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(54) **SYSTEM FOR INJECTING A LIQUID FUEL INTO A COMBUSTION GAS FLOW FIELD**

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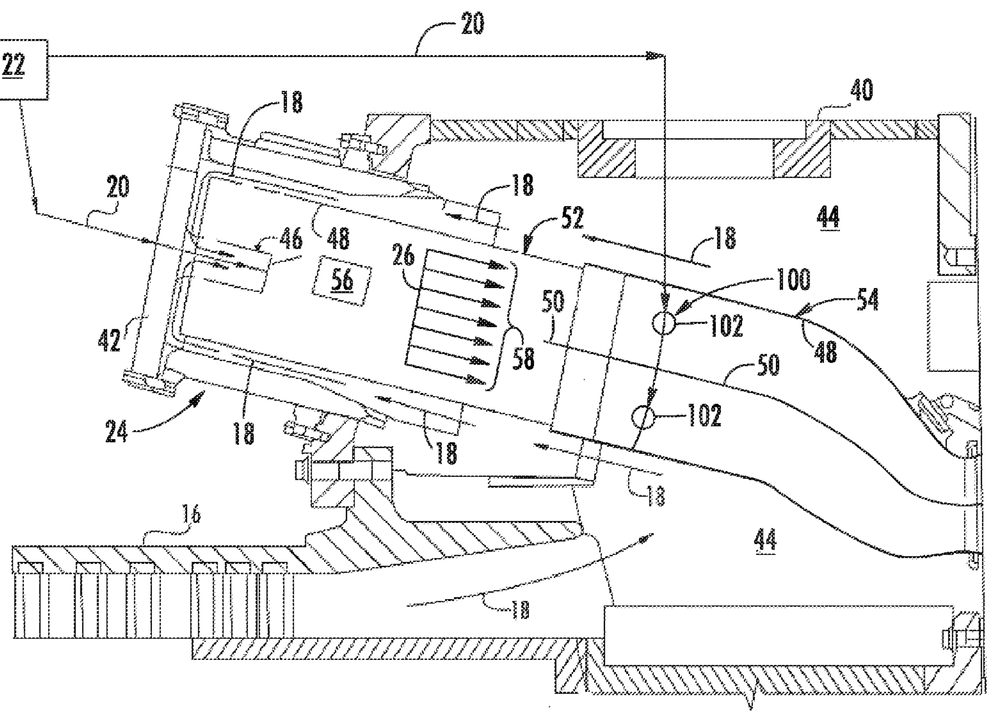
(57) **ABSTRACT**

A system for injecting a liquid fuel into a combustion gas flow field includes an annular liner that defines a combustion gas flow path. The annular liner includes an inner wall, an outer wall and a fuel injector opening that extends through the inner wall and the outer wall. The system further includes a gas fuel injector that is coaxially aligned with the fuel injector opening. The gas fuel injector includes an upstream end and a downstream end. The downstream end terminates substantially adjacent to the inner wall. A dilution air passage is at least partially defined by the gas fuel injector. A liquid fuel injector extends partially through the dilution air passage. The liquid fuel injector includes an injection end that terminates upstream from the inner wall.



