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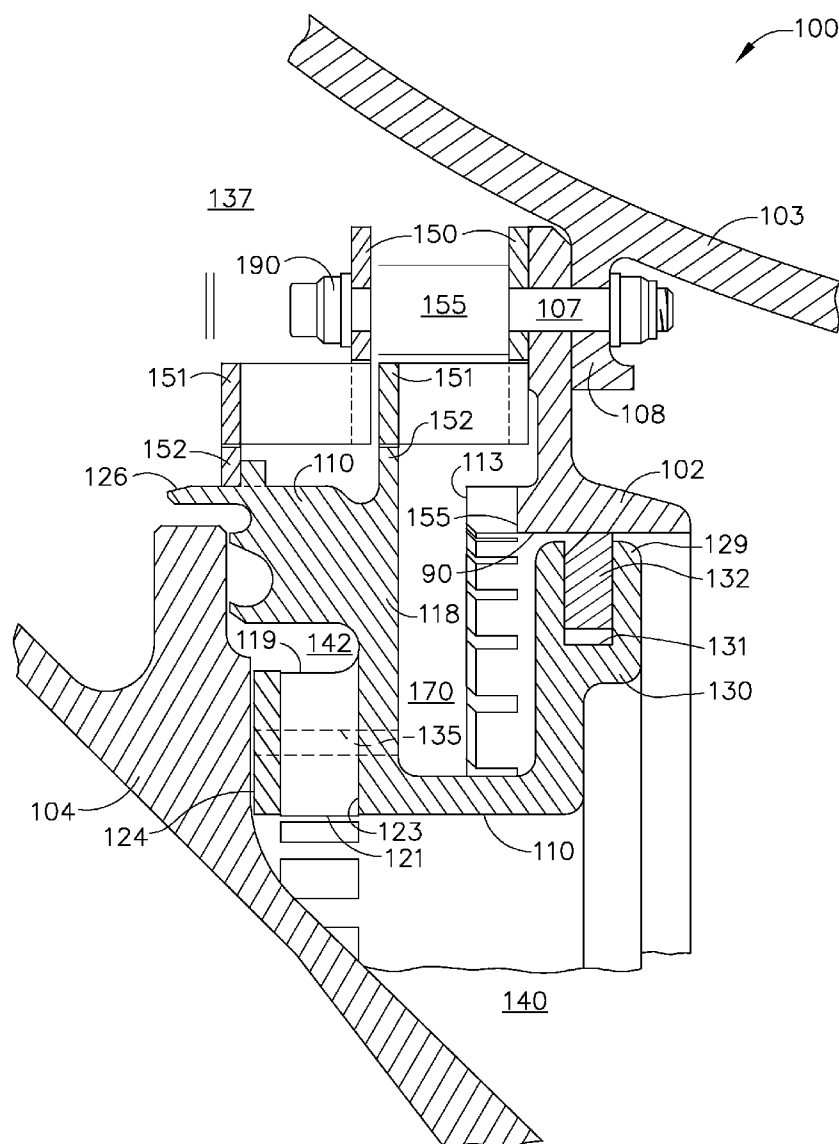
## Publication Classification

(52) **U.S. Cl.** ..... 277/355

(57) **ABSTRACT**

A seal assembly comprising a first movable stator member movable between a sealing position and a non-sealing position, a second fixed stator member, the first stator member being movable relative to the second stator member, the seal assembly further comprising at least one flexure member coupled to the second stator member, and at least one biasing member coupled between the at least one flexure and the movable stator for biasing the movable stator to a non-sealing position.

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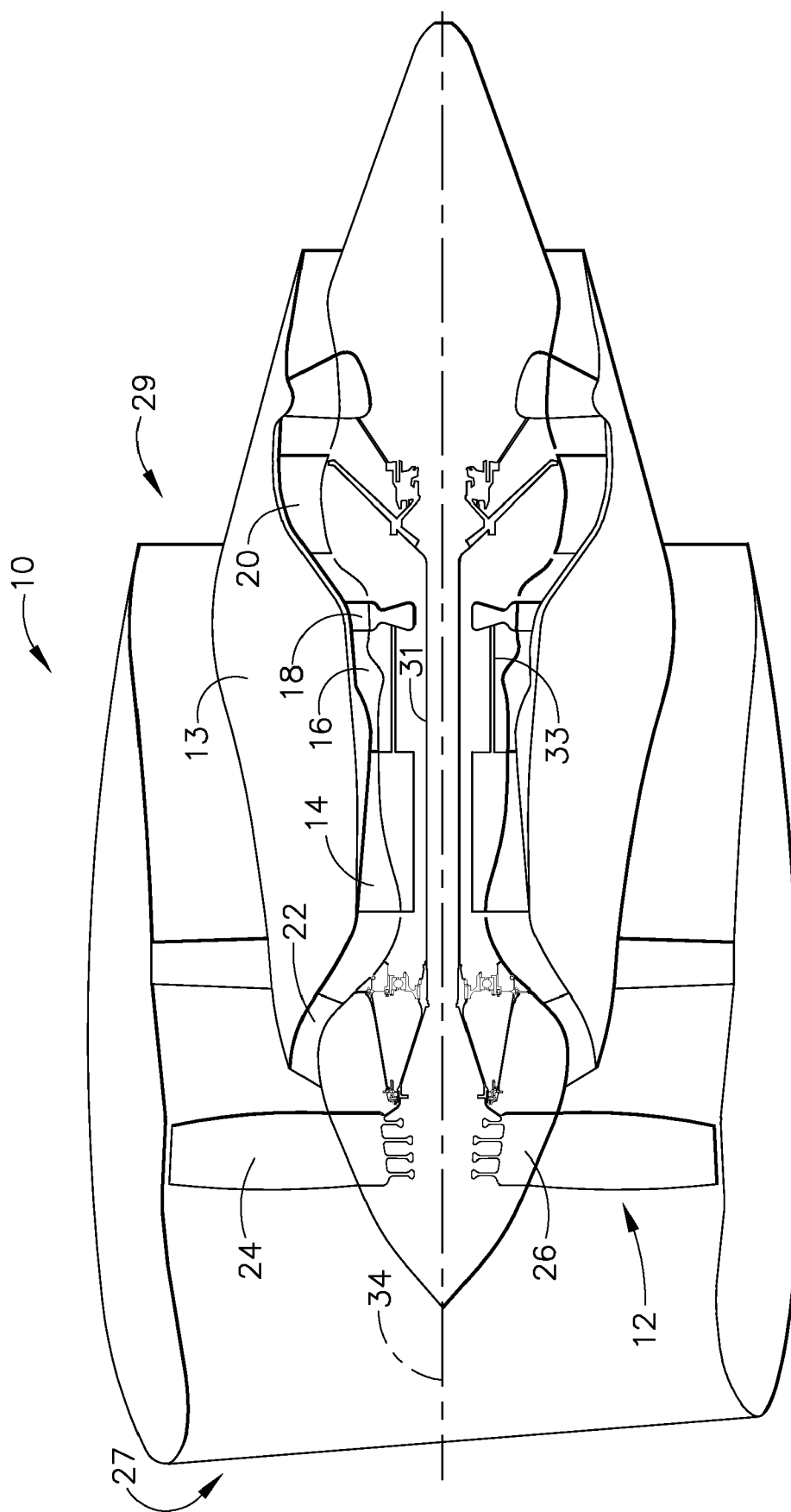


