(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 January 2016 (21.01.2016)

(10) International Publication Number
WO 2016/010663 A1

(51) International Patent Classification:
F01D 11/00 (2006.01) *F01D 11/22* (2006.01)
F01D 11/12 (2006.01) *F16J 15/44* (2006.01)

(21) International Application Number:
PCT/US2015/035902

(22) International Filing Date:
16 June 2015 (16.06.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
14/330,183 14 July 2014 (14.07.2014) US

(71) Applicant: GENERAL ELECTRIC COMAPNY [US/US]; 1 River Road, Schenectady, NY 12345 (US).

(72) Inventors: LUSTED, Roderick, Mark; One Research Circle, Niskayuna, NY 12309 (US). BRISSON, Bruce, William; 2083 East Street, Galway, NY 12074 (US). SARRI, Franco; Via F. Matteucci, 2, I-50127 Firenze (IT). GHASRIPOOR, Farshad; 5 Pinewood Drive, Glenville, NY 12302 (US).

(74) Agents: DOMBROWSKI, Joanna, M. et al.; General Electric Comapny, Global Patent Operation, 3135 Easton Turnpike, Fairfield, CT 06828 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: ELLIPTICAL SEALING SYSTEM

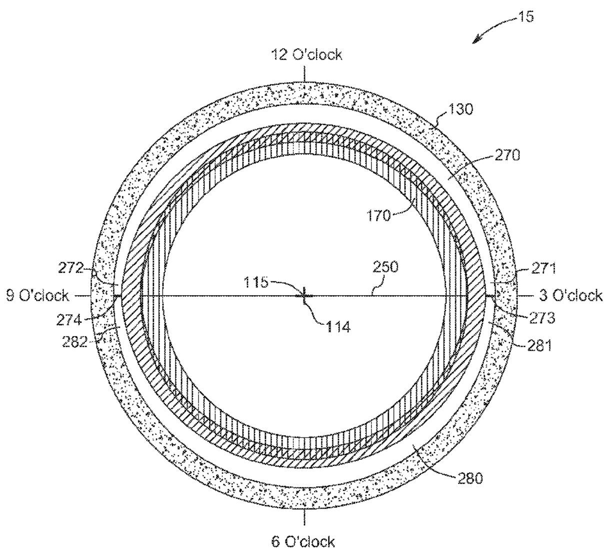

FIG. 4

(57) Abstract: Some embodiments of the invention are directed to an elliptical sealing system for use with a rotor and a stator housing of a rotary machine. The elliptical sealing system includes a plurality of sealing segments; and an abradable coating having a uniform thickness disposed on each of the plurality of sealing segments, such that the plurality of sealing segments with the abradable coating disposed thereon has a substantially elliptical shape under all conditions when the rotor rotates and the rotor remains stationary. A rotary machine having the elliptical sealing system is also disclosed.

WO 2016/010663 A1

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))*

ELLIPTICAL SEALING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application is a continuation-in-part of U.S. Application Serial No. 12/986226 filed on January 7, 2011, the entire contents of which are hereby incorporated by reference.

BACKGROUND

[002] The present application relates generally to seals for use with rotary machines and more particularly relates to a compliant and an abradable labyrinth sealing system having an elliptical shape for use with a rotary machine such as a rotary compressor and the like.

[003] In a rotary machine, one or more seal generally extend along an interface between the rotating and the stationary components. For example, compressors, turbines, and the like may have one or more seals at the interface between a series of rotating blades or buckets disposed within a casing or a vane. These seals are intended to preserve a pressure differential across the rotating components between upstream and downstream sides thereof. A smaller clearance dimension at the seal generally increases the performance of the seal and the efficiency of the overall rotary machine by limiting the leakage thereacross.

[004] The seals and the components thereof, however, may be subject to relatively high temperatures, thermal gradients, and thermal expansion and contraction during various operational stages of the rotary machine such as during start-up and during other types of transient operations. Typically, the seal includes an extra clearance dimension to reduce the likelihood of contact and damage between the rotating and the stationary components during such transient operations. This extra clearance dimension, however, also may reduce the performance and efficiency of the seal and the overall rotary machine because of the leakage flow across the seal. Fluid leakage between the rotor and the casing may lower the efficiency of the compressor and hence lead to increased fuel costs.

[005] There is thus a desire for an improved sealing system for a rotary machine such as a compressor and the like that reduces leakage therethrough while maintaining adequate clearance during transient operations as well as during steady state operating conditions. Such reduced leakage should improve overall efficiency while preventing damage to the components herein.

BRIEF DESCRIPTION

[006] One embodiment of the invention is directed to an elliptical sealing system for use with a rotor and a stator housing of a rotary machine. The elliptical sealing system includes a plurality of sealing segments; and an abradable coating having a uniform thickness disposed on each of the plurality of sealing segments, such that the plurality of sealing segments with the abradable coating disposed thereon has a substantially elliptical shape under all conditions when the rotor rotates and the rotor remains stationary.

[007] Another embodiment of the invention is directed to a rotary machine. The rotary machine includes a stator housing, a rotor including a plurality of teeth mounted thereon. The rotary machine further includes a first semielliptical sealing segment and a second semielliptical sealing segment mechanically coupled to each other at about a 3 o'clock position and about a 9 o'clock position. Each of the first semielliptical sealing segment and the second semielliptical sealing segment includes an abradable coating of a uniform thickness disposed thereon. The first semielliptical sealing segment and the second semielliptical sealing segment with the abradable coating disposed thereon have an elliptical shape under all conditions when the rotor rotates and the rotor remains stationary. The abradable coating has an interference engagement with the plurality of teeth at about a 12 o'clock position and at about a 6 o'clock position, and the abradable coating has a line on line engagement with the plurality of teeth at about the 3 o'clock position and at about the 9 o'clock position

DRAWINGS

[008] These and other features, aspects, and advantages of the present invention 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:

[009] FIG. 1 is a schematic view of a rotary machine, in accordance with one embodiment of the invention;

[0010] FIG. 2 depicts an axial view of a rotor, in accordance with one embodiment of the invention;

[0011] FIG. 3 depicts an axial view of an elliptical sealing system, in accordance with one embodiment of the invention;

[0012] FIG. 4 depicts an axial view of a compressor of a gas turbine engine, in accordance with one embodiment of the invention;

[0013] FIG. 5 depicts a cross-sectional view of a compressor having an elliptical sealing system, in accordance with one embodiment of the invention;

[0014] FIG. 6 depicts an axial view of a compressor when the rotor 120 rotates, in accordance with one embodiment of the invention; and

[0015] FIG. 7 depicts an axial view of a compressor in a steady state condition, in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

[0016] The present disclosure may be best understood with reference to the figures and detailed description set forth herein. Various embodiments are discussed below with reference to the figures. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is just for explanatory purposes as the system extends beyond the described embodiments.

