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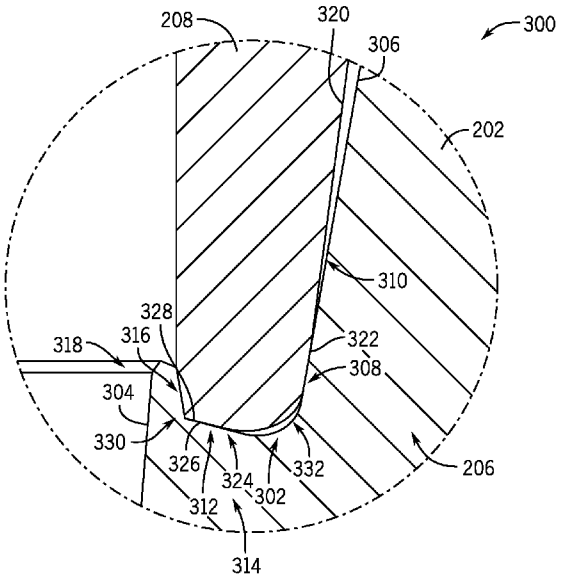


FIG. 3

(57) Abstract: A wellbore system includes a hanger body (202) with a recessed portion (302), a primary sealing surface (322), a secondary sealing surface (326), and a retaining skirt (330). The recessed portion (302) receives a nose (208) of an associated tool component (204) to form at least two metal to metal seals (308, 312) between the hanger body (202) and the associated tool component (204). The primary sealing surface (322) may be formed at a radially outward position to resist bore pressure and the secondary sealing surface (326) may be formed between the recessed portion (302) and a face (328) of associated tool component (204) to resist a radially inward pressure.

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[Continued on next page]

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BI-DIRECTIONAL METAL TO METAL SEALING SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a PCT Application of U.S. Non-Provisional Patent Application No. 18/938,904, titled "BI-DIRECTIONAL METAL TO METAL SEALING SYSTEMS AND METHODS," filed on November 6, 2024, which are both related to and claim the benefit of priority from U.S. Provisional Application No. 63/597,064, titled "BI-DIRECTIONAL METAL TO METAL SEALING SYSTEMS AND METHODS," filed November 8, 2023, and which are both incorporated by reference herein in their entirety for all intents and purposes.

BACKGROUND

1. Field of the Disclosure

[0002] The present disclosure relates to wellbore operations. Specifically, the present disclosure relates to systems and methods for forming seals between wellbore components, which may include one or more metal to metal seals.

2. Description of Related Art

[0003] Different wellbore operations may include conductors or tubulars that extend into a formation and then hang or otherwise suspend other conductors or tubulars with smaller diameters in order to form a wellbore. In certain applications, the conductors or tubulars may be secured to different components, such as surface components or subsea components, as examples. Additionally, certain wells may use mudline suspension systems where conductors and/or tubulars are suspended at the mudline, and in certain applications, may be suspended in place and supported by material such as cement. Mudline systems may provide for faster, more economical drilling operations, such as with test or exploration wells, but are often formed such that internal sealing configurations only accommodate for borehole pressures (e.g., unidirectional pressure). These

unidirectional sealing arrangements are not resilient to situations, such as poor installation, formation collapse, leaks, and/or the like that may cause additional pressure scenarios, such as tubing and casing annulus pressures.

SUMMARY

[0004] Applicant recognized the problems noted above herein and conceived and developed embodiments of systems and methods, according to the present disclosure, for wellbore sealing systems.

[0005] In an embodiment, a wellbore system includes a mandrel hanger body and an associated tool component. The mandrel hanger body includes a recessed portion, a primary sealing surface, a secondary sealing surface forming at least a part of the recessed portion, and a retaining skirt. An associated tool component configured to couple to the mandrel hanger body includes a nose including a first nose sealing surface and a second nose sealing surface. The nose is configured to be positioned, at least in part, within the recessed portion such that the primary sealing surface engages the first nose sealing surface to form a first metal to metal seal and the secondary sealing surface engages the second nose sealing surface to form a second metal to metal seal.