FIG. 1

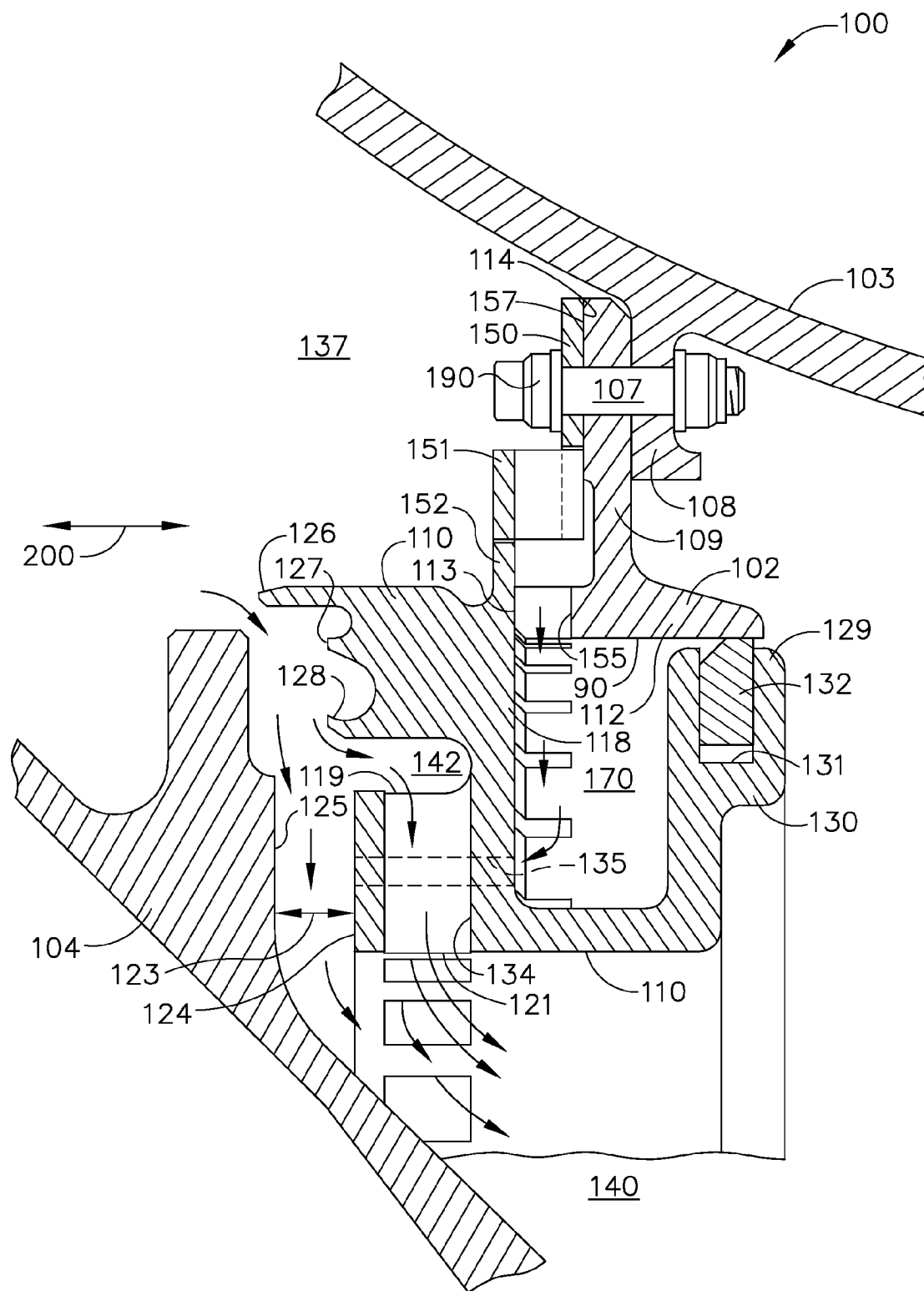


FIG. 2

FIG. 3

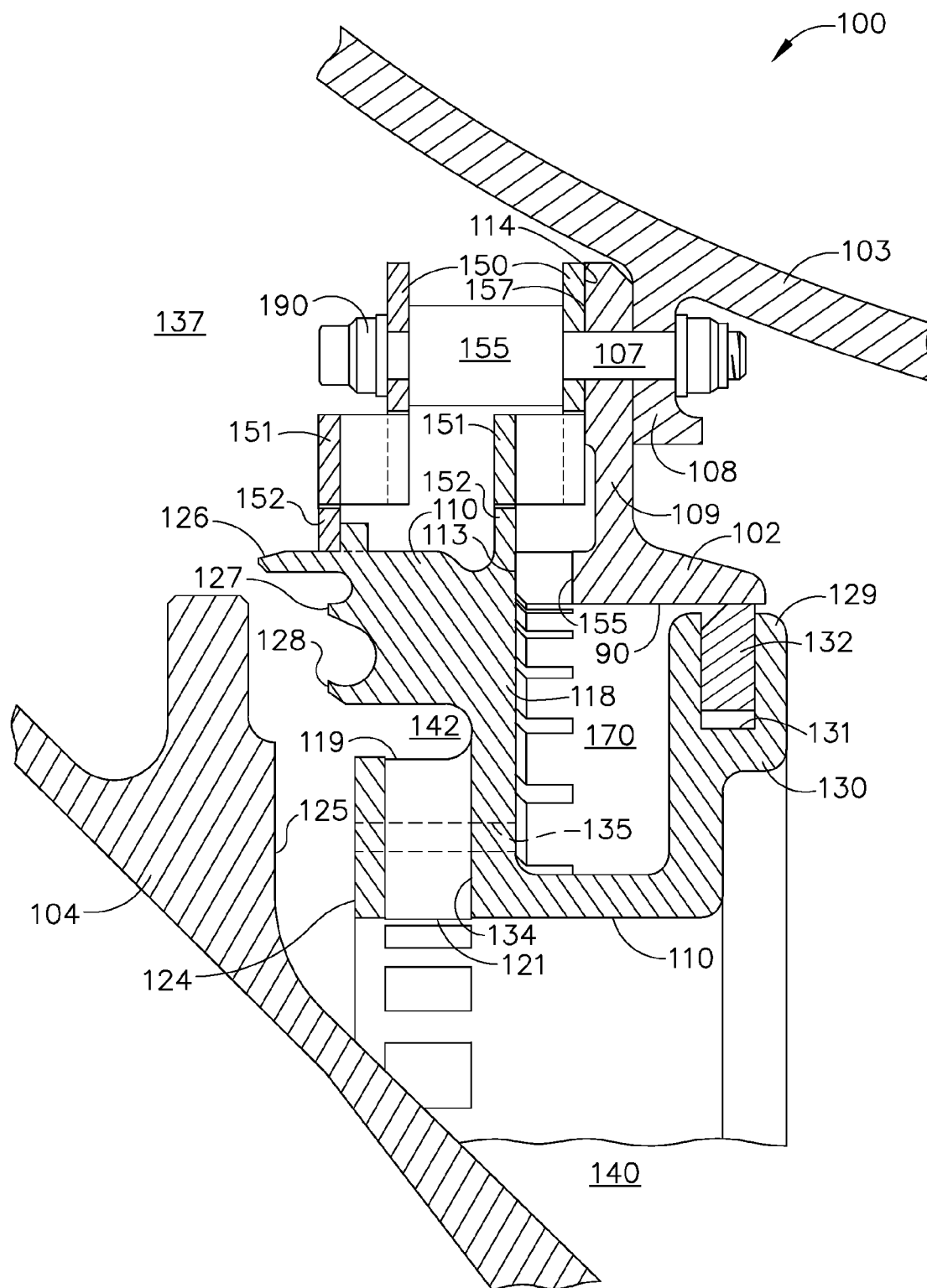


FIG. 4

FIG. 5

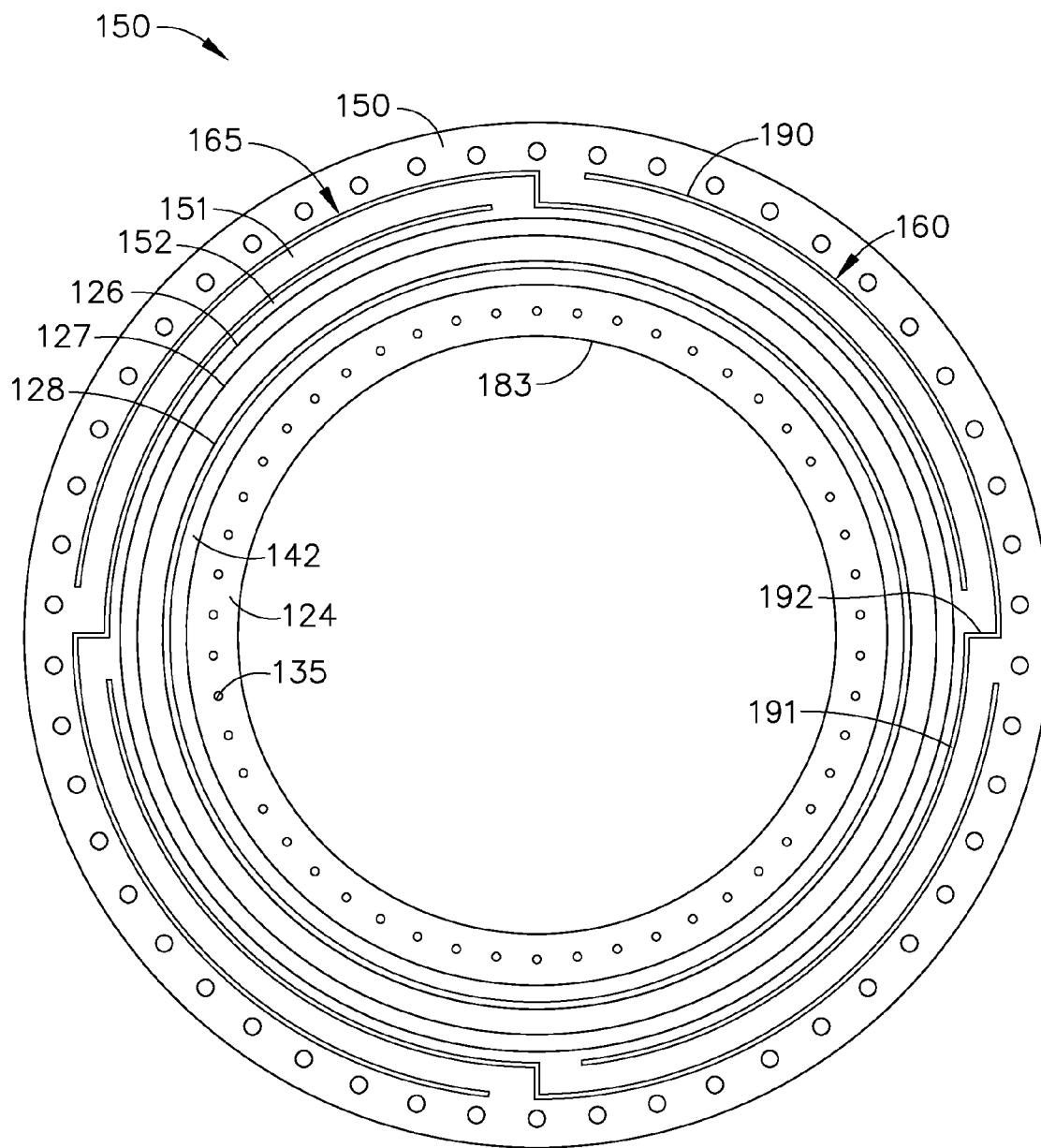


FIG. 6

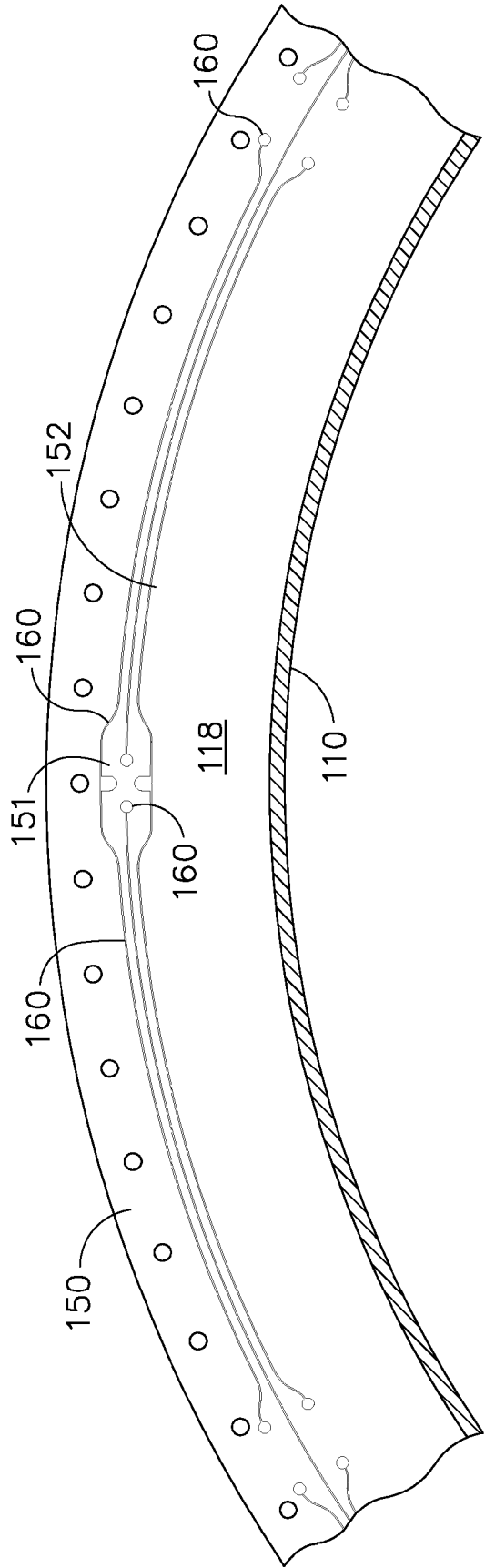


FIG. 7

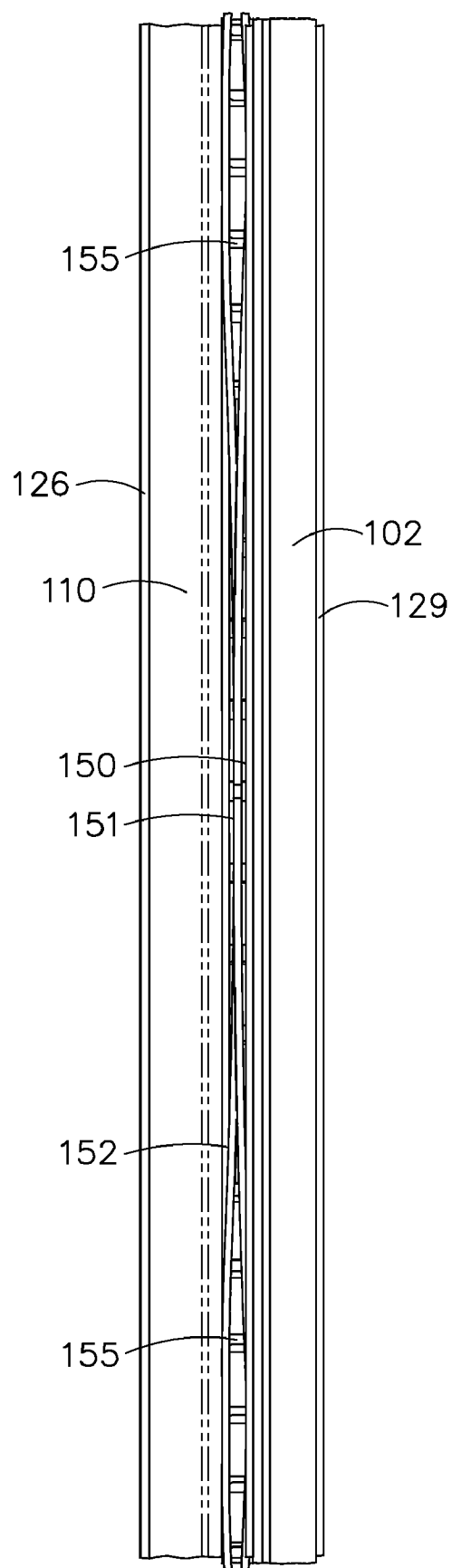


FIG. 8

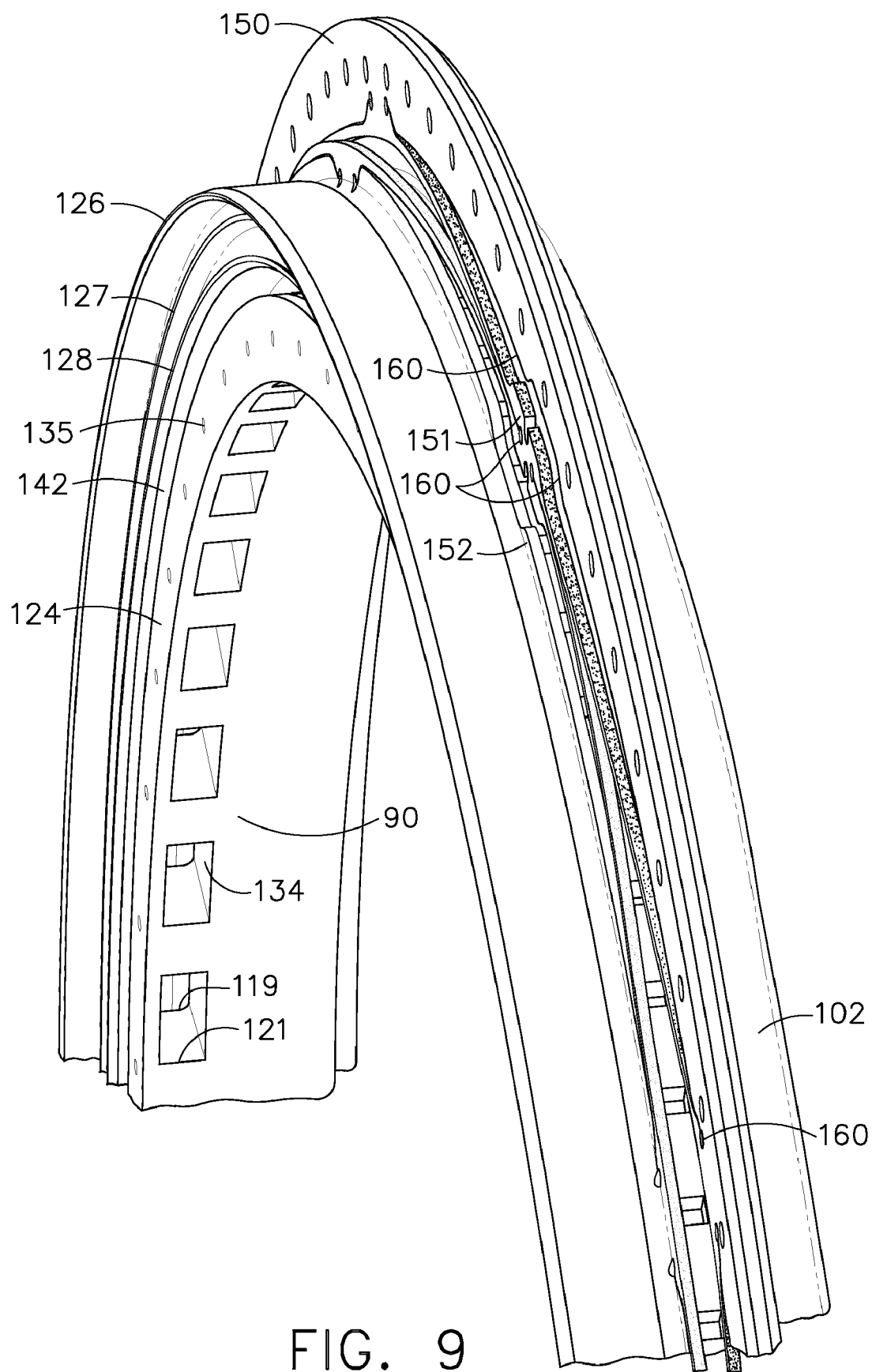


FIG. 9

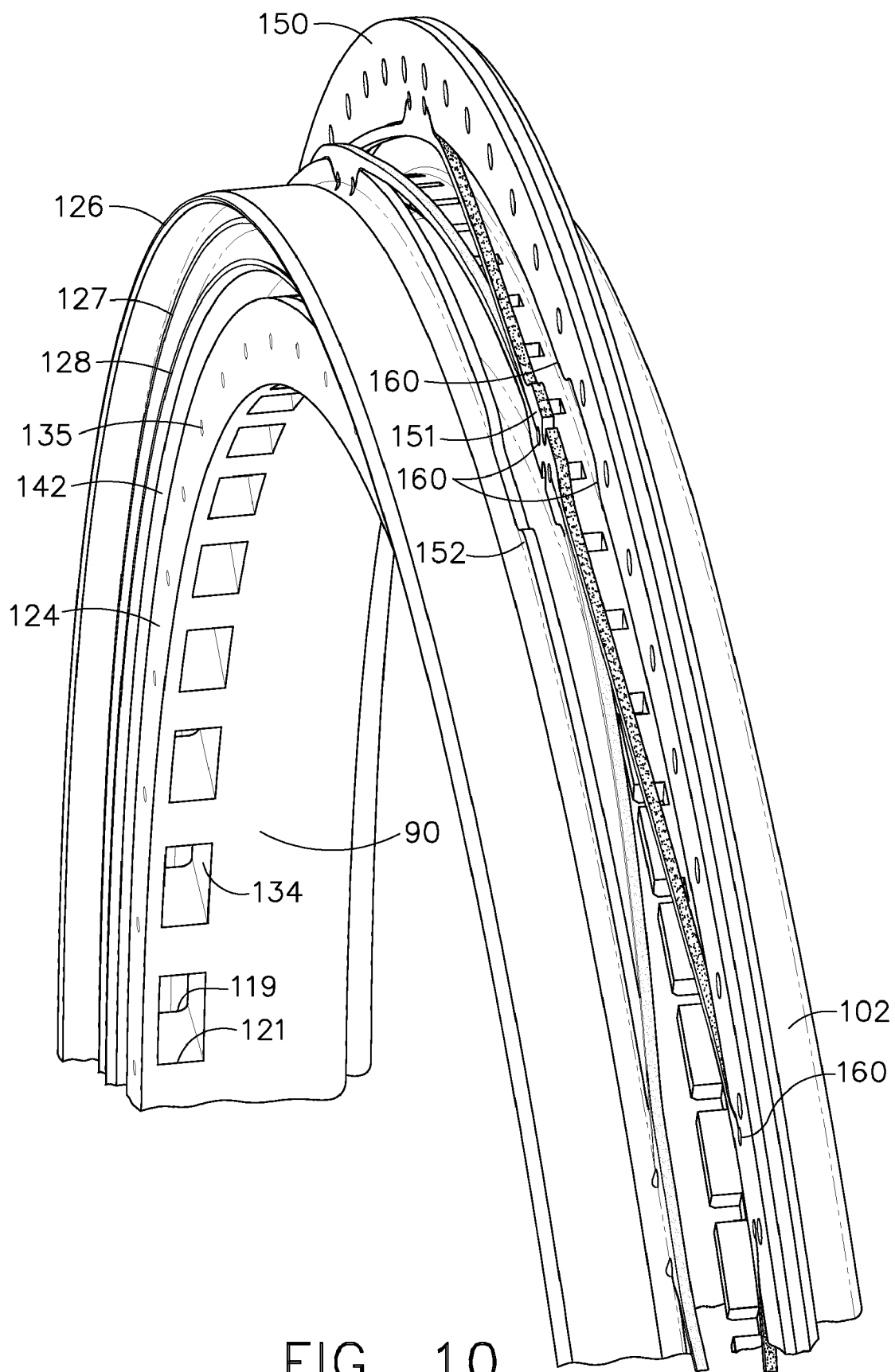


FIG. 10

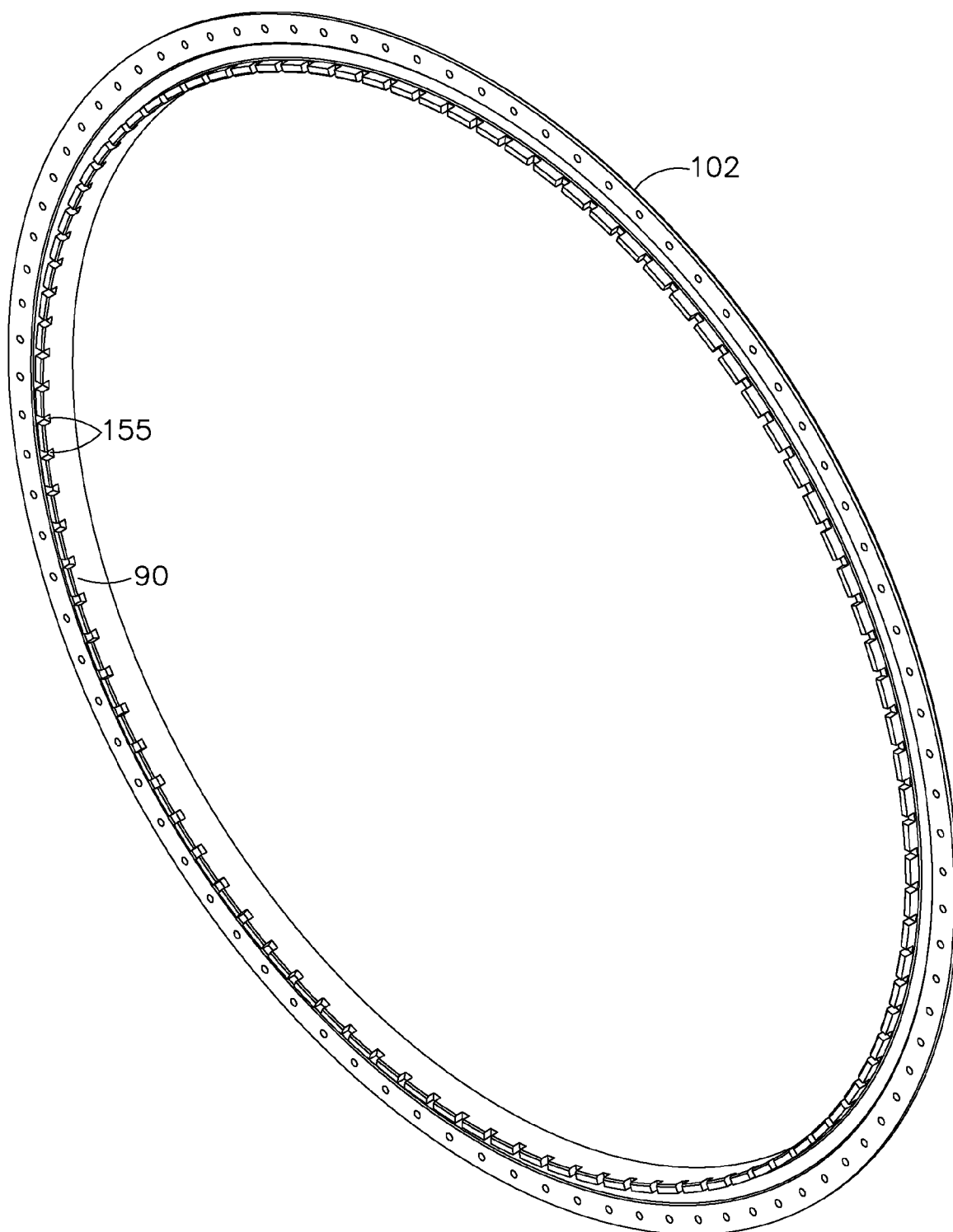


FIG. 11

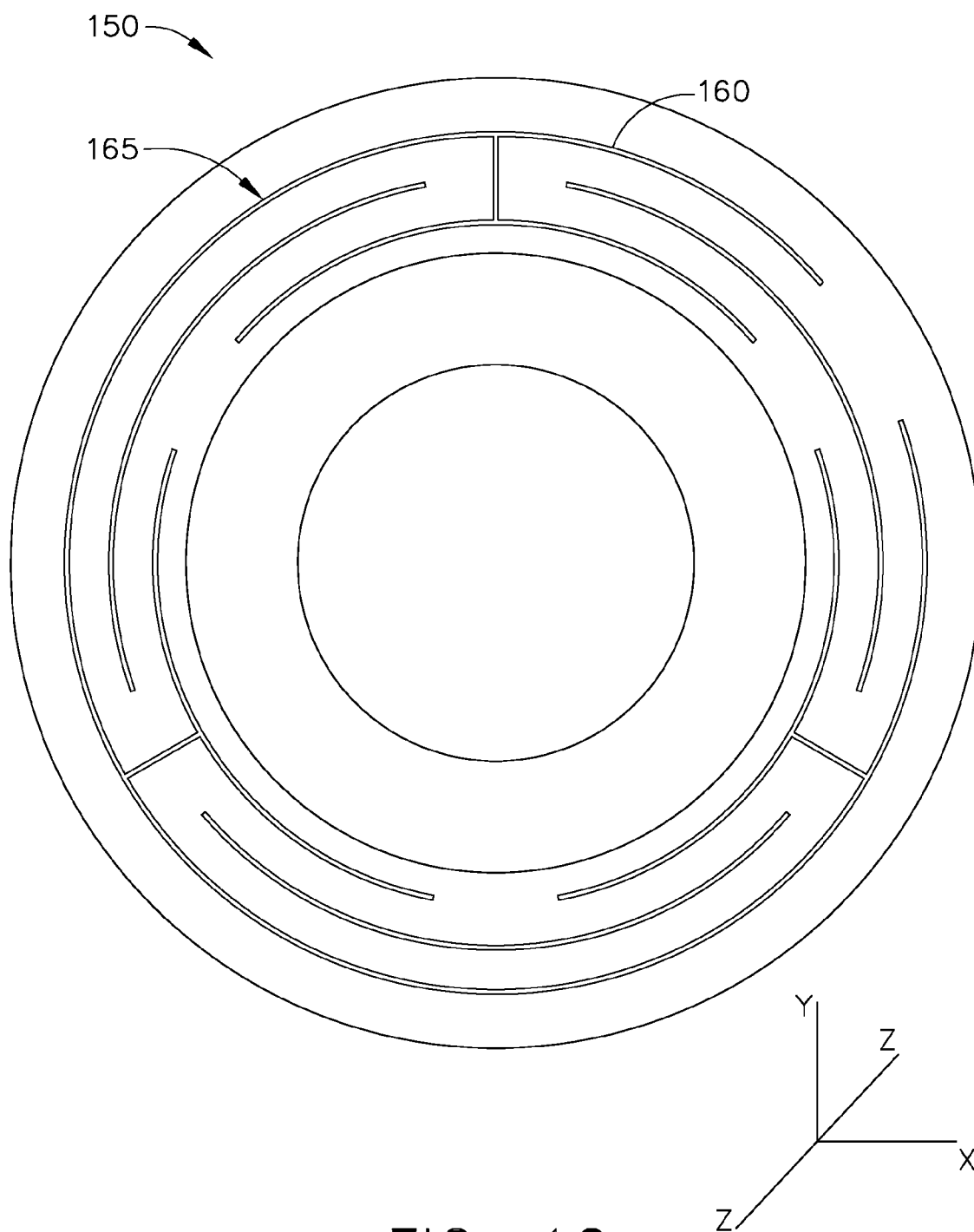


FIG. 12

## SEAL ASSEMBLY

### FIELD OF THE INVENTION

[0001] The invention generally relates to gas turbine engines and more specifically to seal assemblies used with gas turbine engines.

### BACKGROUND OF THE INVENTION

[0002] Gas turbine engines displace large volumes of pressurized fluid, such as air through the engine fluid flowpath, during operation. Seal assemblies prevent the fluid from leaking undesirably by restricting fluid flow from areas of higher pressure to areas of lower pressure. The seal assemblies may be positioned between engine stationary and rotating members. The seals compensate for transient variations in the gaps between adjacent engine component parts.

