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(54) **Opposed flow combustor**

(57) In accordance with one embodiment of the present invention a combustor (10) is provided. The combustor (10) includes a combustion chamber (14), a first inlet (22) adapted to provide a first air flow (20) to the combustion chamber (14) in a first direction, a fuel controller (32) adapted to provide a fuel flow (34) to the com-

bustion chamber (14) in the first direction, an opposing inlet (28) adapted to provide an opposing air flow (26) to the combustion chamber (14) in a second direction generally in opposition to the first direction, and wherein the first air flow (20) and the fuel flow (34) interact with the opposing air (26) flow to form a stagnation zone (38) in the combustion chamber (14).

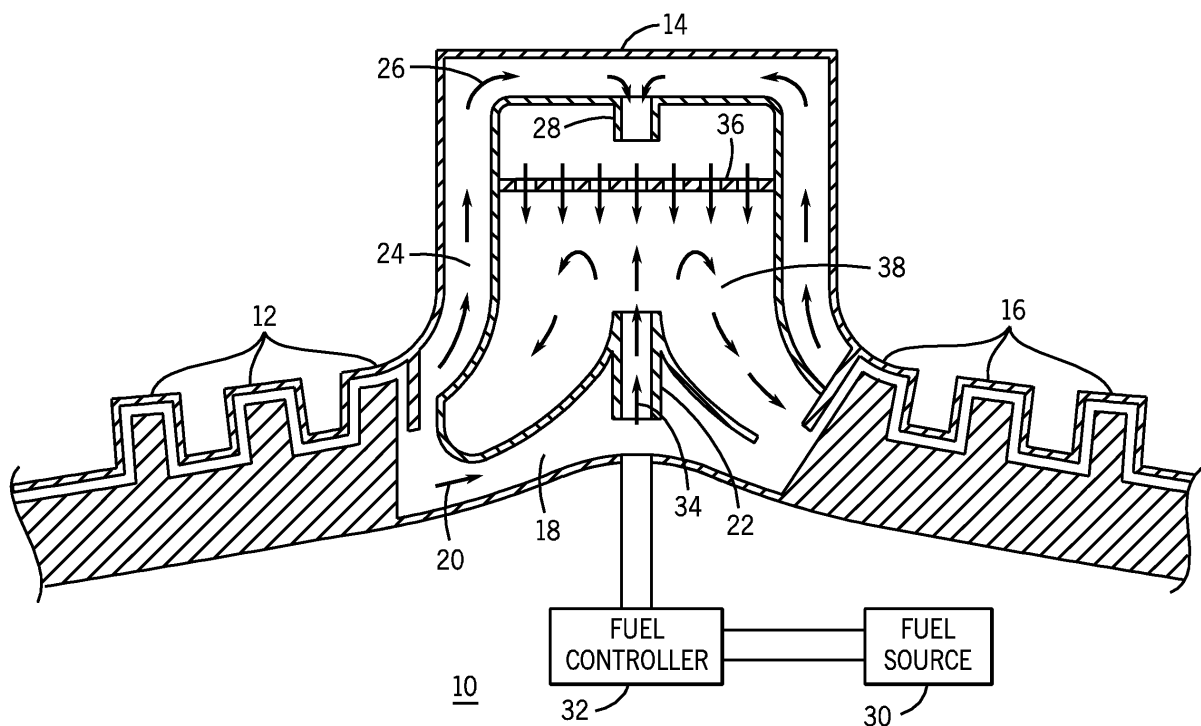


FIG. 1

Description

[0001] The present invention relates generally to gas turbine devices and, in particular, to a system and method for providing opposed flows of fuel and air in a combustor.

[0002] In traditional gas turbine devices, air is drawn from the environment, mixed with fuel and, subsequently, ignited to produce combustion gases, which may be used to drive a machine element or to generate power, for instance. Traditional gas turbine devices generally include three main systems: a compressor, a combustor and a turbine. The compressor pressurizes air and sends this air towards the combustor. The compressed air and a fuel are delivered to the combustor. The fuel and air delivered to the combustor are ignited, with the resulting combustion gases being employed to actuate a turbine or other mechanical device. When used to drive a turbine, the combustion gases flow across the turbine to drive a shaft that powers the compressor and produces output power for powering an electrical generator or for powering an aircraft, to name but few examples.

