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GAS BURNER AND METHOD FOR BURNING GAS IN OIL AND GAS WELLS

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FIG. 1

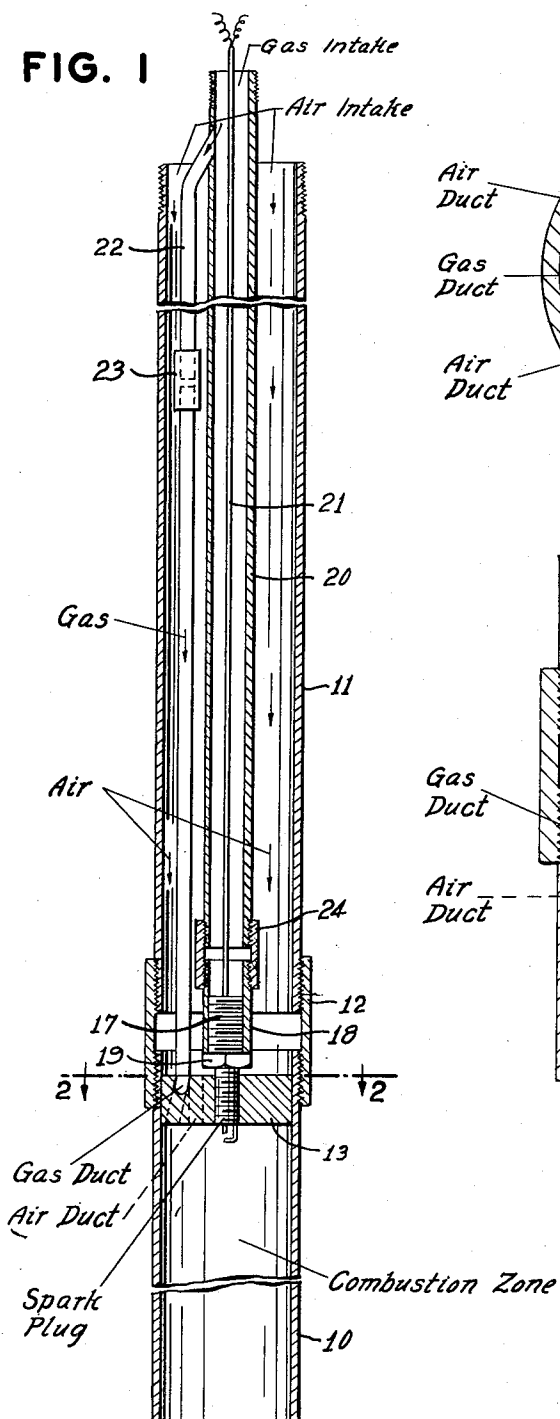


FIG. 2

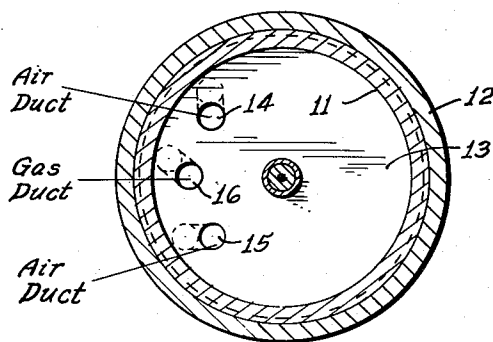
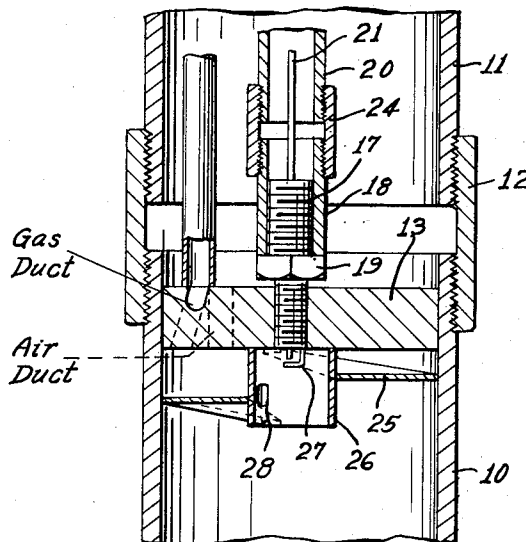


FIG. 3



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GAS BURNER AND METHOD FOR BURNING
GAS IN OIL AND GAS WELLS

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6 Claims. (Cl. 166-17)

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This invention relates to an improved method and apparatus for burning gas at high rates of heat release. More particularly it resides in a novel method and apparatus for burning large quantities of combustible gas in a confined space at superatmospheric pressures to obtain high rates of heat release.