[0003] Because of the working environment of the seal assemblies, and/or the operating environment, at least some known seal assemblies may deteriorate over time. If the seals do not provide the required seal, fluid will leak past the seal detrimentally affecting the operation of the engine. Fluid leakage through gas turbine engine seal assemblies may significantly increase fuel consumption and adversely affect engine efficiency. Additionally, fluid leakage may cause damage to other engine components and increase overall engine maintenance costs.

[0004] To facilitate sealing gaps defined between regions of high and low pressure at least some known seal assemblies, such as the seal assembly described in U.S. Pat. No. 5,284,347, for example, use aspirating air to control leakage. The aspirating air prevents the rotating member from contacting the stationary member to facilitate accommodating transient variations in the gap defined between the rotating and stationary members with little or no deterioration of the seal over the life of the seal assembly. However, because of the number of discrete components comprising such a seal assembly, such seal assemblies may be complex to install in the engine, and the weight of such assemblies will increase engine weight which has a direct negative impact on engine performance. Moreover, because of the number of seal assembly components, the operating efficiency of such seal assemblies may be contingent on the tolerances between the rotating and stationary members.

[0005] There is a need to develop a seal assembly that has relatively few parts, effectively prevents leakage of fluid within a turbine engine and does not deteriorate over time.

### BRIEF DESCRIPTION OF THE INVENTION

[0006] A seal assembly comprising a first movable stator member movable between a sealing position and a non-sealing position, a second fixed stator member, the first stator member being