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- (71) **Applicant:** GGB, INC. [US/US]; 700 Mid-Atlantic Parkway, Thorofare, New Jersey 08086 (US).
- (72) **Inventors:** DEPRES, Bertrand; 14 Rue Du 8 Mai 1945, 95530 La Frette/Seine (FR). ISSAAD, Imad; 144 Rue La Fayette, 75010 Paris (FR). LEFEBVRE, Baptiste; 268 Chemin du Château, 74540 Gruffy (FR). PROVENCE, Marc; 3, Allée De Grange Morin, 74570 Groisy (FR).
- (74) **Agents:** BRAIRTON, Scott, A. et al.; Perkins Coie LLP, P.O. Box 1247, Seattle, Washington 98111-1247 (US).
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(54) **Title:** PLAIN BEARING SHELL WITH ANTI-ROTATION FEATURES

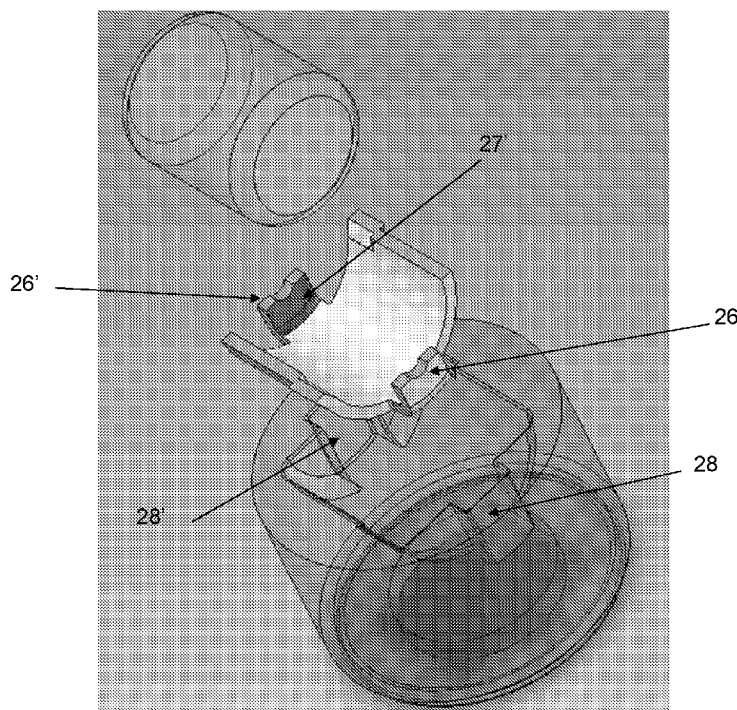


FIGURE 2c

(57) **Abstract:** Plain bearing shells including anti-rotations features are described. In some embodiments, a plain bearing shell having a semi-cylindrical shape includes a recess in each axial end of the shell. Protrusions included in the piston recess in which the plain bearing shell is disposed engage with the recesses and prevent rotation of the plain bearing shell. In some embodiments, a plain bearing shell having a semi-cylindrical shape includes a radially outwardly protruding tab at each circumferential end of the shell. A female imprint included in the piston recess in which the plain bearing shell is disposed receives the tabs, thereby preventing rotation of the plain bearing shell.

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GW, KM, ML, MR, NE, SN, TD, TG).

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

## PLAIN BEARING SHELL WITH ANTI-ROTATION FEATURES

## CROSS-REFERENCE TO RELATED APPLICATION(S)

**[0001]** This application claims priority to U.S. Provisional Patent Application No. 62/264,994, filed December 9, 2015, the entirety of which is hereby incorporated by reference.

## BACKGROUND

**[0002]** Plain bearing shells have previously been used as an interface layer between, for example, a piston and a roller or shaft disposed in the recess of a piston. Plain bearing shells can help to reduce friction between a rotating roller or shaft and the walls of the recess in the piston, as well as improve alignment of the roller or shaft within the recess. However, in some instances, the plain bearing shell begins to rotate as the roller or shaft rotates, thereby potentially causing friction and or alignment issues. Accordingly, a need exists for plain bearing shells that do not rotate when serving as an interface layer between pistons and rollers or shafts.

## SUMMARY

**[0003]** This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary, and the foregoing Background, is not intended to identify key aspects or essential aspects of the claimed subject matter. Moreover, this Summary is not intended for use as an aid in determining the scope of the claimed subject matter.

**[0004]** In some embodiments, a plain bearing shell with anti-rotation features is described. The plain bearing shell can have a generally semi-cylindrical geometry. In some embodiments, a recess is formed at each axial end of the plain bearing shell. The piston recess in which the plain bearing shell is disposed may include protrusions sized and shaped to mate with the recess at the axial ends of the plain bearing shell to thereby prevent rotation of the plain bearing shell when the plain bearing shell is disposed in the piston recess. In some embodiments, the plain bearing shell further includes thrust bearings at the axial ends of the plain bearing shell. The thrust bearings extend radially inwardly and provide an interface between axial ends of the roller or shaft and the axial ends of the piston recess.

**[0005]** In some embodiments, a plain bearing shell has a generally semi-cylindrical geometry and further includes radially outwardly angled tabs formed in a portion of the circumferential ends of the plain bearing shell. The tabs provide an edge that is perpendicular to the axis of the plain bearing shell. The piston recess includes female imprints shaped and sized to receive the tabs and thereby prevent rotation of the plain bearing shell and assist with axial alignment of the plain bearing shell in the piston recess. The plain bearing shell can also include thrust bearing extending from the axial ends of the plain bearing shell to provide an interface between axial ends of the roller or shaft and the axial ends of the piston recess

**[0006]** These and other aspects of the plain bearing shell described herein will be apparent after consideration of the Detailed Description and Figures herein. It is to be understood, however, that the scope of the claimed subject matter shall be determined by the claims as issued and not by whether given subject matter addresses any or all issues noted in the Background or includes any features or aspects recited in this Summary.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** Non-limiting and non-exhaustive embodiments of the disclosed plain bearing shell, including the preferred embodiment, are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified.

**[0008]** Figures 1a-1e illustrate plain bearing shells with anti-rotation features according to various embodiments described herein;

**[0009]** Figures 2a-2e illustrate plain bearing shells with anti-rotation features according to various embodiments described herein;

**[0010]** Figures 3a and 3b illustrate plain bearing shells with anti-rotation features according to various embodiments described herein; and

**[0011]** Figure 4 illustrates plain bearing shells with anti-rotation features according to various embodiments described herein.

## DETAILED DESCRIPTION

**[0012]** Embodiments are described more fully below with reference to the accompanying figures, which form a part hereof and show, by way of illustration, specific exemplary embodiments. These embodiments are disclosed in sufficient detail to enable those skilled in the art to practice the invention. However, embodiments may be implemented in many different forms and should not be construed as being limited to the embodiments set forth herein. The following detailed description is, therefore, not to be taken in a limiting sense.

**[0013]** With reference to Figure 1a, a plain bearing shell 100 is generally adapted to reside within a recess of a piston 2. The piston 2 may be, for example, for use with a radial piston engine. A roller or a shaft 3 (shown in phantom) may then be housed within plain bearing shell 100.

**[0014]** With reference to Figure 1b, the plain bearing shell 100 has a generally semi-cylindrical geometry. The plain bearing shell 100 includes two opposing axial ends 10, 10', an external surface 11 that is shaped to fit the piston 2, and an internal surface 12 opposite the external surface 11. All or a portion of the internal surface 12 can be covered with, for example, an antifriction overlay/liner. The internal surface 12 is adapted to support a roller or shaft 3 and allow the latter to rotate in the plain bearing shell 100 with a reduced coefficient of friction. The plain bearing shell 100 is also provided with two opposing circumferential ends 13, 13'.

