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(54) **Combustor and method for supplying fuel to a combustor**

(57) A combustor (10) includes an end cap (18) having an upstream surface (26) axially separated from a downstream surface (28). A casing (12) circumferentially surrounds at least a portion of the end cap (18) to define an annular passage (20). A first tube bundle (40) extends from the upstream surface (28) through the downstream surface to provide fluid communication through the end cap (18). A first fuel conduit (44) is in fluid communication with the first tube bundle (40) to supply fuel through the annular passage (20) to the first tube bundle (40), and a liquid fuel supply (48) is in fluid communication with the first tube bundle (40) through the first fuel conduit (44). A method for supplying fuel to a combustor (10) includes flowing a working fluid (14) through a first tube bundle (40) and flowing a liquid fuel through an annular passage (20) surrounding the end cap (18) and into the first tube bundle (40).

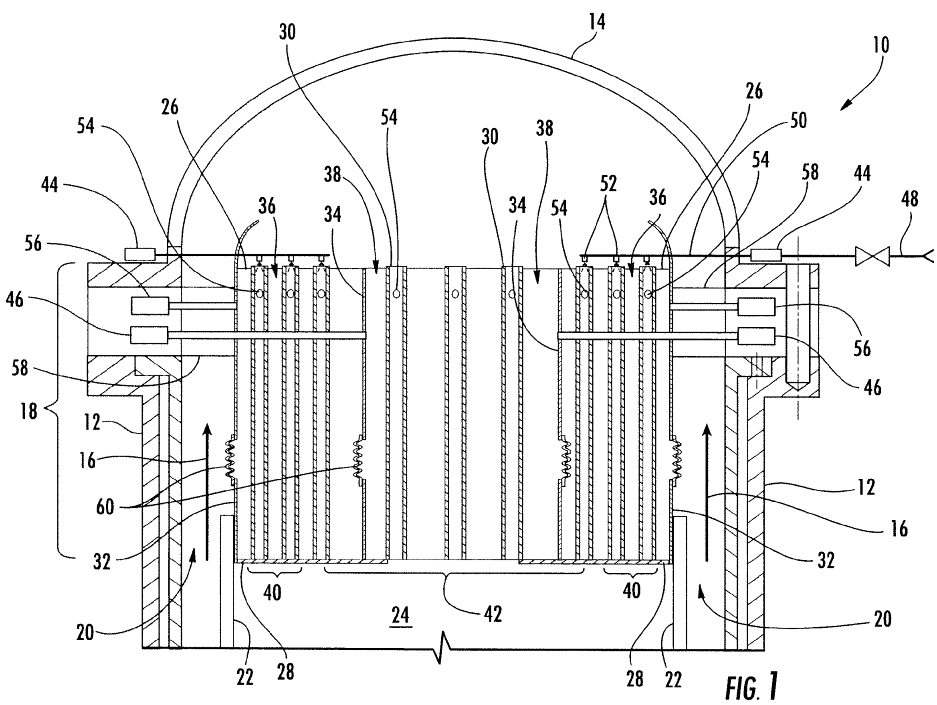

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention generally involves a combustor and method for supplying fuel to a 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. For example, gas turbines typically include one or more combustors to generate power or thrust. A typical gas turbine used to generate electrical power includes an axial compressor at the front, one or more combustors around the middle, and a turbine at the rear. Ambient air may be supplied to the compressor, and rotating blades and stationary vanes in the compressor progressively impart kinetic energy to the working fluid (air) to produce a compressed working fluid at a highly energized state. The compressed working fluid exits the compressor and flows through one or more nozzles into a combustion chamber in each combustor where the compressed working fluid mixes with fuel and ignites to generate combustion gases having a high temperature and pressure. The combustion gases expand in the turbine to produce work. For example, expansion of the combustion gases in the turbine may rotate a shaft connected to a generator to produce electricity.

