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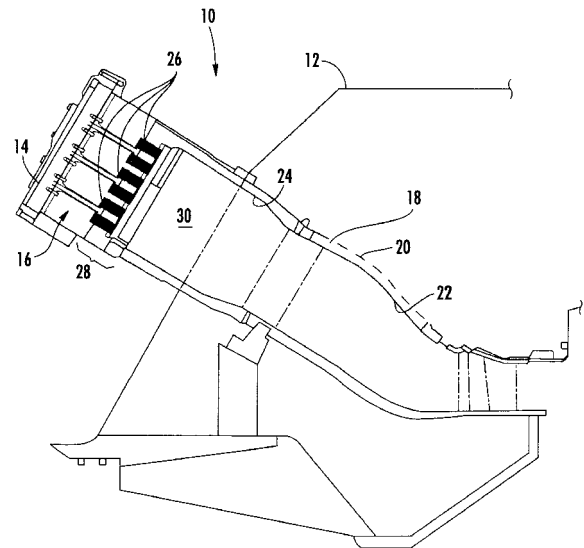
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(54) **Combustor and method for conditioning flow through a combustor**

(57) A combustor (10) includes an end cover (14) and a casing (12) adjacent to the end cover (14), wherein the end cover (14) and casing (12) at least partially define a volume (16) inside the combustor (10). The combustor (10) further includes an end cap (28) that extends radially across at least a portion of the combustor (10), at least one nozzle (26) arranged in the end cap (28) to provide fluid communication through the end cap (28), and means for conditioning flow through the volume (16). A method for conditioning flow through a combustor (10) includes flowing a working fluid through a volume (16) at least partially defined by an end cover (14), a casing (12), and an end cap (28) that extends radially across at least a portion of the combustor (10) and flowing the working fluid across an annular insert (40) adjacent to the end cover (14).



**FIG. 1**

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## Description

### FIELD OF THE INVENTION

**[0001]** The present invention generally involves a combustor and method for conditioning flow through the combustor. In particular embodiments of the present invention, one or more modular inserts may be installed inside the combustor to reduce the combustion dynamics and/or recirculation zones inside 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. 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 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, higher combustion gas temperatures generally increase the dissociation rate of diatomic nitrogen, increasing the production of nitrogen oxides ( $\text{NO}_x$ ). A leaner fuel-working fluid stoichiometry and/or water or steam injection into the combustion chamber may reduce flame temperatures and  $\text{NO}_x$  production. However, the leaner fuel mixture and/or water or steam injection may create vibrations and/or pressure pulses collectively referred to as combustion dynamics.

**[0004]** Increased combustion dynamics may adversely affect the useful life of the combustor hardware and/or downstream components. Alternately, or in addition, high frequencies of combustion dynamics may produce pressure pulses inside the nozzles and/or combustion chamber that affect the stability of the combustion flame, re-

duce the design margins for flashback or flame holding, and/or increase undesirable emissions. Therefore, a combustor and method that conditions flow through the combustor to reduce combustion dynamics would be useful to enhancing the thermodynamic efficiency of the combustor, protecting the combustor from catastrophic damage, and/or reducing undesirable emissions over a wide range of combustor operating levels.

### 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]** In one aspect, the present invention resides in a combustor that includes an end cover and a casing adjacent to the end cover, wherein the end cover and casing at least partially define a volume inside the combustor. The combustor further includes an end cap that extends radially across at least a portion of the combustor, at least one nozzle arranged in the end cap to provide fluid communication through the end cap, and means for conditioning flow through the volume.

**[0007]** In another aspect, the present invention resides in a combustor that includes an end cover and a casing adjacent to the end cover, wherein the end cover and casing at least partially define a volume inside the combustor. An end cap extends radially across at least a portion of the combustor, and at least one nozzle is arranged in the end cap to provide fluid communication through the end cap. The combustor further includes at least one of an annular insert adjacent to the end cover, a first arcuate insert adjacent to the end cover, or a second arcuate insert adjacent to the end cap, wherein the second arcuate insert has a convex surface.

**[0008]** In yet another aspect, the present invention resides in a method for conditioning flow through a combustor. The method includes flowing a working fluid through a volume at least partially defined by an end cover, a casing, and an end cap that extends radially across at least a portion of the combustor and flowing the working fluid across an annular insert adjacent to the end cover.

**[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 of an exemplary combustor;

Fig. 2 is a perspective view of modular inserts ac-

ording to a first embodiment of the present invention;

Fig. 3 is a perspective view of modular inserts according to a second embodiment of the present invention;

Fig. 4 is a perspective view of modular inserts according to a third embodiment of the present invention;

Fig. 5 is a perspective view of a combustor head end with the modular inserts shown in Fig. 2;

Fig. 6 is a perspective view of a combustor head end with the modular inserts shown in Fig. 3;

Fig. 7 is a perspective view of a combustor head end with the modular inserts shown in Fig. 4;

Fig. 8 is a perspective view of modular inserts according to a fourth embodiment of the present invention;

Fig. 9 is a perspective view of a combustor head end with the modular inserts shown in Fig. 8; and

Fig. 10 is a perspective view of a combustor head end with the modular inserts shown in Figs. 2 and 8.

