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METHOD AND APPARATUS FOR BURNING A COMBUSTIBLE MIXTURE IN A WELL

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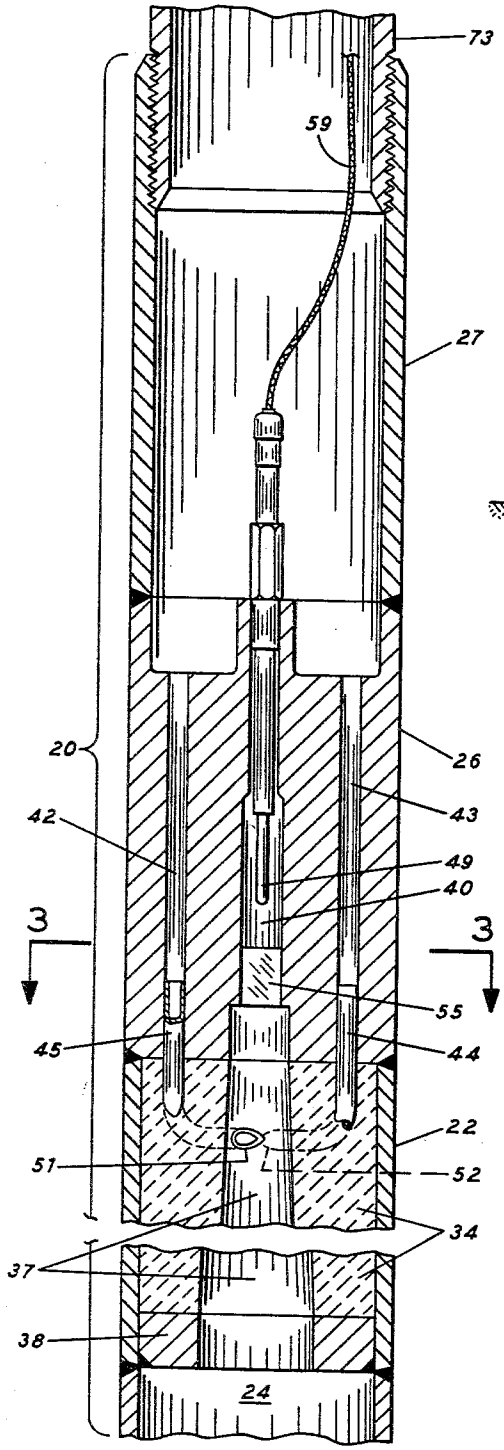