[0017] 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”, and “substantially” is not to be limited to the precise value specified. 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.

[0018] In the following specification and the claims, the singular forms “a”, “an” and “the” include plural referents unless the context clearly dictates otherwise. As used herein, the term “or” is not meant to be exclusive and refers to at least one of the referenced components being present and includes instances in which a combination of the referenced components may be present, unless the context clearly dictates otherwise.

[0019] As used herein, the terms “may” and “may be” indicate a possibility of an occurrence within a set of circumstances; a possession of a specified property, characteristic or function; and/or qualify another verb by expressing one or more of an ability, capability, or possibility associated with the qualified verb. Accordingly, usage of “may” and “may be” indicates that a modified term is apparently appropriate, capable, or suitable for an indicated capacity, function, or usage, while taking into account that in some circumstances, the modified term may sometimes not be appropriate, capable, or suitable.

[0020] FIG. 1 is a schematic view of a rotary machine such as a gas turbine engine 10, in accordance with one embodiment of the invention. The gas turbine engine 10 may include a compressor 15. The compressor 15 compresses an incoming flow of air 20. The compressor 15 delivers the compressed flow of the air 20 to a combustor 25. The combustor 25 mixes the compressed flow of the air 20 with a compressed flow of fuel 30 and ignites the mixture to create a flow of combustion gases 35. Although only a single combustor 25 is shown, the gas turbine engine 10 may include any number of combustors. The flow of the combustion gases 35 is delivered in turn to a turbine 40. The flow of the combustion gases 35 drives the turbine 40 so as to produce mechanical work. The mechanical work produced in the turbine 40 drives the compressor 15 and an external load 45 such as an electrical generator and the like.

[0021] The gas turbine engine 10 may use natural gas, various types of syngas, and/or other types of fuels. The gas turbine engine 10 may be one of any number of different gas turbine engines offered by General Electric Company of Schenectady, New York and the like. The gas turbine engine 10 may have other configurations and may use other types of components. Other types of gas turbine engines also may be used herein. Multiple gas turbine engines 10, other types of turbines, and other types of power generation equipment also may be used herein together. Other types of rotary machines also may be used herein.

[0022] Gas leakage out of the gas path or into the gas path of the gas turbine engine 10 from an area of higher pressure to an area of lower pressure generally is undesirable. As described above, gas path leakage in the compressor 15 and/or in the turbine 40 may lower the efficiency of the overall gas turbine engine 10 and lead to increased fuel costs. The gas turbine engine 10 therefore may include a sealing system 50 provided in the compressor 15 and/or the turbine 40. The sealing system 50 facilitates a minimum clearance between the stationary components and the rotating components therein. As a result, fluid leakage through these components may be minimized so as to enhance overall efficiency.

[0023] FIG. 2 depicts an axial view of a rotor 120, in accordance with one embodiment of the invention. For example, the rotor 120 may form a part of the compressor 15 or the turbine 40 of the rotary machine such as the gas turbine engine 10. It is apparent to a person of ordinary skill in the art that the rotor 120 may also be implemented in other suitable sections of any other type of rotary machines without departing from the scope of the present specification. As depicted in

FIG. 2, the rotor 120 may have a circular shape. The rotor 120 includes a plurality of teeth mounted thereon. In one example, the plurality of teeth is in a form of J-strips. A numeral 113 in the axial view of FIG. 2 represents an area occupied by the plurality of teeth. The area 113 occupied by the teeth is depicted by a texture having vertical lines. A center of the rotor 120 is hereinafter also referred to as a rotoric center 114 which is depicted using + symbol. The rotor 120 may be mounted on a rotor bearing (not shown) through a rotor journal (not shown).

[0024] FIG. 3 depicts an axial view of an elliptical sealing system 140, in accordance with one embodiment of the invention. The elliptical sealing system 140 is similar to the sealing system 50 that may be placed in the rotary machine. As depicted in FIG. 3, the elliptical sealing system 140 includes a first semielliptical sealing segment 270 and a second semielliptical sealing segment 280. In one embodiment of the invention, the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280 may form a packing ring (see FIG. 5). Each of the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280 has an abradable coating 170 having uniform thickness disposed thereon. The abradable coating 170 is shown using a texture having angled lines.

[0025] The abradable coating 170 may include an alloy of cobalt, nickel, chromium, aluminum, yttrium, hexagonal boron nitride, and polymers such as polyesters, polyimides, or the like. Alternatively, the abradable coating 170 may include nickel, chromium, aluminum, and clay (bentonite). Further, the abradable coating 170 may include nickel, graphite, and stainless steel. Furthermore, the abradable coating 170 may include nickel, chromium, iron, aluminum, boron and nitrogen. Furthermore, the abradable coating 170 may also include non-metallic materials (e.g., polytetrafluoroethylene applied by electrostatic powder coating process or polytetrafluoroethylene filled synthetic mica which may be attached by a mechanical device). The abradable coating 170 may use any desired material in any desired size, shape, and/or orientation.

[0026] As depicted in FIG. 3, a first end 271 of the first semielliptical sealing segment 270 is mechanically coupled to a first end 281 of the second semielliptical sealing segment 280 at about a 3 o'clock position. Similarly, a second end 272 of the first semielliptical sealing segment 270 is mechanically coupled to a second end 282 of the second semielliptical sealing segment 280 at about a 9 o'clock position. Numerals 273 and 274 represent coupling joints between the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280. In sharp contrast to traditional designs where a sealing system is formed using more than two segments, the embodiments of the present invention are implemented using only two semielliptical sealing segments such as the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280.

