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(54) **Apparatus and method for a combustor**

(57) A combustor (14) includes an end cover (22), a combustion chamber (28) downstream of the end cover (22), and nozzles (24) disposed radially in the end cover (22). A fixed shroud (36) surrounds at least one of the nozzles (24) and extends downstream into the combustion chamber (28). The shroud includes an inner wall surface (38) and an outer wall surface (40). A method for operating a combustor (14) includes flowing compressed working fluid through nozzles (32, 34) into a combustion

chamber (28), flowing fuel through each nozzle (32) in a first subset of the nozzles (32, 34) into the combustion chamber (28), and igniting the fuel from each nozzle (32) in the first subset of nozzles (32, 34) in the combustion chamber (28). In addition, the method includes extending into the combustion chamber (28) a separate fixed shroud (36) around each nozzle (34) in a second subset of the nozzles (32, 34) and isolating fuel to each nozzle (34) in the second subset of nozzles (32, 34).

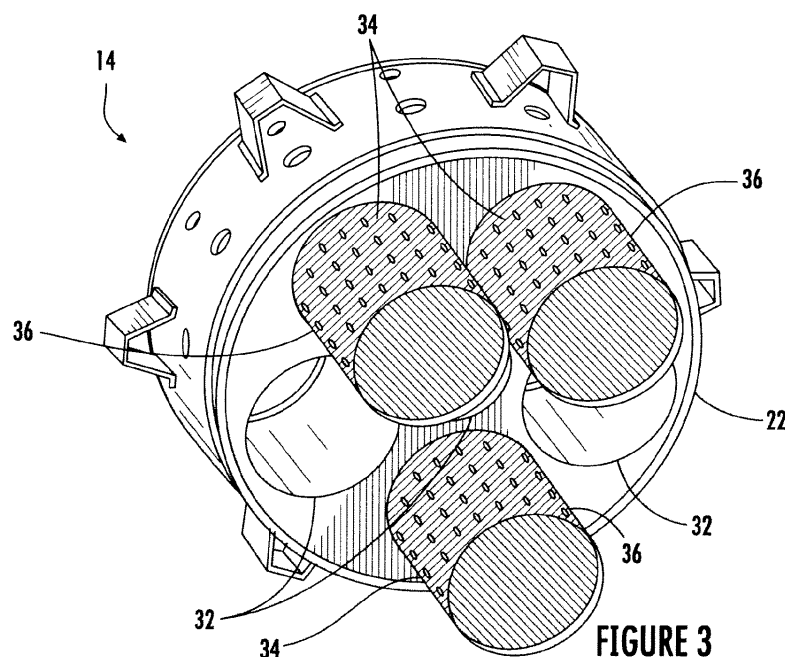


FIGURE 3

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Description

FIELD OF THE INVENTION

[0001] The present invention generally involves a combustor for a gas turbine. Specifically, the present invention describes and enables a combustor with multiple fuel nozzles that can operate in various turndown regimes to reduce fuel consumption.

BACKGROUND OF THE INVENTION

[0002] Gas turbines are widely used in commercial operations for power generation. A gas turbine compresses ambient air, mixes fuel with the compressed air, and ignites the mixture to produce high energy combustion gases that flow through a turbine to produce work. The turbine may drive an output shaft connected to a generator to produce electricity which is then supplied to a power grid. The turbine and generator must operate at a relatively constant speed, regardless of the amount of electricity being generated, to produce electricity at a desired frequency.

[0003] Gas turbines are typically designed to operate most efficiently at or near the designed base load. However, the power demanded of the gas turbine may often be less than the designed base load. For example, power consumption, and thus demand, may vary over the course of a season and even over the course of a day, with reduced power demand common during nighttime hours. Continuing to operate the gas turbine at its designed base load during low demand periods wastes fuel and generates excessive emissions.

[0004] One alternative to operating the gas turbine at base load during low demand periods is to simply shut down the gas turbine and start it back up once the power demand increases. However, starting up and shutting down the gas turbine creates large thermal stresses across many components that lead to increased repairs and maintenance. Moreover, gas turbines are often operated with additional auxiliary equipment in a combined cycle system. For example, a heat recovery steam generator may be connected to the turbine exhaust to recover heat from the exhaust gases to increase the overall efficiency of the gas turbine. Shutting down the gas turbine during low demand periods therefore also requires shutting down the associated auxiliary equipment, further increasing the costs associated with shutting down the gas turbine.

