

(43) International Publication Date
27 December 2013 (27.12.2013)

- (51) **International Patent Classification:**
F16J 15/24 (2006.01) *F16J 15/34* (2006.01)
- (21) **International Application Number:**
PCT/US2012/057699
- (22) **International Filing Date:**
28 September 2012 (28.09.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
13/527,122 19 June 2012 (19.06.2012) US
- (71) **Applicant (for all designated States except US):** **STEIN SEAL COMPANY** [US/US]; 1500 Industrial Boulevard, Kulpsville, PA 19443 (US).
- (72) **Inventor; and**
- (71) **Applicant (for US only):** **VASAGAR, Thurai, Manik** [US/US]; 1580 Lynrose Circle, Hatfield, PA 19440 (US).
- (74) **Agent:** **CRILLY, Michael, G.**; Law Offices of Michael Crilly, 104 South York Road, Hatboro, PA 19040 (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, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, 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.

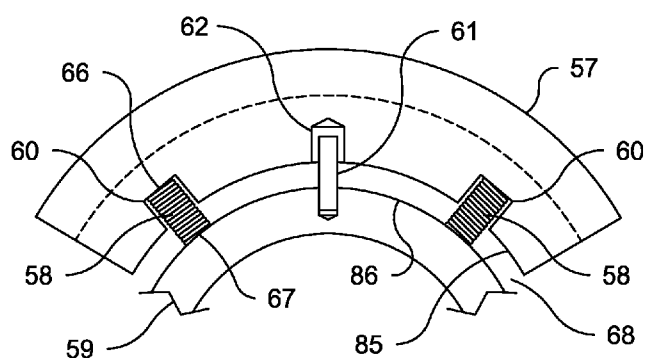
- (84) **Designated States (unless otherwise indicated, for every kind of regional protection available):** ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, 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, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) **Title:** SEGMENTED INTERSHAFT SEAL ASSEMBLY**Fig. 12a**

(57) **Abstract:** A segmented intershaft seal assembly (11) for counter-rotating and co-rotating turbine engines is described. The assembly includes a pair of end rings (63, 64), an annular seal element (54), and at least one resilient element (58, 81, or 83). At least one end ring (63, 64) has a flange (74, 75) that extends from one side thereof. The flange (74, 75) has a lower annular surface (70). The seal element (54) includes at least two seal segments (57). Each seal segment (57) includes a ring segment (55) and a ring flange segment (56). The ring segment (55) has an upper radial surface (69). The ring flange segment (56) directly contacts and extends from the upper radial surface (69) forming either a substantially "T"-shaped or "L"-shaped cross section. The seal segments (57) are disposed between the end rings (63, 64). At least one resilient element (58, 81, or 83) biases each seal segment (57) away from the inner shaft (19) so that the upper radial surface (69) contacts the lower annular surface (70) and a portion of the ring flange segment (56) extends beyond the flanges (74, 75).

TITLE

Segmented Intershaft Seal Assembly

DESCRIPTION**1. Technical Field**

The invention generally relates to a sealing device for turbine engines. Specifically, the invention is a segmented intershaft seal having a cross section which is generally either T-shaped or L-shaped. Each seal segment is biased in an outward radial direction so as to contact an inner annular surface along one or both end rings disposed about the seal. Seal segments are further seated onto one or both end rings via centrifugal forces and pressures during operation a turbine engine.

2. Background Art

Applicant describes an intershaft seal for counter-rotating and co-rotating turbine engines in U.S. Patent Application Number 12/210,246 now U.S. Patent Number 8,205,891 and PCT Application Number PCT/US2009/052328. The intershaft seal is a clearance-type seal applicable between inner and outer shafts of a turbine engine. The seal assembly includes a pair of end rings and a seal element. The end rings are secured to an inner shaft. At least one end ring has a flange, with upper and lower surfaces, disposed along and extending from one side of the ring. The seal element includes a ring, with inner and outer surfaces, and a ring flange. The ring flange is disposed along and extends diametrically outward from the outer surface. The seal element is disposed between the end rings so that the ring flange extends beyond the flanges. The outer radial surface of the ring seats with the lower surface along at least one end ring when rotation of the inner shaft imparts an outward centrifugal force onto the seal ring.

The intershaft seal described above minimizes wear and friction induced heat by contacting the inner shaft but not the outer shaft during normal operating conditions; however, heat and thrust induced misalignments between the shafts do occur from time-to-time causing the seal to briefly contact the outer shaft. When contact between the intershaft seal and outer shaft is properly minimized, the weight of the seal is relatively constant during the operational life of the seal. This feature ensures a relatively constant outward centrifugal force which secures the intershaft seal to end rings along the inner shaft when the inner shaft is rotated.

The diameter of an intershaft seal is often constrained by manufacturing considerations. In one example, the uniformity and consistency of material properties

1 is inversely related to the size of the material stock, examples including a sheet, bar,
2 or block, from which the seal ring is fabricated. This means that larger diameter seal
3 rings are inherently less uniform mechanically and thermally when manufactured
4 from a single, large material stock. In other example, material and manufacturing
5 costs increase with the size of the material stock. Materials costs increase with stock
6 size by virtue of the raw material, processing, and handling costs. Manufacturing
7 costs increase with stock size because of the equipment required to handle and
8 properly machine a seal to proscribed tolerances and the waste or scrap associated
9 with unused portions of the stock material. In yet another example, manufacturability
10 decreases inversely with stock size because of the difficulties associated with holding
11 proscribed tolerances and avoiding warp and other manufacturing induced defects
12 which may or may not be related to imperfections or inconsistencies within the stock
13 material.

14 One solution is to construct a large diameter intershaft seal from two or more
15 segments which interlock to form a single ring structure whereby each seal segment is
16 manufactured from a separate, smaller, more uniform, and less costly material stock.
17 However, this approach is problematic for the intershaft seal described above because
18 the seal, by virtue of its design and function, is unsupported before centrifugal forces
19 cause it to move radially outward to seat onto flanges along the end rings. The result
20 is a segmented seal which is difficult to properly assemble within a turbine engine and
21 difficult to properly control below the centrifugal forces and pressures which secure
22 the seal ring to the end rings.

23 Accordingly, what is required is a segmented intershaft seal capable of
24 replicating the performance characteristics of a non-segmented intershaft seal in large
25 diameter applications while avoiding the problems inherent to these applications.

26 **3. Disclosure of the Invention**

27 An object of the invention is to provide a segmented intershaft seal capable of
28 replicating the performance characteristics of a non-segmented intershaft seal in large
29 diameter applications while avoiding the problems inherent to these applications.

30 In accordance with embodiments of the invention, the segmented intershaft
31 seal assembly includes a pair of end rings, an annular seal element, and at least one
32 resilient element. At least one end ring has a flange which is disposed along and
33 extends from one side of the end ring. The flange further includes a lower annular
34 surface. The annular seal element includes at least two seal segments. Each seal

1 segment includes a ring segment and a ring flange segment. The ring segment is wider
2 than the ring flange segment so as to form either a substantially “T”-shaped cross
3 section or a substantially “L”-shaped cross section. Each ring segment has an upper
4 radial surface. The ring flange segment is disposed along and extends from the upper
5 radial surface. At least one resilient element biases each seal segment away from the
6 inner shaft so that the upper radial surface directly contacts a portion of the lower
7 annular surface so that a portion of the ring flange segments extends beyond the
8 flange.

9 In accordance with other embodiments of the invention, the resilient element
10 is a compression spring, a flat spring, or an extension spring.

11 In accordance with other embodiments of the invention, the resilient element
12 is partially recessed within each seal segment.

13 In accordance with other embodiments of the invention, a spacer ring is
14 disposed between the end rings and directly contacts the inner shaft and the resilient
15 element is partially recessed within the spacer ring.

16 In accordance with other embodiments of the invention, at least two pins are
17 separately secured to the spacer ring. Each pin partially resides within an oversized
18 cavity along a seal segment. The oversized cavity is dimensioned to minimize contact
19 between the pin and the seal segment when the seal segment is displaced by direct
20 contact with the outer shaft.

21 In accordance with other embodiments of the invention, the seal segments are
22 mechanically secure to at least one end ring.

23 In accordance with other embodiments of the invention, at least two pins are
24 separately secured to at least one end ring. Each pin partially resides within a slot-
25 shaped cavity. The slot-shaped cavity is oriented radially outward to minimize contact
26 between the pin and the seal segment when the seal segment is displaced by direct
27 contact with the outer shaft.

28 In accordance with other embodiments of the invention, each ring flange
29 segment has a convex-shaped surface adjacent to an outer shaft.

30 In accordance with yet other embodiments of the invention, a locking nut
31 directly contacts one end ring to secure the seal assembly to an inner shaft.

32 In accordance with other embodiments of the invention, seal segments are
33 composed of a metal, a metal alloy, or a carbon. The end rings, inner shaft, and outer

1 shaft have substantially similar thermal expansion properties to minimize contact
2 between the seal segments and outer shaft.

3 Several advantages are offered by the invention. The invention avoids the
4 wear caused by relative axial movement between the seal element and end ring faces.
5 The invention avoids wear along the outer diameter of the seal ring caused by
6 translations between the inner and outer shafts. The invention avoids friction induced
7 heating along the seal element, via a substantially non-wearable sealing system,
8 allowing the seal element to be composed of a metal, metal alloy, or carbon graphite,
9 thereby reducing the cost of the seal system. The combination of a segmented seal and
10 resilient elements disposed between a pair of end rings allows for localized and
11 limited deflection of the seal thereby minimizing damage to the segmented seal during
12 excursions between the inner and outer shafts which result in contact of the seal by
13 the outer shaft. The oversized cavities within the seal segments further minimize
14 damage to the segmented seal by providing adequate clearance to allow the segments
15 to move radially without contacting the anti-rotation pin during excursions between
16 the inner and outer shafts which result in contact of the seal by the outer shaft. The
17 seal is properly seated on a structure attached to the inner shaft at the onset of rotation
18 further minimizing mass loss and variation in the centrifugal forces acting on the
19 segment seal. Centrifugal forces further secure the seal element to the inner shaft
20 during rotation.

21 The above and other objectives, features, and advantages of the preferred
22 embodiments of the invention will become apparent from the following description
23 read in connection with the accompanying drawings, in which like reference numerals
24 designate the same or similar elements.

25 **4. Brief Description of the Drawings**

26 Additional aspects, features, and advantages of the invention will be
27 understood and will become more readily apparent when the invention is considered
28 in the light of the following description made in conjunction with the accompanying
29 drawings, wherein:

30 FIG. 1 is a cross-sectional view illustrating a seal assembly disposed between
31 a pair of rotating shafts in accordance with an embodiment of the invention;

32 FIG. 2 is a side elevation view illustrating a seal element with a single joint in
33 accordance with an embodiment of the invention;

1 FIG. 3 is an enlarged cross-sectional view illustrating a seal assembly with an
2 inverted generally T-shaped seal element in accordance with an embodiment of the
3 invention;

4 FIG. 4 is an enlarged cross-sectional view illustrating a seal assembly with a
5 generally L-shaped seal element in accordance with an embodiment of the invention;

6 FIG. 5 is an enlarged cross-sectional view illustrating an inverted and
7 generally T-shaped seal element with contoured surface upper surface in accordance
8 with an embodiment of the invention;

9 FIG. 6 is an enlarged cross-sectional view illustrating a generally L-shaped
10 seal element with contoured upper surface in accordance with an embodiment of the
11 invention;

12 FIG. 7a is an enlarged perspective view illustrating a step joint formed by
13 interlocking wedge-shaped steps in accordance with an embodiment of the invention;

14 FIG. 7b is an enlarged perspective view illustrating a step joint formed by
15 interlocking rectangular-shaped steps in accordance with an embodiment of the
16 invention;

17 FIG. 8a is an enlarged cross-sectional view illustrating a T-shaped seal
18 element having a spring disposed along the inner diameter thereof in accordance with
19 an embodiment of the invention;

20 FIG. 8b is an enlarged cross-sectional view illustrating an L-shaped seal
21 element having a spring disposed along the inner diameter thereof in accordance with
22 an embodiment of the invention;

23 FIG. 9 is a cross-sectional view illustrating a serial arrangement of seal
24 assemblies disposed between an inner shaft and an outer shaft in accordance with an
25 embodiment of the invention;

26 FIG. 10 is a cross-sectional view illustrating a serial arrangement of seal
27 assemblies with a single intermediate ring disposed between an inner shaft and an
28 outer shaft in accordance with an embodiment of the invention;

29 FIG. 11 is a side elevation view illustrating a segmented intershaft seal with
30 multiple joints in accordance with an embodiment of the invention;

31 FIG. 12a is a cross-sectional elevation view illustrating a pair of compression
32 springs and an optional pin disposed between a seal segment and a spacer ring
33 whereby the compression springs are partially recessed within the seal segment in
34 accordance with an embodiment of the invention;

1 FIG. 12b is a cross-sectional elevation view illustrating a pair of compression
2 springs and an optional pin disposed between a seal segment and a spacer ring
3 whereby the compression springs are partially recessed within the spacer ring in
4 accordance with an embodiment of the invention;

5 FIG. 12c is an enlarged cross-sectional view of the seal segments in FIGS. 12a
6 and 12b illustrating a seal assembly whereby the seal segment has a generally T-
7 shaped cross section and the optional pin is secured to the spacer ring and resides
8 within an oversized cavity within the seal segment in accordance with an embodiment
9 of the invention;

10 FIG. 13 is an enlarged cross-sectional view illustrating a seal assembly
11 whereby a seal segment has a generally L-shaped cross section and a compression
12 spring is partially recessed within a spacer ring and contacts an inner radial surface
13 along the seal segment in accordance with an embodiment of the invention;

14 FIG. 14 is an enlarged cross-sectional view illustrating a seal assembly
15 whereby a seal segment has a generally L-shaped cross section and a compression
16 spring is partially recessed within the seal segment and contacts an outer radial
17 surface along a spacer ring and an optional pin secures the spacer ring to a pair of end
18 rings disposed about the seal segment in accordance with an embodiment of the
19 invention;