[0003] Gas turbine engines are typically operated for extended periods of time, and exhaust emissions from the combustion gases are a concern. For example, during combustion, nitrogen combines with oxygen to produce oxides of nitrogen (NO_x), and these NO_x emissions are often subject to regulatory limits and are generally undesired. Traditionally, gas turbine devices reduce the amount of NO_x emissions by decreasing the fuel-to-air ratio, and these devices are often referred to as lean devices. Lean devices reduce the combustion temperature within the combustion chamber and, in turn, reduce the amount of NO_x emissions produced during combustion.

[0004] Some regions of the United States require as little as three parts per million (ppm) NO_x levels in natural gas operation. NO_x emissions from a gas turbine have been significantly reduced using premixed combinations of natural gas. The degree of premixing has a strong impact on NO_x reduction. However, highly premixed flames demonstrate increased instability and have proven difficult to anchor. Conventional premixed systems do not adequately reach NO_x emission targets or theoretical limits so selective catalytic reduction (SCR) of NO_x through ammonia injection has been employed. SCR is an expensive approach and improvements to the combustion system would reduce operating costs, such as the cost of electricity for operating the system. In systems powered by syngas or hydrogen, a diffusion flame has been used because high flame velocities associated with the hydrogen content may result in flashback into the pre-mixer. Diluents are added at the injection tip to potentially reduce NO_x emissions.

[0005] In addition to natural gas, combustors may employ other fuels, such as syngas (synthetic gas) or hydrogen. Syngas poses challenges to flame stabilization and emission reduction at high firing temperatures. Premixed hydrogen combustion may result in a risk of flashback and typically produces significant NO_x without premixing. Thus, there exists a need to provide an improved system and method to reduce the temperature of combustion in gas turbine systems to facilitate a reduction in NO_x emissions from such systems.

[0006] Briefly, in accordance with one embodiment of the present invention, a combustor is provided. The combustor comprises a combustion chamber, a first inlet adapted to provide a first air flow to the combustion chamber in a first direction, a fuel controller adapted to provide a fuel flow to the combustion chamber in the first direction, an opposing inlet adapted to provide an opposing air flow to the combustion chamber in a second direction generally in opposition to the first direction and wherein the first air flow and the fuel flow interact with the opposing air flow to form a stagnation zone in the combustion chamber.

[0007] A method of operating a combustion chamber in accordance with an exemplary embodiment of the present invention is also provided. The method comprises injecting a first air flow and a fuel flow into the combustion chamber in a first direction, and injecting an opposing air flow into the combustion chamber in opposition to the first air flow to form a stagnation zone in the combustion chamber.

[0008] Various features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1 is a diagrammatic representation of a gas turbine device, in accordance with an exemplary embodiment of the present invention;

FIG. 2 is a partial and diagrammatic, cross-sectional view of a combustor assembly, in accordance with an exemplary embodiment of the present invention;

FIG. 3 is a partial and diagrammatic, cross-sectional view of a combustor assembly, in accordance with another exemplary embodiment of the present invention;

FIG. 4 is a partial and diagrammatic, cross-sectional view of a combustor assembly, in accordance with yet another exemplary embodiment of the present invention;

FIG. 5 is a partial and diagrammatic, cross-sectional view of a combustor assembly, in accordance with still another exemplary embodiment of the present invention; and

FIG. 6 is a flowchart illustrating an exemplary process for establishing an opposing flow in a combustor in accordance with an exemplary embodiment of the present invention.

[0009] As a preliminary matter, the definition of the term "or" for the purpose of the following discussion and the appended claims is intended to be an inclusive "or." That is, the term "or" is not intended to differentiate between two mutually exclusive alternatives. Rather, the term "or" when employed as a conjunction between two elements is defined as including one element by itself, the other element itself, and combinations and permutations of the elements. For example, a discussion or recitation employing the terminology "A" or "B" includes: "A", by itself "B" by itself and any combination thereof, such as "AB" and/or "BA."

[0010] A flexible fuel combustor in accordance with an exemplary embodiment of the present invention is capable of burning hydrogen, natural gas or syngas in a gas turbine while maintaining low NO_x emissions and low dynamics. Such systems may utilize opposed flows of fuel-air mixtures to create aerodynamic flame stabilization and to produce a highly stable flame zone in a combustor. Embodiments of the present invention may be compact in size and may provide low peak flame temperatures to help reduce undesirable NO_x emissions.