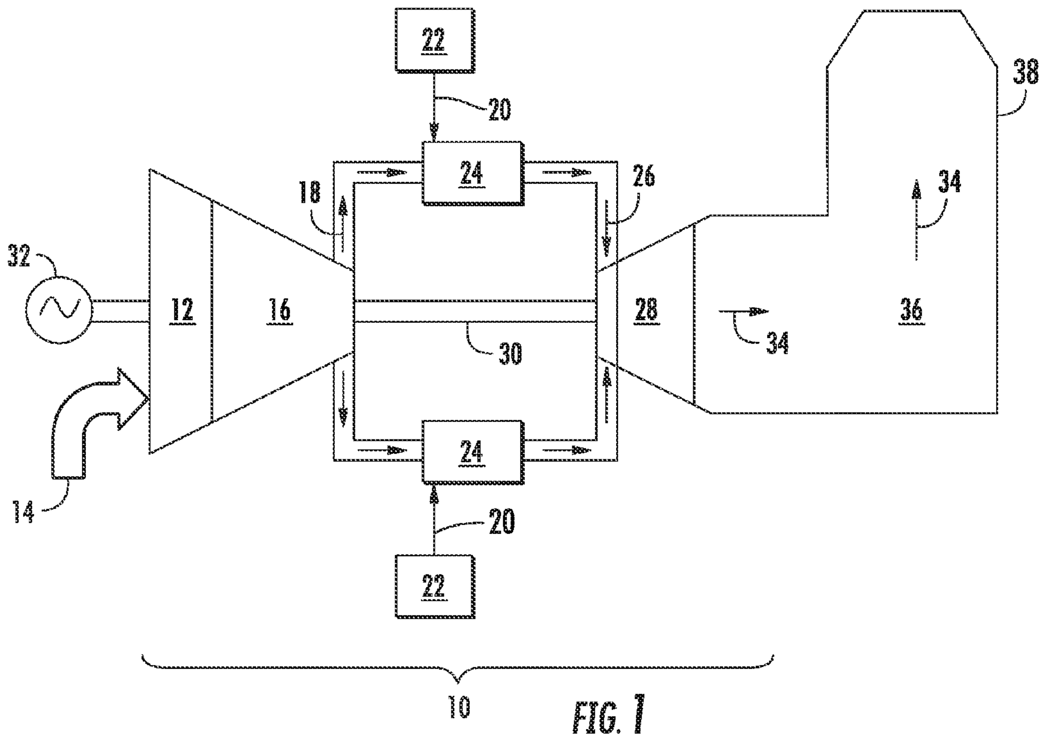


FIG. 1
PRIOR ART

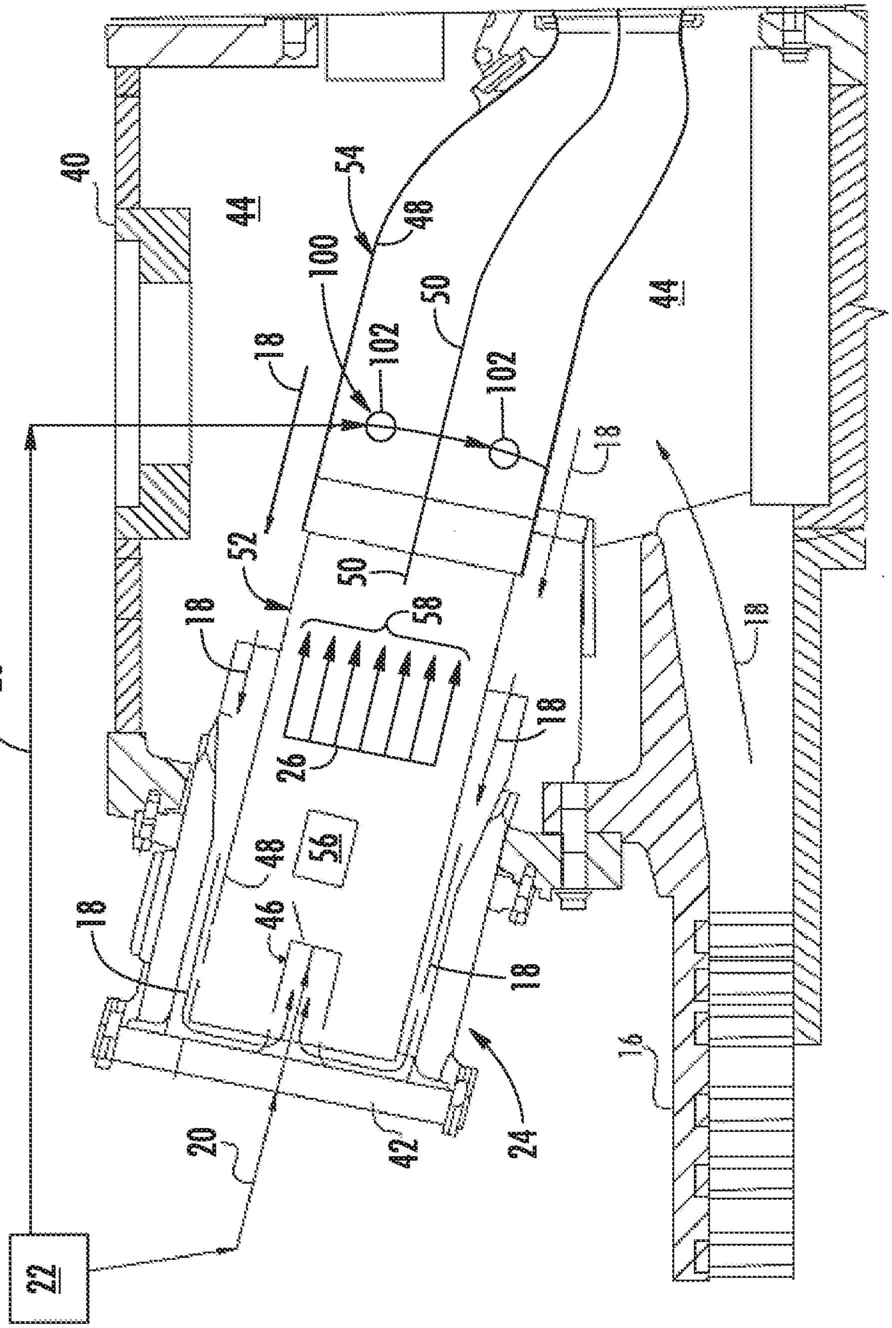

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FIG. 2

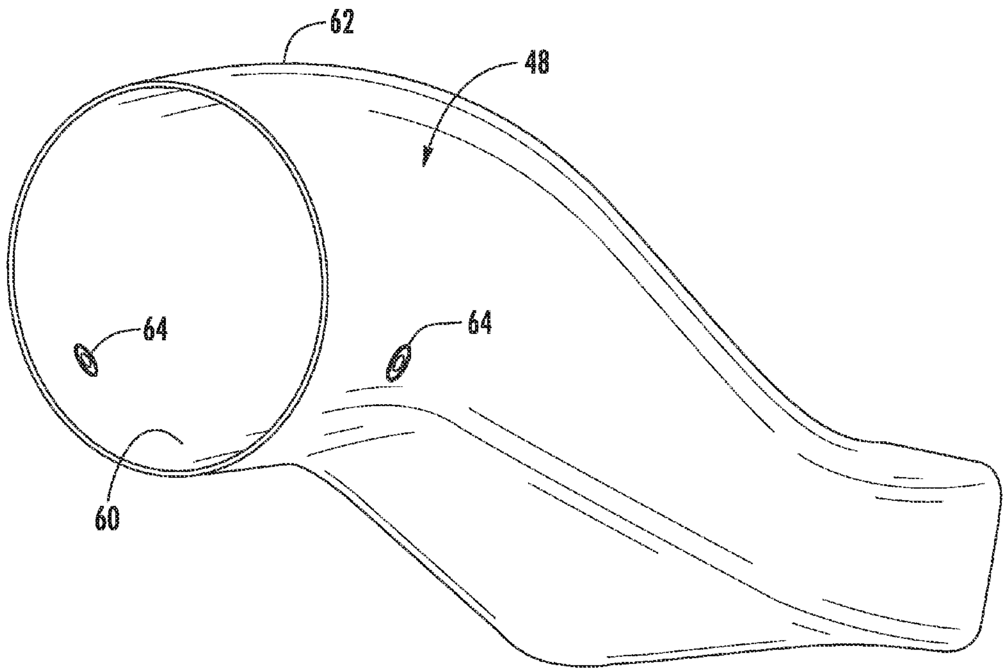