**[0015]** As shown in Figure 1b and as shown and referenced in Figure 1c, the two axial ends 10, 10' of the plain bearing shell 100 can be under-cut to form an elongated semi-circular shaped recess 14. This recess 14 is configured to interact (e.g., mate) with a semi-circular concentric protrusion 16, 16' located at opposite ends of the recess formed in the piston 2, thereby preventing the rotation of the plain bearing shell 100 in either direction within the recess of piston 2 when a roller or shaft 3 is disposed in the piston 2 and rotating.

**[0016]** This anti-rotation function is assisted by the fact that the thickness of the plain bearing shell 100 (i.e., the distance between the internal surface 12 and the external surface 11) at point A is larger than its thickness at point B. If the plain bearing shell 100 is subjected to a rotating motion in the piston 2 via the rotation of the roller or shaft 3 in the piston 2, the axial ends 10, 10' (having an increased thickness at point A)

will come into contact with the protrusions 16, 16' of the piston 2 and thereby stop any rotation of the plain bearing shell 100.

**[0017]** In summary, the plain bearing shell 100 is prevented from rotating in the piston 2 by virtue of axial ends 10, 10' forming two semi-cylindrical recess 14 that interact with corresponding protrusions 16, 16' of the piston 2. This configuration helps to assure axial positioning of the plain bearing shell 100 in the piston 2, and helps to prevent axial movement of the plain bearing shell 100.

**[0018]** In some embodiments, the plain bearing shell 100 is sized so that there is no contact between the angled ends of the roller or the shaft and the load area of the plain bearing shell 1 in order to satisfy tribological principles.

**[0019]** In order to meet this requirement, the usable length ( $L_{\max}$ ) in the load area of the plain bearing shell is determined by the formula:

**[0020]** 
$$L_{\max} = L_g - (2 \times r_g)$$

**[0021]** wherein  $L_g$  is the total length of the roller or the shaft and  $r_g$  is the value of the radius of the curved portion of the roller or shaft that extends between the outer diameter of the roller or the shaft and its end faces (see, e.g.,  $r_g$  as illustrated in Figure 2d).  $L_{\max}$  is also illustrated in Figure 1d.

**[0022]** With reference to Figure 1e, in some embodiments the plain bearing shell 100 further includes two plain thrust bearings 14, 14' extending from the axial ends 10, 10' in a radially inward direction. The orientation of the thrust bearings 14, 14' can also be considered perpendicular to the axis of the plain bearing shell 100. The thrust bearings 14, 14' help to ensure an axial plain bearing thrust function for the roller or the shaft. This prevents an increase of the coefficient of friction resulting from contact between the roller/shaft ends and the axial walls of the recess in the piston. An antifriction overlay/liner present on some or all of the opposing side walls 15, 15' of the thrust bearings 14, 14' enables a low coefficient of friction between the plain bearing shell 1 and the roller or the shaft 3.

**[0023]** The shape and the section (width x height) of the thrust bearings 14, 14' can be defined by the factor **PV** (MPa x m/s) arising from the contact between the roller or shaft and the thrust bearings, wherein **P** (MPa) is the pressure of contact between

the opposing parts, and  $V$  (m/s) is the circumferential speed of the roller or shaft at the contact point.

**[0024]** As a reminder, the pressure of contact is the quotient of the axial load  $F$  (daN) delivered by the roller or the shaft on the thrust bearings and from the surface  $S$  (mm<sup>2</sup>) of each of the plain thrust bearing ( $P=F/S$ ).

**[0025]** Thus, according to the axial load applied by the roller or the shaft and its circumferential speed, the size of the thrust bearings 14, 14' will be determined in order that the factor PV will remain acceptable for the chosen plain bearing material. The width of the aforementioned thrust bearings 14, 14' must be less than the width of side slots 17, 17' formed in the axial ends of the recess of the piston 2 in order not to interfere with the bearing assembly and not to influence the anti-rotation function of the plain bearing.

**[0026]** As shown in Figure 1e, the protrusions 15, 15' may be configured to accommodate a plain bearing shell 100 having thrust bearings 14, 14'. Thus, in some embodiments, the protrusions 15, 15' will each include two separate protruding segments that engage with the recess 14 but which also permit the thrust bearings 14, 14' to be positioned between the two separate protruding segments of the protrusion 16, 16'.

**[0027]** With reference now to Figures 2a-2e, embodiments of an alternate plain bearing shell with anti-rotation features are shown.

**[0028]** With reference to Figure 2a, the plain bearing shell 200 has a generally semi-cylindrical geometry. The plain bearing shell 200 includes two opposing axial ends 20, 20', an external surface 21 shaped to fit with a piston, and an internal surface 22 opposite the external surface 21. The internal surface 22 may be fully or partially covered with an antifriction overlay/liner. The plain bearing shell 200 is also provided with two opposing circumferential ends 23, 23'.

**[0029]** In some embodiments the two circumferential ends 23, 23' include two semi-cut tabs 24, 24' issued from the face 22 and protruding radially outwardly. These tabs 24, 24' are accommodated in a female imprint of the piston 2, which thereby prevents plain bearing shell 200 from rotating when the roller or the shaft turns in one or the other direction.

**[0030]** With reference to Figure 2b, plain bearing shell 200 can be characterized by the fact that the two tabs 24, 24' form two parallel edges 25, 25' perpendicular to the axis of the roller or shaft and which fit against female imprint 20, 20' of the piston. This helps to assure that the axial positioning of the plain bearing shell 200 within the piston and prevents axial movement of the plain bearing shell 200.

**[0031]** With reference to Figure 2c, the plain bearing shell 200 can further include two plain thrust bearings 26, 26' issued from ends 20, 20'. The thrust bearings 26, 26' can be oriented perpendicular to the axis of the plain bearing shell 200 in order to assure an axial plain bearing thrust function for the roller or the shaft, preventing an increase of the coefficient of friction with a direct contact of roller/shaft ends to piston faces, and to allow a low coefficient of friction of the roller/shaft thanks the two plain thrust bearing faces 27, 27'.

**[0032]** The shape and the section (width x height) of the thrust bearings 26, 26' can be defined by the factor **PV** (MPa x m/s) arising from the contact between the roller or shaft and the thrust bearings, wherein **P** (MPa) is the pressure of contact between the opposing parts, and **V** (m/s) is the circumferential speed of the roller or shaft at the contact point.

**[0033]** As a reminder, the pressure of contact is the quotient of the axial load **F** (daN) delivered by the roller or the shaft on the thrust bearings and from the surface **S** (mm<sup>2</sup>) of each of the plain thrust bearings ( $P=F/S$ ).

**[0034]** Thus, according to the axial load applied by the roller or the shaft and its circumferential speed, the size of the thrust bearings will be determined in order that the factor **PV** will remain acceptable for the chosen plain bearing material. The width of the aforementioned thrust bearings must be less than the width of the side slots of the piston 28, 28' in order not to interfere with the bearing assembly and not to influence the anti-rotation function of the plain bearing.

**[0035]** With reference to Figure 2d, the plain bearing shell 200 can be sized so that there is no contact between the angled ends of the roller or the shaft and the load area of the plain bearing shell 200 in order to satisfy tribological principles.

**[0036]** The usable length in the load area is determined by the formula:

**[0037]** 
$$L_{\max} = L_g - (2 \times r_g)$$

**[0038]** wherein  $L_g$  is total length of the roller or the shaft and  $r_g$  is the value of the radius of the curved portion of the roller or shaft that extends between the outer diameter of the roller or the shaft and its end faces.  $L_{max}$  is also illustrated in Figure 2d.

**[0039]** With reference to Figure 2e, in some embodiments the two plain thrust bearings 26, 26' can be linked to the ends 20, 20' of the plain bearing shell 100 by ties 28, 28'. These ties 28, 28' may be tilted at an angle, such as in a radially outward direction. In some embodiments, the ties are angled outwardly such that the plain thrust bearings 26, 26' extend beyond the circumference of the plain bearing shell 200. This can help to ensure no contact between the roller or the shaft in this area and thus satisfy the tribological principles described above.

