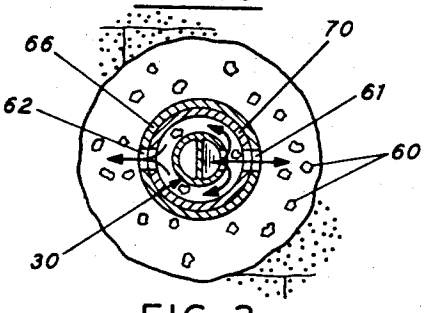


FIG. 3

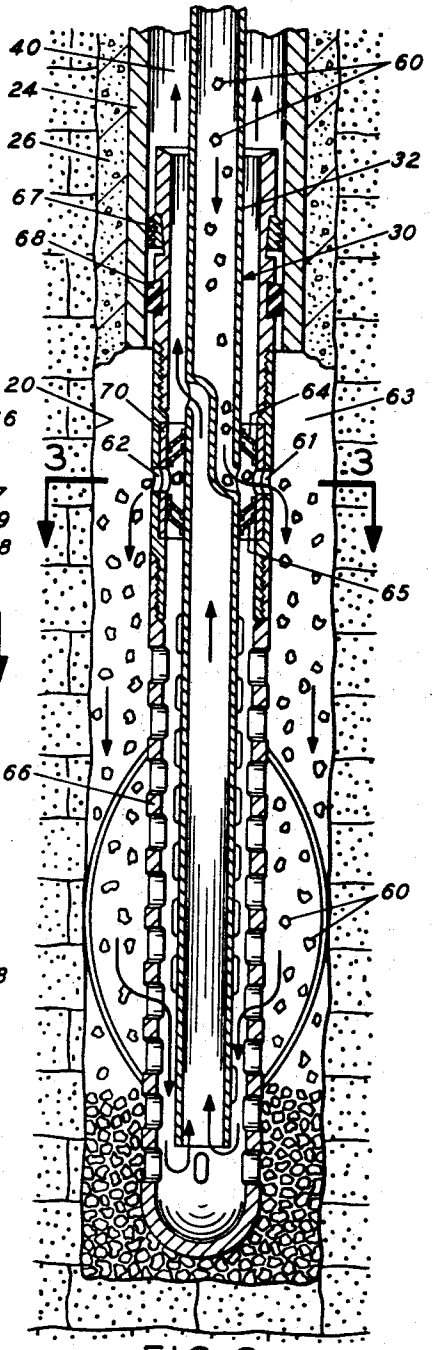


FIG. 2

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METHOD FOR INITIATING UNDERGROUND COMBUSTION

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ABSTRACT OF THE DISCLOSURE

A method of igniting underground petroleum formations having a perforated liner in the well adjacent the formation by packing the annular space between the exterior of the perforated liner and the well wall with a combustible material, igniting the combustible material and injecting air through the perforations of the liner to burn the combustible material and to cause the ignition of the petroliferous material in the formation.

Briefly the present invention provides a method for igniting a petroleum bearing formation penetrated by a well and having a perforated liner in the well adjacent to the formation by packing the annular space between the formation and the liner with a combustible material. The combustible material is ignited and an oxygen containing gas is injected down the well and out through the perforations of the liner into the combustible material to support the combustion thereof and to ignite the petroleum bearing formation.

This invention relates to igniting underground petroleum-bearing formations penetrated by a well; and, more particularly, this invention relates to an improved method for placing a combustion initiator in a well behind a perforated liner to elevate the temperature of an underground hydrocarbon-bearing formation so that combustion in the formation may be started without damage to the perforated well liner or the well casing.

Underground combustion, wherein a portion of the oil in an oil-bearing formation is burned to assist in producing an unburned portion of the oil, has become a conventional tool of secondary recovery engineers. One problem, however, that is still not completely solved concerns igniting the petroleum in the formation. Heretofore, ignition was accomplished in a variety of ways. However, a serious problem has been encountered when it is desired to ignite cased or lined wells because the heat generated during ignition is often sufficient to burn out the liner or casing and cause collapse of the liner or casing possibly resulting in loss of the well.

The present invention is directed to a method for igniting a petroliferous formation penetrated by a well and having a perforated liner positioned adjacent the petroleum-bearing interval. In accordance with the present invention, the annular space between the exterior of the perforated liner and the well wall is packed with a combustible material. At least the upper portion of the combustible material is brought into contact with a pyrophoric material of a type which will permit autoignition of the combustible material in the presence of oxygen. An oxygen-containing gas, for example air, is then injected into the well and out through the perforations in the liner into the combustible material to cause ignition to occur. The injection of oxygen-containing gas is continued and ignition of the entire amount of combustible material in the annular space is accomplished. The oxygen-contained gas passes outward through the slots into the charcoal and then into the formation. The relatively cool gas passing through the perforations prevents overheating of the liner and thus damage to the liner is avoided. In addition, the ash from the combustible material is carried into the more permeable portions of the oil-bearing interval and assists in reducing the flow of gas into these more permeable portions. This assists in redirecting air into somewhat less permeable portions of the formation to help establish a more uniform gas injection profile which in turn results in more uniform ignition and combustion in the formation.