[0011] In an exemplary embodiment of the present invention, the combustor flame stabilization zone is removed from the burner. Reactants from the combustion process entrained the diluent rich products in the combustor before reacting. The flame is aerodynamically stabilized by an opposed flow of an ultra-lean fuel-air mixture, which creates a stagnation zone. The opposed flow also cools the combustor wall close to the stagnation zone. The combustion products flow toward the burner and then flow into the turbine hot section.

[0012] Turning now to the drawings, FIG. 1 is a diagrammatic representation of a gas turbine device in accordance with an exemplary embodiment of the present invention. In FIG. 1, the gas turbine device is generally referred to by the reference numeral 10. The gas turbine device 10 comprises one or more compressor stages 12, a combustor 14 and one or more turbine stages 16. The compressor stages 12 provide a first air flow 20, which is adapted by the shape of a first air flow chamber 18 to flow into the combustor 14 via a first inlet 22. The combustor 14 also includes an opposing airflow chamber 24 to accommodate an opposing air flow 26. Moreover, the output of the compressor stages 12 is split to form the first air flow 20 and the opposing air flow 26. In the embodiment illustrated in FIG. 1, the opposing air flow 26 is delivered to the combustor 14 via an opposing inlet 28.

[0013] A fuel source 30 provides fuel to a fuel controller 32. The fuel controller 32 delivers a first fuel flow 34 to the combustor 14 via the first inlet 22. The first airflow 20 and the first fuel flow 34 may be partially premixed. The first airflow 20 and the first fuel flow 34 are directed into the combustor 14 in a first direction, as indicated by the arrow 34 that represents the fuel flow. The opposing airflow 26 enters the combustor 14 in a second direction that is generally opposition to the first direction followed by the first airflow 20 and the first fuel flow 34.

[0014] A perforated plate 36 may be disposed inside the combustor 14 between the first inlet 22 and the opposing inlet 28. The opposition between the first air flow 20 and the opposing air flow 26 creates a stagnation zone in the combustor 14. The stagnation zone, which may also be referred to as a reaction/combustion zone, is identified in FIG. 1 by the reference numeral 38. When combustion occurs, the combustion tends to happen near the stagnation zone 38.

[0015] The air-fuel mixture in the combustor 14 is ignited to produce a combusted gas flow, as indicated by the arrow 40. The combusted gas flow 40 exits the combustor 14 and is delivered to the turbine stages 16. The reactants from the combustion process are directed toward the perforated plate 36 with an effusion flow of ultra-lean fuel-air. The jet thus created entrains hot products of combustion and the fuel does not ignite until the jet is very diluted with the hot combustion products. This action lowers peak flame temperatures and NO_x production without requiring premixing. The stagnation zone 38 stabilizes the combustion process under lean conditions and reduces dynamic instabilities.

[0016] An exemplary embodiment of the present invention may employ syngas and hydrogen combustion without the use of diluents. This approach provides a stable combustion zone and reduces dynamics in the system. Reduced combustor cooling is enabled by reduced combustor size and lower peak gas temperatures.

[0017] FIG. 2 is a partial and diagrammatic cross-sectional view of a combustor assembly, in accordance with an exemplary embodiment of the present invention. In the embodiment illustrated in FIG. 2, the first air flow 20 and the first fuel flow 34 are delivered to the combustor 14 coaxially via the first inlet 22 from the left-hand side of FIG. 2. The first air flow 20 and the first fuel flow 34 form a jet that travels across the combustor 14, entraining hot products from combustion. In the embodiment illustrated in FIG. 2, a second jet of fuel and air comprising the opposing air flow 26 and an opposing fuel flow 42 is desirably premixed and injected into the combustor 14 via the opposing inlet 28, as shown at the right-hand side of FIG. 2. The premixing of the opposing air flow 26 and the opposing fuel flow 42 may be either full or partial. The opposing inlet 28 may comprise multiple openings in the right-hand side wall.

