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(54) Title: FUEL-AIR MIXER ASSEMBLY FOR USE IN A COMBUSTOR OF A TURBINE ENGINE

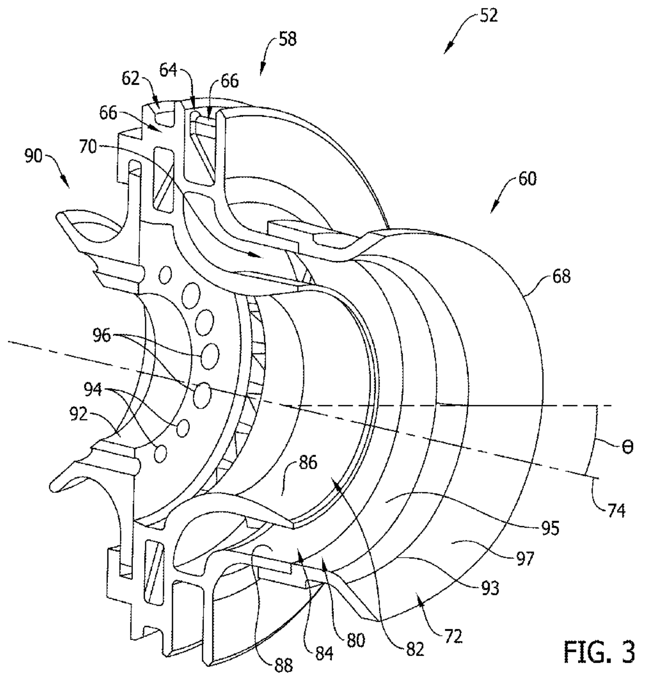

FIG. 3

(57) Abstract: A fuel-air mixer assembly (52) that includes a mixer portion, and a flare cup portion (60) coupled to the mixer portion. The flare cup portion includes a side wall (68) that including an inlet opening and a discharge opening (72) defined therein. The side wall is oriented such that the discharge opening is axi-asymmetrically shaped relative to a centerline (74) of the fuel-air mixer assembly.

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[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:
— *with international search report (Art. 21(3))*

FUEL-AIR MIXER ASSEMBLY FOR USE IN A COMBUSTOR OF A TURBINE ENGINE

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH & DEVELOPMENT

[0001] This invention was made with Government support under contract number FA8650-09-D-2922 awarded by the Department of the Air Force. The Government has certain rights in this invention.

BACKGROUND

[0002] The present disclosure relates generally to turbine engines and, more specifically, to a fuel-air mixer assembly having axi-asymmetric characteristics for reducing combustion dynamics.

[0003] A combustion section of a gas turbine generally includes a plurality of combustors that are arranged in an annular array about an outer casing, such as a compressor discharge casing. Pressurized air flows from a compressor towards the compressor discharge casing, and is then channeled to each combustor. Fuel from a fuel nozzle is mixed with the pressurized air in each combustor to form a combustible mixture within a primary combustion zone of the combustor. The combustible mixture is burned to produce hot combustion gases having a high pressure and high velocity. In at least some known combustors, high combustion dynamics are formed when the combustible mixture is burned. High combustion dynamics adversely affect the operability and service life of the combustors. Moreover, high combustion dynamics can result in damage to components of the combustors, thereby causing service outages and increasing repair costs.

BRIEF DESCRIPTION

[0004] In one aspect, a fuel-air mixer assembly for use in a combustor is provided. The fuel-air mixer assembly includes a mixer portion, and a flare cup portion coupled to the mixer portion. The flare cup portion includes a side wall that including an inlet opening and a discharge opening defined therein. The side wall is oriented such that the discharge opening is axi-asymmetrically shaped relative to a centerline of the fuel-air mixer assembly.

[0005] In another aspect, a combustor for use in a turbine engine is provided. The combustor includes a fuel nozzle assembly, and a fuel-air mixer assembly including a mixer portion configured to receive fuel from the fuel nozzle assembly. The fuel-air mixer assembly also includes a flare cup portion coupled to the mixer portion. The flare cup portion includes a side wall that including an inlet opening and a discharge opening defined therein. The side wall is oriented such that the discharge opening is axi-asymmetrically shaped relative to a centerline of the fuel-air mixer assembly.

[0006] In yet another aspect, a turbine engine is provided. The turbine engine includes a combustor including a fuel nozzle assembly and a fuel-air mixer assembly coupled to the fuel nozzle assembly. The fuel-air mixer assembly includes a mixer portion configured to receive fuel from the fuel nozzle assembly, and a flare cup portion coupled to the mixer portion. The flare cup portion includes a side wall that including an inlet opening and a discharge opening defined therein. The side wall is oriented such that the discharge opening is axi-asymmetrically shaped relative to a centerline of the fuel-air mixer assembly.

DRAWINGS

[0007] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. 1 is a schematic diagram of an exemplary turbine engine;

[0009] FIG. 2 is a cross-sectional view of a portion of an exemplary combustor that may be used with the turbine engine shown in FIG. 1;

[0010] FIG. 3 is a cross-sectional view of an exemplary fuel-air mixer assembly that may be used in the combustor shown in FIG. 2;

[0011] FIG. 4 is an axial view of the fuel-air mixer assembly shown in FIG. 3;

[0012] FIG. 5 is a cross-sectional view of an alternative fuel-air mixer assembly that may be used in the combustor shown in FIG. 2;

[0013] FIG. 6 is an axial view of the fuel-air mixer assembly shown in FIG. 5; and

[0014] FIG. 7 is an axial view of an exemplary swirler vane assembly that may be used in the fuel-air mixer assemblies shown in FIGS. 3 and 5.

[0015] Unless otherwise indicated, the drawings provided herein are meant to illustrate features of embodiments of the disclosure. These features are believed to be applicable in a wide variety of systems comprising one or more embodiments of the disclosure. As such, the drawings are not meant to include all conventional features known by those of ordinary skill in the art to be required for the practice of the embodiments disclosed herein.

DETAILED DESCRIPTION

[0016] In the following specification and the claims, reference will be made to a number of terms, which shall be defined to have the following meanings.

[0017] The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise.

[0018] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not.

[0019] Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about”, “approximately”, and “substantially”, are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged. Such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise.

