



(51) International Patent Classification:

F16J 15/3248 (2016.01) F16J 15/00 (2006.01)

(21) International Application Number:

PCT/US2017/055873

(22) International Filing Date:

10 October 2017 (10.10.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

15/349,348 11 November 2016 (11.11.2016) US

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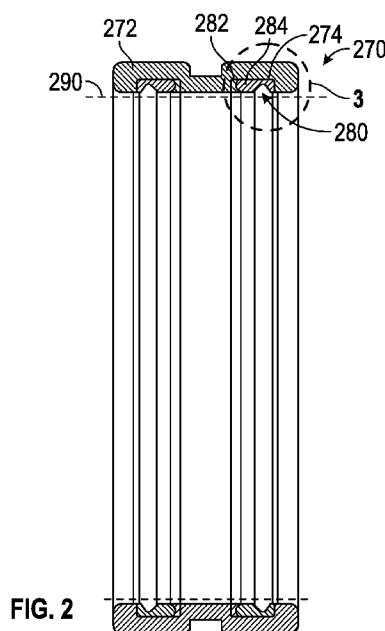
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB,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

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: DOWNHOLE SEALING APPARATUS



(57) Abstract: In one aspect, a seal apparatus for use with a mandrel is disclosed that in one non-limiting embodiment contains a seal housing disposed about the mandrel, wherein the seal housing is spaced apart from the mandrel to form a seal gap, a seal member disposed between the seal housing and the mandrel, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material, and a seal support disposed between the seal housing and the mandrel, wherein the seal support is formed from a second material, wherein the second material is stiffer than the first material, and the seal support extends across the seal gap in response to an energizing force applied to the seal support.

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

DOWNHOLE SEALING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 15/349348, filed on November 11, 2016, which is incorporated herein by reference in its entirety.

BACKGROUND

Field of the Disclosure

[0002] This disclosure relates generally to seals for use in wellbores.

Background

[0003] Wellbores are drilled in subsurface formations for the production of hydrocarbons (oil and gas). Modern wells can extend to great well depths, often more than 15,000 ft. Hydrocarbons are trapped in various traps or zones in the subsurface formations at different depths. Such zones are referred to as reservoirs or hydrocarbon-bearing formations or production zones and further include lower completion tools to control the flow therein. In a multi-zone well bore, it is often desired to seal or isolate certain components or regions while allowing for components to pass through during installation.

[0004] The disclosure herein provides a downhole assembly that includes at least one seal, wherein the seal includes an expanding seal support.

SUMMARY

[0005] In one aspect, a seal apparatus for use with a mandrel is disclosed that in one non-limiting embodiment contains a seal housing disposed about the mandrel, wherein the seal housing is spaced apart from the mandrel to form a seal gap, a seal member disposed between the seal housing and the mandrel, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material, and a seal support disposed between the seal housing and the mandrel, wherein the seal support is formed from a second material, wherein the second material is stiffer than the first material, and the seal support extends across the seal gap in response to an energizing force applied to the seal support.

[0006] In another aspect, a method for providing a seal against a mandrel is disclosed that in one non-limiting embodiment includes providing a seal housing, the seal housing including a seal member and a seal support, wherein the seal member is bonded to the seal housing, the seal member is formed from a first material, , the seal support is formed from a second material, and the second material is stiffer than the first material, disposing the

mandrel against the seal housing, wherein the seal housing is spaced apart from the mandrel to form a seal gap, the seal member is disposed between the seal housing and the mandrel, and the seal support is disposed between the seal housing and the mandrel, extending the seal support across the seal gap in response to disposing the mandrel against the seal housing.

[0007] In another aspect, an isolation system is disclosed that in one non-limiting embodiment contains a tubing, an isolation device associated with the tubing, and a seal apparatus associated with the tubing, the seal apparatus including a seal housing disposed about the tubing, wherein the seal housing is spaced apart from the tubing to form a seal gap, a seal member disposed between the seal housing and the tubing, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material, and a seal support disposed between the seal housing and the tubing, wherein the seal support is formed from a second material, wherein the second material is stiffer than the first material, and the seal support extends across the seal gap in response to an energizing force applied to the seal support.

