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[Continued on next page]

(54) Title: HIGH PRESSURE COMBUSTOR WITH HOT SURFACE IGNITION

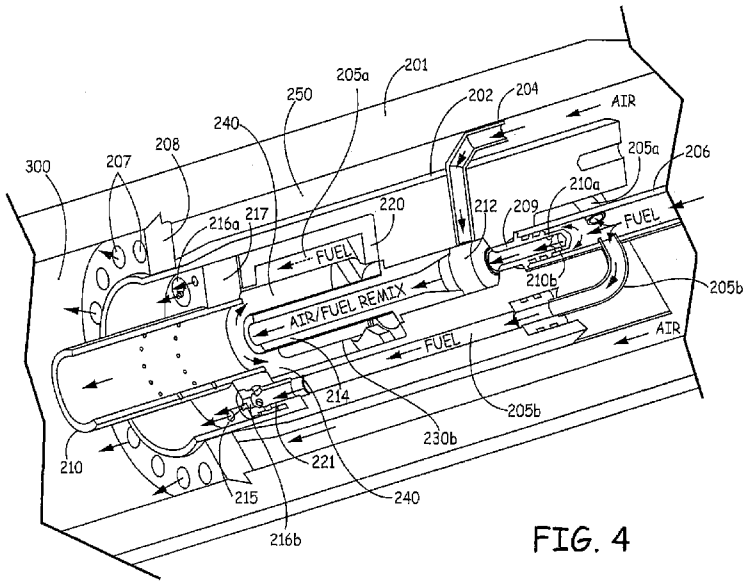


FIG. 4

(57) Abstract: A combustor (200) including a housing (102), an injector body (202), insulation (220), an air/fuel premix injector (214), a hot surface igniter (230a, b), a fuel injector and a burner. The housing forms a main combustion chamber (300). The injector body is coupled within the housing, the injector body includes an initial combustion chamber (240). The insulation lines the initial combustion chamber. The air/fuel premix injector assembly is configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber. The hot surface igniter is configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber. The fuel injector dispenses a flow of fuel and the burner dispenses a flow of air. The flow of fuel from the fuel injector and the flow of air from the burner are ignited in the main combustion chamber by the ignition of the air/ fuel mixture in the initial combustion chamber.

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HIGH PRESSURE COMBUSTOR WITH HOT SURFACE IGNITION

BACKGROUND

[0001] Ignition at high pressure, such as that seen in oilfield downhole applications, has proven to be difficult. At pressures above 600 psi traditional ignition methods such as spark ignition ceases to be viable. Thus, the industry has turned to other ignition sources such as pyrophoric fuels and hot surface ignition. Pyrophoric fuels ignite upon mixing with an oxidizer, such as air or oxygen, which contributes to their high success rate. However, they can leave traces of foreign object debris inside the combustor and adjacent systems which can cause failures, they are typically very hazardous to store and transport, expensive to supply, and can even be carcinogenic. Therefore, Pyrophorics are usually considered as a secondary source for ignition, and their elimination from downhole systems would be desirable. On the other hand, hot surface ignition has none of the chemical or cost drawbacks associated with Pyrophorics; rather, the challenge is to utilize the limited power available downhole to raise and keep the temperature of the oxidizer (air) and gaseous hydrocarbon mixture above auto-ignition temperature.

[0002] For the reasons stated above and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for an effective and efficient combustion system.

SUMMARY OF INVENTION

[0003] The above-mentioned problems of current systems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. The following summary is made by way of example and not by way of limitation. It is merely provided to aid the reader in understanding some of the aspects of the invention.

[0004] In one embodiment, a combustor is provided. The combustor includes a housing, an injector body, insulation, an air/fuel premix injector, a hot surface igniter, a fuel injector and a burner. The housing forms a main combustion chamber. The injector body is coupled within the housing, and the injector body includes an initial combustion chamber. The initial combustion chamber is deliberately lined with the insulation. The air/fuel premix injector assembly is configured and arranged to dispense a flow of air/fuel mixture into the initial

combustion chamber. The hot surface igniter is configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber. The fuel injector is configured and arranged to dispense a flow of fuel. The burner is configured and arranged to dispense a flow of air. The flow of fuel from the fuel injector and the flow of air from the burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber.

[0005] In another embodiment, another combustor is provided. This combustor also includes a housing, an injector body, insulation, an air/fuel premix injector, at least one glow plug, a fuel injector plate and a burner. The housing forms a main combustion chamber. The injector body is coupled within the housing. The injector body includes an initial combustion chamber. The insulation lines the initial combustion chamber. The air/fuel premix injector assembly is configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber. The at least one glow plug is configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber. The fuel injector plate is coupled within the injector body a select distance from the air/fuel premix injector. The fuel injector plate is positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber. The burner is configured and arranged to dispense a flow of air. The flow of fuel from the injector plate and the flow of air from the burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber.