A particular object of the present invention is to provide a method for igniting an underground formation in a manner to prevent damage to a well liner and to assist in assuring uniform ignition over an entire vertical interval of an oil-bearing formation.

Further objects and advantages of the present invention will become apparent from the following detailed description read in light of the accompanying drawing which is made a part of this specification and in which:

FIGURE 1 is an elevational view with parts broken away for clarity of presentation showing the preferred form of apparatus assembled in accordance with the present invention;

FIGURE 2 is an enlarged sectional view of a portion of the apparatus of FIGURE 1 and illustrates apparatus for placing a combustible material in the annulus between the perforated well liner and the well wall;

FIGURE 3 is a sectional view taken at line 3—3 of FIGURE 2;

FIGURE 4 is a sectional view showing apparatus for placing pyrophoric material adjacent the upper portion of the combustible material; and

FIGURE 5 is a sectional view taken at line 5—5 of FIGURE 4.

In accordance with the invention, a well **20** is drilled to a hydrocarbon-bearing formation **22**. A protective casing string **24** is cemented into the upper portion of the hole **20** by means of suitable cement **26**. The protective casing string terminates above the upper portion of the hydrocarbon-bearing formation **22**. The well is then drilled through the hydrocarbon formation utilizing a suitable circulating fluid, such as, for example, gas, oil, air, foam or an emulsion. The portion of the well adjacent the hydrocarbon-formation is preferably underreamed to a radius about two inches greater than the outside diameter of the protective casing string.

A perforated liner **66** is installed opposite the hydrocarbon-bearing formation. A conventional gravel packing tool, indicated generally as **30**, is placed in the perforated or slotted liner and is connected with the surface by means of tubing **32**. A wellhead **34** having connections for various fluids is located at the top of the well. Compressed air is supplied to the casing through line **36** and valve **38**. Compressed inert gas is supplied to the casing through line **42** and valve **44**. A combustible material, such as charcoal, and a circulating fluid, such as oil, are injected into the interior of pipe **32** by means of pipe **46**, pipe **48** and valves **50** and **52**. The oil pipe **48** enters the charcoal pipe **46** at a suitable junction **53**, preferably downstream of the charcoal control valve **50**.

The preferred method of placing the charcoal behind the perforated liner is shown in FIGURES 2 and 3 which is an enlarged sectional view of the lower portion of the apparatus useful in accordance with the present invention. The pieces of charcoal indicated generally by the number **60**, are carried by suitable circulating fluid such as oil down the interior of pipe **32**. The lower portion of pipe **32** terminates in a conventional gravel packing tool indicated generally as **30**. The gravel packing tool diverts

the flow of oil and charcoal through side ports **61** and **62** into the annular space **63** between the exterior of the perforated liner and the well wall. Packing cups **64** and **65** are adapted to direct the flow through the ports **61, 62.**

In carrying out the method of the present invention a well is drilled to a location immediately above a hydrocarbon-bearing formation. A protective casing string **24** is then cemented down to the top of the hydrocarbon-bearing formation **22.** The well is then drilled below the protective casing string to the bottom of the hydrocarbon-bearing formation using a suitable circulating fluid such as oil, gas, air or foam. The portion of the well penetrating the hydrocarbon-bearing formation is then widened by underreaming to a radius greater than the outside diameter of the protective casing string located immediately above the hydrocarbon-bearing formation. Preferably, the wall adjacent the hydrocarbon formation is underreamed to a radius of about two inches greater than the outside diameter of the protective casing string. The underreaming is accomplished using one of the above-mentioned circulating fluids. A perforated liner **66** is installed opposite the hydrocarbon-bearing formation interval. The liner is preferably equipped with a liner hanger device comprising lugs **67** and packing means **68.** Alternatively the perforated liner may be simply set down on the bottom of the well and left uncentralized or centralized with an adapter having fluid passages rather than hung on the protective casing string as shown in FIGURE 2. A port collar arrangement **70** is preferably provided in the upper portion of the liner where a hanger is employed. The port collar can be moved to a closed position after the charcoal is in place behind the liner.

Coarse, particulate charcoal is then packed in the annulus between the perforated liner and the hydrocarbon formation over the entire hydrocarbon formation interval. The charcoal is brought into intimate contact with the hydrocarbon-bearing formation. The charcoal is circulated into the annulus through the ports in the gravel packing cross-over tool or around the liner top before setting an adapter utilizing one of the above-mentioned circulating fluids. The fluid returns are either taken to the surface via the well bore annulus **40** or displaced directly into the hydrocarbon-bearing formation. After the charcoal has been placed, the gravel packing tool, if one is used, is retrieved from the well and the inside of the perforated liner is cleaned out to total depth.

An inert atmosphere is established in the well by circulating an inert gas such as nitrogen or carbon dioxide into the well bore to fill the well from total depth to the surface. A pyrophoric material capable of causing the charcoal to autoignite is then introduced into the well bore through a suitable lubricator and placed on and in the uppermost portions of the charcoal in the liner-formation annulus. Suitable pyrophoric materials include tri-ethyl-borane, yellow phosphorus, carbon disulfide and nitric acid. Other suitable materials may be used.

