DOWNHOLE BURNER FOR WELLS

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Filed June 27, 1963, Ser. No. 291,126
10 Claims. (Cl. 166—59)

This invention relates to downhole gas and air burners for use in wells to stimulate production therefrom and more particularly this invention relates to improved apparatus for supplying a combustible mixture to the combustion chamber of a downhole burner.

As known in the petroleum producing art, production from a well can be improved by heating the fluids such as oil in the well and in the adjacent producing formation. Heretofore there have been many methods of heating fluids in a petroleum-bearing formation penetrated by a well. The most successful of the methods includes burning a combustible mixture in a downhole burner. Examples of downhole gas and air burners are shown in U.S. Patents 2,887,160 and 2,895,555. Generally, downhole burners comprise a combustion chamber having an exhaust section, an ignition means and a means for supplying a combustible mixture to the combustion chamber.

Briefly, the present invention is directed to improved apparatus for supplying a combustible mixture to the combustion chamber of a downhole burner. In a broad aspect this invention provides an improved delivery tube means for directing a combustible mixture to a combustion chamber. The delivery tube means includes a flashback prevention means and a check valve means for controlling the flow of combustible mixture into the combustion chamber. The delivery tube means directs the combustible mixture from the gas and air supply means to the combustion chamber of the downhole burner. The flashback prevention means are positioned in the delivery tube means near the combustion chamber to prevent combustion from flashing up the gas and air supply tube means. The flashback prevention means function to prevent flashback up the tubing in a manner which does not cause excessive pressure drop in the supply system which would greatly increase compression costs. Flashback preventers of the present invention comprise a porous material having restricted flow throughout. The check valve means controls the flow of combustible mixture to the combustion chamber and prevents undesirable pulsating flow through the combustion chamber and the delivery tube means. The check valve means is positioned in the delivery tube means above the combustion chamber and prevents the backflow of gases through the tube means which otherwise could result in a pressure pulse during ignition. The check valve means traps gas in the burner combustion chamber on shutdown and thereby aids in preventing flooding of the combustion chamber by well fluids.

It is a principal object of the present invention to provide an improved combustible gas and air delivery tube means for supplying a combustible mixture to the combustion chamber of a downhole burner.

Further objects and advantages of the present invention will be apparent from the following detailed description read in light of the accompanying drawings which are a part of this specification.

FIG. 1 is a diagrammatic view illustrating apparatus assembled in accordance with the present invention positioned in a well.

FIG. 2 is a longitudinal view with portions broken away of the present invention and illustrates the preferred embodiment of apparatus of the present invention.

FIG. 3 is section 3—3 of FIG. 2.

FIG. 4 is an enlarged sectional view of a portion of the preferred embodiment of apparatus and illustrates a means for preventing flashback.

FIG. 5 is section 5—5 of FIG. 4.

FIG. 6 is a graph showing the relationship of flow velocity to exit gap to prevent flashback according to the present invention.

FIG. 6A is an isometric view of a simple test device useful in selecting flashback prevention means in accordance with this invention.

FIG. 7 is a greatly enlarged sectional view illustrating an alternative means for preventing flashback.

FIG. 8 is section 8—8 of FIG. 7.

FIG. 1 which is useful in understanding the present invention shows an earth formation 70 penetrated by well 71. A downhole gas-air burner, represented generally by 40, is shown in the well 71. The burner 40 is located in a position to cause maximum allowable heat transfer to the fluids in well 71 and to oil-bearing formation 72. The burner is connected to a supply of combustible mixture by means of tubing 53. A combustible gas and air mixture is provided for flow through tubing 53 by any suitable means. For example, a combustible gas and air mixture may be supplied for flow through tubing 53 from a gas source 74 and an air source 75 through valves 76 and 78 and conduits 77 and 79. A method and apparatus for controlling the flow of gas-air mixture to a downhole burner is described and claimed in U.S. Patent 3,012,607.