[0006] In another embodiment, still another combustor is provided. The combustor includes a housing, an injector body, insulation, an air/fuel premix injector assembly, at least one glow plug, a fuel injector plate, a swirl plate burner and a jet extender. The housing forms a main combustion chamber. The injector body is coupled within the housing. The injector body includes an initial combustion chamber. The insulation lines the initial combustion chamber. The air/fuel premix injector assembly is configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber. The at least one glow plug is configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber. The fuel injector plate is coupled within the injector body a select distance from the air/fuel premix injector. The fuel injector plate is positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber. The fuel injector plate has an injector plate central opening. The swirl plate burner is coupled around an outer surface of the injector body. The swirl plate burner is

configured and arranged to dispense a flow of air. The flow of fuel from the injector plate and the flow of air from the swirl plate burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber. A jet extender generally tubular in shape extends from the fuel injector central opening of the fuel injector plate into the main combustion chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present invention can be more easily understood and further advantages and uses thereof will be more readily apparent, when considered in view of the detailed description and the following figures in which:

[0008] Figure 1 is a side cross-sectional view of a downhole combustion assembly in one embodiment of the present invention;

[0009] Figure 2 is a side perspective view of a combustor of one embodiment of the present invention;

[0010] Figure 3A is a cross-sectional view along line 3A-3A of the combustor of Figure 2;

[0011] Figure 3B is a cross-sectional view along line 3B – 3B of the combustor of Figure 2; and

[0012] Figure 4 is a cross-sectional side view of the combustor of Figure 2 illustrating gas flow through the combustor.

[0013] In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize specific features relevant to the present invention. Reference characters denote like elements throughout Figures and text.

DETAILED DESCRIPTION

[0014] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the inventions may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the claims and equivalents thereof.

[0015] Embodiments provide a combustor for a downhole application. In embodiments, the combustor 200 takes separate air and fuel flows and mixes them into a single premix air/fuel stream. This premix flow is injected into the combustor 200. As described below, the combustor includes an initial ignition chamber 240 (secondary chamber) and a main combustion chamber 300. The momentum from a premix injection 214 stirs the ignition chamber 240 at extremely low velocities relative to the total flow of air and fuel through the combustor 200. Diffusion and mixing caused by the stirring effect changes the initial mixture within the ignition chamber (oxidizer and/or fuel) to a premixed combustible flow. This premixed combustible flow is then ignited by a hot surface igniter 230a or 230b, such as but not limited to, one or more glow plugs 230a and 230b. Insulated walls 220 limit heat loss therein helping to raise the temperature of the premixed gases. Once the gases reach the auto-ignition temperature, an ignition occurs. This ignition acts as a pulse sending a deflagration wave into the main combustor chamber 300 of the combustor 200 therein igniting the main flow field. Once this is accomplished, the one or more glow plugs 230a and 230b are turned off and the initial ignition chamber 240 no longer sustains combustion. One benefit to this system is that only a relatively small amount of power (around 300 Watts) is needed to heat up the glow plugs at a steady state. The main combustion chamber 300 and the initial combustor chamber 240 are configured such that when the main combustion chamber 300 is operated in the stoichiometric lean range, i.e., equivalence ratio less than 0.5, the initial combustion chamber 240 is being operated in the 'near stoichiometric' range, i.e., equivalence ratios varying from 0.5 to 2.0. When the main combustion chamber 300 is operated in the 'near stoichiometric' range, i.e., equivalence ratios varying from 0.5 to 2.0, the initial combustion chamber 240 is being operated in the stoichiometric rich range, i.e., equivalence ratio greater than 2.0.

[0016] Referring to Figure 1, a cross-sectional side view of a downhole combustion assembly 100 of one embodiment is illustrated. In this example, an embodiment of the downhole combustion assembly 100 is positioned within a casing 120 of a wellbore that has been drilled through the earth to an oil reservoir. An embodiment of a combustion assembly is further discussed in commonly owned patent application having Application No. 13/745,196 entitled "Downhole Combustor" filed on January 22, 2013 which is incorporated herein in its entirety. The downhole combustion assembly 100 of Figure 1 includes a housing 102. The housing 102 includes a first housing portion 102a, a second housing portion 102b and a third housing portion 102c. A plurality of delivery connectors 108 (although only one

is shown) are coupled to the housing 102. The delivery connectors 108 provide a delivery port to the housing for gases such as air and fuel as well as a connection to deliver power to the glow plugs 230a and 230b. Passages (not shown) in the housing 102 deliver the gases and power to the combustor 200 which is received in the third housing portion 102c. In this example of the downhole combustor assembly 100, the first housing portion 102a includes oil inlet ports 106 that are configured and arranged to receive oil from an oil reserve. A heat exchange system 109, in this embodiment, in the first housing portion 102a heats up the oil received in the oil inlet ports 106. Gas and exhaust fumes from the combustor 300 are expelled through oil and exhaust outlet ports 107 in a top side of the first housing portion 102a. Positioned between the oil inlet ports 106 and the oil and exhaust outlet ports 107 is a packing seal 124 that causes oil from the oil reservoir to pass through the housing 102 via the oil input ports 106 and the oil and exhaust outlet ports 107. As discussed above, gases are combusted in combustor chamber 300 in the second housing portion 102b via combustor 200. Exhaust from the main combustion chamber 300 is passed through the heat exchange system 109 into the oil entering into the oil inlet port 106.