[0008] Examples of the more important features of certain embodiments and methods have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features that will be described hereinafter and which will form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a detailed understanding of the apparatus and methods disclosed herein, reference should be made to the accompanying drawings and the detailed description thereof, wherein like elements are generally given same numerals and wherein:

[0010] **FIG. 1** shows an exemplary cased hole multi-zone wellbore containing a completion system that includes an isolation system and a lower completion system for separately producing fluids from two zones, according to one non-limiting embodiment of the disclosure;

[0011] **FIG. 2** shows a partial cross section of a non-limiting embodiment of a seal for use with the isolation system shown in **FIG. 1**; and

[0012] **FIG. 3** shows a detail view of the seal components of the seal shown in **FIG.**

2.

DETAILED DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a line diagram of a completion system or completion assembly 100 for the production of formation fluids from a multi-zone well, which completion assembly 100 includes a lower completion system 106 and an isolation system 160. The assembly 100 is shown to include a casing 110 deployed in wellbore 101 formed in a formation 102. The formation 102 includes a number of production zones, such as zones Z1 and Z2. Perforations 118a and 118b respectively are formed through the casing 110 into zones Z1 and Z2 to flow the formation fluid 150a from zone Z1 into the casing 110 and fluid 150b from zone Z2.

[0014] The lower completion string 106 includes an inner pipe or tubular 120 and an outer pipe 130. The lower completion system 106 includes a sand screen 132 in lower pipe 130 proximate to the zone Z1 and a sand screen 122 in lower pipe 120 inside and proximate to the sand screen 132. The inner pipe also includes a sand screen 124 in front of the perforation 118b in Zone Z2. The lower completion string 106 further includes packers 142 and 144 isolate the annulus 152 between the casing 110 and the outer pipe 130 above and below the perforations 118a in zone Z1, while packers 144 and 146 isolate the annulus 152 between the casing 110 and the outer pipe 130 above and below the perforation 118b in zone Z2. In addition, lower completion system 106 includes packer 148 to isolate the annulus 154 between the inner pipe 120 and the outer pipe 130 above the zone Z1. In this manner, fluid 150a from zone Z1 flows only into the inner pipe 120 through the perforations 118a, sand screens 132 and 122 and fluid 150b from zone Z2 enters only into the annulus 154 above the zone Z2. Thus, in the string 100, fluid 150a from zone Z1 will flow uphole via the inner pipe 120 while fluid 150b from Zone Z2 will flow uphole via the annulus 154 between the inner pipe 120 and the outer pipe 130.

[0015] In an exemplary embodiment, isolation system 160 is associated with lower completion system 106 to isolate and control fluid flows 150a and 150b. Isolation system 160 includes a wet connect 162, packer 164, a first flow control device 166, and a second flow control device 168. Isolation system 160 may be located to associate with the upper end of lower completion 106 and interface with upper packer 146.

[0016] In the illustrated embodiment, the isolation system 160 can include one or more seals 170. In the illustrated embodiment, the seals 170 can isolate fluid flow from desired regions or components within the isolation system 160.

[0017] FIGS. 2 and 3 show a seal 270 suitable for use with the isolation system 160 shown in FIG. 1. In the illustrated embodiment, the seal 270 includes a seal housing 272 and seal components 280 including a seal support 282, and a seal member 284. In the illustrated embodiment, the seal 270 can be utilized to seal against a mandrel 290. The mandrel 290 can be stabbed into the seal 270. In certain embodiments, the mandrel 290 is inserted through the seal 270 or slid around the seal 270. In certain embodiments, the seal 270 can be utilized to provide a leak proof seal with isolation systems 160 or any other suitable downhole application. In the illustrated embodiment, the seal support 282 can extend to support the seal member 284 as the seal member 284 is energized to prevent extrusion and other damage to the seal member 284. Advantageously, the seal 270 can be utilized for high pressure and high load applications and can withstand high debris environments.

