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

(57) A combustor includes an end cover (16), an end cap (18) downstream from the end cover (16), and tubes (30) that extend through the end cap (18). An outer support tube (42) extends downstream from the end cover (16) and connects to an upstream surface (26) of the end cap (18). An inner support tube (40) extends downstream from the end cover (16) and connects to a downstream surface (28) of the end cap (18). A first plenum (50) surrounds the inner support tube (40) between the end cover (16) and the upstream surface (26) and extends radially between the upstream and downstream surfaces (26,28). A second plenum surrounds the first plenum (50) between the end cover (16) and the upstream surface (28) and extends radially between the upstream and downstream surfaces (16,28).

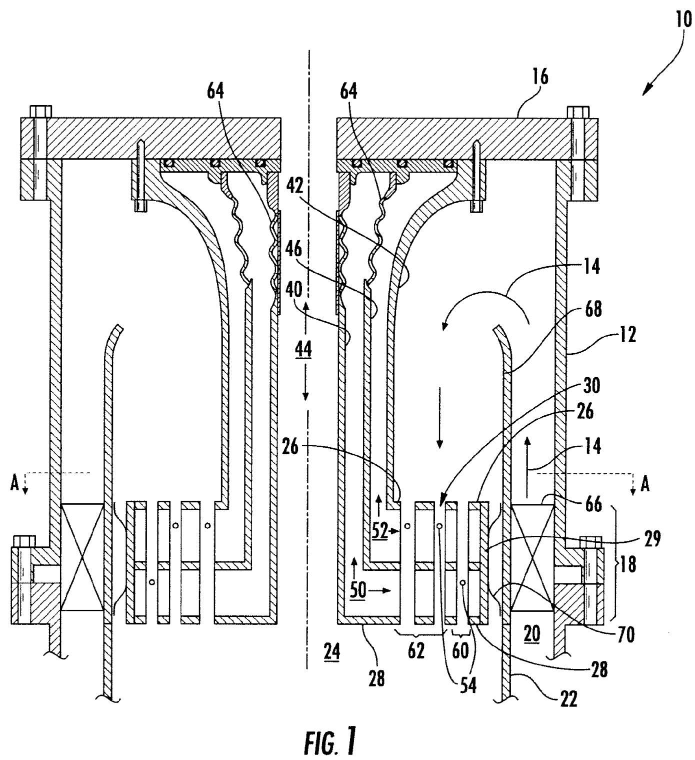

FIG. 1

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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 to flow through the end cap and into the combustion chamber. A fuel and/or a diluent may be supplied to the end cap and injected into the tubes to enhance mixing between the working fluid and fuel prior to combustion. The enhanced mixing between the working fluid and fuel prior to combustion reduces hot streaks in the combustion chamber 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 combustor that allows for staged fueling, multiple fuels, and/or diluents to be supplied to the tubes without obstructing the tubes 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 cover and an end cap downstream from the end cover that extends radially across at least a portion of the combustor. The end cap includes an upstream surface axially separated from a downstream surface. A plurality of tubes extends from the upstream surface through the downstream surface to provide fluid communication through the end cap. An outer support tube extends downstream from the end cover and connects to the upstream surface of the end cap. An inner support tube extends downstream from the end cover and connects to the downstream surface of the end cap. A first plenum surrounds the inner support tube between the end cover and the upstream surface, and the first plenum extends radially between the upstream and downstream surfaces. A second plenum surrounds the first plenum between the end cover and the upstream surface, and the second plenum extends radially between the upstream and downstream surfaces.

[0007] Another aspect of the present invention is a combustor that includes an end cover and a fuel conduit that extends downstream from the end cover. A downstream surface connected to the fuel conduit extends radially across at least a portion of the combustor. An upstream surface axially separated from the downstream surface extends radially across at least a portion of the combustor. A plurality of tubes extends from the upstream surface through the downstream surface to provide fluid communication through the upstream and downstream surfaces. A first plenum surrounds the fuel conduit between the end cover and the upstream surface, and the first plenum extends radially between the upstream and downstream surfaces. A second plenum that surrounds the first plenum between the end cover and the upstream surface, and the second plenum extends radially between the upstream and downstream surfaces.