[0017] The combustor 200 is illustrated in Figures 2 through Figure 4. Figure 2 is a side perspective view of the combustor 200 which includes an injector body 202. The injector body 202 is generally cylindrical in shape having a first end 202a and a second end 202b. A fuel inlet tube 206 enters the first end of the injection body 202 to provide fuel to the combustor 200. As also illustrated in Figures 2 and 3B, a premix air inlet tube 204 passes through the injector body 202 to provide a flow of air to the combustor 200. A burner (such as but not limited to an air swirl plate 208) is coupled proximate the second end of the injector body 202. The air swirl plate 208 includes a plurality of angled air passages 207 that cause air passed through the air passages 207 to flow into a vortex. Also illustrated in Figure 2 is a jet extender 210 that extends from the second end 202b of the injector body 202. In particular, the tubular shaped jet extender 210 extends from a central passage of a fuel injector plate 217 past the second end 202b of the injector body 202. The jet extender 210 separates the premix air/fuel flow used for the initial ignition, for a select distance, from the flow of air/fuel used in the main combustor 300. An exact air/fuel ratio is needed for the initial ignition in the ignition chamber 240. The jet extender 210 prevents fuel delivered from the fuel injector plate 217 from flowing into the ignition chamber, therein unintentionally changing the air/fuel ratio in the ignition chamber 240. In this example of a jet extender 210, the jet extender includes a plurality of aligned rows of passages 211 through a mid portion of

the jet extender's body. The plurality of aligned rows 211 through the mid portion of the jet extender's body 210 serve to achieve the desired air/fuel ratio between the ignition chamber 240 and the main combustor 300. This provides passive control of ignition at the intended air/fuel ratio of the main combustor 300.

[0018] As discussed above, the jet extender 210 extends from a central passage of a fuel injector plate 217. As Figures 3A and 3B illustrate, the injector plate 217 is generally in a disk shape having a select height with a central passage. An outer surface of the injector plate 217 engages an inner surface of the injector body 202 near and at a select distance from the second end 202b of the injector body 202. In particular, a portion of a side of the injector plate 217 abuts an inner ledge 202c of the injector body 202 to position the injector plate 217 at a desired location in relation to the second end 202b of the injector body 202. The injector plate 217 includes internal passages 217a and 217b that lead to fuel exit passages 215. Chokes 221 and 223 are positioned in respective openings 219a and 219b in the internal passages 217a and 217b of the injector plate 217. The chokes 221 and 223 restrict fuel flow and distribute the fuel flow through respective choke fuel discharge passages 221a and 223a that exit the injector plate 217 as well as into the internal passages 217a and 217b of the injector plate 217 via a plurality of openings 221b and 223b. Fuel passed into the internal passages 217a and 217b exit out of the injector plate 217 via injector passages 215.

[0019] The fuel inlet tube 206 provides fuel to the combustor 200. In particular, as illustrated in Figure 3A, an end of the fuel inlet tube 206 receives a portion of a premix fuel member 209. The premix fuel member 209 includes inner cavity 209a that opens into a premix chamber 212. In particular, the premix fuel member 209 includes a first portion 209b that fits inside the fuel inlet tube 206. The first portion 209b of the premix fuel member 209 includes premix fuel passage inlet ports 210a and 210b to the inner cavity 209a. Fuel from the fuel inlet tube 206 is passed through the premix fuel passage inlet ports 210a and 210b and then into the inner cavity 209a to the premix chamber 212. The premix fuel member 209 further includes a second portion 209c that is positioned outside the fuel inlet tube 206. The second portion 209c of the premix fuel member 209 is coupled to the premix chamber 212. The second portion 209c further includes an engaging flange 209d that extends from a surface of the fuel inlet tube 206. The engaging flange 209d engages the end of fuel inlet tube 206. In one embodiment, a seal is positioned between the engaging flange 209d and the end of the inlet tube 206. Although not shown, another end of the fuel inlet tube 206 is coupled to an internal passage in the housing of the downhole combustor 100 to receive fuel.

As also illustrated in Figure 3A, branch fuel delivery conduits 205a and 205b, coupled to the fuel inlet tube 206, provide a fuel flow to the respective chokes 221 and 223 in the fuel injector plate 217. As illustrated in Figure 3B, the premix air inlet 204 provides air to the premix chamber 212. The air/fuel mix is then passed to the air/fuel premix injector 214 which distributes the fuel/air mixture into an initial ignition chamber 240. The initial ignition chamber 240 is lined with insulation 220 to minimize heat loss. The air/fuel mixture from the premix injector 214 is ignited via one or more glow plugs 230a and 230b.

[0020] Referring to Figure 4, a description of the operation of the combustor 200 is provided. Fuel, such as but not limited to methane, is delivered through passages in the housing 102 to the fuel inlet tube 206 under pressure. As illustrated, the fuel passes through the fuel inlet tube 206 into the plurality of branch fuel delivery conduits 205a and 205b and into the premix fuel inlets 210a and 210b of the premix fuel inlet member 209. Although only two branch fuel delivery conduits 205a and 205b and two premix fuel inlets 210a and 210b to the premix fuel inlet member 109 are shown, any number of fuel delivery conduits and premix fuel inlets could be used and the present invention is not limited by the number. Fuel entering the premix fuel inlet 210a and 210b of the premix fuel inlet member 209 is delivered to the premix chamber 212 where it is mixed with air from the premix air inlet 204, as discussed below. Fuel passing through the branch fuel delivery conduits 205a and 205b is delivered to the chokes 221 and 223 and out the fuel injectors 216a and 216b and fuel passages 215 in the fuel injector plate 217 to provide a flow of fuel for the main combustion chamber 300.