The burner 40 may include an exhaust section 44 connected to a combustion chamber section 42 to receive exhaust gas from the combustion chamber inside combustion chamber section 42. A burner head section 43 contains the burner ignition means and controls the flow of gas and air to the combustion chamber section 42. A tubing connecting means, which may be for example a tubing collar 47, connects the burner head section 43 to the combustible mixture tubing 53.

As shown in FIG. 1 the downhole gas and air burner 40 is located in a well 71 adjacent a producing formation 72. The burner is ignited by suitable means such as an electrical ignition means supplied by electrical source 73, and combustion occurs in combustion chamber section 42. The heat given off to the surrounding formation 72 improves the viscosity and mobility of the oil in formation 72 thereby making it more easily recovered by conventional means. For example, the downhole gas and air burner of the present invention may be positioned with a conventional pump and sucker rod string in the borehole and the less viscous oil pumped to the surface. In addition to improving the mobility of the oil, the downhole burner of the present invention is also useful in increasing solubility of various oil constituents such as waxes and asphaltenates, thus improving recovery.

The downhole burner of the present invention is adapted to be positioned in a well up to many thousands of feet beneath the earth's surface; therefore the apparatus must be reliable in operation since it is a difficult and expensive procedure to remove the burner from the hole to clean it or to make minor repairs. It is also highly desirable that only a single conduit be used to supply both gas and air to the burner. Thus a combustible mixture must be flowed through many feet of tubing from the surface to the burner.

In a broad aspect the present invention includes delivery tube means for flowing a combustible mixture to the combustion chamber of a downhole gas and air burner, said tube means having check valve means incorporated therein and located near the entry port into the combustion chamber, which check valve means allows fluid flow through said tube means to the combustion chamber but does not...
permit fluid flow from the combustion chamber up through said tube means. It has been found that locating the check valve means above the combustion chamber and in the delivery tube means insures that the check valve means will be operable under difficult conditions including the presence of dirt or unconsolidated particles in the well. Flashback prevention means are positioned in the delivery tube means to prevent combustion from flashing up the delivery tube means.

FIG. 2 shows a longitudinal view with portions broken away to show apparatus of the preferred embodiment of the present invention. FIG. 3 is a sectional view taken at line 3—3 of FIG. 2. The downhole burner represented generally by the numeral 40 includes a combustion chamber section 42 having an exhaust section 64 for receiving exhaust gases at its lower end. The combustion chamber section 42 preferably has a ceramic liner 50 which forms the combustion chamber 52. Entry port means, such as ports 54 and 55 are provided in the ceramic liner 50 to allow a combustible mixture to flow into the combustion chamber 52. Ignition means, such as plug 56, having a glow element 59, are mounted by suitable means 57 in operable relationship with the combustion chamber 52 and entry port means 54 and 55 so as to ignite a combustible mixture passing into the combustion chamber 52. Suitable electrical connection between a source of electricity and the glow plug 56 is provided by insulated cable 58 and the tubing 53. The downhole burner is connected to the tubing 53 by suitable means such as the mating threads 60 on collar 47. The tubing forms a flow path for gas and air from the surface to the downhole burner 40.

A burner head section 43 closes off the upper end of the combustion chamber 54. The glow element of glow plug 56 is located in a recess of the burner head section 43 in operable communication with the combustion chamber. A fluid-tight seal at 51 prevents fluid flow up the glow plug taphole.

Fluid flow means through the burner head section 43 provide for communication to the combustion chamber 52 through the entry ports 54 and 55 therein. Flow paths such as shown by numerals 61 and 62 are provided in the burner head section 43. Flashback prevention means, indicated generally by 64 and 65, are located in suitable inserts 68 and 69 in the flow paths 61 and 62. Tube means, indicated generally by the numeral 30, direct the flow of combustible gas into the combustion chamber 52 and entry port means 54 and 62 to the combustion chamber. The tube means are connected to the flow paths 61 and 62 in a fluid-tight manner and provide therewith a means for flowing combustible mixture from a surface supply conduit such as conduit 53 to the combustion chamber 52 of the downhole burner.