FIG. 2

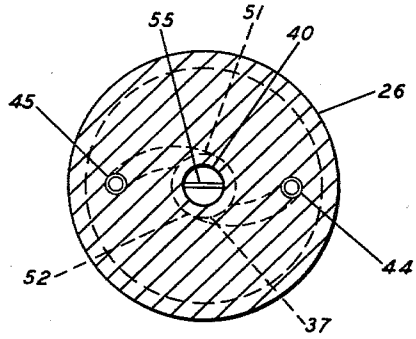

FIG. 3

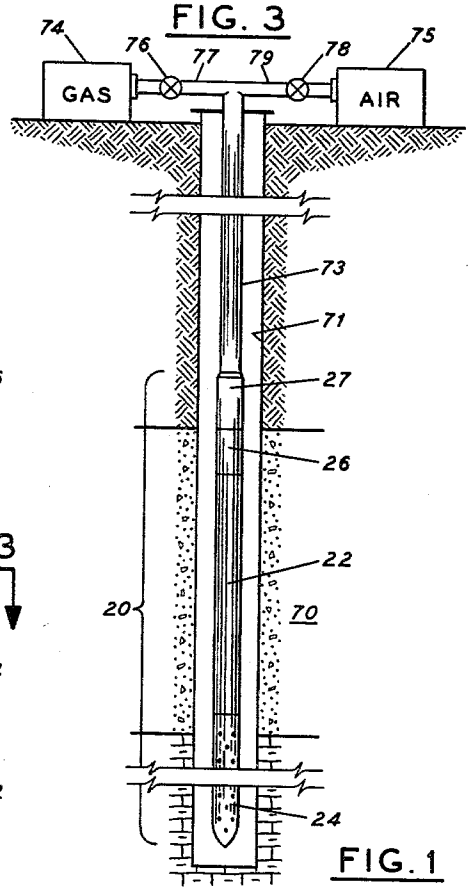

FIG. 1

INVENTORS
HERBERT R. HAZARD
JOHN D. HUMMELL
EARL J. SCHULZ

BY P. E. Johnston
Edward J. Keeling
ATTORNEYS

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METHOD AND APPARATUS FOR BURNING A COMBUSTIBLE MIXTURE IN A WELL

Herbert R. Hazard, Columbus, John D. Hummell, Brice, and Earl J. Schulz, Columbus, Ohio, assignors, by mesne assignments, to California Research Corporation, San Francisco, Calif., a corporation of Delaware

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This invention relates to improved methods and apparatus for burning a combustible mixture, and more particularly this invention relates to improved methods and apparatus for providing reliable ignition and stable combustion of a gaseous combustible mixture in a well to improve the production of oil from a petroliferous formation penetrated by the well.

It is known in the oil producing art that production from wells penetrating oil-bearing formations can be materially improved by heating the oil in the well and in the formation. Oil is less viscous at higher temperatures and therefore it will move more readily from the formation into the well from where it can be more easily moved to the surface. The most successful method of heating oil in a formation penetrated by a well is by burning a combustible mixture of gas and air in a burner located in the well near the producing formation. Various types of apparatus for burning a combustible gas and air mixture in a borehole are known. For example, U.S. Patents 2,887,160 and 2,668,592 show methods and apparatus for burning a combustible mixture in a borehole. The present invention is directed to improved methods and apparatus for burning a combustible gas mixture in a well. The invention is useful in stimulating production of gas and oil from a producing formation. The method and apparatus of the present invention also increase pumping efficiency of pumps located in a well with the apparatus. The burner may also be used to heat oil to keep waxes in solution within the oil.

A particularly serious problem at which the present invention is directed is the problem of maintaining stable combustion in the combustion chamber of the burner commensurate with reliability of ignition and reignition of the combustible gaseous mixture. Since high flow rates of the combustible mixture to the burner must be maintained to provide adequate heat, stable combustion in the combustion chamber of the burner is difficult. The problem of maintaining stable combustion is further compounded by the limited space in which the combustion must occur. The high velocity flow of the mixture in the combustion chamber causes a serious problem not only of stable combustion but also of ignition.

Since the burner must be located far below the surface of the earth in a borehole to provide heat for a petroliferous formation, the ignition means must be reliable. The ignition means must initially light the combustible mixture in the burner. If combustion in the burner is lost for some reason, for example due to temporary loss of the gas and air supply because of power failure in the producing field, the ignition means must be able to reignite the combustible mixture after the flow of gas and air to the burner has been restored. Ignition failure may be caused by any of a number of reasons. For example, the ignition means may fail to ignite the combustible mixture because flow of combustible mixture past the ignition means cools the igniter and makes it difficulty to ignite the mixture. On the other hand ignition may not occur because insufficient combustible mixture is directed to the ignition means. Once the burner has been fired and for some reason extinguished, reignition failure may be caused by burning out the ignition means by the heat of combustion. If the ignition means fails to initially light the

burner, or if the ignition means fails to reignite the burner after combustion is lost, the burner must be pulled from the hole and the needed adjustments in the apparatus made on the surface. Since pulling the burner involves removing the tubing string it is a costly and time consuming operation. It has been found that special precautions must be taken in delivering the combustible mixture to the combustion chamber and in supplying the combustible mixture to the ignition means to provide reliable ignition and stable combustion.