[0003] Various design and operating parameters 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 the nozzles, possibly causing severe damage to the nozzles in a relatively short amount of time. In addition, localized hot streaks in the combustion chamber may increase the disassociation rate of diatomic nitrogen, increasing the production of nitrogen oxides (NO_X) at higher combustion gas temperatures. 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.

[0004] In a particular combustor design, a plurality of tubes may be radially arranged in an end cap to provide fluid communication for the working fluid and fuel flowing through the end cap and into the combustion chamber. The tubes enhance mixing between the working fluid and fuel to reduce hot streaks that can be problematic with higher combustion gas temperatures. As a result, the tubes are effective at preventing flashback or flame holding and/or reducing NO_X production, particularly at higher operating levels. However, an improved combustor and method for supplying fuel to the tubes that allows for staged fueling and/or operation of the tubes at varying operational levels with both liquid and gaseous fuels would be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0005] 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.

[0006] One aspect of the present invention is a combustor that includes an end cap that extends radially across at least a portion of the combustor, wherein the end cap comprises an upstream surface axially separated from a downstream surface. A casing circumferentially surrounds at least a portion of the end cap to define an annular passage between the end cap and the casing. A first tube bundle extends from the upstream surface through the downstream surface to provide fluid communication through the end cap. A first fuel conduit is in fluid communication with the first tube bundle to supply fuel through the annular passage to the first tube bundle, and a liquid fuel supply is in fluid communication with the first tube bundle through the first fuel conduit.

[0007] Another aspect of the present invention is a combustor that includes an end cap that extends radially across at least a portion of the combustor, wherein the end cap comprises an upstream surface axially separated from a downstream surface. A casing circumferentially surrounds at least a portion of the end cap to define an annular passage between the end cap and the casing. A plurality of tubes extend from the upstream surface through the downstream surface to provide fluid communication through the end cap. A barrier extends axially through the end cap to separate the plurality of tubes into a first tube bundle and a second tube bundle. A first fuel conduit is in fluid communication with the first tube bundle to supply fuel through the annular passage to the first tube bundle, and a liquid fuel supply is in fluid communication with the first tube bundle through the first fuel conduit.

[0008] The present invention also includes a method for supplying fuel to a combustor that includes flowing a working fluid through a first tube bundle that extends axially through an end cap that extends radially across at least a portion of the combustor. The method further includes flowing a liquid fuel through an annular passage surrounding the end cap and into the first tube bundle.

[0009] 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

[0010] 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 a first embodiment of the present invention;

Fig. 2 is a downstream axial view of the combustor shown in Fig. 1;

Fig. 3 is a simplified cross-section view of an exemplary combustor according to a second embodiment of the present invention; and

Fig. 4 is a downstream axial view of the end cap shown in Fig. 3.

DETAILED DESCRIPTION OF THE INVENTION

[0011] 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.

[0012] 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.

[0013] Various embodiments of the present invention provide a combustor and method for supplying fuel to a combustor. A plurality of tubes may be 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 liquid fuel may be supplied through an annular passage that surrounds the end cap and sprayed or injected into one or more tubes. In particular embodiments, the tubes may be grouped into multiple tube bundles that enable the combustor to be operated using liquid and/or gaseous fuels over a wide range of operating conditions without exceeding design margins associated with flashback, flame holding, and/or emissions limits. 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.

[0014] Fig. 1 shows a simplified cross-section view of an exemplary combustor 10 according to one embodiment of the present invention, and Fig. 2 provides a downstream axial view of the combustor 10 shown in Fig. 1. As shown, a casing 12 and an end cover 14 generally surround the combustor 10 to contain a working fluid 16 flowing to the combustor 10. An end cap 18 may extend radially across at least a portion of the combustor 10, and the casing 12 may circumferentially surround at least a portion of the end cap 18 to define an annular passage 20 between the end cap 18 and the casing 12. The end cap 18 and a liner 22 may define at least a portion of a combustion chamber 24 downstream from the end cap 18. In this manner, the working fluid 16 may flow through the annular passage 20 along the outside of the liner 22 to provide convective cooling to the liner 22. When the working fluid 16 reaches the end cover 14, the working fluid 16 may reverse direction to flow through the end cap 18 and into the combustion chamber 24.