[0005] Another solution for operating a gas turbine during low demand periods is to operate the gas turbine under a turndown regime. In existing turndown regimes, the gas turbine still operates at the speed required to produce electricity at the desired frequency, and the flow rate of fuel and air to the combustors is reduced to reduce the amount of combustion gases generated in the combustors, thereby reducing the power produced by the gas turbine. However, the operating range of typical com-

pressors limits the extent to which the air flow may be reduced, thereby limiting the extent to which the fuel flow may be reduced while maintaining the optimum fuel to air ratio. At lower operating levels, one or more nozzles in each combustor are "idled" by securing fuel flow to the idled nozzles. The fueled nozzles continue to mix fuel with the compressed working fluid for combustion, and the idled nozzles simply pass the compressed working fluid through to the combustion chamber without any fuel for combustion. The turndown regime produces sufficient combustion gases to operate the turbine and generator at the required speed to produce electricity with the desired frequency, and the idled nozzles reduce the fuel consumption. When the power demand increases, fuel flow may be restored to all nozzles to allow the gas turbine to operate again at the designed base load.

[0006] Existing turndown regimes are limited in the amount of power reduction that can be achieved. For example, the compressed working fluid passing through the idled nozzles in a turndown regime mixes with the combustion gases from the fueled nozzles and tends to prematurely quench the fuel combustion in the combustion chamber. The incomplete combustion of fuel generates increased CO emissions that may exceed emissions limits. As a result, the minimum operating level during existing turndown regimes may need to be as high as 40-50% design base load to comply with emissions limits for CO and NOx.

BRIEF DESCRIPTION OF THE INVENTION

[0007] 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.

[0008] One embodiment of the present invention is a combustor that includes an end cover, a combustion chamber downstream of the end cover, and a plurality of nozzles disposed radially in the end cover. A fixed shroud surrounds at least one of the plurality of nozzles and extends downstream from the at least one of the plurality of nozzles into the combustion chamber. The fixed shroud includes an inner wall surface and an outer wall surface. A nozzle center body within the fixed shroud extends downstream from the at least one of the plurality of nozzles into the combustion chamber.

[0009] Another embodiment of the present invention is a combustor that includes an end cover, a combustion chamber downstream of the end cover, and a plurality of nozzles disposed radially in the end cover. A fixed shroud surrounds at least one of the plurality of nozzles and extends downstream from the at least one of the plurality of nozzles into the combustion chamber. The fixed shroud comprises a double-walled tube. A nozzle center body within the fixed shroud extends downstream from the at least one of the plurality of nozzles into the combustion chamber.

[0010] A further embodiment of the present invention

is a method for operating a combustor. The method includes flowing compressed working fluid through a plurality of nozzles into a combustion chamber and flowing fuel through each nozzle in a first subset of the plurality of nozzles into the combustion chamber. The method further includes igniting the fuel from each nozzle in the first subset of the plurality of nozzles in the combustion chamber. In addition, the method includes extending into the combustion chamber a separate fixed shroud around each nozzle in a second subset of the plurality of nozzles and isolating fuel to each nozzle in the second subset of the plurality of nozzles.

[0011] 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

[0012] 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:

Figure 1 shows a simplified cross-section of a gas turbine within the scope of the present invention;

Figure 2 shows a perspective view of the combustor shown in Figure 1 with the liner removed for clarity;

Figure 3 shows a perspective view of the combustor shown in Figure 2 being operated in a particular turn-down regime;

Figure 4 shows a perspective view of the shroud shown in Figure 3;

Figure 5 shows a side view of a nozzle center body and fixed shroud according to one embodiment of the present invention; and

Figures 6, 7, 8, and 9 illustrate idled and fueled nozzles in particular turn-down regimes within the scope of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] 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.

[0014] 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.

[0015] Figure 1 shows a simplified cross-section of a gas turbine 10 within the scope of the present invention. The gas turbine 10 generally includes a compressor 12 at the front, one or more combustors 14 around the middle, and a turbine 16 at the rear. The compressor 12 and the turbine 16 typically share a common rotor 18.

[0016] The compressor 12 imparts kinetic energy to a working fluid (air) by compressing it to bring it to a highly energized state. The compressed working fluid exits the compressor 12 and flows through a compressor discharge plenum 20 to the combustors 14. Each combustor 14 generally includes an end cover 22, a plurality of nozzles 24, and a liner 26 that defines a combustion chamber 28 downstream of the end cover 22. The nozzles 24 mix fuel with the compressed working fluid, and the mixture ignites in the combustion chamber 28 to generate combustion gases having a high temperature, pressure, and velocity. The combustion gases flow through a transition piece 30 to the turbine 16 where they expand to produce work.

[0017] Figure 2 shows a perspective view of the combustor 14 shown in Figure 1 with the liner 26 removed for clarity. As shown, the end cover 22 provides structural support for the nozzles 24. The nozzles 24 are generally arranged radially in the end cover 22 in various geometries, such as the five nozzles surrounding a single nozzle, as shown in Figure 2. Additional geometries within the scope of the present invention include six or seven nozzles surrounding a single nozzle or any suitable arrangement according to particular design needs. The nozzles 24 may have uniform diameters or differing diameters, as illustrated in Figure 2.

