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(54) **Combustor and Method for Supplying Fuel To A Combustor**

(57) A combustor (10) includes a casing (12) that encloses at least a portion of the combustor (10). A fuel conduit (60) extends downstream from the casing (12) and includes a tortuous path for fuel flow inside the fuel conduit (60). A method for supplying fuel to a combustor (10) includes flowing a working fluid (14) through tubes

(34) that extend axially through an end cap (20). The method further includes supplying a fuel through a fuel conduit (60) into the end cap (20), supplying a diluent through a diluent conduit (62) that extends axially inside the fuel conduit (60), and swirling the fuel flowing through the fuel conduit (60) around the diluent flowing through the diluent conduit (62).

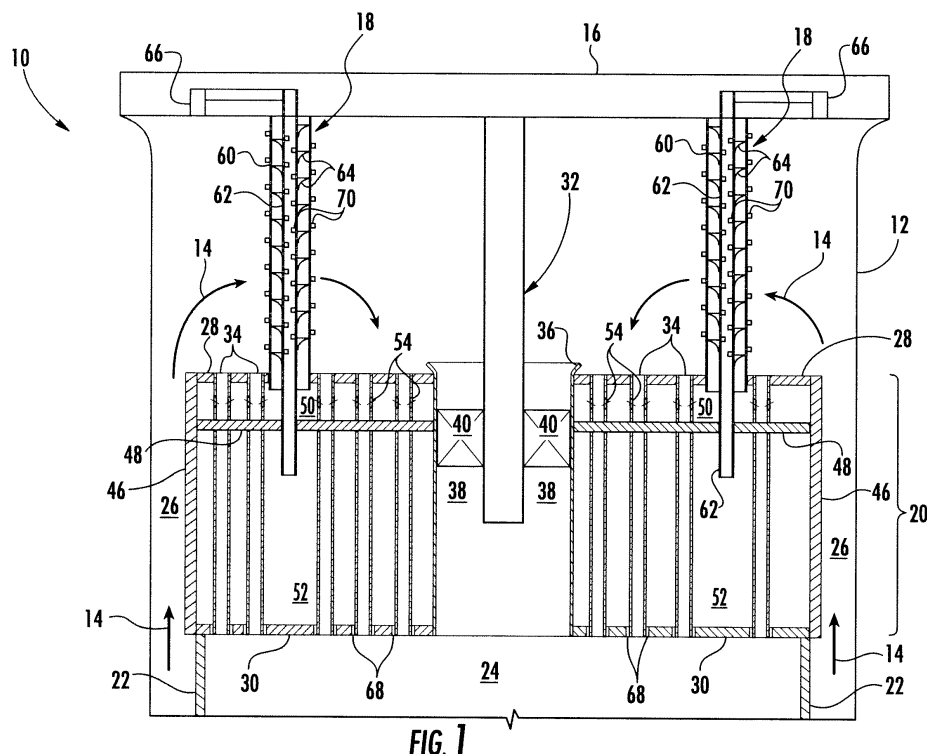


FIG. 1

EP 2 592 347 A2

Description

FIELD OF THE INVENTION

[0001] The present invention generally involves a combustor and a method for supplying fuel to the combustor.

BACKGROUND OF THE INVENTION

[0002] Combustors are commonly used in industrial and power generation operations to ignite fuel to produce combustion gases having a high temperature and pressure. Various competing considerations influence the design and operation of combustors. For example, higher combustion gas temperatures generally improve the thermodynamic efficiency of the combustor. However, higher combustion gas temperatures also promote flashback or flame holding conditions in which the combustion flame migrates towards the fuel being supplied by nozzles, possibly causing severe damage to the nozzles in a relatively short amount of time. In addition, higher combustion gas temperatures generally increase the dissociation rate of diatomic nitrogen, increasing the production of nitrogen oxides (NO_x). Conversely, lower combustion gas temperatures associated with reduced fuel flow and/or part load operation (turndown) generally reduce the chemical reaction rates of the combustion gases, increasing the production of carbon monoxide and unburned hydrocarbons.