[0027] The shapes of the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280 are such that when coupled to each other, the coupling joints 273 and 274 define a major axis 250 of the elliptical shape of the sealing system 140. In one embodiment, the length of the major axis 250 is substantially equal to the outside diameter of the rotor 120 defined by the plurality of teeth mounted on the outer surface of the rotor 120. Further, as depicted in FIG. 3, the abradable coating 170 has a uniform thickness. Consequently, an inner surface of the elliptical sealing system 140 resembles a substantially elliptical or an elliptical shape under all conditions when the rotor 120 rotates and the rotor 120 remains stationary (e.g., does not rotate). By use of the term “elliptical”, we also include various types of hyperboloid, parabaloid, and other types of similar shapes.

[0028] FIG. 4 depicts an axial view of the compressor 15 of the gas turbine engine 10, in accordance with one embodiment of the invention. The axial view of FIG. 4 may be realized when the rotor 120 and the elliptical sealing system 140 are assembled into a stator housing 130 (depicted using dotted texture) of the compressor 15. Although, in the embodiment of FIG. 4, the elliptical sealing system 140 is shown as a part of the compressor 15, the elliptical sealing system 140 may also be implemented in other suitable components (e.g., the turbine 40) of the gas turbine engine 10 or any other type of rotary machines without departing from the scope of the present specification.

[0029] A center of the stator housing 130 is hereinafter also referred to as a statoric center 115 which is represented by + symbol. In one embodiment of the invention, the rotor 120 and the elliptical sealing system 140 are assembled such that the rotoric center 114 and the statoric center 115 are centrally aligned. Further, in one embodiment of the invention, the rotor 120 and the elliptical sealing system 140 are assembled such that the abradable coating 170 has an interference engagement with the teeth of the rotor 120 at about the 12 o’clock position and at about the 6 o’clock position, and the abradable coating 170 has a line on line engagement with the teeth at about the 3 o’clock position and at about the 9 o’clock position. The term “line on line arrangement” as used herein refers to providing no engagement between the abradable coating 170 and the teeth at the 3 o’clock and the 9 o’clock positions such that no end gap is introduced at the 3 o’clock and the 9 o’clock positions. Such line on line engagement is achieved by designing the rotary machine such that the major axis 250 of the elliptical sealing system 140 is substantially equal to the outside diameter of the rotor 120 defined by the teeth.

[0030] Once assembled, the gas turbine engine 10 may be operated for about a few seconds or minutes (hereinafter also referred to as an initial period of rotation). For example, when operated at a certain speed (e.g., at about 4500 rpm) during the initial period of rotation, the rotor journal may be lifted-up into the rotor bearing from its initial position. Consequently, the rotor 120 also lifts-up and the teeth of the rotor 120. The teeth in turn abrade the abradable coating 170 defining an elliptical groove (at times herein referred to as a path) in the abradable coating 170. In one embodiment of the invention, the teeth of the rotor 120 abrade the abradable coating 170 at about the 12 o'clock position and at bout the 6 o'clock position. More particularly, due to the upward lift of the rotor 120, the teeth abrade more material at about the 12 o'clock position than at about the 6 o'clock position. Further, since the line on line arrangement is provided at about the 3 o'clock position and at bout the 9 o'clock position, and due to the upward lift of the rotor 120, no material is abraded from the abradable coating 170 at about the 3 o'clock position and at about the 9 o'clock position. Therefore, before the gas turbine engine 10 is implemented for a real-time application/operation the elliptical path has already been cut/defined in-to the abradable coating 170.

[0031] FIG. 5 depicts a cross-sectional view of the compressor 15 having the elliptical sealing system 140, in accordance with one embodiment of the invention. The cross-sectional view of the elliptical sealing system 140 as depicted in FIG. 5 may be realized at the 12 o'clock position of the axial view of FIG. 4, for example. The rotor 120 is disposed inside the stator housing 130. The stator housing 130 may include a number of suction ports and discharge ports (not shown) communicating fluid to and from the rotor 120 and the components thereof or otherwise. During rotation of the rotor 120, an incoming fluid may be sucked through the suction ports and a compressed fluid may be discharged through the discharge ports. Other configurations and other components may be used herein.

[0032] The elliptical sealing system 140 may be positioned between the rotor 120 and the stator housing 130. The elliptical sealing system 140 may be configured to control the leakage of the fluid therethrough without damaging the components thereof. Although described herein in the context of the compressor, the elliptical sealing system 140 may be used with any type of rotary machine, including steam turbines, gas turbines, and the like.

[0033] The elliptical sealing system 140 may include a retractable packing ring 150 positioned within a slot 160 of the stator housing 130. As noted previously, a packing ring such as the packing ring 150 in its entirety is formed by the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280. In the cross-sectional view of FIG. 5, a portion of the packing ring 150 that is visible is a cross-sectional view of the first semielliptical sealing segment 270 at the 12 o'clock position. The packing ring 150 may be generally I-shaped although other configurations may be used herein. The packing ring 150 may include the abradable coating 170 facing the rotor 120.

[0034] A plurality of biasing members 180 such as springs 190 may be disposed between the packing ring 150 and the stator housing 130. The biasing members 180 may include leaf springs, coil springs, helical springs, hydraulic springs, pneumatic springs, stacked washers, and the like. The biasing members 180 may be configured to bias the packing ring 150 towards the rotor 120. In this example, the biasing members 180 may be positioned at about a 12 o'clock position and about a 6 o'clock position. Other positions may be used herein. Any number or type of biasing members 180 may be used herein. Other configurations and other components may be used herein.

[0035] The rotor 120 also may include a plurality teeth 200 (represented by the area 113 in the axial view of FIG. 2) extending towards the elliptical sealing system 140. In one example, the teeth 200 may be in the form of a number of "J"-type strips (alternatively also referred to as J-strips) positioned within a number of rotor slots 220 on the rotor 120. The J-strips may be held in place within the rotor slots 220 via a number of wires 230 or other types of connection means. The J-strips may be made of stainless steel or other types of substantially rigid materials. Some or all of the J-strips may be in contact with the abradable coating 170 of the rotor 120. The J-strips may be detachable from the rotor 120 for replacement if damaged or worn via contact with the abradable coating 170. Other configurations and other components may be used herein.