#### 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.

**[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 include a combustor and method for conditioning flow through the combustor. In particular embodiments, one or more modular inserts may be installed inside the combustor to reduce the acoustic volume and/or recirculation zones inside the combustor, producing a corresponding decrease in the pressure drop across the combustor and/or dynamics produced by the combustor. The opti-

um location, number, size, and shape of the modular inserts may be readily determined by one of ordinary skill in the art through computational fluid dynamics calculations and/or validated in laboratory testing. 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. In addition, 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 particular structure, location, function, or importance of the individual components.

**[0014]** Fig. 1 provides a simplified cross-section of an exemplary combustor 10, such as may be included in a gas turbine. A casing 12 and an end cover 14 may surround the combustor 10 to define a volume 16 inside the combustor 10, a volume that may also be referred to as the head end of the combustor 10. A working fluid may pass through flow holes 18 in an impingement sleeve 20 to flow along the outside of a transition piece 22 and a liner 24 to provide convective cooling to the transition piece 22 and liner 24. When the working fluid reaches the head end or volume 16, the working fluid reverses direction to flow through one or more nozzles 26 radially arranged in an end cap 28. The end cap 28 extends radially across at least a portion of the combustor 10 and generally separates the head end or volume 16 from a combustion chamber 30. The one or more nozzles 26 extend through the end cap 28 to provide fluid communication through the end cap 28 to the combustion chamber 30 downstream from the end cap 28. As used herein, 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.

**[0015]** The various embodiments of the present invention include means for conditioning flow through the volume 16. As used herein, the function "conditioning flow through the volume" includes improving one or more features of the working fluid flowing through the head end. For example, the function "conditioning flow through the volume" may include reducing the size of low flow regions or areas in the head end to reduce the differential pressure of the working fluid across the head end. Alternately or in addition, the function "conditioning flow through the volume" may include reducing the acoustic volume of the head end to reduce combustion dynamics produced by the working fluid flowing through the head end.

**[0016]** The structure for "conditioning flow through the volume" may include one or more modular inserts as shown, for example, in Figs. 2-4. As shown in Figs. 2-4, the means for conditioning flow may include one or more

annular inserts 40 sized to circumferentially extend around the end cover 14. The annular insert 40 may include one or more scalloped features 42 that create a desired pattern on the end cover 14 to optimally reduce the acoustic volume of the head end while not interfering with penetrations through the end cover 14. In particular embodiments, the annular insert 40 may further include one or more angled or concave surfaces 44 to reduce the size of low flow regions and/or reduce the pressure drop of the working fluid across the head end.

**[0017]** Alternately or in addition, the means for conditioning flow may include one or more arcuate inserts 50, alone or in combination with the annular insert 40, as shown in Figs. 2-4. For example, as shown in Fig. 2, the arcuate insert 50 may circumferentially extend around the annular insert 40 and/or end cover 14. In this manner, the dimensions of the arcuate insert 50 may be adjusted as necessary to supplement or optimize the conditioning provided by the annular insert 40. Alternately, multiple arcuate inserts 50 may be strategically arranged in low flow regions around the end cover 14 and/or nozzles 26 to reduce the size of the low flow regions and/or reduce the pressure drop across the head end without excessively reducing the acoustic volume of the head end. In particular embodiments, the arcuate inserts 50 may include one or more angled or sloped surfaces 52, as shown in Fig. 2, concave surfaces 54, as shown in Fig. 3, and/or convex surfaces 56, as shown in Fig. 4.

**[0018]** Figs. 5-7 provide perspective views of various embodiments of the combustor head end with the modular inserts shown in Figs. 2-4, respectively. In each particular embodiment, the annular insert 40 circumferentially extends around the end cover 14, and the scalloped features 42 allow the annular insert 40 to reduce the acoustic volume of the head end while not interfering with penetrations through the end cover 14. The annular insert 40 is generally located adjacent to or proximate to the end cover 14 and may be bolted, clamped, or otherwise attached to at least one of the casing 12 and/or the end cover 14 to fixedly hold the annular insert 40 in place.

**[0019]** In the particular embodiment shown in Fig. 5, the arcuate insert 50 circumferentially extends around the end cover 14 to supplement or optimize the conditioning provided by the annular insert 40. In the particular embodiments shown in Figs. 6 and 7, the multiple arcuate inserts 50 are strategically arranged in low flow regions around the end cover 14 and/or nozzles 26 to reduce the size of the low flow regions and/or reduce the pressure drop across the head end without excessively reducing the acoustic volume of the head end. In each embodiment shown in Figs. 5-7, the arcuate inserts 50 are adjacent to or proximate to the annular insert 40 and may be bolted, clamped, or otherwise attached to at least one of the casing 12, end cover 14, and/or annular insert 40 to fixedly hold the arcuate inserts 50 in place. In other particular embodiments, the arcuate inserts 50 may be installed adjacent to or proximate to the end cover 14 without the use of the annular insert 40.