**[0040]** With reference to Figures 3a and 3b, in some embodiments, a semi-cylindrical plain bearing shell 300 is secured to the piston 2 via welded spots or beads 37, 37' to thereby prevent rotation of the plain bearing shell. As shown in Figure 3a, the welded spots 37, 37' may be located between the piston 2 and the portion of external surface 32 proximate the circumferential ends 33, 33'. As shown in Figure 3b, the welded spots 37, 37' may be located in the countersunk areas of the piston recess.

**[0041]** The configurations shown in Figures 3a and 3b are in some respects less desirable and then other previously described embodiments, since they include anti-rotation features that will still prevent rotation even when welding spots or beads break down.

**[0042]** With reference to Figure 4, a plain bearing shell 400 is described wherein the plain bearing shell 400 extends more than 180 degrees in the circumferential direction. This plain bearing shell 400 may also be described as having a distance between circumferential ends 43, 43' that is less than the diameter of the roller or shaft 3 disposed therein. In such configurations, the roller or shaft is disposed in the plain bearing shell by sliding the roller or shaft in from either axial end of the plain bearing shell. The sub assembly of the plain bearing shell and the roller or shaft is then disposed in the piston recess. In some embodiments, the sub-assembly is spot welded to the piston in order to prevent rotation of the plain bearing shell. Once constructed in this manner, the full assembly provides the benefit of being made from three indissociable components.

**[0043]** From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

## CLAIMS

I/We claim:

1. A plain bearing shell and piston system comprising:

a semi-cylindrical shell having a first axial end and a second axial end opposite the first axial end; and

an elongated semi-circular recess formed in the first axial end and the second axial end.

2. The system of claim 1, further comprising:

a cylindrical piston;

a semi-cylindrical recess formed in an axial end of the cylindrical piston, the recess being sized and shaped to receive the semi-circular shell therein; and

a protrusion extending into the semi-cylindrical recess from each axial side wall of the semi-cylindrical recess, each protrusion being shaped and sized to mate with one of the elongated semi-circular recesses formed in the axial ends of the semi-cylindrical shell.

3. The system of claim 1, wherein the thickness of the semi-cylindrical shell is greater proximate the elongated semi-circular recesses than proximate circumferential ends of the semi-cylindrical shell.

4. The system of claim 1, further comprising:

a roller disposed in the semi-circular shell, wherein the roller has a length  $L_g$  and curved axial ends, each curved axial end having a radius  $r_g$ ;

wherein the length  $L_{max}$  of the semi-circular shell between the recess formed in first axial end and the second axial end is determined by the equation:

$$L_{max} = L_g - (2 \times r_g).$$

5. The system of claim 1, wherein an antifriction overlay or liner is disposed on at least a portion of an internal surface of the semi-cylindrical shell.

6. The system of claim 1, wherein the semi-cylindrical shell further comprises:

a thrust bearing positioned within each elongated semi-circular recess, the thrust bearing extending in a radially inwardly direction.

7. The system of claim 6, further comprising:

a cylindrical piston;

a semi-cylindrical recess formed in an axial end of the cylindrical piston, the recess being sized and shaped to receive the semi-cylindrical shell therein; and

a set of protrusions extending into the semi-cylindrical recess from each axial side wall of the semi-cylindrical recess, each set of protrusions being shaped and sized to mate with one of the elongated semi-circular recesses formed in the axial ends of the semi-cylindrical shell and receive a thrust bearing between the set of protrusions.

8. A plain bearing shell and piston system comprising:

a semi-cylindrical shell comprising:

a first axial end and a second axial end opposite the first axial end; and

a first circumferential end and a second circumferential end opposite the first circumferential end;

a first tab located at the first circumferential end and a second tab located at the second circumferential end, wherein the first tab and the second tab are angled in a radially outwardly direction.

9. The system of claim 8, further comprising:

a cylindrical piston; and

a semi-cylindrical recess formed in an axial end of the cylindrical piston, the recess being sized and shaped to receive the semi-cylindrical shell therein;

wherein the recess includes a first and second female imprint sized and shaped to receive the first and second tabs, respectively.

10. The system of claim 8, further comprising:

a roller disposed in the semi-circular shell, wherein the roller has a length  $L_g$  and curved axial ends, each curved axial end having a radius  $r_g$ ;

wherein the length  $L_{max}$  of the semi-circular shell is determined by the equation:

$$L_{max} = L_g - (2 \times r_g).$$

11. The system of claim 8, wherein an antifriction overlay or liner is disposed on at least a portion of an internal surface of the semi-cylindrical shell.

12. The system of claim 1, wherein the semi-cylindrical shell further comprises:

a thrust bearing extending from each axial end of the semi-cylindrical shell, each thrust bearing comprising a first segment oriented in a generally axial direction and a second segment extending in a radially inwardly direction.

13. The system of claim 12, wherein the first segment is angled to extend beyond an outer diameter of the semi-cylindrical shell.

14. The system of claim 12, further comprising:

a cylindrical piston; and

a semi-cylindrical recess formed in an axial end of the cylindrical piston, the recess being sized and shaped to receive the semi-cylindrical shell therein; and

wherein the recess includes:

a first and second female imprint sized and shaped to receive the first and second tabs, respectively; and

a first and second slot formed in the axial end side walls of the semi-cylindrical recess, the first and second slots being sized and shaped to receive one of the thrust bearings.