[0018] In the embodiment illustrated in FIG. 2, the first air flow 20 and the first fuel flow 34 exhibit a flammability that is greater than the lean flammability limit for the system. The opposing airflow 26 and opposing fuel flow 42 exhibit a

flammability that is less than the lean flammability limit. The jet entering the combustor 14 from the left hand side is at a relatively high velocity. A stagnation control pressure p_{sc} is defined to be the pressure in the combustion chamber 14 in the region around the entry point of the opposing airflow 26, but prior to the point where the opposing airflow 26 encounters the perforated plate 36. As illustrated in FIG. 2, the stagnation control pressure p_{sc} is greater than a stagnation zone pressure $p_{stagnation}$. Inside the combustor 14, the flame stabilizes in the stagnation region between the two flows and hot products flow back to the opening on the left hand side, as illustrated by the arrow representing the combusted gas flow 40. In the exemplary embodiment illustrated in FIG. 2, the combusted gas flow 40 exits the combustion chamber 14 upstream relative to the first direction (as indicated by the arrow 34) from the stagnation zone 38. Moreover, the exit of the combusted gas flow 40 is not coaxial with the first direction (as indicated by the arrow 34) in the exemplary embodiment illustrated in FIG. 2.

[0019] The opposing fuel flow may be provided by a fuel controller (see FIG. 1). The amount and velocity of fuel injected into the combustor 14 via the opposing fuel flow 42 is desirably variable. It may be controlled in by fluidic means or the like to cause a uniform temperature distribution within the combustor 14. In fluidic control, an area of a flow, which is proportional to its velocity, is changed by introducing a second flow in the general region such as through the same inlet. In such a manner, the magnitude of the opposing airflow 26 and/or the opposing fuel flow 42 may be adjusted to move the stagnation zone leftward in the combustion chamber 14. By moving the stagnation zone away from the right-hand side of FIG. 2 in this manner, the temperature of the right-hand wall of the combustor 14 adjacent to the opposing inlet 28 may be desirably reduced.

[0020] FIG. 3 is a partial and diagrammatic, cross-sectional view of a combustor assembly in accordance with another exemplary embodiment of the present invention. In the exemplary embodiment illustrated in FIG. 3, the first fuel flow 34 and opposing fuel flow 42 are omitted for clarity. The combustor 14 is disposed at an angle θ relative to the horizontal. The first inlet 22 and the opposing inlet 28 extend outwardly into the combustion chamber 14.

[0021] The value of θ may be in the range of 0 degrees to 90 degrees depending on design criteria for the combustor 14. At a θ of 0 degrees, the combustor may extend too far into space to be practical. At a θ value of 90 degrees, escaping gases may have a more direct path to the turbine stages 16.

[0022] FIG. 4 is a partial and diagrammatic, cross-sectional view of a combustor assembly in accordance with yet another exemplary embodiment of the present invention. In the embodiment illustrated in FIG. 4, the first airflow 20 enters the combustor 14 from a relatively central location. The combusted gas flow 40 exits the combustor 14 from a radially removed location relative to the position of the first inlet 22, as indicated by the arrow 40.

[0023] FIG. 5 is a partial and diagrammatic, cross-sectional view of a combustor assembly in accordance with still another exemplary embodiment of the present invention. In the embodiment illustrated in FIG. 5, the combustor 14 is connected to the turbine stages (not shown) via a horn seal 44. Those of ordinary skill in the art will appreciate that the horn seal 44 facilitates the detachment of the combustion chamber 14 for maintenance.

[0024] With FIG. 1 in mind, FIG. 6 is a flowchart illustrating an exemplary process for establishing an opposing flow in a combustor in accordance with an exemplary embodiment of the present invention. The process is generally referred to by the reference numeral 44. At block 46, a first air flow and a fuel flow are injected into a combustion chamber in a first direction. At block 48, an opposing air flow is injected into the combustion chamber in opposition to the first air flow and the fuel flow to form a stagnation zone in the combustion chamber. Further, the first air flow and the fuel flow interact with the opposing air flow to form a vortex flow inside the combustion chamber.