[0036] FIG. 6 depicts an axial view of the compressor 15 when the rotor 120 rotates (e.g., during the real-time operation), in accordance with one embodiment of the invention. The elliptical shape of the sealing system 140 allows for an interference engagement (represented by an overlapped region of the textures having vertical and angled lines) between the abradable coating 170 and the teeth of the rotor 120. As depicted in FIG. 6, an engagement of the teeth of the rotor 120 in the abradable coating 170, is deeper at about a 12 o'clock position when compared to an engagement at a 6 o'clock position as the rotor 120 lifts upward during the rotation. Due to the upward lift of the rotor 120, the rotoric center 114 shifts above the statoric center 115. As the rotor 120 lifts upward towards the 12 o'clock position, the biasing member positioned at about the 6 o'clock position is configured to effect an upward movement of an associated sealing segment (e.g., the second semielliptical sealing segment 280). Such upward movement of the second semielliptical sealing segment 280 at the 6 o'clock position eliminates leakage that may have resulted due to the lift of the rotor 120.

[0037] FIG. 7 depicts an axial view of the compressor 15 in a steady state condition, in accordance with one embodiment of the invention. For example, the steady state condition may refer to a situation when the rotor 120 is stationary (e.g., not rotating). As previously noted, the teeth have already abraded some of the abradable coating 170 during the initial period of rotation. Hence, when stationary, the rotor 120 rests on the abradable coating 170 such that the rotoric center 114 shifts below the statoric center 115.

[0038] Various advantages that may be realized in the practice of some embodiments of the invention include, but are not limited to, improved leakage sealing, improved reliability, and improved efficiency of the rotary machine. For example, by only using the two sealing segments, such as, the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280, no additional end gap leakage may be introduced through the elliptical sealing system 140. As noted previously, the traditional designs include a use of more than two sealing segments. In stark contrast, embodiments of the present invention utilize only the two sealing segments. Also, the coupling joints 273 and 274 are made at the positions (e.g., at about the 3 o'clock position and at about the 9 o'clock position, respectively) where an effect of a force caused by the lifting of the rotor 120 during rotation is minimum. Consequently, the possibility of displacement and/or bending/twisting of the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280 may be substantially eliminated. This also results in improved reliability/lifetime of the rotary machine. Moreover, as the displacement and/or the bending/twisting of the first semielliptical sealing segment 270 and the second semielliptical sealing segment 280 may be substantially eliminated, any additional leakage that may have resulted due to the lifting of the rotor 120 is effectively eliminated. Likewise, the use of the biasing members 180 at about the 12 o'clock position and about at the 6 o'clock position generally force the elliptical sealing system 140 towards the teeth of the rotor 120 for contact therewith. Such an adaptive action by the biasing members 180 also eliminates the leakage. Reduction/elimination of the leakage leads to an improvement in the efficiency of the rotary machine.

[0039] It will be appreciated that variants of the above disclosed and other features and functions, or alternatives thereof, may be combined to create many other different systems or applications. Various unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art and are also intended to be encompassed by the following claims.

CLAIMS

1. An elliptical sealing system for use with a rotor and a stator housing of a rotary machine, comprising:

a plurality of sealing segments; and

an abradable coating having a uniform thickness disposed on each of the plurality of sealing segments, such that the plurality of sealing segments with the abradable coating disposed thereon has a substantially elliptical shape under all conditions when the rotor rotates and the rotor remains stationary.

2. The elliptical sealing system of claim 1, wherein the plurality of sealing segments comprises a packing ring.

3. The elliptical sealing system of claim 1, further comprising a plurality of biasing members mechanically coupled to the plurality of sealing segments and the stator housing.

4. The elliptical sealing system of claim 3, wherein the plurality of biasing members is positioned at about a 12 o'clock position and at about a 6 o'clock position to bias the plurality of sealing segments towards the rotor.

5. The elliptical sealing system of claim 4, wherein the plurality of biasing members positioned at about the 6 o'clock position is configured to effect an upward movement of an associated sealing segment when the rotor rotates.

6. The elliptical sealing system of claim 3, wherein the plurality of biasing members comprises a plurality of springs to bias the plurality of sealing segments towards the rotor.

7. The elliptical sealing system of claim 1, wherein the plurality of sealing segments comprises a first semielliptical sealing segment and a second semielliptical sealing segment.

8. The elliptical sealing system of claim 7, wherein a first end of the first semielliptical sealing segment is mechanically coupled to a first end of the second semielliptical sealing segment at about a 3 o'clock position, and a second end of the first semielliptical sealing segment is mechanically coupled to a second end of the second semielliptical sealing segment at about a 9 o'clock position.

9. The elliptical sealing system of claim 7, wherein coupling joints between the first semielliptical sealing segment and the second semielliptical sealing segment define a major axis of the substantially elliptical shape.

10. The elliptical sealing system of claim 1, wherein the rotor comprises a plurality of teeth mounted thereon, and wherein the plurality of teeth engages the abradable coating.

11. The elliptical sealing system of claim 10, wherein the plurality of teeth comprises a plurality of J-strips, and wherein the plurality of J-strips engages at different depths in the abradable coating along an inner circumference of the stator housing.

12. The elliptical sealing system of claim 10, wherein the plurality of teeth and the abradable coating are configured such that the plurality of teeth defines an elliptical path in the abradable coating during an initial period of rotation.

13. The elliptical sealing system of claim 10, wherein the plurality of teeth and the abradable coating are configured such that when the rotor rotates, an engagement of the plurality of teeth in the abradable coating, is deeper at about a 12 o'clock position when compared to an engagement at a 6 o'clock position.

14. The elliptical sealing system of claim 10, wherein the plurality of sealing segments with the abradable coating disposed thereon has an interference engagement with the plurality of teeth at about a 12 o'clock position and at about a 6 o'clock position.

15. The elliptical sealing system of claim 10, wherein the plurality of sealing segments with the abradable coating disposed thereon has a line on line engagement with the plurality of teeth at about a 3 o'clock position and at about a 9 o'clock position.