[0003] In a particular combustor design, a plurality of tubes may be radially arranged in an end cap to provide fluid communication for a working fluid to flow through the end cap and into a combustion chamber. A fuel may be supplied to a plenum inside the end cap to flow over the outside of the tubes to provide convective cooling to the tubes before flowing into the tubes to mix with the working fluid. The enhanced mixing between the fuel and working fluid in the tubes allows leaner combustion at higher operating temperatures while protecting against flashback or flame holding and controlling undesirable emissions. However, the convective cooling provided by the fuel before entering the tubes may result in uneven heating of the fuel. As a result, temperature and density variations in the fuel flowing through the tubes may produce thermal stress in the tubes and/or uneven fuel-working fluid ratios that adversely affect flame stability, combustor performance, and/or undesirable emissions. Therefore, an improved combustor and method for supplying fuel to the combustor that reduces thermal stress in the tubes and/or temperature and density variations in the fuel flowing through the tubes would be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0004] 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.

[0005] One aspect of the present invention is a combustor that includes a casing that encloses at least a portion of the combustor. A fuel conduit extends downstream from the casing and includes a tortuous path for fuel flow inside the fuel conduit.

[0006] Another aspect of the present invention is a combustor that includes an end cover and an end cap axially separated from the end cover and configured to extend radially across at least a portion of the combustor, wherein the end cap comprises an upstream surface axially separated from a downstream surface. A fuel conduit extends from the end cover to the end cap to provide fluid communication to the end cap and includes tortuous path for fuel flow inside the fuel conduit.

[0007] Yet another aspect of the present invention includes a method for supplying fuel to a combustor that includes flowing a working fluid through a plurality of tubes that extends axially through an end cap. The method further includes supplying a fuel through a fuel conduit into the end cap, supplying a diluent through a diluent conduit that extends axially inside the fuel conduit, and swirling the fuel flowing through the fuel conduit around the diluent flowing through the diluent conduit.

[0008] 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

[0009] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a simplified cross-section view of an exemplary combustor according to one embodiment of the present invention;

Fig. 2 is an upstream axial view of the combustor shown in Fig. 1 according to an embodiment of the present invention; and

Fig. 3 is an enlarged cross-section view of the conduit shown in Fig. 1 according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] 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. In addition, the

terms "upstream" and "downstream" refer to the relative location of components in a fluid pathway. For example, component A is upstream from component B if a fluid flows from component A to component B. Conversely, component B is downstream from component A if component B receives a fluid flow from component A.

[0011] 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.

[0012] Various embodiments of the present invention include a combustor and method for supplying fuel to the combustor. The combustor generally includes a casing that encloses a working fluid flowing through the combustor. A plurality of tubes radially arranged in an end cap enhances mixing between the working fluid and fuel prior to combustion. In particular embodiments, a fuel conduit may extend between the casing and the end cap to supply fuel to the end cap. The fuel may flow through a tortuous path inside the fuel conduit adjacent to a diluent conduit that extends axially inside the fuel conduit to evenly heat the fuel before the fuel flows into the end cap. The improved heating of the fuel reduces the thermal stress across the tubes and/or the temperature and density variations in the fuel flowing through the tubes to enhance flame stability, combustor performance, and/or undesirable emissions. 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 and are not limited to a gas turbine combustor unless specifically recited in the claims.

[0013] Fig. 1 provides a simplified cross-section view of an exemplary combustor 10 according to one embodiment of the present invention, and Fig. 2 provides an upstream axial view of the combustor 10 shown in Fig. 1. As shown, a casing 12 generally encloses at least a portion of the combustor 10 to contain a working fluid 14 flowing to the combustor 10. The casing 12 may include an end cover 16 at one end that provides an interface for supplying fuel, diluent, and/or other additives to the combustor 10. Possible diluents may include, for example, water, steam, working fluid, air, fuel additives, various inert gases such as nitrogen, and/or various non-flammable gases such as carbon dioxide or combustion exhaust gases supplied to the combustor 10. One or more fluid conduits 18 may extend axially from the end cover 16 to an end cap 20 to provide fluid communication for fuel, diluents, and/or other additives to the end cap 20.

The end cap 20 is configured to extend radially across at least a portion of the combustor 10, and the end cap 20 and a liner 22 generally define a combustion chamber 24 downstream from the end cap 20. The casing 12 circumferentially surrounds the end cap 20 and/or the liner 22 to define an annular passage 26 that surrounds the end cap 20 and liner 22. In this manner, the working fluid 14 may flow through the annular passage 26 along the outside of the liner 22 to provide convective cooling to the liner 22. When the working fluid 14 reaches the end cover 16, the working fluid 14 may reverse direction to flow through the end cap 20 and into the combustion chamber 24.

