



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
31.05.2017 Bulletin 2017/22

(51) Int Cl.:
F02M 55/04 (2006.01) **F02M 59/44** (2006.01)
F04B 39/00 (2006.01) **F02M 59/10** (2006.01)

(21) Application number: **16200359.4**

(22) Date of filing: **23.11.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **24.11.2015 GB 201520677**

(54) **HIGH PRESSURE FUEL PUMP**

(57) The invention comprises a high pressure diesel fuel pump (20) comprising a pumping assembly (30) and a drivetrain assembly (40). The pumping assembly (30) comprises a plunger (32) extending from a pump head (34) along a pumping axis (A-A'). The drivetrain assembly (40) comprises a drive shaft (42) and a cam (44) mounted thereon within a cambox (46) of a housing (48), a plunger-driving assembly (50) for contact with a lower end

(32a) of the plunger (32) and mounted substantially between said plunger (32) and the cam (44). The plunger (32) is arranged for reciprocating linear movement along the pumping axis (A-A') within a pumping chamber (36) of the housing (48) upon rotation of the cam (44). The pumping chamber (36) comprises a pressure regulating member (60, 80) adapted to adjust its volume in response to changes in pressure in the cambox (46).

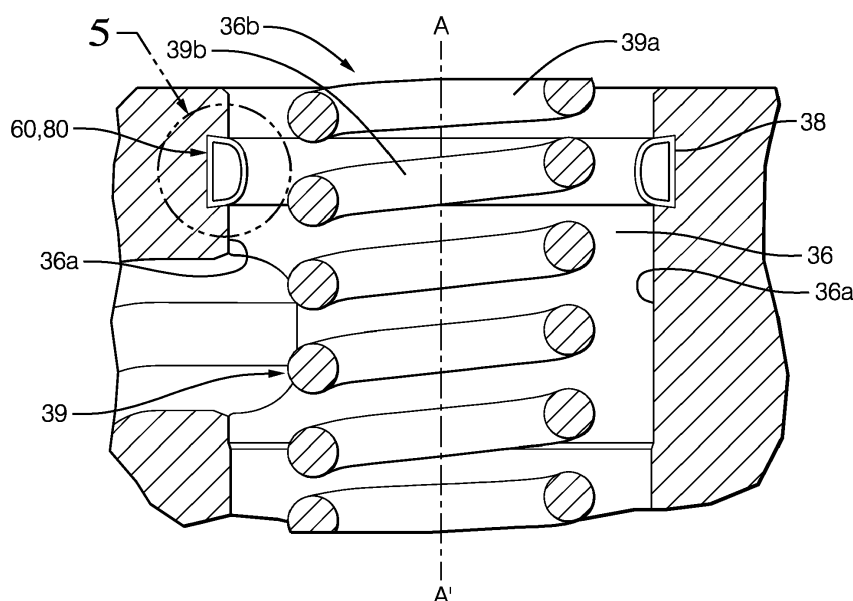


FIG. 3

Description**BACKGROUND****Technical Field**

[0001] The present invention relates generally to the field of high pressure fuel pumps. More particularly, but not exclusively, the present invention concerns a pressure regulation arrangement for high pressure diesel fuel pumps.

Description of the Related Art

[0002] As shown in Figure 1, a typical high pressure diesel fuel pump 1 comprises a plunger 2 extending from a hydraulic head 5 along a pumping axis A-A'. A plunger return spring 3 is seated around the head 5 and extends to the top of a spring seat 4 fixed near a lower end 2a of the plunger 2. The lower end 2a of the plunger 2 contacts a plunger-driving configuration, which may comprise a roller-shoe assembly 6. The roller-shoe assembly 6 is driven in a reciprocating path along the pumping axis A-A' by the rotation of a cam 8 on a driveshaft 9. The reciprocation of the roller-shoe assembly 6, in turn drives the plunger 2 along the pumping axis A-A'.

[0003] During rotation of the cam 8 and as the roller-shoe assembly 6 and plunger 2 reciprocate, pressure fluctuations are observed in the cambox 10. In particular, pressure spikes (short periods of high pressure) can have detrimental effects on pump 1 and upstream engine components.

[0004] It is an object of the present invention to address one or more of the problems of known designs, particularly, but not exclusively high pressure pumps.

[0005] Therefore, it is now desired to provide an improved arrangement for a high pressure diesel fuel pump to minimise the effects of such pressure spikes. More particularly, it is desired to provide an improved drivetrain assembly and a pressure regulating arrangement for high pressure diesel fuel pumps.

SUMMARY OF THE INVENTION

[0006] In a first aspect of the present invention there is provided a high pressure diesel fuel pump comprising a pumping assembly and a drivetrain assembly, the pumping assembly comprising a plunger extending from a pump head along a pumping axis, the drivetrain assembly comprising a drive shaft and a cam mounted thereon within a cambox of a housing, a plunger-driving assembly for contact with a lower end of the plunger and mounted substantially between said plunger and the cam, wherein the plunger is arranged for reciprocating linear movement along the pumping axis within a pumping chamber of the housing upon rotation of the cam, characterised in that the pumping chamber comprises a pressure regulating member adapted to adjust its volume in response to changes in pressure in the cambox.

[0007] With this arrangement, pressure fluctuations in the cambox can be lessened by the pressure regulating member, which is adapted to reduce its volume as the pressure in the cambox rises, which has the effect of increasing cambox volume and causing the cambox pressure to fall. The pressure regulating member is also adapted to increase its volume as the pressure in the cambox falls, which has the opposite effect of decreasing cambox volume and causing the cambox pressure to rise. Accordingly, pressure spikes, as well as pressure depressions, are balanced out.

[0008] Preferably, the pressure regulating member comprises a volume adjustment means. Preferably, the volume adjustment means comprises a flexible component. Preferably, the flexible component comprises a flexible membrane. Preferably, the flexible component comprises a hollow formed shape having a maximum internal volume.

[0009] Preferably, the flexible component comprises a maximum internal volume adapted to decrease by at least 0.2 cc³ (when subjected to 4 Bar pressure), more preferably, by at least approximately 0.22 cc³, most preferably, by at least approximately 0.677 cc³.