[0006] In an embodiment, a sealing system includes a first sealing surface associated with a first wellbore component, the first sealing surface arranged along an outer region of the first wellbore component. The sealing system also includes a second sealing surface associated with the first wellbore component, the second sealing surface arranged within a recess formed in the first wellbore component. The sealing system further includes a third sealing surface associated with a second wellbore component, the third sealing surface arranged along an outer diameter of the second wellbore component. The sealing system also includes a fourth sealing surface associated with the second wellbore component, the fourth sealing surface arranged along a base region of the second wellbore component. The second wellbore component is coupled to the first wellbore

component to drive the third sealing surface against the first sealing surface to establish a first seal and to drive the fourth sealing surface against the second sealing surface to establish a second seal, and wherein the first seal is configured to resist a bore pressure and the second seal is configured to resist a tubing and casing annulus pressure.

[0007] In an embodiment, a system for establishing a bi-directional metal to metal seal between a first downhole component and a second downhole component includes a first metal to metal seal between the first downhole component and the second downhole component, the first metal to metal seal formed at a first contact location between a first sealing surface along an outer region of the first downhole component and a second sealing surface along an outer diameter of the second downhole component. The system also includes a second metal to metal seal between the first downhole component and the second downhole component, the second metal to metal seal formed at a second contact location between a third sealing surface within a recessed portion of the first downhole component and a fourth sealing surface along a base region of the second downhole component. Each of the first metal to metal seal and the second metal to metal seal are configured to resist pressure from an opposite radial direction.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The present technology will be better understood on reading the following detailed description of non-limiting embodiments thereof, and on examining the accompanying drawings, in which:

[0009] FIG. 1A is a schematic side view of an embodiment of an offshore drilling operation, in accordance with embodiments of the present disclosure;

[0010] FIG. 1B is a cross-sectional side view of an embodiment of a wellbore system, in accordance with embodiments of the present disclosure;

[0011] FIG. 1C is a schematic side cross-sectional view of an embodiment of a mudline suspension system, in accordance with embodiments of the present disclosure;

[0012] FIG. 2 is a schematic side cross-sectional view of an embodiment of a wellbore component including a mandrel hanger body and an associated tool component, in accordance with embodiments of the present disclosure;

[0013] FIG. 3 is a detailed schematic sectional view of an embodiment of a sealing configuration taking along section 3-3, in according with embodiments of the present disclosure;

[0014] FIGS. 4A-4E are schematic side cross-sectional views of embodiments of sealing configurations, in accordance with embodiments of the present disclosure; and

[0015] FIGS. 5A-5F are schematic side sectional views of embodiments of sealing configurations, in accordance with embodiments of the present disclosure.

DETAILED DESCRIPTION

[0016] The foregoing aspects, features, and advantages of the present disclosure will be further appreciated when considered with reference to the following description of embodiments and accompanying drawings. In describing the embodiments of the disclosure illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

[0017] When introducing elements of various embodiments of the present disclosure, the articles "a", "an", "the", and "said" are intended to mean that there are one or more of the elements. The terms "comprising", "including", and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Any examples of operating parameters and/or environmental conditions are not exclusive of other parameters/conditions of the disclosed

embodiments. Additionally, it should be understood that references to "one embodiment", "an embodiment", “certain embodiments”, or “other embodiments” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Furthermore, reference to terms such as “above”, “below”, “upper”, “lower”, “side”, “front”, “back”, or other terms regarding orientation or direction are made with reference to the illustrated embodiments and are not intended to be limiting or exclude other orientations or directions. It should be further appreciated that terms such as approximately or substantially may indicate +/- 10 percent.