[0015] The end cap 18 may include an upstream surface 26 axially separated from a downstream surface 28, and a plurality of tubes 30 may extend axially from the upstream surface 26 to the downstream surface 28 to provide fluid communication through the end cap 18. The particular shape, size, number, and arrangement of the tubes 30 may vary according to particular embodiments. For example, the tubes 30 are generally illustrated as having a cylindrical shape; however, alternate embodiments within the scope of the present invention may include tubes having virtually any geometric cross-section. In addition, the tubes 30 may be radially arranged across the end cap 18 in one or more tube bundles of various shapes and sizes, with each tube bundle having one or more separate fuel supplies. For example, multiple tubes 30 may be radially arranged around a single tube bundle, or multiple tube bundles may be radially arranged across the end cap 18. One or more fuel conduits may provide one or more fuels to each tube bundle, and the type, fuel content, and reactivity of the fuel may vary for each fuel conduit or tube bundle. In this manner, different fuels, different fuel types, and/or different fuel flow rates may be supplied to one or more tube bundles to allow for staged fueling of the tubes 30 over a wide range of operating conditions.

[0016] In the particular embodiment shown in Figs. 1 and 2, a cap shield 32 may circumferentially surround the upstream and downstream surfaces 26, 28 to define a fuel plenum inside the end cap 18. A barrier 34 may extend generally axially through the end cap 18 to separate the fuel plenum and tubes into first and second fuel plenums 36, 38 and first and second tube bundles 40, 42. First and second fuel conduits 44, 46 may extend radially through the casing 12 to supply fuel through the annular passage 20 to the first and second tube bundles 40, 42, respectively. For example, a liquid fuel supply 48 outside of the combustor 10 may supply liquid fuel to the first fuel conduit 44. The first fuel conduit 44 may include a radially extending fuel line 50 for each tube 30 in the first tube bundle 40. Each radially extending fuel line 50 may terminate at a fuel port 52 upstream from each tube 30 in the first tube bundle 40, and each fuel port 52 may be aligned with an axial centerline of each tube 30 in the first tube bundle 40. In this manner, the first fuel conduit 44 may provide fluid communication between the liquid fuel supply 48 and the first tube bundle 40, and the fuel ports 52 may spray the liquid fuel into each tube 30 in the first tube bundle 40 to atomize and mix the liquid fuel with the working fluid flowing through the tubes 30.

[0017] The second fuel conduit 46 may similarly provide fluid communication between another fuel supply (not shown) and the second tube bundle 42. Specifically, the second fuel conduit 46 may extend radially through the casing 12, annular passage 20, and cap shield 32 to supply fuel to the second fuel plenum 38. One or more of the tubes 30 in the second tube bundle 42 may include a fuel passage 54 that provides fluid communication through the tube 30 from the second fuel plenum 38. The fuel passages 54 may be angled radially, axially, and/or azimuthally to project and/or impart swirl to the fuel flowing through the fuel passages 54 and into the tubes 30. In this manner, the fuel from the second fuel conduit 46 may flow around the tubes 30 in the second tube bundle 42 to provide convective cooling to the second tube bundle 42 before flowing through the fuel passages 54 and mixing with the working fluid. The fuel-working fluid mixture from the second tube bundle 42 may then flow into the combustion chamber 24.

[0018] The combustor 10 may further include a third fuel conduit in fluid communication with one or more tube bundles. For example, as shown in Figs. 1 and 2, a third fuel conduit 56 may supply fuel through the annular passage 20 to the first tube bundle 40. One or more of the tubes 30 in the first tube bundle 40 may include a fuel passage 54 that provides fluid communication through the tube 30 from the first fuel plenum 36 as previously described. In this manner, the fuel from the third fuel conduit 56 may flow around the tubes 30 in the first tube bundle 40 to provide convective cooling to the first tube bundle 40 before flowing through the fuel passages 54 and mixing with the working fluid. The fuel-working fluid mixture from the first tube bundle 40 may then flow into the combustion chamber 24.