[0010] Preferably, the hollow formed shape of the flexible component is adapted to at least partially deform as pressure rises in the cambox, thereby decreasing an internal volume of the pressure regulating member. Preferably, the flexible component is adapted to adopt a concave configuration.

[0011] Preferably, the hollow formed shape of the flexible component is configured to at least partially reform as pressure falls in the cambox, thereby increasing an internal volume of the pressure regulating member. Preferably, the flexible component is adapted to reform to adopt a convex configuration.

Preferably, the flexible membrane comprises a shear modulus of between approximately 9 MPa and approximately 46 MPa (when using the Yeoh hyperelastic model), more preferably between approximately 12 MPa and approximately 40 MPa, most preferably approximately 13 MPa.

[0012] Preferably, the pressure regulating member comprises an anchor component. Preferably, the anchor component comprises a dovetail-shaped annulus. Preferably, the anchor component comprises an outwardly-disposed curved wall. Preferably, the outwardly-disposed curved wall is substantially uncontoured, e.g. flat.

[0013] Preferably, the anchor component comprises a pair of short side walls connected to the flexible component to form a ring-shaped member. Preferably, at least one of said short side walls is inwardly-tapered. Preferably, both side walls are inwardly-tapered. Preferably, the inwardly-tapered side walls are integrally-formed with the flexible component. Preferably, the inwardly-tapered side walls are integrally-formed with the outwardly-disposed curved wall.

[0014] Preferably, the anchor component is resiliently flexible. Preferably, the anchor component is substantially hollow.

[0015] Preferably, the hollow formed shape of the flexible component comprises a substantially dome-shaped annulus. Preferably, the dome-shaped annulus is inwardly-disposed.

[0016] Preferably, the flexible component comprises a plurality of reinforcement ribs. Preferably, the reinforcement ribs are curved to adopt the hollow formed shape of the flexible component. Preferably, the reinforcement ribs are resiliently flexible. Preferably, the reinforcement ribs are disposed inside the hollow formed shape of the flexible component.

[0017] Preferably, at least the flexible membrane comprises a fluorocarbon rubber. Preferably, the flexible membrane comprises a thickness of up to approximately 0.5 mm, most preferably approximately 0.3 mm. Preferably, the flexible component comprises a fluorocarbon rubber.

[0018] Preferably, the anchor component comprises a fluorocarbon rubber.

[0019] Preferably, therefore, the hollow formed shape of the flexible component comprises an internal height of approximately 4 mm and an internal depth of approximately 2 mm.

[0020] Preferably, the pressure regulating member is disposed in a top half of the pumping chamber, more preferably in a top quarter of the pumping chamber. Most preferably, the pressure regulating member is disposed proximal to a top end of the pumping chamber.

[0021] Preferably, the pressure regulating member is arranged around a spring in the pumping chamber. The pressure regulating member may be arranged around the pump head in the pumping chamber. The pressure regulating member may be disposed proximal to a top end of the pumping chamber.

[0022] Preferably, the pressure regulating member is mounted within an internal wall of the pumping chamber. Preferably, the anchor component is mounted in an internal wall of the pumping chamber.

[0023] Preferably, therefore, the internal chamber wall comprises a retention means for the anchor component. Preferably, the retention means comprises an annular slot in said internal wall. Preferably, the slot comprises an interlocking arrangement with the anchor component. Most preferably, the slot comprises a dovetail-shape, e.g. having a narrow opening and tapering towards a wider back slot wall.

[0024] Preferably, the pump is a diesel pump.

[0025] In a second aspect of the present invention there is provided a drivetrain assembly for a high pressure fuel pump comprising a drive shaft and a cam mounted thereon within a cambox of a housing, a plunger-driving assembly for contact with a lower end of the plunger and mounted substantially between said plunger and the cam, characterised in that the drivetrain assembly further comprises a pressure regulating member adapted to adjust its volume in response to changes in pressure in the cambox.

[0026] It will be appreciated that the preferred features described in relation to the first aspect of the invention also apply to the second aspect of the invention.

[0027] In a third aspect of the present invention there is provided a pressure regulating member for a drivetrain assembly of a high pressure fuel pump comprising a volume adjustment means adapted to respond to changes in pressure.

[0028] It will be appreciated that the preferred features described in relation to the first aspect of the invention also apply to the third aspect of the invention.

[0029] In a fourth aspect of the present invention there is provided a high pressure diesel fuel pump comprising a pumping assembly and a drivetrain assembly, the pumping assembly comprising a plunger extending from a pump head along a pumping axis, the drivetrain assembly comprising a drive shaft and a cam mounted thereon within a cambox of a housing, a plunger-driving assembly for contact with a lower end of the plunger and mounted substantially between said plunger and the cam, wherein the plunger is arranged for reciprocating linear movement along the pumping axis within a pumping chamber of the housing upon rotation of the cam, characterised in that the pumping chamber comprises a retention means for a pressure regulating member.

[0030] It will be appreciated that the preferred features described in relation to the first aspect of the invention also apply to the fourth aspect of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] For a better understanding of the invention, and to show how exemplary embodiments may be carried into effect, reference will now be made to the accompanying drawings in which:

Figure 1 is a cross-sectional partial view of a **prior art** pumping assembly and drivetrain assembly of a high pressure diesel fuel pump;

Figure 2 is a cross-sectional partial view of a high pressure diesel fuel pump according to the invention;

Figure 3 is an exploded cross-sectional partial view of the high pressure fuel pump of Figure 2;

Figure 4 is a schematic perspective view of a first embodiment of a pressure regulating member for a drivetrain assembly of the high pressure fuel pump of Figure 2; and

Figure 5 is an exploded cross-sectional partial view of the pressure regulating member of Figure 3 within a pumping chamber;

Figure 6 is a schematic perspective view of a second embodiment of a pressure regulating member for a drivetrain assembly of the high pressure fuel pump of Figure 2.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0032] The invention is shown in Figures 2 to 5. A high pressure diesel fuel pump 20 comprises a pumping assembly 30 and a drivetrain assembly 40. The pumping assembly 30 comprises a plunger 32 extending from a pump head 34 along a pumping axis A-A'. The drivetrain assembly 40 comprises a drive shaft 42 and a cam 44 mounted thereon within a cambox 46 of a housing 48, a plunger-driving assembly 50 for contact with a lower end 32a of the plunger 32 and mounted substantially between said plunger 32 and the cam 44. The plunger 32 is arranged for reciprocating linear movement along the pumping axis A-A' within a pumping chamber 36 of the cambox 46 upon rotation of the cam 44, characterised in that the pumping chamber 36 comprises a pressure regulating member 60, 80 adapted to adjust its volume in response to changes in pressure in the cambox 46.