**[0020]** In still further embodiments within the scope of the present invention, the structure for "conditioning flow through the volume" may include one or more modular inserts as shown, for example, in Figs. 8 and 9. As shown in Figs. 8 and 9, the means for conditioning flow may include one or more arcuate inserts 60 configured to fit between one or more nozzles 26 on or adjacent to the end cap 28. As such, the arcuate inserts 60 may include concave sides 62 to fit between, conform to, and/or complement the shape of the nozzles 26. In addition, the arcuate inserts 60 may include a convex surface 64 to assist in distributing working fluid to adjacent nozzles 26. In this manner, the thickness of the arcuate inserts 60 may be adjusted to optimally reduce the acoustic volume of the head end, and the concave sides 62 and convex surface 64 may enhance working fluid flow through into the nozzles 26, reduce the size of low flow regions adjacent to the nozzles 26, and/or reduce the pressure drop of the working fluid across the head end.

**[0021]** Fig. 10 provides a perspective view of the combustor head end with the modular inserts shown in Figs. 2 and 8. Specifically, the means for conditioning flow through the volume includes the arcuate insert 50 shown in Fig. 2, without the annular insert 40, with the arcuate insert 50 adjacent to the end cover 14. In addition, in this particular embodiment, the means for conditioning flow also includes the arcuate inserts 60 shown in Fig. 8 adjacent to the end cap 28. The particular combination of the arcuate insert 50 adjacent to the end cover 14 and the arcuate inserts 60 adjacent to the end cap 28 reduces the size of low flow regions in the volume 16 and between adjacent nozzles 26 and/or reduces the pressure drop of the working fluid across the head end to reduce combustion dynamics associated with the working fluid flow through the head end.

**[0022]** The various embodiments of the present invention shown in Figs. 2-10 may also provide a method for conditioning flow through the combustor 10. The method generally includes flowing the working fluid through the volume 16 at least partially defined by the end cover 14, the casing 12, and the end cap 28 and flowing the working fluid across one or more of the modular inserts shown in Figs. 2-4. For example, the method may include flowing the working fluid across the annular insert 40 adjacent to the end cover 14, as shown specifically in Figs. 5-7. Alternately or in addition, the method may include flowing the working fluid across the arcuate inserts 50 adjacent to the annular insert 40, as shown specifically in Figs. 5-7, or adjacent to the end cover 14, as shown specifically in Fig. 10. In still further embodiments, the method may include flowing the working fluid across the arcuate inserts 60 adjacent to the end cap 28, as shown specifically in Figs. 9 and 10.

**[0023]** The various embodiments shown and described with respect to Figs. 2-10 provide one or more technical advantages to enhance flow through the combustor 10. For example, the modular nature of the various inserts shown in Figs. 2-4 and 8 allow various combina-

tions of the modular inserts to optimally adjust one or more of the size of low flow regions, the differential pressure of the working fluid across the head end, and/or the acoustic volume of the head end to reduce combustion dynamics produced by the working fluid flowing through the head end. The reduction or removal of destructive dynamics may enhance the thermodynamic efficiency of the combustor 10, protect the combustor 10 from catastrophic damage, and/or reduce undesirable emissions over a wide range of combustor 10 operating levels.

**[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 casing adjacent to the end cover, wherein the end cover and casing at least partially define a volume inside the combustor;
- c. an end cap that extends radially across at least a portion of the combustor;
- d. at least one nozzle arranged in the end cap to provide fluid communication through the end cap; and
- e. at least one of an annular insert adjacent to the end cover, a first arcuate insert adjacent to the end cover, or a second arcuate insert adjacent to the end cap, wherein the second arcuate insert has a convex surface.

2. The combustor as in clause 1, wherein the annular insert has a concave surface.

3. The combustor as in clause 1, wherein the first arcuate insert has a concave surface.

4. The combustor as in clause 1, wherein the second arcuate insert has a convex surface.

5. The combustor as in clause 1, further comprising a plurality of first arcuate inserts adjacent to the end cover.

6. The combustor as in clause 1, further comprising

any combination of at least two of the annular insert adjacent to the end cover, the first arcuate insert adjacent to the end cover, or the second arcuate insert adjacent to the end cap.

7. The combustor as in clause 1, further comprising the annular insert adjacent to the end cover, the first arcuate insert adjacent to the end cover, and the second arcuate insert adjacent to the end cap.

## Claims

1. A combustor (10) comprising:

- a. an end cover (14);
- b. a casing (12) adjacent to the end cover (14), wherein the end cover (14) and casing (12) at least partially define a volume (16) inside the combustor (10);
- c. an end cap (28) that extends radially across at least a portion of the combustor (10);
- d. at least one nozzle (26) arranged in the end cap (28) to provide fluid communication through the end cap (28); and
- e. means for conditioning flow through the volume (16).