The present invention provides an improved method and apparatus for introducing a combustible gaseous mixture into a combustion chamber of a gas and air burner for ignition and combustion therein. In one aspect the present invention provides for flowing a gaseous combustible mixture to a gas and air burner located in a borehole and directing the flow of the combustible mixture into the combustion chamber of the burner. The mixture is caused to enter the combustion chamber from at least a pair of ports on the periphery of said combustion chamber. The ports are arranged to direct the flow of the mixture entering the chamber tangential to the periphery of the chamber and normal to the center line of the chamber thus causing the major portion of said mixture to swirl down the combustion chamber. A small portion of the combustible mixture is diffused to a remote ignition means. This small portion of combustible mixture is ignited to cause combustion near the ignition means. This combustion is flashed to the major part of the combustible mixture. Combustion is extinguished in the immediate vicinity of the remote ignition means to prevent burning out of the ignition means.

It is a particular object of this invention to provide an improved method and apparatus for causing stable combustion and reliable ignition of a combustible gaseous mixture in the combustion chamber of a downhole gas and air burner.

Further objects and advantages of this invention will be apparent from the following detailed description and accompanying drawings.

FIG. 1 is a cross section of an earth formation penetrated by a borehole and a diagrammatic view of the preferred embodiment of apparatus of the present invention.

FIG. 2 is a sectional view illustrating the preferred embodiment of apparatus of the present invention.

FIG. 3 is section 3—3 of FIG. 2.

Referring specifically to FIG. 1, an earth formation 70 penetrated by well 71 is shown. Formation 70 contains petroleum. A downhole burner, indicated generally as 20, is located in well 71 adjacent formation 70. The burner 20 is located in a position to provide maximum heat transfer to the oil in well 71 and formation 70. The burner 20 is operably connected by tubing 73 with a surface supply of a combustible mixture. For example, a combustible gas and air mixture is supplied burner 20 through tubing 73 from gas source 74 and air source 75. Appropriate surface piping which includes a valve 76 in gas line 77 and a valve 78 in air line 79 connects the gas and air to the combustible mixture tubing 73. Arrangements could be made to provide separate piping for the gas and air to the burner, however, it is highly preferred to mix the gas and air at the surface rather than at a position down in the well prior to flowing the combustible mixture to the burner. In any event the gas and air must be mixed in a combustible mixture prior to entering the combustion chamber of the burner. Control systems for controlling the flow of gas and air to downhole burners are described in U.S. Patent 3,012,607 and in copending U.S. application Serial No. 153,808 which application is assigned to the assignee of the present invention.

In FIG. 1, a preferred embodiment of apparatus, generally designated 20, for burning a combustible mixture

in a borehole is shown. Apparatus of this type are called downhole burners or gas and air burners. Downhole burner 20 includes an exhaust section 24, a combustion chamber section 22, a burner head section 26, and a tubing connecting means 27. The tubing connecting means is adapted to be operably connected with surface tubing such as tubing 73. A combustible gas and air mixture is supplied to burner 20 from the surface through tubing 73. The combustible mixture from tubing 73 passes through burner head section 26 to combustion chamber section 22. Combustion of the mixture occurs in combustion chamber section 22 and the hot gaseous products of combustion are passed to exhaust section 24. Exhaust section 24 receives the combustion gases and exhausts them to the well bore. An embodiment of apparatus forming a suitable exhaust section is described and illustrated in U.S. Patent 2,895,555. The exhaust section in U.S. Patent 2,895,555 includes a check valve to prevent invasion of the combustion chamber section by well fluids when the burner is shut down. The exhaust section of the present invention however may be adapted to exhaust combustion gases directly to the well. Alternatively the exhaust section may include a U-bend and suitable connecting piping to exhaust the combustion gases to a position above the liquid level of the well. If desired, the combustion gases may be returned directly to the surface through an appropriate stack from exhaust section 24.