[0008] The present invention may also resides in a method for supplying fuel to a combustor. The method includes flowing a working fluid through a plurality of tubes radially arranged in an end cap, wherein the end cap extends radially across at least a portion of the combustor. The method further includes flowing at least one of a first fuel or a first diluent through a first plenum, wherein the first plenum is at least partially defined by an inner support tube that connects to a downstream surface of the end cap, and flowing at least one of a second fuel or a second diluent through a second plenum that circumferentially surrounds at least a portion of the first plenum, wherein the second plenum is at least partially defined by an outer support tube that connects to an upstream surface of the end cap.

[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 one embodiment of the present invention; and

Fig. 2 is a downstream cross-section view of the combustor shown in Fig. 1 taken along line A-A.

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. The combustor generally includes a plurality of tubes radially arranged in an end cap to enhance mixing between a working fluid and fuel prior to combustion. In particular embodiments, an inner and an outer support may connect to the end cap, and multiple plenums may supply one or more fuels and/or diluents to the end cap to flow through the tubes. In other particular embodiments, a fuel conduit may connect to the end cap to support the end cap, and plenums surrounding the fuel plenum may supply one or more fuels and/or diluents to the end cap to flow through the tubes. In this manner, the various embodiments within the scope of the present invention may reduce flow disturbances through the tubes, increase structural support provided to the end cap, reduce manufacturing costs of the combustor, and/or enable staged fueling and/or multiple fuels and/or diluents to be supplied to the tubes 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 provides a simplified cross-section view of an exemplary combustor 10 according to one embodiment of the present invention, and Fig. 2 provides a downstream cross-section view of the combustor shown in Fig. 1 taken along line A-A. As shown, a casing 12 generally surrounds the combustor 10 to contain a working fluid 14 flowing to the combustor 10, and an end cover 16 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. 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 14 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 14 reaches the end cover 16, the working fluid 14 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 shroud 29 may surround the upstream and downstream surfaces 26, 28. 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 sets or groups of various shapes and sizes, with each set of tubes 30 having one or more separate fuel supplies. For example, multiple tubes 30 may be radially arranged around a fuel nozzle, or multiple sets of tubes 30 may be radially arranged across the end cap 18. One or more fluid conduits may provide one or more fuels, diluents, and/or other additives to each set of tubes 30, and the type, fuel content, and reactivity of the fuel and/or diluent may vary for each fluid conduit or set of tubes. In this manner, different types, flow rates, and/or additives may be supplied to one or more sets of tubes to enhance staged fueling of the tubes 30 over a wide range of operating conditions.

[0016] The combustor 10 may include one or more structures that extend downstream from the end cover 16 to support the end cap 18 and/or provide various fluid passages between the end cover 16 and the end cap 18. For example, as shown in Fig. 1, the combustor 10 may include an inner support tube 40 and an outer support tube 42 that extend downstream from the end cover 16. The inner support tube 40 may connect to the downstream surface 28 of the end cap 18 to partially support the end cap 18 axially inside the combustor 10. In particular embodiments, the inner support tube 40 may also function as or include a fuel conduit 40 that extends downstream from the end cover 16 to define a fuel plenum 44 inside the inner support tube 40. In this manner, the inner support tube/fuel conduit 40 may provide fluid communication from the end cover 16 to the end cap 18 to supply fuel to the end cap 18 and/or combustion chamber 24.

[0017] The outer support tube 42 may circumferentially surround the inner support tube 40 and connect to the upstream surface 26 of the end cap 18 to partially support the end cap 18 axially inside the combustor 10. In addition, the outer support tube 42 may define one or more fluid passages between the end cover 16 and the end cap 18. For example, as shown in Fig. 1, a barrier 46 may extend axially between the inner and outer support tubes 40, 42 upstream from the upstream surface 26 to partially define first and second plenums 50, 52 between the inner and outer support tubes 40, 42. Downstream from the upstream surface 26, the barrier 46 may extend radially between the first and second plenums 50, 52 to further separate the first and second plenums 50, 52 inside the end cap 18. As a result, the first plenum 50 may circumferentially surround the inner support tube/fuel conduit 40 between the end cover 16 and the upstream surface 26 before extending radially inside the end cap 18 between the upstream and downstream surfaces 26, 28. Similarly, the second plenum 52 may circumferentially surround the first plenum 50 between the end cover 16 and the upstream surface 26 before extending radially inside the end cap 18 between the upstream and downstream surfaces 26, 28. In the particular embodiment shown in Fig. 1, the first plenum 50 thus extends radially inside the end cap 18 downstream from the second plenum 52 with respect to the direction of the working fluid 14 through the end cap 18.