[0033] As shown more clearly in Figures 4 and 5, a first embodiment of the pressure regulating member 60 is substantially ring-shaped comprising an outer wall 62 and an inner dome 64. The outer wall 62 is substantially circular and planar and is outwardly-facing. The dome 64 comprises a relatively shallow convex curve and is inwardly-facing. It will be appreciated that the shape of the pressure regulating member 60 is primarily chosen for ease of machining, but may take on another suitable shape.

[0034] Connecting the outer wall 62 with the inner dome 64 is a tapered section 66. The tapered section 66 comprises a pair of short walls 66a, 66b protruding inwardly of the outer wall 62 to join ends 64a, 64b of the dome 64. The outer wall 62 and the tapered section 66 form a dovetail shape, which serves as an anchor component for mounting of the pressure regulating member 60 in an internal wall 36a of the pumping chamber 36 (as later described).

[0035] The outer wall 62, short walls 66a, 66b of the tapered section 66 and dome 64 form a substantially hollow body 61 with a maximum possible volume V1.

[0036] The outer wall 62, short walls 66a, 66b of the tapered section 66 and dome 64 each comprise a resiliently deflectable material, which in the described embodiment comprise thin walls of fluorocarbon rubber. However, it is to be appreciated that other suitable resiliently flexible materials demonstrating resilience in a diesel fuel environment may be utilised.

[0037] Under normal or low pressure conditions, the dome 64 is able to retain a convexly curved shape and a maximum volume V1. Under rising or high pressure conditions, at least the dome 64 is configured to allow deflection inwardly to adopt a flattened, or concavely curved shape as can be seen in Figures 7a - c, with a reduced volume V2, V3, V4.

[0038] The exact shape and minimum possible volume of the pressure regulating member 60 following the inward deflection, depends upon (a) the shear modulus of the material, namely the material composition, (b) wall thickness of the material used and (c) the presence of any additional resilient components (e.g. see Figure 6). However, it will be appreciated that the actual pressure in the pumping chamber 36 will impact on whether the pressure regulating member 60 reaches its minimum possible volume V2, V3, V4 at any one time.

[0039] In a specific embodiment, the outer diameter of the pressure regulating member 60 is approximately 32 mm. To achieve a maximum volume V1 of 0.677 cc³, the approximate geometry of a cross-section of the pressure-regulating member 60 is as follows: a maximum internal height H1 of the pressure regulating member 60 is measured as an internal length of the outer wall 62 and comprises approximately 4 mm; a maximum internal depth D1 of the pressure regulating member 60 is measured at approximately 2 mm; the short tapered walls 66a, 66b are measured at approximately 1.25 mm long and are disposed at an approximate angle of 8° from the horizontal; and the dome 64 comprises a radius of curvature of approximately 3.5 mm. The body 61 of the pressure regulating member 60 is formed of thin walls of fluorocarbon rubber at approximately 0.3 mm thick. However, it will be appreciated that the outer diameter, geometry and maximum volume of the pressure regulating member may be increased or decreased depending upon the diameter of the pumping chamber into which it is being disposed.

[0040] In an alternative embodiment as shown in Figure 6, the pressure regulating member 80 is substantially ring-shaped comprising an outer wall 82 and an inner dome 84. The outer wall 82 is substantially circular and planar and is

outwardly-facing. The dome 84 comprises a relatively shallow convex curve and is inwardly-facing. Connecting the outer wall 82 with the inner dome 84 is a tapered section 86. The tapered section 86 comprises a pair of short walls 86a, 86b protruding inwardly of the outer wall 82 to join ends 84a, 84b of the dome 84. The outer wall 82 and the tapered section 86 form a dovetail shape, which serves as an anchor component for mounting of the pressure regulating member 80 in an internal wall 36a of the pumping chamber 36 (as later described). The body 81 of the pressure regulating member 60 is hollow as described in relation to the first embodiment. In this embodiment, inside the body 81 of the pressure regulating member 80, there are a plurality of additional resilient components in the form of reinforcing ribs 88 disposed at regular intervals. The reinforcing ribs 88 comprises a curved section 88a mirroring the shape of the dome 64 and a pair of outwardly-deflected legs 88b that mirror the angle of the tapered section 66. The reinforcing ribs 88 comprise a resiliently deflectable material that, under normal or low pressure conditions, retain their convexly curved shape and under high pressure conditions, are configured to allow at least the curved section 88a to deflect inwardly to adopt a concavely curved shape. The reinforcing ribs 88 help to prevent permanent deformation of the dome 64.

[0041] As is shown in Figure 3, the pressure regulating member 60, 80 is mounted within the internal wall 36a of the pumping chamber 36. The internal wall 36a is provided with an annular slot 38, which comprises a dovetail shape and is configured to receive and retain the anchor component (outer wall 62, 82 and the tapered section 66, 86) of the pressure regulating member 60, 80. Better seen in Figure 8, the slot 38 comprises a narrow annular aperture 38a and an annular wedge- or dovetail-shaped cavity 38c with a rear wall 38b, and is sized to be a clearance fit with the outer wall 62, 82 and the tapered section 66, 86.

[0042] As shown in Figure 3, the slot 38 can be located proximal to an upper end 36b of the pumping chamber 36 so as to generally surround the pump head 34, the plunger 32 and a plunger spring 39. In this embodiment, the slot 38 is disposed in the wall between a first turn 39a and a second turn 39b of the spring 39 in a resting condition, primarily for ease of machining. However, other positions within the pumping chamber are possible.