FIG. 3

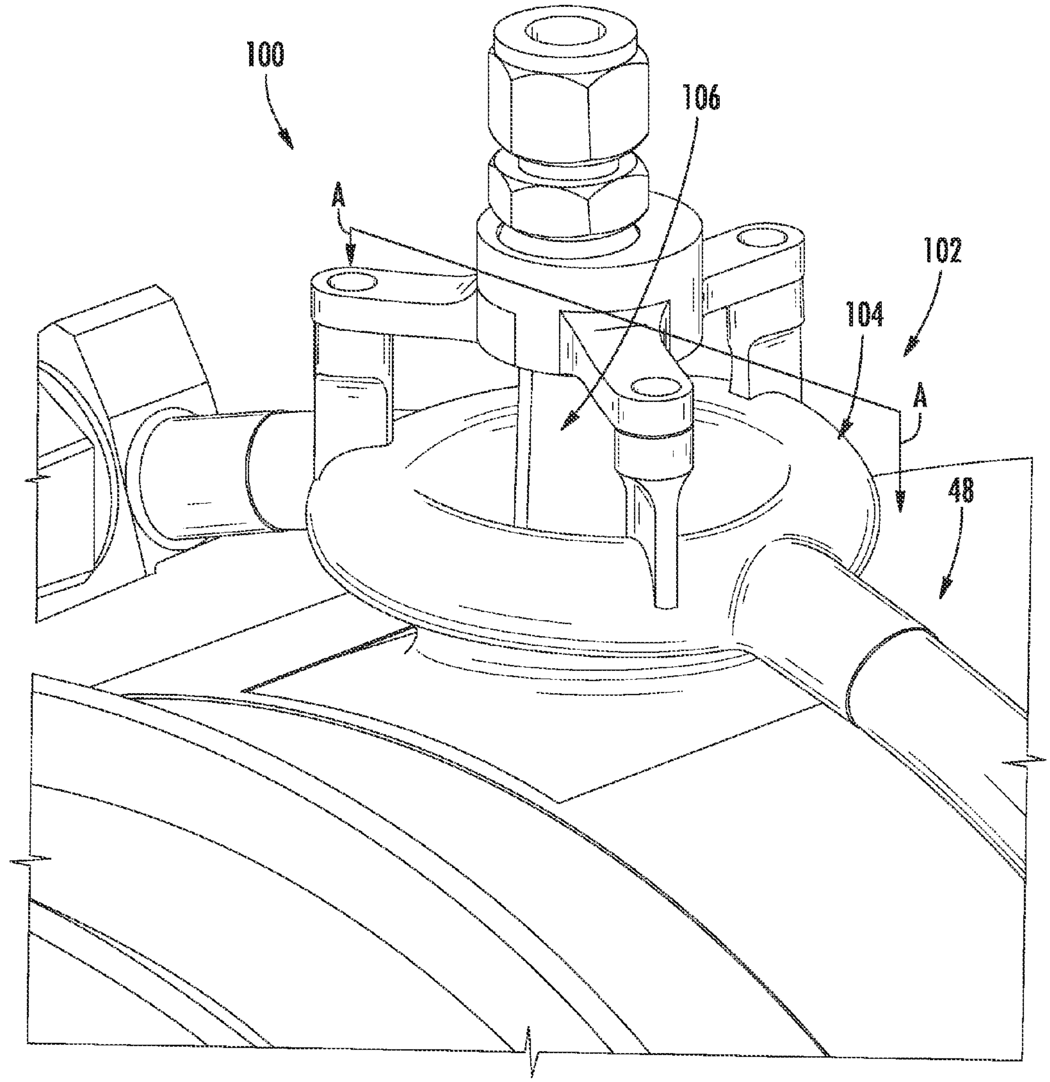

FIG. 4

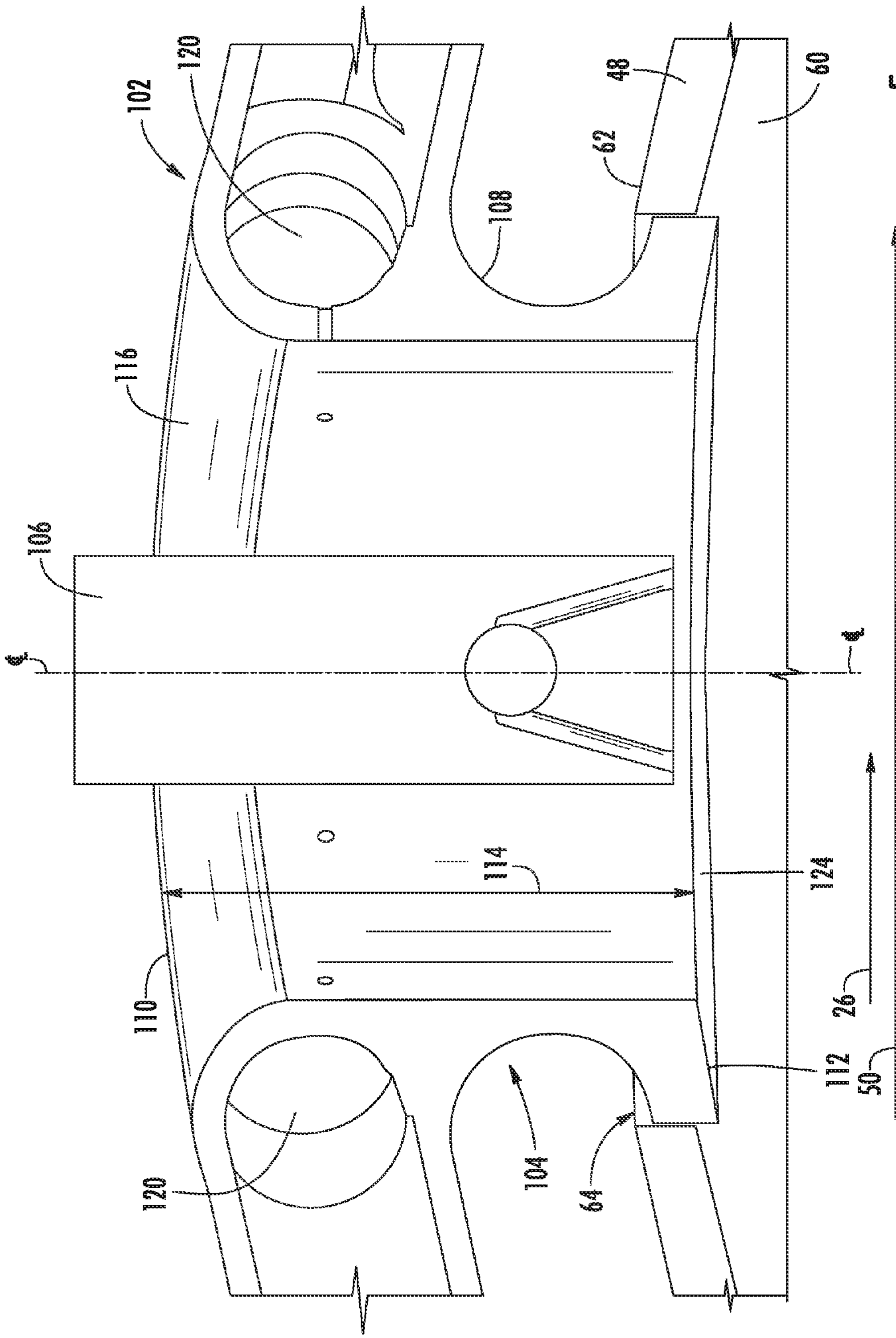

FIG. 5

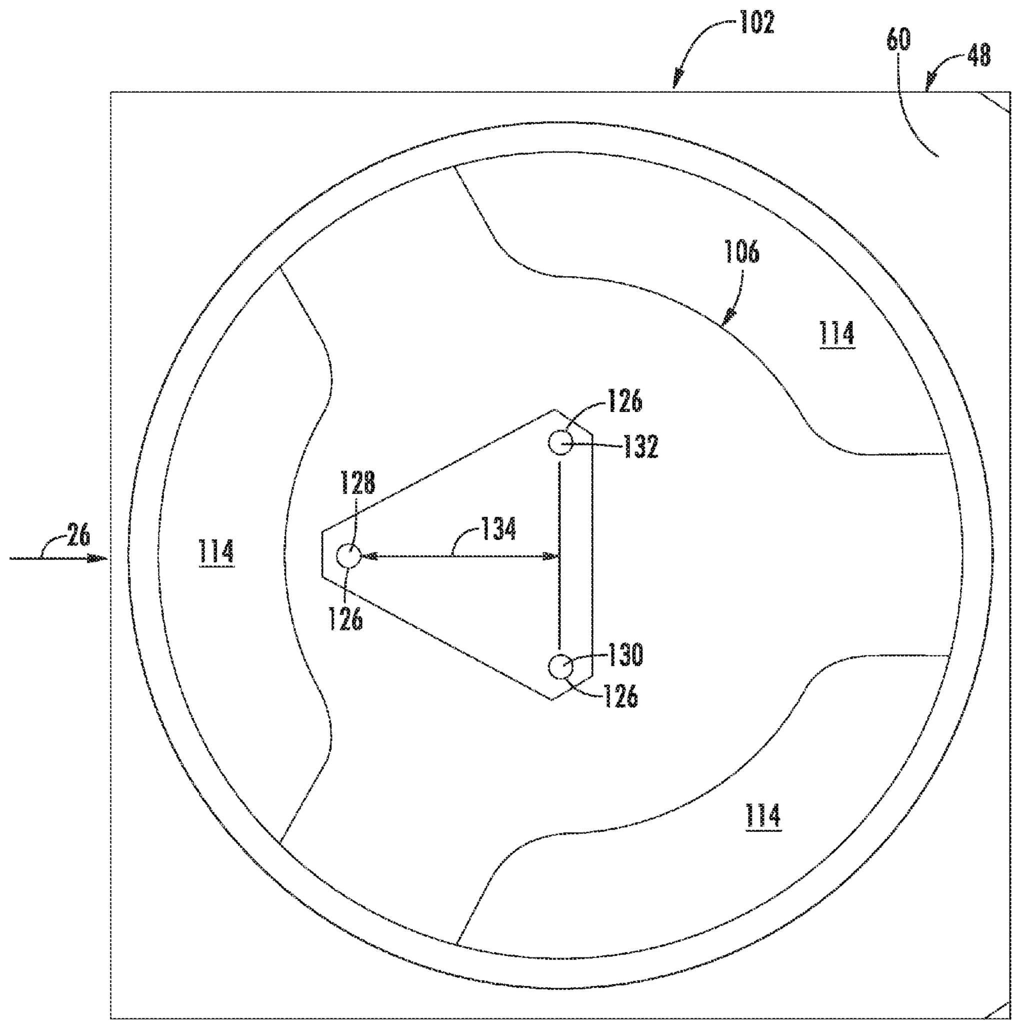

FIG. 6

