PROCESS FOR THE PARTIAL COMBUSTION OF HYDROCARBONS TO PRODUCE ACETYLENE

Filed Sept. 24, 1963 2 Sheets-Sheet 1

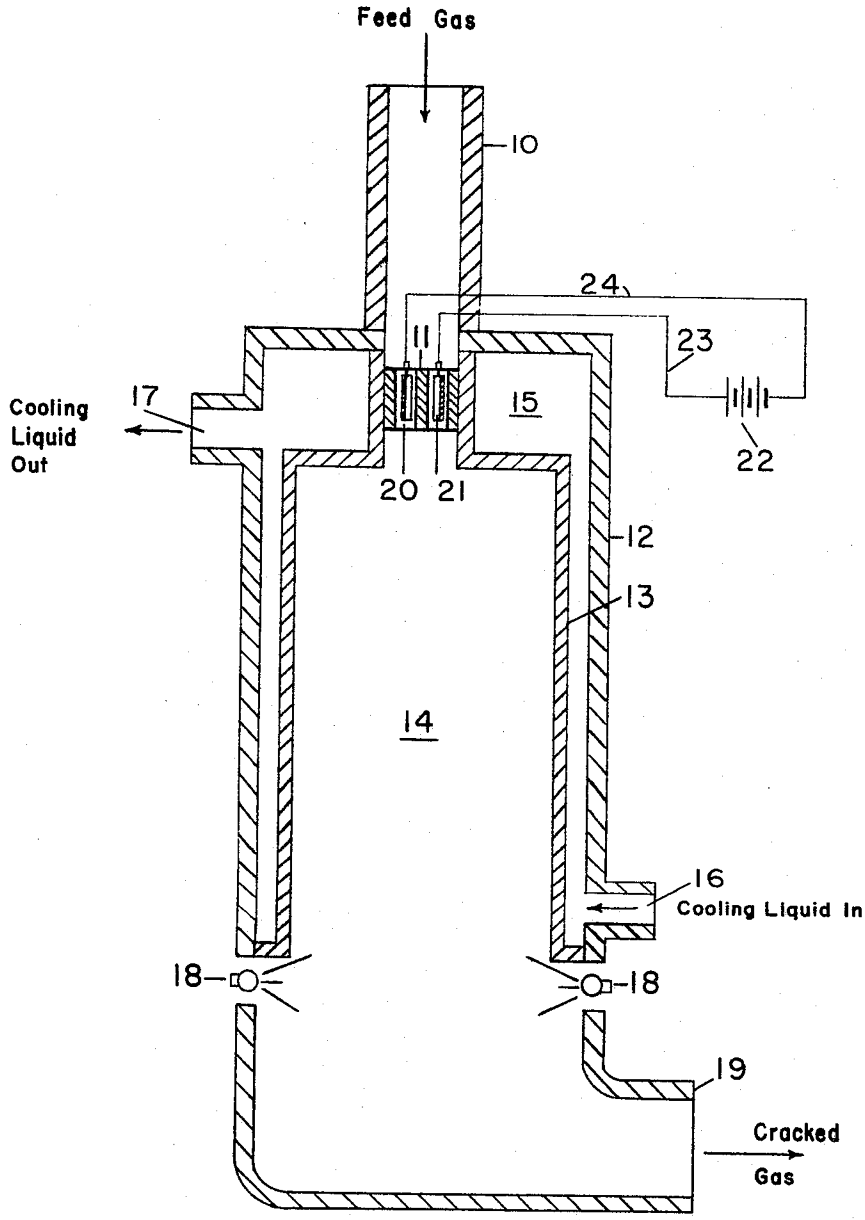

FIG. 1

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Nov. 22, 1966 W. H. STANTON ETAL 3,287,434