[0014] The end cap 20 generally includes an upstream surface 28 axially separated from a downstream surface 30, and one or more nozzles 32 and/or tubes 34 may extend from the upstream surface 28 through the downstream surface 30 to provide fluid communication through the end cap 20 to the combustion chamber 24. The particular shape, size, number, and arrangement of the nozzles 32 and tubes 34 may vary according to particular embodiments. For example, the nozzles 32 and tubes 34 are generally illustrated as having a cylindrical shape; however, alternate embodiments within the scope of the present invention may include nozzles and tubes having virtually any geometric cross-section.

[0015] The nozzle 32 may extend axially from the end cover 16 through the end cap 20. A shroud 36 may circumferentially surround the nozzle 32 to define an annular passage 38 around the nozzle 32 and provide fluid communication through the end cap 20. The working fluid 14 may thus flow through the annular passage 38 and into the combustion chamber 24. In addition, the nozzle 32 may supply fuel, diluents, and/or other additives to the annular passage 38 to mix with the working fluid 14 before entering the combustion chamber 24. One or more vanes 40 may extend radially between the nozzle 32 and the shroud 36 to impart swirl to the fluids flowing through the annular passage 38 to enhance mixing of the fluids before reaching the combustion chamber 24.

[0016] The tubes 34 may be radially arranged across the end cap 20 in one or more tube bundles 42 of various shapes and sizes, with each tube bundle 42 in fluid communication with one or more fluid conduits 18. For example, as shown in Fig. 2, one or more dividers 44 may extend downstream from the fluid conduits 18 axially inside the end cap 20 between the upstream and downstream surfaces 28, 30 to separate or group the tubes 34 into pie-shaped tube bundles 42 radially arranged around the nozzle 32. One or more fluid conduits 18 may provide one or more fuels, diluents, and/or other additives to each tube bundle 42, and the type, fuel content, and reactivity of the fuel and/or diluent may vary for each fluid conduit 18 or tube bundle 42. In this manner, different types, flow rates, and/or additives may be supplied to one or more tube bundles 42 to allow staged fueling of the tubes 34 over a wide range of operating conditions.

[0017] A cap shield 46 may circumferentially surround

at least a portion of the upstream and downstream surfaces 28, 30 to at least partially define one or more plenums inside the end cap 20 between the upstream and downstream surfaces 28, 30. For example, as shown most clearly in Fig. 1, a barrier 48 may extend radially inside the end cap 20 between the upstream and downstream surfaces 28, 30 to at least partially define a fuel plenum 50 and a diluent plenum 52 inside the end cap 20. Specifically, the upstream surface 28, cap shield 46, and barrier 48 may define the fuel plenum 50, and the downstream surface 30, cap shield 46, and barrier 48 may define the diluent plenum 52. One or more of the tubes 34 may include one or more fuel ports 54 that provide fluid communication from the fuel plenum 50 into the tubes 34. The fuel ports 54 may be angled radially, axially, and/or azimuthally to project and/or impart swirl to the fuel flowing through the fuel ports 54 and into the tubes 34. The fuel may then mix with the working fluid 14 flowing through the tubes 34 before entering the combustion chamber 24.

[0018] Fig. 3 provides an enlarged cross-section view of the fluid conduit 18 shown in Fig. 1 according to one embodiment of the present invention. As shown, the fluid conduit 18 may include a fuel conduit 60 that surrounds a diluent conduit 62. The fuel conduit 60 may extend downstream from the casing 12 or end cover 16 to the end cap 20 to provide fluid communication to the fuel plenum 50 inside the end cap 20. The fuel conduit 60 may include a tortuous path for fuel flow inside the fuel conduit 60 to increase the distance that the fuel travels, and thus the heat transferred to the fuel from the surrounding working fluid 14 and/or other diluent, before the fuel reaches the fuel plenum 50 inside the end cap 20. For example, the fuel conduit 60 may include a plurality of baffles 64 or other flow guides arranged on an inside surface of the fuel conduit 60 that direct and/or disrupt the fuel flow inside the fuel conduit 60 to enhance the heat exchange from the working fluid 14 or other diluent to the fuel. In the particular embodiment shown in Fig. 3, the baffles 64 may be attached to or machined into the inside surface of the fuel conduit 60 to create a spiral path for fuel flow around the diluent conduit 62.