[0021] Air under pressure is also delivered to the combustor 200 through passages in the housing 102. In this embodiment, air under pressure is between the injector body 202 and the housing 102. Air further passes through air passages 207 in the air swirl plate 208 therein providing an air flow for the main combustion chamber 300. As illustrated, some of the air enters the premix air inlet 204 and is delivered to the premix chamber 212. The air and the fuel mixed in the premix chamber 212 are passed on to the air/fuel premix injector 214 which is configured and arranged to deliver the air/fuel mixture so that the air/fuel mixture from the air/fuel premix injector 214 swirls around in the initial ignition chamber 240 at a relatively low velocity. One or more glow plugs 230a and 230b heat this relatively low velocity air/fuel mixture to an auto-ignition temperature wherein ignition occurs. The combustion in the initial ignition chamber 240 passing through the jet extender 210 ignites the air/fuel flow from the fuel injector plate 217 and the air swirl plate 208 in the main combustion chamber

300. Once combustion has been achieved in the main combustion chamber 300, power to the glow plugs 230a and 230b is discontinued. Hence, combustion in the initial ignition chamber 240 is a transient event so that the heat generated will not melt the components. The period of time the glow plugs 230a and 230b are activated to ignite the air/fuel mix in the initial ignition cavity 240 can be brief. In one embodiment it is around 8 to 10 seconds.

[0022] In an embodiment, an air/fuel equivalence ratio in the range of 0.5 to 2.0 is achieved in the initial ignition chamber 240 via the air/fuel premix injector 214 during initial ignition. Concurrently, the air/fuel equivalence ratio in the main combustion chamber 300 is in the range of 0.04 to 0.25, achieved by the air swirl plate 208 and the fuel injector plate 217. After ignition of the flow in the initial combustion chamber 240 and the main combustion chamber 300, the glow plugs 230a and 230b are shut down. An air/fuel equivalence ratio within a range of 5.0 to 25.0 is then achieved within the initial ignition chamber 240, while concurrently, an air/fuel equivalence ratio in the range of 0.1 to 3.0 is achieved in the main combustion chamber 300, by the air swirl plate 208 and the fuel injector plate 217. This arrangement allows for a transient burst from the initial ignition chamber 240 to light the air/fuel in the main chamber 300, after which any combustion in the initial ignition chamber 240 is extinguished by achieving an air/fuel equivalence ratio too fuel rich to support continuous combustion. To cease combustion in the main combustion chamber 300 either or both the air and the fuel is shut off to the combustor 200.

[0023] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

CLAIMS

1. A combustor comprising:

a housing forming a main combustion chamber;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber;

a hot surface igniter configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber;

a fuel injector configured and arranged to dispense a flow of fuel; and

a burner configured and arranged to dispense a flow of air, wherein the flow of fuel from the fuel injector and the flow of air from the burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber.

2. The combustor of claim 1, wherein the burner is an air swirl plate burner.

3. The combustor of claim 1, the air/fuel premix injector assembly further comprising:

a fuel inlet tube to provide a fuel flow;

a premix chamber in fluid communication with the fuel inlet tube to receive the fuel flow from the fuel inlet tube;

a premix air inlet in fluid communication with the premix chamber, the premix air inlet providing a flow of air to the premix chamber; and

an air/fuel premix injector configured and arranged to dispense the flow of air/fuel mixture into the initial combustion chamber.

4. The combustor of claim 3, further comprising:

a premix fuel connecting member coupled to provide the fluid communication between the fuel inlet tube and the premix chamber, the premix fuel connecting member having an inner cavity, the premix fuel member having a first portion that is positioned within an inner passage of the fuel inlet tube, the first portion of the premix fuel member having at

least one premix fuel inlet passage to the cavity of the premix fuel connecting member to receive a fuel flow from the fuel inlet tube.

5. The combustor of claim 3, wherein the premix chamber includes a first portion that is generally cylindrical in shape and a second portion extending from the first portion that is generally in a funnel shape.

6. The combustor of claim 1, further comprising:

the fuel injector including a fuel injector plate;

at least one fuel delivery conduit configured and arranged to provide a flow of fuel to the fuel injector plate; and

a choke for each fuel delivery conduit, each choke having a fuel injector passage and at least one passage to at least one internal injector plate passage in the fuel injector plate.

7. The combustor of claim 6, wherein the at least one internal injector plate passage includes a plurality of fuel passages out of the fuel injector plate and into the main combustion chamber.

8. The combustor of claim 1, further comprising:

a jet extender generally tubular in shape extending from the fuel injector plate past the burner and into the main combustion chamber.

9. The combustor of claim 1, further comprising:

the fuel injector including a fuel injector plate, the fuel injector plate having a fuel injector central opening, combustion in the initial combustion chamber passing through the fuel injector central opening; and

the burner having a burner central opening, the fuel injector central opening of the fuel injector plate being aligned with the burner central opening of the burner.

10. The combustor of claim 9, further comprising:

a jet extender generally tubular in shape extending from the fuel injector central opening of the fuel injector plate through the burner central opening of the burner into the main combustion chamber.

11. The combustor of claim 10, wherein the jet extender has at least one row of aligned passages.

12. The combustor of claim 1, wherein the hot surface igniter is at least one glow plug.

13. A combustor comprising:

a housing forming a main combustion chamber;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mix into the initial combustion chamber;

at least one glow plug configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber;

a fuel injector plate coupled within the injector body a select distance from the air/fuel premix injector, the fuel injector plate positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber; and

a burner configured and arranged to dispense a flow of air, wherein the flow of fuel from the injector plate and the flow of air from the burner are ignited in the main combustion chamber by the ignition of the air fuel mixture in the initial combustion chamber.