[0018] The first and second plenums 50, 52 provide fluid communication between the end cover 16 and the end cap 18 to allow various fuels, diluents, or other fluid additives to be supplied to the tubes 30. Each tube 30 in turn may include one or more ports 54 that provide fluid communication through the tube 30 from the first and/or second fuel plenums 50, 52. The ports 54 may be angled radially, axially, and/or azimuthally to project and/or impart swirl to the fluid flowing through the ports 54 and into the tubes 30. In addition, the particular number, size, and location of the ports 54 in the tubes 30 may be varied to allow staged fluid flow to the tubes 30. For example, as shown in Fig. 1, a first set of tubes 60 may include ports 54 that provide fluid communication with only the first plenum 50, and a second set of tubes 62 may include ports 54 that provide fluid communication with only the second plenum 52. In this manner, the working fluid 14 may flow outside of the end cap 18 through the annular passage 20 until it reaches the end cover 16 and reverses direction to flow through the tubes 30. In addition, a first fuel or diluent may flow around the tubes 30 in the first plenum 50 to provide convective cooling to the tubes 30 before flowing through the ports 54 and into the first set of tubes 60 to mix with the working fluid 14. Similarly, a second fuel or diluent may flow around the tubes 30 in the second plenum 52 to provide convective cooling to the tubes 30 before flowing through the ports 54 and into the second set of tubes 60 to mix with the working fluid 14. The mixture from each set of tubes 60, 62 may then flow into the combustion chamber 24.

[0019] The combustor 10 may also include additional structures for supporting the end cap 18 and/or allowing thermal expansion between the various components. For example, as shown in the particular embodiment illustrated in Figs. 1 and 2, the combustor 10 may include a flexible coupling 64 between the end cover 16 and the inner support tube/fuel conduit 40 and/or the barrier 46. The flexible coupling 64 may include an expansion joint, bellows, or other device that allows for axial displacement of the inner support tube/fuel conduit 40 and/or barrier 46 caused by thermal expansion and contraction of the outer support tube 42 and/or tubes 30.

[0020] One of ordinary skill in the art will readily appreciate that alternate locations and/or combinations of flexible couplings 64 are within the scope of various embodiments of the present invention, and the specific location or number of flexible couplings 64 is not a limitation of the present invention unless specifically recited in the claims.

[0021] As further shown in Figs. 1 and 2, the combustor

10 may also include a support 66 that extends radially between the end cap 18 and the casing 12 in the annular passage 20. The support 66 may have an airfoil shape to reduce flow resistance of the working fluid 14 flowing across the support 66 in the annular passage 20. In particular embodiments, the support 66 may be angled to impart swirl to the working fluid 14 flowing through the annular passage 20. Alternately or in addition, the combustor 10 may include a cap shield 68 that circumferentially surrounds the end cap 18 and/or a sliding engagement 70 between the end cap 18 and the cap shield 68.

[0022] The cap shield 68 may be connected to the support 66 and/or the shroud 29 that surrounds the end cap 18. The sliding engagement 70 may include a spring washer, a hula seal, or similar device and may extend continuously around the end cap 18 or in segments around the end cap 18, as shown in Fig. 2, to allow axial movement of the end cap 18 with respect to the cap shield 68 and/or support 66. In particular embodiments, the sliding engagement 70 may also provide a variable radial stiffness to the end cap 18 to allow slight modifications to the natural or resonant frequency of the end cap 18.

[0023] The various embodiments shown in Figs. 1 and 2 provide multiple combinations of methods for supplying fuel to the combustor 10. For example, the working fluid 14 may be supplied through the annular passage 20 and tubes 30 radially arranged in the end cap 18. A first fuel or a first diluent may be supplied through the first plenum 50 to the first set of tubes 60, and a second fuel or a second diluent may be supplied through the second plenum 52 to the second set of tubes 62. Alternately, or in addition, a third fuel or third diluent may be supplied through the fuel plenum 44 to the combustion chamber 24. The first, second, and third fuels and diluents may be the same or different, thus providing 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.