[0018] Embodiments of the present disclosure are directed toward systems and methods for bi-directional metal to metal (MTM) seals used with wellbore components, which may include surface applications, subsea applications, mudline applications, and various others. Various embodiments are directed toward flex-type meal seals that are configured to provide sealing characteristics from two directions (e.g., radially inward toward a wellbore axis and radially outward away from a wellbore axis), as opposed to merely sealing in one direction as various present seal configurations. In at least one embodiment, a reverse rake profile is incorporated into a mandrel hanger body to provide a contact area to form a secondary seal along with a primary seal formed between a metal flex nose and a different portion of the mandrel hanger body. In this manner, the flex type seal may accommodate and maintain sealing contact forces from pressure from two directions. Systems and methods of the present disclosure overcome problems with existing applications that only provide unidirectional sealing capabilities. Furthermore, various embodiments may permit forming bi-directional MTM seals with reduced torque requirements for makeup and break out, thereby providing for faster, cheaper installation, and as well providing capabilities to remove and reuse components. In at least one embodiment, systems and methods

provide seals, such as flexible metal seals, that provide sealing for a full pressure well bore rating, which may be approximately 10,000 psi in various non-limiting example embodiments. Embodiments may further provide seals with bi-directional sealing capabilities of the full bore pressure rating, thereby overcoming problems associated with existing techniques which may only provide fractional sealing for different pressure directions.

[0019] At least one embodiment is directed toward bi-directional MTM seals used in mudline systems, but it should be appreciated that embodiments are not limited to such configurations and may be used in a variety of other applications, including but not limited to surface applications and/or subsea applications. Systems and methods overcome problems that may be found in not only mudline systems, but others provided herein, in which seals are either formed from elastomers and/or are unidirectional MTM seals. Embodiments may incorporate a reverse rake that is formed on a body, such as a mandrel hanger body, to provide a contact surface to engage a nose of a metal flex seal in order to form a sealing configuration that accounts for both borehole pressure (e.g., radially outward from a wellbore axis) and also tubing and casing annulus pressure (e.g., radially inward toward a wellbore axis).

[0020] Systems and methods may incorporate a reverse rake profile to provide bi-directional sealing capabilities for a metal flex seal. In at least one embodiment, a body (e.g., a mandrel hanger body) suspends casing and receives an associated tool component, which may include, by way of non-limiting example, a running tool and/or a tieback tool. The mandrel hanger body may include one or more components with features and dimensions that are particularly selected to provide a primary metal sealing interface through a differential angle between the mandrel hanger body and the associated tool component. In various embodiments, the primary MTM seal is produced when torque is applied to make up the associated tool component, thereby driving a nose (e.g., a metal

flex nose) into the mandrel hanger body. The torque may be provided by threading the running tool and/or tieback tool into position. In at least one embodiment, embodiments are configured to use less torque to make up the MTM seals compared to traditional setting and/or installation techniques. The mandrel hanger body is furnished with second seal profile comprising a reverse rake and various other features to generate a second sealing interface between the mandrel hanger body and the associated tool component (e.g., the nose of the associated tool component). In operation, the associated tool component threads into the mandrel hanger body. As noted herein, the associated tool components may include a nose that provides a primary metal seal between the inner diameter of the mandrel hanger body and the outer diameter of the associated tool component nose. Furthermore, various embodiments also provide a secondary metal seal that is produced when the inner diameter of the nose interfaces with a differential angle on the reverse rake of the mandrel hanger body. In at least one embodiment, the primary metal seal is located on the furthest most point on a tapered outer diameter of the associated tool component. The primary metal seal me be arranged at various locations along an axial length of the tool component, which may vary based on a type of tool. The primary metal seal is energized responsive to torque and produces a metal seal when the outer diameter comes in contact with a differential angle on the mandrel hanger body. In certain embodiments, the secondary metal seal is located on a bottom face of the associated running tool (e.g., a bottom face of the nose). It is energized and produces a metal seal when the bottom face comes in contact with a differential angle on the mandrel hanger body. Systems and methods may further incorporate a retaining skirt (e.g., skirt) as an inner leg inside the mandrel hanger body. This skirt acts to retain the nose and prevent the nose from radially collapsing and deflecting into the bore, as well as maintain contact stress and hence a metal seal on the secondary metal seal. Various embodiments may also provide a third metal seal between

the skirt and the nose. In at least one embodiment, different dimensions of the nose may be particularly selected to provide the flexibility for the leg to radially deflect to maintain a metal to metal seal.