[0019] The diluent conduit 62 may extend generally axially inside the fuel conduit 60 between the end cover 16 and the end cap 20 to provide fluid communication to the diluent plenum 52. Possible diluents supplied through the diluent conduit 62 may include, for example, water, steam, working fluid, fuel additives, various inert gases such as nitrogen, and/or various non-flammable gases such as carbon dioxide or combustion exhaust gases supplied to the combustor 10. The diluent may be supplied to the diluent conduit 62 through the end cover 16 from an external source. Alternately, or in addition, a bypass passage 66 in the end cover 16 may provide fluid communication for a portion of the working fluid 14 to flow into the diluent conduit 62 to heat the fuel flowing around the diluent conduit 62. After reaching the end cap 20, the working fluid 14 or other diluent may flow into the

diluent plenum 52 and around the tubes 34 to convectively cool to tubes 34. The working fluid 14 or other diluent may then flow through one or more diluent passages 68 in the downstream surface 30 and into the combustion chamber 24.

[0020] A plurality of turbulators of various shapes and sizes may be arranged on or around the fuel and/or diluent conduits 60, 62 to disrupt the laminar flow of the working fluid 14 or other diluent across these surfaces. For example, as shown in Fig. 3, turbulators 70 may be radially arranged around the outside surface of the fuel conduit 60 and/or the inside surface of the diluent conduit 62 to reduce the laminar layer formed on these surfaces and thereby enhance the heat transfer to the fuel flowing through the fuel conduit 60.

[0021] The temperature of the fuel and working fluid 14 flowing around and through the combustor 10 may vary considerably during operations, causing the casing 12, fluid conduits 18, and/or tubes 34 to expand or contract at different rates and by different amounts. As a result, a flexible coupling 72 may be included in one or more fuel and/or diluent conduits 60, 62 between the end cover 16 and the end cap 20. The flexible coupling 72 may include one or more expansion joints or bellows that accommodate axial displacement by the casing 12, fluid conduits 18, and/or tubes 34 caused by thermal expansion or contraction. One of ordinary skill in the art will readily appreciate that alternate locations and/or combinations of flexible couplings 72 are within the scope of various embodiments of the present invention, and the specific location or number of flexible couplings 72 is not a limitation of the present invention unless specifically recited in the claims.

[0022] The various embodiments shown and described with respect to Figs. 1-3 may also provide a method for supplying fuel to the combustor 10. The method may include, for example, flowing the working fluid 14 through the tubes 34 that extend axially through the end cap 20 and supplying fuel through the fuel conduit 60 into the end cap 20. The method may further include supplying the working fluid 14 or other diluent through the diluent conduit 62 that extends axially inside the fuel conduit 60 and swirling the fuel flowing through the fuel conduit 60 around the working fluid 14 or other diluent flowing through the diluent conduit 62. In particular embodiments, the method may further include disrupting the fluid flow across the outside surface of the fuel conduit 60 and/or the inside surface of the diluent conduit 62 and/or separating the fuel from the working fluid 14 or other diluent inside the end cap 20.

[0023] The various embodiments shown and described with respect to Figs. 1-3 provide one or more commercial and/or technical advantages over previous combustors. For example, the tortuous path for the fuel flow through the fuel conduit 60 enables the working fluid 14 or other diluent flowing inside the diluent conduit 62 or outside of the fuel conduit 60 to evenly heat the fuel before the fuel reaches the fuel plenum 50. The improved

heating of the fuel reduces thermal stresses in the tubes 34 and/or temperature and density variations in the fuel flowing through the tubes 34 to enhance flame stability, combustor performance, and/or undesirable emissions.

[0024] 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 languages of the claims.

Claims

1. A combustor (10), comprising:

- a. a casing (12) that encloses at least a portion of the combustor (10);
- b. a fuel conduit (60) that extends downstream from the casing (12); and
- c. a tortuous path for fuel flow inside the fuel conduit (40).

2. The combustor as in claim 1, wherein the tortuous path for fuel flow comprises a spiral path for fuel flow inside the fuel conduit (60).

3. The combustor as in claim 1 or 2, further comprising a plurality of baffles (64) arranged on an inside surface of the fuel conduit (60).