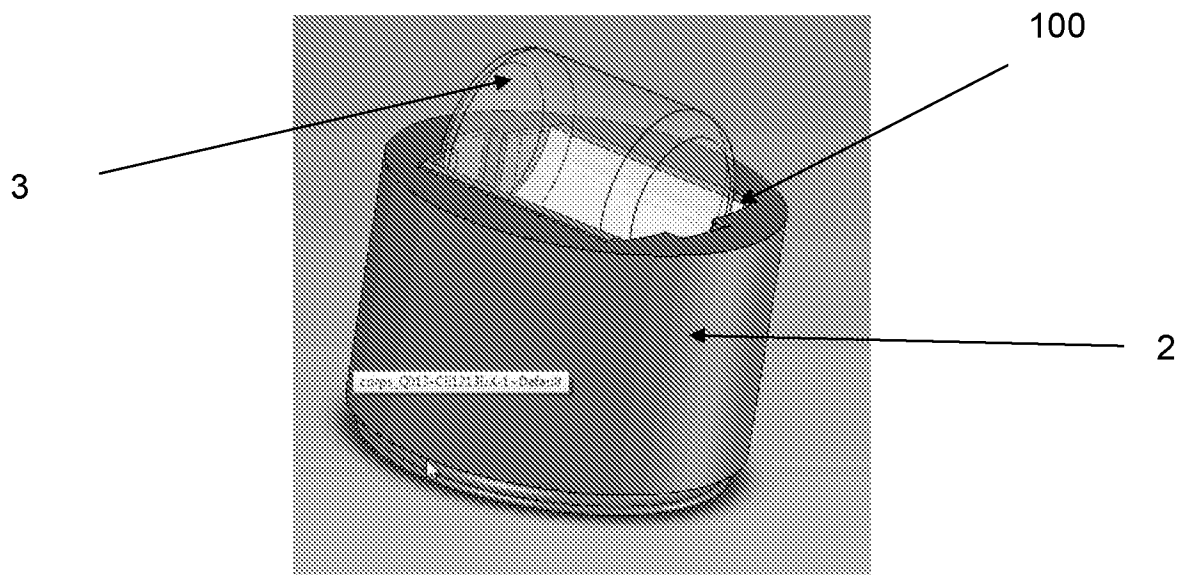


FIGURE 1a

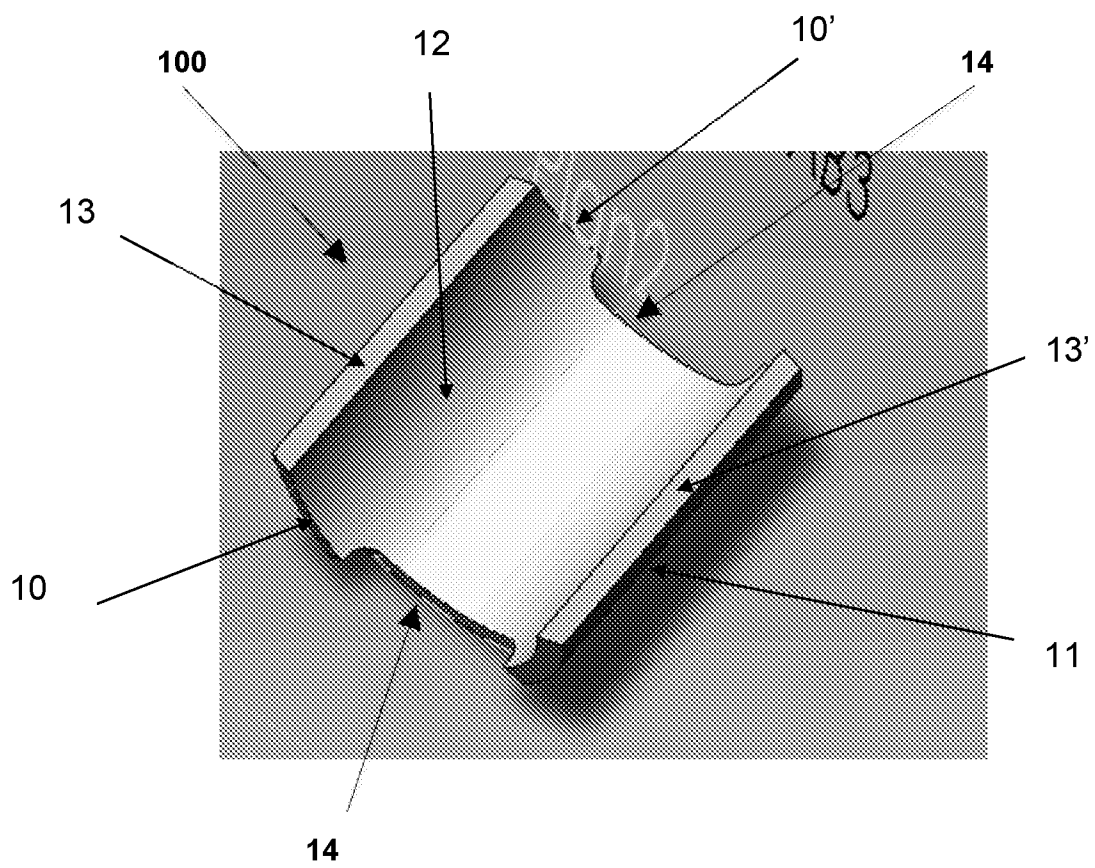


FIGURE 1b

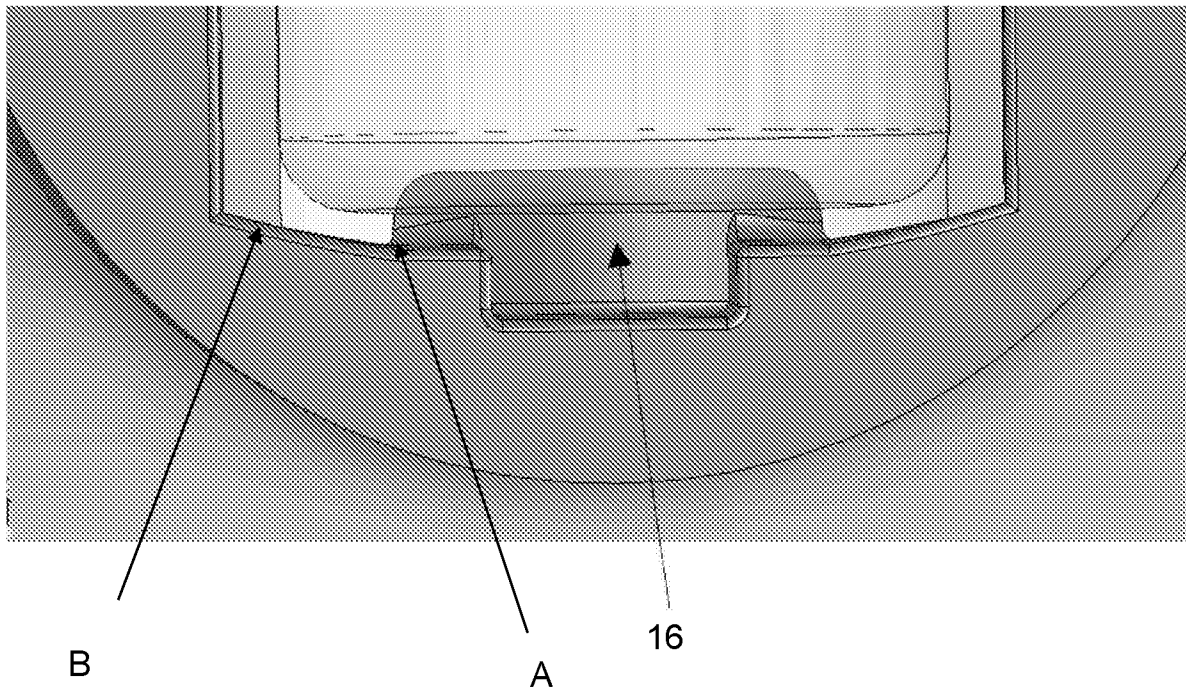