[0020] As used herein, the terms “axial” and “axially” refer to directions and orientations that extend substantially parallel to a centerline of the turbine engine or the combustor. Moreover, the terms “radial” and “radially” refer to directions and orientations that extend substantially perpendicular to the centerline of the turbine engine or the fuel-air mixer assembly. In addition, as used herein, the terms “circumferential” and “circumferentially” refer to directions and orientations that extend arcuately about the centerline of the turbine engine or the fuel-air mixer assembly.

[0021] Embodiments of the present disclosure relate to a fuel-air mixer assembly having axi-asymmetric characteristics for reducing combustion dynamics. More specifically, the fuel-air mixer assembly includes one or more design features of a mixer portion, a flare cup portion, or a ferrule portion of the assembly that are implemented, either alone or in combination, to reduce combustion dynamics by disrupting symmetries within the assembly. For example, at least one of the orientation, shape, and/or design of swirler vanes within the mixer portion, inlets and outlets of the flare cup portion, and purge holes within the ferrule portion are formed axi-asymmetrically relative to a centerline of a combustor to facilitate disrupting a swirling flow of fuel and air discharged from the fuel-air mixer assembly. As such, combustion dynamics are reduced in a simplified and efficient manner.

[0022] FIG. 1 is a schematic diagram of an exemplary turbine engine 10 including a fan assembly 12, a low-pressure or booster compressor assembly 14, a high-pressure compressor assembly 16, and a combustor assembly 18. Fan assembly 12, booster compressor assembly 14, high-pressure compressor assembly 16, and combustor assembly 18 are coupled in flow communication. Turbine engine 10 also includes a high-pressure turbine assembly 20 coupled in flow communication with combustor assembly 18 and a low-pressure turbine assembly 22. Fan assembly 12 includes an array of fan blades 24 extending radially outward from a rotor disk 26. Low-pressure turbine assembly 22 is coupled to fan assembly 12 and booster compressor assembly 14 through a first drive shaft 28, and high-pressure turbine assembly 20 is coupled to high-pressure compressor assembly 16 through a second drive shaft 30. Turbine engine 10 has an intake 32 and an exhaust 34. Turbine engine 10 further includes a centerline 36 about which fan assembly 12, booster compressor assembly 14, high-pressure compressor assembly 16, and turbine assemblies 20 and 22 rotate.

[0023] In operation, air entering turbine engine 10 through intake 32 is channeled through fan assembly 12 towards booster compressor assembly 14. Compressed air is discharged from booster compressor assembly 14 towards high-pressure compressor assembly 16. Highly compressed air is channeled from high-pressure compressor assembly 16 towards combustor assembly 18, mixed with fuel, and the mixture is combusted within combustor assembly 18. High temperature combustion gas generated by combustor assembly 18 is channeled towards turbine assemblies 20 and 22. Combustion gas is subsequently discharged from turbine engine 10 via exhaust 34.

[0024] FIG. 2 is a cross-sectional view of a portion of an exemplary combustor 38 that may be used with turbine engine 10. Combustor 38 defines a combustion chamber 40 in which the highly compressed air is mixed with fuel and combusted. Combustor 38 includes an outer liner 42 and an inner liner 44. Outer liner 42 defines an outer boundary of the combustion chamber 40, and inner liner 44 defines an inner boundary of combustion chamber 40. An annular dome 46 is mounted upstream from outer liner 42 and inner liner 44 defines an upstream end of combustion chamber 40. One or more fuel injection systems 48 are positioned on annular dome 46. In the exemplary embodiment, each fuel injection system 48 includes a fuel nozzle assembly 50 and a fuel-air mixer assembly 52 coupled to fuel nozzle assembly 50. Fuel-air mixer assembly 52 receives fuel from fuel nozzle assembly 50, receives air from high-pressure compressor assembly 16 (shown in FIG. 1) via a diffuser 54, and discharges a fuel-air mixture 56 into combustion chamber 40.

[0025] FIG. 3 is a cross-sectional view of fuel-air mixer assembly 52 that may be used in combustor 38 (shown in FIG. 2), and FIG. 4 is an axial view of fuel-air mixer assembly 52. In the exemplary embodiment, fuel-air mixer assembly 52 includes a mixer portion 58 and a flare cup portion 60 coupled to mixer portion 58. Mixer portion 58 includes a first radial flow passage 62 and a second radial flow passage 64 each having a swirler vane assembly 66 positioned therein, as will be described in more detail below. Flare cup portion 60 includes a side wall 68 that has an inlet opening 70 and a discharge opening 72 defined therein. Side wall 68 is oriented such that discharge opening 72 is axi-asymmetrically shaped relative to a centerline 74 of fuel-air mixer assembly 52. As described above, fuel-air mixture 56 (shown in FIG. 2) is discharged from fuel-air mixer assembly 52 during operation of combustor 38. More specifically, fuel-air mixture 56 generally swirls circumferentially about centerline 74 before being discharged from fuel-air mixer assembly 52. As such, shaping discharge opening 72 axi-asymmetrically relative to centerline 74 facilitates disrupting a symmetrical flow field of fuel-air mixture 56 before being discharged from fuel-air mixer assembly 52.

[0026] For example, referring to FIG. 4, discharge opening 72 is defined by a major axis 76 and a minor axis 78 oriented perpendicularly relative to each other. Discharge opening 72 is shaped axi-asymmetrically in that major axis 76 is longer than minor axis 78. Moreover, fuel-air mixer assembly 52 is oriented within combustor 38 (shown in FIG. 2) such that major axis 76 is oriented tangentially relative to a circumference of turbine engine 10 (shown in FIG. 1). As such, flame propagation is enhanced and impingement of fuel-air mixture 56 and heat against outer liner and inner liner 44 (shown in FIG. 2) is reduced.

[0027] Referring again to FIG. 3, side wall 68 of flare cup portion 60 is divergently oriented relative to centerline 74 of fuel-air mixer assembly 52 at opposing ends of major axis 76 and minor axis 78. As such, side wall 68 is angled relative to centerline 74 at the opposing ends of major axis 76 and minor axis 78 by any angle that enables flare cup portion 60 to function as described herein. In the exemplary embodiment, side wall 68 at opposing ends of major axis 76 is oriented at an angle Θ equal to or less than about 60 degrees relative to centerline 74. Moreover, side wall 68 at opposing ends of minor axis 78 is oriented at an angle less than angle Θ such that a planar opening is formed at discharge opening 72.