4. The combustor as in any of claims 1 to 3, further comprising a plurality of turbulators (70) arranged on an outside surface of the fuel conduit (60).

5. The combustor as in any of claims 1 to 4, further comprising a diluent conduit (62) that extends axially inside the fuel conduit (60).

6. The combustor as in claim 5, further comprising a diluent plenum (52) downstream from the fuel conduit (60), wherein the diluent conduit (62) provides fluid communication to the diluent plenum (50).

7. The combustor as in any preceding claim, further comprising a plurality of tubes (34) radially arranged across the combustor (70) and in fluid communication with the fuel conduit (60).

8. The combustor as in claim 7, further comprising a divider (44) that extends downstream from the fuel

conduit (60) to separate the plurality of tubes (34) into tube bundles (42).

9. The combustor as in any preceding claim, further comprising a fuel plenum (50) downstream from the fuel conduit (60), wherein the fuel conduit (60) provides fluid communication to the fuel plenum (50).

10. The combustor any preceding claim, further comprising:

- an end cover (16); and
- an end cap (20) axially separated from the end cover (16) and configured to extend radially across at least a portion of the combustor (10), wherein the end cap (20) comprises an upstream surface (28) axially separated from a downstream surface (30), and wherein the fuel conduit (60) extends from the end cover (16) to the end cap (20) to provide fluid communication to the end cap (20).

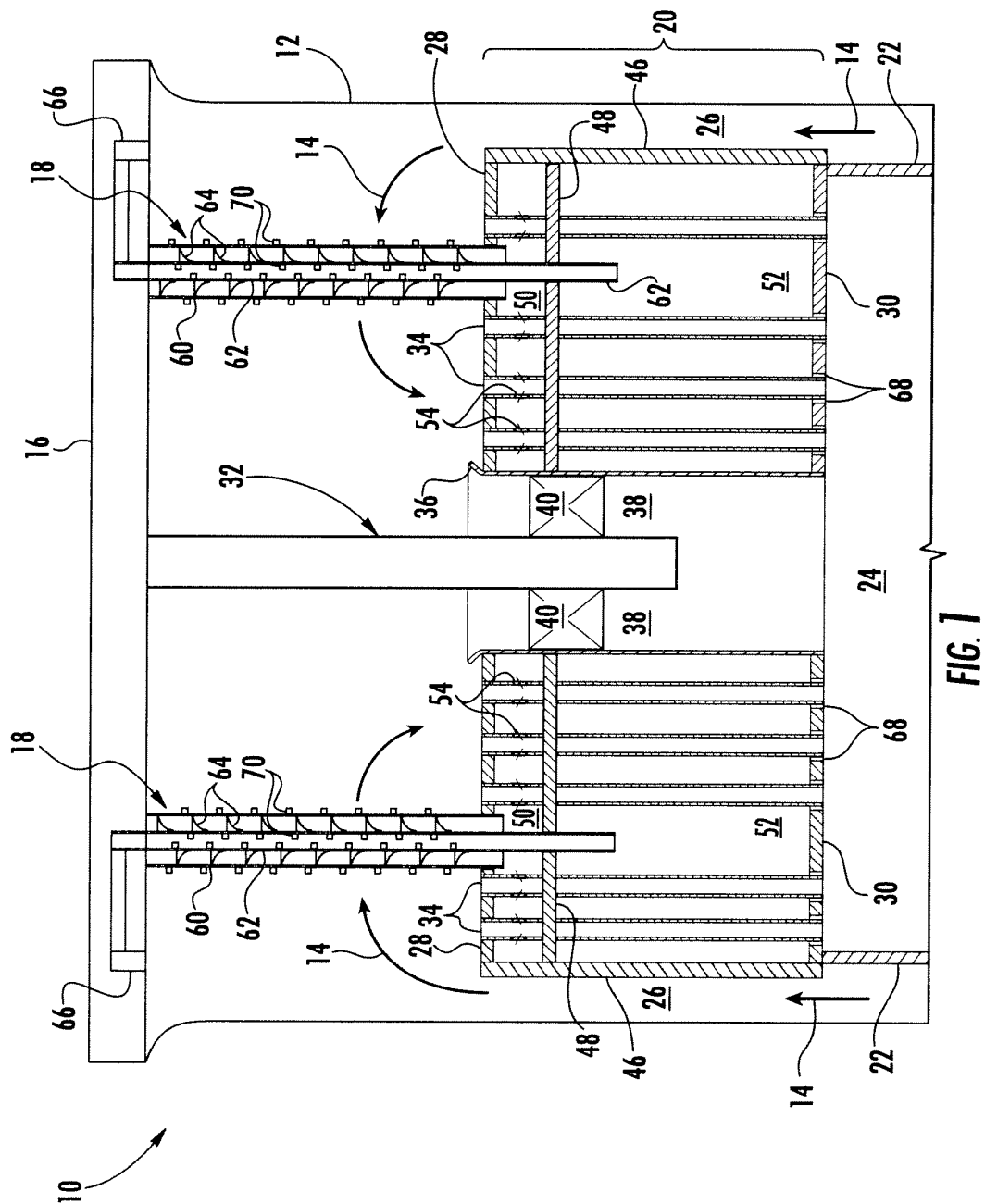
11. The combustor as in any preceding claim, further comprising a fuel nozzle (32) that extends axially through the end cap (20).