16. The elliptical sealing system of claim 1, wherein the rotary machine comprises a compressor.

17. A rotary machine, comprising:

a stator housing;

a rotor comprising a plurality of teeth mounted thereon;

a first semielliptical sealing segment and a second semielliptical sealing segment mechanically coupled to each other at about a 3 o'clock position and about a 9 o'clock position, each of the first semielliptical sealing segment and the second semielliptical sealing segment comprising an abradable coating of a uniform thickness disposed thereon,

wherein the first semielliptical sealing segment and the second semielliptical sealing segment with the abradable coating disposed thereon have an elliptical shape under all conditions when the rotor rotates and the rotor remains stationary, and

wherein the abradable coating has an interference engagement with the plurality of teeth at about a 12 o'clock position and at about a 6 o'clock position, and the abradable coating has a line on line engagement with the plurality of teeth at about the 3 o'clock position and at about the 9 o'clock position.

18. The rotary machine of claim 17, further comprising a plurality of biasing members mechanically coupled to the first semielliptical sealing segment, the second semielliptical sealing segment, and the stator housing, wherein the plurality of biasing members is positioned at about the 12 o'clock position and about the 6 o'clock position to bias the plurality of sealing segments towards the rotor.

19. The rotary machine of claim 17, wherein the plurality of teeth and the abradable coating are configured such that the plurality of teeth define an elliptical path in the abradable coating when the rotor lifts-up during an initial period of rotation.

20. The rotary machine of claim 17, wherein the plurality of teeth and the abradable coating are configured such that when the rotor rotates, an engagement of the plurality of teeth in the abradable coating, is deeper at about a 12 o'clock position when compared to an engagement at a 6 o'clock position.