2. The combustor (10) as in claim 1, wherein the means for conditioning flow comprises an annular insert (40) adjacent to the end cover (14).

3. The combustor (10) as in claim 2, wherein the annular insert (40) has a concave surface (44).

4. The combustor (10) as in any of claims 2 or 3, wherein the means for conditioning flow further comprises an arcuate insert (50) adjacent to the annular insert (40), wherein the arcuate insert (50) has a concave surface (54).

5. The combustor (10) as in any of claims 2 to 4, wherein the means for conditioning flow further comprises an arcuate insert (60) adjacent to the end cap (28).

6. The combustor (10) as in claim 5, wherein the arcuate insert (60) has a convex surface (64).

7. The combustor (10) as in any preceding claim, wherein the means for conditioning flow comprises a plurality of arcuate inserts (50) adjacent to the end cover (14).

8. The combustor (10) as in any preceding claim, wherein the means for conditioning flow comprises an arcuate insert (60) adjacent to the end cap (28), wherein the arcuate insert (60) has a convex surface (64).

9. A method for conditioning flow through a combustor (10), comprising:
- a. flowing a working fluid through a volume (16) at least partially defined by an end cover (14), a casing (12), and an end cap (28) that extends radially across at least a portion of the combustor (10); 5
  - b. flowing the working fluid across an annular insert (40) adjacent to the end cover (14). 10
10. The method as in claim 9, further comprising flowing the working fluid across a first arcuate insert (50) adjacent to the annular insert (40). 15
11. The method as in any of claims 9 or 10, further comprising flowing the working fluid across a first arcuate insert (50) adjacent to the annular insert (40), wherein the first arcuate insert (50) has a concave surface (54). 20
12. The method as in any of claims 9 to 11, further comprising flowing the working fluid across a second arcuate insert (60) adjacent to the end cap (28). 25
13. The method as in any of claims 9 to 12, further comprising flowing the working fluid across a second arcuate insert (60) adjacent to the end cap (28), wherein the second arcuate insert (60) has a convex surface (64). 30