20 FIG. 15a is an enlarged cross-sectional view illustrating a seal assembly
21 whereby a seal segment has a generally T-shaped cross section and a compression
22 spring is partially recessed within the seal segment and contacts an outer radial
23 surface along a spacer ring and a first optional pin secures the spacer ring to a pair of
24 end rings and a second optional pin is secured at a first end to one end ring and at a
25 second end resides within an oversize cavity along the seal segment in accordance
26 with an embodiment of the invention;

27 FIG. 15b is a cross-sectional elevation view of the embodiment in FIG. 15a
28 illustrating a pair of compression springs partially recessed within the seal segment
29 and contacting the outer radial surface along the spacer ring and the second optional
30 pin is disposed within the oversized cavity within the seal segment in accordance with
31 an embodiment of the invention;

32 FIG. 16a is an enlarged cross-sectional view illustrating a seal assembly
33 whereby a seal segment has a generally T-shaped cross section and a compression
34 spring is partially recessed within the seal segment and contacts an outer radial

1 surface along a spacer ring and a first optional pin secures the spacer ring to a pair of
2 end rings disposed about the seal segment and a second optional pin at a first end is
3 secured to one end ring and at a second end is disposed within a slot along the seal
4 segment in accordance with an embodiment of the invention;

5 FIG. 16b is a cross-sectional elevation view of the embodiment in FIG. 16a
6 illustrating a pair of compression springs partially recessed within the seal segment
7 and contacting the outer radial surface of the spacer ring and the second optional pin
8 is disposed within the slot oriented radially outward along the seal segment in
9 accordance with an embodiment of the invention;

10 FIG. 17a is a cross-sectional elevation view illustrating a flat spring partially
11 recessed within a spacer ring and contacting an inner radial surface along a seal
12 segment and an optional pin disposed within an oversized cavity within the seal
13 segment in accordance with an embodiment of the invention;

14 FIG. 17b is an enlarged cross-sectional view of the embodiment in FIG. 17a
15 illustrating the seal segment with a generally T-shaped cross section and the flat
16 spring is disposed between and contacts both the seal segment and the spacer ring and
17 the optional pin at a first end is disposed within an oversized cavity along the seal
18 segment and at a second end is secured to an end ring in accordance with an
19 embodiment of the invention;

20 FIG. 18 is an enlarged cross-sectional view illustrating a seal assembly
21 whereby a seal segment has a generally T-shaped cross section and an extension
22 spring is partially recessed within the seal segment and a first optional pin secures a
23 spacer ring to a pair of end rings disposed about the seal segment and a second
24 optional pin at a first end is disposed within an oversized cavity along the seal
25 segment and at a second end is secured to an end ring in accordance with an
26 embodiment of the invention; and

27 FIG. 19 is an enlarged cross-sectional view illustrating a seal assembly
28 whereby a seal segment has a generally L-shaped cross section and an extension
29 spring is partially recessed within the seal segment and a first optional pin secures a
30 spacer ring to a pair of end rings disposed about the seal segment and a second
31 optional pin at a first end is disposed within an oversized cavity along the seal
32 segment and at a second end is secured to an end ring in accordance with an
33 embodiment of the invention.

34 **5. Modes for Carrying out the Invention**

1 This application is based upon and claims priority from U.S. Non-Provisional
2 Application No. 13/527,122 filed June 19, 2012, entitled *Segmented Intershaft Seal*
3 *Assembly*, which is hereby incorporated in its entirety by reference thereto.

4 Reference will now be made in detail to several embodiments of the invention
5 that are illustrated in the accompanying drawings. Wherever possible, same or similar
6 reference numerals are used in the drawings and the description to refer to the same or
7 like parts. The drawings are in simplified form and are not to precise scale.

8 While features of various embodiments are separately described throughout
9 this document, it is understood that two or more such features could be combined into
10 a single embodiment.

11 It is also understood that the various embodiments of the seal assembly are
12 shown in enlarged view for descriptive purposes and that all such embodiments are
13 applicable to a turbine engine with inner and outer shafts as generally described in
14 FIG. 1.

15 As represented in FIG. 1, the seal assembly 11 is shown including a pair of
16 end rings 13, 14, a seal element 12, an optional gap 17, an optional spacer ring 16, and
17 an optional locking ring 15 disposed between an inner shaft 19 and an outer shaft 20.
18 Elements are disposed about a common centerline 23 or axis-of-rotation. A clearance
19 40 is provided between the inner surface 42 along the outer shaft 20 and a second
20 outer surface 28 along the seal element 12. The height of the clearance 40 should be
21 sufficient to avoid contact between the outer shaft 20 and seal element 12 and to
22 minimize fluid leakage across the seal element 12. Inner shaft 19 and outer shaft 20
23 are structures understood in the art which rotate in either a counter-rotational or co-
24 rotational fashion.

25 Each end ring 13 and 14 includes a flange 18 and 21, respectively, so as to
26 have a substantially L-shaped cross section. End rings 13, 14 are disposed in a
27 substantially symmetrical arrangement about the seal element 12 and contact the inner
28 shaft 19 so that the flanges 18, 21 are arranged immediately adjacent to but do not
29 contact the outer shaft 20. This arrangement forms a structure having a generally
30 inverted T-shaped cross section which complements the cross-sectional design of the
31 seal element 12.

32 The seal assembly 11 is designed so as to rotate with the inner shaft 19. One
33 end ring 13 could be secured to the inner shaft 19 via a mechanical stop 47 and the
34 other end ring 14 could be secured via a locking ring 15 threaded, pinned, other

1 otherwise fastened or secured onto the inner shaft 19. It is likewise possible for both
2 end rings 13, 14 to be secured to the inner shaft 19 via a pair of locking rings 15
3 separately disposed at the ends of the seal assembly 11. It is further possible for one
4 end ring 13 or 14 to be an integral or unitary part of the inner shaft 19. Also, the seal
5 assembly 11 could include a variety of stacking arrangements including additional
6 spacers or the like which contact or are immediately adjacent to the locking ring 15.

7 The seal element 12 is disposed between and could contact the end rings 13,
8 14. A spacer ring 16 having an overall diameter less than the seal element 12 also
9 resides between the end rings 13, 14. In preferred embodiments, the outer diameter of
10 the spacer ring 16 is less than the inner diameter of the seal element 12 so as to
11 provide a gap 17 between the elements. The radial height of the gap 17 is preferred to
12 be dimensioned so as to avoid contact between the inner diameter of the seal element
13 12 and the outer diameter of the spacer ring 16 during excursions of the inner and
14 outer shafts 19, 20. Seal element 12 and/or spacer ring 16 could contact both end rings
15 13, 14.

16 The seal assembly 11 avoids the problems of temperature and load capacity
17 associated with many fluid-film seals. The seal element 12 is a piston ring with a gap
18 and a cross-sectional profile with an inverted T-shape. The seal element 12 has an
19 interior flange that mates with the end rings 13, 14 attached to the inner shaft 19.
20 Centrifugal force drives the seal element 12 against the overhang of the end rings 13,
21 14 and causes the seal element 12 to rotate with the inner shaft 19. Leakage occurs
22 across a controlled clearance at the outer diameter of the seal element 12.

23 The advantage of this design is its simplicity and avoidance of fluid-film
24 problems. Since there is no relative movement between the seal element 12 and
25 mating components, the seal element 12 minimizes wear. Materials comprising the
26 end rings 13, 14, spacer ring 16, inner shaft 19, and outer shaft 20 are selected to have
27 substantially similar thermal expansion properties to ensure the clearance 40 between
28 the outer diameter of the seal element 12 and the inner diameter of the outer shaft 20
29 is closely controlled. Exemplary materials include, but are not limited to, metal, metal
30 alloys, and carbon. The clearance 40 could dynamically vary because of the relative
31 movement between the inner and outer shafts 19, 20.

32 As represented in FIG. 2, the seal element 12, 38 is comprised of a ring 24 and
33 a ring flange 25 disposed about a common centerline 23. The ring 24 is a substantially
34 circular element of uniform thickness with a generally square or rectangular cross

1 section between an inner surface 26 and a first outer surface 27. The ring flange 25 is
2 a substantially circular structure which extends from the first outer surface 27 along
3 the ring 24. The ring flange 25 could have a substantially square or rectangular cross
4 section. The cross-sectional width of the ring flange 25 is less than the corresponding
5 dimension along the ring 24, as represented in FIGS. 3 and 4.

6 In some embodiments, the ring flange 25 is located along the ring 24 in a
7 symmetric or non-symmetric arrangement to form a substantially inverted T-shaped
8 cross section, as represented in FIG. 3. The stepwise cross section of the T-shaped
9 seal element 12 provides a single second outer surface 28, corresponding to the outer
10 diameter of the ring flange 25, disposed between a pair of first outer surfaces 27,
11 corresponding to the interface between the outer diameter of the ring 24 and inner
12 diameter of the ring flange 25.

13 In other embodiments, the ring flange 25 is positioned at one end of the ring
14 24 to form a substantially L-shaped cross section, as represented in FIG. 4. The
15 stepwise cross section of the L-shaped seal element 38 provides a single first outer
16 surface 27, along the interface between the outer diameter of the ring 24 and inner
17 diameter of the ring flange 25, and a single second outer surface 28, along the outer
18 diameter of the ring flange 25.

19 In preferred embodiments, ring 24 and ring flange 25 are manufactured via
20 methods understood in the art from a single or monolithic structure. However, it is
21 possible for the ring 24 and ring flange 25 to be separately manufactured and
22 assembled via methods understood in the art to form the seal element 12.

23 In some embodiments, the seal element 12 or 38 could include at least one
24 joint 41 which partially or completely transverses the cross section of the element, the
25 latter arrangement allowing the seal element 12, 38 to open outward as centrifugal
26 forces push the seal element 12, 38 against one or both flanges 18, 21 to seat the seal
27 element 12, 38 thereto. In other embodiments, the seal element 12, 38 could include
28 two or more such joints 41 facilitating a segmented rather than continuous seal
29 element 12, 38.

30 Joints 41 could include a variety of structures understood in the art. For
31 example, FIG. 2 shows a straight cut joint. In another example, FIG. 7a shows a
32 tongue/groove joint 41 including a pair of wedge-shaped steps 50a, 50b which
33 interlock to minimize leakage across the joint 41. In yet another example, FIG. 7b
34 shows a tongue/groove joint 41 including a pair of rectangular-shaped steps 51a, 51b

1 which also interlock to minimize leakage across the joint 41. Steps 50a, 50b or 51a,
2 51b are disposed along the seal element 12 or 38 and could traverse the ring 24 and/or
3 the ring flange 25 structures described herein.

4 As represented in FIG. 3, the seal assembly 11 is shown for a seal element 12
5 with a generally inverted T-shaped cross section. The seal element 12 is disposed
6 between the end rings 13, 14 so that the ring 24 is bounded by the end rings 13, 14.
7 The ring flange 25 is disposed between the flanges 18, 21 so as to at least extend in a
8 radial fashion beyond the upper surfaces 46, 45 of both flanges 18, 21, respectively.

9 In some embodiments, it is preferred to include a gap 44, disposed between
10 one or both flanges 18, 21 and the vertical walls of the ring flange 25, to ensure that
11 the seal element 12 floats inside the seal assembly 11 and has sufficient radial motion
12 to properly adjust with thermal effects. In other embodiments, a gap 44 could be
13 disposed between adjacent vertical walls along the ring 24 and one end ring 13. In yet
14 other embodiments, a gap 31 could be disposed between lower surface 30 along one
15 flange 18 and the first outer surface 27 along the ring 24. In still other embodiments,
16 at least one first outer surface 27 should contact the lower surface 29 along the flange
17 21, because of manufacturing tolerance variations along the outer surfaces 27 of the
18 ring 24 and lower surfaces 29 of the flanges 18, 21. In preferred embodiments, no gap
19 31 is present when components are precision machined so that the upper surfaces 29,
20 30 of the end rings 13, 14 and first outer surface 27 of the ring 24 are dimensionally
21 identical.

22 In some embodiments, a spacer ring 16 is provided between the end rings 13,
23 14 so as to contact the outer surface of the inner shaft 19. One or more cavities 32
24 could traverse the spacer ring 16 about its circumference and one or both end rings 13,
25 14. Roll pins 35 and cavities 32 are complementary shaped so as to allow a roll pin 35
26 to be inserted into each cavity 32. Each cavity 32 along the end rings 13, 14 could be
27 dimensioned to form an interference fit with a roll pin 35, while the cavity 32 through
28 the spacer ring 16 could provide an interference or clearance fit. The roll pins 35
29 secure the seal element 12, end rings 13, 14, and spacer ring 16 so as to form a
30 cartridge-like assembly.

31 In other embodiments, the spacer ring 16 could be spaced apart from the seal
32 element 12 via a gap 17 of circular extent. The gap 17 should have sufficient radial
33 height to accommodate the relative radial motion of the seal element 12 about the
34 cavity 33 because of the clearance fit of the anti-rotation pin 34.

1 In preferred embodiments, there is no relative movement between the seal
2 element 12 and other components comprising the seal assembly 11. One or more
3 cavities 33 could completely or partially traverse the seal element 12 about its
4 circumference and one or both end rings 13, 14. Anti-rotation pins 34 and cavities 33
5 are shaped so as to allow an anti-rotation pin 34 to be inserted into each cavity 33

6 Each anti-rotation pin 34 could be press fitted onto the end ring 14 by
7 providing an interference fit between the anti-rotation pin 34 and cavity 33 along the
8 thickness of the end ring 14. However, the cavity 33 portion through the seal element
9 12 should be larger than the diameter of the anti-rotation pin 34 so as to allow the seal
10 element 12 to slide or move axially and radially in response to mechanical and
11 thermal effects to avoid binding along the seal element 12. For example, the cavity
12 33 portion through the seal element 12 could be either circular or slot-shaped. If
13 movement of the seal element 12 is overly restricted due to inadequate clearance
14 between the diameter of the cavity 33 along the seal element 12 and the diameter of
15 anti-rotation pin 34 therein, the first outer surface 27 along the seal element 12 will
16 not follow and seat onto the lower surface 29 of the flange 21. The result could be an
17 unsteady condition without uniform radial support along the seal element 12 by the
18 flanges 18, 21, potentially causing the seal element 12 to crack or explode. Other anti-
19 rotation elements and approaches known within the art are applicable.