Numerous difficulties are encountered in attempting to burn gas with high rates of heat release in conventional burners. In the flames from gas burners of the conventional Bunsen type, the rate of heat release is of the order of 100,000 B. t. u. per hour or less. If such a flame is confined to an enclosed space, such as an open-end pipe, the flame is blown out by the velocity of the gas when it is attempted to obtain rates of heat release higher than this magnitude.

We have now discovered that heat release rates of over 600,000 B. t. u. per hour may be obtained in a flame entirely confined within a pipe as small as 2" in diameter and 24" long. But we have found that it is necessary to introduce the gas and air separately to the combustion area for operation under superatmospheric pressures if excessive flash-back rendering the burner inoperable is to be avoided. At the same time we have found that it is necessary to obtain extreme turbulence and whirling motion of the flame to obtain satisfactory ignition and burning characteristics. Limited pre-mixture of gas and air just prior to the point of ignition is advantageous, however, from the standpoint of ignition behavior. Accordingly, we have devised a system, characterized by a mixing plate at the head of an elongated combustion chamber, to which all air and fuel gas are separately passed, and, through which, to develop turbulence and tangential motion of the flame, all primary air and fuel gas are introduced by means of angularly directed ducts to the combustion zone. The flame is ignited by a spark plug or other igniter located in the mixing plate.

We have experimented with burners which theoretically provide the necessary turbulence and velocities for high pressure work, but found that conventional pre-mixing arrangements result in flash-back difficulties beyond velocity or pressure control. For example, in operations utilizing pre-mixed gas and air, we provided a mixing plate with 10 holes equally distributed, with each at a 30° by 30° compound angle. When the burner was operated at substantially atmospheric pressure on a mixture of air and propane in approximately theoretical proportions which were pre-mixed in the chamber upstream

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from the mixing plate of the burner, we found that the burner ignited positively and gave stable operation over a wide range of rates. However, when we attempted to operate such a burner under superatmospheric pressures, e. g., at gauge pressures in the range of 30 to 70 p. s. i. g. the flame would strike back through the mixing plate and burn in the pipe all the way back to the point of first admixture of gas and air. To minimize this tendency to flash back, the number of holes in the mixing plate was reduced from 10 to 2, which had the effect of increasing the velocity of the gas flow through these ports to more than 800 feet per second. Even at these high velocities, the flame continued to flash back through the mixing plate, rendering the burner inoperable. We are unable to account for this behavior, for it is totally unexpected in light of published data on rates of flame propagation, which indicate that, for hydrocarbons at atmospheric pressure, these rates are of the order of 1 foot per second. Evidently increased pressure has a very large effect in increasing the rate of flame propagation.

We have further found that our burner and method of operation possess superior utility in those methods of oil recovery from oil-containing formations depending upon thermal means where problems created by demands of high heat release rates through combustion of large quantities of gas in a confined space under elevated pressure are magnified to an extreme, although they may be adapted to any operation demanding very high rates of heat release, especially where the pressure conditions are high. In the thermal recovery of oil and gas from oil fields, however, the prime desideratum is to obtain high rates of heat release to the porous oil-bearing formation through combustion gases which are forced into the porous structure under pressure through an input well so as to sweep out the oil, which is released from the structure by the high temperature which cracks and lowers the viscosity of the heavier hydrocarbon components while vaporizing the lighter components, in the direction of one or more producing wells. There are definite advantages in utilizing a combustion system situated at the bottom of the input well, for if an external system is used, expensive temperature-resistant alloy tubing with expandable joints must be used from surface to formation level. Moreover, the entire length of the tubing string must be reckoned in considering heat losses. Quite obviously, however, a burner in a process demanding high heat releases over a