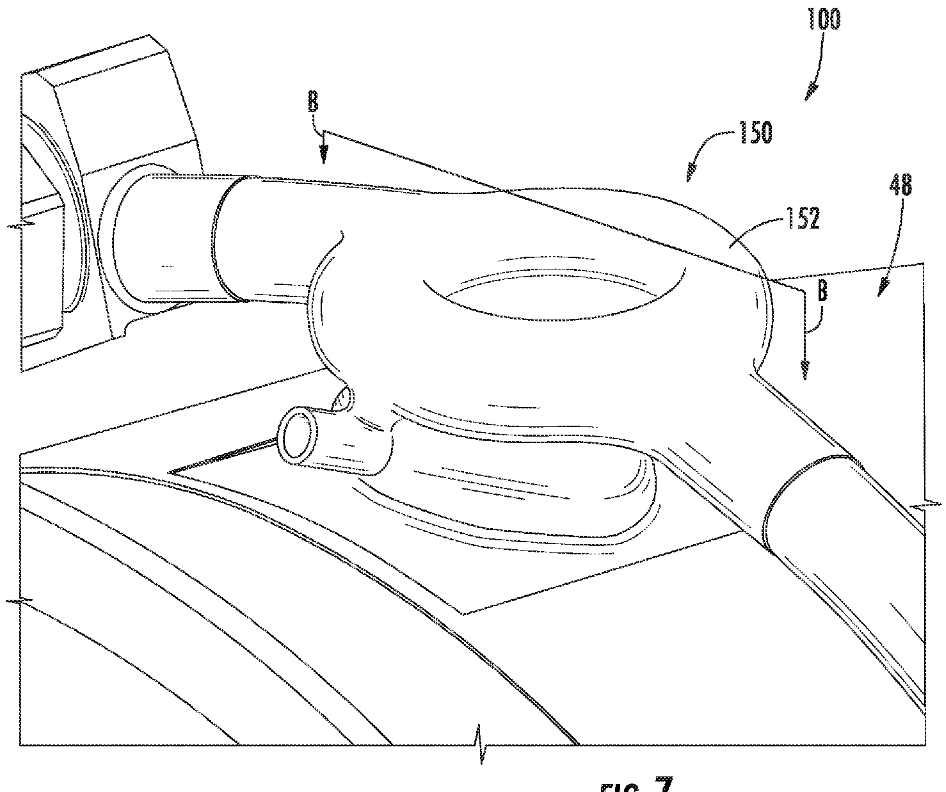

FIG. 7

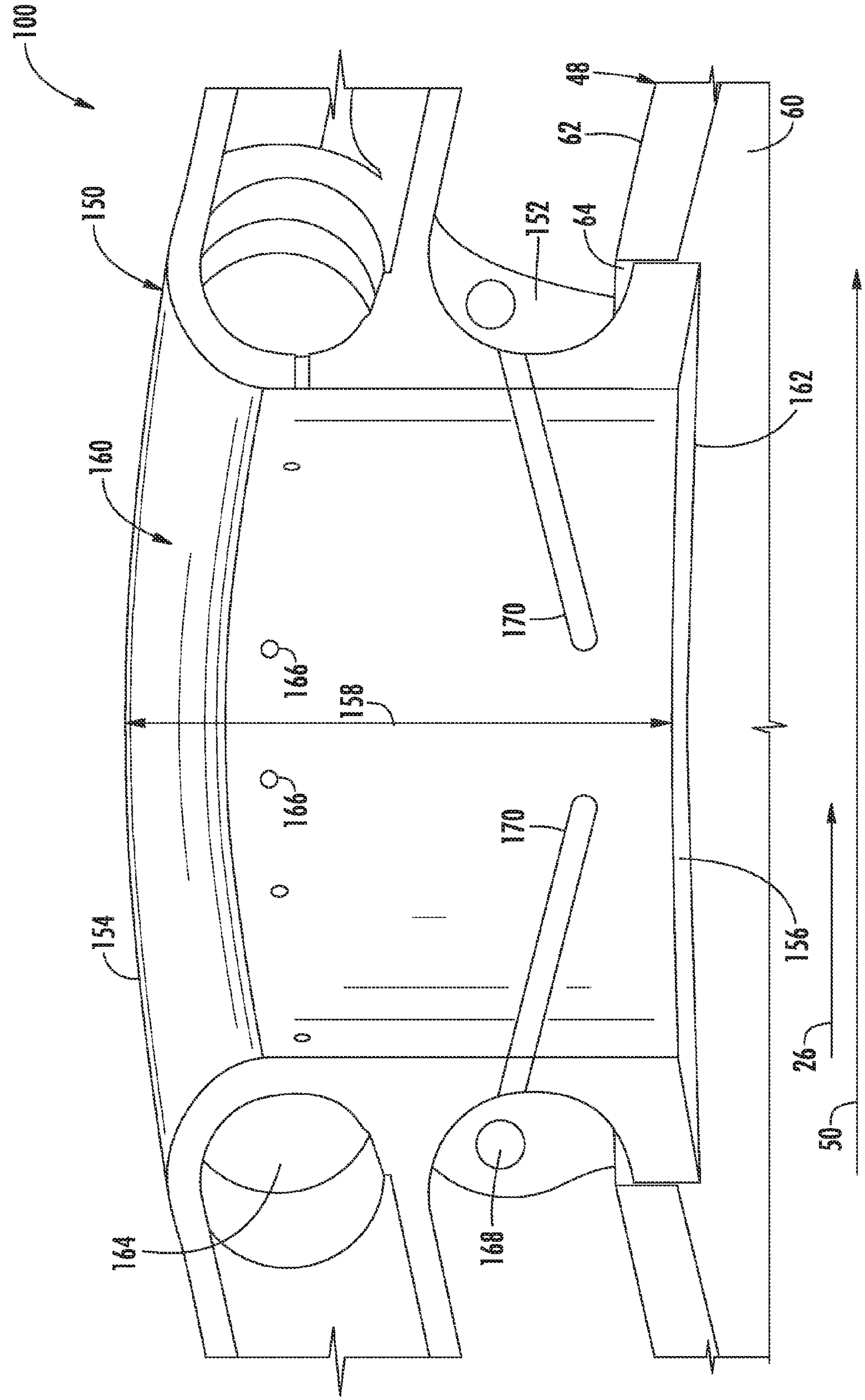

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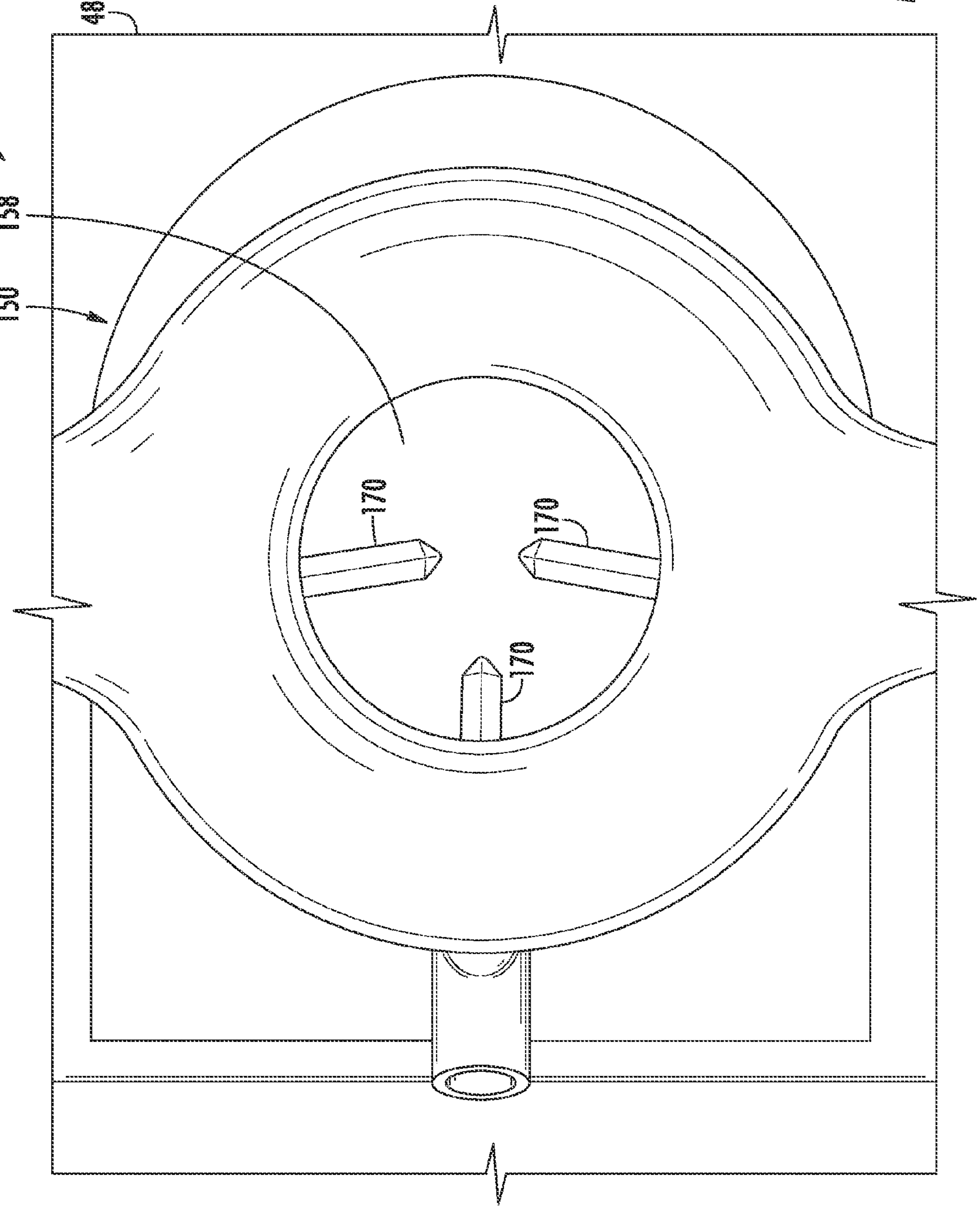
FIG. 8