[0025] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A combustor, comprising:

a. an end cover;

b. a fuel conduit that extends downstream from the end cover;

c. a downstream surface connected to the fuel conduit, wherein the downstream surface extends radially across at least a portion of the combustor;

d. an upstream surface axially separated from the downstream surface, wherein the upstream surface extends radially across at least a portion of the combustor;

e. a plurality of tubes that extends from the upstream surface through the downstream surface to provide fluid communication through the upstream and downstream surfaces;

f. a first plenum that surrounds the fuel conduit between the end cover and the upstream surface, wherein the first plenum extends radially between the upstream and downstream surfaces; and

g. a second plenum that surrounds the first plenum between the end cover and the upstream surface, wherein the second plenum extends radially between the upstream and downstream surfaces.

2. The combustor as in clause 1, wherein the first plenum extends radially between the upstream and downstream surfaces downstream from the second plenum.

3. The combustor as in clause 1 or 2, wherein the first plenum is in fluid communication with a first set of the plurality of tubes and the second plenum is in fluid communication with a second set of the plurality of tubes.

4. The combustor as in any of clauses 1 to 3, further comprising a barrier that extends between the first and second plenums.

5. The combustor as in any of clauses 1 to 4, further comprising an outer support tube that extends downstream from the end cover and connects to the upstream surface.

6. The combustor as in any preceding clause, further comprising a flexible coupling between the end cover and the fuel conduit.

7. The combustor as in any preceding clause, further comprising a barrier that extends between the first and second plenums, wherein the barrier extends axially between the first and second plenums upstream from the upstream surface.

8. The combustor as in clause 7, wherein the barrier extends radially between the first and second ple-

nums downstream from the upstream surface.

Claims

1. A combustor (10), comprising:

   a. an end cover (16);
   b. an end cap (18) downstream from the end cover (16) 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);
   c. a plurality of tubes (30) that extends from the upstream surface (26) through the downstream surface (28) to provide fluid communication through the end cap (18);
   d. an outer support tube (42) that extends downstream from the end cover (16) and connects to the upstream surface (28) of the end cap (18);
   e. an inner support tube (40) that extends downstream from the end cover (16) and connects to the downstream surface (28) of the end cap (18);
   f. a first plenum (50) that surrounds the inner support tube (40) between the end cover (16) and the upstream surface (26), wherein the first plenum (50) extends radially between the upstream and downstream surfaces (26,28); and
   g. a second plenum (52) that surrounds the first plenum (50) between the end cover (16) and the upstream surface (26), wherein the second plenum (52) extends radially between the upstream and downstream surfaces (26,28).

2. The combustor as in claim 1, wherein the first plenum (50) extends radially inside the end cap (18) downstream from the second plenum (52).

3. The combustor as in claim 1 or 2, wherein the first plenum (50) is in fluid communication with a first set of the plurality of tubes (60) and the second plenum (52) is in fluid communication with a second set of the plurality of tubes (62).

4. The combustor as in any of claims 1 to 3, further comprising a barrier (46) that extends between the first and second plenums (50,52), wherein the barrier (46) extends axially between the first and second plenums (50,52) upstream from the upstream surface (26).

5. The combustor as in claim 4, wherein the barrier (46) extends radially between the first and second plenums (50,52) downstream from the upstream surface (26).

6. The combustor as in any of claims 1 to 5, further comprising a fuel plenum (44) inside the inner support tube (40).

7. The combustor as in any preceding claim, further comprising a casing (12) that circumferentially surrounds at least a portion of the end cap (18) to define an annular passage (20) between the end cap (18) and the casing (12) and a support extends (66) radially between the end cap (18) and the casing (12) in the annular passage (20).

8. The combustor as in any preceding claim, further comprising a cap shield (68) that circumferentially surrounds the end cap (18).

9. The combustor as in claim 8, further comprising a sliding engagement (70) between the end cap (18) and the cap shield (68).