Referring now to FIG. 2 and to FIG. 3, combustion chamber section 22 preferably contains liner 34 which forms combustion chamber 37. The liner 34 is preferably made up of an insulating material which has a relatively low thermal conductivity. It is necessary to prevent an undesirably high rate of heat flux to the oil surrounding the burner. If the temperature at the exterior of the burner should become excessively high, coking of the oil at the surface of the burner will occur. A method and material for providing an excellent heat-resistant ceramic liner for use in a combustion chamber section as a liner 34 is described in U.S. application Serial No. 165,675, which application is assigned to the assignee of the present invention. The liner 34 is held in position in combustion chamber section 22 by a suitable means. For example, the liner 34 may be bonded to the wall of the combustion chamber section 22. Shoulder 38 aids in supporting the liner 34. Liner 34 forms combustion chamber 37. It is preferred that combustion chamber 37 have a generally circular cross section, the diameter of which increases slightly going down the chamber from top to bottom. The slight taper of the combustion chamber 37 aids in establishing a desirable flow pattern of the combustible mixture down the combustion chamber. Increasing the diameter going down the chamber also aids in equalizing heat transfer over the length of the chamber. An increase in diameter of about 0.1 inch per foot going down the chamber has been found desirable.

In accordance with the preferred embodiment of the invention, a combustible mixture is introduced into the upper portion of the combustion chamber 37. It has been found that stable combustion of a combustible mixture can be maintained in combustion chamber 37 at high rates of flow by introducing the mixture tangentially into the combustion chamber 37. Entry port means such as entry port 51 serve to introduce the combustible mixture into chamber 37. Passageway means 42 and passageway means 43 are the flow paths through the burner head section to flow the mixture into combustion chamber 37. The burner head section 26 prevents the gaseous mixture from entering the combustion chamber 37 except through the passageway means. The passageway means through the burner head section 26 are continued in a suitable manner through the combustion chamber liner 34 to entry port 51 and entry port 52. For example, passageway means 42 is continued through liner 34 to entry port 51 by passageway 45. In a similar manner passageway 44 provides a flow path through liner 34 from passageway means 43.

Introducing the mixture into the combustion chamber 37 in a stream tangential to the periphery of the combustion chamber 37 causes a vortex flow of the mixture down the chamber 37. The gas and air must be mixed in a combustible mixture prior to being injected into the combustion chamber 37 to obtain the advantages of the present invention. In the preferred embodiment the combustible mixture is directed into the combustion chamber 37 by a pair of entry port means such as port 51 and port 52 in the wall of combustion chamber liner 34. Three or more entry ports could be used in keeping with the present invention. However, a single entry port would not be desirable. In accordance with the preferred embodiment of the invention, port means 51 and port means 52 are positioned to direct the combustible mixture into the combustion chamber tangential to the periphery of the chamber 37. Both port means direct the flow in the same direction, i.e., clockwise or counterclockwise to increase the vortex flow action down the chamber 37. The combustible mixture stream is directed into the combustion chamber tangential to the periphery of the chamber. Tangential to the periphery means the direction of flow as it is initially directed into the combustion chamber 37 is in a plane normal to the center line of the chamber and tangent a circle in that plane having the center line as a center. A particular feature of the present invention combines the tangentially directed flow into the combustion chamber with a novel arrangement of the ignition means to provide both stable combustion of the mixture and reliable ignition and reignition of the mixture.

A preferred arrangement for directing the combustible mixture into the combustion chamber 37 according to this invention is to arrange the entry port means, such as port 51, on the periphery of the combustion chamber and to direct the flow into chamber 37 in a plane normal its center line. The two ports are preferably 180° apart on the periphery of chamber 37. Stable combustion has been maintained with this arrangement with 70 to 220 percent of stoichiometric air.

In accordance with this invention the gas and air are mixed in a combustible mixture before entering the combustion chamber. Mixture of the component gases, for example air and methane or propane, prior to entry into the combustion chamber results in stable combustion and reliable ignition. Suitable flashback preventers and filters may be required in the combustible mixture conduits to prevent flashback of flame up the conduit in the event of pressure surge. It is desirable to provide the flashback preventers in the passageway means such as passageway means 42 and passageway means 43. One example of a flashback preventer and filters is described in U.S. Patent 2,887,160.