[0021] Various embodiments discussed herein are directed toward systems and methods for a bi-directional MTM sealing profile for wellbore systems, which may include, as a non-limiting example, mudline systems. Embodiments may provide simple and cost effective solutions to forming bi-directional seals. For example, various dimensions and components of a metal flex nose may be selected to engage different associated sealing surfaces and interfaces to reduce a torque required to form the MTM seal. The seal formed by the various associated wellbore components and mandrel hanger body may also be standardized so that a variety of different associated wellbore components may include a nose to facilitate formation of the bi-directional seal with the mandrel hanger body. Embodiments also provide a robust, reliable MTM seal with low torque requirements in order to facilitate make up and break out. Therefore, various embodiments provide a bi-directional MTM sealing configuration to hold both bore pressure and annulus pressures that may be installed, removed, and then reused. That is, the MTM seal(s) may be set, broken, and reset a number of times, providing reusability for the system.

[0022] FIG. 1A is a side schematic view of an embodiment of a subsea drilling operation 100. It should be appreciated that one or more features have been removed for clarity with the present discussion and that removal or inclusion of certain features is not intended to be limiting, but provided by way of example only. Furthermore, while the illustrated embodiment describes a subsea drilling operation, it should be appreciated that one or more similar processes may be utilized for surface applications and, in various embodiments, similar arrangements or substantially similar arrangements described herein may also be used in surface applications.

Furthermore, a drilling application is provided as a non-limiting example and various systems or methods could also be used in other applications, including recovery, inspection, data collection, and/or the like. The drilling operation includes a vessel 102 floating on a sea surface 104 substantially above a wellbore 106. As noted, the vessel 102 is for illustrative purposes only and systems and methods may further be illustrated with other structures, such as floating/fixed platforms, and the like. A wellbore housing 108 sits at the top of the wellbore 106 and is connected to a blowout preventer (BOP) assembly 110, which may include shear rams 112, sealing rams 114, and/or an annular ram 116. One purpose of the BOP assembly 110 is to help control pressure in the wellbore 106. The BOP assembly 110 is connected to the vessel 102 by a riser 118. During drilling operations, a drill string 120 passes from a rig 122 on the vessel 102, through the riser 118, through the BOP assembly 110, through the wellhead housing 108, and into the wellbore 106. It should be appreciated that reference to the vessel 102 is for illustrative purposes only and that the vessel may be replaced with a floating/fixed platform or other structure. The lower end of the drill string 120 is attached to a drill bit 124 that extends the wellbore 106 as the drill string 120 turns. Additional features shown in FIG. 1A include a mud pump 126 with mud lines 128 connecting the mud pump 126 to the BOP assembly 110, and a mud return line 130 connecting the mud pump 126 to the vessel 102. A remotely operated vehicle (ROV) 132 can be used to make adjustments to, repair, or replace equipment as necessary. Although a BOP assembly 110 is shown in the figures, the wellhead housing 108 could be attached to other well equipment as well, including, for example, a tree, a spool, a manifold, or another valve or completion assembly.

[0023] One efficient way to start drilling a wellbore 106 is through use of a suction pile 134. Such a procedure is accomplished by attaching the wellhead housing 108 to the top of the suction pile 134 and lowering the suction pile 134 to a sea floor 136. As interior chambers in the suction pile

134 are evacuated, the suction pile 134 is driven into the sea floor 136, as shown in FIG. 1A, until the suction pile 134 is substantially submerged in the sea floor 136 and the wellhead housing 108 is positioned at the sea floor 136 so that further drilling can commence. As the wellbore 106 is drilled, the walls of the wellbore are reinforced with concrete casings 138 that provide stability to the wellbore 106 and help to control pressure from the formation. It should be appreciated that this describes one example of a portion of a subsea drilling operation and may be omitted in various embodiments. In at least one embodiment, systems and methods of the present disclosure may be used for drilling operations that are completed through a BOP and wellhead, where a casing hanger and string are landed in succession. As noted above, configurations with respect to a sea floor or any offshore application are for illustrative purposes and embodiments of the present disclosure may also be utilized in surface drilling applications.