FIGURE 1c

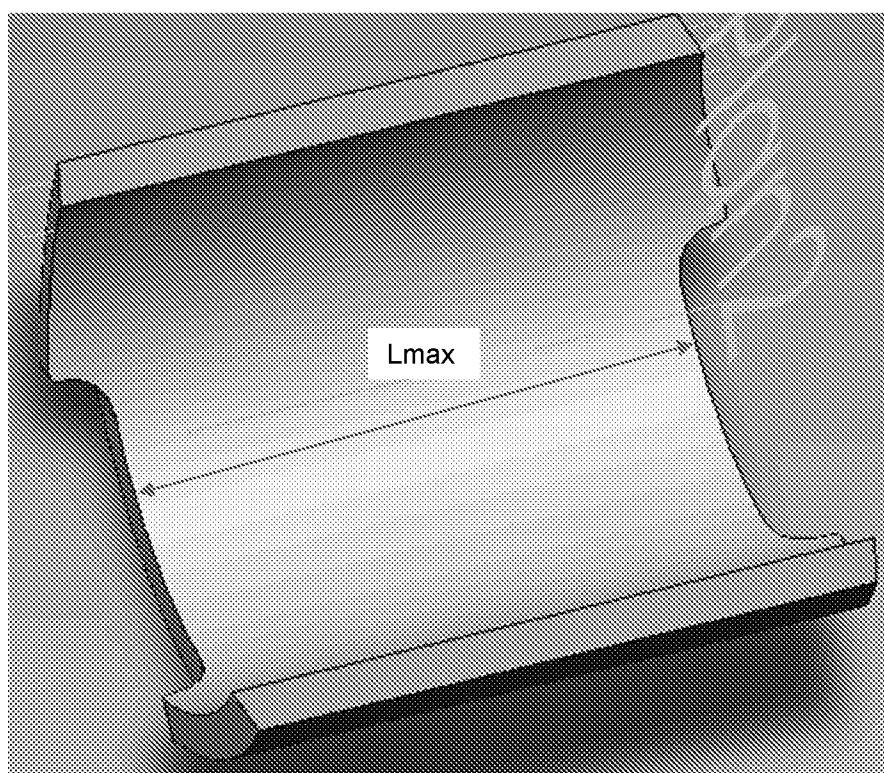


FIGURE 1d

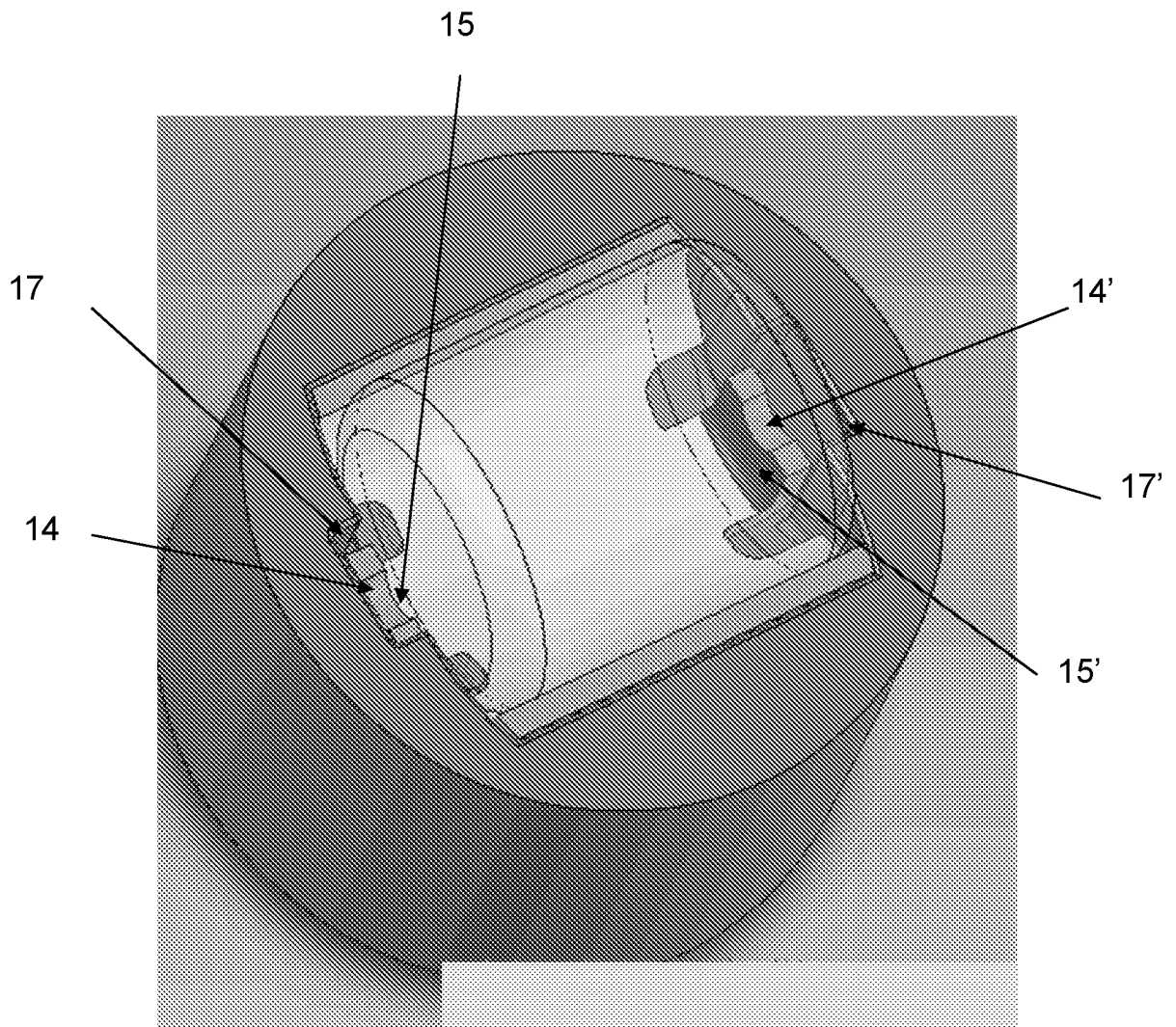
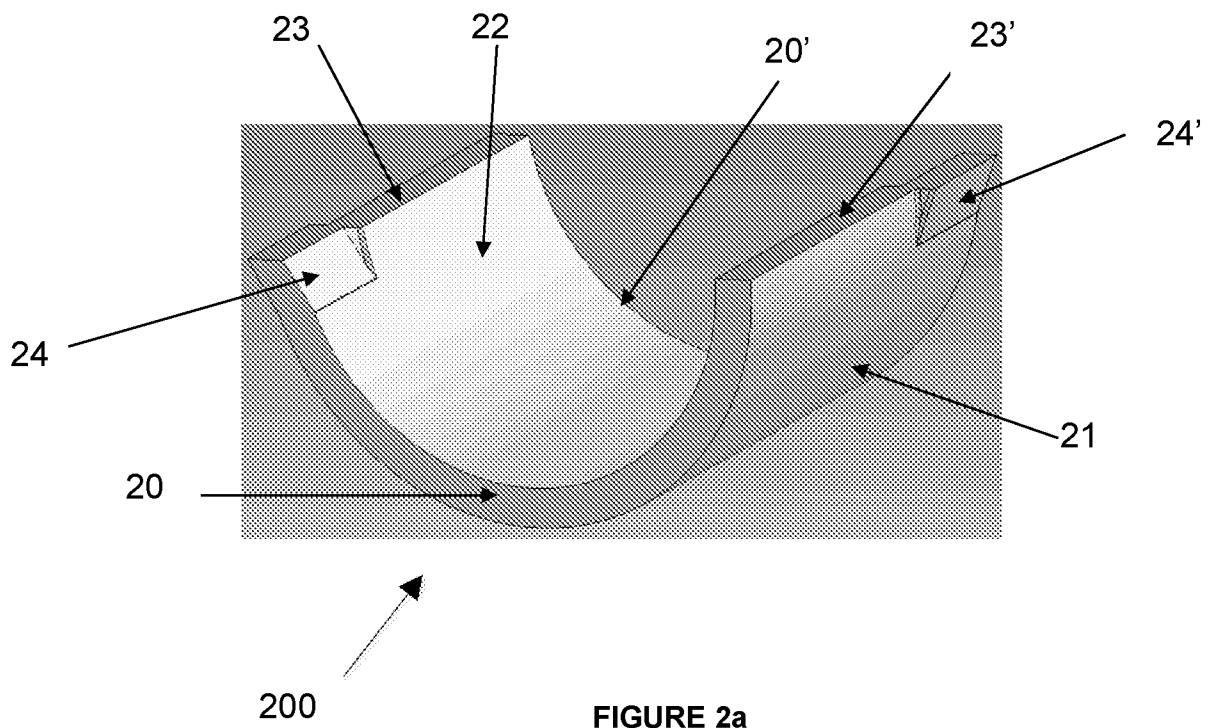