[0043] During installation, the resiliently deflectable nature of the anchor component (outer wall 62, 82 and the tapered section 66, 86) of the pressure regulating member 60, 80 allows it to be deflected/ reduced in height to clear the narrow aperture 38a and pass into the cavity 38b, where it opens back out to substantially fill the cavity 38b with the outer wall 62, 82 resting against the back wall 38c of the slot 38. The dome 64, 84 protrudes from the slot 38, beyond the internal wall 36 into the pumping chamber 36. Due to the cooperating dovetail shaped anchor component (outer wall 62, 82 and the tapered section 66, 86) and slot cavity 38b, the pressure regulating member 60, 80 is not easily dislodged from the slot 38 without force or intention.

[0044] In use, in normal or low pressure conditions, the dome 64, 84 of the pressure regulating member 60, 80 adopts a normal convex configuration (as seen in Figure 7 as C1) comprising the maximum possible internal volume V1. As the pressure conditions in the pumping chamber 36 of the cambox 46 rise, the dome 64, 84 of the pressure regulating member 60, 80 is encouraged to deform inwardly, to reduce the internal volume of from the maximum internal volume V1 to a reduced internal volume V2, V3, V4 and reduced depth D2, D3, D4 respectively.

[0045] The extent of deformation and therefore, the extent to which the volume is reduced depends upon how high the pressure rises in addition to (a) the shear modulus (elasticity) of the material forming the dome 64, 84, (b) wall thickness of the material used and (c) the presence of any additional resilient components (e.g. see Figure 6).

[0046] A material with a high shear modulus (when using the Yeoh hyperelastic model), e.g. 86.81 MPa as in Figure 7a, may only achieve a small degree of deformation by flattening the dome 64, 84 and therefore a volume V2 reduced by approximately 0.04 cc³ (when subjected to pressures of 4 Bar). On the other hand, a material with a medium shear modulus, e.g. 45.58 MPa as in Figure 7b, may achieve a greater degree of deformation by creating a concave dome and therefore a volume V3 reduced by approximately 0.25 cc³ (when subjected to pressures of 4 Bar). Other examples of Shear modulus and volume reduction are shown in the table below:

Shear Modulus of flexible material at 4 Bar pressure	Volume Reduction [cc]
8.68	0.000
13.02	0.534
30.39	0.463
43.41	0.300
45.58	0.249
47.75	0.188
52.09	0.116
86.81	0.035

[0047] By using fluorocarbon rubber with a relatively low shear modulus of approximately 13 MPa (when using the Yeoh hyperelastic model), a minimum reduced volume V_4 is expected to be achievable, namely a reduction of 0.534 cc³ (when subjected to pressures of 4 Bar) in the internal volume of the pressure regulating member 60, 80. In this case, the dome 64, 84 is able to reach an inverse configuration where a peak of the dome 64, 84 contacts the outer wall 62, 82 of the anchor member and the tapered section 66 retaining a relatively normal configuration.

[0048] With the described embodiments, the pressure in the cambox 46 can be effectively regulated by providing a change in volume of the cambox 46 using one of the described pressure regulating members 60, 80. The possible changes in volume of the pressure regulating members 60, 80 in response to fluctuating pressures, helps to minimise pressure spikes and equalise the pressure in the cambox 46 during a pumping cycle. In other words, a decrease in pressure regulating member 60, 80 volume, provides an equivalent increase in the cambox 46 volume, thereby reducing pressure, and *vice versa*.

[0049] Although a few preferred embodiments have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims.

Claims

1. A high pressure diesel fuel pump (20) comprising a pumping assembly (30) and a drivetrain assembly (40), the pumping assembly (30) comprising a plunger (32) extending from a pump head (34) along a pumping axis (A-A'), the drivetrain assembly (40) comprising a drive shaft (42) and a cam (44) mounted thereon within a cambox (46) of a housing (48), a plunger-driving assembly (50) for contact with a lower end (32a) of the plunger (32) and mounted substantially between said plunger (32) and the cam (44), wherein the plunger (32) is arranged for reciprocating linear movement along the pumping axis (A-A') within a pumping chamber (36) of the housing (48) upon rotation of the cam (44), **characterised in that** the pumping chamber (36) comprises a pressure regulating member (60, 80) adapted to adjust its volume in response to changes in pressure in the cambox (46), wherein the pressure regulating member (60, 80) comprises a volume adjustment means, wherein the volume adjustment means comprises a flexible component (64, 84) comprising a flexible membrane, wherein the flexible component (64, 84) comprises a hollow formed shape having a maximum internal volume (V_1).
2. The pump according to any one of claim 1, wherein the flexible component (64, 84) comprises a maximum internal volume (V_1) adapted to decrease by at least approximately 0.2 cc³.
3. The pump according to any one of claims 1 to 2, wherein the hollow formed shape of the flexible component (64, 84) is adapted to at least partially deform as pressure rises in the cambox (46), thereby decreasing an internal volume of the pressure regulating member (64, 84).
4. The pump according to any one of claims 1 to 3, wherein the hollow formed shape of the flexible component (64, 84) is configured to at least partially reform as pressure falls in the cambox (46), thereby increasing an internal volume of the pressure regulating member (64, 84).
5. The pump according to any one of claims 1 to 4, wherein the flexible membrane comprises a shear modulus of between approximately 9 MPa and approximately 46 MPa (when using the Yeoh hyperelastic model).
6. The pump according to any one of claims 1 to 4, wherein the pressure regulating member (60, 80) comprises an anchor component (62, 82).
7. The pump according to claim 5, wherein the anchor component (62, 82) comprises a dovetail-shaped annulus.
8. The pump according to any one of claims 5 to 6, wherein the anchor component (62, 82) is resiliently flexible and substantially hollow.
9. The pump according to any one of claims 1 to 7, wherein the flexible component (84) comprises a plurality of resiliently flexible reinforcement ribs (88).
10. The pump according to any one of claims 1 to 8, wherein at least the flexible membrane comprises a fluorocarbon rubber.

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11. The pump according to any one of claims 5 to 10, wherein the pressure regulating member (60, 80) is mounted within an internal wall (36a) of the pumping chamber (36) via a retention means (38) for the anchor component (62, 82).
- 5 12. The pump according to claim 11, wherein the retention means (38) comprises an annular dovetail-shaped slot in said internal wall (36a).