[0018] In the illustrated embodiment, the seal 270 includes a seal housing 272. In the illustrated embodiment, the seal housing 272 is a cylindrically formed housing having an inner diameter and an outer diameter. The seal housing 272 can support the seal components 280 by containing the seal components 280 therein. In certain embodiments, the seal housing 272 is formed from steel, or any other suitable metal. In certain embodiments, the seal housing 272 includes a recessed portion 274. In the illustrated embodiment, the recessed portion 274 is disposed within the inner diameter. In other embodiments, the recessed portion 274 is disposed on the outside diameter of the seal housing 272. The recessed portion 274 can be utilized to retain the seal components 280 therein. In the illustrated embodiment, the seal housing 272 is disposed around the mandrel 290. The seal housing 272 is spaced apart from the mandrel 290 by a seal gap 292 to allow clearance for installation and operation.

[0019] Seal components 280 are disposed between the seal housing 272 and the mandrel 290. In the illustrated embodiment, the seal components 280 are disposed within the inner diameter of the seal housing 272. In certain embodiments, the seal components 280 are disposed on the outer diameter of the seal housing 272.

[0020] In the illustrated embodiment, the seal components 280 include a seal support 282 and a seal member 284. The seal member 284 is a ring that is disposed within the seal housing 272. In the illustrated embodiment, the seal member 284 is an elastomeric member. In certain embodiments, the seal member 284 is formed from rubber or any other suitable material. In certain embodiments, the seal member 284 is disposed within the recessed portion 274 of the seal housing 272. In certain embodiments, the seal member 284 is bonded to the seal housing 272 to prevent unwanted movement or removal of the seal member 284 from the seal housing 272.

[0021] In the illustrated embodiment, before the seal member **284** is energized by either pressure or force of the mandrel **290**, the seal member **290** is machined to allow the mandrel **290** to pass therethrough to allow sufficient clearance for installation. In certain embodiments, the seal member **284** is machined to final dimensions after the seal member **284** is placed in the seal housing **272**.

[0022] In certain embodiments, the seal member **284** includes a circumferential groove **285**. The circumferential groove **285** can allow for stress relief during stab in of the mandrel **290** by allowing the seal member **284** to move or compress within the groove **285**. In certain embodiments, the circumferential groove **285** is formed by machining the groove into the seal member **284** or otherwise removing material from the seal member **284**, to form a groove from an otherwise solid or unitary seal member **284**.

[0023] In the illustrated embodiment, as the seal member **284** is energized by the movement of the mandrel **290** or by high pressure, seal member **284** moves outwardly to expand and seal against the mandrel **290**. In certain embodiments, as the seal member **284** is energized, seal edges **286** can be forced toward the seal gap **292**. In certain applications the seal member **284** may be damaged by forcing or extruding the seal edges **286** into the seal gap **292**, limiting high pressure applications.

[0024] In the illustrated embodiment, the seal support **282** can be utilized to prevent the seal edges **286** from being extruded into the seal gap **292**. In the illustrated embodiment, the seal support **282** is a ring that is disposed within the seal housing **272**. In the illustrated embodiment, the seal support **282** is formed from a material that is stiffer than the seal member **284** to support the seal member **284** during operation. In the illustrated embodiment, the seal support **282** is formed from a stiff and flexible material. In the illustrated embodiment, the seal support **282** can be formed from polyether ether ketone (PEEK), or any other suitable thermoplastic material, thermoset material, etc. In certain embodiments, the seal support **282** is a non-elastomeric material. In certain embodiments, the seal support **282** is an elastomeric material that is stiffer than the seal member **284**. In certain embodiments, the seal support **282** can be fully intact, while in other embodiments, the seal support **282** can be scarf cut. In certain embodiments, the seal support **282** can be formed together with the seal member **284** to form a unitary sealing component **280**. In certain embodiments, the unitary sealing component **280** is formed by molding the seal support **282** and the seal member **284** together. Advantageously, by forming the seal support **282** and the seal member **284** from a single piece the unitary sealing component **280** can be inserted into the seal housing **272** as a single element.

[0025] In the illustrated embodiment, the seal support **282** is disposed within the recessed portion **274** of the seal housing **272**. In certain embodiments, the seal support **282** is bonded to the seal housing **272** to prevent unwanted movement or removal of the seal support **282** from the seal housing **272**. In certain embodiments, the seal support **282** is bonded to the seal member **284**. In certain embodiments, the seal support **282** includes a retaining feature to remain retained within the seal housing **272**. In certain embodiments, the seal support **282** is dovetailed with the seal housing **272**.