movable relative to the second stator member, the seal assembly further comprising at least one flexure member coupled to the second stator member, and at least one biasing member coupled between the at least one flexure and the movable stator for biasing the movable stator to a non-sealing position.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0007] While the specification concludes with claims particularly pointing out and distinctly claiming the invention, it is believed that the embodiments set forth herein will be better understood from the following description in conjunction

with the accompanying figures, in which like reference numerals identify like elements, and in which:

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

[0009] FIG. 2 is a cross-sectional view of an exemplary seal assembly that may be used with the gas turbine engine shown in FIG. 1, with a movable sealing member in a first position;

[0010] FIG. 3 is a cross-sectional view of the exemplary seal assembly of FIG. 2 with the movable sealing member in a second sealing position;

[0011] FIG. 4 is a cross-sectional view of an exemplary seal assembly that may be used with the gas turbine engine shown in FIG. 1, with a movable sealing member in a first open position;

[0012] FIG. 5 is a cross-sectional view of the exemplary seal assembly of FIG. 4 with the movable sealing member in a second sealing position;

[0013] FIG. 6 is a front view of a flexure member useful with the seal assembly;

[0014] FIG. 7 is an alternate embodiment flexure member useful with the seal assembly;

[0015] FIG. 8 is a side view of the exemplary seal of FIG. 2, in a first position;

[0016] FIG. 9 is an isometric view of the exemplary seal of FIG. 2, in the first position;

[0017] FIG. 10 is an isometric view of the seal of FIG. 2 in the second sealing position, similar to the cross-sectional view shown in FIG. 3;

[0018] FIG. 11 is an isometric view of the second stator member (102 of FIG. 2); and

[0019] FIG. 12 is an illustration of a possible alternate flexure member.