[0018] When operating at base load power, each nozzle 24 mixes fuel with the compressed working fluid. The mixture ignites downstream of the end cover 22 in the combustion chamber 28 to produce combustion gases. During periods of reduced power demand, the combustor 14 may be operated in a turn-down regime in which one or more nozzles 24 are "idled" by securing fuel flow to the idled nozzles.

[0019] Figure 3 shows the combustor 14 shown in Figure 2 being operated in a particular turn-down regime for a particular extended nozzle arrangement. In this particular turn-down regime and nozzle arrangement, three nozzles are fueled nozzles 32, and three nozzles are idled nozzles 34. Fuel and compressed working fluid flow through the fueled nozzles 32, while only compressed working fluid flows through the idled nozzles 34. In addition, a shroud 36 surrounds each idled nozzle 34 and extends downstream from each idled nozzle 34 into the combustion chamber. The shrouds 36 may be fixedly at-

tached to the idled nozzles 34 and/or the end cover 22. Each shroud 36 guides the compressed working fluid through a portion of the combustion chamber to prevent the compressed working fluid from the idled nozzles 34 from prematurely quenching the combustion. When the power demand increases, the combustor 14 may return to base load power levels by restoring fuel flow to the idled nozzles 34 and igniting the fuel mixture in the combustion chamber.

[0020] Figure 4 shows a perspective view of the shroud 36 shown in Figure 3. The shroud 36 may be made from any alloy, superalloy, coated ceramic, or other suitable material capable of withstanding combustion temperatures of more than 2,800-3,000 degrees Fahrenheit. The shroud 36 may be a multiple-walled construction with an inner wall surface 38 facing the associated idled nozzle, an outer wall surface 40 facing away from the associated idled nozzle, and a cavity 42 between the inner 38 and outer 40 wall surfaces. In alternate embodiments, the shroud 36 may be a single wall construction with the inner 38 and outer 40 wall surfaces being simply opposite sides of the single wall. Regardless of the construction, the shroud 36 may include a plurality of apertures 44 having a diameter between approximately 0.02 inches and 0.05 inches in either or both of the inner 38 and outer 40 wall surfaces.

[0021] A cooling fluid may be supplied through the cavity 42 and/or apertures 44 to cool the surfaces 38, 40 of the shroud 36. Suitable cooling fluids include steam, water, diverted compressed working fluid, and air. Other structures and methods known to one of ordinary skill in the art may be used to cool the shroud 36. For example, U.S. Patent Publication 2006/0191268 describes a method and apparatus for cooling gas turbine nozzles which may be adapted for use cooling shrouds as well.

[0022] Each shroud 36 has a slightly larger diameter than the associated idled nozzle and may be cylindrical in shape, as shown, or may have a convergent or divergent shape, depending on the particular embodiment and design needs. The length of the shroud 36 should be sufficient to extend the shroud 36 far enough into the combustion chamber to prevent the compressed working fluid from the idled nozzles from mixing with the combustion gases from the fueled nozzles and prematurely quenching the combustion. Suitable lengths may be 3 inches, 5 inches, 7 inches, or longer depending on the particular combustor design and anticipated turndown regime.

[0023] Figure 5 provides a side view of a fixed shroud 46 and nozzle center body 48 according to one embodiment of the present invention. As shown in Figure 5, the fixed shroud 46 and nozzle center body 48 extend downstream from the end cover 22 into the combustion chamber. During turndown operations, compressed air continues to flow through mixing or swirler vanes 50 and through the fixed shroud 46 into the combustion chamber, but fuel flow is secured to this nozzle. During base load operations, fuel flow is restored to this nozzle, and

the nozzle center body 48 enhances the stability of the flame at the end of the shroud 46.

[0024] The embodiment shown in Figure 5 produces a type of staged combustor that may result in additional emissions benefits compared to conventional, single staged combustors. For example, during reduced load or turndown operations, the fixed shroud 46 prevents the compressed air from the idled nozzles from mixing with and prematurely quenching the combustion gases from the fueled nozzles, thereby reducing CO emissions during turndown operations. During base load operations, the nozzle center body 48 maintains the flame at the end of the fixed shroud. This may reduce NOx emissions during base load operations due to a lower residence time of the combustion in the combustion chamber. In addition, during based load operations, the extended nozzle center body 48 distributes the heat release along the length of the combustion chamber which may result in reduced pressure pulsations normally inherent in combustors that premix the compressed working fluid with fuel prior to combustion.

[0025] Figures 6, 7, 8, and 9 illustrate fueled 32 and idled 34 nozzles in particular turndown regimes within the scope of the present invention. The shaded circles in each figure represent fueled nozzles 32, and the empty circles represent idled nozzles 34. A fixed shroud, as shown in Figures 4 and 5, surrounds each idled nozzle 34 and extends downstream from each idled nozzle 34 into the combustion chamber.