[0028] In the exemplary embodiment, mixer portion 58 includes a discharge end 80 coupled to flare cup portion 60 at inlet opening 70. In operation, fuel and air are mixed within mixer portion 58 and discharged from mixer portion 58 through an outlet 82 defined at discharge end 80. In addition, air enters mixer portion 58 radially and is discharged from mixer portion 58 through an annular opening 84 defined at discharge end 80. Outlet 82 is defined by a first side wall 86 and annular opening 84 is defined by a second side wall 88. In one embodiment, first side wall 86 and second side wall 88 are both shaped axi-symmetrically relative to centerline 74. Likewise, side wall 68 of flare cup portion 60 at inlet opening 70 is shaped axi-symmetrically relative to centerline 74. As such, flare cup portion 60 is retrofittable onto an existing cylindrical discharge end 80 of mixer portion 58.

[0029] Fuel-air mixer assembly 52 also includes a ferrule portion 90 coupled to mixer portion 58. Ferrule portion 90 includes a fuel inlet 92 and a plurality of purge holes defined therein. The plurality of purge holes direct axial airflow into mixer portion 58. In addition, the plurality of purge holes include first purge holes 94 and second purge holes 96 defined in ferrule portion 90 and arranged circumferentially relative to centerline 74. First purge holes 94 are sized smaller than second purge holes 96. More specifically, first purge holes 94 and second purge holes 96 are arranged axi-asymmetrically based on the size of first purge holes 94 and second purge holes 96 relative to centerline 74. In the exemplary embodiment, sets of first purge holes 94 and sets of second purge holes 96 are alternatingly arranged relative to centerline 74. Alternatively, first purge holes 94 and second purge holes 96 are individually alternatingly arranged relative to centerline 74.

[0030] In the exemplary embodiment, flare cup portion 60 includes a transition section 93 defined between a cylindrical section 95 and a flared section 97 of flare cup portion 60. Transition section 93 has any shape that enables fuel-air mixer assembly 52 to function as described herein. For example, transition section 93 may be defined by a sharp corner or have a radius of less than or equal to about 0.15 inches. In addition, flared section 97 has either a flat surface or a curved surface. When curved, flared section 97 curves outwardly relative to centerline 74 from transition section 93 by an angular increase of less than or equal to about 50 degrees.

[0031] FIG. 5 is a cross-sectional view of an alternative fuel-air mixer assembly 98 that may be used in combustor 38 (shown in FIG. 2), and FIG. 6 is an axial view of fuel-air mixer assembly 98. In the exemplary embodiment, mixer portion 58 includes a discharge end 100 coupled to flare cup portion 60 at an inlet opening 102. In operation, fuel and air are mixed within mixer portion 58 and discharged from mixer portion 58 through an outlet 104 defined at discharge end 100. In addition, air enters mixer portion 58 radially and is discharged from mixer portion 58 through an annular opening 106 defined at discharge end 100. Outlet 104 is defined by first side wall 86 and annular opening 106 is defined by second side wall 88. In one embodiment, first side wall 86 and second side wall 88 are both shaped axi-asymmetrically relative to centerline 74. Likewise, side wall 68 of flare cup portion 60 at inlet opening 102 is shaped axi-asymmetrically relative to centerline 74 to facilitate coupling between mixer portion 58 and flare cup portion 60. Axi-asymmetrically shaping outlet 104 and annular opening 106 further facilitates disrupting a symmetrical flow field of fuel-air mixture 56 (shown in FIG. 2) before being discharged from fuel-air mixer assembly 52.

[0032] FIG. 7 is an axial view of an exemplary swirler vane assembly 66 that may be used in mixer portion 58 of fuel-air mixer assemblies 52 and 98 (shown in FIGS. 3 and 5). In the exemplary embodiment, swirler vane assembly 66 includes first swirler vanes 108 and second swirler vanes 110 arranged circumferentially within mixer portion 58 relative to centerline 74. First swirler vanes 108 direct airflow into mixer portion 58 in a different direction than second swirler vanes 110. More specifically, first swirler vanes 108 and second swirler vanes 110 are angled differently relative to a radial axis 112 of fuel-air mixer assembly 52. For example, an angle α defined between radial axis 112 and first swirler vanes 108 is less than an angle β defined between radial axis 112 and second swirler vanes 110. In the exemplary embodiment, sets of first swirler vanes 108 and sets of second swirler vanes 110 are alternatingly arranged relative to centerline 74 (shown in FIG. 3). Alternatively, first swirler vanes 108 and second swirler vanes 110 are individually alternatingly arranged relative to centerline 74.

[0033] An exemplary technical effect of the systems and methods described herein includes at least one of: (a) improving combustion dynamics in a combustor of a turbine engine; (b) forming a fuel-air mixer assembly with axi-asymmetric design features; and (c) improving the service life and operability of the turbine engine.

[0034] Exemplary embodiments of a turbine engine and related components are described above in detail. The system is not limited to the specific embodiments described herein, but rather, components of systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. For example, the configuration of components described herein may also be used in combination with other processes, and is not limited to practice with only turbofan assemblies and related methods as described herein. Rather, the exemplary embodiment can be implemented and utilized in connection with many applications where reducing combustion dynamics is desired.

[0035] Although specific features of various embodiments of the present disclosure may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of embodiments of the present disclosure, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0036] This written description uses examples to disclose the embodiments of the present disclosure, including the best mode, and also to enable any person skilled in the art to practice embodiments of the present disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the embodiments described herein 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 have 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

WHAT IS CLAIMED IS:

1. A fuel-air mixer assembly for use in a combustor, said fuel-air mixer assembly comprising:

a mixer portion; and

a flare cup portion coupled to said mixer portion, said flare cup portion comprising a side wall that comprises an inlet opening and a discharge opening defined therein, wherein said side wall is oriented such that said discharge opening is axi-asymmetrically shaped relative to a centerline of the fuel-air mixer assembly.

2. The assembly in accordance with Claim 1, wherein said discharge opening is defined by a major axis and a minor axis oriented perpendicularly relative to each other, the major axis longer than the minor axis.

3. The assembly in accordance with Claim 2, wherein said side wall is divergently oriented relative to the centerline of the fuel-air mixer assembly at opposing ends of the major axis, said side wall oriented at an angle equal to or less than about 60 degrees relative to the centerline.