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

    a. flowing a working fluid (14) through a plurality of tubes (30) radially arranged in an end cap (18), wherein the end cap (18) extends radially across at least a portion of the combustor (10);
    b. flowing at least one of a first fuel or a first diluent through a first plenum (50), wherein the first plenum (50) is at least partially defined by an inner support tube (40) that connects to a downstream surface (28) of the end cap (18); and
    c. flowing at least one of a second fuel or a second diluent through a second plenum (52) that circumferentially surrounds at least a portion of the first plenum (50), wherein the second plenum (52) is at least partially defined by an outer support tube (42) that connects to an upstream surface (26) of the end cap (18).

11. The method as in claim 10, further comprising flowing a third fuel inside the inner support tube (40).

12. The method as in claim 11, further comprising flowing at least one of the first fuel or first diluent radially inside the end cap (18) downstream from the second plenum (52).

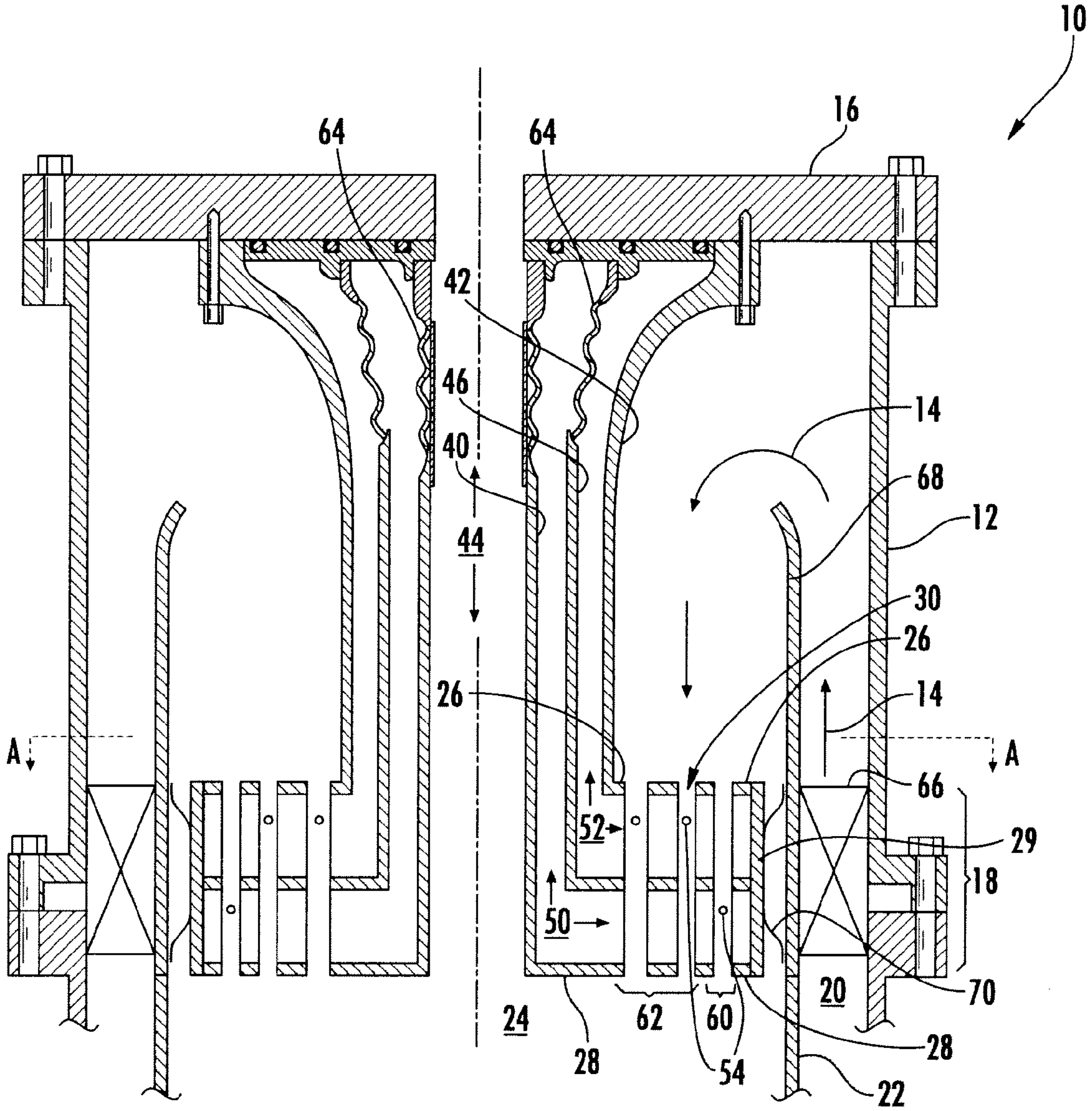
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FIG. 1