FIG. 9



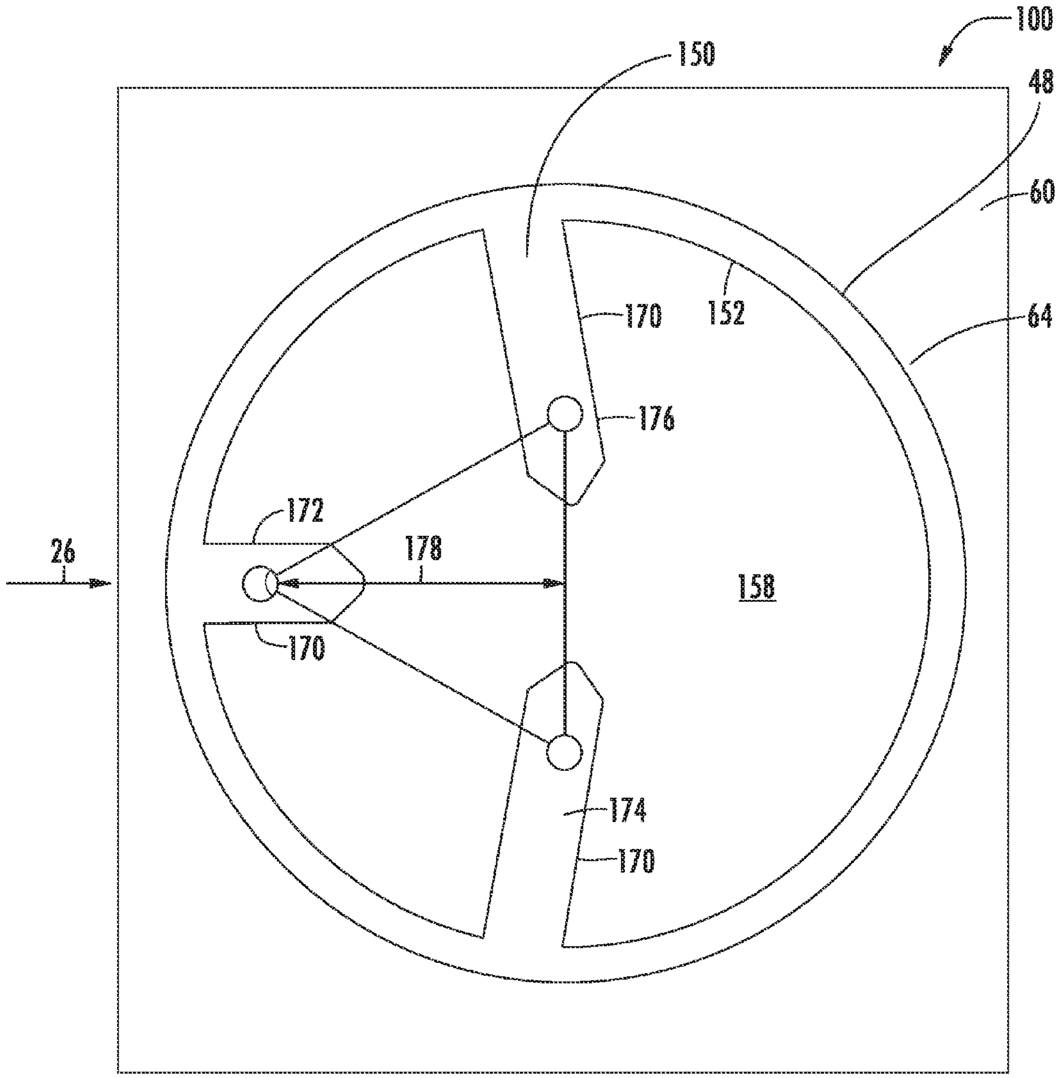


FIG. 10

SYSTEM FOR INJECTING A LIQUID FUEL INTO A COMBUSTION GAS FLOW FIELD

FIELD OF THE INVENTION

[0001] The present invention generally involves a system for supplying fuel to a combustor. In particular, the invention relates to a system for increasing penetration of a axially staged liquid fuel into a combustion gas flow field.

BACKGROUND OF THE INVENTION

[0002] A gas turbine generally includes a compressor section, a combustion section having a combustor and a turbine section. The compressor section progressively increases the pressure of the working fluid to supply a compressed working fluid to the combustion section. The compressed working fluid is routed through and/or around an axially extending fuel nozzle that extends within the combustor. A fuel is injected into the flow of the compressed working fluid to form a combustible mixture. The combustible mixture is burned within a combustion chamber to generate combustion gases having a high temperature, pressure and velocity. The combustion gases flow through one or more liners or ducts that define a hot gas path into the turbine section. The combustion gases expand as they flow through the turbine section to produce work. For example, expansion of the combustion gases in the turbine section may rotate a shaft connected to a generator to produce electricity.

[0003] The temperature of the combustion gases directly influences the thermodynamic efficiency, design margins, and resulting emissions of the combustor. For example, higher combustion gas temperatures generally improve the thermodynamic efficiency of the combustor. However, higher combustion gas temperatures may increase the disassociation rate of diatomic nitrogen, thereby increasing the production of undesirable emissions such as oxides of nitrogen (NO_X) for a particular residence time in the combustor. Conversely, a lower combustion gas temperature associated with reduced fuel flow and/or part load operation (turndown) generally reduces the chemical reaction rates of the combustion gases, thereby increasing the production of carbon monoxide (CO) and unburned hydrocarbons (UHCs) for the same residence time in the combustor.

[0004] In order to balance overall emissions performance while optimizing thermal efficiency of the combustor, certain combustor designs include multiple fuel injectors that are arranged around the liner and positioned generally downstream from the primary combustion zone. The fuel injectors generally extend radially through the liner to provide for fluid communication into the combustion gas flow field. This type of system is commonly known in the art and/or the gas turbine industry as Late Lean Injection (LLI) and/or as axial fuel staging.

[0005] In operation, a portion of the compressed working fluid is routed through and/or around each of the fuel injectors and into the combustion gas flow field. A liquid or gaseous fuel from the fuel injectors is injected into the flow of the compressed working fluid to provide a lean or air-rich combustible mixture which spontaneously combusts as it mixes with the hot combustion gases, thereby increasing the firing temperature of the combustor without producing a corresponding increase in the residence time of the combustion gases inside the combustion chamber. As a result, the overall thermodynamic efficiency of the combustor may be increased without sacrificing overall emissions performance

[0006] One challenge with injecting a liquid fuel into the combustion gas flow field using existing LLI or axial fuel staging systems is that the momentum of the combustion gases generally inhibits adequate radial penetration of the liquid fuel into the combustion gas flow field. As a result, local evaporation of the liquid fuel occurs along an inner wall of the liner at or near the fuel injection point, thereby resulting in a high temperature zone and high thermal stresses.

[0007] Current solutions to address this issue include extending at least a portion of the fuel injector radially inward through the liner and into the combustion gas flow field. However, this approach creates a bluff body in the combustion gas flow field that results in the formation of a high temperature recirculation zone downstream from the bluff body. In addition, this approach exposes the fuel injectors to the hot combustion gases which may impact the mechanical life of the component and lead to fuel coke buildup. Therefore, an improved system for injecting a liquid fuel into the combustion gas flow field for enhanced mixing would be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0008] Aspects and advantages of the invention are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0009] One embodiment of the present invention is a system for injecting a liquid fuel into a combustion gas flow field. The system includes an annular liner that defines a combustion gas flow path. The annular liner includes an inner wall, an outer wall and a fuel injector opening that extends through the inner wall and the outer wall. The system further includes a gas fuel injector that is coaxially aligned with the fuel injector opening. The gas fuel injector includes an upstream end and a downstream end. The downstream end terminates substantially adjacent to the inner wall. A dilution air passage is at least partially defined by the gas fuel injector. A liquid fuel injector extends partially through the dilution air passage. The liquid fuel injector includes an injection end that terminates upstream from the inner wall.