20 Each end ring 13, 14 is preferred to include a relief 37 disposed in a
21 circumferential arrangement at the intersection of the horizontal flange 18, 21 with the
22 vertical structure of each ring, so as to avoid stress concentrations within the end rings
23 13, 14 and fit and wear problems with the seal element 12. The relief 37 could be a
24 radius, if space constraints preclude a relief 37. For example, a chamfer could be
25 included at the interfaces of the first outer surface 27 and the vertical face of the ring
26 24.

27 As represented in FIGS. 1-3, the left hand side of the seal assembly 11 is the
28 high pressure side. When pressure is introduced, the seal element 12 seats onto the
29 low pressure side of the end ring 14. The joint 41 includes a space which is
30 compressed when the seal element 12 is assembled to form a seal assembly 11. Also,
31 the first outer surface 27 seats and seals onto the lower surface 29. If the tension
32 along the seal element 12 is inadequate to radially seat the first outer surface 27
33 against lower surface 29, an expander spring 48 could be used along the inner
34 diameter of the seal element 12, as shown in FIGS. 8a and 8b. During operation of the

1 inner and outer shafts 19, 20, centrifugal force seats the seal element 12 as the inner
2 shaft 19 rotates; however, the tension described herein is required along the seal
3 element 12 in order to properly seat the seal element 12 when the inner shaft 19 is
4 stationary.

5 By selecting materials with coefficient of thermal expansion rates which are
6 sufficiently similar, it is possible for the end rings 13, 14, spacer ring 16, inner shaft
7 19, and outer shaft 20 to expand and contract at similar rates. When the lower surface
8 29 expands, the first outer surface 27 follows the lower surface 29 because of the
9 centrifugal force produced by the rotating inner shaft 19. The joint 41 opens to
10 accommodate diametrical changes along the lower surface 29 caused by thermal
11 effects, thus closely maintaining the clearance 40 shown in FIG. 1 between the outer
12 diameter of the seal element 12 and inner diameter of the outer shaft 20.

13 As represented in FIGS. 1, 3 and 4, the gap 17, 22 should be sufficiently large
14 to accommodate thermally-induced expansion variations along the inner diameter of
15 the seal element 12, 38. The segment of the cavity 33 within the seal element 12, 38 is
16 sized to likewise accommodate thermally-induced expansion variations along the seal
17 element 12, 38. Accordingly, the size and shape of the cavity 33 within the seal
18 element 12, 38 could differ from the portion of the cavity 33 disposed along the end
19 ring 14. Furthermore, the clearance 40 in FIG. 1 is well defined, since the outer shaft
20 20 should not contact the seal element 12, 38. The end rings 13, 14 restrict radial
21 movement of the seal element 12 and 38, thus avoiding the radial excursions possible
22 with other seal designs.

23 As represented in FIG. 4, the seal assembly 11 from FIG. 3 is shown having a
24 seal element 38 with a generally L-shaped cross section composed of a ring 24 and
25 ring flange 25. The seal element 38 is disposed between a generally planar-shaped end
26 ring 36 and an L-shaped end ring 14 so that the ring 24 is bounded by both end rings
27 14, 36. The ring flange 25 is disposed between the end ring 36 and a flange 21
28 extending from the second end ring 14 so as to at least extend in a radial fashion
29 beyond the upper surface 45 of the flange 21.

30 In some embodiments, it is preferred to include a gap 44, disposed between
31 the vertical sides of flange 21 and/or the end ring 36 and the vertical walls of the ring
32 flange 25, to ensure that the seal element 38 floats inside the seal assembly 11 and has
33 sufficient radial motion to properly adjust to thermal effects. The first outer surface 27
34 should contact the lower surface 29 along the flange 21.

1 In other embodiments, a spacer ring 16 is provided between the end rings 14,
2 36 so as to contact the outer surface of the inner shaft 19. One or more cavities 32
3 could traverse the spacer ring 16 about its circumference and one or both end rings 14,
4 36. Roll pins 35 and cavities 32 are complementary shaped so as to allow a roll pin 35
5 to be inserted into each cavity 32. The roll pins 35 secure the seal element 38, end
6 rings 14, 36, and spacer ring 16 so as to form a cartridge-like assembly, providing a
7 structure which is readily shippable and handle-able. Each cavity 32 along the end
8 rings 14, 36 could provide an interference fit with the roll pin 35, while the cavity 32
9 along the spacer ring 16 could provide either an interference or clearance fit.

10 In yet other embodiments, the spacer ring 16 could be separated from the seal
11 element 38 via a gap 22 of circular extent. The gap 22 should have sufficient radial
12 height to accommodate the relative radial motion of the seal element 38 about the
13 cavity 33 because of the clearance fit of the anti-rotation pin 34.

14 In preferred embodiments, there is no relative movement between the seal
15 element 38 and other components comprising the seal assembly 11. One or more
16 cavities 33 could completely or partially traverse the seal element 38 about its
17 circumference and one or both end rings 14, 36. Anti-rotation pins 34 and cavities 33
18 are shaped so as to allow an anti-rotation pin 34 to be inserted into each cavity 33.
19 However, other anti-rotation elements and approaches known within the art are
20 likewise applicable to the embodiments described herein.

21 Each anti-rotation pin 34 should be press fitted onto the end ring 14 by
22 providing an interference fit between anti-rotation pin 34 and cavity 33 along the
23 thickness of the end ring 14. However, the cavity 33 portion along the seal element
24 38 should be larger than the diameter of the anti-rotation pin 34 so as to allow the seal
25 element 38 to slide or move axially and radially in response to mechanical and
26 thermal effects without binding the seal element 12. For example, the cavity 33 along
27 the seal element 38 could be either circular or slot-shaped. If movement of the seal
28 element 38 is overly restricted due to inadequate clearance between the diameter of
29 the cavity 33 along the seal element 12 and the diameter of anti-rotation pin 34
30 therein, the first outer surface 27 along the seal element 38 would not follow and seat
31 onto the lower surface 29 of the flange 21, as described herein.

32 The end ring 14 is preferred to include a relief 37 disposed in a circumferential
33 arrangement at the intersection of the horizontal flange 21 with the vertical structure
34 of the end ring 14, so as to avoid stress concentrations therein and fit and wear

1 problems with the seal element 38. The relief 37 could include a radius depending on
2 space constraints.

3 In some embodiments, it might be advantageous for seal and/or wear purposes
4 to include a non-linear profile along the second outer surface 28 of the seal elements
5 12, 38 shown in FIGS. 3 and 4, respectively.

6 Referring now to FIG. 5, an inverted T-shaped seal element 12 is shown
7 having a generally concave-shaped upper surface 39 along the ring flange 25.
8 Remaining features of the ring 24, namely, first outer surface 27 and inner surface 26
9 are as described herein.

10 As represented in FIG. 6, an L-shaped seal element 38 is shown having a
11 generally concave-shaped upper surface 39 along the ring flange 25. Remaining
12 features of the ring 24, namely, first outer surface 27 and inner surface 26 are as
13 described herein.

14 Other contoured geometries composed of one or more concave, convex, and/or
15 linear segments are likewise possible along the upper surface 39. The upper surface
16 39 could be molded onto or machined or shaped into an otherwise linear profile along
17 the outermost diametrical surface of a seal element 12, 38.

18 In other embodiments, it might be advantageous for seal and/or wear purposes
19 to include a spring 48 along the seal elements 12 and 38 shown in FIGS. 8a and 8b,
20 respectively. For example, FIGS. 8a and 8b show a spring 48 disposed along a groove
21 49 about the inner diameter 52 of the inverted T-shaped seal element 12 and L-shaped
22 seal element 38, respectively. The spring 48 could be a garter spring, expander spring,
23 or the like. The groove 49 is a semi-circular structure disposed along the seal element
24 12, 38 which approximates the curvature of the spring 48. The spring 48 imparts a
25 radial force to seat the outer surface 27 of the seal element 12, 38 onto the lower
26 surfaces 29 and/or 30 as the inner shaft 19 rotates. In other embodiments, the spring
27 48 could exert an outward radial force onto the seal element 12, 38 when the seal
28 element 12, 38 is stationary.

29 As represented in FIGS. 9 and 10, it might be advantageous to arrange two or
30 more seal assemblies 11, comprised of T-shaped seal elements 12 and/or L-shaped
31 seal elements 38 described herein, in a stacked or serial fashion between an inner
32 shaft 19 and an outer shaft 20. Seal assemblies 11 could be secured to the inner shaft
33 19 between a mechanical stop 47 and a locking ring 5, however other arrangements
34 are possible. The total number of seal assemblies 11 is dependent on the space

1 constraints along the inner shaft 19. In FIG. 9, the seal assemblies 11 are constructed
2 as described herein. In FIG. 10, the innermost end rings 14, 13 identified in FIG. 9 are
3 replaced by a single intermediate ring 53 having a generally T-shaped cross section.
4 Both multi-seal assemblies reduce the total flow of air across the seal system.

5 The seal elements 12, 38 described herein could be composed of high-
6 temperature, carbon-graphite compositions known within the art. An advantage of
7 carbon-graphite is its ability to wear without damage, unlike metals, when the relative
8 movement between the inner and outer shafts 19, 20 exceeds the clearance 40 shown
9 in FIG. 1. However, the invention described herein also allows for the use of high-
10 temperature metal and metal alloys because the seal assembly 11 avoids the wear
11 problems associated with dual-shaft systems. Exemplary metal and metal alloys could
12 include, but are not limited to, 17-4 PH, 410 SS, titanium, and Inconel-X[®] (the
13 registered trademark of the Huntington Alloys Corporation of Huntington, West
14 Virginia). Metals further allow the matching of thermal expansion coefficients for
15 materials composing the inner and outer shafts 19, 20, seal element 12 or 38, and end
16 rings 13, 14 or 14, 36.

17 Referring now to FIG. 11, the annular seal element 54 is shown including a
18 plurality of joints 43 forming an equal number of separate seal segments 57. Although
19 FIG. 11 shows eight joints 43 and eight seal segments 57, it is understood that the
20 annular seal element 54 could include two or more joints 43 and an equal number of
21 seal segments 57. Each seal segment 57 is generally arc shaped. A complete set of
22 seal segments 57 forms a circular ring-shaped structure. In preferred embodiments,
23 the seal segments 57 are approximately the same size and weight so as to properly
24 balance the seal assembly 11. In some embodiments, a joint 43 could include the
25 tongue and groove features described in FIGS. 7a and 7b. In other embodiments, each
26 joint 43 could be a planar cut which locally traverses the annular seal element 54. The
27 latter joint type is permissible in large diameter seal designs because joint leakage is
28 generally more tolerable. While reference is made to a segmented annular seal
29 element 54, end rings 63, 64 and spacer ring 59 are not segmented.

30 Each seal segment 57 further includes a ring segment 55 and a ring flange
31 segment 56. Each ring segment 55 is arc shaped with a generally quadrilateral cross
32 section. Each ring flange segment 56 is also arc shaped with a generally quadrilateral
33 cross section. A ring flange segment 56 is disposed along and extends from the upper
34 radial surface 69 of a ring segment 55 so as to form a structure with either a "T"-

1 shaped cross section or an “L”-shaped cross section, as generally represented in FIGS.
2 12c and 13 respectively. In some embodiments, the upper radial surface 69 of the ring
3 flange segment 56 could be convex shaped, as represented in FIGS. 5 and 6.

4 Referring now to FIGS. 12a and 12b, a seal segment 57 is shown disposed
5 about a spacer ring 59 with an annular gap 68 there between. The spacer ring 59 could
6 contact the outer diameter of an inner shaft 19, the latter feature described in FIG. 1.
7 A pair of resilient elements or compression springs 58 could be disposed between the
8 seal segment 57 and spacer ring 59 and oriented to apply a spring force onto the seal
9 segment 57 and the spacer ring 59. One non-limiting example of a compression spring
10 58 is a coil spring.

11 In some embodiments, it might be possible to support each seal segment 57
12 with one compression spring 58 depending on the length of the seal segment 57 and
13 other design considerations. In other embodiments, each compression spring 58 could
14 be partially recessed within a cavity 60 along an inner radial surface 85 of the seal
15 segment 57, as represented in FIG. 12a. In this arrangement, each compression spring
16 58 applies a force onto a support surface 66 at the bottom of the cavity 60 and onto a
17 support surface 67 disposed along the outer annular surface 86. In other embodiments,
18 each compression spring 58 could be partially recessed within a cavity 60 along outer
19 annular surface 86 of the spacer ring 59, as represented in FIG. 12b. In this
20 arrangement, each compression spring 58 applies a force onto a support surface 66
21 along the inner radial surface 85 of the seal segment 57 and onto a support surface 67
22 at the bottom of the cavity 60. A cavity 60 could be a cylindrical-shaped hole which
23 approximates the cross section of the compression spring 58. The cavity 60 could be
24 dimensioned for a clearance fit with the compression spring 58; however, an
25 interference fit might be advantageous in some applications.

26 Referring now to FIGS. 12a-12c, the seal segment 57 and spacer ring 59 are
27 shown disposed between a pair of end rings 63, 64. In this embodiment, the seal
28 segment 57 has an inverted “T”-shaped cross section and each end ring 63, 64
29 includes a flange 74, 75, respectively. The spacer ring 59 is wider than the ring
30 segment 55 so as to provide at least a clearance fit between the seal segment 57 and
31 the interior vertical surfaces of the end rings 63, 64. This arrangement allows at least
32 one side of the seal segment 57 to avoid contact with the interior vertical surfaces of
33 one or both end rings 63, 64 and/or flanges 74, 75 or 65, as generally represented by
34 the gap 44 in FIGS. 3 and 4.