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long period of time, which may amount to many months, and which is situated at the end of a tubing string that may be many hundreds or thousands of feet in length, must be reliable. And quite obviously, the combustion space for its operation is very limited and the pressures relatively high. In addition, serious problems obtain in controlling the temperature below that which will fuse or sinter the porous formation, e. g. about 2000° to 2500° F., and of insuring clean combustion; i. e. without formation of carbonaceous matter that may cement or clog the formation. For example, in a process disclosed in application Serial No. 94,506, filed May 20, 1949, now Patent No. 2,642,943, the inlet pressures may approximate as much as 360 p. s. i. g. Moreover, as there pointed out, the average oil well, because of drilling expense, rarely exceeds a diameter sufficient to accommodate 7" O. D. pipe. We have found, however, that our burning system, constructed to enter a 4" O. D. pipe, ignites with a gas and air feed corresponding to a heat release of 600,000 B. t. u. per hour under bottom-hole operating conditions.

A useful burner exemplifying our invention is illustrated somewhat diagrammatically in the accompanying drawing in which:

Fig. 1 is a cross-section of a combustible gas burner embodying the principles of our discovery.

Fig. 2 is an enlarged view of the mixing plate of said burner taken along the line 2-2.

Fig. 3 is a fragmentary view of Fig. 1 illustrating a method for obtaining limited pre-mixture of air and gas between the mixing plate and the point of ignition.

The construction of the burner is advantageously of stainless steel, or other heat resistant alloy calculated to withstand extreme conditions of temperature and pressure. As represented in Fig. 1 the burner is composed of two sections of 2" standard stainless steel pipe, section 10 constituting the elongated combustion chamber and section 11 containing the combustion elements. Combustion chamber 10 is of a length designed to accommodate the turbulent flame and in the embodiment illustrated is 24 inches. Pipe section 11 is of similar length and, as shown, is joined to chamber 10 by stainless steel coupling 12. Situated at the head of combustion chamber 10 is a mixing plate 13 which, in the embodiment shown, is of stainless steel, welded in place. Mixing plate 13 contains three $\frac{1}{8}$ -inch diameter ducts, air ducts 14 and 15 and gas duct 16 (refer to Fig. 2), each drilled at a 30° by 30° compound angle with respect to the center line of the mixing plate. The ducts may be geometrically positioned in plate 13, but air ducts 14 and 15 are shown as advantageously spaced closely adjacent to gas duct 16 so as to "sandwich" it in order to improve mixing. The fuel-air mixture is ignited by spark plug 17 centrally located in mixing plate 13. Plug 17 is mounted in nipple 18 which is welded to hexagonal 19 of plug 17, and is joined by coupling 24 to inner pipe 20 which extends the length of pipe section 11 and provides a protective sheath for high tension cable 21 leading to plug 17.

Fuel gas is admitted to the burner through pipe 20 and at a point well above the combustion zone and is diverted to separate gas line 22, advantageously constructed of $\frac{1}{4}$ by $\frac{3}{8}$ -inch stainless steel tubing sections joined by coupling 23, which leads directly to gas duct 16 of mixing plate 13. Air enters the burner through pipe section 11 in a high velocity stream surrounding and tending

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to cool inner pipe 20 and gas line 22, and passes through air ducts 14 and 15 which impart a whirling tangential motion to the flame by reason of their compound angular construction.

In the modification of Fig. 3, limited pre-mixture of gas and air is achieved by providing a spiral vane 25 leading from the discharge of the gas and air ports so as to cause all the gas and air to pass under the vane before spilling into the combustion zone. The spiral vane is a single turn helix 25 as shown, which may be constructed of stainless steel, and which is welded to the outside of internal cylinder 26. Cylinder 26 is welded around spark plug points 27 and seals spiral vane 25 on the inside. Spiral vane 25 is advantageously welded to mixing plate 13 at a point just behind the first air duct, thus causing all the gas and air to pass underneath vane 25 before entering the combustion zone. In order to supply a small portion of the pre-mixed gas and air to the spark plug igniter, small scoop 28 is formed out of the wall of cylinder 26 advantageously at a point where the gas and air emerge from under vane 25.