[0026] In Figure 6, the five nozzles around the perimeter are fueled nozzles 32, and the center nozzle is an idled nozzle 34. In this turndown regime, combustor exit temperature may be reduced by as much as 70 degrees Fahrenheit without exceeding any emissions requirements. In Figures 7, 8, and 9, additional nozzles are idled to further reduce the power consumption during the turndown regime. In each turndown regime illustrated in Figures 6, 7, 8, and 9, compressed working fluid from the compressor flows through each nozzle 32, 34. In each illustration, a first subset of the nozzles are operated as fueled nozzles 32 and continue to receive fuel for combustion in the combustion chamber. In each illustration, a second set of nozzles are operated as idled nozzles 34 by securing the fuel flow to the idled nozzles 34 and surrounding each idled nozzle 34 with a shroud that extends downstream from the idled nozzles 34 into the combustion chamber.

[0027] A combustor within the scope of the present invention may be operated in a turndown regime as follows. A flow of compressed working fluid may be supplied through each nozzle into the combustion chamber. A flow of fuel may be supplied through a first subset of the nozzles (i.e., the fueled nozzles) into the combustion chamber and ignited in the combustion chamber. One or more fixed shrouds may be extended around each nozzle in a second subset of the nozzles (i.e., the idled nozzles), and fuel may be isolated to each idled nozzle. If desired, each shroud may be cooled, for example, by flowing steam,

water, diverted compressed working fluid, and/or air through apertures in each shroud.

[0028] The combustor may transition to design base load operations by flowing fuel through each idled nozzle into the combustion chamber and igniting the fuel from each previously idled nozzle in the combustion chamber. The shrouds remain extended downstream from the previously idled nozzles into the combustion chamber.

[0029] 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.

[0030] For completeness, various aspects of the invention are now set out in the following numbered clauses:

1. A combustor, comprising:

a. an end cover;

b. a combustion chamber downstream of the end cover;

c. a plurality of nozzles disposed radially in the end cover;

d. a fixed shroud surrounding at least one of the plurality of nozzles and extending downstream from the at least one of the plurality of nozzles into the combustion chamber, wherein the fixed shroud includes an inner wall surface and an outer wall surface; and

e. a nozzle center body within the fixed shroud and extending downstream from the at least one of the plurality of nozzles into the combustion chamber.

2. The combustor of clause 1, wherein the fixed shroud extends at least 3 inches downstream from the at least one of the plurality of nozzles into the combustion chamber.

3. The combustor of clause 1, further including a plurality of apertures through at least one of the inner wall surface or the outer wall surface.

4. The combustor of clause 1, wherein the fixed shroud includes a cavity between the inner wall sur-

face and the outer wall surface.

5. The combustor of clause 1, wherein the fixed shroud is fixed to the end cover.

6. The combustor of clause 1, further including a plurality of fixed shrouds surrounding more than one of the plurality of nozzles, wherein the plurality of fixed shrouds extend downstream from the more than one of the plurality of nozzles into the combustion chamber.

7. The combustor of clause 6, further including a separate nozzle center body within each of the plurality of fixed shrouds and extending downstream from the more than one of the plurality of nozzles into the combustion chamber.

8. A combustor, comprising:

a. an end cover;

b. a combustion chamber downstream of the end cover;

c. a plurality of nozzles disposed radially in the end cover;

d. a fixed shroud surrounding at least one of the plurality of nozzles and extending downstream from the at least one of the plurality of nozzles into the combustion chamber, wherein the fixed shroud comprises a double-walled tube; and

e. a nozzle center body within the fixed shroud and extending downstream from the at least one of the plurality of nozzles into the combustion chamber.

9. The combustor of clause 8, wherein the fixed shroud extends at least 3 inches downstream of the at least one of the plurality of nozzles into the combustion chamber.

10. The combustor of clause 8, wherein the fixed shroud is fixed to the end cover.

11. The combustor of clause 8, wherein the fixed shroud includes a cavity in the double-walled tube.

12. The combustor of clause 8, further including a plurality of apertures through the double-walled tube.

13. The combustor of clause 8, further including a plurality of shrouds surrounding more than one of the plurality of nozzles, wherein the plurality of shrouds extend downstream from the more than one of the plurality of nozzles into the combustion cham-

ber.

14. The combustor of clause 13, further including a separate nozzle center body within each of the plurality of fixed shrouds and extending downstream from the more than one of the plurality of nozzles into the combustion chamber.

15. A method for operating a combustor, comprising:

a. flowing compressed working fluid through a plurality of nozzles into a combustion chamber;

b. flowing fuel through each nozzle in a first subset of the plurality of nozzles into the combustion chamber;

c. igniting the fuel from each nozzle in the first subset of the plurality of nozzles in the combustion chamber;

d. extending into the combustion chamber a separate fixed shroud around each nozzle in a second subset of the plurality of nozzles; and

e. isolating fuel to each nozzle in the second subset of the plurality of nozzles.