1 The compression springs 58 should bias the seal segment 57 away from the
2 spacer ring 59 so as to enable contact between the upper radial surface 69 along the
3 ring segment 55 and the lower annular surface 70 along the flanges 74, 75 in FIG. 12c
4 and flange 65 in FIG. 13. The compression springs 58 should also be sufficiently
5 elastic and deformable so as to allow the seal segment 57 to move radially inward
6 toward the spacer ring 59 when a contact force is applied onto the seal segment 57 by
7 the outer shaft 20 (not shown). Finally, the compression springs 58 should be
8 sufficiently resilient so as to recover their original shape thereby reseating the seal
9 segment 57 against the flanges 65, 74, 75. At least one compression springs 58 could
10 be used with each seal segment 57.

11 The fully extended length of a compression spring 58 should at least ensure
12 that the upper radial surface 69 along a ring segment 55 contacts the lower annular
13 surface 70 along a flange 74, 75 or 65. In these such embodiments, the uncompressed
14 height of the compression spring 58 would be approximately equal to either the
15 distance between the support surfaces 66, 67 when the upper radial surface 69
16 contacts the lower annular surface 70 or the total of the height of the annular gap 68
17 and the depth of the cavity 60.

18 In preferred embodiments, the fully-extended length of the compression spring
19 58 should be greater than the total of the height of the annular gap 68 and the depth of
20 the cavity 60 so that a positive contact force is applied along the interface between the
21 upper radial surface 69 and lower annular surface 70. The applied force is design
22 dependent, yet should be sufficient to prevent or minimize sliding between the seal
23 segment 57 and flanges 74, 75 or 65. In all embodiments, the ring flange segment 56
24 should extend above the flanges 74, 75 or 65. This feature requires the height of the
25 ring flange segment 56 to exceed the maximum thickness of the flanges 74, 75 or 65,
26 as represented in at least FIGS. 12c and 13, respectively.

27 In some embodiments, one or more anti-rotation pins 61 could be secured to
28 the spacer ring 59 in an outward radial arrangement, as represented in FIGS. 12a-12c.
29 Each anti-rotation pin 61 could be partially recessed within and mechanically attached
30 to a cavity 76, which complements the shape of the pin 61, via threads or an
31 interference fit or adhesively secured thereto. The remaining portion of each anti-
32 rotation pins 61 should extend radially outward so as to traverse the annular gap 68
33 and partially penetrate a cavity 62 along the inner radial surface 85 of the seal
34 segment 57.

1 From time-to-time, axial alignment between the inner and outer shafts 19, 20
2 (see FIG. 1) will deviate due to mechanical and thermal conditions. Large deviations
3 may be sufficient to enable the outer shaft 20 to contact a portion of one or more ring
4 flange segments 56 extending above the flanges 74, 75. The cavity 62 could be
5 dimensionally oversized for the anti-rotation pin 61 so as to avoid or minimize contact
6 with the seal segment 57. In this regard, the distance between the depth of the cavity
7 62 and the length of the anti-rotation pin 61 residing with the cavity 62 should be at
8 least the maximum radial translation possible when the outer shaft 20 interacts with
9 the seal segment 57. In one example, the maximum radial translation could be
10 equivalent to the difference between the height of the compression spring 58 within
11 the seal assembly 11 and the height of the compression spring 58 when fully
12 compressed. In another example, the maximum radial translation could be equivalent
13 to the compression distance allowed for the compression spring 58 when less than the
14 maximum allowable compression. The distance between the radius of the cavity 62
15 and the radius of the anti-rotation pin 61 could define the maximum axial translation.
16 In one example, the maximum axial translation could be equivalent to twice the
17 average width of a gap or translation distance at two or more joint 43. In another
18 example, the maximum axial translation could be a fraction of the maximum radial
19 translation to account for compound translations.

20 Referring now to FIG. 13, a seal segment 57, an annular gap 68, and a spacer
21 ring 59 are shown disposed between a pair of end rings 63, 64. In this embodiment,
22 the seal segment 57 has an "L"-shaped cross section so only one end ring 63 includes
23 a flange 65 allowing contact between a lower annular surface 70 and an upper radial
24 surface 69. A compression spring 58 is partially recessed within a cavity 60 along the
25 spacer ring 59 and further contacts the inner radial surface 85 of the seal segment 57.
26 It is likewise possible for the compression spring 58 to be partially recessed within the
27 seal segment 57 as otherwise described herein. While the compression spring 58 is
28 shown equidistant between the vertical walls of the end rings 63, 64, it might be
29 advantageous in certain applications to bias the spring toward one end ring 63 or 64
30 either to maximize the contact force between the upper radial surface 69 and the lower
31 annular surface 70 or to minimize twist of the seal segment 57 within the seal
32 assembly 11.

33 Referring now to FIG. 14, a seal segment 57, an annular gap 68, and a spacer
34 ring 59 are shown disposed between a pair of end rings 63, 64. The compression

1 spring 58 is partially recessed within a cavity 60 along the seal segment 57. The
2 spacer ring 59 and end rings 63, 64 could include an optional cavity 71 into which a
3 roll pin 72 is inserted and secured to fix the spacer ring 59 to the end rings 63, 64.
4 Two or more cavities 71 and roll pins 72 might be required to properly secure the
5 spacer ring 59 to the end rings 63, 64.

6 Referring now to FIGS. 15a and 15b, an inverted "T"-shaped seal segment 57,
7 annular gap 68, and spacer ring 59 are shown disposed between a pair of end rings 63,
8 64. The seal segment 57 is biased away from the spacer ring 59 and inner shaft 19
9 (not shown) via a compression spring 58 partially recessed within the seal segment
10 57. An optional roll pin 72 resides within a complementary shaped cavity 71 to secure
11 the spacer ring 59 to the end rings 63, 64. An optional anti-rotation pin 84 is shown
12 attached to one end to an end ring 63 immediately adjacent to the seal segment 57.
13 The anti-rotation pin 84 could partially reside within a complementary shaped cavity
14 76 and is either mechanically or adhesively secured thereto. The second end of the
15 anti-rotation pin 84 partially resides within a cavity 73 along one side of the seal
16 segment 57. The cavity 73 could be dimensionally oversized for the anti-rotation pin
17 84 so as to avoid or minimize contact with the seal segment 57 during translations
18 between the inner and outer shafts 19, 20 (not shown) which result in contact between
19 the outer shaft 20 and seal segment 57. The distance between the depth of the cavity
20 73 and the length of the anti-rotation pin 84 residing with the cavity 73, when the seal
21 segment 57 contacts the end ring 63, could be at least the maximum axial translation.
22 In one example, the maximum axial translation could be equivalent to the difference
23 between the width of the spacer ring 59 and width of the ring segment 55. The
24 distance between the radius of the cavity 73 and the radius of the anti-rotation pin 84
25 could be at least the maximum radial translation. In one example, the maximum radial
26 translation could be the difference between the height of the compression spring 58
27 within the seal assembly 11 and the height of the compression spring 58 when fully
28 compressed. In another example, the maximum radial translation could be the
29 compression distance allowed for the compression spring 58 when less than the
30 maximum compression allowable. While the compression spring 58 is shown
31 equidistant between the vertical walls of the end rings 63, 64, it may be advantageous
32 in certain applications to bias the spring toward one end ring 63 or 64 either to
33 maximize the contact force between the upper radial surface 69 and the lower annular
34 surface 70 or to minimize twist of the seal segment 57 within the seal assembly 11.

1 However, the clearance between the anti-rotation pin 84 should allow the pin 84 to
2 arrest rotation of the seal segment 57 with respect to the end ring 63. At least one anti-
3 rotation pin 84 could be used with each seal segment 57.

4 Referring now to FIGS. 16a and 16b, a seal assembly 11 is now shown having
5 an optional second pin 78 attached along the interior of one end ring 63. A portion of
6 the anti-rotation pin 78 resides within and is secured to a cavity 79 disposed along the
7 end ring 63. In one example, the anti-rotation pin 78 could be a paddle pin having a
8 head larger than the portion secured to the end ring 63. The ring segment 55 of the
9 seal segment 57 could include a slot-shaped cavity 77 disposed in an outward radial
10 orientation. The free end of the anti-rotation pin 78 would reside within the cavity 77.
11 The width of the cavity 77 could be slightly larger than the major diameter of the anti-
12 rotation pin 78 and the depth of the cavity 77 could be slightly deeper than the
13 extension of the anti-rotation pin 78 so as to enable the anti-rotation pin 78 to freely
14 move with respect to the cavity 77. The radial orientation and oversized width and
15 depth of the slot-shaped cavity 77 would allow the seal segment 57 to freely
16 translation without binding with respect to the anti-rotation pin 78. However, the
17 clearance between the anti-rotation pin 78 should allow the pin 78 to arrest rotation of
18 the seal segment 57 with respect to the end ring 63. At least one anti-rotation pin 78
19 could be used with each seal segment 57.

20 Referring now to FIGS. 17a and 17b, a seal segment 57, annular gap 68, and
21 spacer ring 59 are shown disposed between a pair of end rings 63, 64. A resilient
22 element or flat spring 81 is further disposed between and directly contacts the seal
23 segment 57 along its inner radial surface 85 and spacer ring 59 along its outer annular
24 surface 86. The flat spring 81 could be a strip of metal or other material capable of
25 elastic deformation and recovery. While the flat spring 81 is shown having a generally
26 U-shaped profile in FIG. 17a, other designs are possible including such non-limiting
27 examples as a C-shaped or D-shaped profile. The flat spring 81 should bias the seal
28 segment 57 away from the spacer ring 59 so as to enable contact between the upper
29 radial surface 69 along the ring segment 55 and the lower annular surface 70 along the
30 flange 74, 75 or 65. The flat spring 81 should also be sufficiently elastic and
31 deformable so as to allow the seal segment 57 to move radially inward toward the
32 spacer ring 59 when a contact force is applied onto the seal segment 57 by the outer
33 shaft 20 (not shown). Also, the flat spring 81 should be sufficiently resilient so as to
34 recover its original shape thereby reseating the seal segment 57 against the flanges 74,

1 75 or 65. At least one flat spring 81 could be used with each seal segment 57. This
2 embodiment could further include the various features described herein including, but
3 not limited to the anti-rotation pin 84 and cavities 73, 76.

4 The flat spring 81 could be partially recessed within a notch 80 along the outer
5 annular surface 86 of the spacer ring 59. The notch 80 could include a pair of corners
6 87. The flat spring 81 could be positioned along the notch 80 so that the opposed ends
7 88 of the flat spring 81 separately contact the opposed corners 87, as represented in
8 FIG 17a. This arrangement localizes deflection to the central region of the flat spring
9 81 and increases the restorative forces exerted by the flat spring 81 onto the seal
10 segment 57. In preferred embodiments, distance between the opposed corners 87
11 could be less than the distance between the ends 88 so that the flat spring 81 is at least
12 slightly compressed when assembled onto the notch 80. The outward forces exerts at
13 the ends 88 of the flat spring 81 onto the corners 87 would secure the flat spring 81 to
14 the spacer ring 59.

15 Referring now to FIGS. 18 and 19, a seal segment 57, annular gap 68, and
16 spacer ring 59 are shown disposed between a pair of end rings 63, 64. A resilient
17 element or extension spring 83 is further disposed between and directly contacts the
18 seal segment 57 along its inner radial surface 85. In one example, the flat spring 81
19 could be a ring-shaped compression-type spring. The extension spring 83 should bias
20 the seal segment 57 away from the spacer ring 59 so as to enable contact between the
21 upper radial surface 69 along the ring segment 55 and the lower annular surface 70
22 along the flanges 74, 75 or 65. The extension spring 83 should also be sufficiently
23 elastic and deformable so as to allow the seal segment 57 to move radially inward
24 toward the spacer ring 59 when a contact force is applied onto the seal segment 57 by
25 the outer shaft 20 (not shown). Finally, the extension spring 83 should be sufficiently
26 resilient so as to recover its original shape thereby reseating the seal segment 57
27 against the flanges 74, 75 or 65. A single extension spring 83 contacts all seal
28 segments 57. This embodiment could further include the various features described
29 herein including, but not limited to the roll pin 72 and cavity 71 and anti-rotation pin
30 84 and cavities 73, 76.

31 In some embodiments, the extension spring 83 could be partially recessed
32 within a groove 82 along the inner radial surface 85 of the seal segment 57. In other
33 embodiments, the extension spring 83 could be fully recessed or embedded within the
34 seal segments 57 along the annular seal element 54. In preferred embodiments, the

1 extension spring 83 could have a diameter larger than the inner diameter of the
2 annular seal element 54 so that the extension spring 83 is at least slightly compressed
3 when assembled onto the groove 82. The resultant outward forces exerted by the
4 extension spring 83 would secure the spring 83 to each seal segment 57 along the
5 annular seal element 54. The resultant outward forces would seat the seal segments 57
6 onto the flanges 74, 75 or 65.

7 The description above indicates that a great degree of flexibility is offered in
8 terms of the present invention. Although various embodiments have been described in
9 considerable detail with reference to certain preferred versions thereof, other versions
10 are possible. Therefore, the spirit and scope of the appended claims should not be
11 limited to the description of the preferred versions contained herein.

12 **6. Industrial Applicability**

13 As is evident from the explanation above, the segmented intershaft seal and
14 variations thereof described herein minimizes assembly and control problems inherent
15 to intershaft seal systems in large diameter applications. The invention is expected to
16 be used within applications whereby a housing is provided with a plurality of interior
17 sections having rotating parts passing there through, wherein one of the interior
18 housing sections must be isolated from another by means of a seal system. One
19 specific non-limiting example is a turbine engine.

CLAIMS

What is claimed is:

1. A segmented intershaft seal assembly for use between an inner shaft and an outer shaft disposed about a common axis within a turbine engine comprising:

(a) a pair of end rings with at least one said end ring having a flange disposed along and extending from one side of said end ring, each said flange has a lower annular surface;

(b) an annular seal element formed by at least two seal segments, each said seal segment includes a ring segment and a ring flange segment, said ring segment has an upper radial surface, said ring flange segment disposed along and extending from said upper radial surface to form either a substantially "T"-shaped cross section or a substantially "L"-shaped cross section, said seal segments disposed between said end rings; and

(c) at least one resilient element which biases each said seal segment away from said inner shaft so that said upper radial surface directly contacts said lower annular surface and a portion of said ring flange segment extends beyond said flange.