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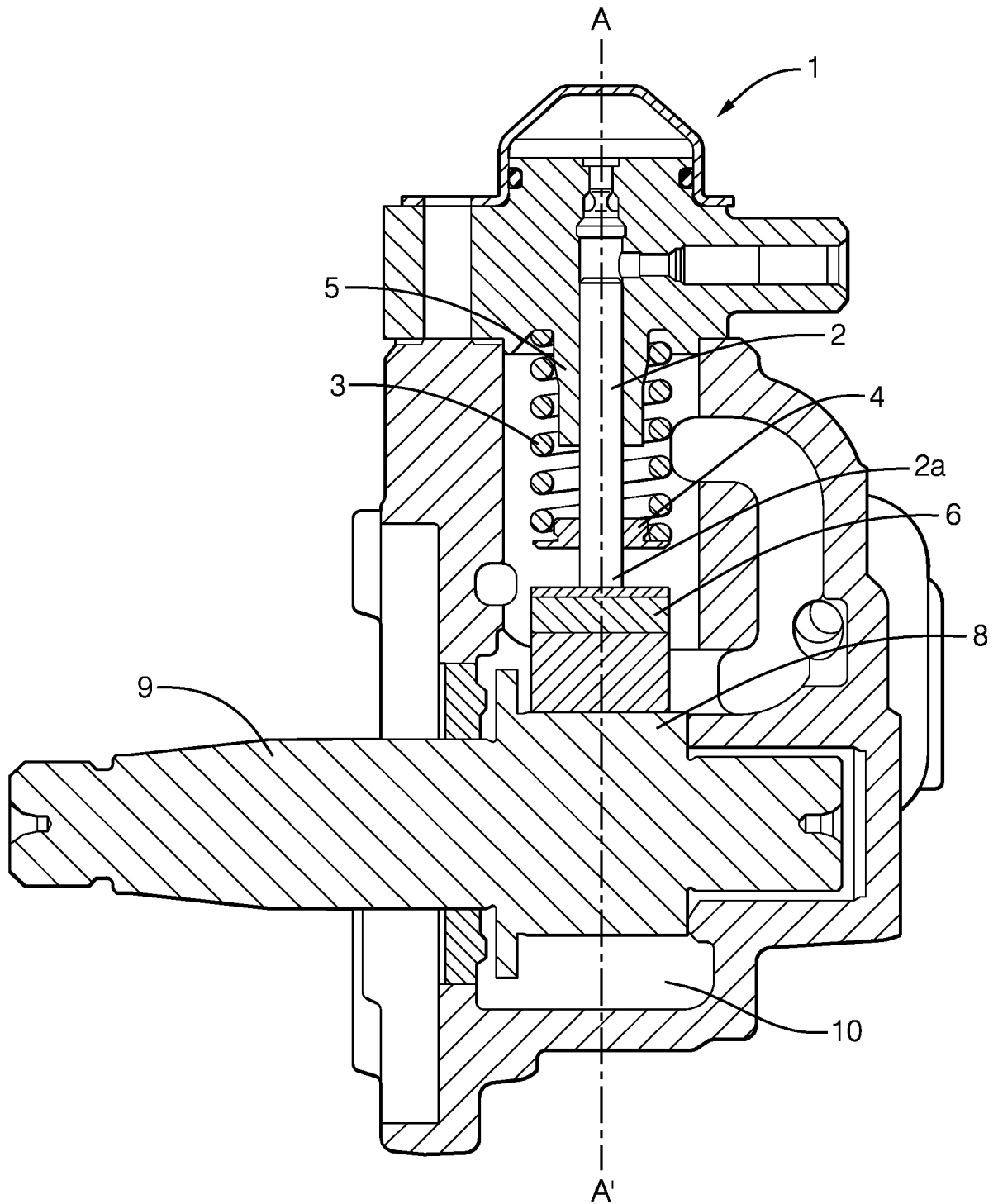