16. The method of clause 15, further including cooling each fixed shroud.

17. The method of clause 15, further including flowing air through apertures in each fixed shroud.

18. The method of clause 15, further including extending a separate nozzle center body within each separate fixed shroud, wherein each separate nozzle center body extends downstream from each nozzle in the second subset of the plurality of nozzles into the combustion chamber.

19. The method of clause 18, further including restoring fuel flow through each nozzle in the second subset of the plurality of nozzles.

20. The method of clause 19, further including igniting the fuel from each nozzle in the second subset of the plurality of nozzles in the combustion chamber.

Claims

1. A combustor (14), comprising:

- a. an end cover (22);
- b. a combustion chamber (28) downstream of the end cover (22);
- c. a plurality of nozzles (24) disposed radially in

the end cover (22);

d. a fixed shroud (36) surrounding at least one of the plurality of nozzles (24) and extending downstream from the at least one of the plurality of nozzles (24) into the combustion chamber (28), wherein the fixed shroud (36) includes an inner wall surface (38) and an outer wall surface (40); and

e. a nozzle center body (48) within the fixed shroud (36) and extending downstream from the at least one of the plurality of nozzles (24) into the combustion chamber (28).

2. The combustor (14) as in claim 1, wherein the fixed shroud (36) extends at least 3 inches downstream from the at least one of the plurality of nozzles (24) into the combustion chamber (28).

3. The combustor (14) as in any of claims 1 or 2, further including a plurality of apertures (44) through at least one of the inner wall surface (38) or the outer wall surface (40).

4. The combustor (14) as in any of claims 1-3, wherein the fixed shroud (36) includes a cavity (42) between the inner wall surface (38) and the outer wall surface (40).

5. The combustor (14) as in any of claims 1-4, wherein the fixed shroud (36) is fixed to the end cover (22).

6. The combustor (14) as in any of claims 1-5, further including a plurality of fixed shrouds (36) surrounding more than one of the plurality of nozzles (24), wherein the plurality of fixed shrouds (36) extend downstream from the more than one of the plurality of nozzles (24) into the combustion chamber (28).

7. The combustor (14) as in claim 6, further including a separate nozzle center body (48) within each of the plurality of fixed shrouds (36) and extending downstream from the more than one of the plurality of nozzles (24) into the combustion chamber (28).

8. A method for operating a combustor (14), comprising:

a. flowing compressed working fluid through a plurality of nozzles (32, 34) into a combustion chamber (28);

b. flowing fuel through each nozzle (32) in a first subset of the plurality of nozzles (32, 34) into the combustion chamber (28);

c. igniting the fuel from each nozzle (32) in the first subset of the plurality of nozzles (32, 34) in the combustion chamber (28);

d. extending into the combustion chamber (28) a separate fixed shroud (36) around each nozzle

(34) in a second subset of the plurality of nozzles (32, 34); and
e. isolating fuel to each nozzle (34) in the second subset of the plurality of nozzles (32, 34).

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9. The combustor of claim 8, wherein the fixed shroud extends at least 3 inches downstream of the at least one of the plurality of nozzles into the combustion chamber.

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10. The combustor of claim 8, wherein the fixed shroud is fixed to the end cover.

11. The method of claim 8, further including extending a separate nozzle center body (48) within each separate fixed shroud (36), wherein each separate nozzle center body (48) extends downstream from each nozzle (34) in the second subset of the plurality of nozzles (32, 34) into the combustion chamber (28).

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12. The method of claim 9, further including restoring fuel flow through each nozzle (34) in the second subset of the plurality of nozzles (32, 34).

13. The method of claim 12, further including igniting the fuel from each nozzle in the second subset of the plurality of nozzles in the combustion chamber.