2. The segmented intershaft seal assembly of claim 1, wherein said at least one resilient element is a compression spring.

3. The segmented intershaft seal assembly of claim 2, wherein at least two said compression springs are separately and partially recessed within each said seal segment.

4. The segmented intershaft seal assembly of claim 2, further comprising:

(d) a spacer ring disposed between said end rings and directly contacts said inner shaft, at least two said compression springs are separately and partially recessed within said spacer ring.

5. The segmented intershaft seal assembly of claim 4, further comprising:

(e) at least two pins separately secured to said spacer ring, each said pin partially residing within an oversized cavity along one said seal segment, said oversized cavity dimensioned to avoid contact between said pin and said seal segment when said seal segment is displaced radially by direct contact with said outer shaft.

6. The segmented intershaft seal assembly of claim 4, wherein said spacer ring is secure to said end rings.

- 1 7. The segmented intershaft seal assembly of claim 2, further comprising:
2 (d) at least two pins separately secured to at least one end ring, each said pin
3 partially residing within a cavity, said cavity either slot shaped and radially
4 oriented or oversized to avoid contact between said pin and said seal segment
5 when said seal segment is displaced radially by direct contact with said outer
6 shaft.
- 7 8. The segmented intershaft seal assembly of claim 1, wherein said at least one
8 resilient element is a flat spring.
- 9 9. The segmented intershaft seal assembly of claim 8, further comprising:
10 (d) a spacer ring disposed between said end rings and directly contacts said
11 inner shaft, each said flat spring separately and partially recessed within said
12 spacer ring.
- 13 10. The segmented intershaft seal assembly of claim 9, further comprising:
14 (e) at least two pins separately secured to said spacer ring, each said pin
15 partially residing within an oversized cavity along one said seal segment, said
16 oversized cavity dimensioned to avoid contact between said pin and said seal
17 segment when said seal segment is displaced radially by direct contact with
18 said outer shaft.
- 19 11. The segmented intershaft seal assembly of claim 9, wherein said spacer ring is
20 secured to said end rings.
- 21 12. The segmented intershaft seal assembly of claim 8, further comprising:
22 (d) at least two pins separately secured to at least one end ring, each said pin
23 partially residing within a cavity, said cavity either slot shaped and radially
24 oriented or oversized to avoid contact between said pin and said seal segment
25 when said seal segment is displaced radially by direct contact with said outer
26 shaft.
- 27 13. The segmented intershaft seal assembly of claim 1, wherein said at least one
28 resilient element is an extension spring which directly contacts said seal segments,
29 said extension spring at least partially recessed within said seal segments.
- 30 14. The segmented intershaft seal assembly of claim 13, further comprising:
31 (d) a spacer ring disposed between said end rings and directly contacts said
32 inner shaft.
- 33 15. The segmented intershaft seal assembly of claim 14, further comprising:
34 (e) at least two pins separately secured to said spacer ring, each said pin

1 partially residing within an oversized cavity along one said seal segment, said
2 oversized cavity dimensioned to minimize contact between said pin and said
3 seal segment when said seal segment is displaced by direct contact with said
4 outer shaft.

5 16. The segmented intershaft seal assembly of claim 14, wherein said spacer ring is
6 secured to said end rings.

7 17. The segmented intershaft seal assembly of claim 13, further comprising:

8 (d) at least two pins separately secured to at least one end ring, each said pin
9 partially residing within a cavity, said cavity either slot shaped and radially
10 oriented or oversized to avoid contact between said pin and said seal segment
11 when said seal segment is displaced radially by direct contact with said outer
12 shaft.

13 18. The segmented intershaft seal assembly of claim 1, wherein each said ring flange
14 segment has a convex shaped surface adjacent to said outer shaft.

15 19. The segmented intershaft seal assembly of claim 1, further comprising:

16 (d) a locking nut directly contacting one said end ring to secure said seal
17 assembly to said inner shaft.

18 20. The segmented intershaft seal assembly of claim 1, wherein said seal segments are
19 composed of a metal, a metal alloy, or carbon,

20 said end rings, said inner shaft, and said outer shaft have substantially similar
21 thermal expansion properties to minimize contact between said seal segments and said
22 outer shaft.