[0025] While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

PARTS LIST

[0026]

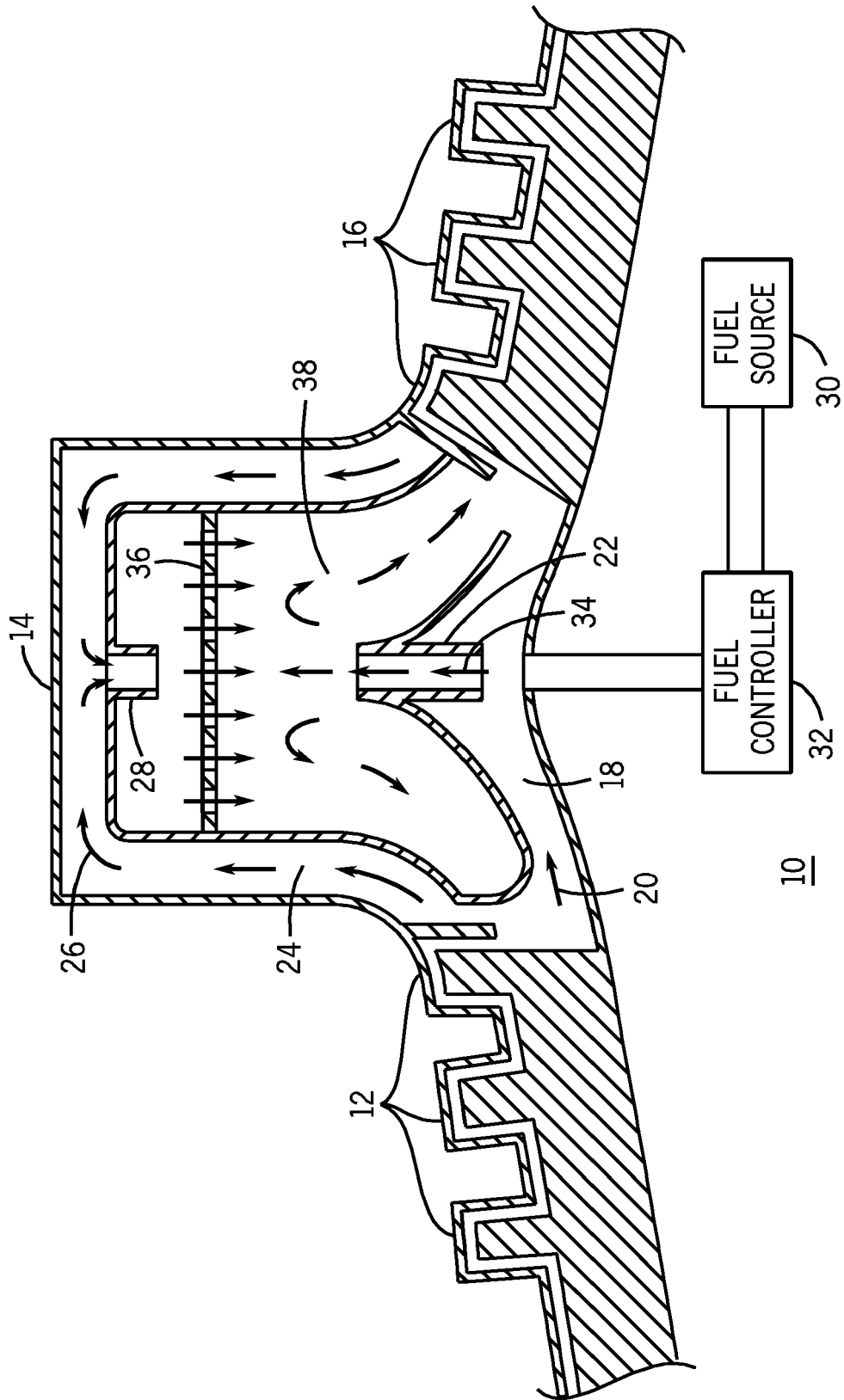
10	combustor
12	Compressor stages
14	Combustion chamber
16	Turbine stages
18	Air flow chamber
20	First air flow
22	First inlet
24	Opposing airflow chamber