### DETAILED DESCRIPTION OF THE SPECIFICATION

[0020] Although the invention is herein described and illustrated in association with a compressor to turbine interface for a gas turbine engine, it should be understood that the present invention may be used to facilitate controlling leakage of any fluid between any region of generally high pressure and any region of lower pressure.

[0021] Herein, the present invention seal assembly provides a simplified seal with a reduced part count relative to prior art seals thereby simplifying the seal assembly, and reducing the weight of the seal assembly. For example, spring assemblies used in related seal assemblies have been replaced by one or more flexure members. As will be described herein the flexure member is attached between a non-contact seal slide and a stator. Also, secondary seal assemblies of prior art sealing devices have been replaced with a single piston ring seal. The single ring seal may be retained within either a fixed or sliding stators. The design may incorporate one or more flexure members, the number thereof depending upon the design requirement.

[0022] FIG. 1 is a schematic illustration of an exemplary gas turbine engine 10 including a fan assembly 12 and a core engine 13 including a high pressure compressor 14, and a combustor 16. Engine 10 also includes a high pressure turbine 18, a low pressure turbine 20, and a booster 22. Fan assembly 12 includes an array of fan blades 24 extending radially outward from a rotor disc 26. Engine 10 has an intake side 27 and an exhaust side 29. In one embodiment, the gas turbine engine is a GE90-115B that is available from General Electric Company, Cincinnati, Ohio. Fan assembly 12 and turbine 20

are coupled by a first rotor shaft 31, and compressor 14 and turbine 18 are coupled by a second rotor shaft 33.

[0023] During operation, air flows axially through fan assembly 12, in a direction that is substantially parallel to a central axis 34 extending through engine 10, and compressed air is supplied to high pressure compressor 14. The highly compressed air is delivered to combustor 16. Airflow (not shown in FIG. 1) from combustor 16 drives turbines 18 and 20, and turbine 20 drives fan assembly 12 by way of shaft 31.

[0024] FIG. 2 is a cross-sectional view of an exemplary seal assembly 100 that may be used within gas turbine engine 10. In the exemplary embodiment, gas turbine engine 10 includes stationary stator member 102 coupled to frame 103 and a rotating member 104. In one embodiment, rotating member 104 is a rotor that is rotatably coupled within engine 10 to rotate about the axis of rotation 34. Frame 103 is a stationary circumferential member positioned around an axis of rotation 34 (not shown in FIG. 2). Frame member 103 includes an attachment flange 108 that extends outwardly away from the frame. In one embodiment, frame 103 may be comprised of the casing of gas turbine engine 10. As air flows through engine 10, frame 103 is configured to help contain flowpath air.

[0025] Stationary stator member 102 of seal assembly 100 is a stationary member that extends circumferentially around the axis of rotation 34 of gas turbine engine 10. The stator is comprised of a base 112 and a flange member 109. The base includes a base sealing surface 90 and a stop surface 113. The flange and base are perpendicular. As shown in FIG. 2, stationary stator member 102 is fixed to frame 103 by fastener 107. The fastener may be comprised of a conventional bolt member or other suitable fastening means. The stator flange 109 and frame flange 108 are coupled by the fastener member 107. A flexure member 150, which will be disclosed in greater detail below is sandwiched between the head 190 of fastener 107 and a surface 114 of flange 109 of fixed stator 102.

[0026] Seal assembly 100 also is comprised of moveable stator member 110 includes a sealing face 124 and a plurality of sealing teeth 127, 128 that extend outward from a portion of the sealing face 124. The stator 110 is movable axially, in direction generally represented by direction arrow 200 in FIG. 2. In the exemplary embodiment, sealing face 124 is substantially parallel to a rotating member surface 125 of rotating member 104. In a first position shown in FIG. 2, the sealing face 124 is located at a distance 123 away from rotating member 104. The moveable stator 110 of seal assembly 100 is located in the first position when the turbine engine is not in use with no fluid flowing through the engine flowpath.

[0027] Moveable stator member 110 also includes an opening 135 defined therein. The opening extends in the axial direction 200 when the movable stator is correctly coupled with flange 108. As shown in FIG. 2, the opening extends through the moveable stator surfaces 124 and contact surface 118. When the movable stator is in the first, retracted position, surfaces 118 and 113 are in contact. This contact between movable stator 110 and flange 108 controls the displacement of the stator 110 to the first position.

[0028] In the exemplary embodiment, openings 135 are oriented substantially perpendicular to rotating member surface 125. As described below in more detail, openings 135 help to prevent contact between the movable member 110, and specifically the plurality of teeth 127, 128; and rotating member 104. The movable stator may include any number of

openings 135 but for purposes of disclosing the exemplary embodiment, one or more openings 135 may be included in movable stator 110. Moveable stator member 110 further includes at least one radially extending opening 134. For purposes of disclosing the exemplary embodiment, a plurality of openings 134 are illustrated. However, any suitable number of radial openings 134 may be provided in stator 110. The opening 134 extends through surfaces 119 and 121 of the moveable stator member 110. In the exemplary embodiment, each opening 135 is located adjacent openings 134.

[0029] Moveable stator member 110 also includes yoke 130. The yoke extends radially and defines an opening 131 that receives a seal member 132. The seal member may be made from any suitable sealing material. As shown in FIGS. 2 and 3, when seated in opening 131, a portion of the seal member extends beyond the free end 129 of the yoke. When the movable and fixed stators are coupled as shown in the figures, the end of the seal that extends beyond free end 129 is in sealing contact with contact surface 90 of the fixed stator 102. The seal member may be a piston ring seal, for example. Note that in an alternate embodiment, the seal may be supported by stator 102 and engage a sealing surface along the movable member.

[0030] FIG. 3 shows the moveable stator member 110 in a second position, also referred to herein as a sealing position. When air is supplied to the gas turbine flowpath, the pressure of the air causes the movable stator to be displaced in direction 200. As the stator member is displaced, seal 132 remains in contact with sealing surface 90. As the moveable stator moves toward member 104, the magnitude of distance 123 is reduced from its maximum value when the movable stator member is in the first position shown in FIG. 2. As shown in FIG. 3, when the movable stator reaches the end of travel and is in the second position, the sealing face 124 and the rotating member surface 125 are proximate each other.

[0031] Seal assembly 100 also comprises at least one flexure member 150. The flexure member is substantially flat. As assembled, one end of flexure member is located proximate the flange member 109. This end is identified as 157 in FIGS. 2 and 3. Ends 157 and 152 are joined by biasing member 151. Member 151 is extendible from its retracted length shown in FIG. 2 to an extended length as shown in the sealing position of FIG. 3.

[0032] The flexure member 150 comprises a weak spring which flexes out of plane to allow axial translation of the moveable stator member 110 relative to the stationary stator member 102. The connection of the flexure member 150 to the moveable stator member 110 is shown in these figures for simplicity as being bolted to the frame 103, but integral with the moveable stator 110. It could alternatively be a separate piece, but such a configuration may increase weight, complexity, and part count.