FIG. 1

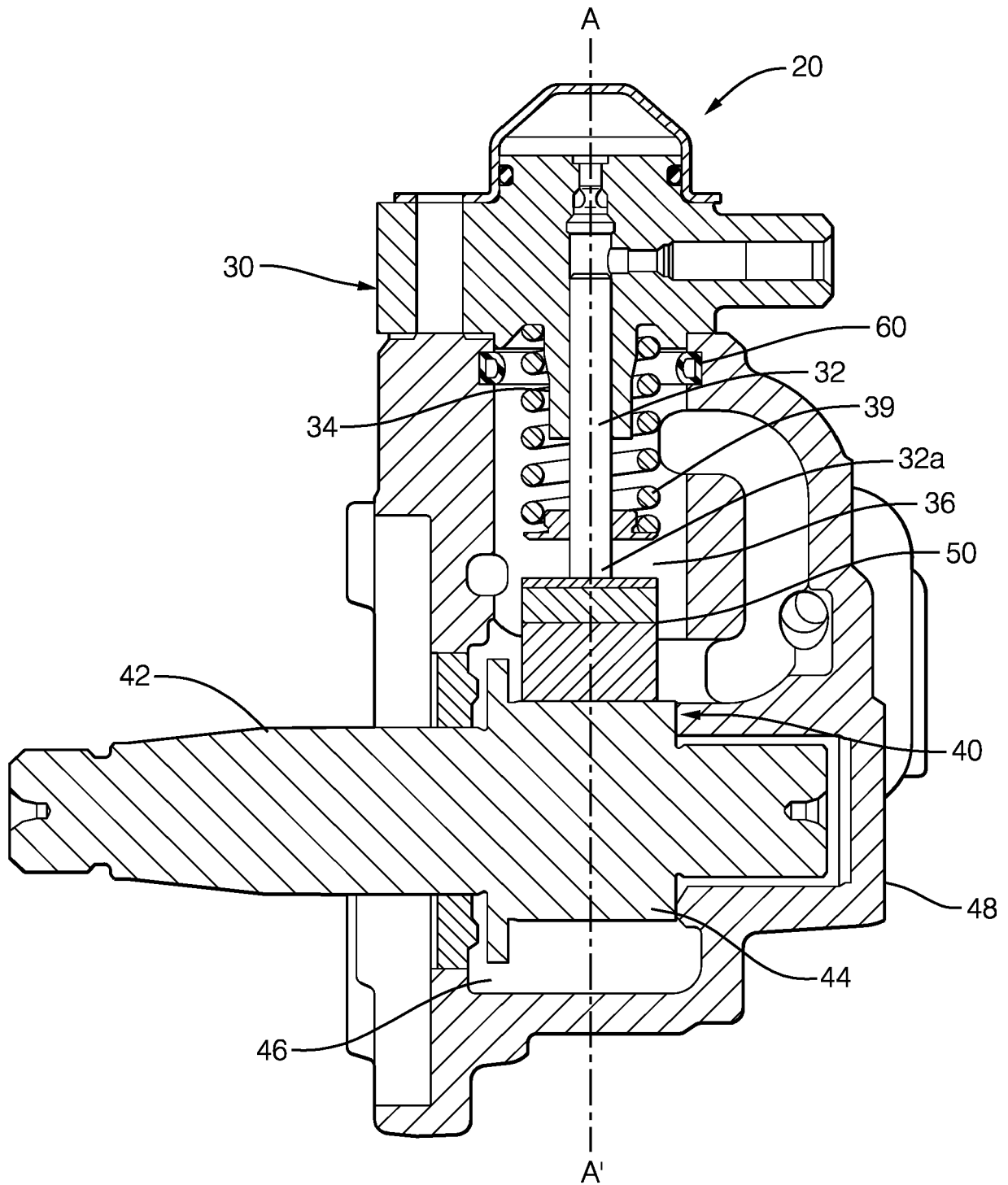


FIG. 2

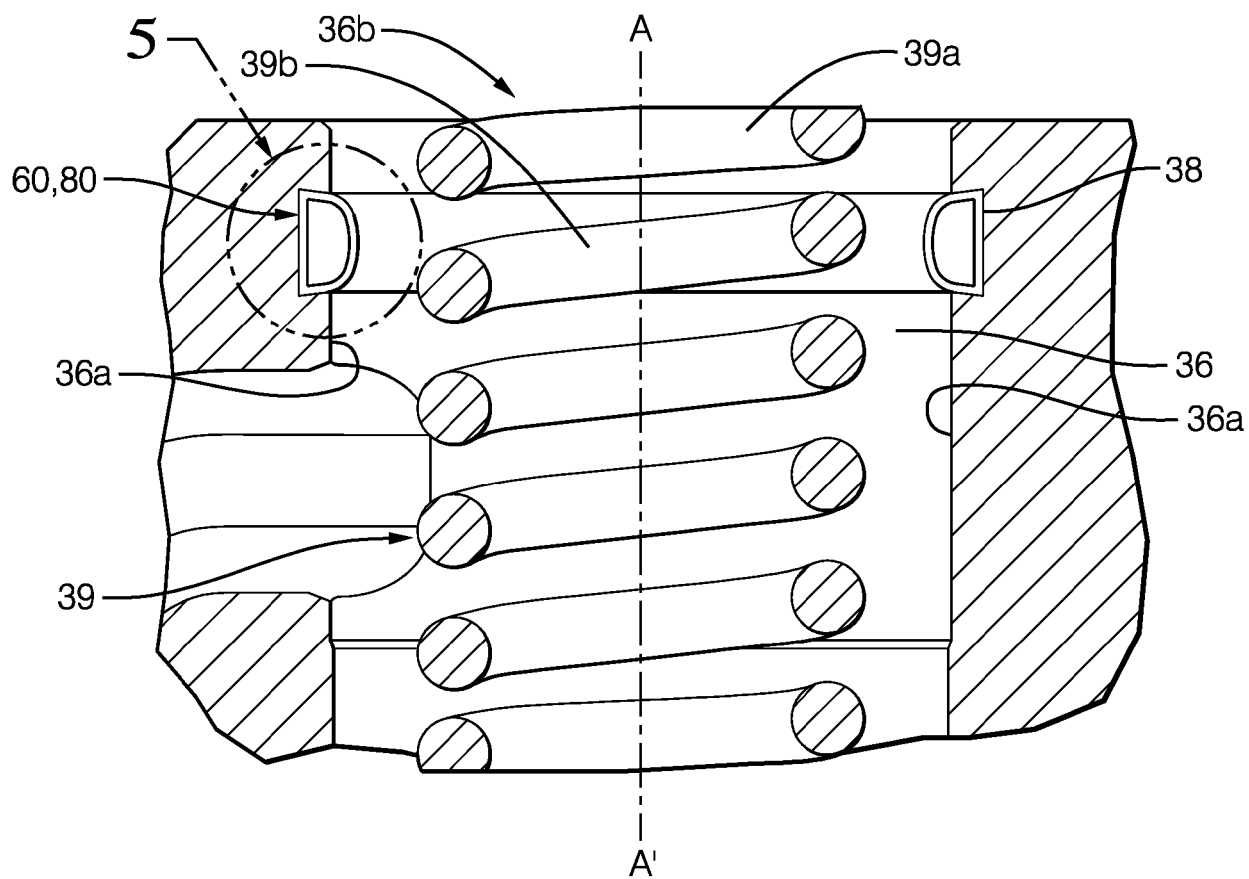


FIG. 3

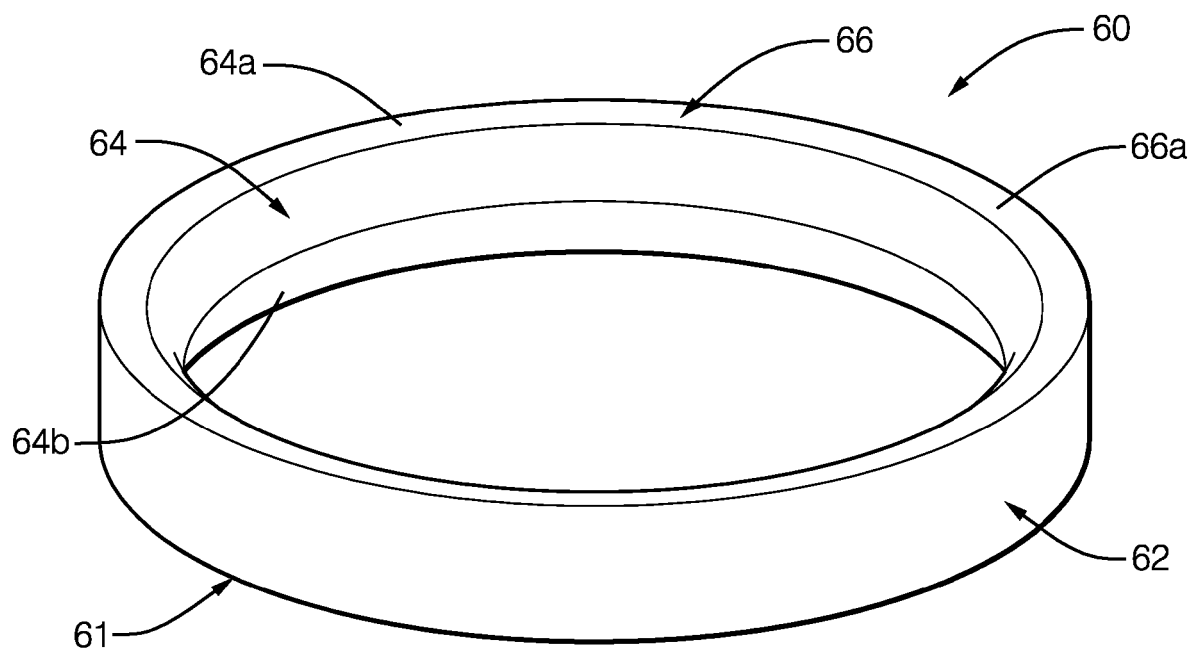


FIG. 4

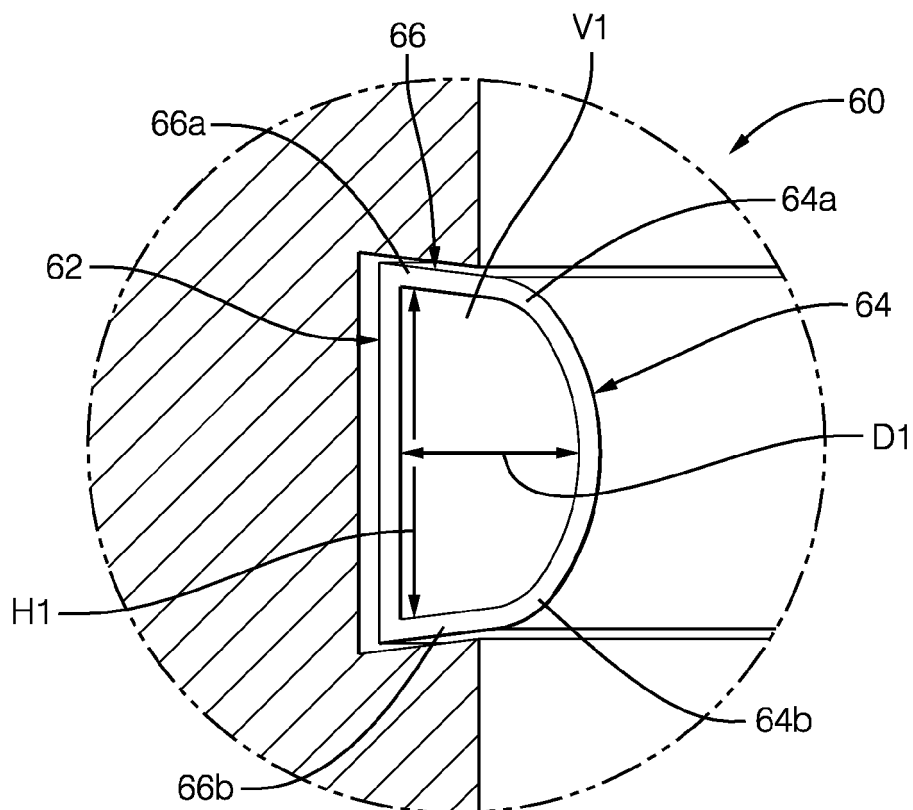


FIG. 5

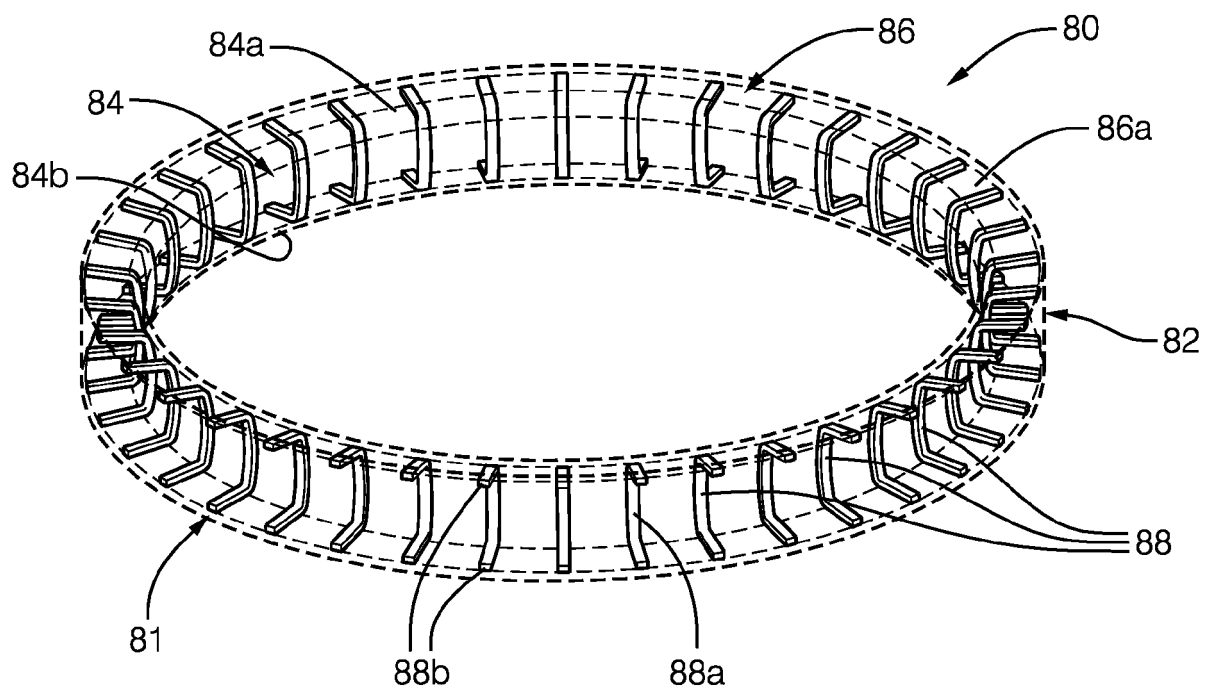


FIG. 6

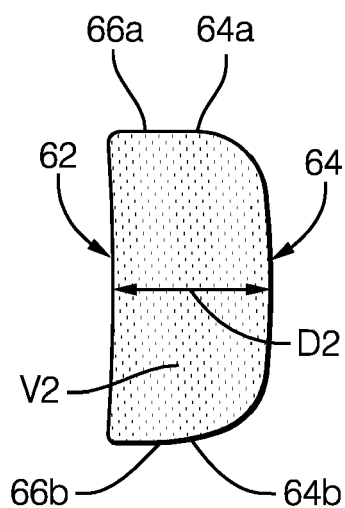


FIG. 7 A

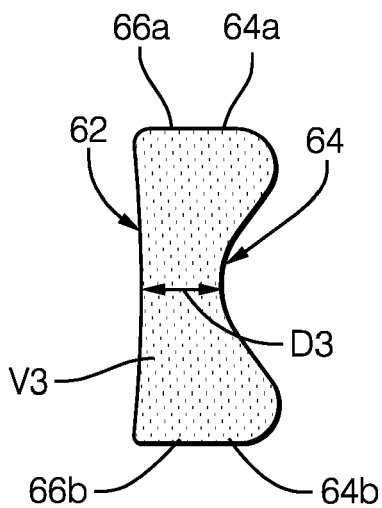


FIG. 7 B

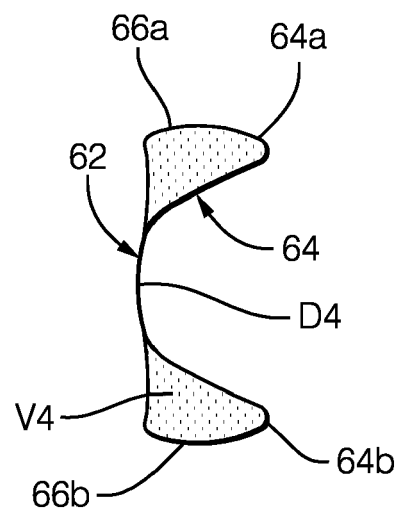


FIG. 7 C

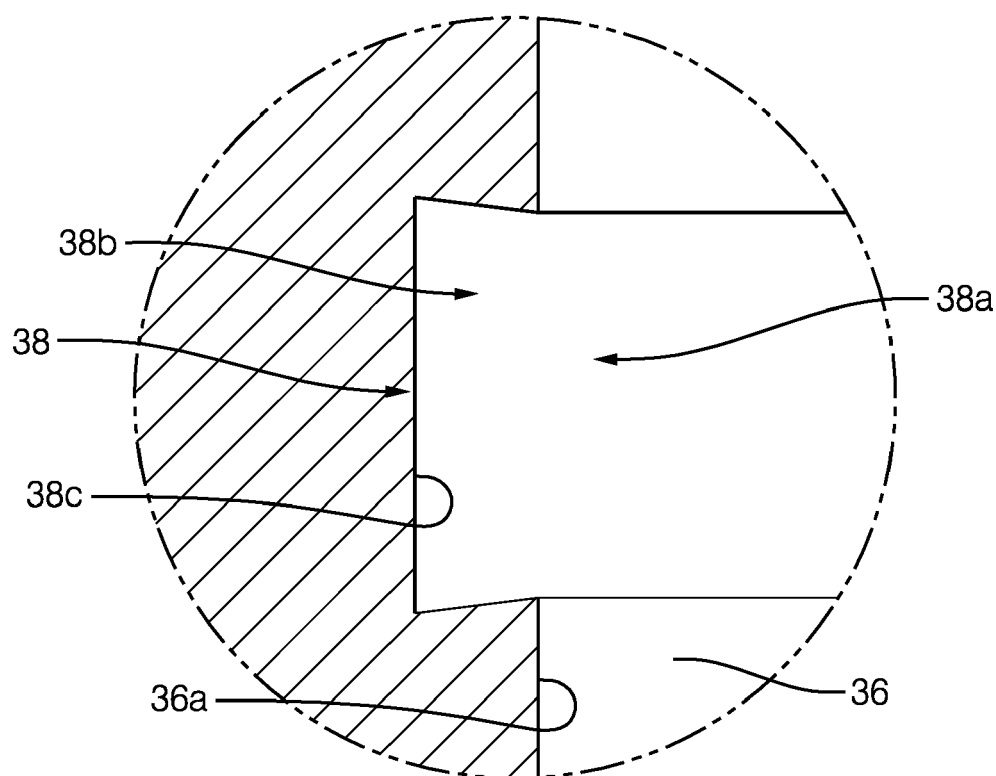


FIG. 8



EUROPEAN SEARCH REPORT

Application Number
EP 16 20 0359

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Y	* abstract; figures 1,2,3 * * claims 1,2,3 * * paragraph [0017] - paragraph [0020] * * paragraph [0021] - paragraph [0025] * * paragraph [0005] * * paragraph [0007] * * paragraph [0016] *	10	
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Y	* abstract; figures 1,2,3 * * claims 1,2,3,4,6 * * paragraph [0004] * * paragraph [0012] * * paragraph [0033] * * paragraph [0025] *	10	
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	* paragraph [0037] *		
	-/--		
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		13 April 2017	Barunovic, Robert
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 16 20 0359

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 April 2017	Examiner Barunovic, Robert
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