A tube 30 having an open end 31 provides for fluid flow from the interior of gas and air supply conduit 53 to combustion chamber 52. The tube 30 is formed in a U-shaped configuration and the open end is located near the floor 32 of the burner head section 43. The combustible gaseous mixture which is flowed down the well in the tubing 53 to a position above the combustion chamber is thus caused to flow in substantially the opposite direction for a short distance prior to flowing to the combustion chamber. When there are exposed electrical connections extending above the burner head section, such as the conduit 53 and electrical conduit 58, it is desirable to locate the open end 31 of tube means 30 below the level of the exposed electrical apparatus. In this manner any accumulated water or brine can be cleared from the gas-air chamber by means of pressure in conduit 53. Short circuiting of the electrical apparatus as a result of wet shorting is thus prevented.

The tube means 30 may be divided so as to flow gas and air to more than one combustion chamber entry port. For example, a pair of tubes 33 and 34 having common openings into tube 30 can flow gas and air to entry ports 54 and 55. Obviously one or more entry ports can be used.

A check valve means indicated generally by the number 80 is positioned in the flow line of tube means 30. The check valve means 80 is located near the entry ports 54 and 55. That is to say that the check valve means should be positioned in a few feet of the entry port means as compared to length of the supply conduit 53 which may be up to 3000 feet or more in length. The check valve means allows fluid flow from the supply conduit 53 through tube means 30 into combustion chamber 52 and prevents fluid from the combustion chamber 52 through tube means 30 into the supply conduit 53. It has been found that locating the check valve means in the combustible mixture delivery tube means 30 above the combustion chamber serves multiple purposes. The check valve means prevents the backflow of gases through the tube means which could result in a pressure pulse during ignition and, also, the check valve means traps gas in the burner combustion chamber on shutdown and thereby aids in preventing flooding of the combustion chamber by well fluids.

A further and particularly important advantage gained by locating the check valve means above the combustion chamber is that the pressure of the combustible mixture in the supply tubing is higher than the pressure in the combustion chamber. This is important because a pulsation of pressure in the combustion chamber can occur; as for example when the level of fluids in the well changes, the pressure in the combustion chamber will change. If no check valve is present, flow of the gas and air mixture into the combustion chamber might stop temporarily until the surface gas and air mixing equipment reacts to the change in pressure to supply the combustible mixture at the higher pressure. The presence of a check valve means having a pressure drop of as little as 5 p.s.i. insures that the supply tubing 53 is always filled with a combustible mixture that is at from 1-5 p.s.i. higher pressure than the pressure in the combustion chamber. Thus where a pressure surge occurs in the well, the combustible mixture will continue to be supplied. A pressure differential of from 1-5 p.s.i. has been found adequate for most operations. If desired for special circumstances where large pressure surges are encountered, a check valve having a higher pressure drop can be installed and the pressure differential increased.

Thus the mixture is flowed to a first position which is immediately above the combustion chamber, for example the space defined by tubing connecting collar 47. The mixture is then flowed to the combustion chamber through check valve means 80. Thus the mixture is at a higher pressure at the first position than the pressure prevailing in the combustion chamber. As noted above, this pressure differential is preferably from 1 to 5 p.s.i.

Means providing a pressure differential may take other forms than the check valve means. For example, a plug of porous material can be positioned across the gaseous flow conduit to cause a desirable pressure differential to exist between the supply tubing and the combustion chamber. When the pressure in the combustion chamber increases a limited amount there will be some incremental pressure available in the supply tubing to maintain partial flow of the combustible mixture into the chamber at least until the surface pumping equipment and control means will adjust.

The check valve means 80 functions to allow flow in only one direction through the tube means 30. A suitable valve means includes a housing 81 having a flow path through its entire length. Means movable, such as ball 82, are provided in the flow path. A resilient means such as a spring is therefore not likely to occur. The spring will normally urge the ball into a seat formed by O-ring 83 to close the flow path to fluid flow. The spring may be overcome by a differential pressure in one direction to allow gas and air to flow through the tube means 30 into the comb-
The differential pressure is preferably 1-5 p.s.i. As is evident, a differential pressure acting with the force of the spring 65 closes the flow path through the check valve to fluid flow. There are commercially available check valve means which function adequately in the present invention.