23

24

25

26

27

28

29

30

31

32

33

34

1/17

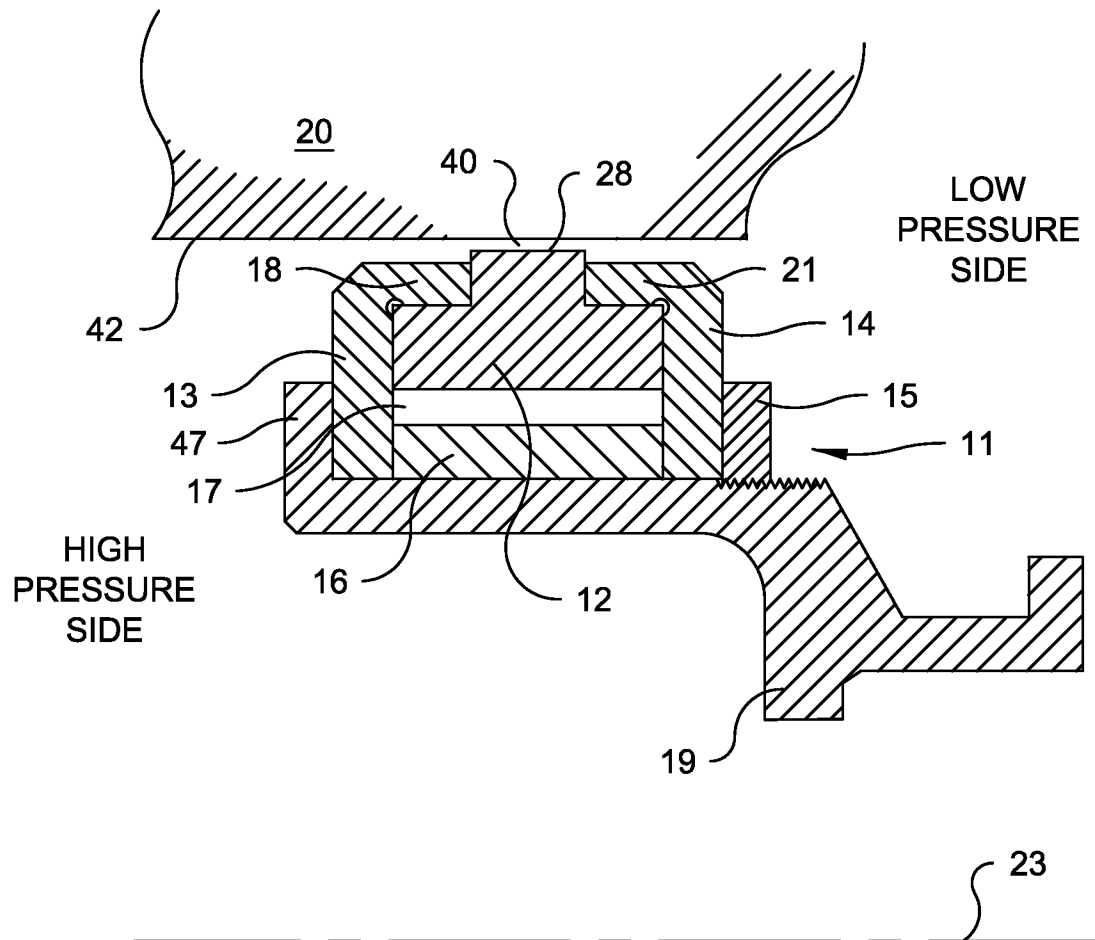


Fig. 1

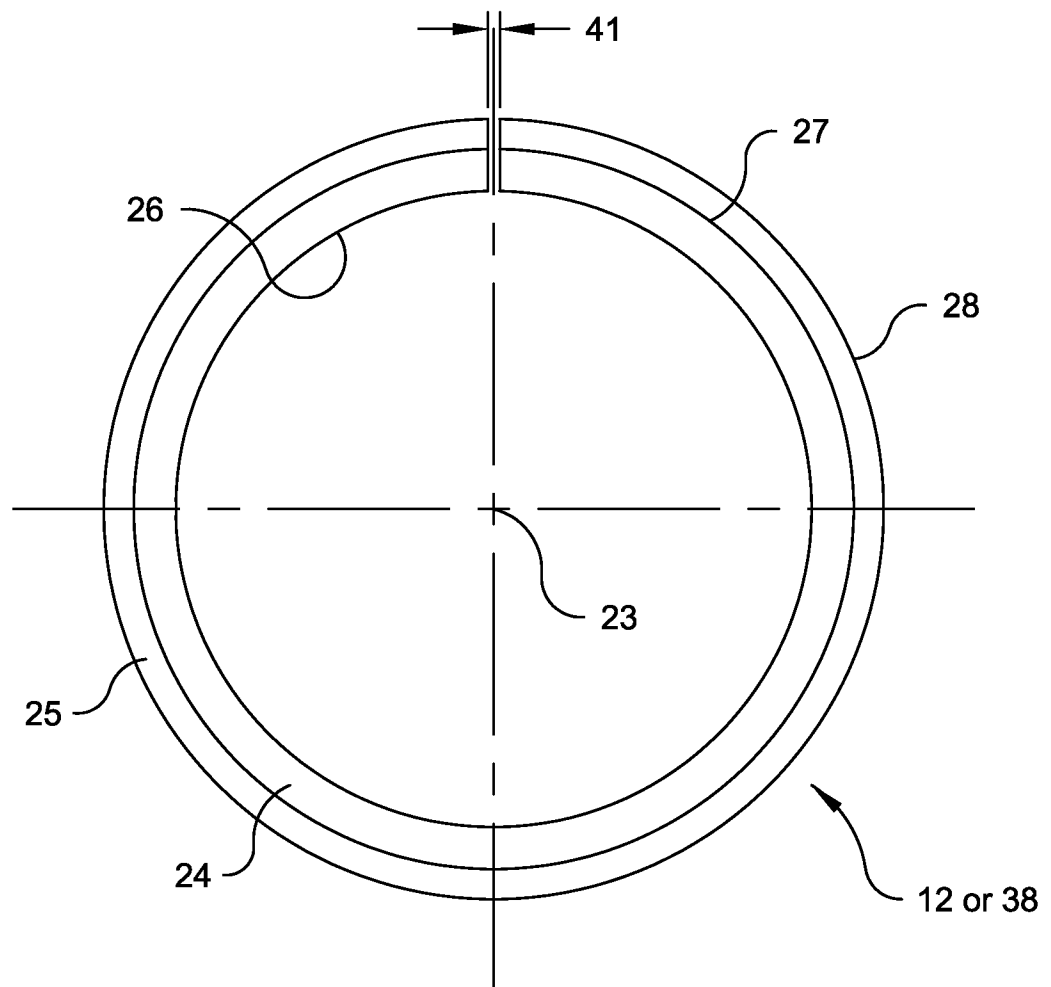


Fig. 2

3/17

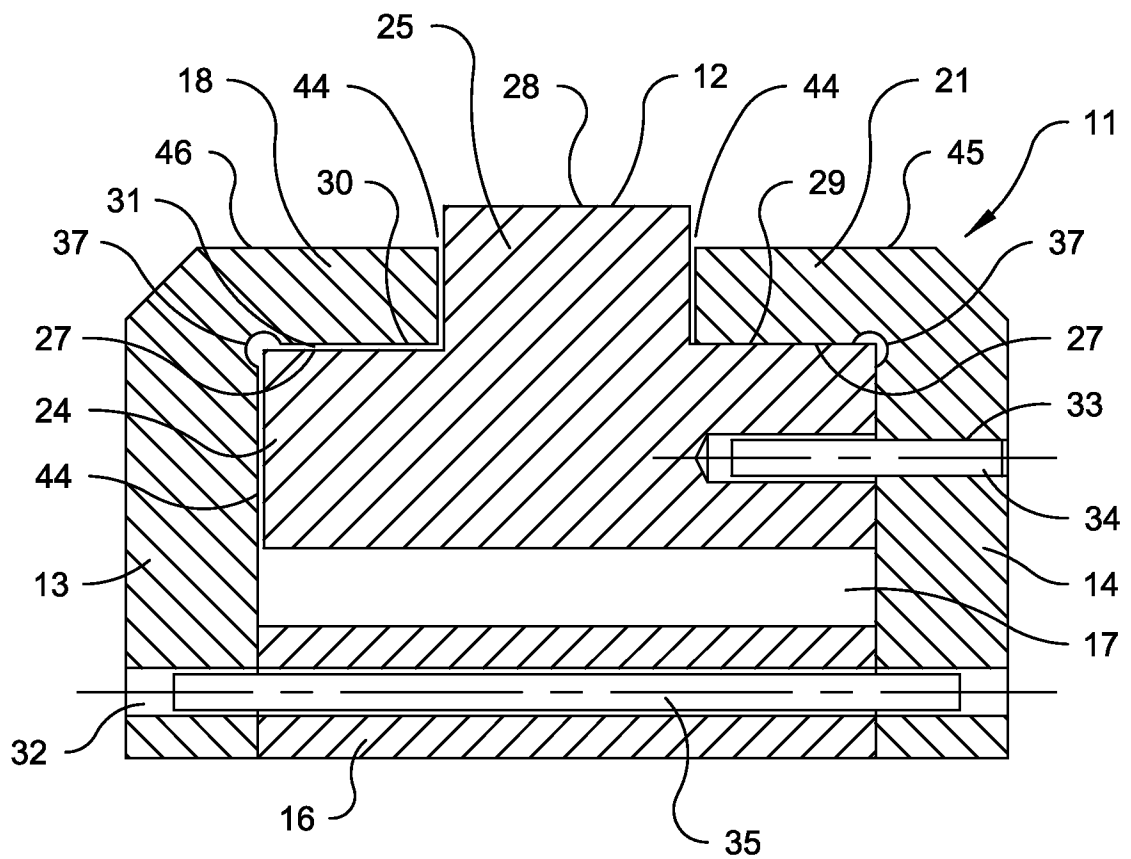
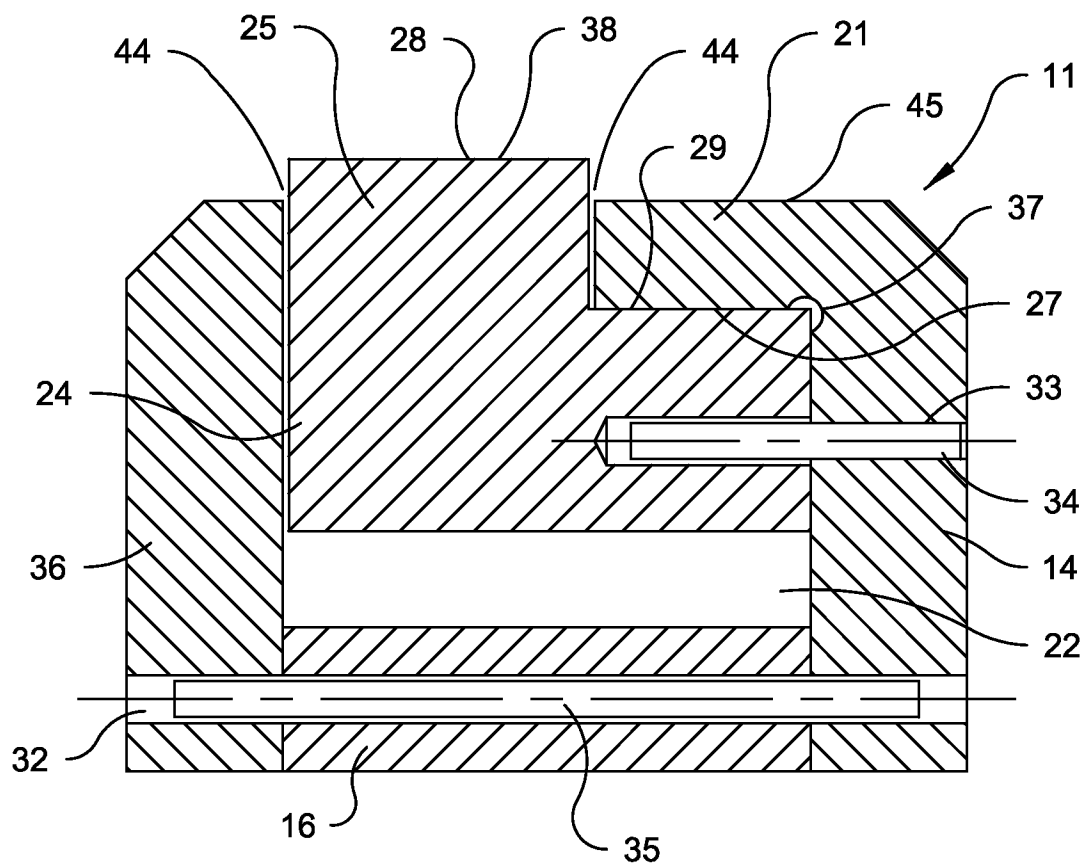
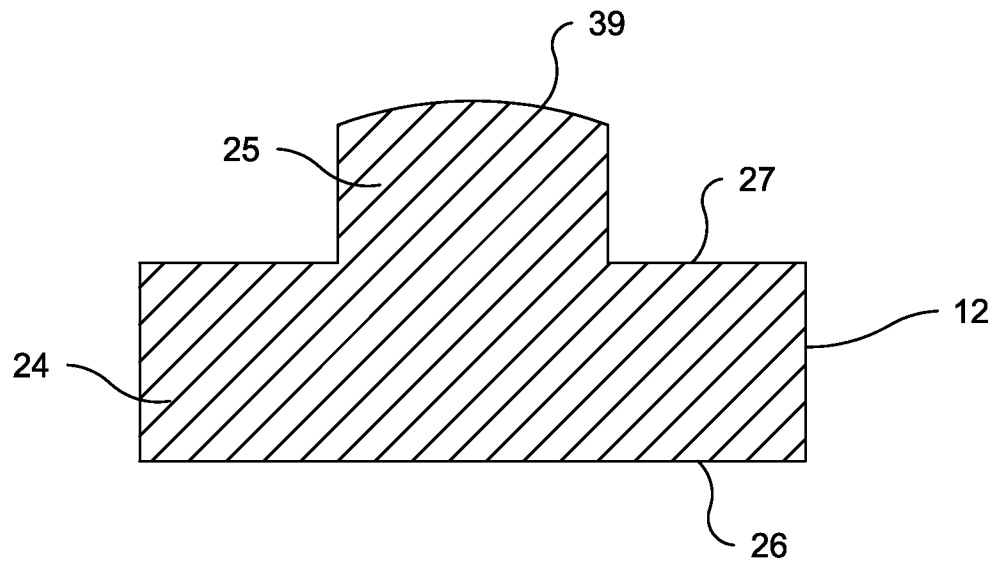
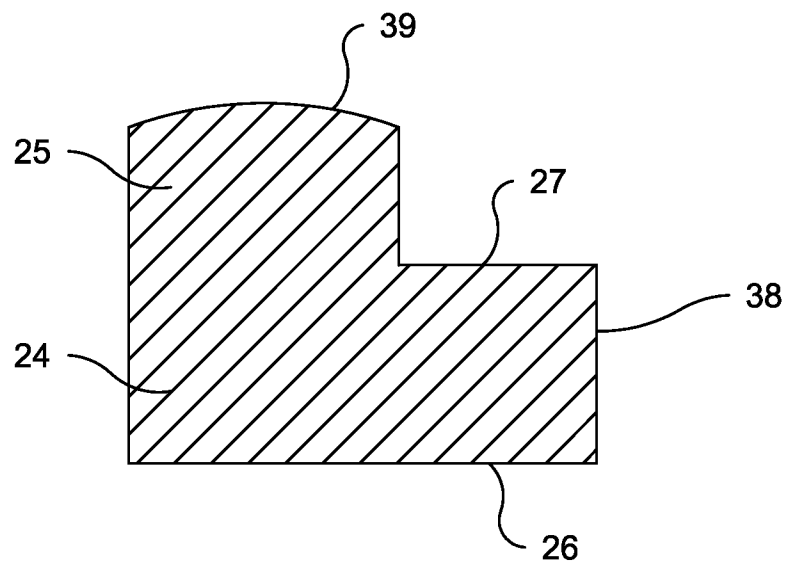