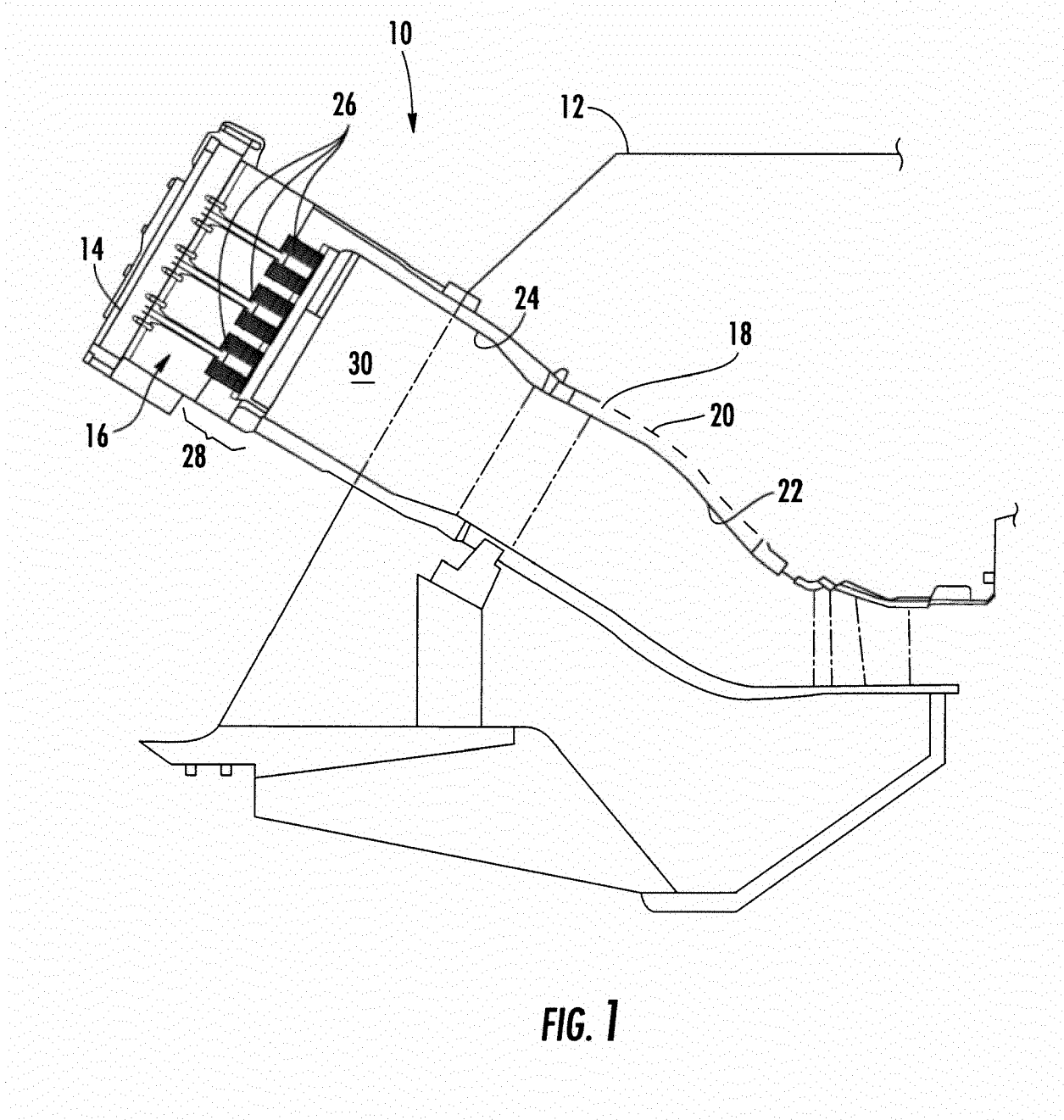
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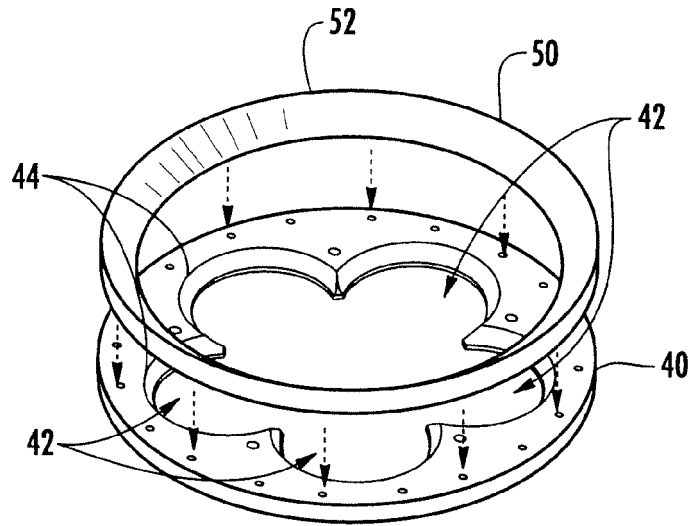
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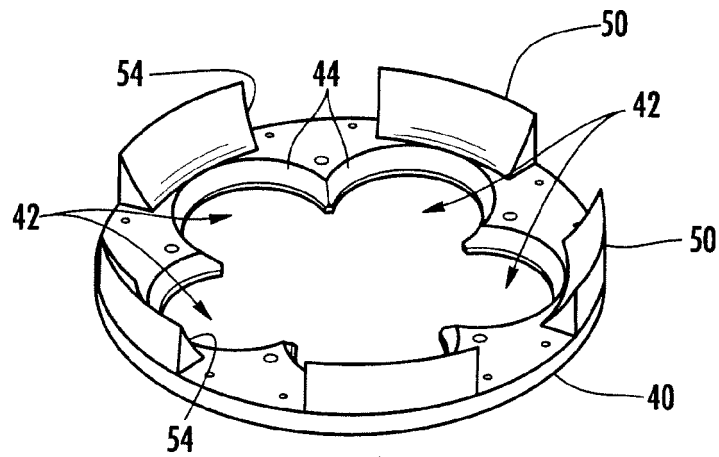
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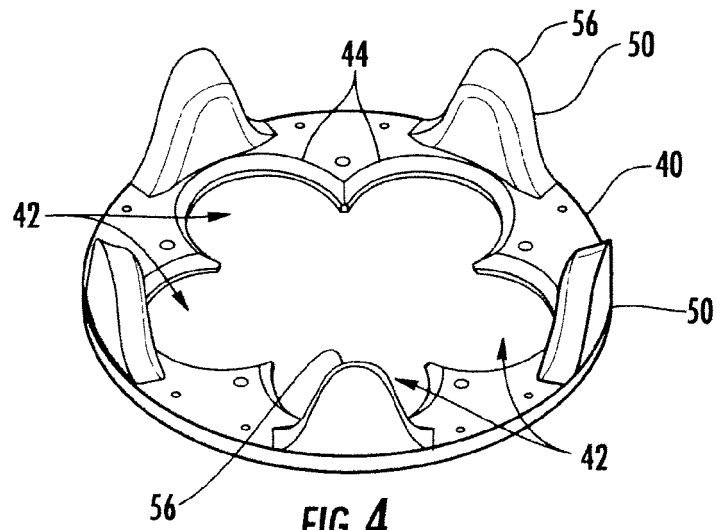
**FIG. 1**