In flowing a combustible mixture to the combustion chamber of a burner where it is combusted, the danger of flashback up the combustible mixture conduit must be minimized. For example, when the mixture is being combusted and for some reason a pressure surge occurs or the flow of gas and air from the burner is halted, the flame can, unless prevented by some means, flash up the supply line and perhaps cause serious damage. Therefore there is a need for flashback prevention means which will function to prevent flashback up the tubing and which will not cause an excessive pressure drop in the supply system which would greatly increase compression costs. Flashback preventers of the present invention comprise a porous material having restricted flow paths therethrough. The porous material is preferably a porous metal having a maximum pore size of about .004 inch in diameter. It has been found that at normal minimum operating pressure of a down burner, for example, 250 p.s.i., a flame can flash back through a hole larger than .004 inch with a stoichiometric methane-air mixture. That is, a stoichiometric mixture of methane and air will not flash back through restricted openings less than .004 inch in diameter at pressures less than 250 p.s.i. Particular size openings will vary for different gases and pressures and an adjustment can be made for the particular gas used and maximum pressure expected.

With reference to FIG. 4 and FIG. 5, flashback preventer means in accordance with the present invention are shown. A thin sheet of porous material is provided in the flow path 61 to the combustion chamber of the burner. The sheet is mounted diagonally across the flow path. It has been found that porous material having openings of less than .004" will prevent flashback when a combustible mixture of methane and air is used at a pressure of 250 p.s.i. or less. However, when a thin wall of .004 inch material is used, the flame on the downstream side of the wall may eventually heat the upstream side of the wall to the ignition temperature of the combustible mixture and ignition of the mixture upstream can result, causing flashback of the flame through the conduit. Since it is highly desirable to use a thin wall of porous material to keep the pressure drop as low as possible, it is a particular feature of this invention to mount the porous material diagonally across the flow path. By mounting the porous metal diagonally across the flow path, a component of gaseous mixture flowing through the porous wall is caused to flow parallel or nearly parallel to the downstream side of the porous material and thus blows the flame off the downstream wall. In this manner a relatively thin porous sheet or wall, for example, $\frac{3}{4}$ of an inch thick can be used as a flashback preventer. Using a thin porous wall is important because of the lower pressure drop across the thin wall compared to the pressure drop across a thick piece of porous material which would be necessary if the porous material were maintained normal or near normal to the center line of the delivery tube. For example, a suitable porous metal is stainless steel Type 316, Grade D, $\frac{3}{8}$" thick, and manufactured by Micro Metallic Corp. of Glen Cove, N.Y. In the preferred embodiment the flashback preventer is mounted in a manner to form an acute angle with the center line of the delivery tube of about 25° to 35°. The component of flow parallel to the underside of the porous metal surface must be of a suitable magnitude to blow the flame off the surface. The flashback preventer comprise a porous material positioned in the combustible mixture flow path so that any flame that is propagated on the downstream side of the surface will be blown off the surface.

The flashback preventers are positioned across the combustible mixture flow path and have a downstream side which makes a determinable angle with the center line of flow to cause at least a portion of the flowing mixture to flow along the downstream side. A depending conically shaped flashback preventer formed of porous material and forming the predetermine angle with the flow path of the mixture is also useful in the present invention. This type of arrangement of the flashback preventer means is illustrated in FIGS. 7 and 8. As there shown, a conically-shaped flashback preventer 94 is positioned in the combustible mixture flow path 91 which is formed by appropriate tubes 98 and 99. The conically shaped flashback preventer 94 may be positioned between the pair of tubes 98 and 99 and held in place by means of a weld 90. In still a further embodiment a thin walled cylindrical or bar-like porous material element can be used when the wall of the conduit which forms the flow path is tapered to form the desired angle with the downstream surface of the porous element 94. A simple device to obtain the information in the curves are shown. The apparatus shown in FIG. 6A comprises a simple box 21 having an entry port 23. A tube 22 is connected to the entry port 23 to allow a combustible mixture to be flown into the lower portion of box 21. As shown in FIG. 6A a porous metal strip 24 is mounted across the box. One end 25 of the tube 22 which is analogous to the exit gap of FIG. 6, is opened above the metal strip 24 for gas flow through the metal strip and out of the box. Thus a combustible mixture can be flown into the box then through the metal strip and finally out of the box. The mixture is ignited at end 25 of the box and the flow rate and velocity can be adjusted to cause the flame to be blown transversely off the strip to determine points on the curves in FIG. 6. The exit gap 25 is adjusted to get a variety of points. This data is incorporated into the design of flashback preventers for use in borehole heaters, which flashback preventers comprise porous material set in the combustible mixture flow path in such a manner that any flame that is propagated on the undersurface of the material will be blown off the surface.