A well 40 is provided in burner head section 26. Well 40 communicates with combustion chamber 37. The upper end of well 40 is sealed off by ignition means 49 and suitable packing. Therefore, the only paths for fluid flow through the burner head section 26 are the passageways in the burner head section 26. The well 40 extends above the location of the entry port means such as entry port 51. The well 40 is adapted to contain a suitable ignition means 49. In the preferred embodiment an armored electric coil serves as the ignition means 49. The ignition means 49 is provided with suitable wiring such as wire 59 to a source of current. Included among suitable ignition means are high-voltage spark igniters, low-voltage spark igniters, electrically heated wires, and electrically heated armored coils. The well 40 is sealed above the ignition means to prevent flow of combustible mixture past the ignition means.

It is a particular feature of the present invention to locate the ignition means in a well above the entry ports for combustible mixture flow into the combustion chamber. In this manner the ignition means 49 is removed

from the direct flow of combustible mixture as it enters the combustion chamber 37. It has been found that the ignition means 49 must be located a substantial distance away from the entry ports to prevent burning out of the ignition means. The ignition means 49 must be close enough to the entry ports to provide for reliable ignition. A suitable distance of the ignition means 49 from the nearest entry port, for example entry port 51, can be expressed in terms of the diameter of the combustion chamber at the entry port. The minimum distance between entry port 51 and the ignition means 49 is about 2½ times the diameter of the combustion chamber 37. A preferred figure is about 4 times the diameter of the combustion chamber. The igniter must be removed from the location where combustion occurs during firing of the burner to prevent burning out the ignition means. If combustion occurs in the vicinity of an igniter, the igniter will likely burn out and reignition will be impossible.

A flow stabilizing means is provided in well 40 to prevent combustible mixture from swirling around ignition means 49. In the preferred embodiment of the invention the flow stabilizing means comprises a vane 55 positioned across well 40. The flow stabilizing means is positioned in well 40 between the ignition means 49 and entry ports 51 and 52 to prevent undesirable flow of combustible mixture around ignition means 49. Vane 55 reduces swirling of the combustible mixture around ignition means 49 and thus prevents undesirable cooling of the ignition means prior to ignition. After ignition of the combustible mixture vane 55 prevents combustion around the ignition means 49 which might burn it out. If the combustible mixture is allowed to swirl freely around the ignition means combustion would occur near the ignition means and burn it out. The flow stabilizing means causes the combustible mixture to be diffused or slowly flowed to the ignition means 49. Thus only a very small portion of the combustible mixture which enters combustion chamber 37 reaches the vicinity of the ignition means 49. Ignition therefore takes place initially in well 40 when the ignition means 49 is activated and then almost immediately combustion flashes to the main portion of the combustible mixture entering combustion chamber 37 through the entry port means. Combustion is extinguished in well 40 and little or no combustion occurs there during firing of the burner. Thus there is no danger of overheating the ignition means 49.

The important features of this envention including particularly the improved method and apparatus for directing a combustible mixture into the combustion chamber of a downhole burner to provide stable combustion in the burner and for igniting and reigniting the mixture in a reliable manner have been fully disclosed. The scope of this invention is not limited to only the specifiec apparatus described herein but by the scope of the appended claims. We claim:

1. Apparatus for burning a combustible mixture in a borehole comprising means defining a combustion chamber having entry port means in the upper portion thereof, an exhaust section receiving combustion gases from the lower end of said combustion chamber, a burner head section at the upper end of said combustion chamber, passageway means for flow of combustible mixture through said burner head section to direct the flow of combustible mixture into said combustion chamber through said entry port means, said passageway means directing flow into said combustion chamber in a direction tangential to the periphery of said combustion chamber and in a plane normal to the center line of said combustion chamber, a well in said burner head section communicating with said combustion chamber and extending a substantial distance above said entry port means, and ignition means in said well removed from the direct flow path of said combustible mixture.