[0024] FIG. 1B is a schematic side view of an embodiment of a wellbore system 150, which may include a completion system, a recovery system, or a drilling system. In this example, the wellbore system 150 a rig 152 and a string 154 coupled to the rig 152. The string 154 may extend through a wellhead assembly (not pictured) such as a blowout preventer (BOP) and/or one or more valve configurations. The wellhead assembly may be a surface assembly, which is not visible in the illustrated embodiment due to a platform of the rig 152, but it should be appreciated that it may be provided in various embodiments. Systems and methods may be utilized in embodiments where one or more completion or recovery operations are initiated, such as when the string 154 is suspended into a wellbore 156. In this example, the string 154 may be a completion or production string, which may include one or more tubulars coupled together and suspended from one or more features, such as the wellhead assembly and/or a casing/tubing hanger, among other options. It should be appreciated that the string 154 may also be a casing string, where one or more cementing

operations may be used to cement and secure the string 154 to a wellbore wall. Furthermore, various embodiments may also implement such configurations during drilling operations, where the string 154 includes a drill bit at an end.

[0025] In this example, the string 154 is suspended into an annulus 158 formed between the string 154 and a wellbore wall 160. The string 154, as noted above, may be secured to one or more assembly that are configured to receive and support the string 154, such as a hanger assembly. In operation, the hanger assembly may be arranged within the wellbore 156, or at a surface location, and may include one or more seals to control pressure within the wellbore. Embodiments of the present disclosure may be incorporated with one or more of exploration, drilling, completion, and/or recovery efforts associated with subsea and/or surface applications. Furthermore, embodiments may also be used with various intervention or injection operations, among other uses for wellbores.

[0026] FIG. 1C is a schematic view of an embodiment of wellbore operation 170. It should be appreciated that one or more features have been removed for clarity with the present discussion and that removal or inclusion of certain features is not intended to be limiting, but provided by way of example only. Furthermore, while the illustrated embodiment describes a mudline system, it should be appreciated that one or more similar processes may be utilized for surface systems, subsea systems, and others and, in various embodiments, similar arrangements or substantially similar arrangements described herein may also be used in different wellbore and non-wellbore applications.

[0027] This illustrated wellbore operation 170 includes a mudline suspension system 172. The mudline suspension system 172 may refer to a system to support weight of different casings to a floor (e.g., a sea floor) 174 at a mudline 176. For example, the mudline suspension system 172

may refer to a series of hangers 178 that provide landing rings and shoulders 180 specifically to transfer the weight of the casing string to a main conductor 182 and the floor 174. The mudline suspension system 172 may include a series of pipes that stack downward, with each new hanger landing on a "shoulder" of the previously installed hanger. The number of hangers installed depends on how deep the well will be. In certain embodiments, the series of hangers may be secured in position using cement 184. The use of a mudline system may also permit disconnection once a drill bit has reached the required depth. While not shown in FIG. 1C, the mudline suspension system may also work with a variety of other wellbore components, such as a blowout preventer, wellhead, drilling rig, and/or the like.

[0028] Typically, seals and various sealing components with mudline systems incorporate unidirectional MTM seals to provide a sealing force to resist pressure from a bore 186. That is, the pressure may be directed radially outward from an axis 188 of the bore 186. Seal configurations may be made such that as pressure increases, sealing forces also increase, such as by forming sealing interfaces in which greater bore pressure drives the seals into different wellbore components. However, these systems may not be effective when pressure is provided from the opposite direction (e.g., radially inward toward the axis 188). For example, if the cement 184 is improperly positioned and/or cracks, leakage may cause a radially inward pressure to be applied to the hangers 178, which may reduce the sealing contact formed by the primary MTM seal. Systems and methods of the present disclosure address and overcome this deficiency by providing a bi-directional seal to provide sealing capabilities for both radially inward and radially outward forces.