[0010] Another embodiment of the present invention is a system for injecting a liquid fuel into a combustion gas flow field. The system includes an annular liner that defines a combustion gas flow path within a combustor. The annular liner having an inner wall, an outer wall and a fuel injector opening. The system further includes a fuel injector that is coaxially aligned with the fuel injector opening. The fuel injector comprises an annular main body having an upstream end and a downstream end. The annular main body defines a dilution air passage that provides for fluid communication through the fuel injector into the combustion gas flow path. A gas fuel plenum is defined within the main body, and a liquid fuel plenum is defined within the main body. A plurality of liquid fuel injectors extend from the main body into the dilution air passage to provide for fluid communication between the liquid fuel plenum and the dilution air passage. The plurality of liquid fuel injectors terminate upstream from the inner wall of the annular liner.

[0011] Another embodiment of the present invention includes a gas turbine. The gas turbine includes a compressor and a combustor disposed downstream from the compressor. The combustor includes an axially extending fuel nozzle that extends downstream from an end cover, a combustion gas flow path defined downstream from the axially extending fuel nozzle and an annular liner that at least partially defines the combustion gas flow path within the combustor. The annular liner includes an inner wall, an outer wall and a fuel injector opening. The gas turbine further includes a turbine that is disposed downstream from the combustor. The combustor further includes a system for injecting a liquid fuel into a combustion gas flow field that is defined within the combustor downstream from the axially extending fuel nozzle. The system comprises a dilution air passage that provides for fluid communication through the annular liner into the combustion gas flow path, and a plurality of liquid fuel injectors disposed within the dilution air passage, wherein the fuel injectors terminate within the dilution air passage upstream from the inner wall of the annular liner.

[0012] Those of ordinary skill in the art will better appreciate the features and aspects of such embodiments, and others, upon review of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A full and enabling disclosure of the present invention, including the best mode thereof to one skilled in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

[0014] FIG. **1** is a functional block diagram of an exemplary gas turbine within the scope of the present invention;

[0015] FIG. **2** is a cross-section side view of a portion of an exemplary can type combustor as may be incorporate various embodiments of the present invention;

[0016] FIG. **3** is a downstream perspective view of an annular liner according to various embodiments of the present invention;

[0017] FIG. **4** is a perspective view of a system for injecting a liquid fuel into a combustion gas flow field, according to one embodiment of the present invention;

[0018] FIG. **5** is a cross section side view of a fuel injector and a portion of an annular liner taken along line A-A as shown in FIG. **4**, according to one embodiment of the present invention;

[0019] FIG. **6** is a bottom view of a fuel injector including a liquid fuel injector and a portion of an annular liner according to various embodiments;

[0020] FIG. **7** is a perspective side view of the system as shown in FIG. **4**, according to another embodiment of the present invention;

[0021] FIG. **8** is a cross section side view of the system taken along section line B-B as shown in FIG. **7**, according to one embodiment of the present invention;

[0022] FIG. **9** is a top view of a fuel injector and a portion of an annular liner as shown in FIG. **7**, according to one embodiment of the present invention; and

[0023] FIG. **10** is a bottom view of the fuel injector and the portion of the liner as shown in FIG. **9**.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention. As used herein, the terms "first", "second", and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "upstream" and "downstream" refer to the relative direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the direction from which the fluid flows, and "downstream" refers to the direction to which the fluid flows. The term "radially" refers to the relative direction that is substantially perpendicular to an axial centerline of a particular component, and the term "axially" refers to the relative direction that is substantially parallel to an axial centerline of a particular component.

[0025] Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present invention without departing from the scope or spirit thereof For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents. Although exemplary embodiments of the present invention will be described generally in the context of a combustor incorporated into a gas turbine for purposes of illustration, one of ordinary skill in the art will readily appreciate that embodiments of the present invention may be applied to any combustor incorporated into any turbomachine and is not limited to a gas turbine combustor unless specifically recited in the claims.

[0026] Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. **1** provides a functional block diagram of an exemplary gas turbine **10** that may incorporate various embodiments of the present invention. As shown, the gas turbine **10** generally includes an inlet section **12** that may include a series of filters, cooling coils, moisture separators, and/or other devices to purify and otherwise condition a working fluid (e.g., air) **14** entering the gas turbine **10**. The working fluid **14** flows to a compressor section where a compressor **16** progressively imparts kinetic energy to the working fluid **14** to produce a compressed working fluid **18**.

[0027] The compressed working fluid **18** is mixed with a fuel **20** from a fuel supply system **22** to form a combustible mixture within one or more combustors **24**. The combustible mixture is burned to produce combustion gases **26** having a high temperature, pressure and velocity. The combustion gases **26** flow through a turbine **28** of a turbine section to produce work. For example, the turbine **28** may be connected to a shaft **30** so that rotation of the turbine **28** drives the compressor **16** to produce the compressed working fluid **18**. Alternately or in addition, the shaft **30** may connect the turbine **28** to a generator **32** for producing electricity. Exhaust gases **34** from the turbine **28** flow through an exhaust section **36** that connects the turbine **28** to an exhaust stack **38** downstream from the turbine **28**. The exhaust section **36** may include, for example, a heat recovery steam generator (not shown) for cleaning and extracting additional heat from the exhaust gases **34** prior to release to the environment.

[0028] The combustors **24** may be any type of combustor known in the art, and the present invention is not limited to any particular combustor design unless specifically recited in the claims. For example, the combustor **24** may be a can type or a can-annular type of combustor. FIG. **2** provides a cross-section side view of a portion of an exemplary gas turbine **10** including a portion of the compressor **16** and an exemplary can type combustor **24**. As shown in FIG. **2**, an outer casing **40** surrounds at least a portion of the combustor **24**. An end cover **42** is coupled to the outer casing **40** at one end of the combustor **24**. The end cover **42** and the outer casing **40** generally define a high pressure plenum **44**. The high pressure plenum **44** receives the compressed working fluid **18** from the compressor **16**.

[0029] At least one axially extending fuel nozzle **46** extends downstream from the end cover **42** within the outer casing **40**. An annular liner **48** extends downstream from the axially extending fuel nozzle **46** within the outer casing **40**. The annular liner **48** extends at least partially through the high pressure plenum **44** so as to at least partially define a combustion gas flow path **50** within the combustor **24** for routing the combustion gases **26** through the high pressure plenum **44** towards the turbine **28** (FIG. **1**).

[0030] The annular liner **48** may be a singular liner or may be divided into separate components. For example, the annular liner **48** may comprise of a combustion liner **52** that is disposed proximate to the axially extending fuel nozzle **46** and a transition duct **54** that extends downstream from the combustion liner **52**. The transition duct **54** may be shaped so as to accelerate the flow of the combustion gases **26** through the combustion gas flow path **50** just upstream from a stage of stationary nozzles (not shown) that are disposed proximate to an inlet of the turbine **28** within the combustion gas flow path **50**. A combustion chamber **56** is defined downstream from the axially extending fuel nozzle **46**. The combustion chamber **56** may be at least partially defined by the annular liner **48**. As shown, the combustion gases **26** define a combustion gas flow field **58** within the combustion gas flow path **50** downstream from the axially extending fuel nozzle **46**.

[0031] FIG. **3** provides a downstream perspective view of the annular liner **48** according to various embodiments of the present invention. As shown, the annular liner **48** generally includes an inner wall **60**, an outer wall **62** and a fuel injector opening **64** that extends through the inner wall **60** and the outer wall **62**. The fuel injector opening **64** provides for fluid communication through the annular liner **48**. As shown, the annular liner **48** may include multiple fuel injector openings **64** arranged circumferentially around the annular liner **48**.

[0032] In particular embodiments, as shown in FIG. **2**, the combustor **24** includes a system for injecting a liquid fuel into the combustion gas flow field **58**, herein referred to as "system **100**". The system generally includes the annular liner **48** and at least one fuel injector **102** that provides for fluid communication through the annular liner **48** and into the combustion gas flow field **58**. The fuel injector **102** may provide for fluid communication through the annular liner **48** including the combustion liner **52** and the transition duct **54** at any point that is downstream from the axially extending fuel nozzle **46**.

[0033] FIG. **4** provides a perspective view of the system **100** including a portion of the annular liner **48** and the fuel injector **102** according to one embodiment of the present invention. As shown, the fuel injector **102** includes a gas fuel injector **104** and a liquid fuel injector **106**. The gas fuel injector **104** may be fluidly coupled to a gas fuel source (not shown) and the liquid gas fuel injector may be fluidly coupled to a liquid fuel supply (not shown).