[0019] As shown most clearly in Fig. 1, at least one of an airfoil 58 or vane may surround at least a portion of the first, second, and/or third fuel conduits 44, 46, 56 in the annular passage 20 to reduce flow resistance of the working fluid flowing across the fuel conduits 44, 46, 56 in the annular passage 20. In particular embodiments, the airfoil 58 or vane may be angled to impart swirl to the working fluid flowing through the annular passage 20.

[0020] The temperature of the fuel and working fluid flowing around and through the tubes 30 may vary considerably during combustor 10 operations. As a result, the end cap 18 may further include one or more expansion joints or bellows between the upstream and downstream surfaces 26, 28 to allow for thermal expansion of the tubes 30 between the upstream and downstream surfaces 26, 28. For example, as shown in Fig. 1, an expansion joint 60 in the cap shield 32 and/or barrier 34 may allow for axial displacement of the upstream and downstream surfaces 26, 28 as the first and second tube bundles 40, 42 expand and contract. One of ordinary skill in the art will readily appreciate that alternate locations and/or combinations of expansion joints between the upstream and downstream surfaces 26, 28 are within the scope of various embodiments of the present invention, and the specific location or number of expansion joints 60 is not a limitation of the present invention unless specifically recited in the claims.

[0021] Fig. 3 shows a simplified cross-section view of an alternate embodiment of the present invention, and Fig. 4 provides a downstream axial view of the combustor 10 shown in Fig. 3. In this particular embodiment, the combustor 10 again includes a casing 12, end cover 14, end cap 18, annular passage 20, liner 22, combustion chamber 24, first and second tube bundles 40, 42, and various fuel conduits 44, 46, 58 as previously described with respect to the embodiment shown in Figs. 1 and 2.

[0022] In addition, the combustor 10 includes a fourth fuel conduit 62 that extends axially through the end cover 14 to provide fluid communication through the upstream surface 26 of the end cap 18. A shroud 64 may circumferentially surround the fourth fuel conduit 62, and one or more swirler vanes 66 may extend radially between the shroud 64 and the fourth fuel conduit 62. In this manner, the fourth fuel conduit 62 may supply additional fuel through the upstream surface 26 to mix with working fluid 16 flowing though the shroud 64, and the swirler vanes 66 may impart swirl to the fuel-working fluid mixture prior to entering the combustion chamber 24.

[0023] The various embodiments shown in Figs. 1-4 provide multiple combinations of methods for supplying fuel to the combustor 10. For example, the method may include flowing the working fluid 16 through the first tube bundle 40 and flowing the liquid fuel through the annular passage 20 surrounding the end cap 18 and into the first tube bundle 40. In particular embodiments, the method may include spraying the liquid fuel into the axial center of each tube 30 in the first tube bundle 40 and/or supplying the same or different fuel through other fuel conduits 46, 56 to the first and/or second tube bundles 40, 42. In still further embodiments, the method may include flowing the same or different fuel axially through yet another fuel conduit 62 and shroud 64 that provides fluid communication through the end cap 18 and into the combustion chamber 24. Each embodiment thus provides very flexible methods for providing staged fueling to various locations across the combustor 10 to enable the combustor 10 to operate over a wide range of operating conditions without exceeding design margins associated with flashback, flame holding, and/or emissions limits.

[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. an end cap (18) that extends radially across at least a portion of the combustor (10), wherein the end cap (18) comprises an upstream surface (26) axially separated from a downstream surface (28);
b. a casing (12) circumferentially surrounding at least a portion of the end cap (18) to define an annular passage (20) between the end cap (18) and the casing (12);
c. a first tube bundle (40) that extends from the upstream surface (26) through the downstream surface (28) to provide fluid communication through the end cap (18);
d. a first fuel conduit (44) in fluid communication with the first tube bundle (40) to supply fuel through the annular passage (20) to the first tube bundle (40); and
e. a liquid fuel supply (48) in fluid communication with the first tube bundle (40) through the first fuel conduit (44).