[0029] FIG. 2 is a schematic cross-sectional view of an embodiment of a wellbore system 200 that may be used with embodiments of the present disclosure. This example may be used with a

mudline suspension system, by way of non-limiting example, but it should be appreciated that various features may be used with other systems for different types of operations. In this example, a mandrel hanger body (MHB) 202 is coupled to an associated tool component (ATC) 204, which may include a running tool, a tieback tool, and/or the like. The illustrated MHB 202 and the ATC 204 may be coupled together via one or more mechanical fittings, such as threads. For example, the MHB 202 may include a set of threads and the ATC 204 may include another mating set of threads. Positions of the various threads may be used to engage different features of the MHB 202 and/or the ATC 204, as discussed herein, and may be particularly selected based on operating conditions, engineering considerations, and/or the like.

[0030] In this example, the MHB 202 includes a shoulder region 206 and, when installed, the ATC 204 may "bottom out" or otherwise contact one or more portions of the shoulder region 206. In certain embodiments, the ATC 204 may not "bottom out" and there may be one or more gaps or spaces between the ATC 204 and the MHB 202, as discussed herein. In at least one embodiment, the ATC 204 may include a nose 208 (e.g., a metal flex nose) that is driven into the shoulder region 206 and/or one or more areas of the shoulder region 206 to form a MTM seal between the MHB 202 and the ATC 204. The MTM seal may refer to an interface between two metallic components in which a contact stress is formed to provide a restriction from fluid (e.g., gas, liquids, solids, or combinations thereof) from flowing between the two metallic components. The illustrated nose 208 may be flexible in that it may deform elastically to permit formation of the MTM seal but then return to its original position after removal. As a result, in at least one embodiment, the ATC 204 may be reused after breaking the MTM seal with the MHB 202. In at least one embodiment, both the MHB 202 and the ATC 204 may be formed from one or more metals, and the metals may be the same or different. Each of the MHB 202 and the ATC 204 may have an associated sealing

surface, which may be machined or otherwise prepped for sealing, that is positioned to engage the opposing surface during operation. In this example, and as described herein, one or more sloped surfaces may be formed such that as the nose 208 is driven into the shoulder region 206, the nose 208 contacts an opposing sealing surface of the MHB 202 to form the MTM seal due to the contact forces generated between the two surfaces. As will be described, systems and methods may be used to form at least two different sealing interfaces between the MHB 202 and the ATC 204 to resist pressures from both a radially outward direction and a radially inward direction.

[0031] FIG. 3 is a detailed schematic view of a sealing area 300, taken along region 3-3. In this example, the nose 208 is arranged within the shoulder region 206, which includes a recessed portion 302 defined, at least in part, by an inner bore 304 and an outer bore 306 of the MHB 202. In this example, the nose 208 has been driven into the recessed portion 302 such that a primary MTM seal 308 is formed at an outer region 310 and a secondary MTM seal 312 is formed at a base region 314. It should be appreciated that one or more embodiments may also include a third MTM seal 316 formed at an inner region 318. Furthermore, as discussed herein, the primary MTM seal 308 may be formed along a variety of different axial locations along the outer region 310, which may include MTM seals proximate the recessed portion 302 and/or MTM seals axially higher than the recessed portion 302.