Referring to FIGURES 4 and 5, a suitable technique for placing the pyrophoric material on the upper portion of the charcoal is shown. With the well closed in, a bailer **75** having pack-off foot **76** is lowered through a lubricator by suitable means such as wireline **78** to a position on top of the upper portion of the perforated liner. Inert gas is contained in the bailer under pressure to blow the pyrophoric material which is usually a liquid, out of the bailer **75** and into the small annular space between the liner and the protective casing string. The discharge is accomplished by the foot **76** opening a discharge valve indicated by the numeral **81** or by the pintle **77,** being constructed in the form of a punch rather than fitted with a valve, puncturing a shear disc located in place of the discharge valve. The liquid runs through the spaces **79** in the liner supporting means and down into the upper portion of the charcoal pack. The bailer is then removed from the well while maintaining the inert atmosphere in the well.

The wellhead is closed in and oxygen-containing gas is pumped into the well at a rate regulated to displace the inert atmosphere in the well and to autoignite the pyrophoric material to initiate combustion of the charcoal in the liner-formation annulus. It is of primary importance to have the oxygen-containing gas which is usually air, flow through the perforations in the slotted liner and thence into the charcoal pack. Sufficient oxygen-containing gas is injected to burn the charcoal at a sufficient rate to ignite the hydrocarbons in the formation with which it is in contact but at an insufficient level to generate heat required to fuse the formation. Generally the temperature at the liner is kept below about 700° F. The combustion of the charcoal is advanced from the top of the pack to the bottom by the continued injection of oxygen-containing gas. A sufficient amount of oxygen-containing gas is injected into the well to provide for continual passage of gas through the perforations in the liner. In this manner the temperature of the liner is maintained at a safe level by the relatively cool gas passing therethrough. The air rate required to effect proper combustion is regulated by the length of interval being processed, the radial thickness of the charcoal or coke bed, the rate of burning of the bed desired and the amount of air by-passing the ignited bed.

As the charcoal is burned the temperature of the hydrocarbons in the formation will be elevated to a temperature sufficient to create combustion in the hydrocarbon-bearing formation. The ashes created by combustion of the charcoal will tend to be carried into the particularly permeable portions of the hydrocarbon formation and will assist in partially plugging the highly permeable portions to thereby assist in establishing a relatively uniform injection profile across the hydrocarbon-bearing interval. If the injection profile can be maintained on a relatively stable basis across the entire interval, the chances of obtaining uniform ignition of the hydrocarbons across the interval is greatly improved. After the ignition of the hydrocarbons in the formation has been established, combustion is moved out into the formation away from the well bore. The rate of injection of oxygen-containing gas can then be adjusted to a rate suitable for accomplishing the purposes of the UGC project.

Although only embodiments of the invention have been described and illustrated, the invention is not to be limited to only such embodiments but rather it is intended that the invention embrace all equivalents falling within the scope of the appended claims:

I claim:

1. A method of igniting an underground petroleum-bearing formation comprising the steps of drilling a well from the earth's surface to penetrate at least a portion of an underground petroleum-bearing formation, installing a perforated linear in the well opposite the said formation in a manner to provide an annular chamber between the well and the outside of said perforated liner, packing the said annular chamber with an ignitable material, establishing an inert gas atmosphere in the well, introducing a pyrophoric material in said well and into at least the upper portion of the ignitable material in said annular chamber, replacing the inert atmosphere in the well with an oxygen-containing gas, continuing to inject oxygen-containing gas into the well and out through the perforations in said perforated liner into the pack of ignitable material to establish combustion in the ignitable material and continuing to inject an oxygen-containing gas into the said well and through said pack at a sufficient rate to ignite the hydrocarbons in said petroleum-bearing formation.

2. A method of igniting an underground petroleum-bearing formation comprising the steps of drilling a well from the earth's surface to penetrate at least a portion of an underground petroleum-bearing formation, enlarging the diameter of the portion of the well penetrating the said formation, installing a perforated liner in the well op-

posite the said formation in a manner to provide an annular chamber between the well and the outside of said perforated liner, packing the said annular chamber with charcoal, establishing an inert gas atmosphere in the well, introducing a pyrophoric material in said well and into at least the upper portion of the charcoal in said annular chamber, replacing the inert atmosphere in the well with an oxygen-containing gas and continuing to inject oxygen-containing gas into the well and out through the perforations in said perforated liner into the charcoal pack to establish combustion in the charcoal, and continuing to inject an oxygen-containing gas into the said well and through said pack at a sufficient rate to ignite the hydrocarbons in said petroleum-bearing formation.

References Cited

UNITED STATES PATENTS

3,004,597	10/1961	Marx et al.	166—39 X
3,010,513	11/1961	Gerner	166—39 X
3,080,919	3/1963	Harlan	166—39
3,134,435	5/1964	Wyllie	166—39 X
3,223,165	12/1965	Hujsak	166—38

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