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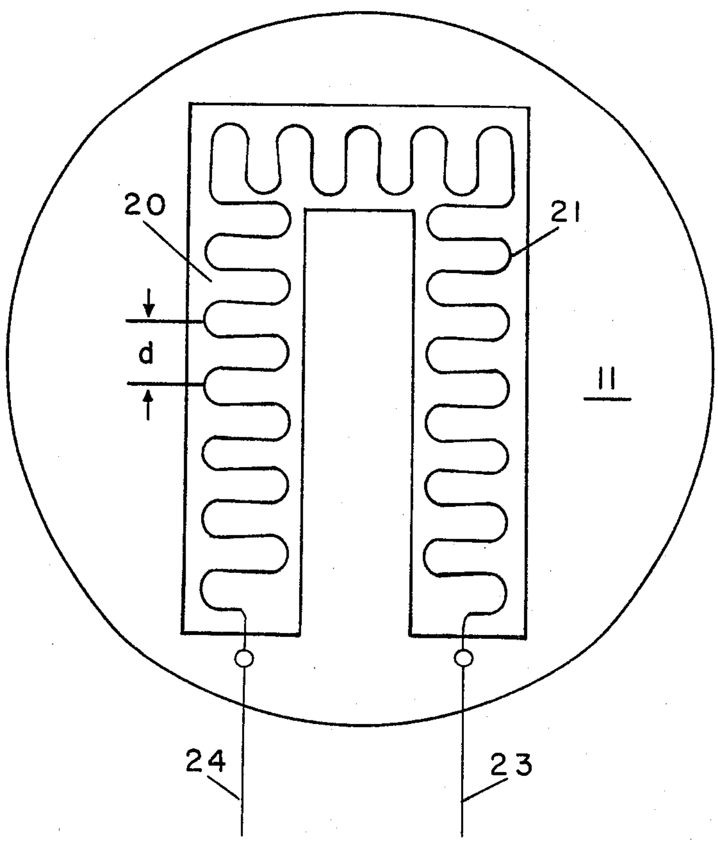

FIG. 2

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3,287,434

Patented Nov. 22, 1966

3,287,434

PROCESS FOR THE PARTIAL COMBUSTION OF HYDROCARBONS TO PRODUCE ACETYLENE

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Filed Sept. 24, 1963, Ser. No. 311,158
7 Claims. (Cl. 260—679)

The present invention is related to the production of acetylene by the partial combustion of methane. More particularly, it is concerned with a method and apparatus for preheating a paraffinic hydrocarbon and an oxygen-containing gaseous mixture from about 600° C. to a temperature up to about 1150° C. without preignition of the hydrocarbon.

The production of acetylene by the reaction between methane and insufficient quantities of oxygen or air is well known. In such a process it is known that acetylene may be produced by conducting the combustion process at a temperature of from about 1200 to about 1800° C. The process is usually carried out at essentially atmospheric conditions. After combustion of part of the methane and the oxygen to produce a high temperature, the excess methane is cracked to acetylene and immediately thereafter the reaction products are quenched with a cooling liquid, generally a water spray. This quenching is necessary to limit the reaction time and minimize decomposition of the hydrocarbon products to facilitate the recovery of acetylene and to eliminate the production of carbon and hydrogen.

Usually, the apparatus comprises an inlet or mixing chamber separated by a perforated or porous plate from the reaction chamber where a portion of the hydrocarbon reactant is burned to provide the heat for effecting the conversion of the remainder of the hydrocarbon reactant into acetylene. The perforated or porous plate is commonly called a "burner block" and creates a gas velocity which is greater than the rate of flame propagation and thereby prevents the flame in the reaction chamber from flashing back into the inlet chamber and igniting the hydrocarbon being supplied to the reaction chamber.

It is also known in the prior art processes to preheat the hydrocarbon reactant and oxygen-containing stream, either separately or admixed together, in order to increase the acetylene yield and reduce the oxygen requirements.

According to one of the processes of the prior art, oxygen and a methane gas, for instance, natural gas, are separately preheated to 600 to 650° C. and mixed with each other in a tangential mixing zone called a diffuser and the resulting mixture introduced into a reaction zone through a perforated block having a plurality of small tubes. The mixed gas velocity through the burner block is in excess of the rate of flame propagation thus preventing flashbacks into the diffuser. Partial combustion of the methane and oxygen and cracking of the excess methane follows and the reaction products are quenched by direct contact with a water spray to limit the total reaction time to less than 0.1 second.