14. The combustor of claim 13, further comprising:

the fuel injector plate having a fuel injector central opening, combustion in the initial combustion chamber passing through the fuel injector central opening.

15. The combustor of claim 14, further comprising:

the burner being a swirl plate burner having a central burner opening; and

the burner having a burner central opening, the fuel injector central opening of the fuel injector plate being aligned with the burner central opening of the burner.

16. The combustor of claim 15, further comprising:

a jet extender generally tubular in shape extending from the fuel injector central opening of the fuel injector plate through the burner central opening of the burner into the main combustion chamber.

17. A combustor comprising:

a housing forming a main combustion chamber;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber;

at least one glow plug configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber;

a fuel injector plate coupled within the injector body a select distance from the air/fuel premix injector, the fuel injector plate positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber, the fuel injector plate having an injector plate central opening;

a swirl plate burner coupled around an outer surface of the injector body, the swirl plate burner configured and arranged to dispense a flow of air, wherein the flow of fuel from the injector plate and the flow of air from the swirl plate burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber; and

a jet extender generally tubular in shape extending from the fuel injector central opening of the fuel injector plate into the main combustion chamber.

18. The combustor of claim 17, the air/fuel premix injector assembly further comprising:

a premix chamber in fluid communication with the fuel inlet tube to receive the fuel flow from the fuel inlet tube;

a premix air inlet in fluid communication with the premix chamber, the premix air inlet providing a flow of air to the premix chamber; and

an air/fuel premix injector configured and arranged to dispense the flow of air/fuel mixture into the initial combustion chamber.

19. The combustor of claim 18, further comprising:

a premix fuel connecting member coupled to provide the fluid communication between the fuel inlet tube and the premix chamber, the premix fuel connecting member having an inner cavity, the premix fuel member having a first portion that is positioned within

an inner passage of the fuel inlet tube, the first portion of the premix fuel member having at least one premix fuel inlet passage to the cavity of the premix fuel connecting member to receive a fuel flow from the fuel inlet tube.

20. The combustor of claim 18, wherein the premix chamber includes a first portion that is generally cylindrical in shape and a second portion extending from the first portion that is generally in a funnel shape.

21. The combustor of claim 17, further comprising:

at least one fuel delivery conduit configured and arranged to provide a flow of fuel to the fuel injector plate; and

a choke for each fuel delivery conduit, each choke having a fuel injector passage and at least one passage to at least one internal injector plate passage in the fuel injector plate.

AMENDED CLAIMS
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1. A combustor comprising:

a housing forming a main combustion chamber the housing including a fuel inlet to receive a flow of fuel and an air inlet to receive a flow of air;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber;

an air premix inlet configured and arranged to direct a portion of the flow of air received from the air inlet to the air/fuel premix injector assembly;

a fuel premix member configured and arranged to direct a portion of the flow of fuel from the fuel inlet to the air/fuel premix injector assembly;

a hot surface igniter configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber to create a transient burst that extends into the main combustion chamber;

a fuel injector configured and arranged to dispense the remaining flow of fuel into the main combustion chamber;

a burner configured and arranged to dispense the remaining flow of air in the main combustion chamber, wherein the flow of fuel from the fuel injector and the flow of air from the burner are ignited in the main combustion chamber by the transient burst from initial combustion chamber; and

a jet extender positioned to prevent fuel from the fuel injector from entering the initial combustion chamber.

2. The combustor of claim 1, wherein the burner is an air swirl plate burner.

3. The combustor of claim 1, the air/fuel premix injector assembly further comprising:

a fuel inlet tube to provide a fuel flow path;

a premix chamber in fluid communication with the fuel inlet tube to receive the fuel flow from the fuel inlet tube;

a premix air inlet in fluid communication with the premix chamber, the premix air inlet providing a flow of air to the premix chamber; and

an air/fuel premix injector configured and arranged to dispense the flow of air/fuel mixture into the initial combustion chamber.

4. The combustor of claim 3, further comprising:

a premix fuel connecting member coupled to provide the fluid communication between the fuel inlet tube and the premix chamber, the premix fuel connecting member having an inner cavity, the premix fuel member having a first portion that is positioned within an inner passage of the fuel inlet tube, the first portion of the premix fuel member having at least one premix fuel inlet passage to the cavity of the premix fuel connecting member to receive a fuel flow from the fuel inlet tube.

5. The combustor of claim 3, wherein the premix chamber includes a first portion that is generally cylindrical in shape and a second portion extending from the first portion that is generally in a funnel shape.

6. The combustor of claim 1, further comprising:

the fuel injector including a fuel injector plate;

at least one fuel delivery conduit configured and arranged to provide a flow of fuel to the fuel injector plate; and

a choke for each fuel delivery conduit, each choke having a fuel injector passage and at least one passage to at least one internal injector plate passage in the fuel injector plate.

7. The combustor of claim 6, wherein the at least one internal injector plate passage includes a plurality of fuel passages out of the fuel injector plate and into the main combustion chamber.

8. The combustor of claim 7, further comprising:

the jet extender being generally tubular in shape and extending from the fuel injector plate past the burner and into the main combustion chamber.