4. The assembly in accordance with Claim 1, wherein said mixer portion comprises a discharge end coupled to said flare cup portion at said inlet opening, said inlet opening and said discharge end both axi-symmetrically shaped relative to the centerline of the fuel-air mixer assembly.

5. The assembly in accordance with Claim 1, wherein said mixer portion comprises a discharge end coupled to said flare cup portion at said inlet opening, said inlet opening and said discharge end both axi-asymmetrically shaped relative to the centerline of the fuel-air mixer assembly.

6. The assembly in accordance with Claim 1, wherein said mixer portion comprises first swirler vanes and second swirler vanes arranged circumferentially within said mixer portion relative to the centerline, wherein said first swirler vanes are configured to direct airflow into said mixer portion in a different direction than said second swirler vanes.

7. The assembly in accordance with Claim 1 further comprising a ferrule portion coupled to said mixer portion, said ferrule portion comprising first purge holes and second purge holes defined therein and arranged circumferentially relative to the centerline, wherein said first purge holes are sized smaller than said second purge holes.

8. The assembly in accordance with Claim 1, wherein said flare cup portion comprises a cylindrical section, a flared section, and a transition section defined therebetween.

9. A combustor for use in a turbine engine, said combustor comprising:

a fuel nozzle assembly; and

a fuel-air mixer assembly comprising:

a mixer portion configured to receive fuel from said fuel nozzle assembly; and

a flare cup portion coupled to said mixer portion, said flare cup portion comprising a side wall that comprises an inlet opening and a discharge opening defined therein, wherein said side wall is oriented such that said discharge opening is axi-asymmetrically shaped relative to a centerline of said fuel-air mixer assembly.

10. The combustor in accordance with Claim 9, wherein said discharge opening is defined by a major axis and a minor axis oriented perpendicularly relative to each other, the major axis longer than the minor axis.

11. The combustor in accordance with Claim 10, wherein said fuel-air mixer assembly is oriented within the combustor such that the major axis is oriented tangentially relative to a circumference of the turbine engine.

12. The combustor in accordance with Claim 10, wherein said side wall is divergently oriented relative to the centerline of said fuel-air mixer assembly at opposing ends of the major axis, said side wall oriented at an angle equal to or less than about 60 degrees relative to the centerline.

13. The combustor in accordance with Claim 9, wherein said mixer portion comprises a discharge end coupled to said flare cup portion at said inlet opening, said inlet opening and said discharge end both axi-symmetrically shaped relative to the centerline of said fuel-air mixer assembly.

14. The combustor in accordance with Claim 9, wherein said mixer portion comprises a discharge end coupled to said flare cup portion at said inlet opening, said inlet opening and said discharge end both axi-asymmetrically shaped relative to the centerline of said fuel-air mixer assembly.

15. The combustor in accordance with Claim 9, wherein said mixer portion comprises first swirler vanes and second swirler vanes arranged circumferentially within said mixer portion relative to the centerline, wherein said first swirler vanes are configured to direct airflow into said mixer portion in a different direction than said second swirler vanes.

16. A turbine engine comprising:

a combustor comprising a fuel nozzle assembly and a fuel-air mixer assembly coupled to said fuel nozzle assembly, said fuel-air mixer assembly comprising:

a mixer portion configured to receive fuel from said fuel nozzle assembly; and

a flare cup portion coupled to said mixer portion, said flare cup portion comprising a side wall that comprises an inlet opening and a discharge opening defined therein, wherein said side wall is oriented such that said discharge opening is axi-asymmetrically shaped relative to a centerline of said fuel-air mixer assembly.

17. The turbine engine in accordance with Claim 16, wherein said discharge opening is defined by a major axis and a minor axis oriented perpendicularly relative to each other, the major axis longer than the minor axis.

18. The turbine engine in accordance with Claim 17, wherein said side wall is divergently oriented relative to the centerline of said fuel-air mixer assembly at opposing ends of the major axis, said side wall oriented at an angle equal to or less than about 60 degrees relative to the centerline.

19. The turbine engine in accordance with Claim 16, wherein said mixer portion comprises first swirler vanes and second swirler vanes arranged circumferentially within said mixer portion relative to the centerline, wherein said first swirler vanes are configured to direct airflow into said mixer portion in a different direction than said second swirler vanes.

20. The turbine engine in accordance with Claim 16 further comprising a ferrule portion coupled to said mixer portion, said ferrule portion comprising first purge holes and second purge holes defined therein and arranged circumferentially relative to the centerline, wherein said first purge holes are sized differently than said second purge holes.