[0034] FIG. **5** provides a cross section side view of the fuel injector **102** and a portion of the annular liner **48** taken along line A-A as shown in FIG. **4**, according to one embodiment of the present invention. As shown in FIG. **5**, at least a portion of the gas fuel injector **104** may be disposed within the fuel injector opening **64**. In one embodiment, the gas fuel injector **104** is coaxially aligned within the fuel injector opening **64** with respect to a centerline of the fuel injector opening **64**. The gas fuel injector **104** generally includes an annular main body **108**. The annular main body **108** includes an upstream end **110** and a downstream end **112**. In particular embodiments, the downstream end **112** terminates substantially adjacent to the inner wall **60** of the annular liner **48**.

[0035] In particular embodiments, the annular main body **108** defines a dilution air passage **114** that provides for fluid communication through the fuel injector **102** and/or through the gas fuel injector **104** into the combustion gas flow path **50**. The upstream end **110** of the gas fuel injector **104** may define an inlet **116** of the dilution air passage **114** and the downstream end **112** may define an outlet **118** of the dilution air passage **114**.

[0036] In particular embodiments, the gas fuel injector **104** includes a gas fuel plenum **120** that is defined within the main body **108**. As shown in FIG. **4**, the gas fuel plenum **120** may extend circumferentially around the main body **108**. In one embodiment, the gas fuel plenum **120** extends circumferentially around the main body **108** generally proximate to the upstream end **110**. One or more gas fuel ports **122** may provide for fluid communication between the gas fuel plenum **120** and the dilution air passage **114**.

[0037] In particular embodiments, as shown in FIG. **5**, the liquid fuel injector **106** extends partially through the dilution air passage **114**. The liquid fuel injector **106** includes an injection end **124** that terminates adjacent to or upstream from the downstream end **112** and/or the outlet **118**. The injection end **124** of the liquid fuel injector **106** is positioned outside of the combustion gas flow path **50**. In one embodiment, the injection end **124** of the liquid fuel injector **106** terminates at a point that is between the inner wall **60** and the outer wall **62** of the annular liner **48**.

[0038] FIG. **6** provides a bottom view of the fuel injector **102** including the liquid fuel injector **106**, particularly the injection end **124** of the liquid fuel injector **106**, and a portion of the annular liner **48** according to various embodiments. As shown in FIG. **6**, the liquid fuel injector **106** may further comprise a plurality of liquid fuel injection ports **126** disposed across the injection end **124**. In one embodiment, as shown in FIG. **6**, the plurality of liquid fuel injection ports **126** comprises a first liquid fuel injection port **128**, a second liquid fuel injection port **130** and a third liquid fuel injection port **132**.

[0039] As shown in FIG. **6**, the first liquid fuel injection port **128**, the second liquid fuel injection port **130** and the third liquid fuel injection port **132** may be arranged in a triangular array across the injection end **124**. In one embodiment, the first liquid fuel injection port **128** is spaced an equal distance **134** from the second liquid fuel injection port **130** and from the third liquid fuel injection port **132**. In particular embodiments, the first liquid fuel injection port **128** is positioned upstream from the second liquid fuel injection port **130** and the third liquid fuel injection port **132** with respect to the direction of flow of the combustion gases **26** within the combustion gas flow path **50** (FIG. **5**).

[0040] In operation, a portion of the compressed working fluid **18** (FIG. **2**) flows through the dilution air passage **114** and into the combustion gas flow path **50**. The liquid fuel is injected simultaneously within the dilution air passage **114** upstream from the inner wall **60** of the liner. As the compressed working fluid **18** interacts with the combustion gas flow field **58**, a low velocity area is created within the combustion gas flow field **58**. As a result, the liquid fuel penetrates deep within the combustion gas flow field **58**, thereby enhancing mixing with the combustion gases before combustion. Local evaporation of the liquid fuel close to the inner wall **60** of the annular liner **48** is substantially reduced, thereby reducing high temperature zones which are typically caused by the evaporated liquid fuel burning close to the inner wall **60**.

[0041] The relative momentum between the liquid fuel and the compressed working fluid **18** provides for the effective atomization of the liquid fuel. The triangular pattern and/or spacing of the first, second and third liquid injection ports **128**, **130**, **132** in the injector end **124** creates three discrete liquid fuel jets in a tripod fashion which enhances penetration of the liquid fuel into the combustion gas flow field **58**, thereby contributing to more complete mixing with the combustion gases. As a result, net NOx production from fuel bound nitrogen is reduced. The exact placement, size and number of liquid fuel injection ports **126** may be optimized using various fluid dynamic analysis tools such as computational fluid dynamic (CFD) models.

[0042] In addition, by terminating the injection end **124** outside of the combustion gas flow path **50**, the liquid fuel injector **106** is shielded from direct exposure to the combustion gases **26**, thereby limiting thermal stress on the liquid fuel injector **106**. In addition, by positioning the liquid fuel injector **106** outside of the combustion gas flow path **50**, undesirable flow patterns such as recirculation zones that are normally associated with flow around a bluff body such as the liquid fuel injector **106** are eliminated at and/or downstream from the fuel injector opening **64**, thereby preventing potentially life limiting hot streaks on the annular liner **48** in that area.

[0043] FIG. **7** provides a perspective side view of the system **100** according to another embodiment of the present invention, and FIG. **8** provides a cross section side view of the system **100** taken along section line B-B as shown in FIG. **7**. In particular embodiments, as shown in FIG. **7**, the system **100** includes the liner **48** and a fuel injector **150** that is coaxially aligned with the fuel injector opening **64** (FIGS. **3** and **8**). As shown in FIGS. **7** and **8**, the fuel injector **150** comprises an annular main body **152**. As shown in FIG. **8**, the annular main body **152** includes an upstream end **154** and a downstream end **156**. The annular main body **150** defines a dilution air passage **158** that provides for fluid communication through the fuel injector **150** and into the combustion gas flow path **50**. The upstream end **154** of the annular main body **152** defines an inlet **160** of the dilution air passage **158** and the downstream end **156** defines an outlet **162** of the dilution air passage **158**.

[0044] A gas fuel plenum **164** is defined within the main body **152**. In one embodiment, a plurality of gas fuel ports **166** provide for fluid communication between the gas fuel plenum **158** and the dilution air passage **158**. In one embodiment, a liquid fuel plenum **168** is defined within the annular main body **152**. The liquid fuel plenum **168** and/or the gas fuel plenum **164** may be in fluid communication with the fuel supply **22** (FIG. **1**).

[0045] FIG. **9** provides a top view of the fuel injector **150** and a portion of the liner **48** as shown in FIG. **7**, according to one embodiment. FIG. **10** provides a bottom view of the fuel injector **150** and a portion of the liner **48** as shown in FIG. **9**. As shown in FIGS. **8**, **9**, and **10**, a plurality of liquid fuel injectors **170** extend from the annular main body **152** into the dilution air passage **158** to provide for fluid communication between the liquid fuel plenum **168** (FIG. **8**) and the dilution air passage **158**.

[0046] In particular embodiments, as shown in FIG. **8**, the plurality of liquid fuel injectors **170** terminate upstream from the inner wall **60** of the annular liner **48** within the dilution air flow passage **158** and/or upstream from the downstream end **156** or outlet **162** of the annular main body **152** within the dilution air flow passage **158**. In this manner, the plurality of liquid fuel injectors **170** are positioned outside of the combustion gas flow path **50**, thereby shielding the liquid fuel injectors **170** from direct exposure to the combustion gases **26**, thereby limiting thermal stress on the liquid fuel injectors **170**. In addition, by positioning the liquid fuel injectors **170** outside of the combustion gas flow path **50**, undesirable flow patterns such as recirculation zones that are normally associated with flow around a bluff body such as the liquid fuel injectors **170** are eliminated at and/or downstream from the fuel injector opening **64**, thereby preventing hot streaks on the annular liner **48** and reducing thermal stress in that area.

[0047] In particular embodiments, as shown in FIG. **10**, the plurality of liquid fuel injectors **170** comprises a first liquid fuel injector **172**, a second liquid fuel injector **174** and a third liquid fuel injector **176** that are arranged in a triangular array within the dilution air passage **158**. In one embodiment, the first liquid fuel injector **172** is positioned upstream from the second liquid fuel injector **174** and the third liquid fuel injector **176** with respect to the flow of combustion gases **26**. In one embodiment, the first liquid fuel injector **172** is spaced an equal distance **178** from the second liquid fuel injector **174** and the third liquid fuel injector **176**.