It is apparent that modifications other than those described herein may be made to the apparatus of this invention without departing from the inventive concept. It is intended that the invention embrace all equivalents within the scope of the appended claims.

We claim:
1. Apparatus for burning a combustible mixture in a well comprising a combustion chamber means having an exhaust means at its lower end, means for positioning said combustion chamber means in a well, entry port means in the upper portion of said combustion chamber means, ignition means for igniting a combustible mixture in said combustion chamber means, tube means for flowing a combustible mixture down the well, the said combustion chamber means, said tube means communicating with said combustion chamber means through said entry port means, check valve means in said tube means above said entry port means and flashback prevention means in said tube means between said check valve means and said entry port means.
2. Apparatus for burning a combustible mixture in a well comprising a combustion chamber means having an exhaust means in the lower portion and entry port
3,241,615

means in the upper portion, means for suspending said combustion chamber means in a well, means closing off the upper portion of said combustion chamber means, tube means communicating with said entry port means and forming therewith the only flow path through said combustion chamber means, said check valve means in said tube means above said entry port means for controlling flow through said tube means to said combustion chamber means, said check valve means allowing flow only through said tube means into said combustion chamber means, and flashback prevention means in said tube means between said check valve means and said entry port means.

3. Well burner apparatus comprising a combustion chamber means positioned in a well and having an exhaust means, entry port means in said combustion chamber means as the only entry for combustible mixture into said combustion chamber means, ignition means to ignite a combustible mixture passing into said combustion chamber means, flow means communicating with said combustion chamber means through said entry port means, well pipe means extending from the surface down the well and communicating with said flow means for supplying combustible mixture to said flow means, flashback preventer means in said flow means, said flashback preventer means comprising porous material positioned in said flow means, said porous material having a downstream surface forming a predetermined acute angle with the centerline of said flow means whereby a component of the combustible mixture flow is caused to flow substantially parallel to the downstream surface of said porous material to blow flame off the downstream surface of said porous material.

4. The apparatus of claim 3 where the predetermined acute angle is between 25° and 35°.

5. The apparatus of claim 3 where the porous material is thin porous metal.

6. The apparatus of claim 5 further characterized in that the porous metal is a flat strip positioned in said flow means.

7. The apparatus of claim 5 where the porous metal is conically shaped and is positioned in said flow path.

8. Apparatus for burning a combustible mixture in a well comprising a combustion chamber means having exhaust means at its lower end, means closing off the upper end of said combustion chamber means, entry port means in the upper end of said combustion chamber means for flowing a combustible mixture into said combustion chamber means, electrical ignition means in said combustion chamber means in operable relationship with said entry port means to ignite a combustible mixture flowing into said combustion chamber means, ignition means having electrical connections extending above said combustion chamber means and through said means closing off the upper end of said combustion chamber means, tube means extending through said means closing off the upper end of said combustion chamber means and communicating with said entry port means, said tube means including a conduit extending above said means closing off said combustion chamber means and having substantially a 180° bend and terminating above said means closing off said combustion chamber means and below the level of the portion of said electrical connections extending above said means closing off said combustion chamber means.

9. Apparatus as in claim 8 further characterized by a check valve means in said tube means.

10. Apparatus as in claim 8 further characterized by flashback preventer means in said tube means.

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