FIGURE 1e



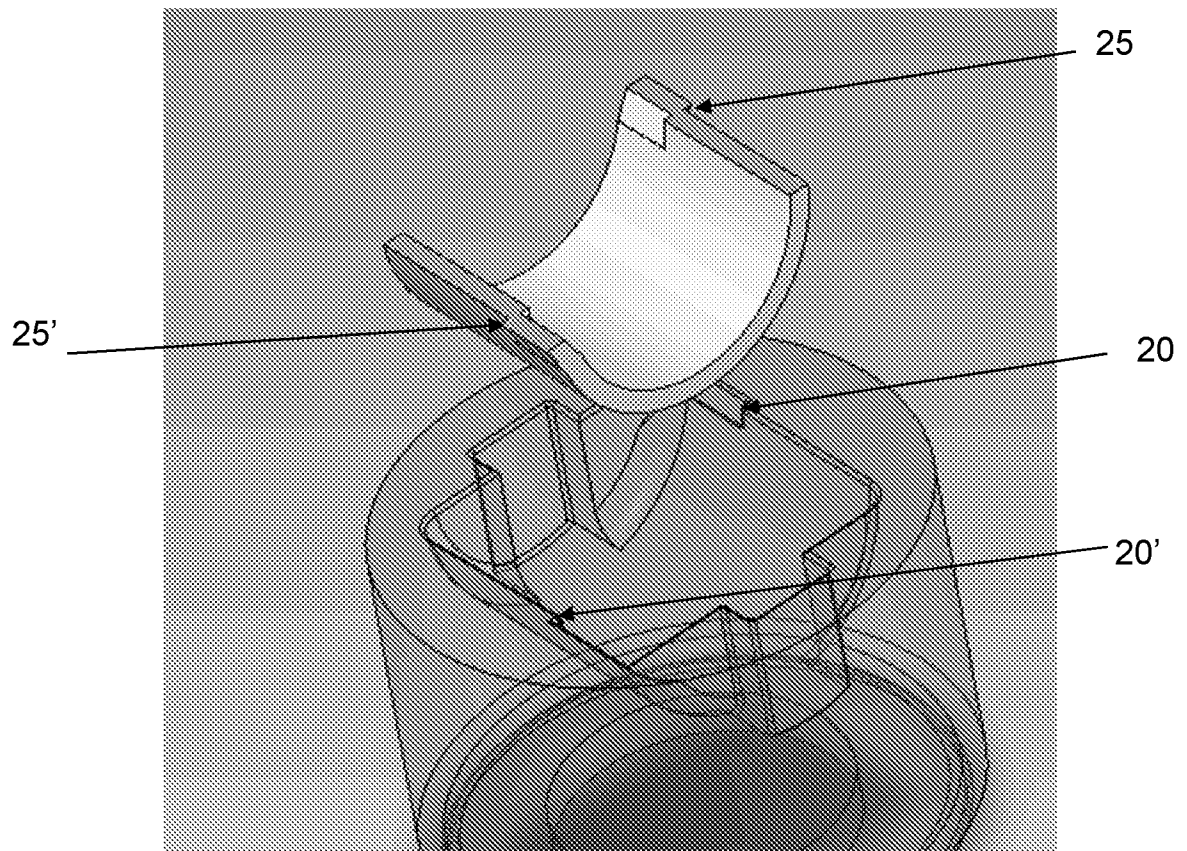


FIGURE 2b

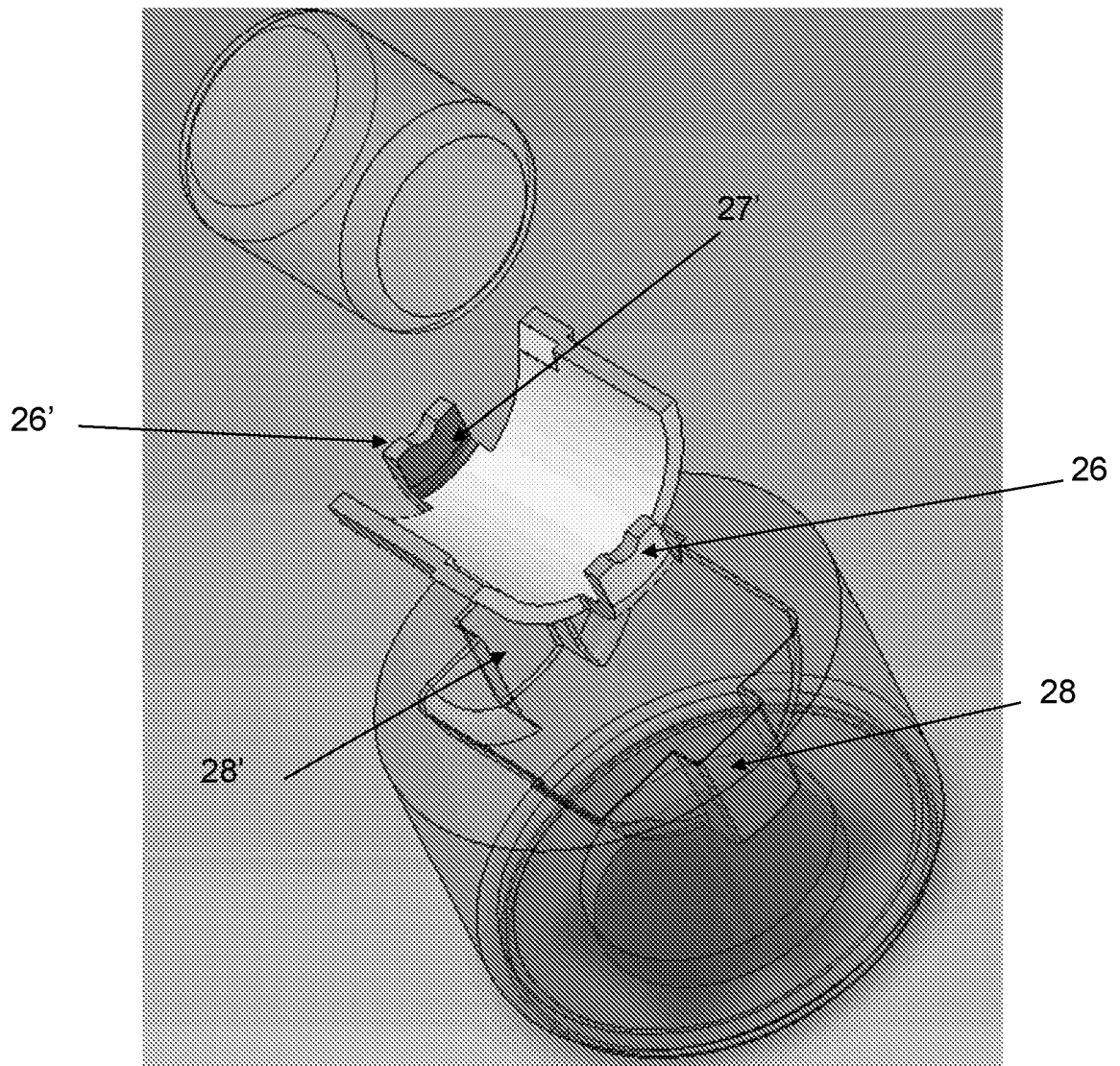


FIGURE 2c

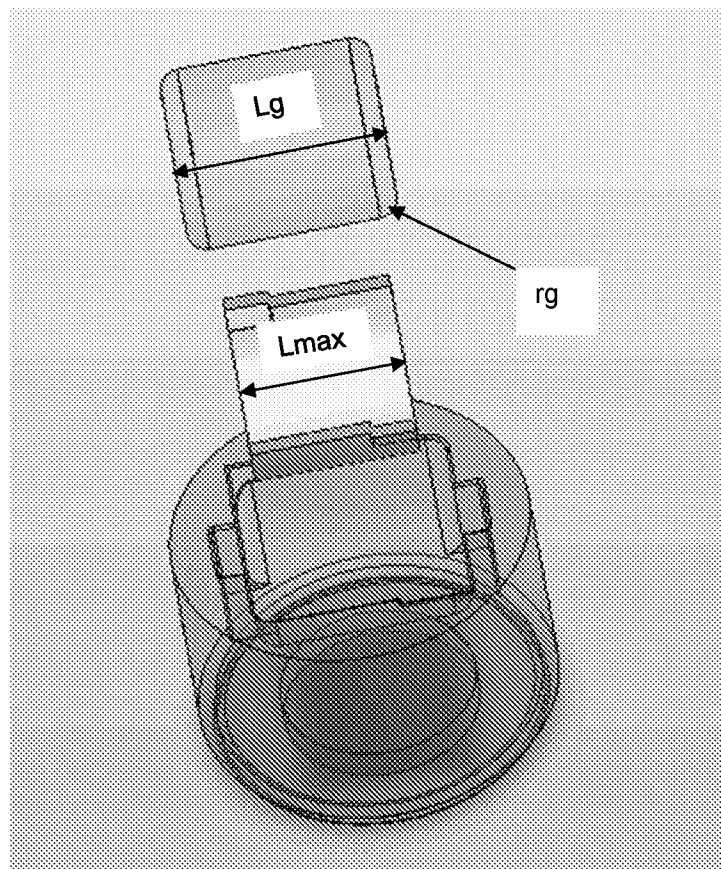


FIGURE 2d

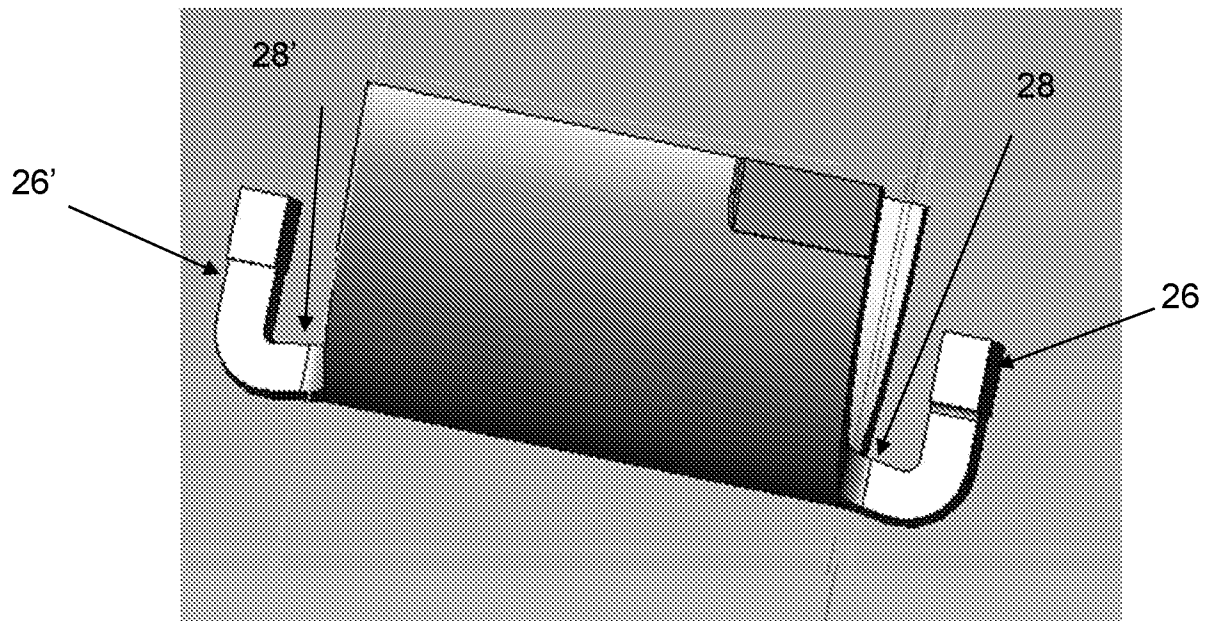


FIGURE 2e

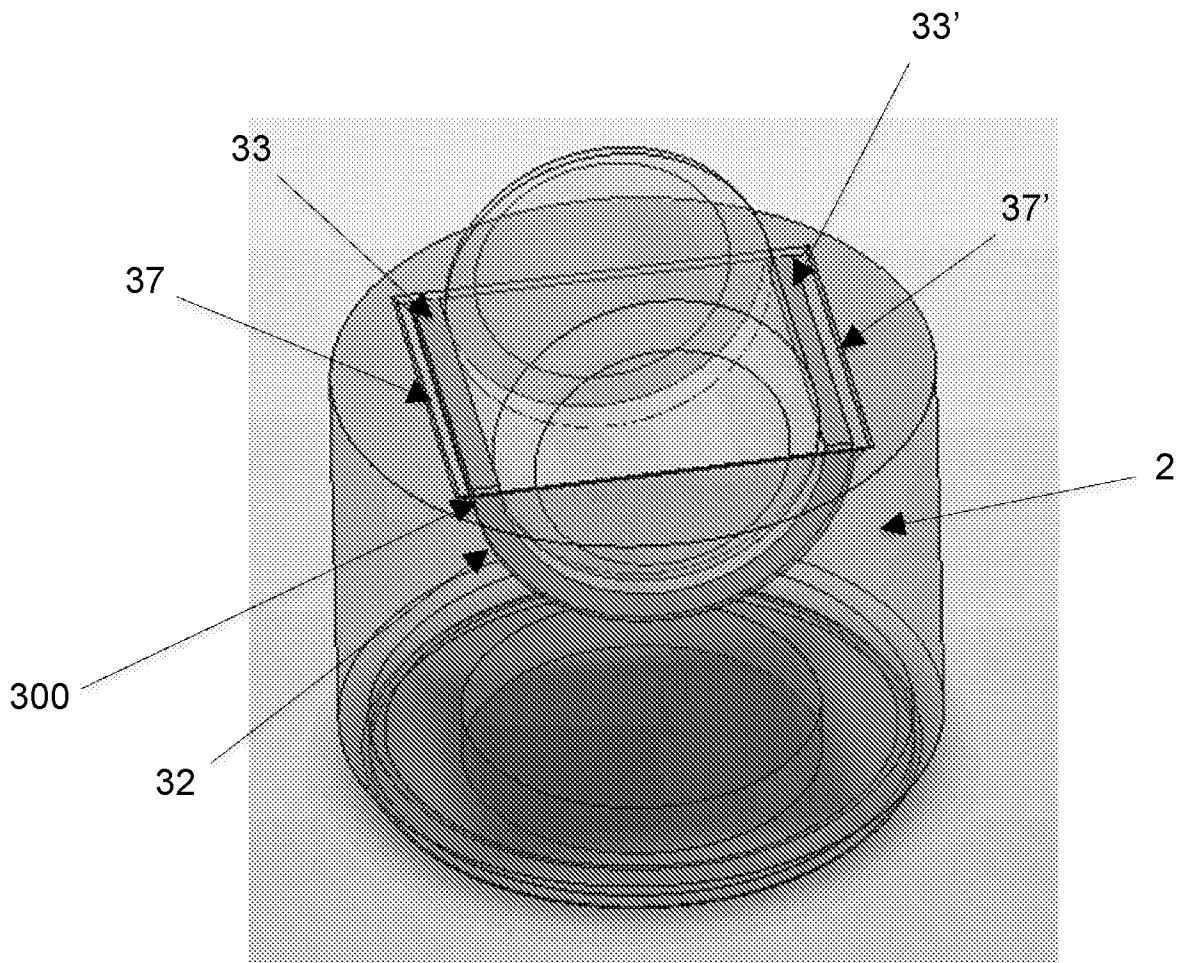


FIGURE 3a

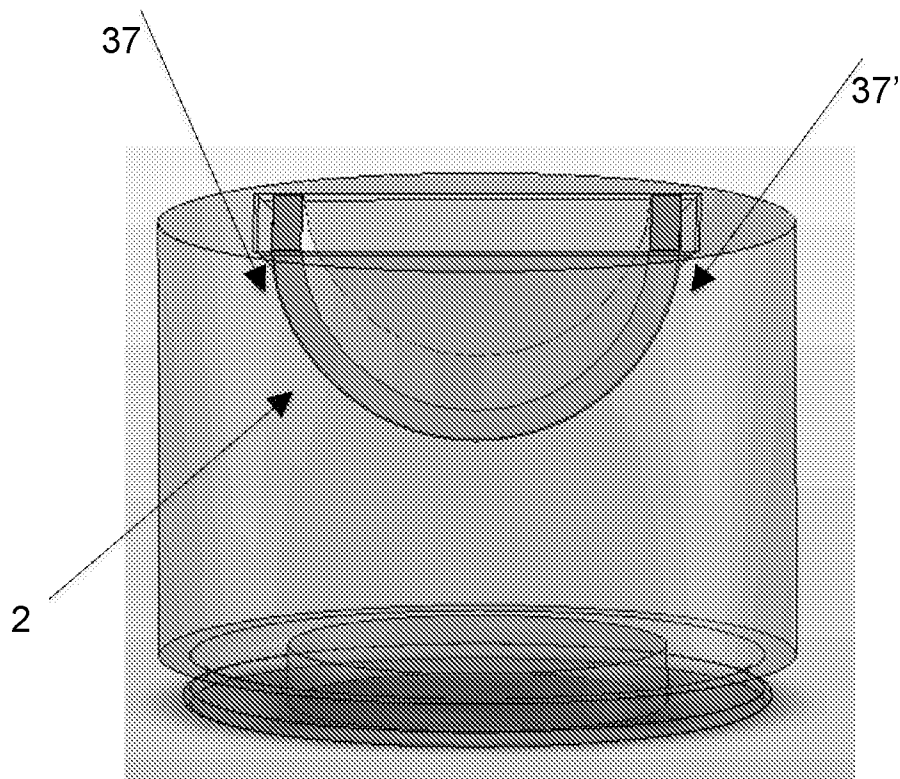


FIGURE 3b

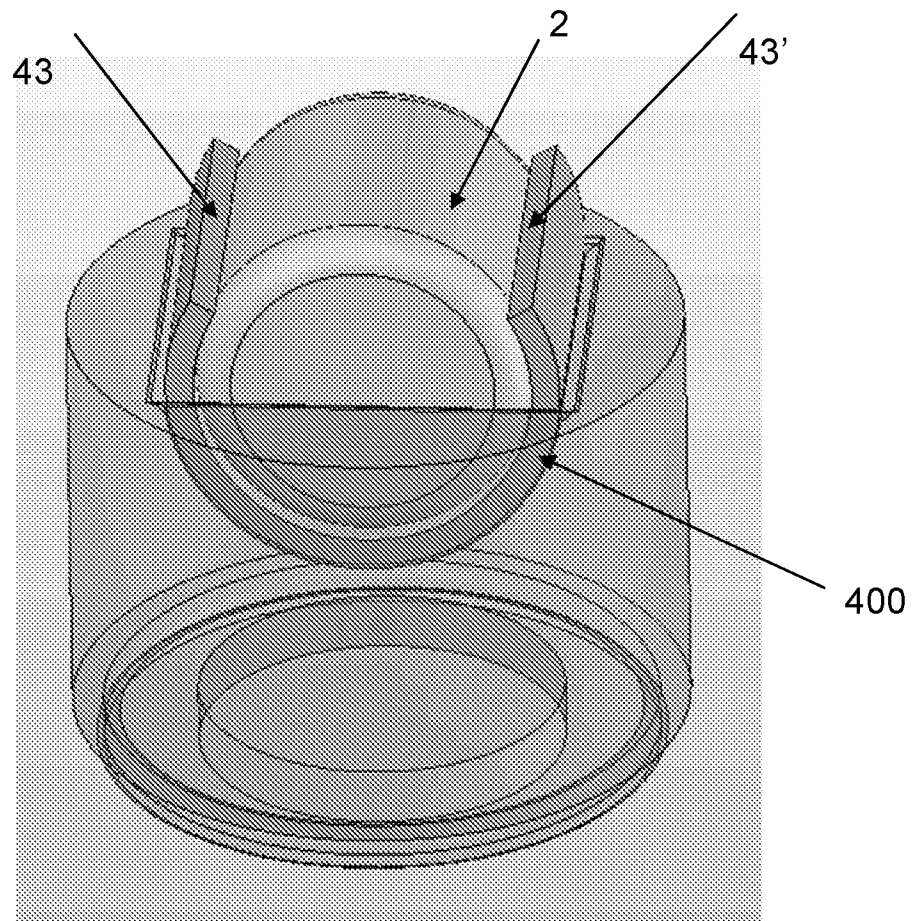


FIGURE 4

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2016/065803**

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| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| <b>F03C 1/04 (2006.01) F16C 17/02 (2006.01) F16C 33/04 (2006.01) F04B 1/04 (2006.01)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| Minimum documentation searched (classification system followed by classification symbols)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| 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)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
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| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Relevant to claim No. |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Documents are listed in the continuation of Box C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                       |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"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)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"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<br>"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<br>"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<br>"&" document member of the same patent family |                       |
| Date of the actual completion of the international search<br>24 January 2017                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Date of mailing of the international search report<br>24 January 2017                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                       |
| Name and mailing address of the ISA/AU<br><br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>Email address: pct@ipaustalia.gov.au                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Authorised officer<br><br>Andrew Spain<br>AUSTRALIAN PATENT OFFICE<br>(ISO 9001 Quality Certified Service)<br>Telephone No. 0262832923                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                       |

| INTERNATIONAL SEARCH REPORT                           |                                                                                              | International application No. |
|-------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------------------|
| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                              | PCT/US2016/065803             |