[0026] In certain embodiments, the seal support **282** is inserted into the seal housing **272** before the seal member **284** is disposed within the housing. Similar to the seal member **284**, before the seal support is energized by the mandrel **290** or the seal member **284**, the seal support **282** is dimensioned to allow the mandrel **290** to pass therethrough to allow sufficient clearance for installation.

[0027] In the illustrated embodiment, as the seal member **284** is energized by the movement of the mandrel **290** or by high pressure, the seal member **284** can energize the seal support **282**. In the illustrated embodiment, the seal support **282** can deform to expand the expanding portion **283** of the seal support **282**. In the illustrated embodiment, the expanding portion **283** is the lower portion of the seal support **282** with a geometry configured to expand downwardly into the seal gap **292** when energized.

[0028] The expanding portion **283** can expand across the seal gap **292**. In the illustrated embodiment, the seal edges **286** of the seal member **284** can be contained and prevented from extrusion and damage by preventing migration into the seal gap **292**. The geometry and the material of the expanding portion **283** can be selected to expand at a desired rate or in relation to the seal member **284**. Advantageously, the use of the seal support **282** allows for the use of the seal **270** in higher pressure environments without any damage to the seal member **284**.

[0029] Therefore, in one aspect, a seal apparatus for use with a mandrel is disclosed that in one non-limiting embodiment contains a seal housing disposed about the mandrel, wherein the seal housing is spaced apart from the mandrel to form a seal gap, a seal member disposed between the seal housing and the mandrel, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material, and a seal support disposed between the seal housing and the mandrel, wherein the seal support is formed from a second material, wherein the second material is stiffer than the first material, and the seal support extends across the seal gap in response to an energizing force applied to the seal support. In certain embodiments, the seal member is contained between the seal support, the seal

housing, and the mandrel. In certain embodiments, the seal housing includes a recessed portion, wherein the seal member and the seal support are disposed within the recessed portion. In certain embodiments, the first material is an elastomeric material. In certain embodiments, the second material is PEEK. In certain embodiments, the energizing force applied to the seal support is applied by the mandrel. In certain embodiments, the seal member includes a groove portion. In certain embodiments, the seal support includes an extension portion. In certain embodiments, the seal housing is disposed around the mandrel. In certain embodiments, the seal housing is disposed within the mandrel. In certain embodiments, the seal support is bonded to the seal housing and the seal member.

[0030] In another aspect, a method for providing a seal against a mandrel is disclosed that in one non-limiting embodiment includes providing a seal housing, the seal housing including a seal member and a seal support, wherein the seal member is bonded to the seal housing, the seal member is formed from a first material, the seal support is formed from a second material, and the second material is stiffer than the first material, disposing the mandrel against the seal housing, wherein the seal housing is spaced apart from the mandrel to form a seal gap, the seal member is disposed between the seal housing and the mandrel, and the seal support is disposed between the seal housing and the mandrel, extending the seal support across the seal gap in response to disposing the mandrel against the seal housing. In certain embodiments, the seal member is contained between the seal support, the seal housing, and the mandrel. In certain embodiments, the seal housing includes a recessed portion, wherein the seal member and the seal support are disposed within the recessed portion. In certain embodiments, the first material is an elastomeric material. In certain embodiments, the second material is PEEK. In certain embodiments, the mandrel applies an energizing force to the seal support. In certain embodiments, the seal member includes a groove portion. In certain embodiments, the seal support includes an extension portion. In certain embodiments, the seal housing is disposed around the mandrel.

[0031] In another aspect, an isolation system is disclosed that in one non-limiting embodiment contains a tubing, an isolation device associated with the tubing, and a seal apparatus associated with the tubing, the seal apparatus including a seal housing disposed about the tubing, wherein the seal housing is spaced apart from the tubing to form a seal gap, a seal member disposed between the seal housing and the tubing, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material, and a seal support disposed between the seal housing and the tubing, wherein the seal support is formed from a second material, wherein the second material is stiffer than the first material, and the

seal support extends across the seal gap in response to an energizing force applied to the seal support.