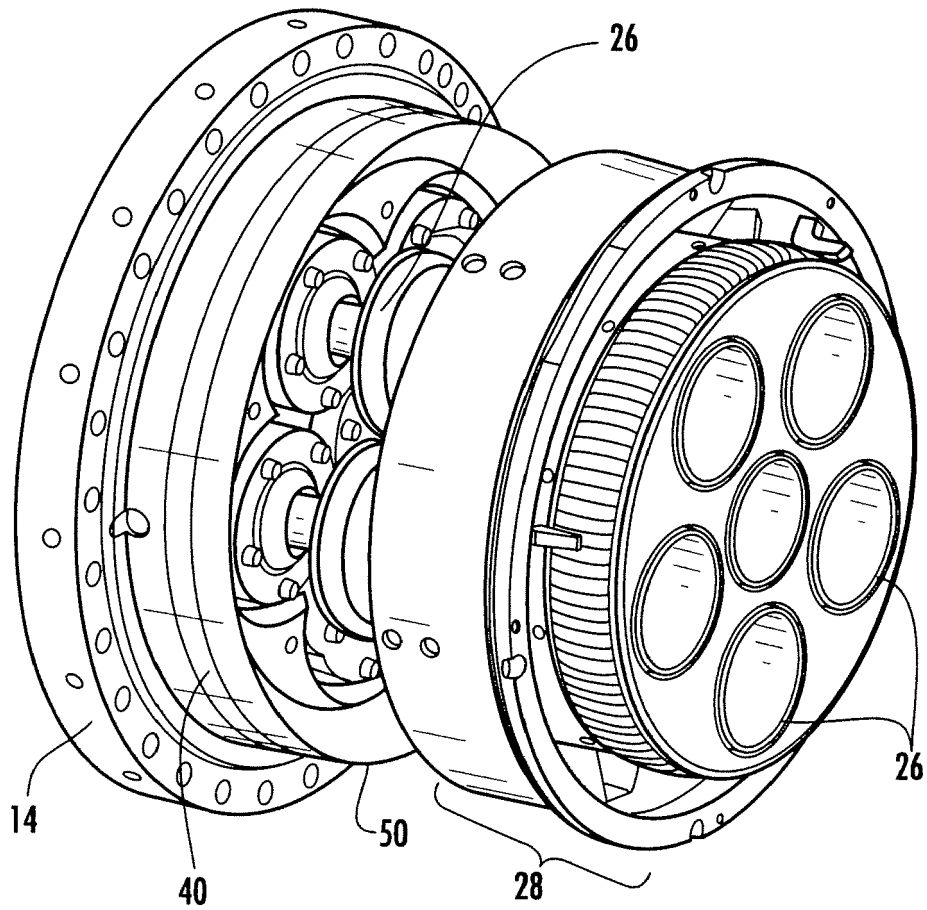
**FIG. 2**



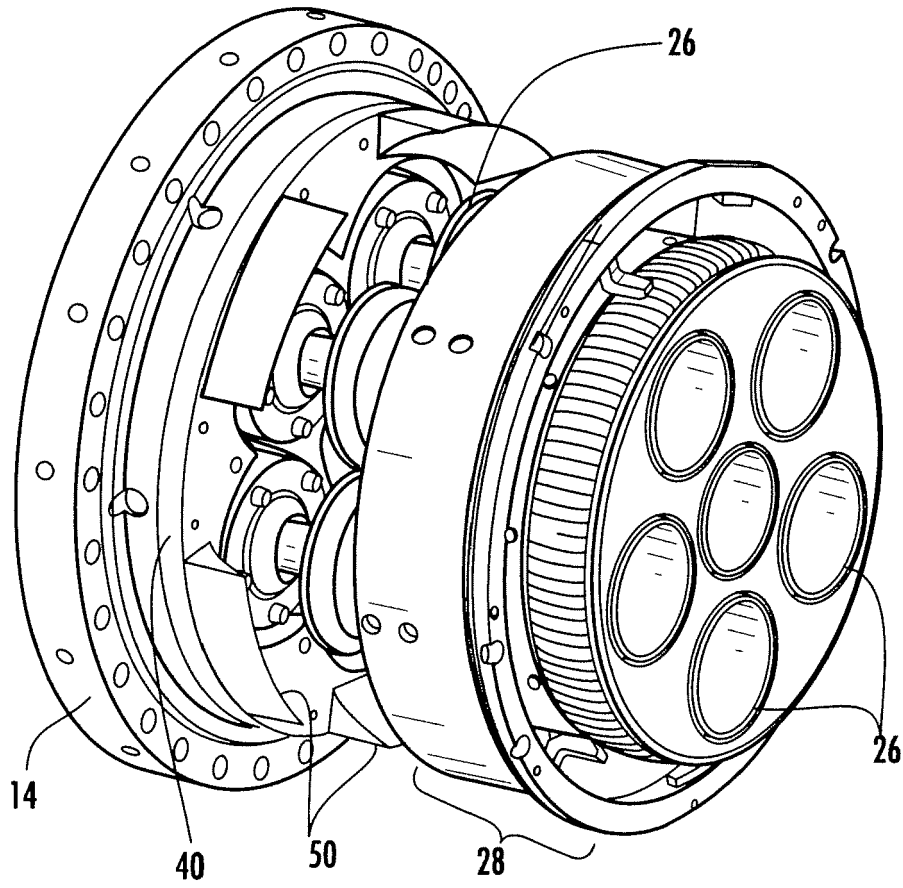
**FIG. 3**