2. The combustor as in claim 1, wherein the first fuel conduit (44) comprises a radially extending fuel line (50) for each tube (30) in the first tube bundle (40).

3. The combustor as in claim 2, wherein each radially extending fuel line (50) terminates upstream from the first tube bundle (40).

4. The combustor as in claim 2 or 3, wherein each radially extending fuel line (50) includes a fuel port (52) aligned with an axial centerline of each tube (30) in the first tube bundle (44).

5. The combustor as in any of claims 1 to 4, further comprising a second tube bundle (42) that extends from the upstream surface (26) through the downstream surface (28) to provide fluid communication through the end cap (18) and a second fuel conduit (46) in fluid communication with the second tube bundle (42) to supply fuel to the second tube bundle (42).

6. The combustor as in claim 5, wherein the second fuel conduit (46) supplies fuel through the annular passage (20) to the second tube bundle (42).

7. The combustor as in any of claim 5 or 6, further comprising a third fuel conduit (56) in fluid communication with the first tube bundle (40) to supply fuel through the annular passage (20) to the first tube bundle (40).

8. The combustor as in any of claims 5 to 7, further comprising a shroud (64) that circumferentially surrounds the second fuel conduit (46), wherein the shroud (64) provides fluid communication through the end cap (18).

9. The combustor as in claim 9, further comprising a swirler vane (66) that extends between the shroud (64) and the second fuel conduit (46).

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

a. flowing a working fluid (14) through a first tube bundle (40) that extends axially through an end cap (18) that extends radially across at least a portion of the combustor (10); and
b. flowing a liquid fuel through an annular passage (20) surrounding the end cap (18) and into the first tube bundle (40).

11. The method as in claim 10, further comprising spraying the liquid fuel into the axial center of each tube (30) in the first tube bundle (40).

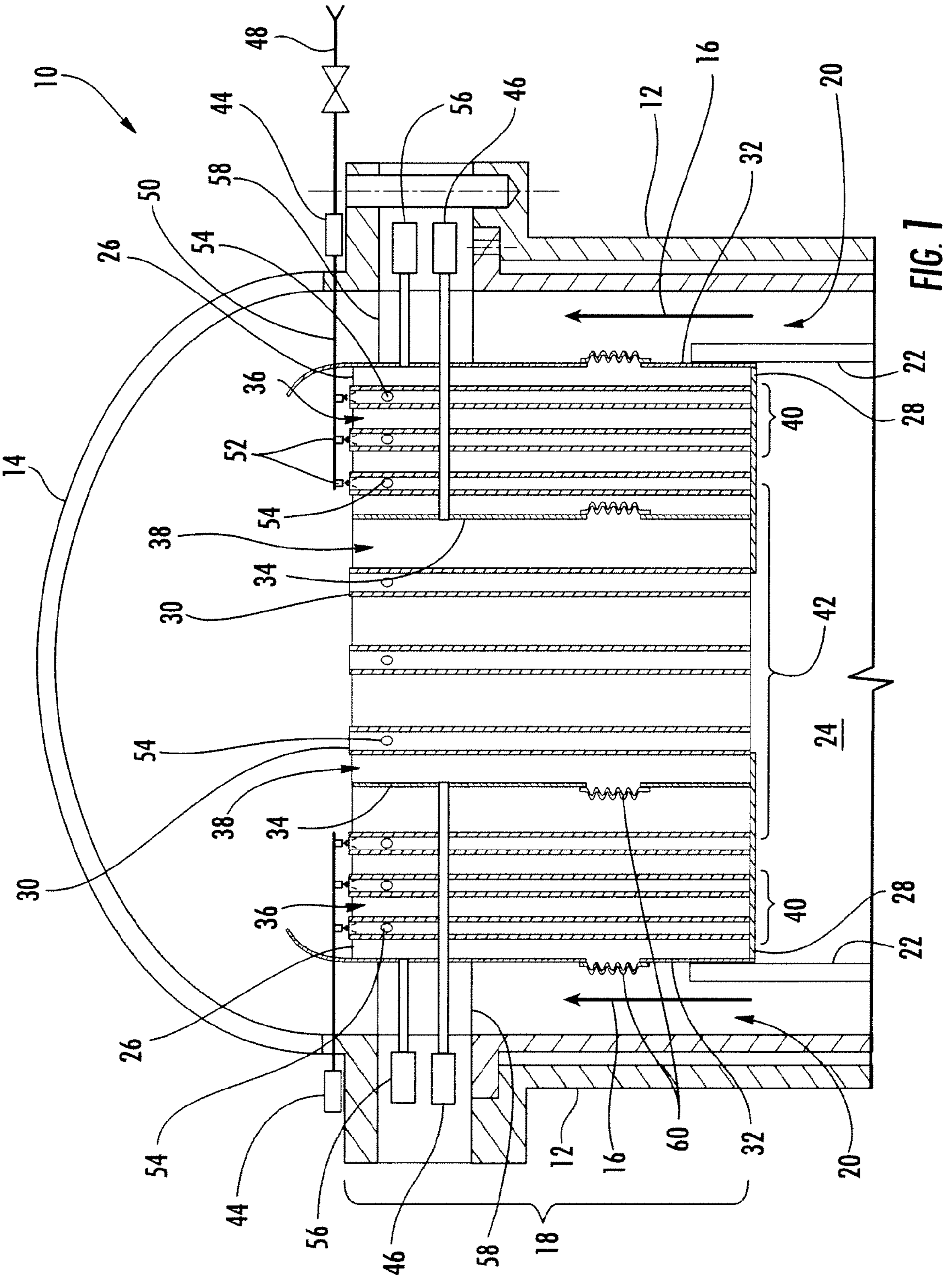
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FIG. 1