CLAIMS

1. A seal apparatus for use with a mandrel, the seal apparatus comprising:
a seal housing disposed about the mandrel, the seal housing including a recessed portion, wherein the seal housing is spaced apart from the mandrel to form a seal gap;
a seal member disposed in the recessed portion between the seal housing and the mandrel, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material; and
a seal support disposed in the recessed portion between the seal housing and the mandrel, wherein the seal support is formed from a second material;
wherein the second material is stiffer than the first material, and the seal support selectively extends across the seal gap.
2. The seal apparatus of claim 1, wherein the seal support extends across the seal gap in response to an energizing force applied to the seal support.
3. The seal apparatus of claim 2, wherein the energizing force is applied by a pressure.
4. The seal apparatus of claim 1, wherein the seal member and the seal support form a unitary sealing component.
5. The seal apparatus of claim 1, wherein the seal member is contained between the seal support, the seal housing, and the mandrel.
6. The seal apparatus of claim 1, wherein the first material is an elastomeric material.
7. The seal apparatus of claim 1, wherein the second material is non-elastomeric.
8. The seal apparatus of claim 1, wherein the energizing force applied to the seal support is applied by the mandrel.
9. The seal apparatus of claim 1, wherein the seal support is a solid member.
10. The seal apparatus of claim 1, wherein the seal member includes a groove portion.
11. The seal apparatus of claim 10, wherein the groove portion is formed in the seal member.
12. The seal apparatus of claim 1, wherein the seal support includes an extension portion.
13. The seal apparatus of claim 1, wherein the seal housing is disposed around the mandrel.

14. The seal apparatus of claim 1, wherein the seal housing is disposed within the mandrel.

15. The seal apparatus of claim 1, wherein the second material is stiffer than the first material.

16. The seal apparatus of claim 1, wherein the seal support is bonded to the seal housing and the seal member.

17. A method for providing a seal against a mandrel, the method comprising:
providing a seal housing, the seal housing including a recessed portion, a seal member, and a seal support, wherein the seal member is bonded to the seal housing, the seal member is formed from a first material, the seal support is formed from a second material, and the second material is stiffer than the first material;

disposing the mandrel against the seal housing, wherein the seal housing is spaced apart from the mandrel to form a seal gap, the seal member is disposed in the recessed portion between the seal housing and the mandrel, and the seal support is disposed in the recessed portion between the seal housing and the mandrel; and

selectively extending the seal support across the seal gap.

18. The method of claim 17, wherein the seal support is selectively extended in response to disposing the mandrel against the seal housing.

19. The method of claim 18, wherein the seal support is selectively extended in response to an applied pressure.

20. An isolation system comprising:
a tubing;
an isolation device associated with the tubing; and
a seal apparatus associated with the tubing, the seal apparatus including:
a seal housing disposed about the tubing, the seal housing including a recessed portion, wherein the seal housing is spaced apart from the tubing to form a seal gap;
a seal member disposed in the recessed portion between the seal housing and the tubing, wherein the seal member is bonded to the seal housing and the seal member is formed from a first material; and
a seal support disposed in the recessed portion between the seal housing and the tubing, wherein the seal support is formed from a second material;
wherein the second material is stiffer than the first material, and the seal support selectively extends across the seal gap.