Fig. 3

4/17

**Fig. 4**

5/17***Fig. 5******Fig. 6***

6/17

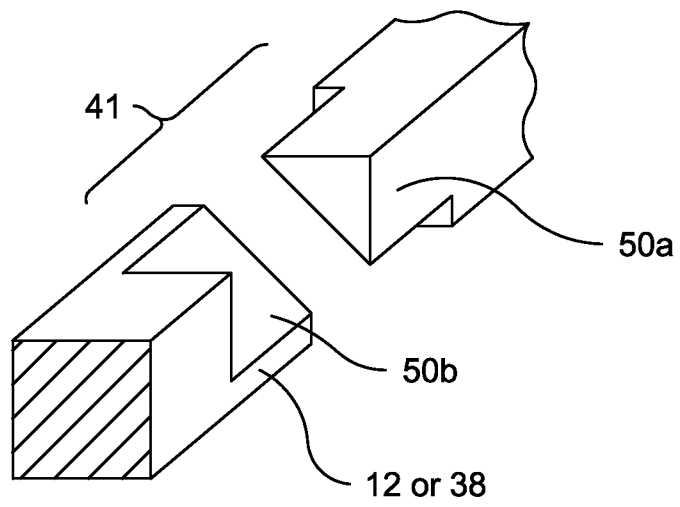


Fig. 7a

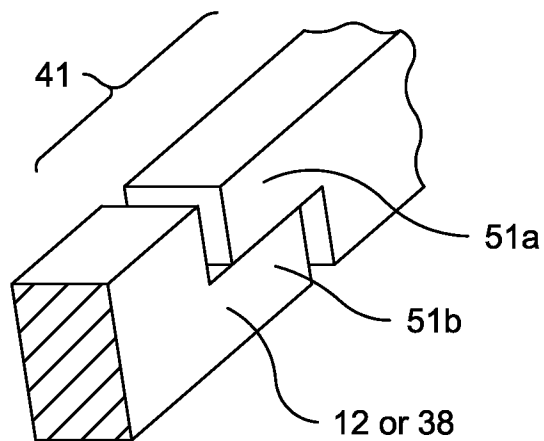


Fig. 7b

7/17

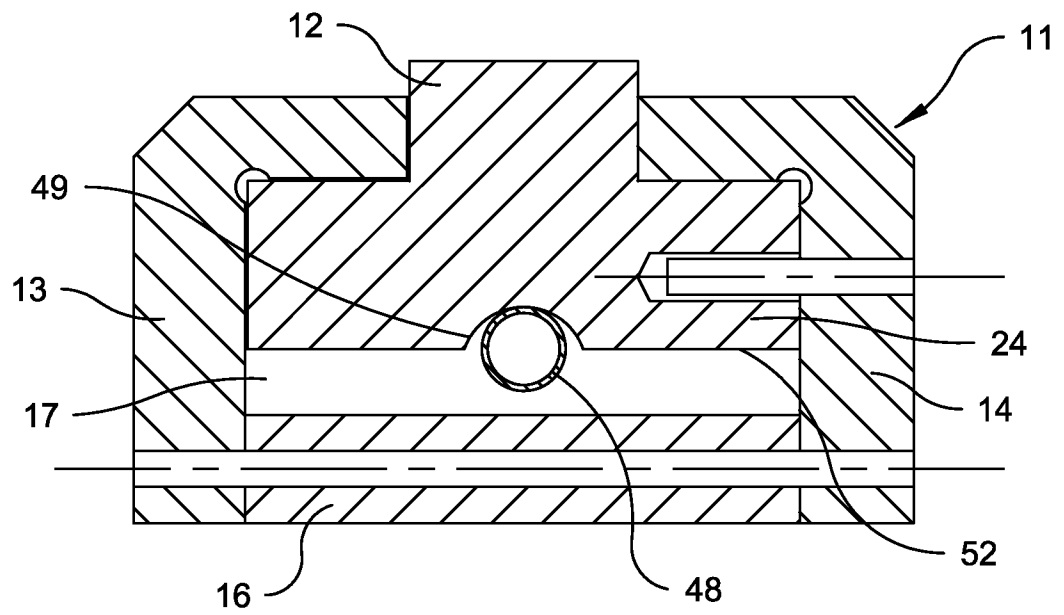


Fig. 8a

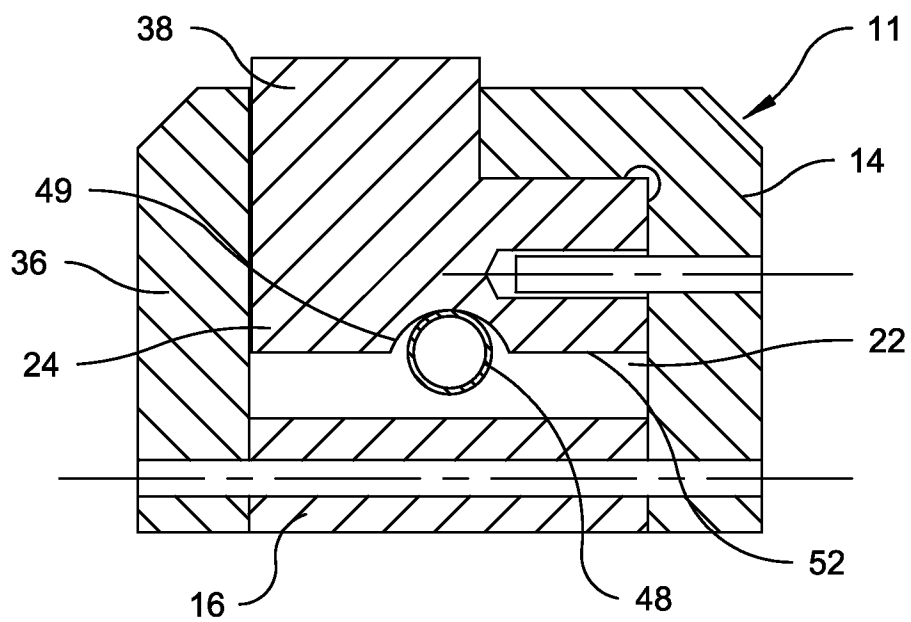


Fig. 8b

8/17

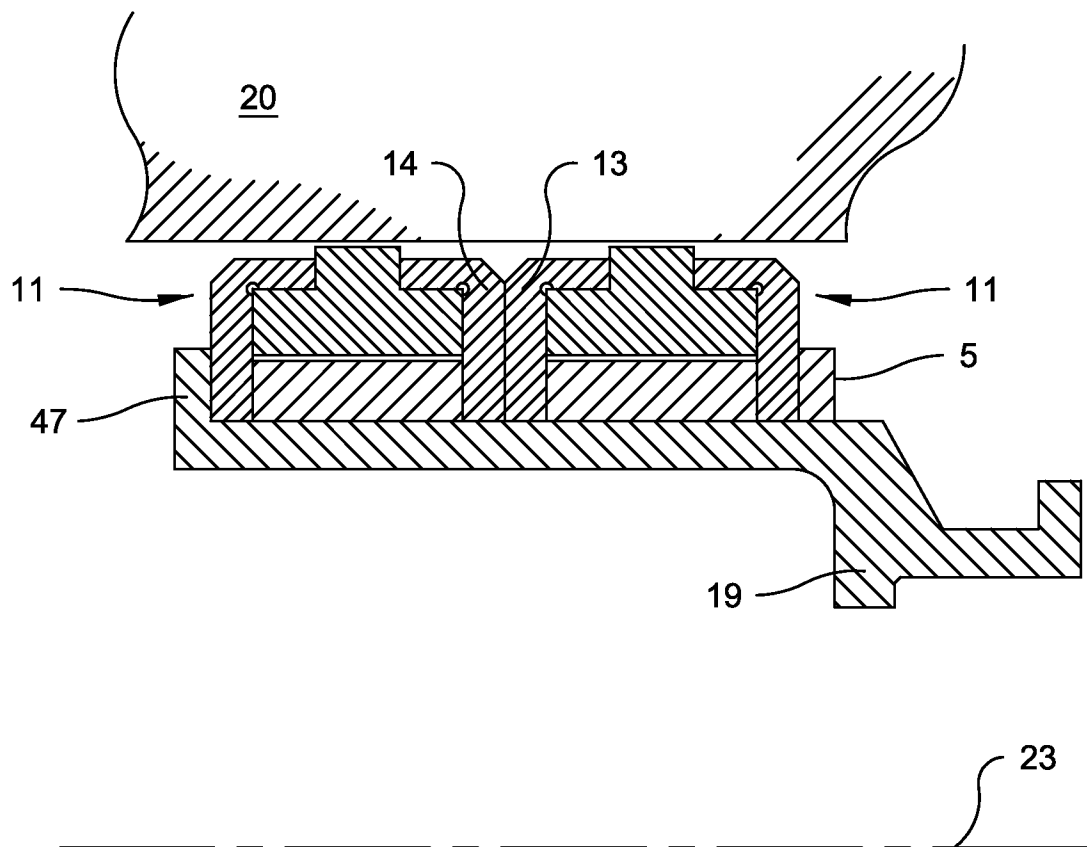


Fig. 9

9/17

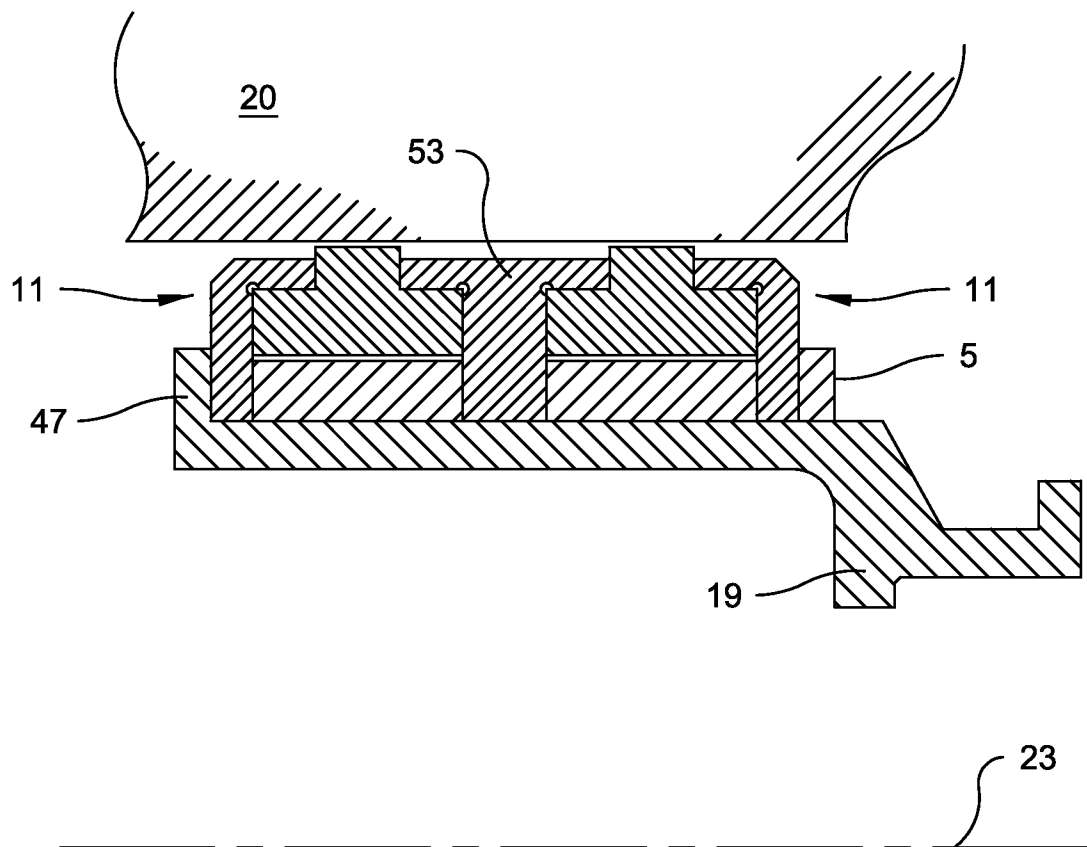


Fig. 10

10/17

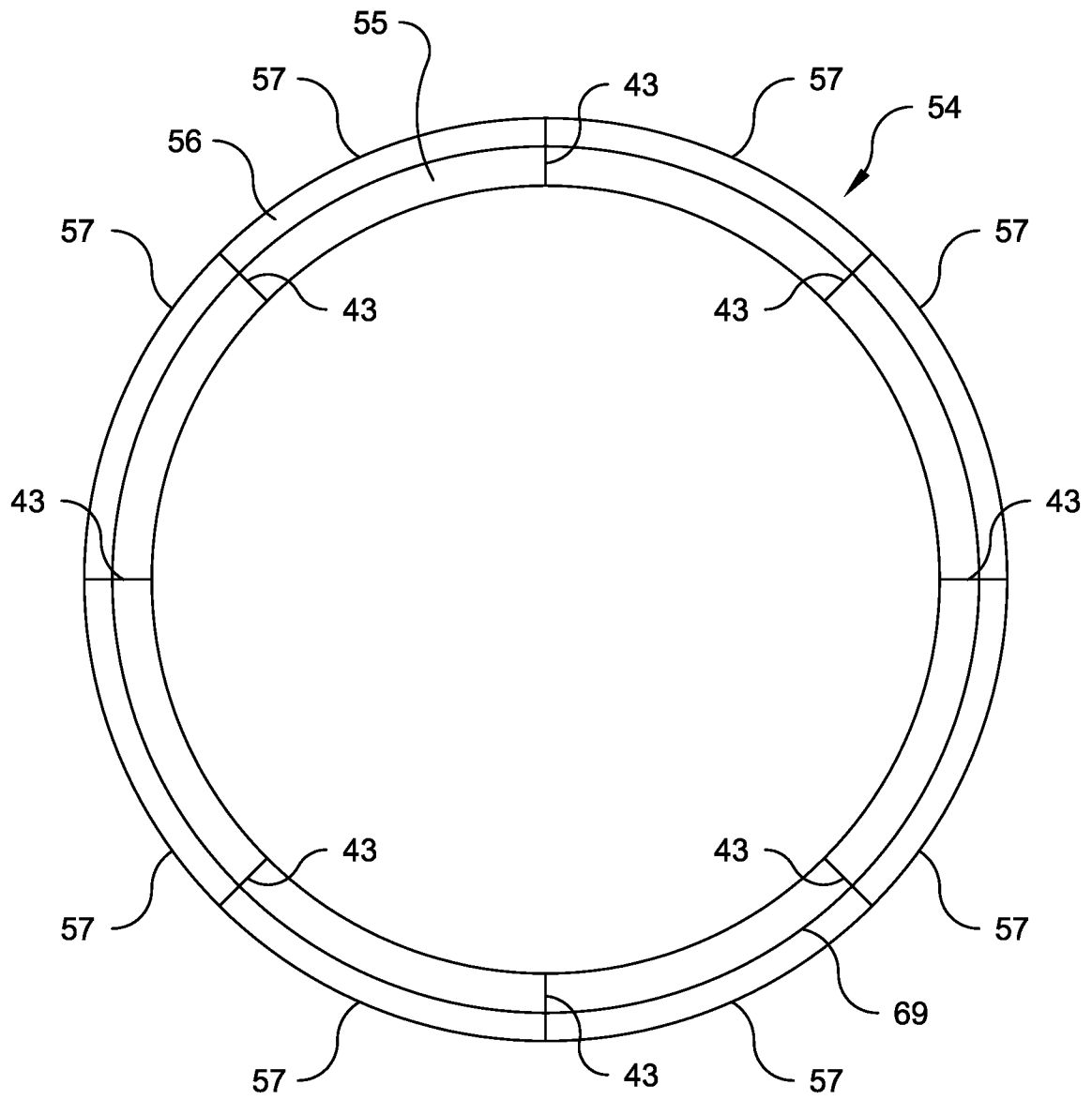


Fig. 11

11/17

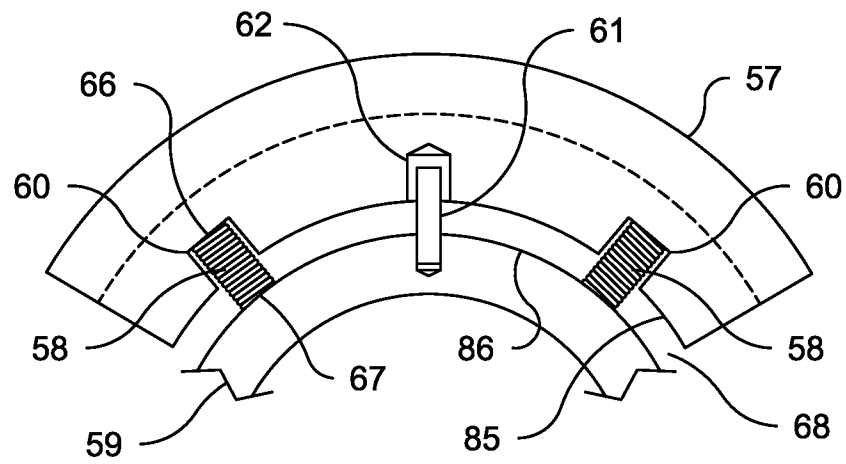


Fig. 12a

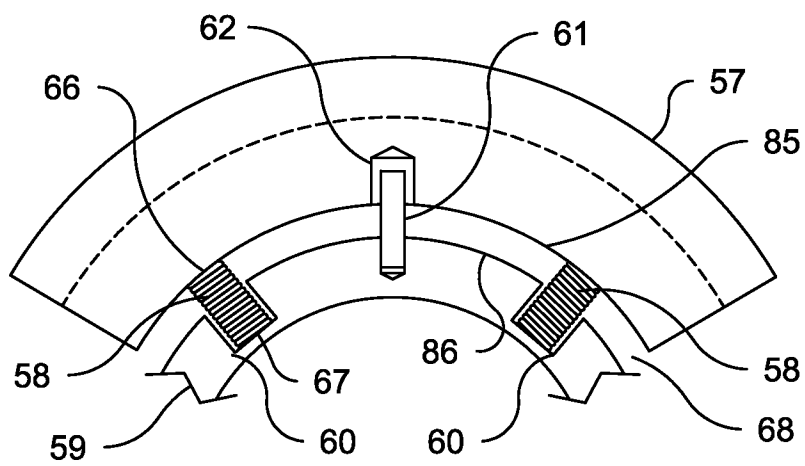


Fig. 12b

12/17

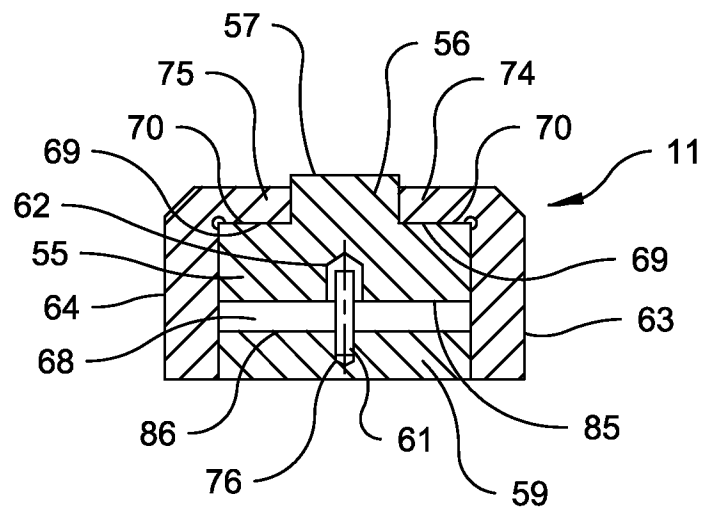


Fig. 12c

13/17

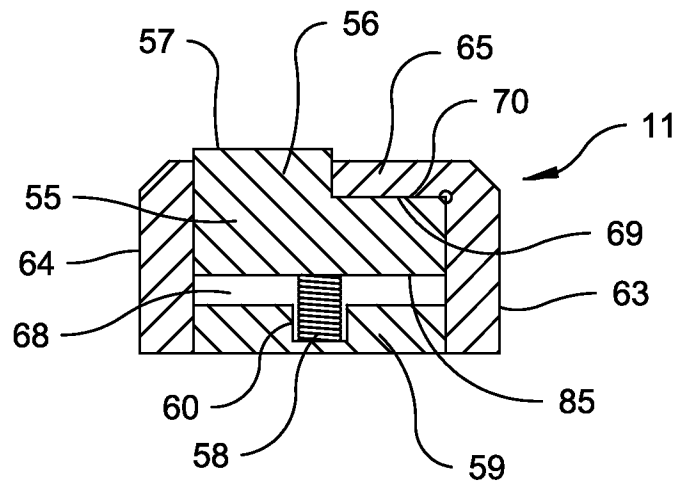


Fig. 13

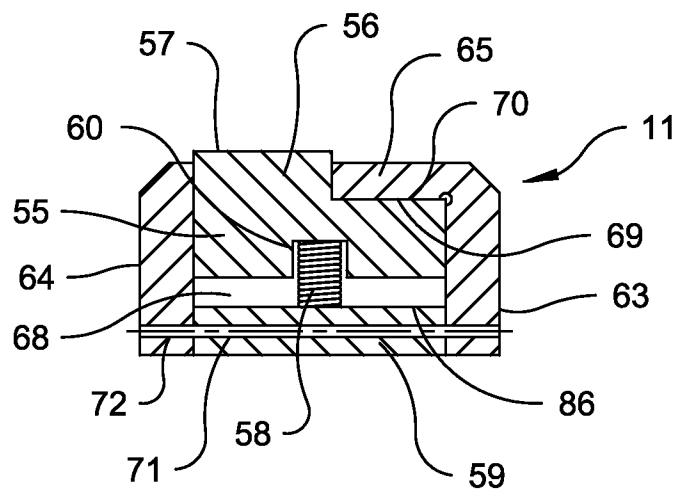


Fig. 14

14/17

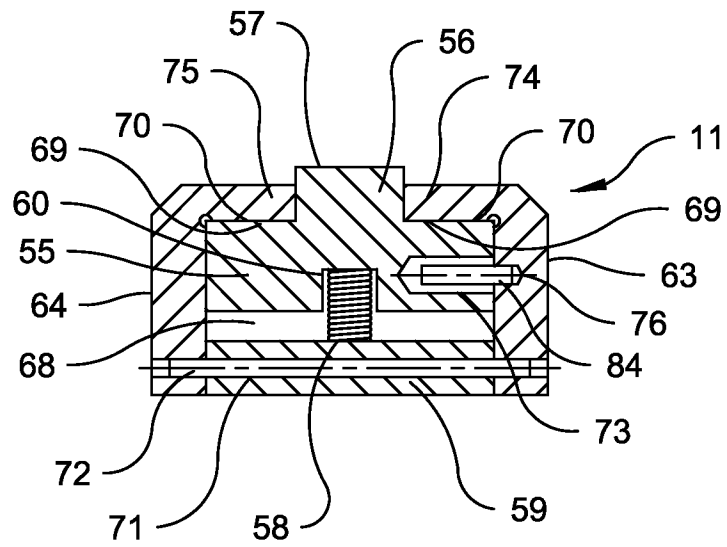


Fig. 15a

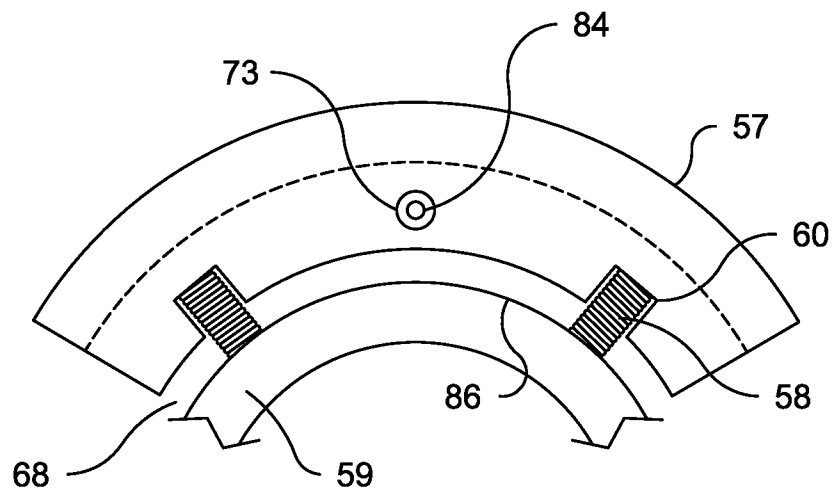


Fig. 15b

15/17

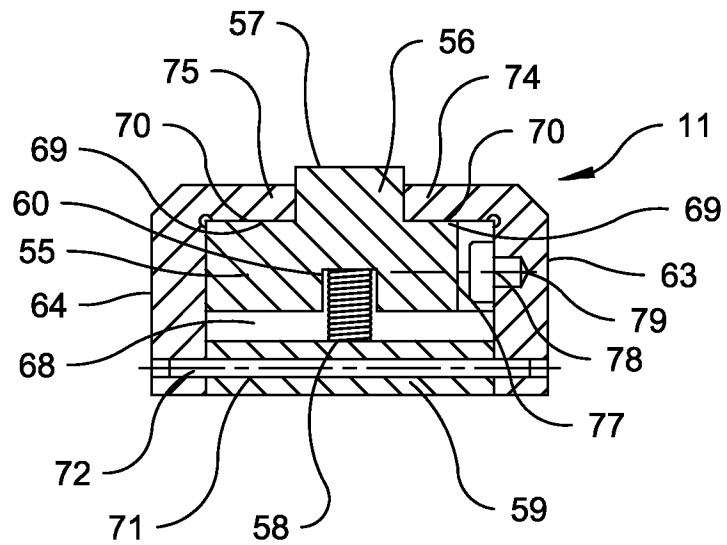


Fig. 16a

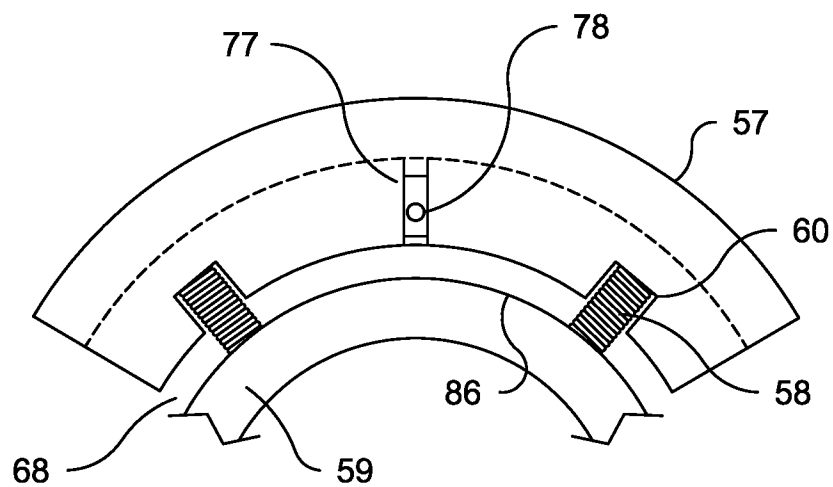


Fig. 16b

16/17

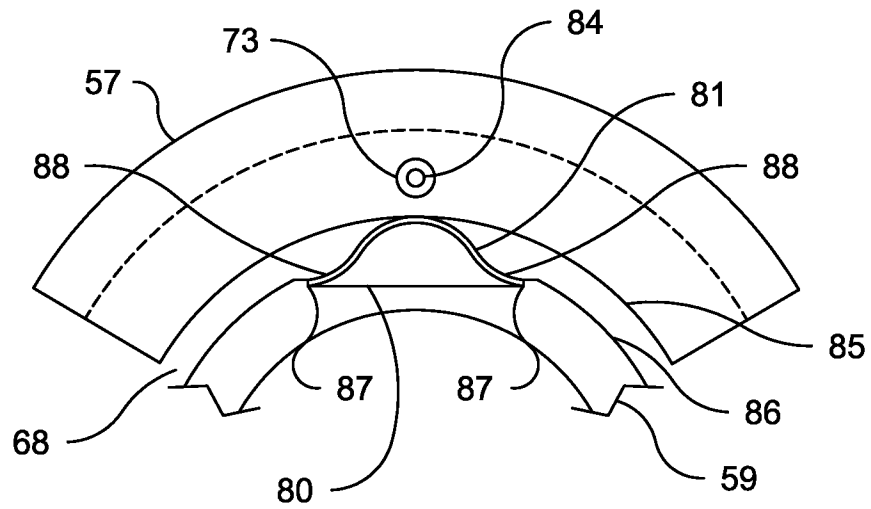


Fig. 17a

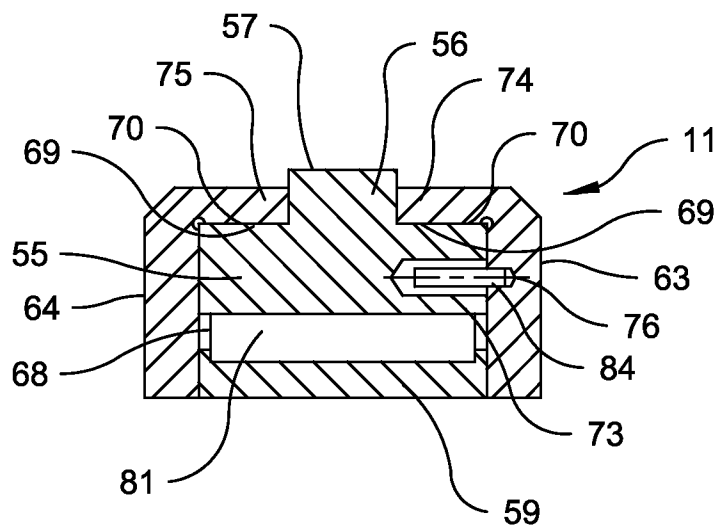


Fig. 17b

17/17

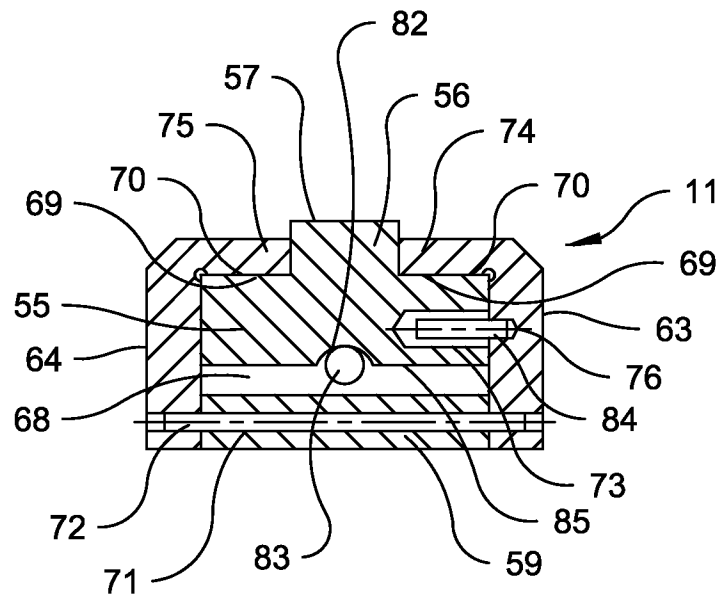


Fig. 18

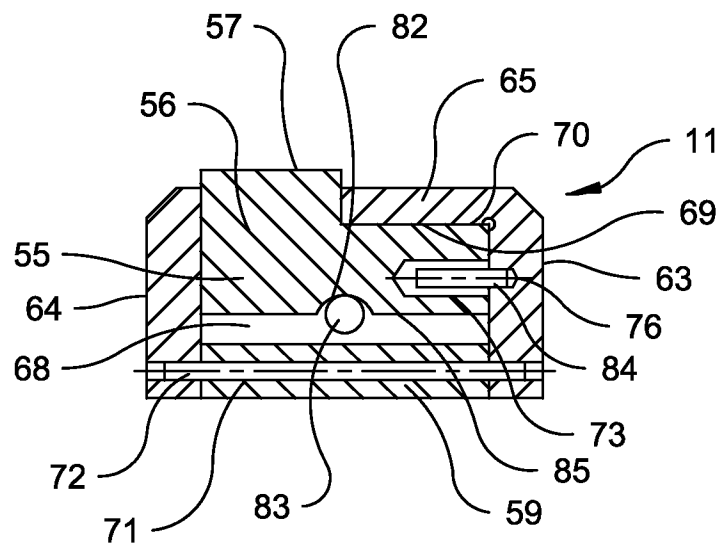


Fig. 19

A. CLASSIFICATION OF SUBJECT MATTER***F16J 15/24(2006.01)i, F16J 15/34(2006.01)i***

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)

IPC: F16J 15/24; F16J 15/447; F01D 11/02; F01D 11/00; F16J 15/44

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: intershaft, segmented, seal, biasing and spacer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0066027 A1 (VASAGAR, THURAI MANIK) 18 March 2010 See abstract; paragraphs 26-27, 45-46, 69; claim 1 and figures 2-9a.	1-20