[0032] In this example, the nose 208 includes a sloped outer face 320 that engages a sloped inner face 322 of the MHB 202. The differential angle formed between the sloped outer face 320 and the sloped inner face may be used to form the primary MTM seal 308 because as the nose 208 is driven into the recessed portion 302, the respective faces 320, 322 will contact one another, which may create contact stresses that form a sealing interface. In this example, the primary MTM seal 308 resists pressure from within the bore (e.g., pressure directed radially outward) and is driven

into the MHB 202 as the pressure increases. That is, pressure from the bore drives the nose 208 radially outward from the axis 188 and into the MHB 202, which increases contact forces to improve the seal. However, responsive to an opposing pressure (e.g., pressure directed radially inward), the contact stresses may be reduced such that the sloped outer face 320 is driven away (e.g., radially inward) from the sloped inner face 322, thereby losing sealing capability. Systems and methods of the present disclosure address and overcome this deficiency, such as by providing one or more mechanisms to form the secondary MTM seal 312.

[0033] Embodiments of the present disclosure include a sloped region 324 within the recessed portion 302, which may also be referred to as a "reverse rake." As shown, the sloped region 324 has an upward facing slope (e.g., a lateral position along the axis of the bore increases along the slope region 324 when moving toward the axis 188). In other words, the sloped region 324 is positioned such that an end closer to the outer bore 306 is axially lower than an end closer to the inner bore 304. An angle of the sloped region 324 may be particularly selected based on operating conditions or desired contact stresses. For example, the angle may be adjusted to increase or decrease contact stresses, which will change how much torque is used to set the seal. It should be appreciated that the sloped region 324 may include multiple different regions, such as steps, arcs, or the like, and that one or more portions of the sloped region 324 may include a sloped region sealing face 326 that is engaged by a nose base sealing face 328 to form the secondary MTM seal 312. As noted herein, as the nose 208 is driven into the recessed portion 302, contact stresses between different regions, such as the sealing faces 326, 328 may increase and form a MTM seal to block fluid flow. In this example, the secondary MTM seal 312 is positioned to resist a radially inward force (e.g., toward the axis). That is, as the radially inward force increases, the sealing faces 326, 328 will be driven into one another to increase contact stresses and improve the sealing

interface. In at least one embodiment, a retaining skirt 330 (e.g., skirt) may prevent the nose 208 from collapsing into the bore, thereby maintaining the secondary MTM seal 312.

[0034] The retaining skirt 330 is illustrated as a lip that may form at least a portion of the inner bore 304 and may, at least in part, define a portion of the recessed portion 302. The retaining skirt 330 may also serve as a guide or directional tool to guide the nose 208 into the recessed portion 302. For example, the nose 208 may contact the retaining skirt 330 prior to bottoming out and forming the secondary MTM seal 312. Various dimensions and shapes of the retaining skirt 330 may be particularly selected based on operating conditions. For example, the retaining skirt 330 may include an inner slopped wall that has a similar slope to an inner diameter of the nose 208, which may help guide the nose into the recessed portion 302 and reduce contact forces, which may be advantageous to reduce torque requirements for setting the ATC 204. In examples where the retaining skirt 330 includes the inner slopped wall, a top portion may be more narrow than a bottom portion. Additionally, a length (e.g., a longitudinal length along the axis) may be particularly selected based on operating conditions.

[0035] Systems and methods may also include a void or gap 332 that may be used to collect debris. For example, as the nose 208 is installed, debris may be driven off of and away from various interfacing components and may collect in the void 332, thereby providing cleaner sealing surfaces and reducing risks of interference (e.g., debris) at the sealing surfaces. A size and depth of the void 332 may be particularly selected and based, at least in part, on other dimensions selected for the recessed portion 302, such as the reverse rake.

[0036] FIGS. 4A-4E illustrate examples embodiments of different sealing configurations associated with at least the secondary MTM seal 312. It should be appreciated that various aspects of the embodiments of FIGS. 4A-4E and FIG. 3 may be mixed and or joined into a single

embodiment and illustration as separate embodiments is provided by way of non-limiting example for clarity. Furthermore, as discussed herein, the location of the primary MTM seal 308 in FIGS. 4A-4E is also provided by way of non-limiting example and the primary MTM seal 308 may be arranged axially higher than the recessed portion 302, as an example.