Preheating the reactants has a beneficial effect on the acetylene yield, the quantity of acetylene in the cracked effluent gas increasing as the preheat temperature is increased. In addition to the increased concentration of acetylene in the effluent gas, the oxygen requirements are also reduced. However, preheating of the reactants to temperatures higher than approximately 600 to 700° C. has been difficult in commercial operations because of the likelihood of preignition of the reactants before introduction into the reaction chamber.

It is desirable to preheat the hydrocarbon-oxygen mixture even higher than the 600 or 700° C. temperature which has heretofore been so difficult to do commercially;

however, higher temperatures, for example up to 1150° C., are unobtainable in the presently known conversion systems.

It is an object, therefore, of the present invention to provide an improved process for the partial combustion of hydrocarbons to produce acetylene at increased yields and conversions. Another object of the present invention is to provide an improved method and apparatus for the preparation of acetylene by incomplete combustion of a paraffinic hydrocarbon where the hydrocarbon-oxygen mixture can be preheated to a temperature up to 1150° C. without danger of either preignition or flashback. Another object of this invention is to provide an improved method and apparatus for preheating a hydrocarbon-oxygen mixture above the preignition temperature and injecting the preheated mixture into a combustion or reaction chamber without the danger of either preignition or flashback of the mixture. Another object of this invention is to provide an improved burner block means to permit a preheated mixture of hydrocarbon and an oxygen-containing gas to be introduced into a combustion or reaction zone without the occurrence of either preignition or flashback. These and other objects of the invention will become apparent from the following description, drawings, and appended claims.

According to the present invention, preheating of a gas mixture containing paraffinic hydrocarbon and an oxygen-containing gas is accomplished in the burner block through which the preheated mixture is introduced into the reaction chamber for conversion into acetylene. The burner block is provided with at least one passage having a heating element arranged therein for heating the gas mixture to a temperature in the range of 800 to 1150° C. The passage in the burner block is of a size to provide a gas velocity which is greater than the rate of flame propagation of the gas mixture, thereby flashback of the flame is prevented. The rate of heat transfer is sufficient that the desired temperature of the high velocity gases is reached and the preheated gas mixture injected into the reaction chamber before the end of the flame induction period; that is, before ignition commences.

A better understanding of the invention can be obtained upon reference to the accompanying drawings which illustrate a specific embodiment of the invention. FIGURE 1 is a cut-away view of an ordinary acetylene converter showing the burner block of this invention containing an electric heating element. FIGURE 2 is a plan view of the inlet end of a burner block which is shown in section in FIGURE 1, showing the physical arrangement of the passage and electric heating element disposed therein.

Referring to FIGURE 1, a gaseous mixture at about 600° C. consisting of oxygen and natural gas enters the acetylene converter through line **10** and burner block **11**. The acetylene converter comprises a cylindrical metal shell **12** containing inner liner **13** which encloses combustion chamber **14**. Liner **13** is separated from metallic shell **12** by annular space **15** through which a cooling fluid is circulated via lines **16** and **17** to maintain liner **13** at a moderate temperature. After partial combustion of the natural gas and the subsequent cracking of the excess methane to acetylene and other by-products, the entire reaction mixture is quenched by water nozzles **18** at the bottom of combustion chamber **14**. The quenched gas stream leaves the converter through line **19** for subsequent cooling and purification to recover the acetylene.

Burner block **11** is constructed of solid material and is provided with a passage **20** for the flow of gas mixture into reaction chamber **14**. Electrical heating element **21** is arranged within passage **20** and heated by the application of an electric current from electric source **22** via electrical conductors **23** and **24** to a maximum temperature in the range of 1100 to 1250° C. Multiple passages may be used if desired.

Referring now to FIGURE 2, burner block **11** is made from a solid non-metallic refractory material, for instance aluminum oxide, with "U-shape" passage **20** therethrough. Electric heating element **21** is arranged within passage **20** and electrically connected through electrical conductors **23** and **24** to a source of electrical energy. Electric heating element **21** may be designed in any of several ways to provide the maximum amount of heat transfer area and still permit uniform gas velocities across the cross-section of gas flow. As shown, heating element **21** is a crimped surface with a crimped distance *d* in the order of 0.1 to 0.25 inch.