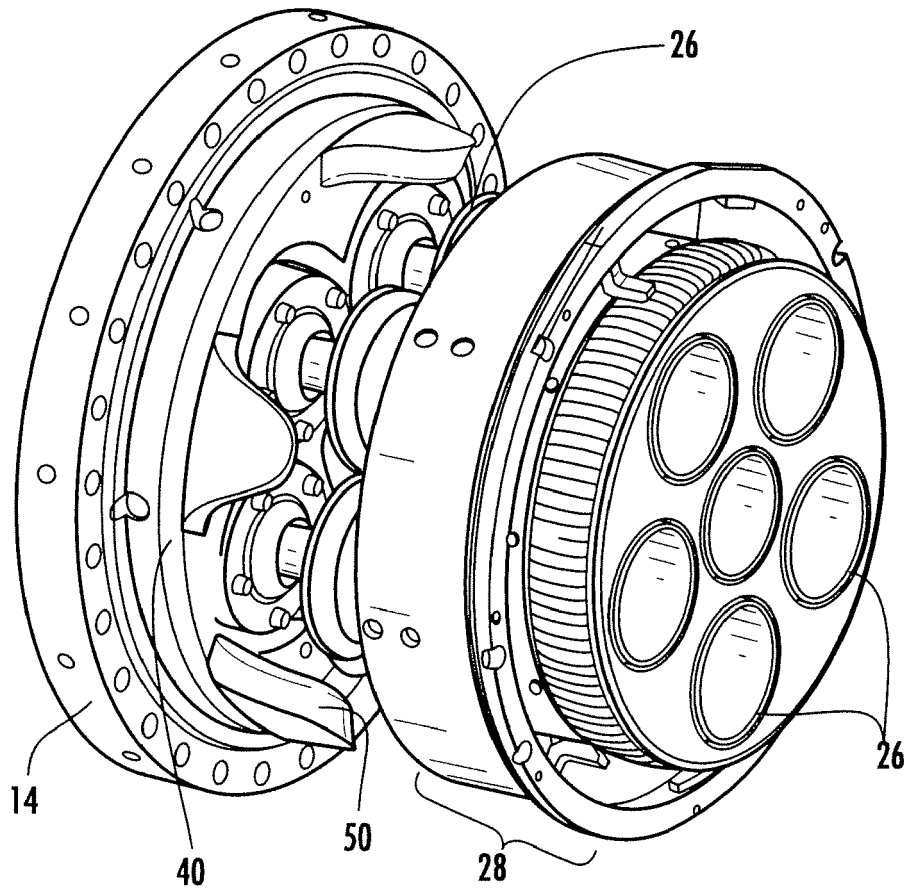
**FIG. 4**



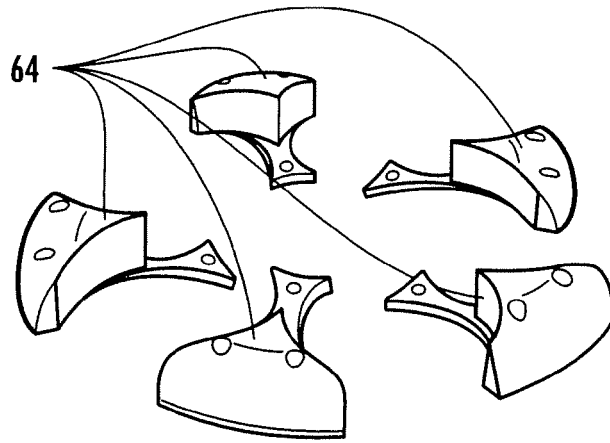
**FIG. 5**



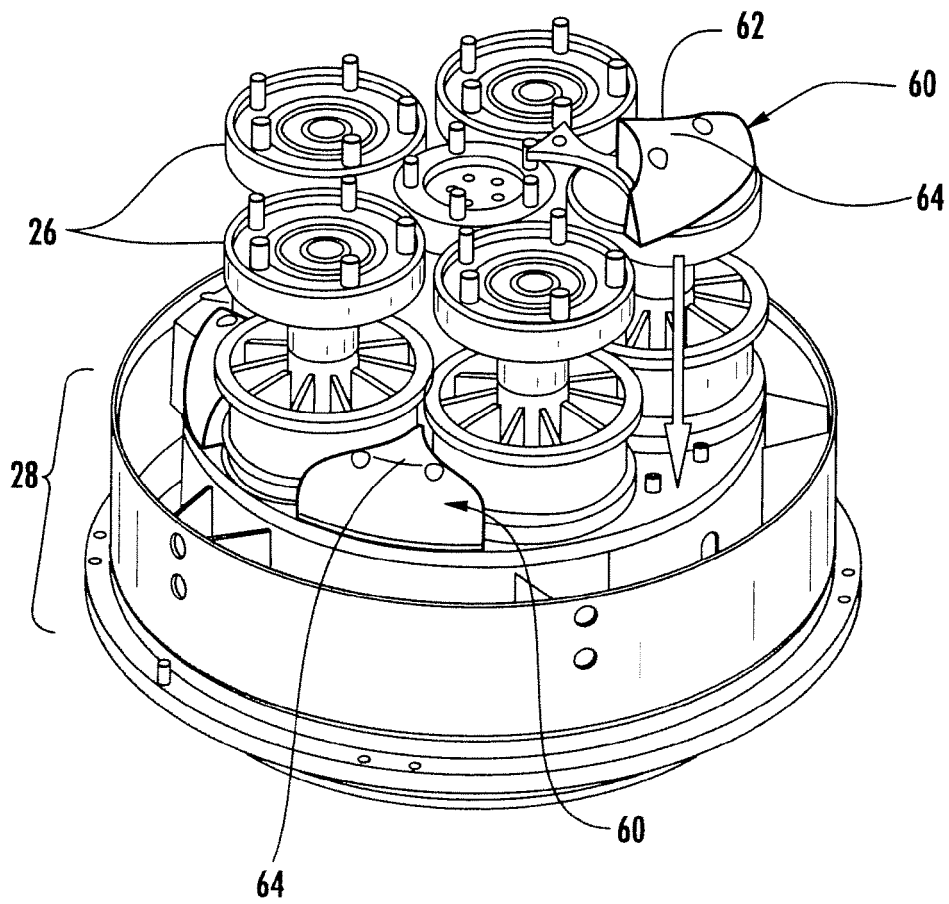