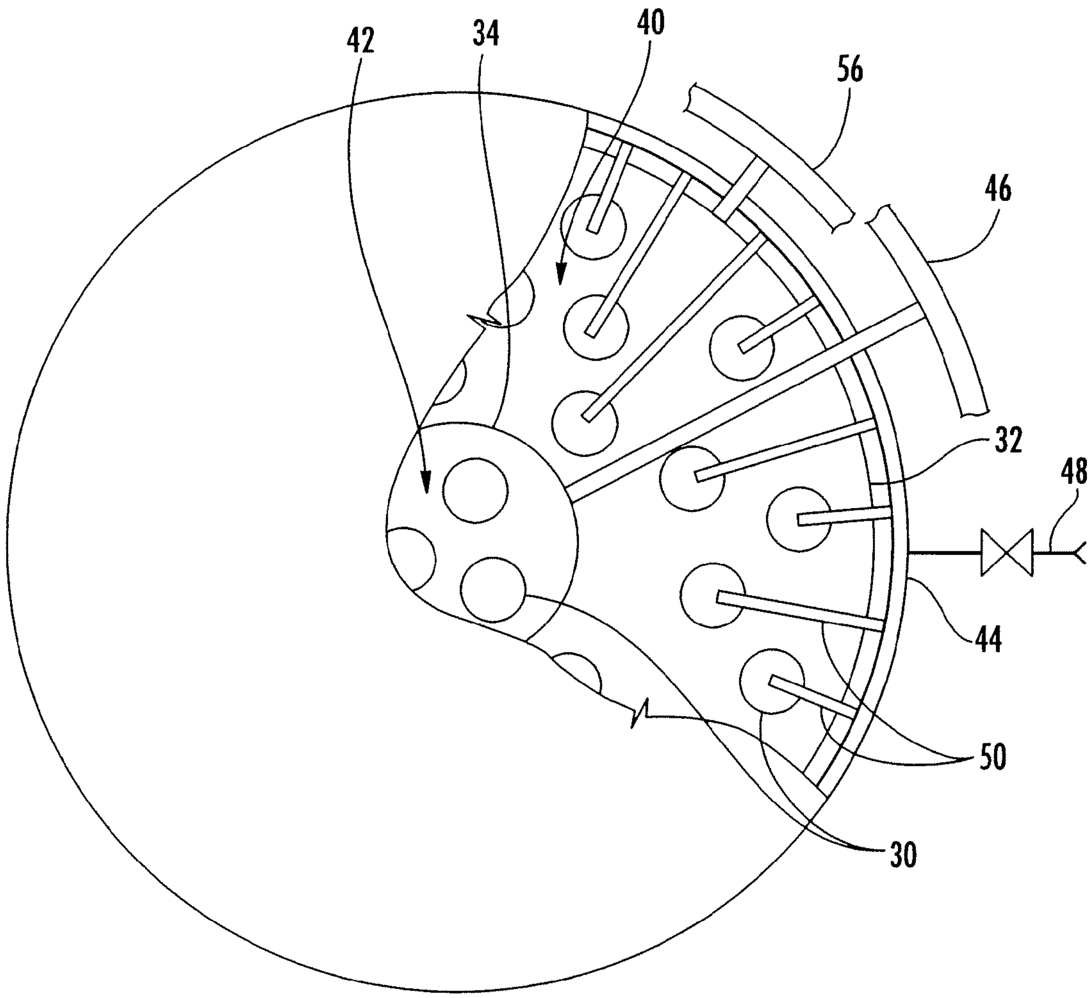

FIG. 2

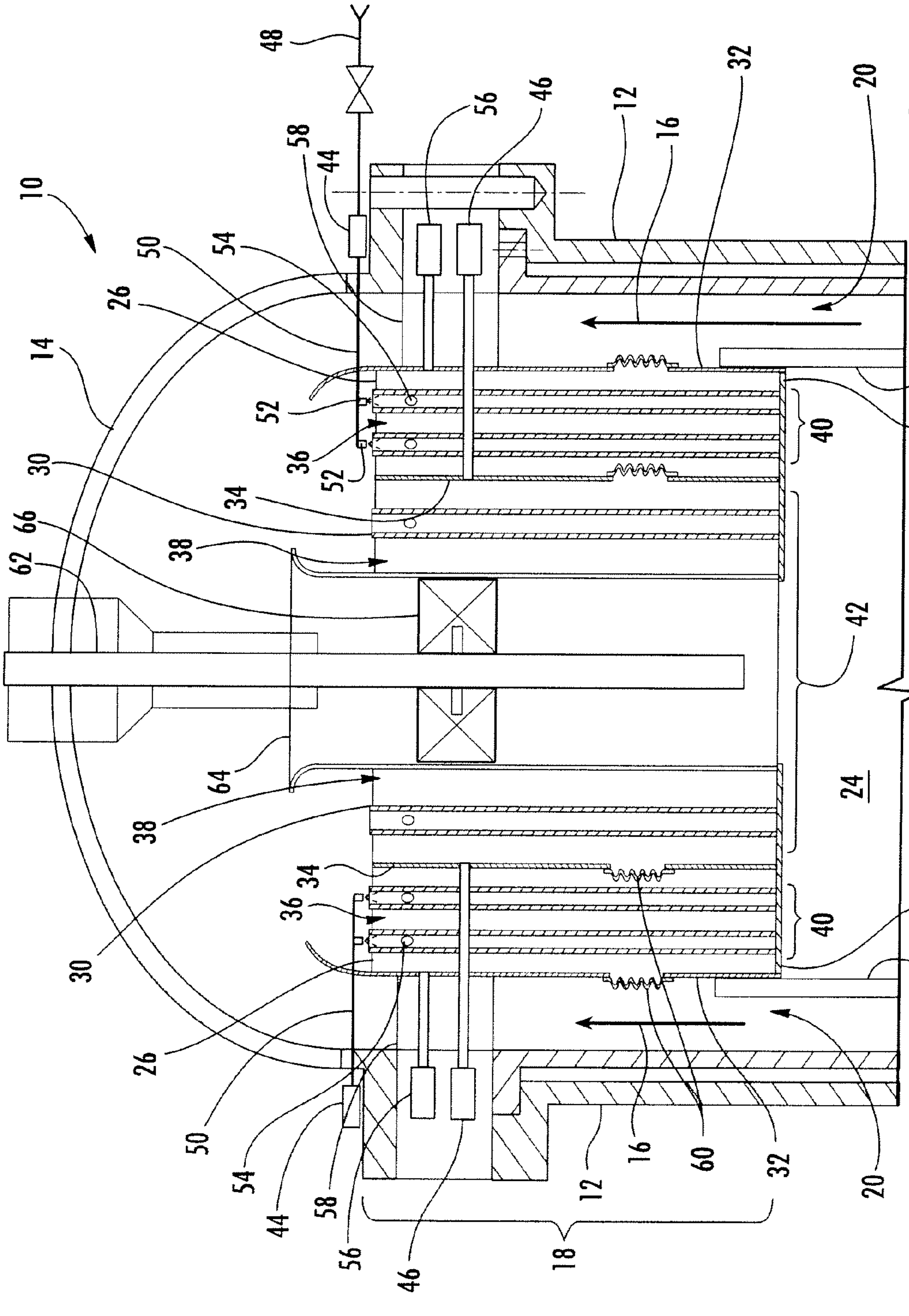
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FIG. 3