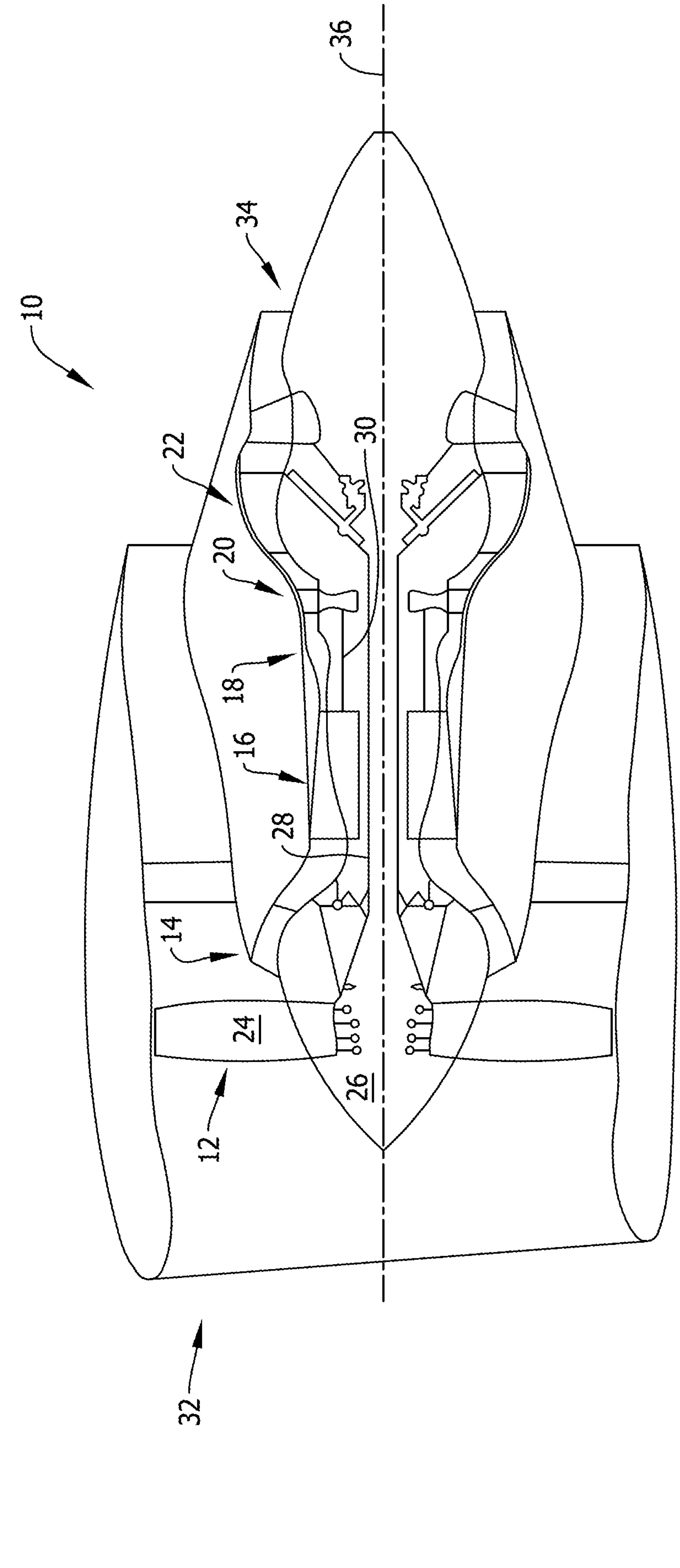

FIG. 1

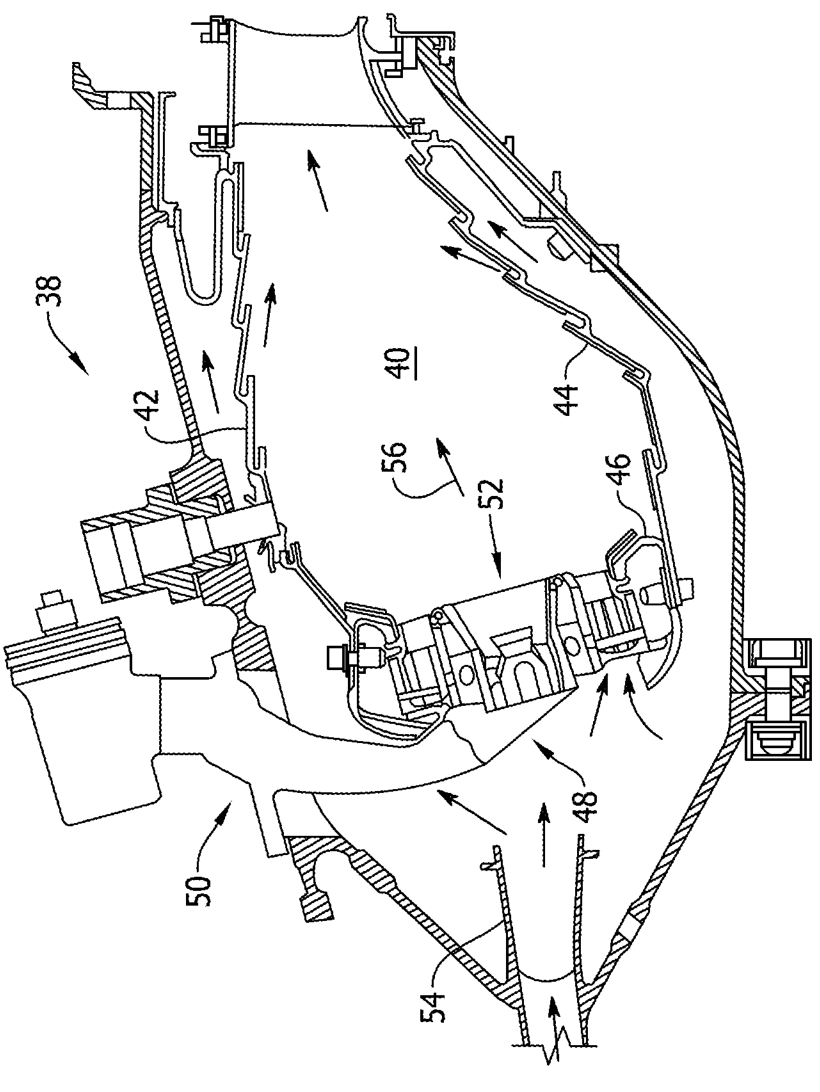

FIG. 2

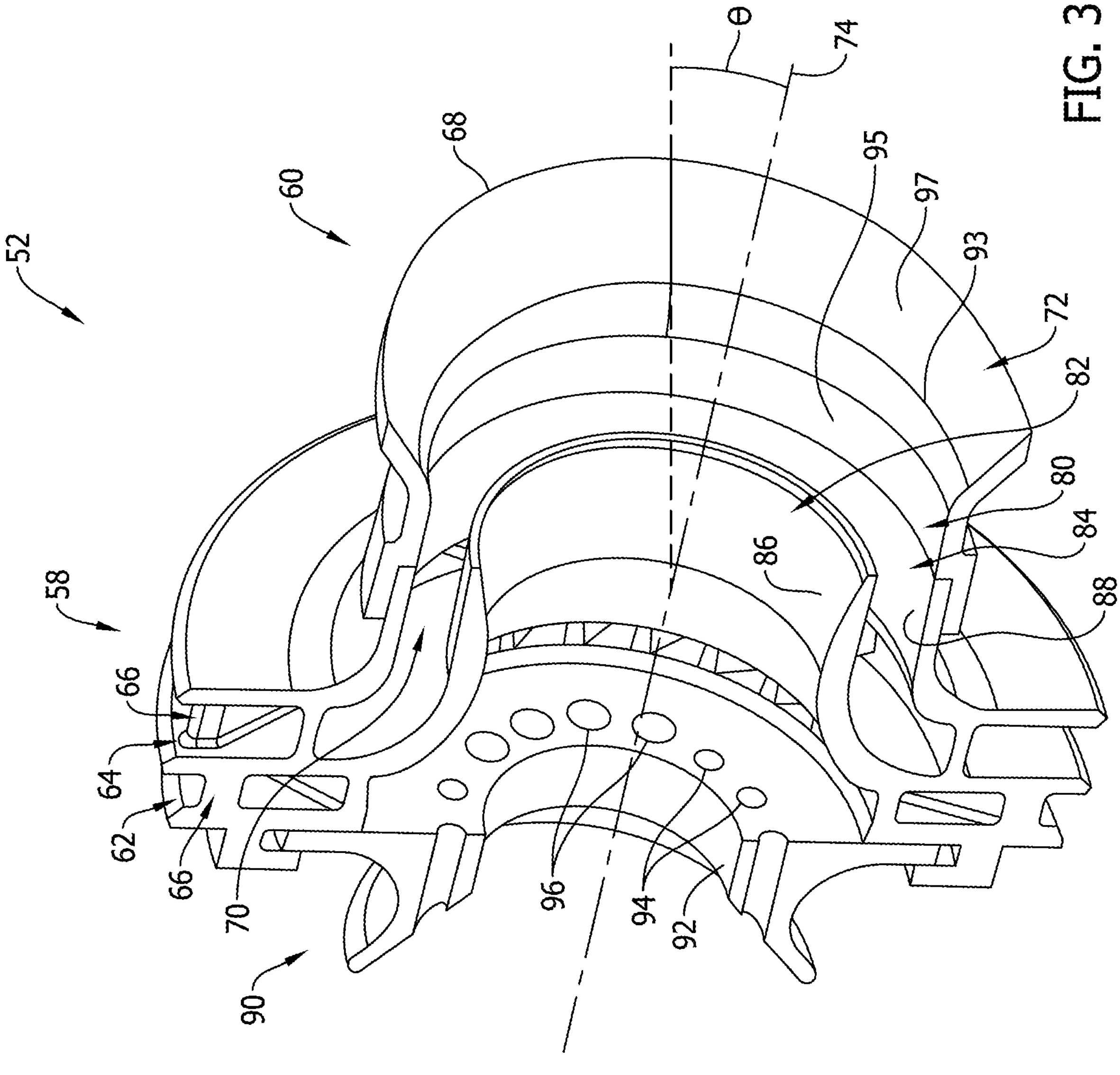

FIG. 3

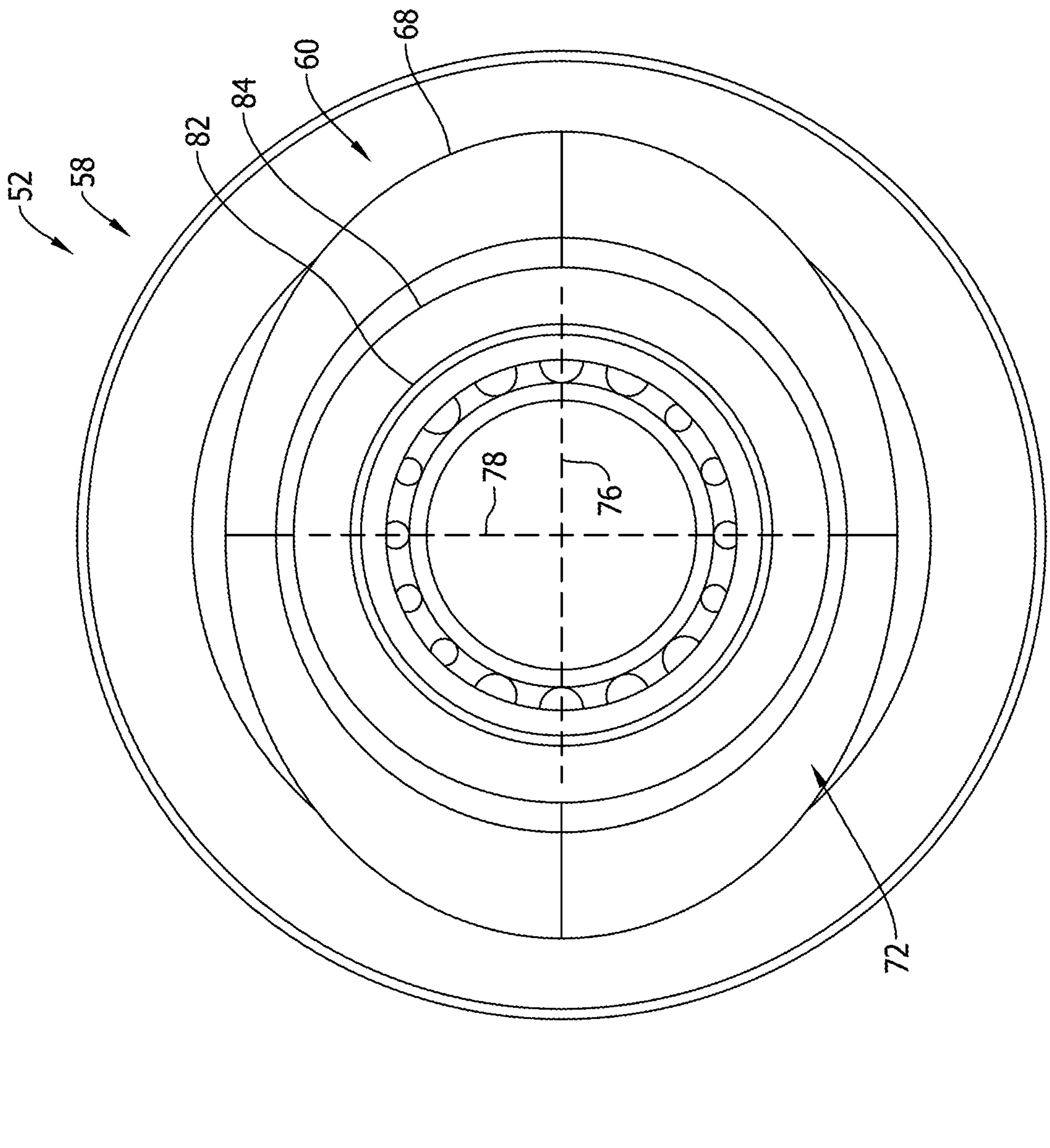

FIG. 4

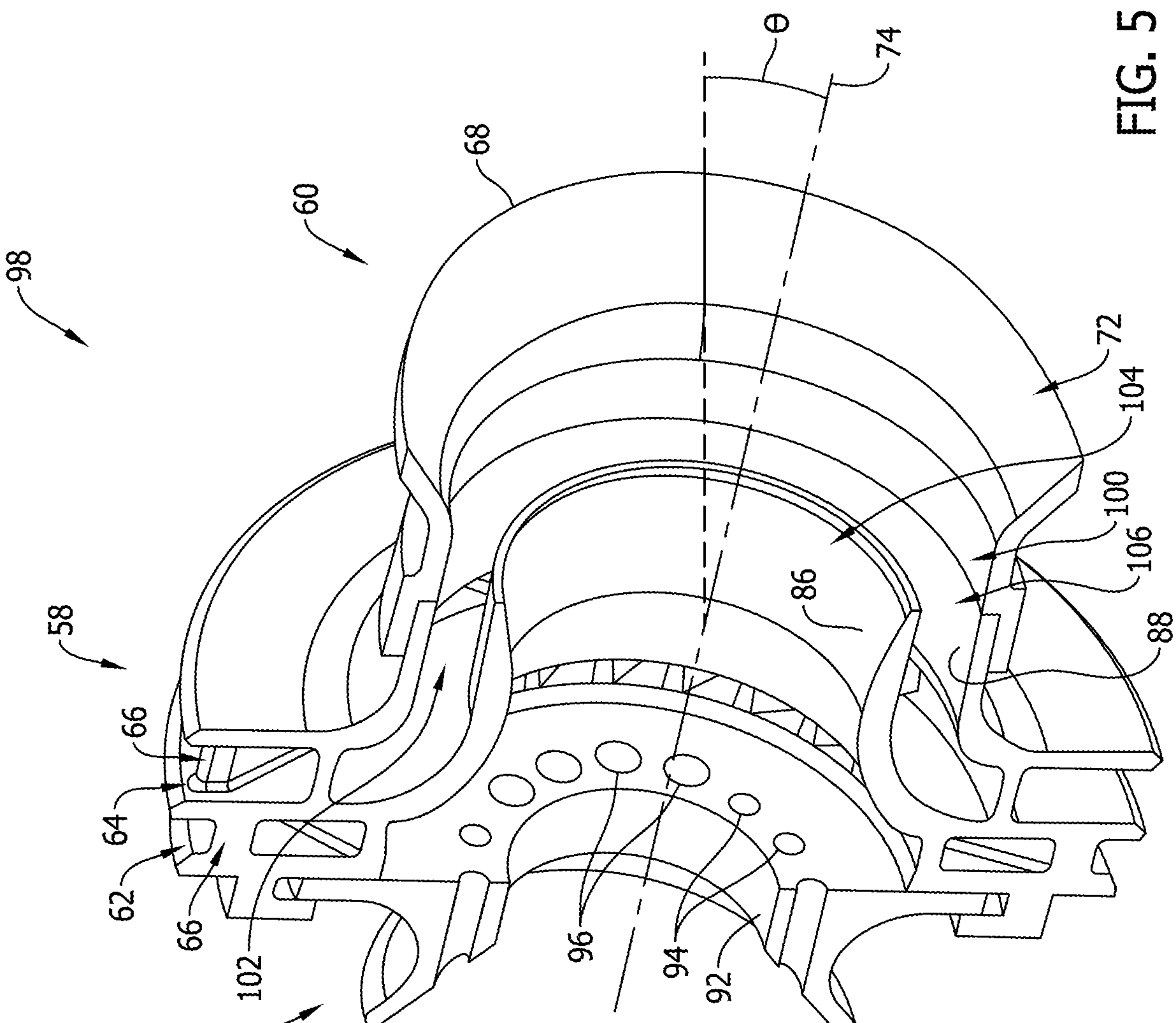

FIG. 5

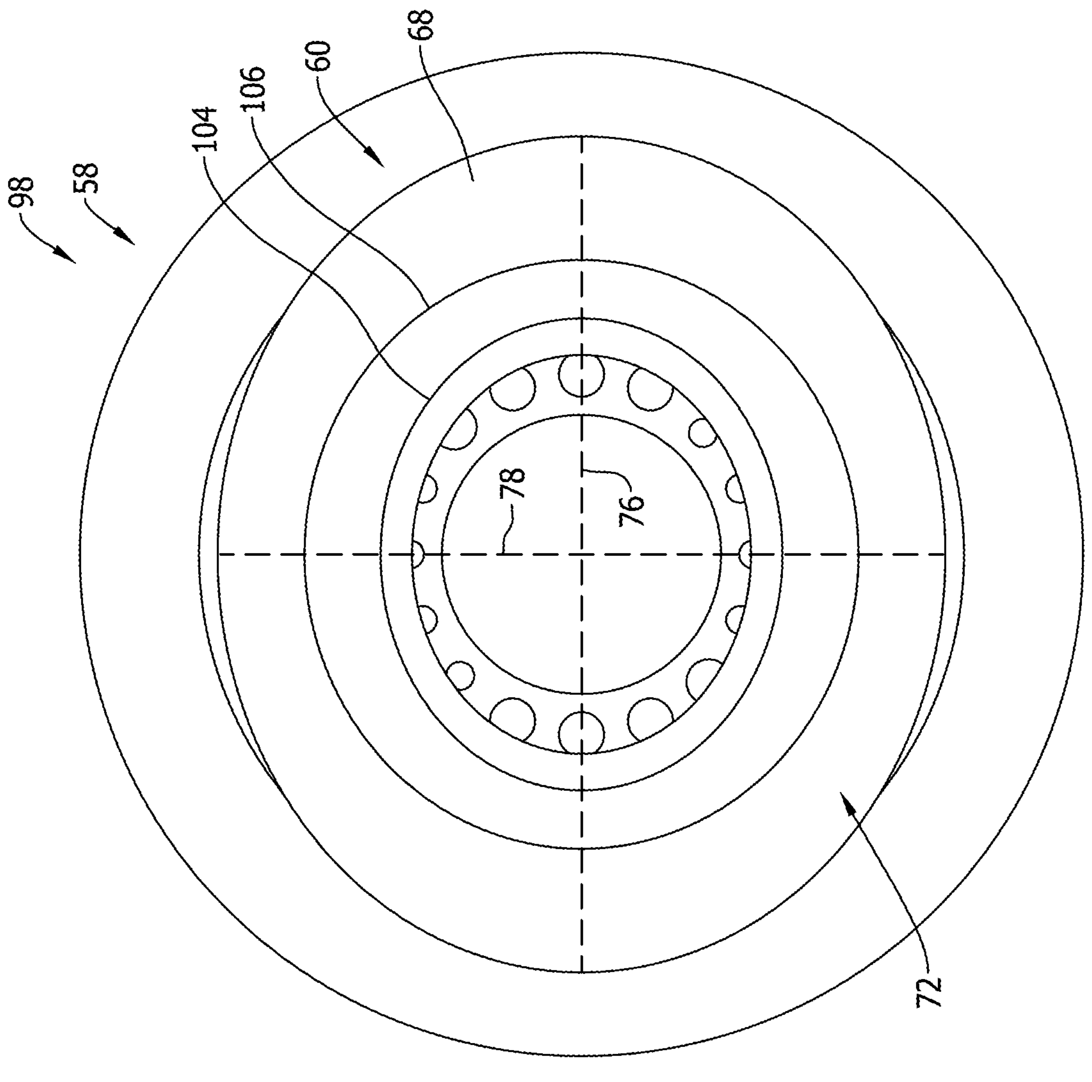

FIG. 6

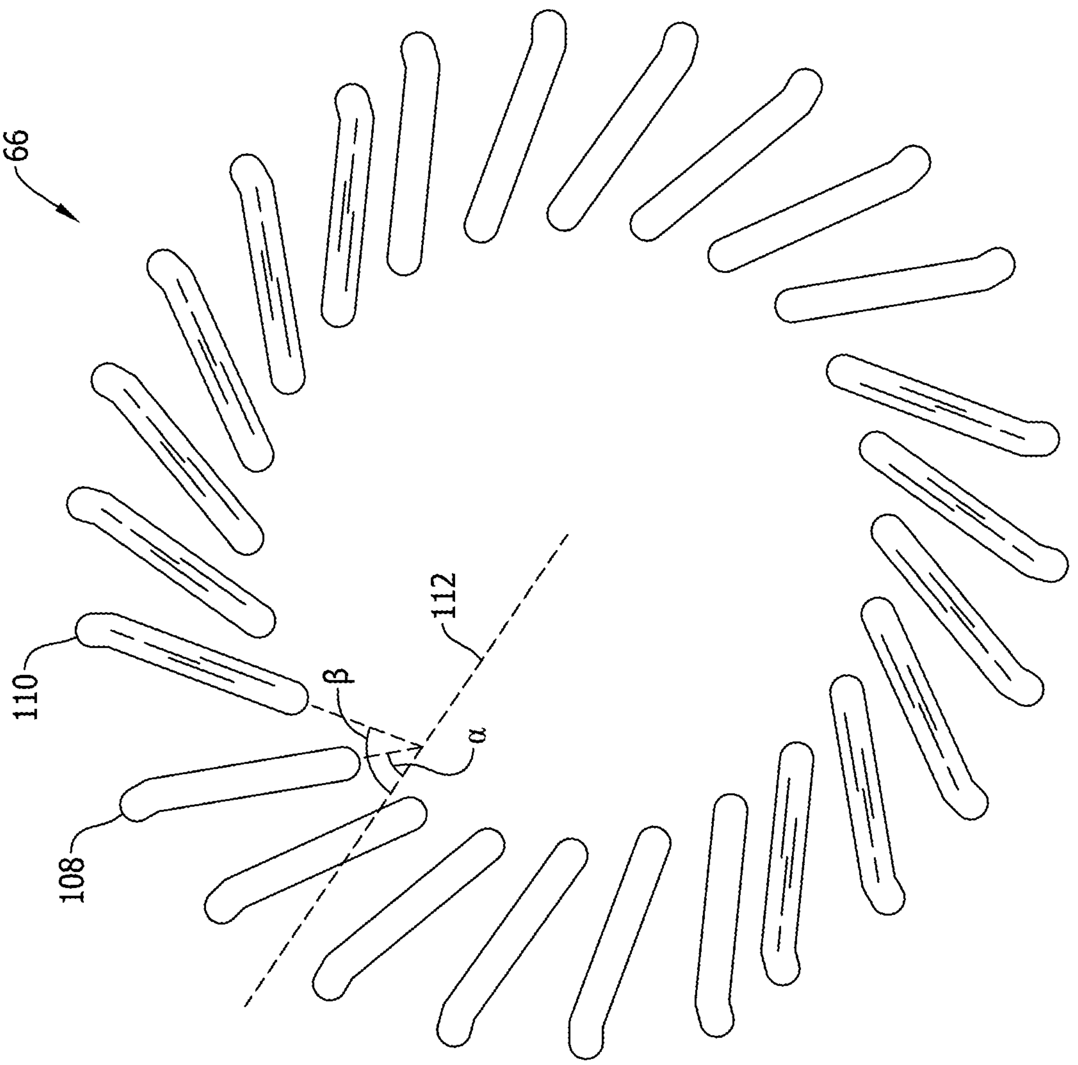