**FIG. 6**



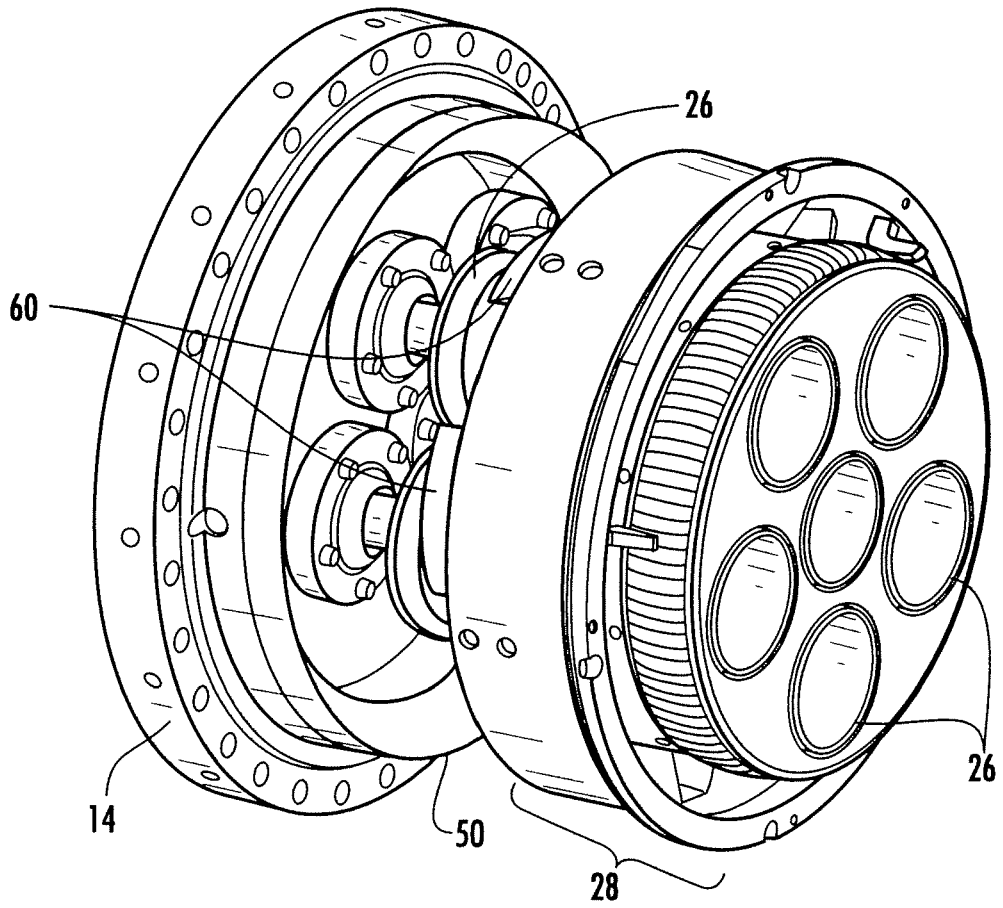
**FIG. 7**



**FIG. 8**



**FIG. 9**



**FIG. 10**