Specific embodiments of this invention are described in the following examples, but they are not to be construed as limiting the invention in any manner whatsoever since they are merely illustrative.

Example I

An electric heating element constructed of Hastelloy X was designed to provide 8.95 square feet of heat transfer area in an acetylene burner block 4 inches in diameter and 12 inches long. The heating element was crimped, as shown in FIGURE 2, with a crimping distance of 0.12 inch. The thickness of the metal was 0.02 inch. The passage or opening in the burner block was U-shaped and had a cross-sectional area which comprised 17.4 percent of the total cross-sectional area of the burner block.

Methane and oxygen at a flow rate of 8.33 moles per hour and 4.33 moles per hour, respectively, and a temperature of 600° C. were introduced into the burner block. Electricity at a rate of 892 amps and 22.9 volts heated the heating element to a temperature of 1150° C. The methane-oxygen mixture exited from the passage of the burner block at a velocity of 400 feet per second with a total retention time in the burner block of 0.0033 second and a pressure drop across the burner block of 2.8 p.s.i. The heat transfer from the heating element of the gas mixture was 147,870 B.t.u./hour (heat flux=16,500 B.t.u/hour per square foot) and the temperature of the gas leaving the burner block was 1041° C. After partial combustion of the methane in the acetylene converter, the percent acetylene in the cracked gas leaving the acetylene converter was 10.8 mole percent on a water-free basis.

Example II

An electric heating element constructed of Hastelloy X was designed to provide 11.0 square feet of heat transfer area in an acetylene burner block 4 inches in diameter and 12 inches long. The heating element was crimped, as shown in FIGURE 2, with crimping distance of 0.10 inch. The thickness of the metal was 0.012 inch. The passage or opening in the burner block was U-shaped and had a cross-sectional area which comprised 23.8 percent of the total cross-sectional area of the burner block.

Methane and oxygen at a flow rate of 8.60 moles per hour and 4.33 moles per hour, respectively, and a temperature of 600° C. were introduced into the burner block. Electricity at a rate of 1440 amps and 36 volts heated the heating element to a temperature at the exit of 1210° C. The methane-oxygen mixture exited from the passage of the burner block at a velocity of 370 feet per second with a total retention time in the burner block of 0.0037 second and a pressure drop across the burner block of 3.1 p.s.i. The heat transfer from the heating element to the gas mixture was 177,000 B.t.u./hour (heat flux=16,100 B.t.u./hour per square foot) and the temperature of the gas leaving the burner block was 1110° C. After partial combustion of the methane in the acetylene converter, the percent acetylene in the cracked gas leaving the acetylene converter was 11.1 mole percent on a water-free basis.

Example III

Methane and oxygen at a flow rate of 7.15 moles per hour and 4.33 moles per hour, respectively, were introduced at a temperature of 600° C. into the acetylene converter of Examples I and II without benefit of preheating in the burner block. After partial combustion and cracking of the methane followed by quenching of the reaction, the effluent gas leaving the acetylene converter had an acetylene content of 8.75 mole percent on a water-free basis.

The foregoing examples illustrate that the feed constituents required for the partial combustion of methane to produce acetylene can be preheated in an electrically heated burner block to a temperature approaching 1150° C. The examples also illustrate that an increase in preheat temperature resulted in a cracking pattern yielding increased amounts of acetylene. This increase in yield was obtained without any flashback of flames of preignition of the methane-oxygen mixture.

The electric heating element used in this invention must be one which has reasonable strength at temperatures up to about 1250° C., can withstand the atmosphere to which it is exposed at high temperatures and has favorable electrical resistance. Such metals as Hastelloy X (about 45% nickel, 2.5% cobalt, 23% chrome, 10% molybdenum, 20% iron, 1% tungsten, 15% carbon), Kanthal Al (about 5% aluminum, 22% chrome, ½% cobalt, and the remainder iron), Chromel A (80% nickel, 20% chrome), and Nichrome V (about 80% nickel, 20% chrome) are materials which can be used.