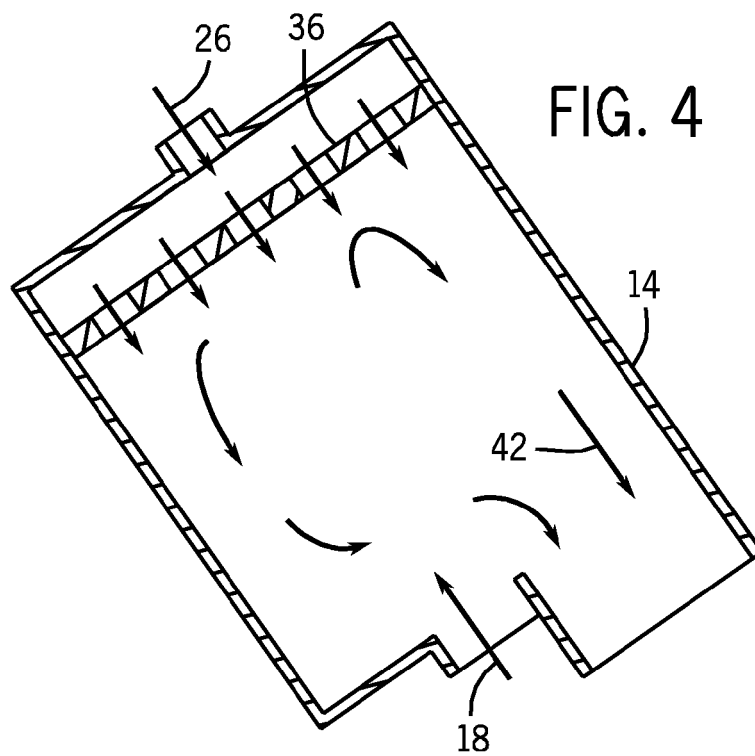
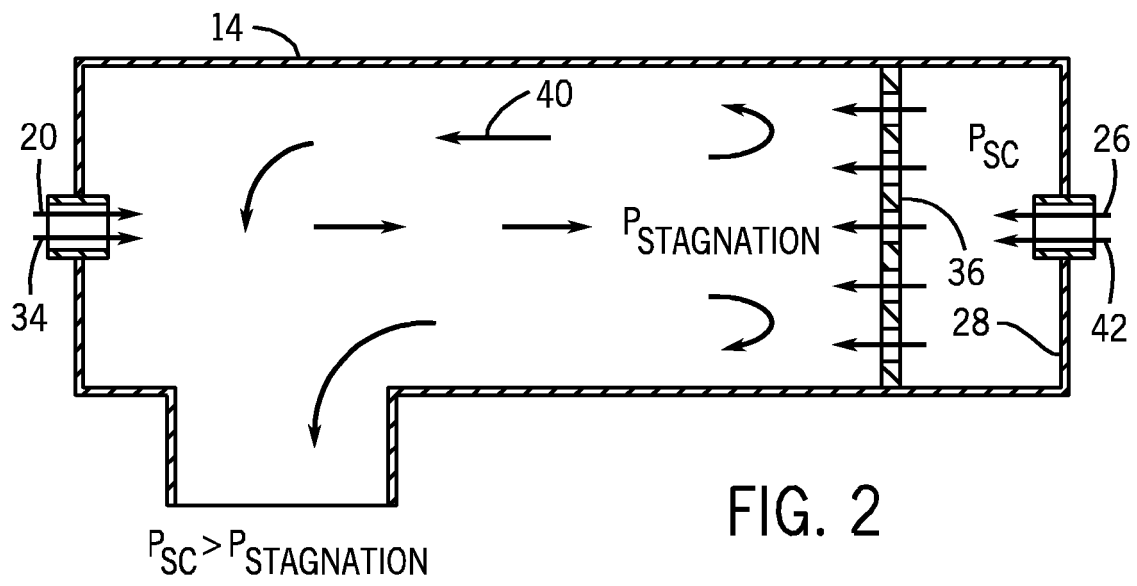
(continued)

5	26	Opposing airflow chamber
	28	Opposing inlet
	30	Fuel source
	32	Fuel controller
	34	First fuel flow
10	36	Perforated plate
	38	Reaction/combustion zone/stagnation zone
	40	Combusted gas flow
15	42	Opposing fuel flow