[0033] FIGS. 9 and 10 show in isometric view (comparable to the views of FIGS. 3 and 4) the bending of the flexure member (150 series of numbers). The flexure member is fixed to stationary stator 108 by bolt connection 107. The flexure member also includes a biasing portion 151 that is made integral with the moveable stator member 110 at flange 152. The flexure member 150 may be integral with moveable stator member 110 and thereby cast with that member 110.

[0034] The flexure member 150 serves as a biasing mechanism for moving the moveable stator member 110. The member 150 biases the movable stator member toward the first position of FIG. 2. The flexure member 150 returns the mov-

able member to the first non-sealing position when the air flow through the engine is reduced to a minimum level or the engine is shut off. The flexure member **150** also controls the translation of movable member **110** to account for relative axial motion between the rotor **104** and the stator **103** during engine operation. A flexure member **150** may be pre-loaded against a stop (surface **113**) such that in an un-pressurized state the sealing face **124** is held in an open position, e.g., when the turbine engine **10** has been disengaged into the off position. This condition prevents slide contact of the moveable stator member **110** with the rotor **104** at low or no activation pressures, such contact, when unintended, operating to damage the seal assembly **100** and thus hinder its performance.

**[0035]** FIG. **6** provides an exemplary flexure member **150**. Flexure member **150** may be made from one or more of known metals in the art including steel, titanium, iron and nickel. As shown, the flexure member **150** includes a central opening **183** that centers the moveable stator member **110** about the engine axis **34**, and seams **160** which are openings that extend through the thickness of the flexure member **150**. The seams **160** permit the flexure member **150** to flex or displace in the desired manner, out of the plane of the figure. Such movement of the flexure member **150** biases a moveable stator member **110** in the required direction for example to either open or close the seal assembly **100** as directed or required.

**[0036]** As shown in FIG. **6**, the flexure member includes three seam segments **160**, however any number of seams in may be provided. In the present embodiment, each of the seams comprises two arcuate segments **190**, **191** that are joined by a non-arcuate segment **192**. The non-arcuate portion is oriented radially. As shown in FIG. **6**, for a single seam, one of the arcuate segments of each adjacent seam in the clockwise and counterclockwise directions relative to the single seam, is located in parallel to the arcuate segments of the single seam, and are separated by a radial distance approximately equal to the length of the radial segment **192**. The flexure member **150** may be configured to be an annular member as shown in FIG. **6** with central opening **183** that receives the moveable stator member **110**. Additionally the flexure member may have any suitable seam arrangement. Alternative designs for the seams are illustrated in FIGS. **7** and **12**.

**[0037]** The seams **160** are openings within each flexure member **150** that have been cut therein into a pattern determined beforehand as suitable to enable the flexure member **150** to flex and therefore bias as required. A suitable method for cutting the seams **160** into the flexure member **150** is by electro discharge machining which process is well known by persons of skill in the art. It is noted herein, though, that the methodology for cutting the seams **160** into the flexure member **150** forms no part of the invention herein. In another embodiment herein, a flexure member **150** may be cast such that the seams **160** are a byproduct of the casting process; i.e., cast such that the openings are part of the process.

**[0038]** FIG. **7** provides a cut-out of a portion of an alternate configuration of the flexure member **150** of FIG. **6**. In particular, a portion of a seam **160** is shown enlarged. Herein, each darkened line of the seam **160** represents an opening through the flexure member **150**. FIG. **6** illustrates a possible configuration of a flexure member **150**(spring). Taking a sheet of material and cutting the indicated slots in it allows a small force to displace the center of the sheet (feature **152** of FIG. **2**)

out of plane from the periphery of the sheet (feature **150** of FIG. **2**). FIG. **7** shows an alternative configuration of these cuts. An infinite number of possible configurations are possible, of which the ones shown in FIGS. **6**, **7**, and **12** are shown as examples.

**[0039]** FIGS. **4** and **5** show an alternate embodiment seal assembly **100** of the present invention. FIG. **4** shows the movable stator in a first non-sealing position and FIG. **5** shows the movable stator in a second, sealing position. The seal **100** includes flexure members **150** located at opposite ends of an elongate fastener **107**. The flexure members are separated by spacer **155** that is slidably located on the fastener **107**. In this alternate configuration, flexure members **150** are positioned in a parallel orientation and are held apart by a spacer **155**. Spacer **155** is a useful but not required device between the two flexure members **150**.

**[0040]** The flexure members **150** always act to open the seal (moving the movable stator member **110** to the position shown in FIG. **4**). Air pressures during engine operation overcome the spring forces of the flexure members **150** to move the moveable stator member **110** to the closed position (FIG. **5**).

**[0041]** As shown in FIGS. **4** and **5**, two flexible members **151** are coupled between ends **150** and **152** as described in conjunction with the description of seal assembly **100**. Both members **151** extend when the movable stator is displaced in direction **200** to a sealing position. Additionally, seal **132** is in sealing contact with surface **90** of fixed stator base **102**.

**[0042]** During operation, cooling air and/or fluids flow through gas turbine engine **10**. When engine **10** is in operation, high pressure air flows toward the aft engine end **29**. A portion of the highly compressed air discharged from high pressure compressor **14** is directed towards seal assembly **100** for use as cooling fluid. Seal assembly **100** facilitates substantially controlling fluid flow from a region of higher pressure **137** to a region of lower pressure **140** within gas turbine engine **10**. The pressure differential between higher pressure region **137** and lower pressure region **140** initiates flow through seal assembly **100**. The pressures acting on the moveable stator member **110** are such that the pressure forces overcome the spring force of the flexure member **151**, and the moveable stator member **110** will translate from the first position (shown in FIGS. **2** and **4**) to the second, sealing position (FIGS. **3** and **5**).

**[0043]** Additionally, during operation, a portion of the high pressure air flows through openings **135**. In the exemplary embodiment, opening **135** is a plurality of feed openings. Openings **135** form a high pressure film or air bearing between surfaces **124** and rotating member surface **125**. The air bearing prevents moveable stator member **110** from contacting rotating member **104**.

**[0044]** After air flows through opening **135**, the air exits to the region of lower pressure **140**. Also, a portion of air may leak past seal teeth **126**, **127**, **128**. Air that leaks past seal teeth **126**, **127**, **128** and that portion of the air that has exited opening **135** and flows radially outward, flows through radial openings **134** to the region of lower pressure **140**.

**[0045]** While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

1. A seal assembly comprising:
  - a first movable stator member movable between a sealing position and a non-sealing position, a second fixed stator

member, the first stator member being movable relative to the second stator member, the seal assembly further comprising at least one flexure member coupled to the second stator member, and at least one biasing member coupled between the at least one flexure member and the movable stator for biasing the movable stator to a non-sealing position.

2. The seal assembly of claim 1 having at least two flexure members and two biasing members, each biasing member coupled to a flexure member.

3. The seal assembly as claimed in claim 1, the second stator comprising a base and a surface along the base, the first stator comprising a sealing member that sealingly engages the contact surface of said base.

4. The seal assembly of claim 3 wherein the first stator comprises a yoke, said member being located in said yoke.

5. The seal assembly as claimed in claim 1 wherein the flexure member is supported on a fastener member.

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