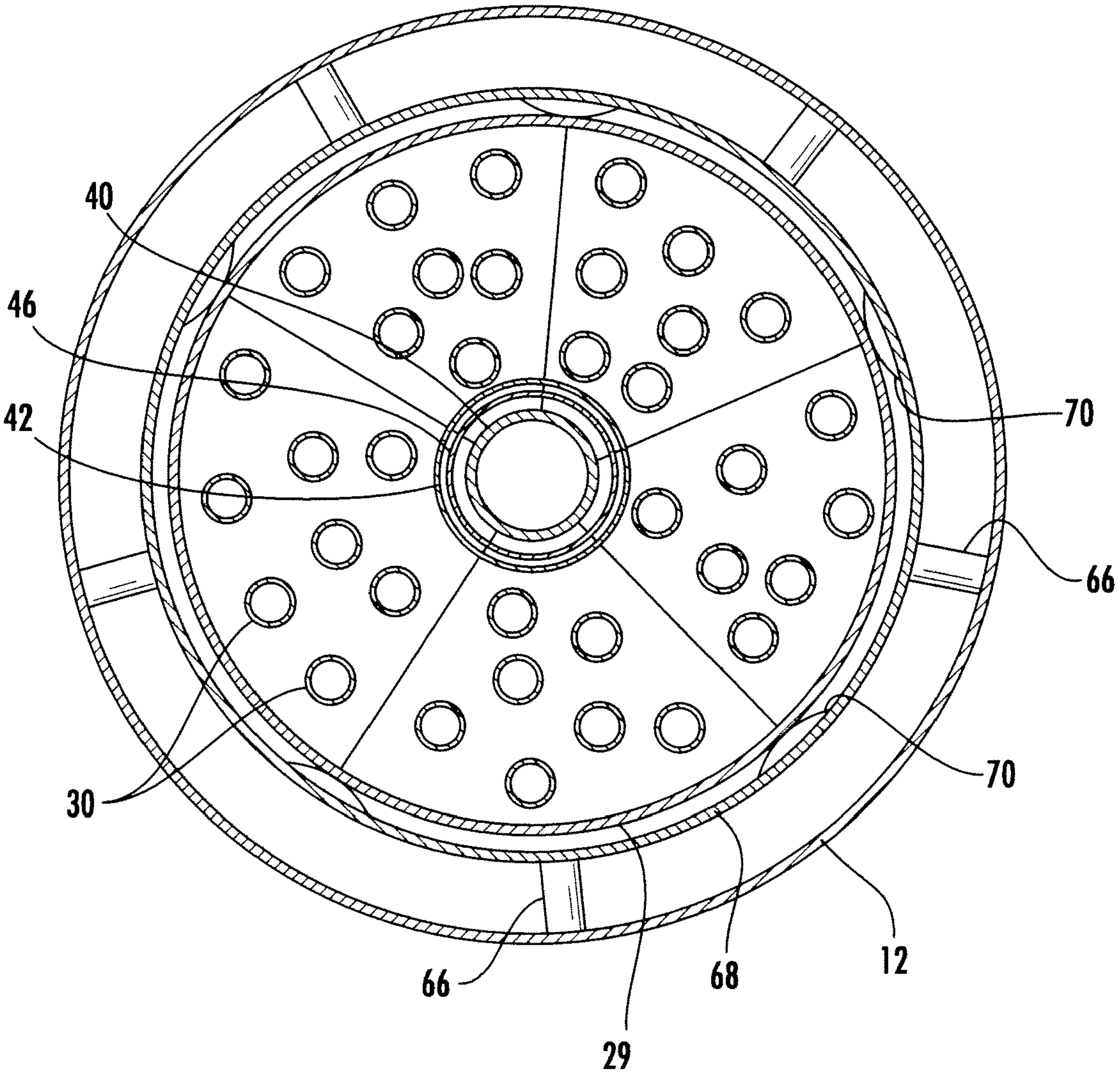

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 1369

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

F23R

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	31 January 2013	Theis, Gilbert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 19 1369

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