In obtaining a maximum temperature of up to 1150° C. in the gas discharged from the burner block, it is desirable to maintain the heating element at a minimum temperature and to provide the heating element with a maximum heat transfer area. Also, gas temperatures in this range necessitate that the temperature of the heating element be within the range of 1100° C. to about 1250° C. The heat transfer area is dependent upon the rate of gas flow, desired exit gas temperature, inlet feed gas temperature, length of the heating element, and thickness of the heating element material.

The thickness of the heating element shown in FIGURES 1 and 2 is at least 5 mils and not more than about 50 mils. The crimp distance *d* is preferably in the range of from 50 to 250 mils for economy of operation and maximum heat transfer. It will be noted in the examples that sufficient heat transfer area is provided to obtain a heat flux, B.t.u./hour per square foot of area, in the range of from about 10,000 to about 25,000.

In the design of the heating element, other factors besides heat transfer area must be taken into account. The pressure drop through the burner block must not be excessive, the velocity of the mixed gas must be greater than the rate of flame propagation to prevent flashbacks, the flow of gas through the burner block must be at uniform velocity throughout the transverse, cross-sectional area and the residence time of the gas in the burner block must be less than the time required for a sufficient concentration of flame initiators to form for combustion to take place.

The pressure drop through the burner block is preferably limited to less than about 20 p.s.i. in order to avoid excessive cost for compression of the feed gases. Ordinarily, the pressure drop is less than about 5 p.s.i.

The length of the flame induction period during which the concentration of flame initiators builds up is dependent primarily on temperature. Therefore, the residence time of the gases in the burner block should be less than about 10 milliseconds when preheating a gas mixture from about 600° C. to about 1150° C., although it is preferred to limit the residence time to about 5 milliseconds. When preheating to only about 800° C., the residence time may be as high as 200 milliseconds without flames developing, but preferably the residence time is limited to about 10 milliseconds. Unless the heated gas is discharged into the reaction chamber before the end of the flame induction period, spontaneous combustion occurs and such combustion may take place in the burner block and thereby result in combustion upstream of the burner block.

The velocity of the mixed gas through the burner block must be greater than the rate of flame propagaton of the gas mixture and, ordinarily, must be at least 300 feet per second at an exit temperature of from 1000° C. to 1150° C. and preferably about 400 to 500 feet per second. At a temperature of 800° C., the velocity may be as low as 200 feet per second. The flow of gas through the burner block must be of a substantially uniform velocity. If the gas flows at a lower velocity in one area than in another area, the lower velocity may not be sufficiently greater than the rate of flame propagation and flashback of the flame would occur. Also, the lower-velocity gas would be heated to a higher temperature, thereby reducing the flame induction period and causing preignition of the gas mixture.

Another important factor in the burner block of this invention is the relation between the cross-sectional area of the passage or opening through the burner block and the total cross-sectional area of the burner block. Sufficient closed area is necessary to permit eddy currents to form downstream from the block and develop a stable flame front at the exit from the burner block. The open area necessary to achieve this condition is ordinarily from about 15 to 30% of the total cross-sectional area of the burner block.

The burner block may be constructed from any convenient nonmetallic refractory material capable of withstanding temperatures of 1250° C. Such materials as aluminum oxide, alumina-silica ceramics, alumina foam and silicon carbide foam are satisfactory for this purpose. Preferably, the material is substantially non-porous in nature. The surface in direct contact with the heating element should be pure aluminum oxide.

The electrical resistance of the heating element ordinarily must be at least about 50 microhm-inches at temperatures of 1000° C. to 1150° C. in order to develop sufficient wattage input in amperages of 1000 to 2000 amps. The heating element may be constructed in various configurations and one configuration has been exemplified in the examples and shown in FIGURE 2. This corrugated design is advantageous because current flows through the entire heater element so that an exceedingly long length can be employed in order to obtain the total resistance desired. Generally, the heating element must be so designed for maximum total resistance so that the amperage required is not excessive. Amperage requirements above 5000 amperes would result in unreasonably large electric leads. A preferred range of electric current is from 1000 to 2000 amperes. Inasmuch as the heating element has a temperature variation of from about 600° C. at the inlet end to as high as 1250° C. at the outlet end, it is beneficial in order to avoid distortion to divide the heating element into at least three sections, for instance, a 12-inch deep heating element should be made up of at least three 4-inch sections.