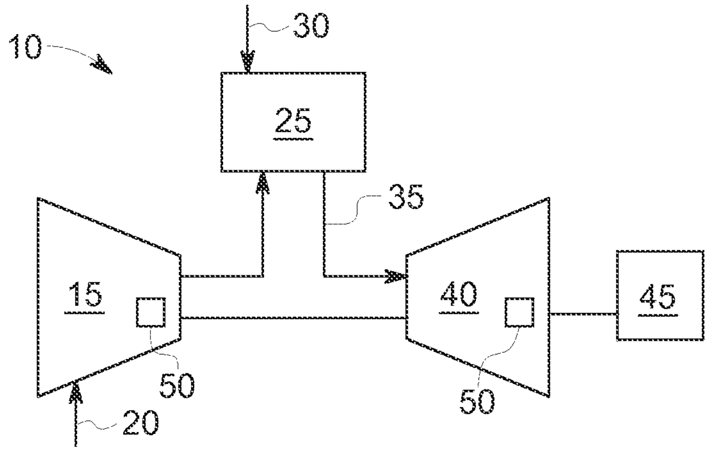

FIG. 1

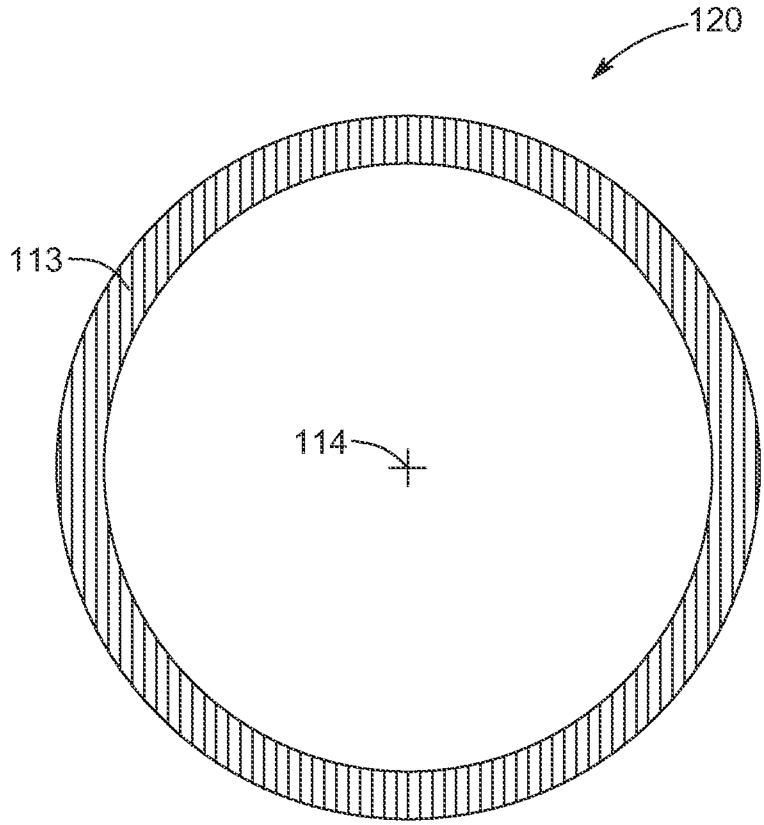

FIG. 2

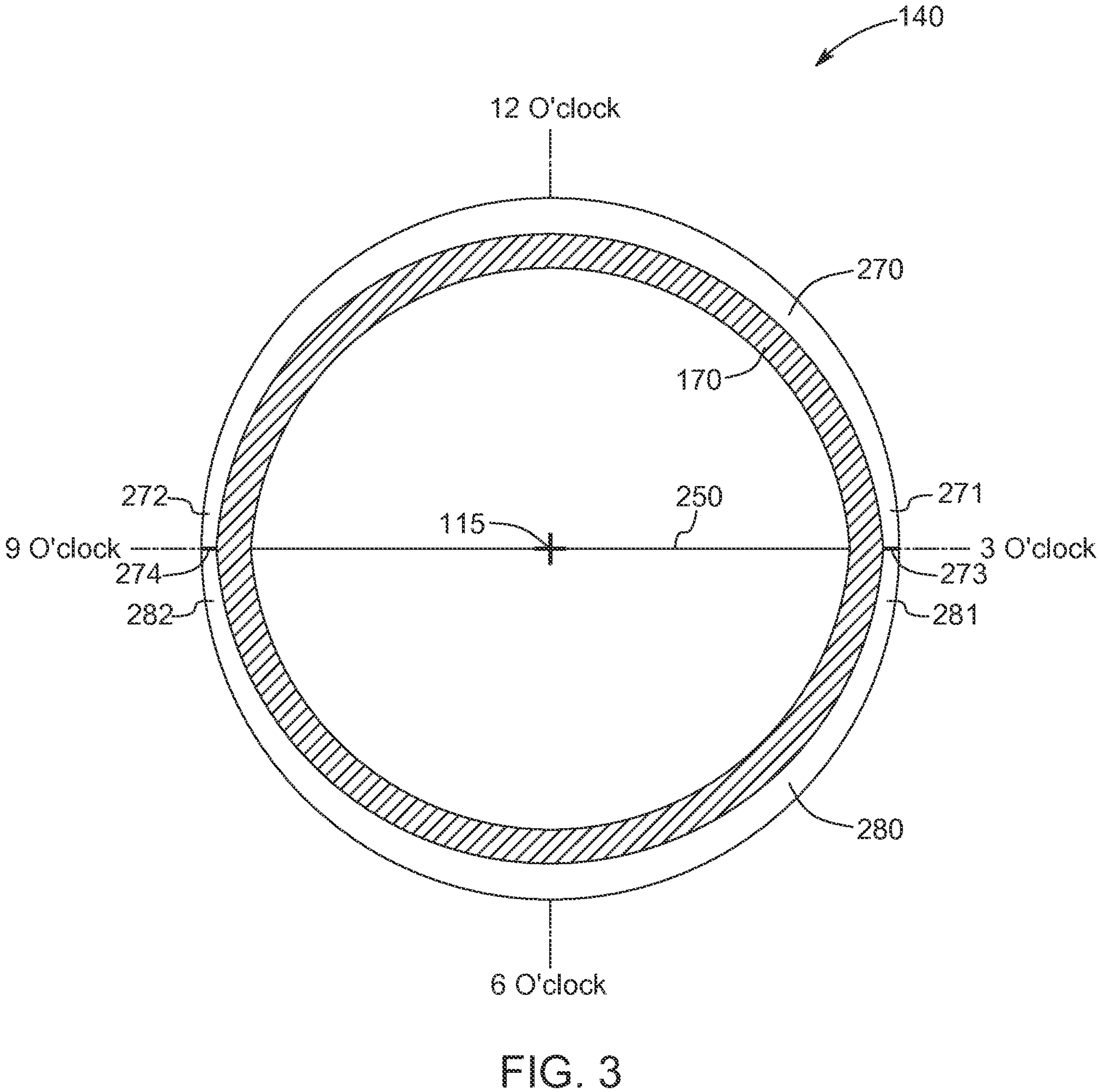
140
12 O'clock
270
170
272
271
250
115
9 O'clock
3 O'clock
274
273
282
281
280
6 O'clock

FIG. 3

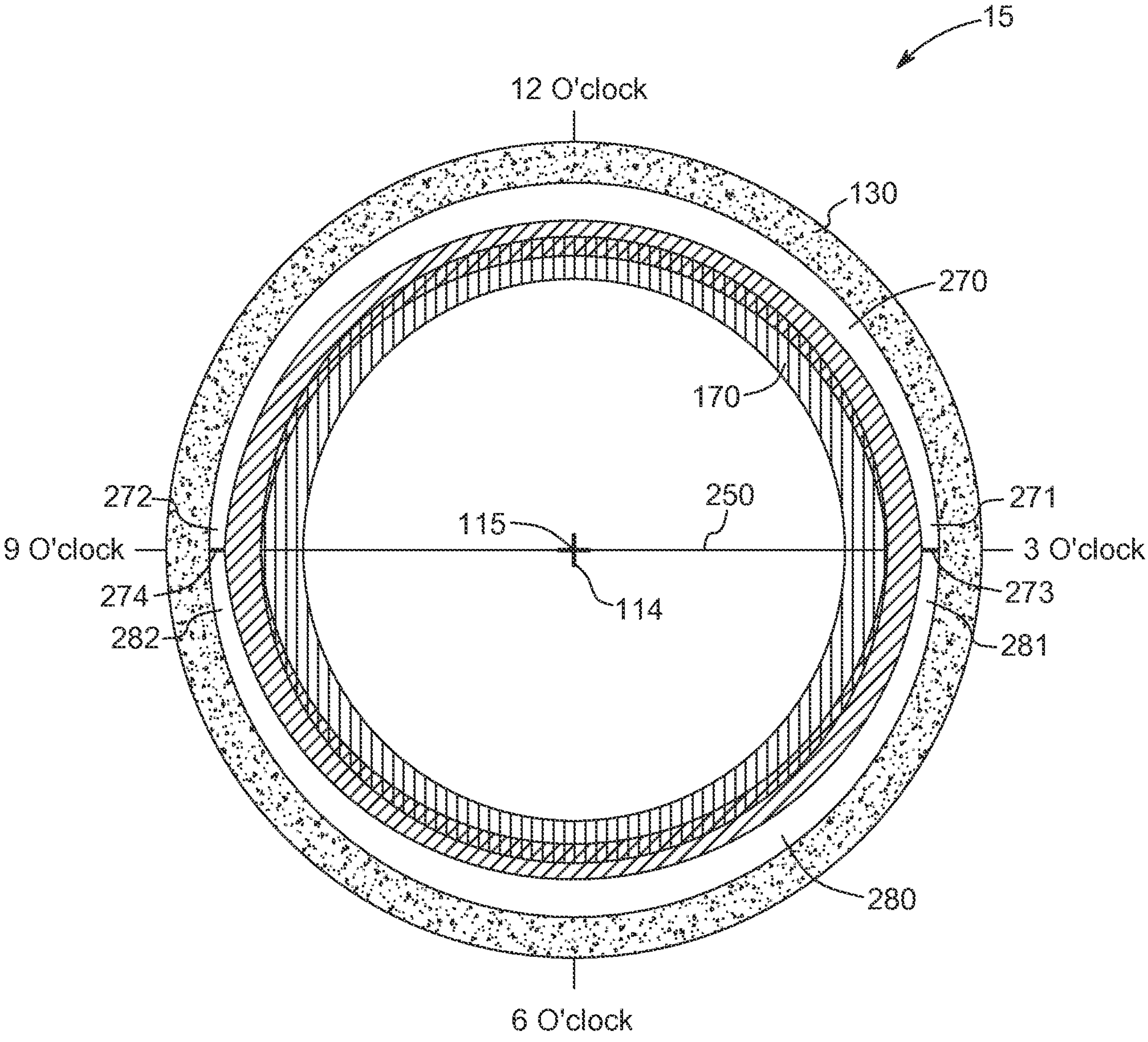
15
12 O'clock
130
270
170
272
250
271
115
9 O'clock
3 O'clock
274
114
273
282
281
280
6 O'clock