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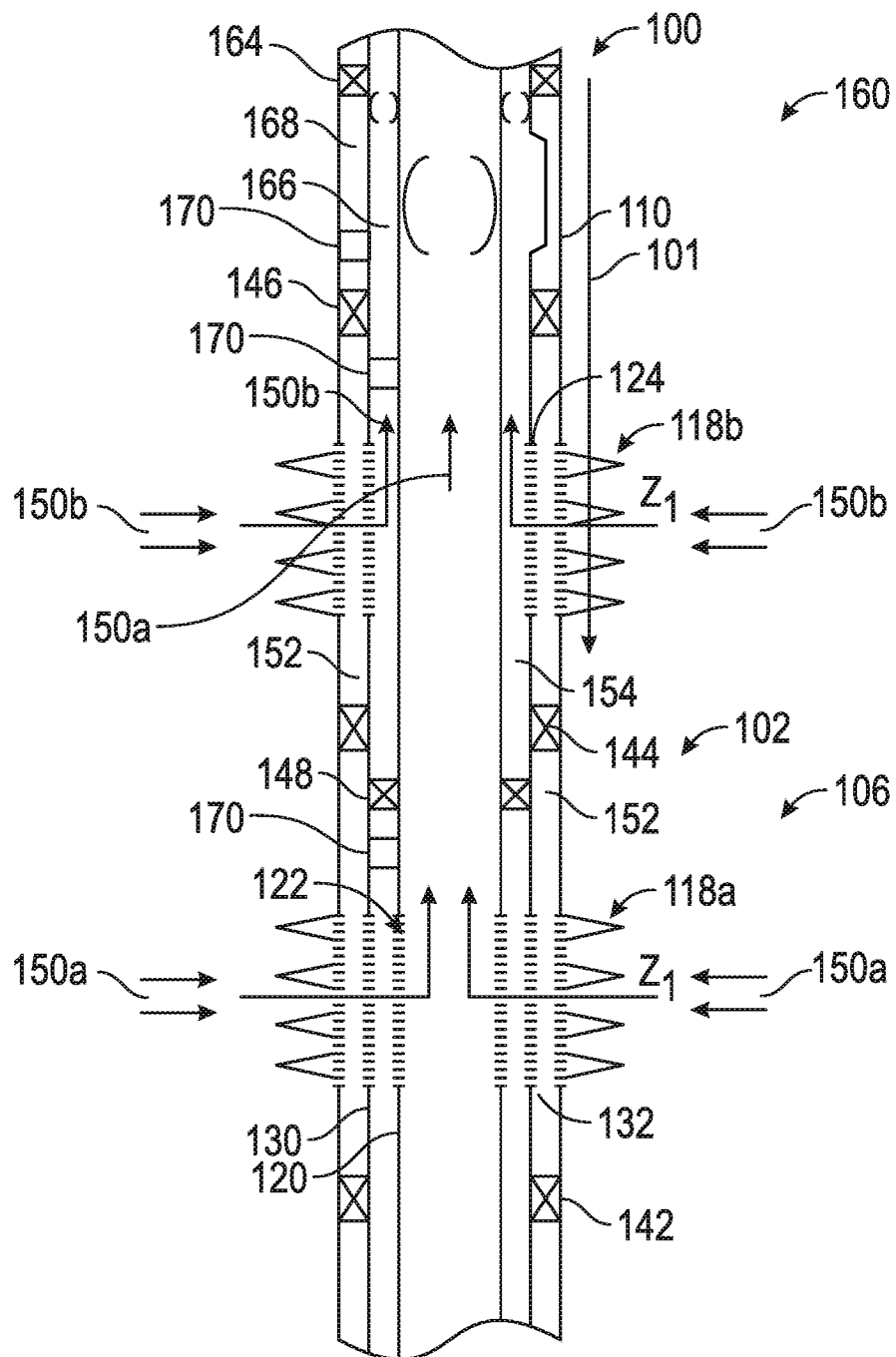


FIG. 1

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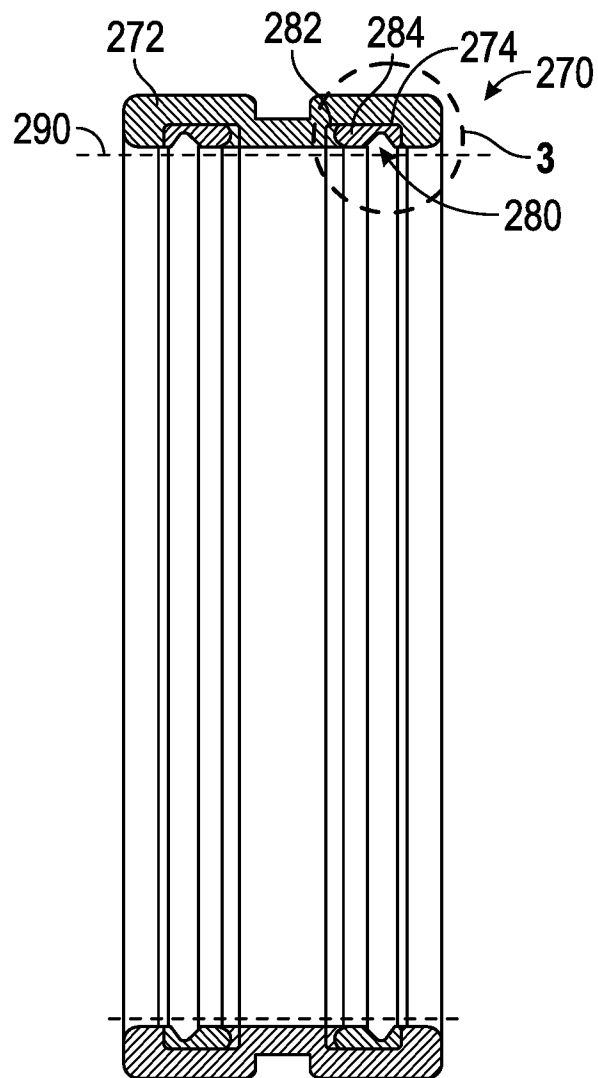