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/037374

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23R3/14 F23R3/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/165585 A1 (BURD STEVEN W [US]) 19 June 2014 (2014-06-19) paragraphs [0001], [0015], [0020], [0024], [0042], [0043], [0050]; figures 8, 9	1-3,5,6, 8-12, 14-19
X	US 2014/165578 A1 (BURD STEVEN W [US]) 19 June 2014 (2014-06-19) paragraphs [0001], [0015], [0020], [0024], [0042], [0043], [0050]; figures 8, 9	2,3,5,6, 8,10,12, 14-19
X	US 5 351 475 A (ANSART DENIS R H [FR] ET AL) 4 October 1994 (1994-10-04) column 2, lines 34-39, 51-58; figures 3, 5	1-3

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014165585 A1	19-06-2014	EP 2932157 A1	21-10-2015
		US 2014165585 A1	19-06-2014
		WO 2014099159 A1	26-06-2014
US 2014165578 A1	19-06-2014	US 2014165578 A1	19-06-2014
		WO 2014099158 A1	26-06-2014
US 5351475 A	04-10-1994	DE 69302078 D1	09-05-1996
		DE 69302078 T2	12-09-1996
		EP 0598662 A1	25-05-1994
		FR 2698157 A1	20-05-1994
		US 5351475 A	04-10-1994