9. The combustor of claim 1, further comprising:

the fuel injector including a fuel injector plate, the fuel injector plate having a fuel injector central opening, combustion in the initial combustion chamber passing through the fuel injector central opening; and

the burner having a burner central opening, the fuel injector central opening of the fuel injector plate being aligned with the burner central opening of the burner.

10. The combustor of claim 9, further comprising:

the jet extender being generally tubular in shape and extending from the fuel injector central opening of the fuel injector plate through the burner central opening of the burner into the main combustion chamber.

11. The combustor of claim 10, wherein the jet extender has at least one row of aligned passages.

12. The combustor of claim 1, wherein the hot surface igniter is at least one glow plug.

13. A combustor comprising:

a housing forming a main combustion chamber;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mix into the initial combustion chamber;

at least one glow plug configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber and turn off after ignition to create a transient burst that extends into the main combustion chamber;

a fuel injector plate coupled within the injector body a select distance from the air/fuel premix injector, the fuel injector plate configured and arranged to provide a flow of fuel, the fuel injector plate positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber; and

a burner configured and arranged to dispense a flow of air, wherein the flow of fuel from the injector plate and the flow of air from the burner are ignited in the main combustion chamber by the transient burst from the initial combustion chamber.

14. The combustor of claim 13, further comprising:

the fuel injector plate having a fuel injector central opening, combustion in the initial combustion chamber passing through the fuel injector central opening.

15. The combustor of claim 14, further comprising:

the burner being a swirl plate burner having a central burner opening; and

the burner having a burner central opening, the fuel injector central opening of the fuel injector plate being aligned with the burner central opening of the burner.

16. The combustor of claim 15, further comprising:

a jet extender generally tubular in shape extending from the fuel injector central opening of the fuel injector plate through the burner central opening of the burner into the main combustion chamber, the jet extender positioned to prevent fuel from the fuel injector from entering the initial combustion chamber.

17. A combustor comprising:

a housing forming a main combustion chamber;

an injector body coupled within the housing, the injector body including an initial combustion chamber;

insulation lining the initial combustion chamber;

an air/fuel premix injector assembly configured and arranged to dispense a flow of air/fuel mixture into the initial combustion chamber;

at least one glow plug configured and arranged to heat up and ignite the air/fuel mixture in the initial combustion chamber and turn off after ignition;

a fuel injector plate coupled within the injector body a select distance from the air/fuel premix injector, the fuel injector plate configured and arranged to provide a flow of fuel, the fuel injector plate positioned to divert a portion of the flow of air/fuel mixture from the air/fuel premix injector into the initial combustion chamber, the fuel injector plate having an injector plate central opening;

a swirl plate burner coupled around an outer surface of the injector body, the swirl plate burner configured and arranged to dispense a flow of air, wherein the flow of fuel from the injector plate and the flow of air from the swirl plate burner are ignited in the main combustion chamber by the ignition of the air/fuel mixture in the initial combustion chamber; and

a jet extender generally tubular in shape extending from the fuel injector central opening of the fuel injector plate into the main combustion chamber, the jet extender positioned to prevent fuel from the fuel injector from entering the initial combustion chamber .

18. The combustor of claim 17, the air/fuel premix injector assembly further comprising:

a premix chamber in fluid communication with the fuel inlet tube to receive the fuel flow from the fuel inlet tube;

a premix air inlet in fluid communication with the premix chamber, the premix air inlet providing a flow of air to the premix chamber; and

an air/fuel premix injector configured and arranged to dispense the flow of air/fuel mixture into the initial combustion chamber.

19. The combustor of claim 18, further comprising:

a premix fuel connecting member coupled to provide the fluid communication between the fuel inlet tube and the premix chamber, the premix fuel connecting member having an inner cavity, the premix fuel member having a first portion that is positioned within an inner passage of the fuel inlet tube, the first portion of the premix fuel member having at least one premix fuel inlet passage to the cavity of the premix fuel connecting member to receive a fuel flow from the fuel inlet tube.

20. The combustor of claim 18, wherein the premix chamber includes a first portion that is generally cylindrical in shape and a second portion extending from the first portion that is generally in a funnel shape.

21. The combustor of claim 17, further comprising:

at least one fuel delivery conduit configured and arranged to provide a flow of fuel to the fuel injector plate; and

a choke for each fuel delivery conduit, each choke having a fuel injector passage and at least one passage to at least one internal injector plate passage in the fuel injector plate.