[0048] In operation, as illustrated in various FIGS., a portion of the compressed working fluid **18** (FIG. **2**) flows through the dilution air passage **158** and into the combustion gas flow path **50**. The liquid fuel is injected simultaneously within the dilution air passage **158** upstream from the inner wall **60** of the liner and/or the downstream end **156** or outlet **162** of the annular main body **152**. As the compressed working fluid **18** interacts with the combustion gases **26**, a low velocity area is created within the combustion gas flow field **58**. As a result, the liquid fuel penetrates into combustion gas flow field **58**, for example a distance equal to at least one diameter of the fuel injector opening **64**, thereby enhancing mixing with the combustion gases before combustion.

[0049] Local evaporation of the liquid fuel close to the inner wall **60** of the annular liner **48** is substantially reduced, thereby reducing high temperature zones which are typically caused by the liquid fuel evaporating and burning close to the inner wall **60**. Relative momentum between the liquid fuel and the compressed working fluid **18** provides for effective atomization of the liquid fuel. The triangular pattern and/or spacing of the first, second and third liquid fuel injectors **172**, **174** and **176** creates three discrete liquid fuel jets in a tripod fashion which enhances penetration of the liquid fuel into the combustion gas flow field **58**, thereby contributing to more complete mixing with the combustion gases. The exact placement, size and number of the liquid fuel injectors **170** may be optimized using various fluid dynamic analysis tools such as computational fluid dynamic (CFD) models.

[0050] In addition, by terminating the liquid fuel injectors **170** outside of the combustion gas flow path **50**, the liquid fuel injectors **170** are shielded from direct exposure to the combustion gases **26**, thereby limiting thermal stress on the liquid fuel injectors **170**. In addition, by positioning the liquid fuel injectors **170** outside of the combustion gas flow path **50**, undesirable flow patterns such as recirculation zones that are normally associated with flow around a bluff body such as the liquid fuel injectors **170** are eliminated at and/or downstream from the fuel injector opening **64**, thereby preventing potentially life limiting hot streaks on the annular liner **48** in that area.

[0051] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A system for injecting a liquid fuel into a combustion gas flow field, comprising:

a. an annular liner that defines a combustion gas flow path, the annular liner having an inner wall, an outer wall and a fuel injector opening that extends through the inner wall and the outer wall;

b. a gas fuel injector coaxially aligned with the fuel injector opening, the gas fuel injector having an upstream end and a downstream end, wherein the downstream end terminates substantially adjacent to the inner wall;

c. a dilution air passage at least partially defined by the gas fuel injector, wherein the dilution air passage provides for fluid communication through the annular liner into the combustion gas flow path; and

d. a liquid fuel injector that extends partially through the dilution air passage, the liquid fuel injector having an injection end that terminates upstream from the inner wall.

2. The system as in claim **1**, wherein the liquid fuel injector further comprises a plurality of liquid fuel injection ports disposed at the injection end.

3. The system as in claim **1**, wherein the liquid fuel injector further comprises a first liquid fuel injection port, a second liquid fuel injection port and a third liquid fuel injection port arranged in a triangular array across the injection end.

4. The system as in claim **3**, wherein the first liquid fuel injection port is spaced an equal distance from the second liquid fuel injection port and from the third liquid fuel injection port.

5. The system as in claim **3**, wherein the first liquid fuel injection port is positioned upstream from the second liquid fuel injection port and the third liquid fuel injection port with respect to a direction of flow of combustion gases within the combustion gas flow path.

6. The system as in claim **1**, wherein the injection end of the liquid fuel injector terminates between the inner wall and the outer wall of the annular liner.

7. The system as in claim **1**, wherein the upstream end of the gas fuel injector defines an inlet of the dilution air passage and the downstream end defines an outlet of the dilution air passage.

8. The system as in claim **1**, wherein the gas fuel injector comprises a gas fuel plenum that extends circumferentially around the upstream end and a plurality of gas fuel ports that provide for fluid communication between the gas fuel plenum and the dilution flow passage.

9. A system for injecting a liquid fuel into a combustion gas flow field, comprising:

a. an annular liner that defines a combustion gas flow path within the combustor, the annular liner having an inner wall, an outer wall and a fuel injector opening; and

b. a fuel injector coaxially aligned with the fuel injector opening, the fuel injector comprising:

i. an annular main body having an upstream end and a downstream end, wherein the annular main body defines a dilution air passage that provides for fluid communication through the fuel injector into the combustion gas flow path;

ii. a gas fuel plenum defined within the main body;

iii. a liquid fuel plenum defined within the main body; and

iv. a plurality of liquid fuel injectors that extend from the main body into the dilution air passage to provide for fluid communication between the liquid fuel plenum and the dilution air passage, wherein the plurality of liquid fuel injectors terminate upstream from the inner wall of the annular liner.

10. The system as in claim **9**, wherein the plurality of liquid fuel injectors comprises a first liquid fuel injector, a second liquid fuel injector and a third liquid fuel injector arranged in a triangular array within the dilution air passage.

11. The system as in claim **10**, wherein the first liquid fuel injector is positioned upstream from the second liquid fuel injector and the third liquid fuel injector with respect to a direction of flow of combustion gases within the combustion gas flow path.

12. The system as in claim **10**, wherein the first liquid fuel injector, the second liquid fuel injector and the third liquid fuel injector are arranged in a triangular array within the dilution air passage.

13. The system as in claim **10**, wherein the first liquid fuel injector is spaced an equal distance from the second liquid fuel injector and the third liquid fuel injector.

14. A gas turbine, comprising:

a. a compressor;

b. a combustor disposed downstream from the compressor, the combustor having an axially extending fuel nozzle that extends downstream from the end cover, a combustion gas flow path defined downstream from the axially extending fuel nozzle and an annular liner that at least partially defines the combustion gas flow path within the combustor, the annular liner having an inner wall, an outer wall and a fuel injector opening;

c. a turbine disposed downstream from the combustor; and

d. wherein the combustor further includes a system for injecting a liquid fuel into a combustion gas flow field within the combusor downstream from the axially extending fuel nozzle, the system comprising:

i. a dilution air passage that provides for fluid communication through the annular liner into the combustion gas flow path; and

ii. a plurality of liquid fuel injectors disposed within the dilution air passage, wherein the plurality of liquid fuel injectors terminate within the dilution air passage upstream from the inner wall of the annular liner.

15. The gas turbine as in claim **14**, wherein the system comprises a gas fuel injector disposed coaxially within the fuel injector opening, the gas fuel injector having an upstream end and a downstream end, wherein the downstream end terminates substantially adjacent to the inner wall.

16. The gas turbine as in claim **15**, wherein the liquid fuel injector includes an injection end that terminates adjacent to or upstream from the downstream end of the gas fuel injector.

17. The gas turbine as in claim **14**, wherein the liquid fuel injector further comprises a first liquid fuel injection port, a second liquid fuel injection port and a third liquid fuel injection port that are arranged in a triangular array across the injection end, wherein the first liquid fuel injection port is positioned upstream from the second liquid fuel injection port and the third liquid fuel injection port with respect to a flow of combustion gases that flow through the combustion gas flow path.

18. The gas turbine as in claim **18**, wherein the system further comprises:

a. an annular main body having an upstream end and a downstream end, wherein the annular main body defines the dilution air passage;

b. a gas fuel plenum that extends within the main body;

c. a liquid fuel plenum that extends within the main body; and

d. wherein the at least one liquid fuel injector extends from the main body into the dilution air passage to provide for fluid communication between the liquid fuel plenum and the dilution air passage.

19. The gas turbine as in claim **18**, wherein the at least one liquid fuel injector comprises of a first liquid fuel injector, a second liquid fuel injector and a third liquid fuel injector arranged in a triangular array within the dilution air passage.

20. The gas turbine as in claim **18**, wherein the first liquid fuel injector is positioned upstream from the second liquid fuel injector and the third liquid fuel injector with respect to a flow of the combustion gases.

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