12. A method for supplying fuel to a combustor (10), comprising:

- a. flowing a working fluid (14) through a plurality of tubes (34) that extends axially through an end cap (20);
- b. supplying a fuel through a fuel conduit (60) into the end cap (20);
- c. supplying a diluent through a diluent conduit (62) that extends axially inside the fuel conduit (60); and
- d. swirling the fuel flowing through the fuel conduit (60) around the diluent flowing through the diluent conduit (62).

13. The method as in claim 12, further comprising disrupting a fluid flow across an outside surface of the fuel conduit (60).

14. The method as in claim 12 or 13, further comprising separating the fuel from the diluent inside the end cap (20).



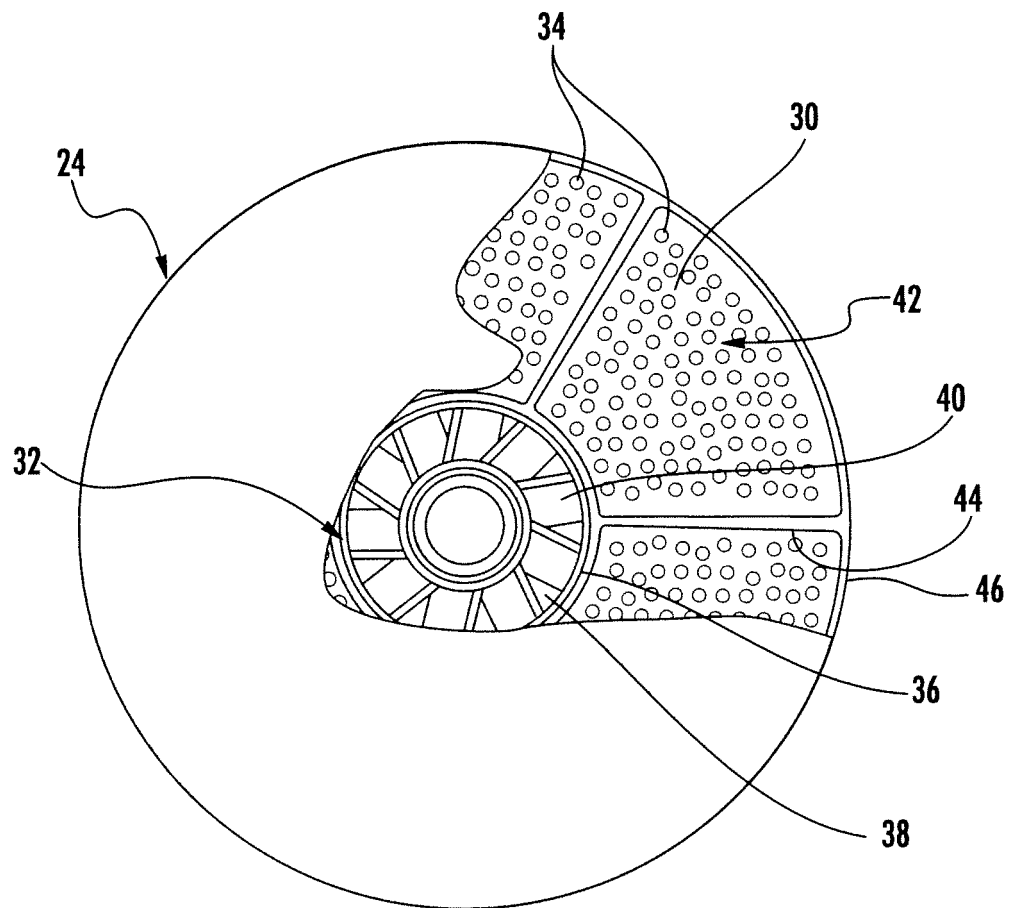


FIG. 2

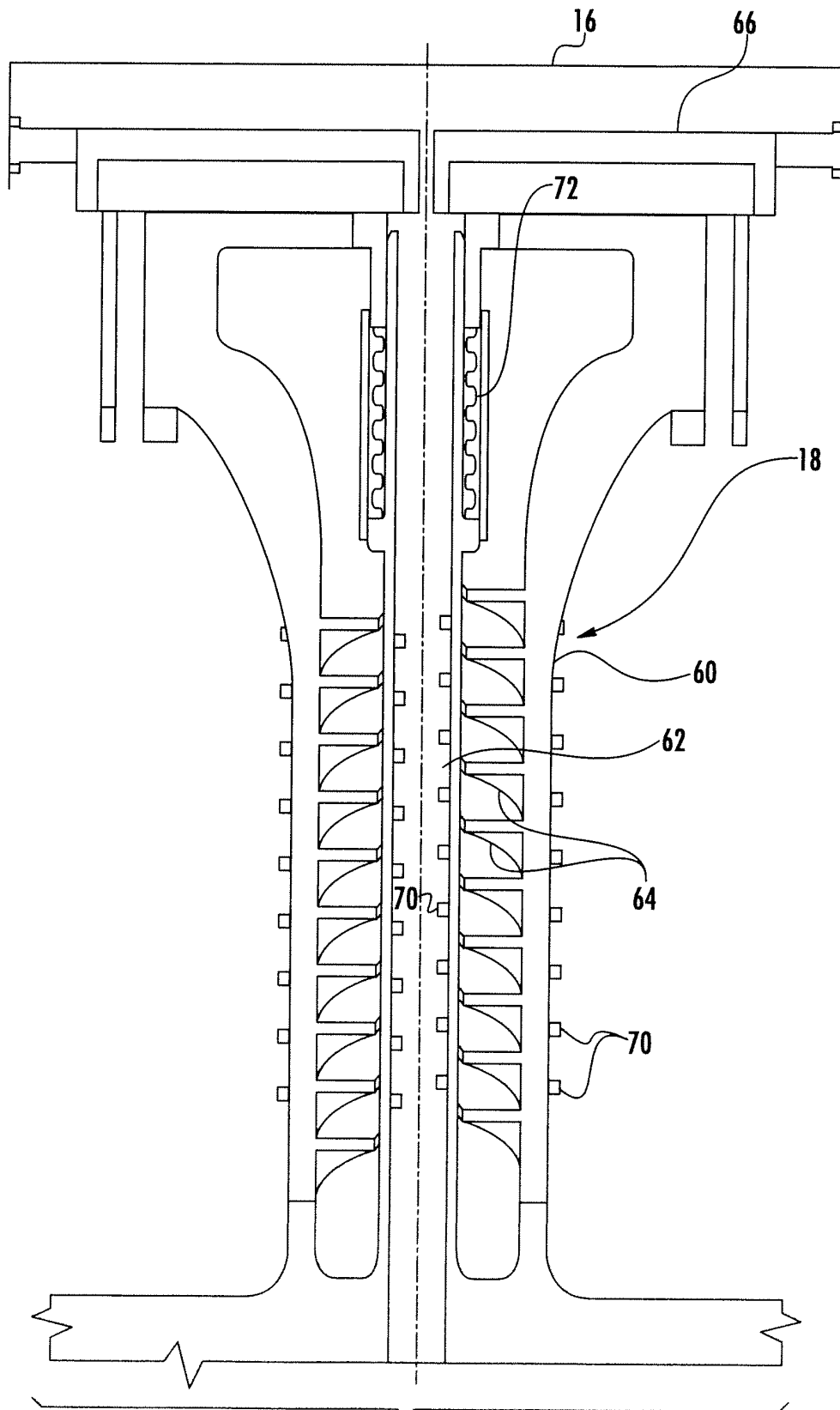


FIG. 3