FIG. 4

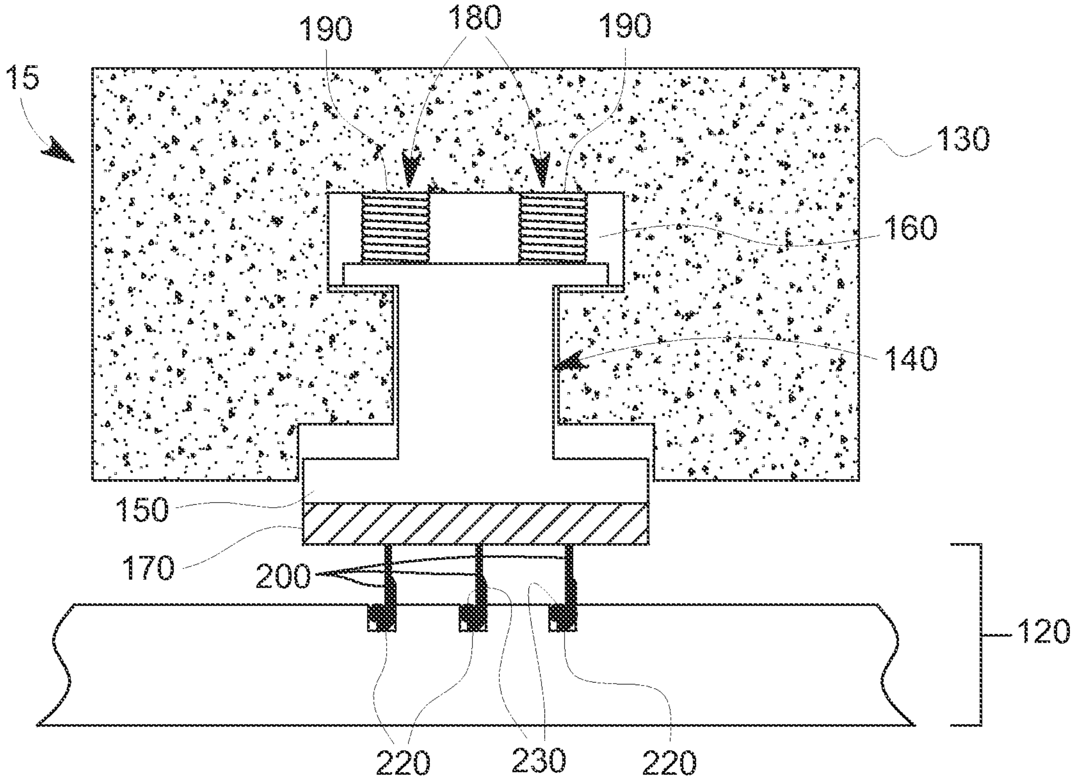

FIG. 5

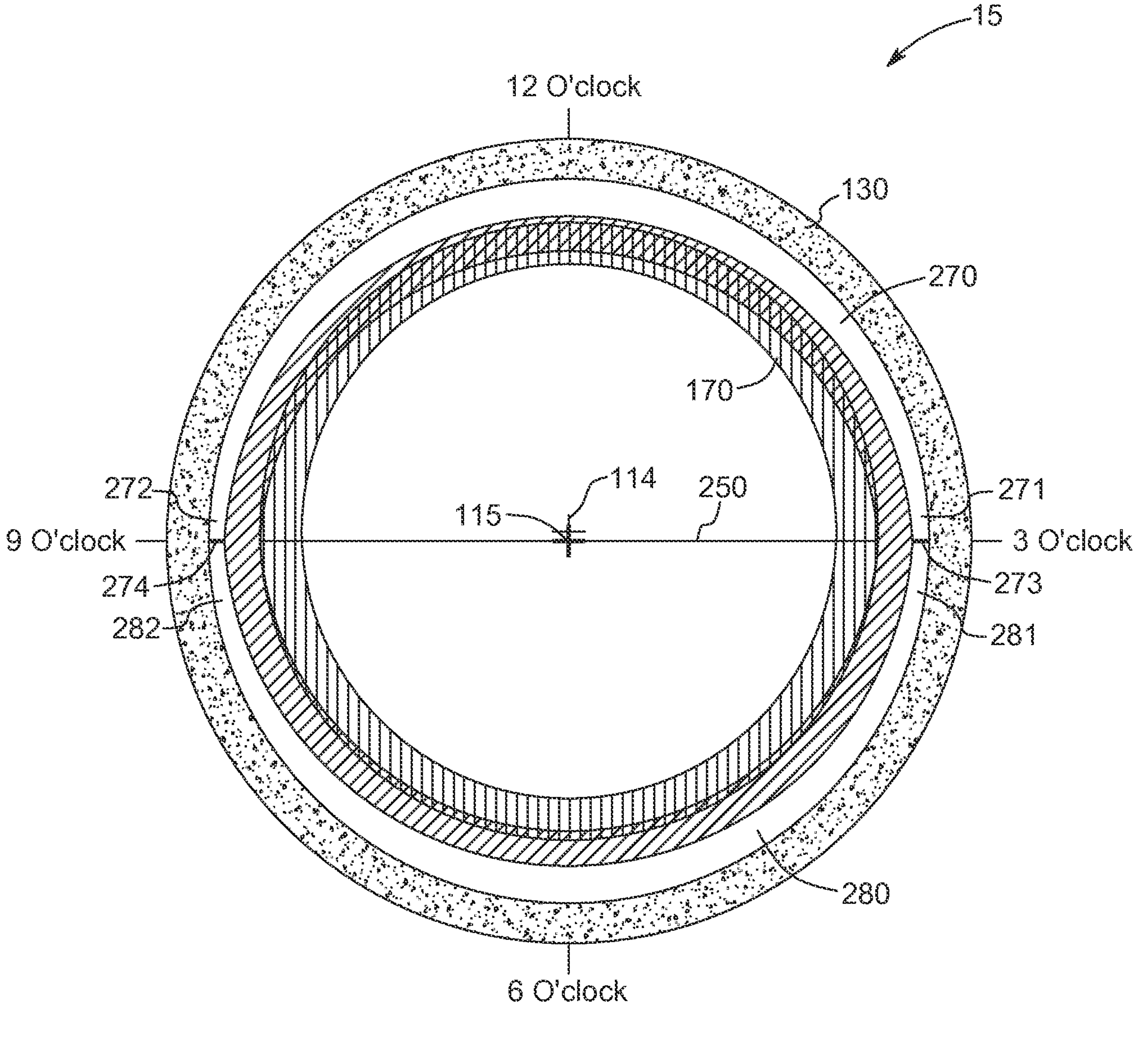
15
12 O'clock
130
270
170
114
250
272
271
115
9 O'clock
3 O'clock
274
273
282
281
280
6 O'clock