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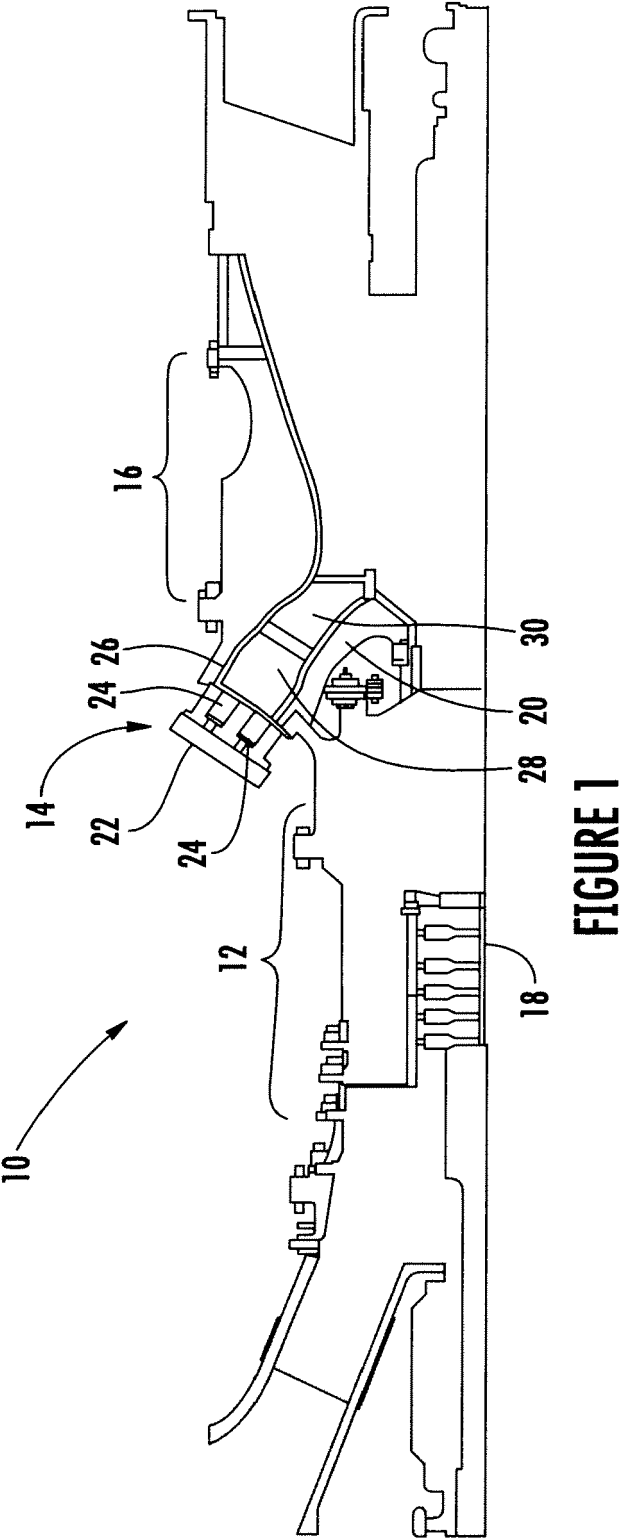
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