Y	US 7344357 B2 (COUTURE, Jr. et al.) 18 March 2008 See abstract; column 4, lines 7-16; column 6, lines 1-11 and figure 4.	1-20
A	EP 0382333 A1 (NORTHERN ENGINEERING INDUSTRIES PLC) 16 August 1990 See abstract; claim 1 and figures 1-5.	1-20
A	US 7726940 B2 (SNOWSILL, GUY DAVID) 01 June 2010 See abstract; column 2, lines 36-44; claim 1 and figure 2.	1-20
A	US 2002-0140176 A1 (TONG, WEI) 03 October 2002 See abstract; claim 1 and figures 5-8.	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 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

12 MARCH 2013 (12.03.2013)

Date of mailing of the international search report

13 MARCH 2013 (13.03.2013)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan
City, 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

AHN, Jae Yul

Telephone No. 82-42-481-8525



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/057699

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0066027 A1	18.03.2010	EP 2324209 A1 EP 2341218 A2 US 8205891 B2 WO 2010-030448 A1	25.05.2011 06.07.2011 26.06.2012 18.03.2010
US 7344357 B2	18.03.2008	CN 1924301 A EP 1760270 A2 EP 1760270 A3 JP 2007-071203 A KR 10-2007-0026217 A US 2007-0053772 A1	07.03.2007 07.03.2007 05.05.2010 22.03.2007 08.03.2007 08.03.2007
EP 0382333 A1	16.08.1990	CA 2007436 A1 DE 69002064 D1 DE 69002064 T2 EP 0382333 B1 JP 03-172502 A	09.07.1990 05.08.1993 23.12.1993 30.06.1993 25.07.1991
US 7726940 B2	01.06.2010	DE 602006013239 D1 EP 1760373 A2 EP 1760373 A3 EP 1760373 B1 GB 0517833 D0 US 2007-0052179 A1	12.05.2010 07.03.2007 27.02.2008 31.03.2010 12.10.2005 08.03.2007
US 2002-0140176 A1	03.10.2002	US 6431550 B1 US 6585270 B2	13.08.2002 01.07.2003