FIG. 6

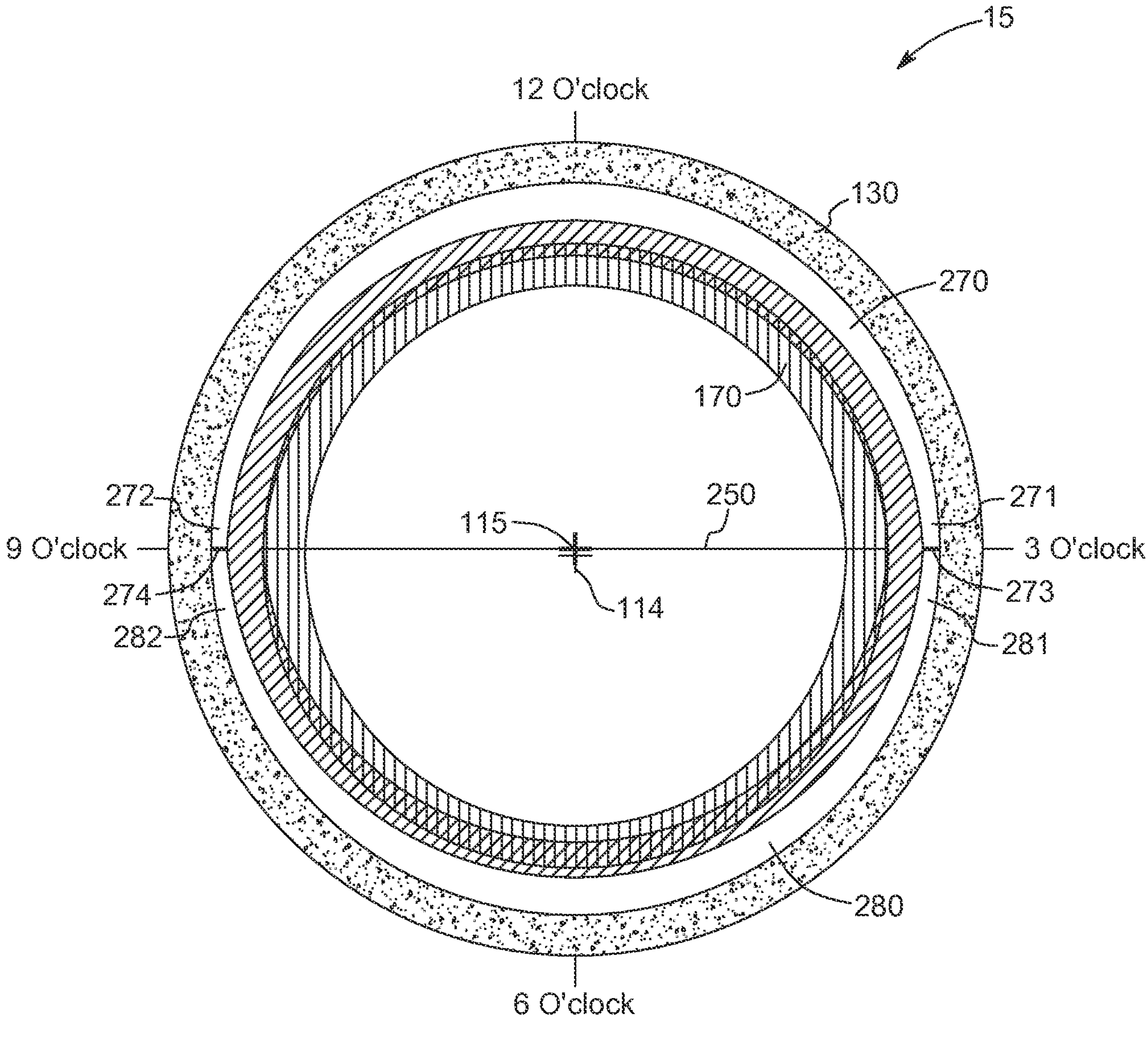
15
12 O'clock
130
270
170
272
250
271
115
9 O'clock
3 O'clock
274
114
273
282
281
280
6 O'clock

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/035902

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D11/00 F01D11/12 F01D11/22 F16J15/44
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)
F01D F16J

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 A	US 2005/129976 A1 (TURNQUIST NORMAN A [US] ET AL) 16 June 2005 (2005-06-16) paragraphs [0012] - [0018] figures 1,2	1,2,7,8, 10,11,16 3-6,9, 12-15, 17-20
X	GB 2 500 793 A (GEN ELECTRIC [US]) 2 October 2013 (2013-10-02) pages 5-7 figures 3,4	1,2,16
A	US 2007/132193 A1 (WOLFE CHRISTOPHER E [US] ET AL) 14 June 2007 (2007-06-14) abstract figures 2,3	1-20

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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
10 August 2015	19/08/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	de la Loma, Andrés

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/035902

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005129976 A1	16-06-2005	CN 1626774 A	15-06-2005
		EP 1541807 A2	15-06-2005
		JP 2005171999 A	30-06-2005
		RU 2362021 C2	20-07-2009
		US 2005129976 A1	16-06-2005
GB 2500793 A	02-10-2013	CN 103362568 A	23-10-2013
		DE 102013103091 A1	02-10-2013
		GB 2500793 A	02-10-2013
		JP 2013204818 A	07-10-2013
		RU 2013112902 A	27-09-2014
		US 2013256992 A1	03-10-2013
		US 2014225326 A1	14-08-2014
US 2007132193 A1	14-06-2007	NONE	