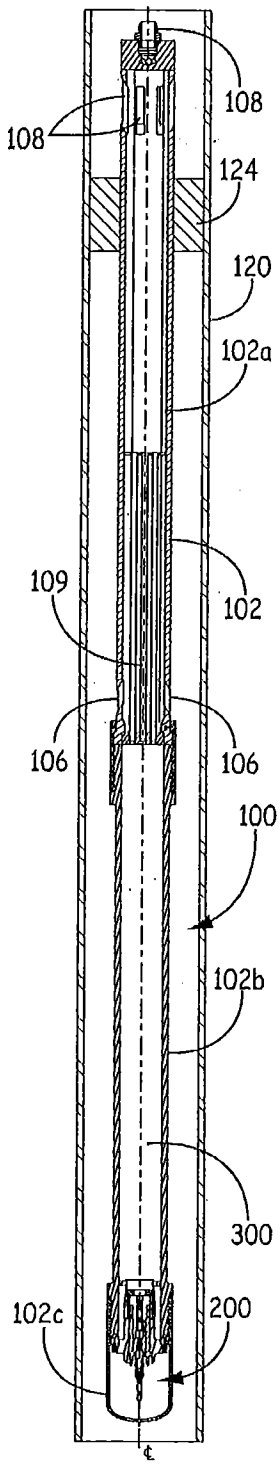


FIG. 1

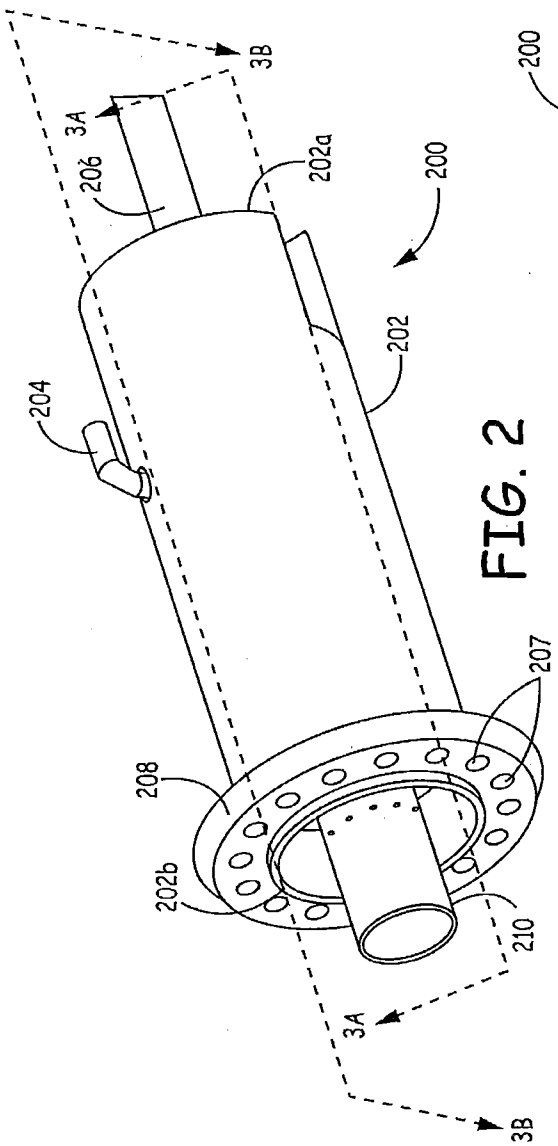


FIG. 2

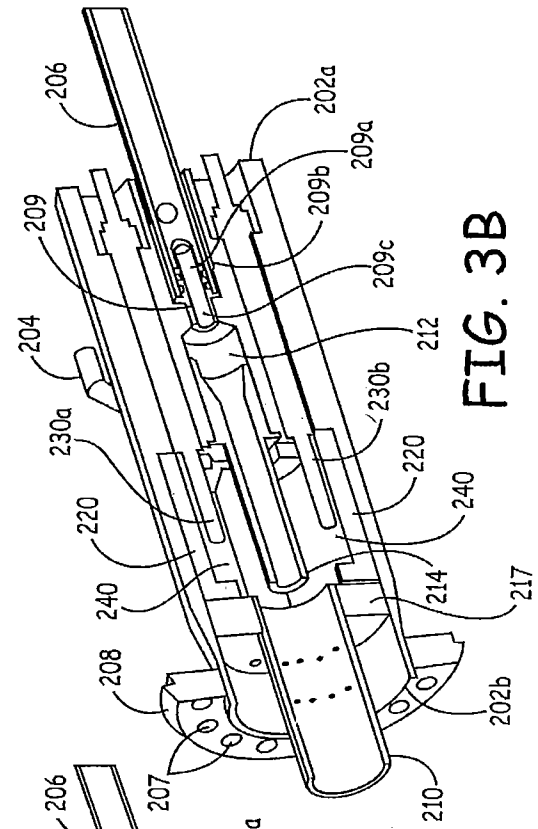


FIG. 3B

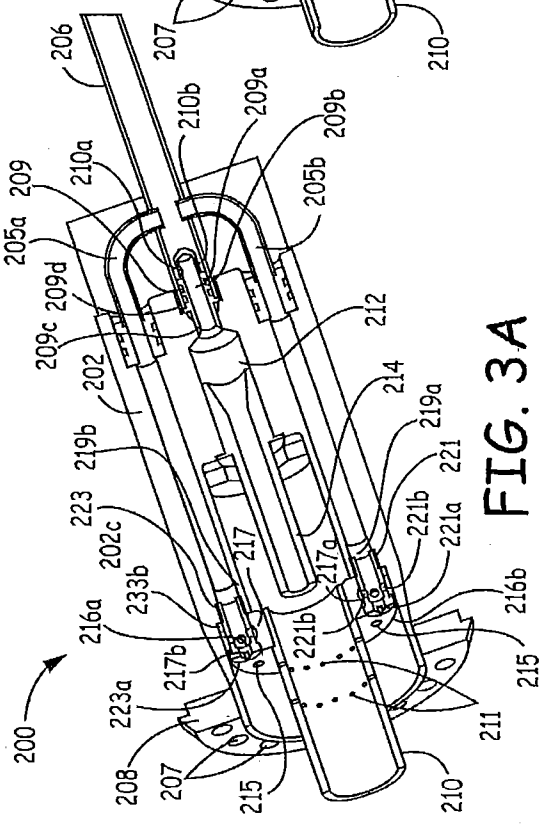


FIG. 3A

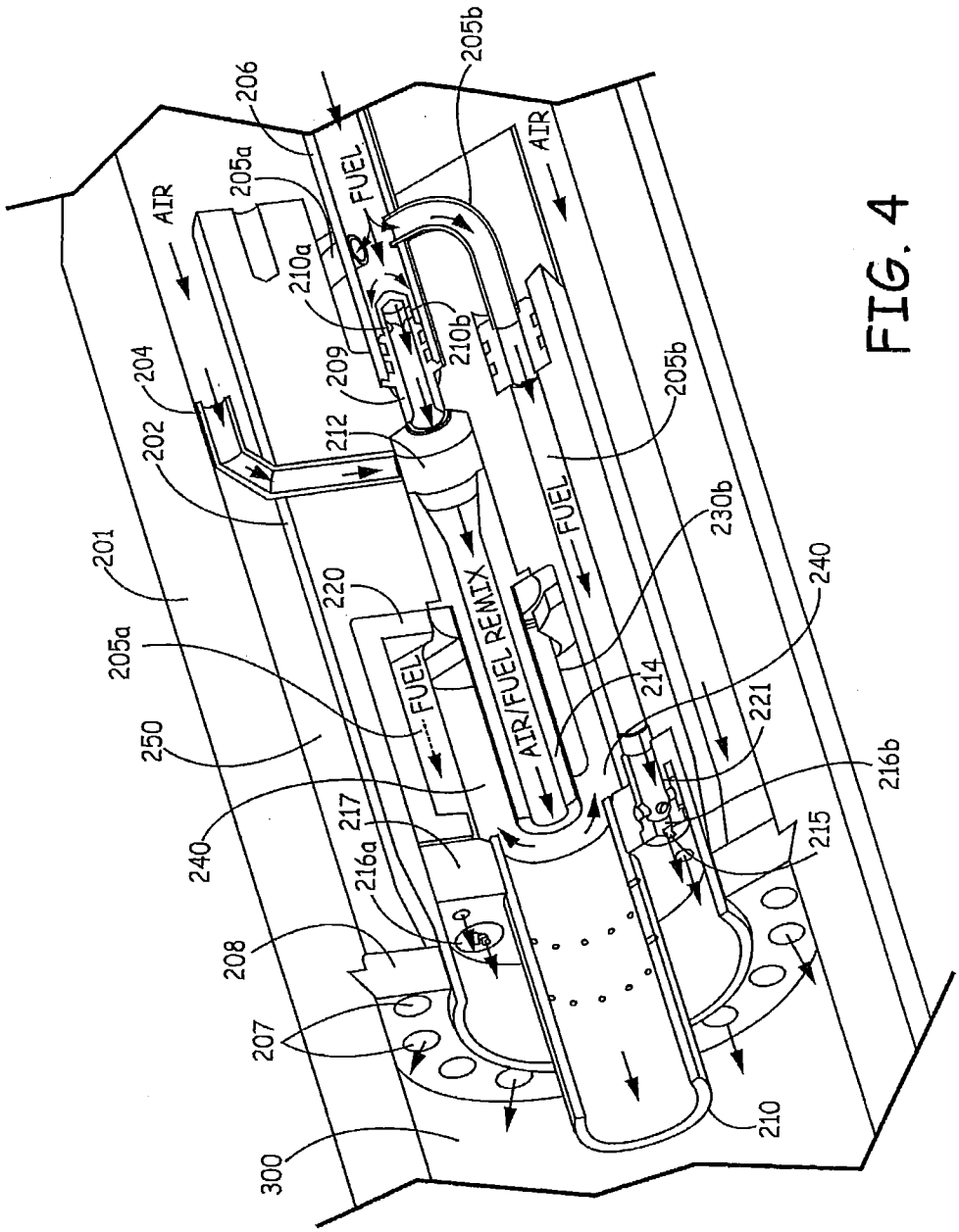

AIR
FUEL
AIR
FUEL
AIR/FUEL REMIX
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205a
210a
210b
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212
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230b
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205a
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221
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216b
240
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216a
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208
207
210
300

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/047272

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B36/02 F23R3/34
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B F23C F23R F23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2 287 312 A (TOSHIBA KK [JP]) 13 September 1995 (1995-09-13) abstract figures 1,4,8,9 page 14, line 24 - page 15, line 5 page 16, line 14 - page 17, line 25 page 20, line 6 - line 8 page 26, line 9 - line 24 -----	1-21
Y	US 3 223 539 A (COLLIN HYDE ET AL) 14 December 1965 (1965-12-14) figures 2,3 column 2, line 53 - column 3, line 8 -----	1-21

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
26 September 2013	07/10/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hustedt, Bernhard

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/047272

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 623 819 A (BOWKER JEFFREY C [US] ET AL) 29 April 1997 (1997-04-29) abstract figure 2 column 2, line 11 - line 26 column 3, line 42 - column 4, line 7 column 4, line 22 - line 53 column 5, line 32 - line 63 column 6, line 11 - line 13 column 6, line 36 - line 63	1-21
A	US 4 205 725 A (CALVIN DOUGLAS G [US] ET AL) 3 June 1980 (1980-06-03) abstract figure 1 column 6, line 7 - line 57	1-21

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Information on patent family members

International application No
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