2. Apparatus for burning a combustible mixture in a borehole comprising means defining a combustion chamber having entry port means in the upper portion thereof, an exhaust section receiving combustible gases from the lower end of said combustion chamber, a burner head section at the upper end of said combustion chamber, passageway means for flow of combustible mixture through said burner head section to direct the flow of combustible mixture into said combustion chamber through said entry port means, said passageway means directing flow into said combustion chamber in a direction tangential to the periphery of said combustion chamber and in a plane normal to the center line of said combustion chamber, a well in said burner head section communicating with said combustion chamber and extending a substantial distance above said entry port means, ignition means in said well, said ignition means removed from the direct flow path of said combustible mixture, and flow stabilizing means in said well between said ignition means and said entry port means, said flow stabilizing means controlling the flow of combustible mixture to said ignition means.

3. Apparatus for burning a combustible mixture in a borehole comprising means defining a combustion chamber having a pair of entry ports in its upper portion, an exhaust section receiving combustion gases from the lower end of said combustion chamber, a burner head section at the upper end of said combustion chamber, passageway means in said burner head section as the only fluid flow means therethrough, said passageway means communicating with said combustion chamber through said entry ports to direct combustible mixture flow into said combustion chamber in a direction tangential to the periphery of said combustion chamber, a well in said burner head section communicating with said combustion chamber, said well extending into said burner head section a substantial distance above said entry ports, ignition means in said well removed from the direct flow path of said combustible mixture, flow stabilizing means in said well between said ignition means and entry ports to control combustible mixture flow to said ignition means, and tubing connecting means on said burner head section.

4. Apparatus as in claim 3 where the flow stabilizing means in a vane positioned in said well between said ignition means and said entry ports.

5. A method of burning a combustible mixture in a downhole burner positioned on a tubing string in a borehole comprising flowing a combustible mixture down said tubing string to said burner, directing the flow of the combustible mixture to the combustion chamber in said burner, introducing the combustible mixture into said combustion chamber in an initial flow direction tangential to the periphery of said chamber and in a plane substantially normal to the centerline of said chamber, causing the major portion of the combustible mixture to swirl down said chamber, diffusing a small portion of the combustible mixture to a remote ignition means, igniting the small portion of the combustible mixture to cause combustion of the combustible mixture in the vicinity of said ignition means, flashing said combustion to the major portion of the combustible mixture, and extinguishing combustion in the immediate vicinity of said ignition means.

6. A method of burning a combustible mixture in a downhole burner positioned in a well comprising flowing a combustible mixture down a well to a burner, directing the flow of the combustible mixture to the combustion chamber of said burner, introducing the combustible mixture into said combustion chamber in an initial flow direction in a plane substantially normal to the centerline of said combustion chamber, flowing combustible mixture to an ignition means and igniting the combustible mixture in said combustion chamber.

7. A method of burning a combustible mixture in a downhole burner positioned in a well comprising flowing a combustible mixture to a burner, directing the flow of the combustible mixture to the combustion chamber of said

burner, introducing the combustible mixture into said combustion chamber in an initial flow direction substantially tangential to the periphery of said chamber and in a plane substantially normal to the centerline of said combustion chamber, igniting the combustible mixture and burning the combustible mixture in said combustion chamber.

8. Apparatus for burning a combustible mixture in a well comprising means defining a combustion chamber, exhaust means receiving combustion gases from said combustion chamber, flow direction means for directing the flow of a combustible mixture into the combustion chamber in a direction tangential to the periphery of said combustion chamber and in a plane substantially normal to the centerline of said combustion chamber, said flow direction means providing the only flow path into said combustion chamber and ignition means for igniting the combustible mixture in said combustion chamber.

9. The apparatus of claim 8 further characterized in that the ignition means are removed from the direct flow path of the combustible mixture.

10. The apparatus of claim 9 further characterized in that the flow direction means are arranged to initially direct the flow of combustible mixture into the combustion chamber from two entry ports spaced 180° apart on the periphery of the means defining the combustion chamber.

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BENJAMIN HERSH, *Primary Examiner.*