| Category*                                             | Citation of document, with indication, where appropriate, of the relevant passages           | Relevant to claim No.         |
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| A                                                     | US 2012/0027328 A1 (INAGAKI et al.) 02 February 2012<br>Figure 5                             | 8-11                          |
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|                                                       |                                                                                              |                               |

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:  
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

**See Supplemental Box for Details**

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**Supplemental Box****Continuation of: Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- **Claims 1-7** are directed to, inter alia, a plain bearing shell and piston system comprising: a semi-cylindrical shell having a first axial end and a second axial end opposite the first axial end; and an elongated semi-circular recess formed in the first axial end and the second axial end. The feature of the shell comprising an elongate semi-circular recess in the first and second axial ends is specific to this group of claims.
- **Claims 8-14** are directed to, inter alia, a plain bearing shell and piston system comprising: a semi-cylindrical shell comprising: a first axial end and a second axial end opposite the first axial end; and a first circumferential end and a second circumferential end opposite the first circumferential end; a first tab located at the first circumferential end and a second tab located at the second circumferential end, wherein the first tab and the second tab are angled in a radially outwardly direction. The feature of a first tab located at the first circumferential end and a second tab located at the second circumferential end, wherein the first tab and the second tab are angled in a radially outwardly direction is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is a plain bearing shell and piston system comprising a semi-cylindrical shell having a first axial end and a second axial end opposite the first axial end. However this feature does not make a contribution over the prior art because it is disclosed in:

This is disclosed in: WO 2015/128362 A1 (KS GLEITLAGER GMBH) 3 September 2015

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

| INTERNATIONAL SEARCH REPORT                                                                                                                                                                                                                                           |                   | International application No. |                  |
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| Information on patent family members                                                                                                                                                                                                                                  |                   | PCT/US2016/065803             |                  |
| This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information. |                   |                               |                  |
| Patent Document/s Cited in Search Report                                                                                                                                                                                                                              |                   | Patent Family Member/s        |                  |
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Form PCT/ISA/210 (Family Annex)(July 2009)

| INTERNATIONAL SEARCH REPORT                                                                                                                                                                                                                                           |                  | International application No. |                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------------------------|------------------|
| Information on patent family members                                                                                                                                                                                                                                  |                  | PCT/US2016/065803             |                  |
| This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information. |                  |                               |                  |
| Patent Document/s Cited in Search Report                                                                                                                                                                                                                              |                  | Patent Family Member/s        |                  |
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| End of Annex                                                                                                                                                                                                                                                          |                  |                               |                  |
| Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.<br>Form PCT/ISA/210 (Family Annex)(July 2009)                                                                                               |                  |                               |                  |