In the operation of the burner, as in a bottom-hole combustion system, for example, it is placed near the end of the oil well tubing string at formation level. Sections of ordinary extension pipe are used to extend burner pipe sections 11 and 20 to the surface. Fuel gas is introduced through the inner pipe to pipe 20 and thence to line 22, and primary air, in the theoretical proportion for perfect combustion, is supplied through the extensions of outer pipe section 11 at pressures regulated by gas quantities necessary for the desired rate of heat release. The fuel and air are mixed at the mixing plate by discharge from angularly directed ducts 14, 15, 16. The mixture is ignited at a pressure of about 40 to 50 p. s. i. g. by electric spark from spark plug 17 which is controlled from the surface through cable 21, properly extended. The flame temperature is controlled by admitting secondary air through the tubing or outer case. In this manner, high rates of heat release are achieved under the subterranean combustion conditions while soot production that might clog the porous oil structure is obviated.

For example, a burner of the type shown in Fig. 1 but with the ducts positioned 108° from each other was placed in a pressure tight 4" casing. When propane gas and air were fed to the burner in theoretically correct proportion for perfect combustion, plus enough air feed to the casing to limit the resulting temperature to 1500° F., the burner ignited at 40 p. s. i. g. We found that the pressure could be built up to 75 p. s. i. g. while maintaining combustion. The pressure was maintained on the casing by using a valve to pinch down on the flue gas bled out of the casing. Once the burner was ignited at the higher pressure, the pressure on the casing could be reduced to a value slightly above atmospheric and the combustion still maintained. This test was conducted at a gas feed rate sufficient to give about 500,000 B. t. u. per hour dissipation.

We found however that it was not possible to ignite such a burner at atmospheric pressure. Accordingly, for operation at atmospheric pressure it is desirable to provide a separate gas tube passing through the mixing plate to emerge close to the outlet of each air duct and so arranged that the gas flows directly into the high velocity air jet as it emerges from the duct. This arrange-

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ment insures an explosive mixture at all points down stream from the mixing plate.

For operation with natural gas, which is chiefly methane, we have found that a burner incorporating a limited pre-mixture system of the type shown in Figs. 2 and 3 shows greatly improved ignition behavior. Pre-mixing of gas and air at the spark plug igniter is increased by reducing the spacing between the gas and air ducts so as to "sandwich" the gas duct between the two air ducts and by providing a spiral mixing vane and internal cylinder which together form a mixing passageway from the discharge ports of the gas and air ducts and opening into the combustion chamber. The internal cylinder is vented or provided with a scoop to supply mixture to the igniter at the face of the mixing plate.

We have described our invention in its basic forms which include a burner characterized by an elongated combustion chamber with a mixing plate at its head containing separate angularly directed air and fuel ducts and separate passages for fuel and air to these ports, including a spiral mixing vane with internal cylinder and side scoop for effecting limited pre-mixing prior to the point of ignition; a method of burning fuel gas under conditions of high pressure to obtain high rates of heat release characterized by introducing fuel gas and air separately and angularly to the head of an elongated combustion zone so as to impart a turbulent and whirling tangential motion to the flame resulting from the mixture; and an improvement in thermal methods for recovering oil and gas from oil-bearing formations characterized by burning fuel gas at formation level in an input well in a system wherein fuel gas and air under pressure in approximately theoretical proportion for perfect combustion are separately and angularly introduced to an elongated combustion zone fitted within the oil well casing so as to impart a turbulent whirling tangential motion to the flame resulting from the mixture and controlling the temperature of the flame by introducing secondary air through the oil well casing. There are obvious variations and substitutions, of course, which can be made by those skilled in the art in the number, position and form of mechanical elements involved, the materials and dimensions of the structural elements, the proportioning of air and fuel and control of temperature and soot formation, etc. We contemplate that such changes in form or substitution of equivalents lie within the following claims.