In the manufacture of acetylenes, the combustion of the gas mixture must develop temperatures in the range of about 1200° C. to about 1800° C. in order to furnish sufficient heat to convert the remaining hydrocarbon, ordinarily methane, in the feed gas to acetylene. Although it is possible to carry out the combustion and conversion reactions at temperatures higher than 1800° C., it is not possible to achieve the optimum acetylene content in the stack gas, also, large quantities of carbon or coke are produced at the higher temperatures. Preferably, the reaction is carried out below 1800° C. For example, from about 1400° C. to about 1600° C. has proved to be very desirable.

The preferred hydrocarbon used in the process of this invention is methane; however, any paraffinic hydrocarbon which can be converted into acetylene by a partial combustion process may be used. Ordinarily, the paraffinic hydrocarbon will have less than seven carbon atoms. Examples of suitable hydrocarbons, besides methane, include ethane, propane, butane and pentane. Natural gas, comprising essentially methane, is a preferred hydrocarbon stream for use in this invention.

The oxygen-containing stream mixed with the paraffinic hydrocarbon for use in this invention is preferably oxygen; however, any oxygen-containing stream can be used. For example, either a relatively pure oxygen stream or oxygen-enriched air can be used.

Pressure is not critical in the partial combustion of hydrocarbons to produce acetylene. The converter operates at essentially atmospheric pressure under normal conditions but also operates satisfactorily at as high as 40 p.s.i.a. and as low as 5 p.s.i.a.

Although preheating of the feed gases to at least 1000° C. is preferred for the best results, the scope of this invention includes preheating feed gases from about 600° C. to at least 800° C. and up to a temperature of about 1150° C. A temperature of about 1150° C. is a practical limit for heating the feed gas because of the materials of construction problem. Also, the flame induction period becomes too short above that temperature.

What is claimed is:

1. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing stream are discharged through a burner block into a combustion zone, the improvement comprising preheating said gas mixture above the ignition temperature of said gas mixture in said burner block during passage therethrough and discharging the resulting preheated gas mixture into said combustion zone before the end of the flame induction period of said preheated gas mixture.

2. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing stream are discharged through a burner block into a combustion zone, the improvement comprising preheating said gas mixture to a temperature in the range of 800 to 1150° C. in said burner block during passage therethrough and discharging the resulting preheated gas mixture into said combustion zone before the end of the flame induction period of said preheated gas mixture.

3. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing gas are discharged through a burner block into a combustion zone, the improvement comprising preheating said gas mixture to a temperature in the range of 800 to 1150° C. in said burner block during passage therethrough and discharging the resulting preheated gas mixture into said combustion zone within 200 milliseconds from the time said gas mixture entered said burner block.

4. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing stream are discharged through a burner block into a combustion zone, the improvement comprising preheating said gas mixture to a temperature in the range of 1000 to 1150° C. in said burner block during passage therethrough and discharging the resulting preheated gas mixture into said combustion zone within 10 milliseconds from the time said gas mixture enters said burner block.

5. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing stream are discharged through a burner block into a combustion zone, the improvement comprising flowing said gas mixture at high velocity through openings in said burner block, contacting said gas mixture while flowing through said openings in said burner block with electrical heating elements at elevated temperature to thereby preheat said

gas mixture to a temperature in the range of 800 to 1150° C., and discharging said preheated gas mixture from said burner block into said combustion zone before the end of the flame induction period of said preheated gas mixture.

6. The process of claim **5** wherein said velocity through said openings in said burner block is at least 200 feet per second.

7. In a process for the partial combustion of a paraffinic hydrocarbon to produce acetylene wherein a gas mixture of said paraffinic hydrocarbon and an oxygen-containing stream are discharged through a burner block into a combustion zone, the improvement comprising flowing said gas mixture at high velocity through openings in said burner block, contacting said gas mixture while flowing through said openings in said burner block with an electrical heating element at a temperature in the range of 1100° C. to 1250° C. to thereby preheat said gas mixture to a temperature in the range of 1000 to 1150° C., and discharging said preheated gas mixture from said burner block into said combustion zone within 10 milliseconds from the time said gas mixture entered said burner block.

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