FIG. 2

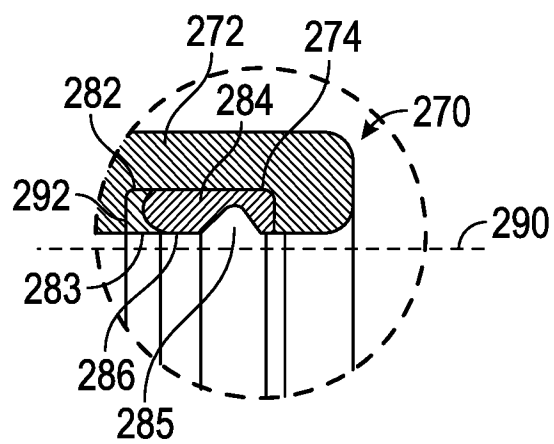


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/055873**A. CLASSIFICATION OF SUBJECT MATTER****F16J 15/3248(2016.01)i, F16J 15/00(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)

F16J 15/3248; E21B 47/00; F16J 15/32; E21B 33/12; G01D 11/26; F16J 15/00

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: seal housing, recessed portion, seal gap, seal member, seal support

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0052267 A1 (CASTLEMAN et al.) 04 March 2010 See paragraphs [0004], [0027]-[0036], [0047]-[0049]; and figure 1.	1-20
A	US 2016-0123469 A1 (APS TECHNOLOGY, INC.) 05 May 2016 See paragraphs [0018]-[0026]; and figures 2-3.	1-20
A	US 2008-0087417 A1 (DOANE et al.) 17 April 2008 See paragraphs [0023]-[0039]; and figures 1-5.	1-20
A	WO 2010-127240 A1 (WEATHERFORD/LAMB, INC. et al.) 04 November 2010 See paragraphs [0058]-[0059]; and figures 10A-10B, 11A-11B, 12A-12B.	1-20
A	US 2016-0138948 A1 (AK RESEARCH LLC) 19 May 2016 See paragraphs [0030]-[0035]; and figures 1-4.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 January 2018 (19.01.2018)

Date of mailing of the international search report

19 January 2018 (19.01.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsu-ro, Seo-gu, Daejeon, 35208, Republic of Korea



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/055873

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0052267 A1	04/03/2010	EP 2159459 A1 EP 2253870 A2 EP 2253870 A3 EP 2253870 B1 EP 2287499 A2 EP 2287499 A3 EP 2287499 B1 US 2012-0313327 A1 US 8215646 B2 US 9803752 B2	03/03/2010 24/11/2010 21/09/2011 09/10/2013 23/02/2011 21/09/2011 09/10/2013 13/12/2012 10/07/2012 31/10/2017
US 2016-0123469 A1	05/05/2016	US 9746080 B2	29/08/2017
US 2008-0087417 A1	17/04/2008	US 7448445 B2 WO 2008-045873 A1	11/11/2008 17/04/2008
WO 2010-127240 A1	04/11/2010	CA 2759401 A1 CA 2759401 C CA 2856678 A1 CA 2856678 C CA 2882455 A1 CA 2882455 C EP 2425093 A1 EP 2425093 A4 US 2012-0055667 A1 US 2014-0284046 A1 US 8763687 B2 US 9567821 B2	04/11/2010 16/12/2014 04/11/2010 21/07/2015 04/11/2010 30/05/2017 07/03/2012 04/06/2014 08/03/2012 25/09/2014 01/07/2014 14/02/2017
US 2016-0138948 A1	19/05/2016	None	