We claim:

1. A gas burner which comprises first means having an elongated, substantially cylindrical wall forming a combustion chamber; second means connected to the head of the combustion chamber for directing streams of fuel gas and air into the combustion chamber in a manner to accomplish mixing therein; third means for separately delivering fuel gas and air to said second means; said second means including means for separately introducing each of said separate streams of fuel gas and air into the combustion zone at a location spaced from the axis of the combustion chamber and adjacent said cylindrical wall and in a downstream direction having a directional component outward from said axis and a directional component tangential to a circle normal to said axis having its center at said axis and passing through said location, the last named tangential directional component of each of said streams being in the same direction circumferentially of said second means thereby accom-

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plishing tangential swirling and mixing of the fuel gas and air adjacent the wall of the combustion chamber; and fourth means for igniting the fuel gas-air mixture.

2. A gas burner which comprises an elongated combustion chamber having a longitudinal axis and radial planes along said axis, a mixing plate at the head of said chamber, separate passages for fuel gas and air to said mixing plate, separate fuel gas and air ducts angularly directed through said plate, said fuel gas and air ducts communicating respectively with said fuel gas and air passages, said ducts being similarly positioned at substantially the same distance from the axis of said chamber and each duct in its passage through said plate in downstream direction having a directional component outward from said axis and a directional component normal to its respective radial plane which passes through the upstream entrance to said duct, the last named directional component of each of the ducts being in the same direction circumferentially of said plate, thereby accomplishing tangential swirling and mixing of the fuel gas and air adjacent the wall of the combustion chamber, means for supplying fuel gas and air to said fuel gas and air passages respectively, and means for igniting the fuel gas-air mixture.

3. A gas burner which comprises an elongated combustion chamber having a longitudinal axis and radial planes along said axis, a mixing plate at the head of said chamber, a fuel gas duct in said plate, a plurality of angularly directed air ducts in said plate sandwiching said gas duct, said ducts being similarly positioned at substantially the same distance from the axis of said chamber and each duct in its passage through said plate in downstream direction having a directional component outward from said axis and a directional component normal to its respective radial plane which passes through said axis and the upstream entrance to said duct, the last named directional component of each of the ducts being in the same direction circumferentially of said plate thereby accomplishing tangential swirling and mixing of the fuel gas and air adjacent the wall of the combustion chamber, a gas line feeding said gas duct, a tubular air passage charging said air ducts and containing said gas line, means for supplying fuel gas and air to said gas line and air passage respectively, and means for igniting the fuel gas-air mixture at the face of the mixing plate.

4. A gas burner in accordance with claim 2 and including a cylinder extending downstream from said mixing plate and surrounding said igniting means, and a spiral mixing vane surrounding said cylinder and forming a mixing passage way from said ducts opening into said combustion chamber, said cylinder having a scoop arranged to supply a small portion of the fuel gas-air mixture to said igniting means.

5. In the method of burning fuel gas, the improvement which comprises separately passing fuel gas and air streams to a mixing point at the head of a substantially cylindrical combustion zone, separately introducing each of said streams into the combustion zone at a location spaced from the longitudinal axis of the combustion zone and in a downstream direction having a directional component outward from said axis and a directional component tangential to a circle having its center at said axis and passing through said location, the last named tangential directional component of each of said streams being

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in the same direction circumferentially of said zone, directing the flow of said streams in a manner to produce peripheral flow in said combustion zone to accomplish tangential swirling and mixing of the fuel gas and air at the periphery of said combustion zone, and igniting the resultant fuel gas-air mixture.

6. In the method of producing hot combustion gases at an input well for the thermal recovery of oil and gas, the improvement which comprises separately passing fuel gas and air streams to a mixing point at the head of a substantially cylindrical combustion zone in said well, separately introducing each of said streams into the combustion zone at a location spaced from the longitudinal axis of the combustion zone and in a downstream direction having a directional component outward from said axis and a directional component tangential to a circle having its center at said axis and passing through said location, the last named tangential directional component of each of said streams being in the same direction circumferentially of said zone, directing the flow of said streams in a manner to produce peripheral flow in said combustion zone to accomplish tangential swirling and mixing of the fuel gas and air

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at the periphery of said combustion zone, igniting the resultant fuel gas-air mixture, and controlling the temperature of the flame by introducing secondary air into said well and around said combustion zone.

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