Claims

1. A combustor (10), comprising:
 - a combustion chamber (14);
 - a first inlet (22) adapted to provide a first air flow (20) to the combustion chamber (14) in a first direction;
 - a fuel controller (32) adapted to provide a fuel flow (34) to the combustion chamber (14) in the first direction;
 - an opposing inlet (28) adapted to provide an opposing air flow (26) to the combustion chamber (14) in a second direction generally in opposition to the first direction; and
 - wherein the first air flow (20) and the fuel flow (34) interact with the opposing air (26) flow to form a stagnation zone (38) in the combustion chamber (14).
2. The combustor (10) as recited in claim 1, wherein the fuel controller (32) is adapted to provide an opposing fuel flow (42) to the combustion chamber (14) in the second direction.
3. The combustor (10) as recited in claim 2, wherein the opposing air flow (26) and the opposing fuel flow (42) are premixed before being provided to the combustion chamber (14).
4. The combustor (10) as recited in claim 2, wherein the opposing air flow (26) and the opposing fuel flow (42) are partially premixed before being provided to the combustion chamber (14).
5. The combustor (10) as recited in claim 2, wherein the opposing air flow (26) and the opposing fuel flow (42) are fully premixed before being provided to the combustion chamber (14).
6. A method (44) of operating a combustion chamber (14), the method (44) comprising:
 - injecting (46) a first air flow (20) and a fuel flow (34) into the combustion chamber (14) in a first direction; and
 - injecting (48) an opposing air flow (26) into the combustion chamber (14) in opposition to the first air flow (20) to form a stagnation zone (38) in the combustion chamber (14).
7. The method (44) recited in claim 6, comprising injecting an opposing fuel flow (42) into the combustion chamber (14) in opposition to the first air flow (20).
8. The method (44) recited in claim 7, comprising premixing the opposing air flow (26) and the opposing fuel flow (42).
9. The method (44) recited in claim 7, comprising partially premixing the opposing air flow (26) and the opposing fuel flow (42).
10. The method (44) recited in claim 7, comprising fully premixing the opposing air flow (26) and the opposing fuel flow (42).