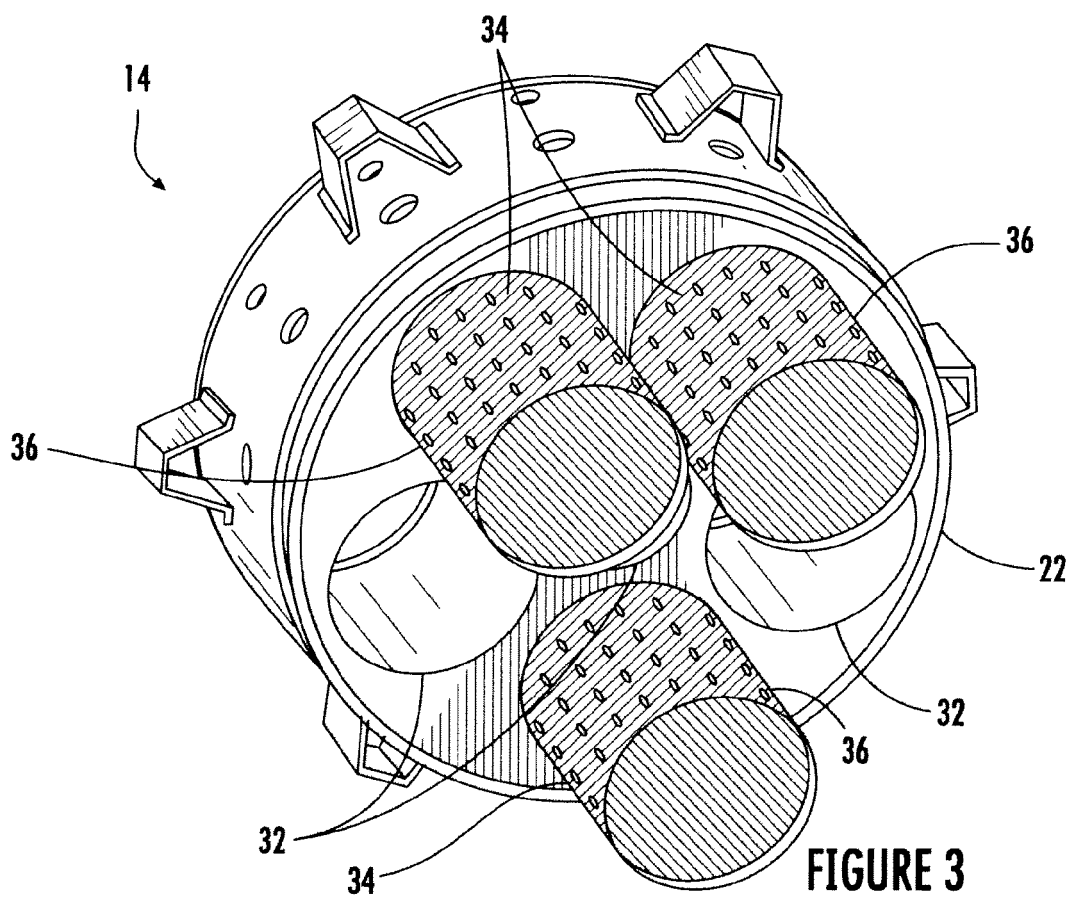
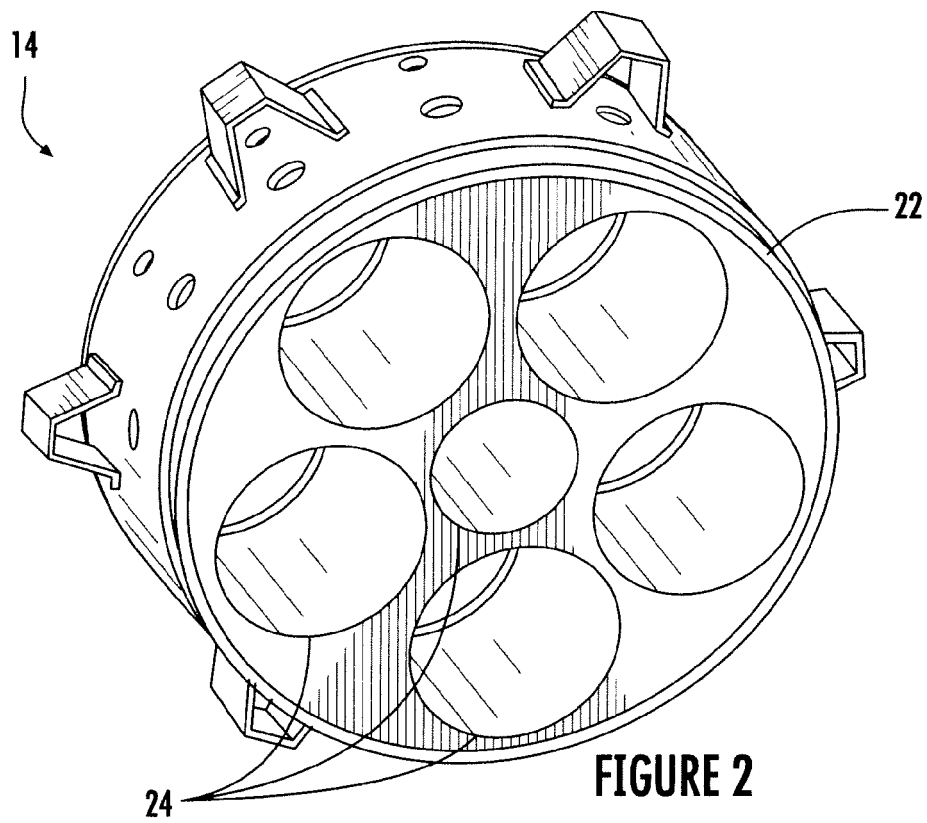
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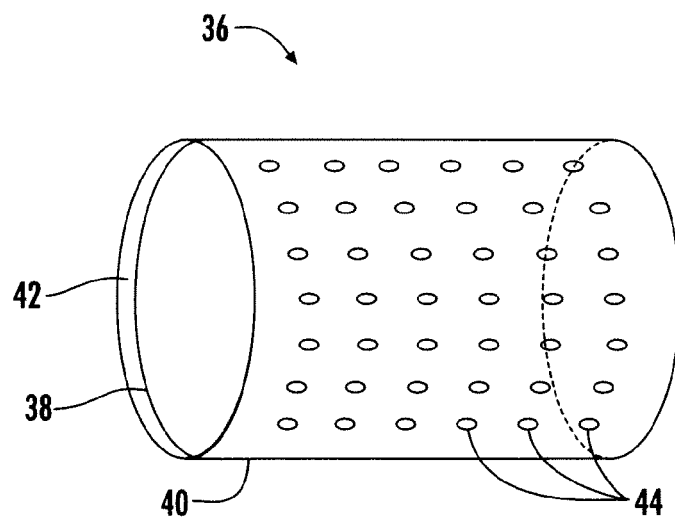