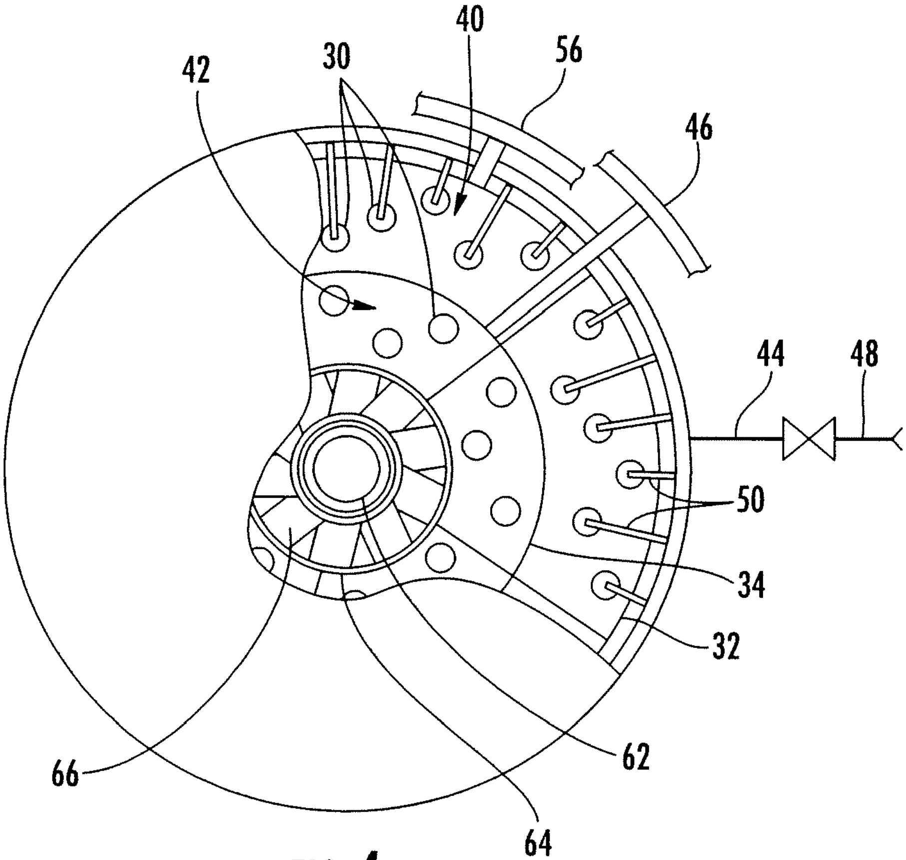

FIG. 4