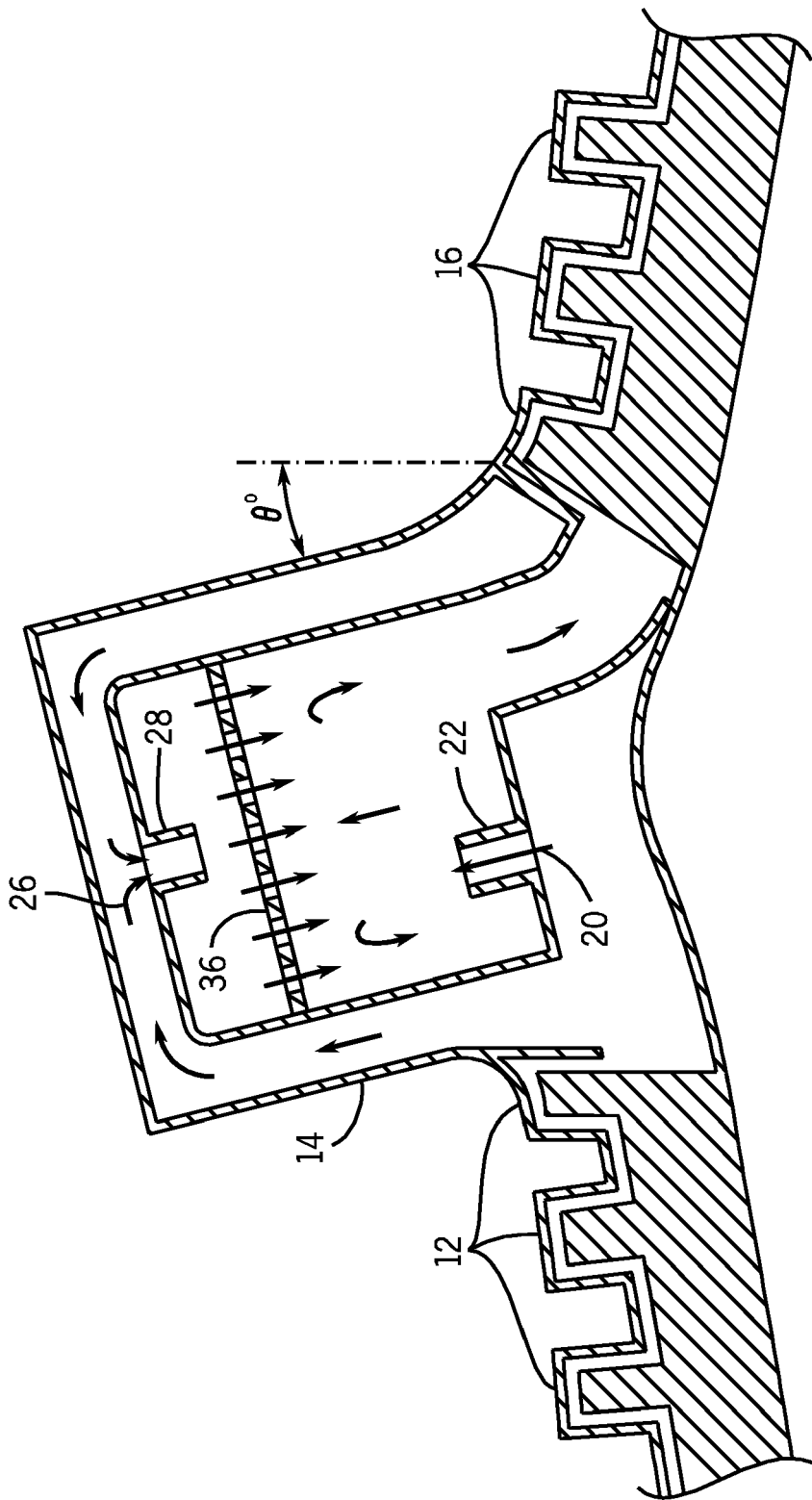


FIG. 3

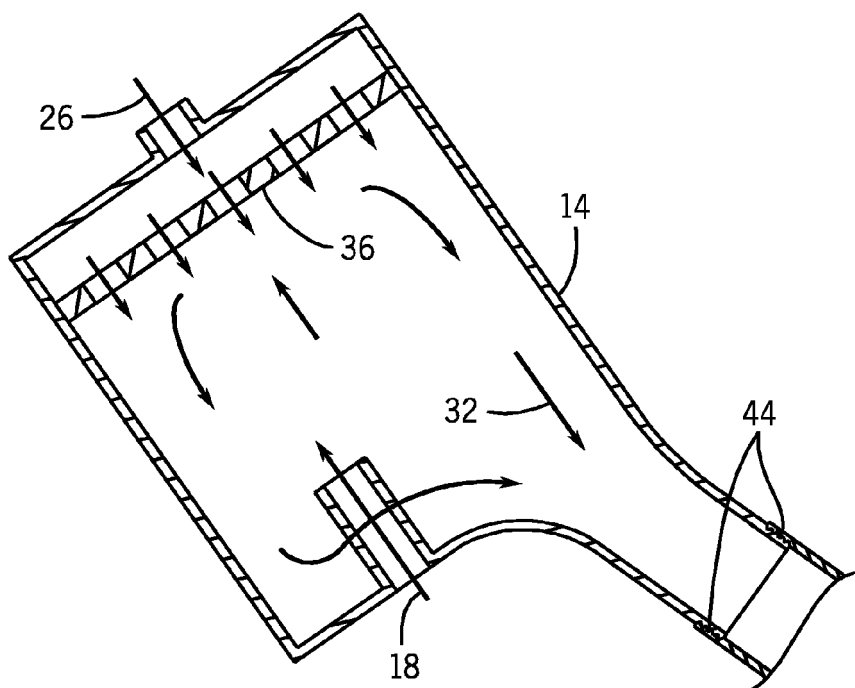
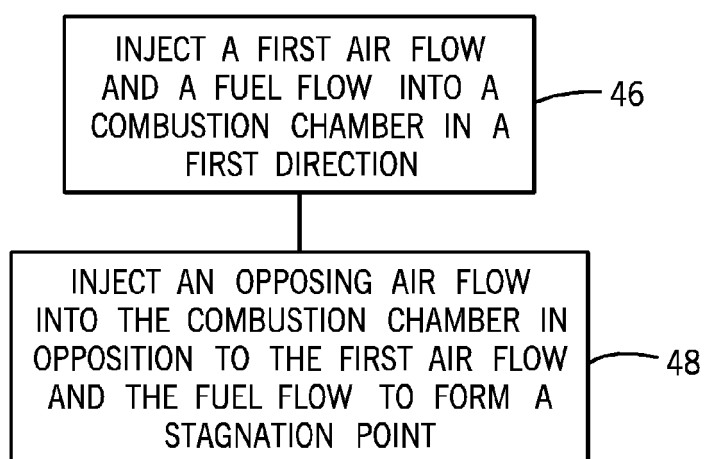


FIG. 5



44

FIG. 6