FIGURE 4

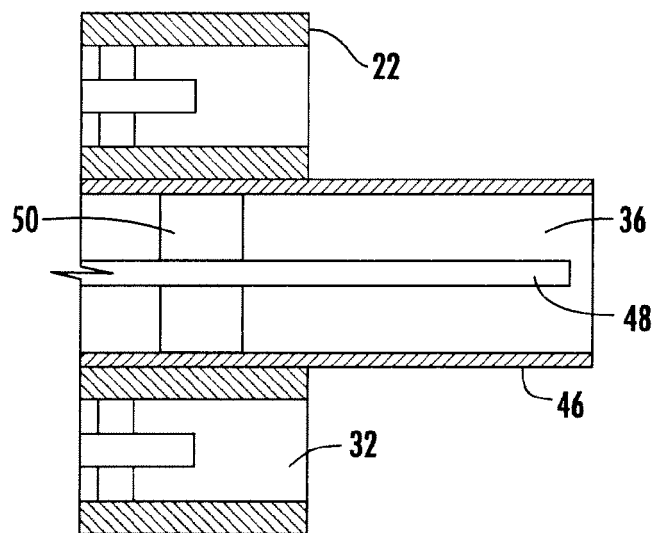


FIGURE 5

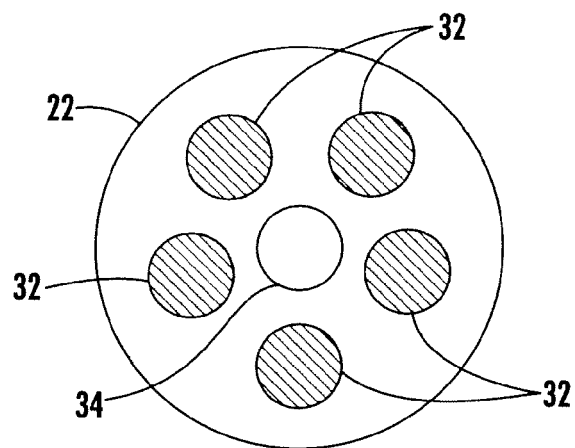


FIGURE 6

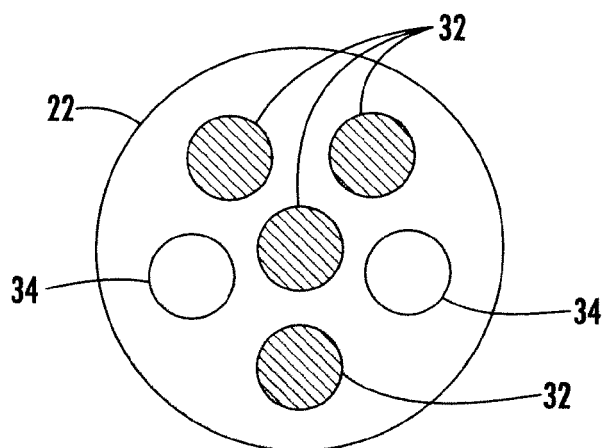


FIGURE 7

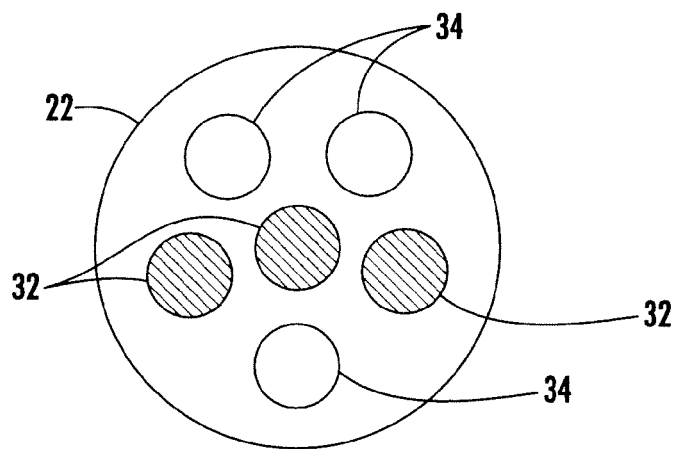


FIGURE 8

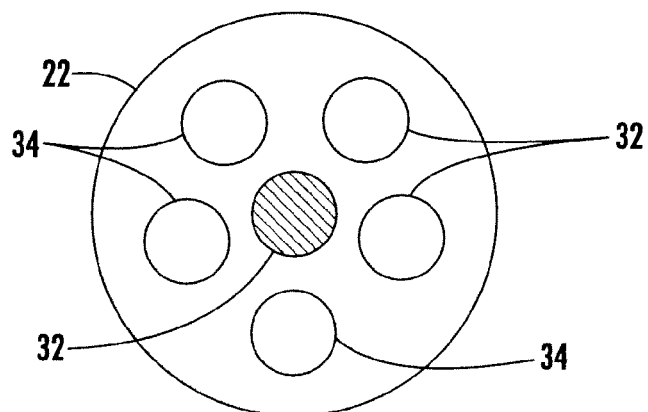


FIGURE 9



EUROPEAN SEARCH REPORT

Application Number
EP 11 15 9343

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 427 446 B1 (KRAFT ROBERT J [US] ET AL) 6 August 2002 (2002-08-06)	1-5	INV. F23R3/34
A	* column 4, line 11 - column 8, line 8; figures 2,3,7-9 *	6,8	
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A	* page 3, paragraph 3 - page 6, paragraph 4; figures 1-3 *	6,8	
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F23R
Place of search		Date of completion of the search	Examiner
Munich		29 June 2011	Theis, Gilbert
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EP 11 15 9343

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29-06-2011

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