[0037] FIG. 4A illustrates a cross-sectional detailed view of the sealing area 300 in which the secondary MTM seal 312 is illustrated with a bottom face (e.g., nose base sealing face 328) having a differential angle with the sloped region 324 (e.g., the sloped region sealing face 326) such that the two faces are in contact with one another to form the secondary MTM seal 312. As noted herein, the angles of the different sloped faces may be adjusted to change a length of the sealing interface, which may change the surface area, and which may therefore change a torque required to form the seal. In this example, a length of the secondary MTM seal 312 extends substantially along a length of the sloped region 324 due to an associated length of the nose base sealing face 328. However, it should be appreciated that one or both of the sloped region 324 and/or the nose base sealing face 328 may have different lengths to adjust a contact area for the secondary MTM seal 312.

[0038] FIG. 4B illustrates a cross-sectional detailed view of the sealing area 300 in which the secondary MTM seal 312 is illustrated with a bottom face (e.g., nose base sealing face 328) having a differential angle with the sloped region 324 (e.g., the sloped region sealing face 326) such that the two faces are in contact with one another to form the secondary MTM seal 312. In this example, the secondary MTM seal 312 may be described as using a radius to provide a sealing line contact with the sloped region 324. That is, the nose base sealing face 328 forms a contact with the sloped region sealing face 326. In at least one embodiment, the radius may extend to an associated flat that contacts the sloped region 324. The configuration illustrated in FIG. 4B, compared to FIG.

4A, has a shorter seal length. That is, a space 400 is shown between the nose 208 and the skirt 330, which when compared to the embodiment of FIG. 4A, may be missing due to the size and/or shape of the nose. For example, rather than having a flat 402, as shown in FIG. 4A, the nose 208 in FIG. 4B includes the radius 404.

[0039] FIG. 4C illustrates a cross-sectional detailed view of the sealing area 300 in which the secondary MTM seal 312 is formed, at least in part, by a bump 406 formed on the bottom face of the nose 208. That is, the bottom face of the nose 208 includes a raised sealing band providing a sealing band contact. In at least one embodiment, the bump 406 may include a radius or curved face. In another embodiment, the bump 406 may be a sloped portion or a stepped portion compared to an adjacent area of the bottom face of the nose 208. In the illustrated configuration, the bump 406 is on a radially inward portion of the nose 208 (e.g., closer to the skirt 330 than to the outer region 310), but it should be appreciated that the bump 406 may be located along any portion of the nose 208.

[0040] The illustrated bump 406 is positioned proximate a flat 408 forming the remainder of the nose 208, but in other embodiments the bump 406 may be an extension off of a radius, such as the radius 404 of FIG. 4B. The bump 406 may be used to form at least a portion of the nose base sealing face 328, which may be driven into contact with the sloped region sealing face 326 to form the secondary MTM seal 312. As discussed herein, as pressure is applied radially inward, the bump 406 is further driven into the sloped region 324, thereby increasing a sealing contact face to maintain the seal between the MHB 202 and the ATC 204.

[0041] FIG. 4D illustrates a cross-sectional detailed view of the sealing area 300 in which the secondary MTM seal 312 is formed with two flat faces are various differential angles providing a sealing line contact. As shown, each of the sloped region sealing face 326 and the nose base sealing

face 328 are substantially sloped areas that, due to their differential angles, engage to form the secondary MTM seal 312. In this example, the sloped region sealing face 326 is proximate a flat, which may form a portion of the void 332 to collect debris.

[0042] FIG. 4E illustrates a cross-sectional detailed view of the sealing area 300 in which the skirt 330 has been removed and the sloped region 324 is set at an acute angle to retain the nose 208 within the recessed portion 302. That is, the bottom of the face of the nose 208 is "wedged" or otherwise driven into the recessed portion 302 and maintained due to the acute angle and the MTM seal 312 may be formed by differential angles providing a sealing line contact. As result, in the illustrated configuration, the acute angle that sets the sloped region 324 at an upwardly facing angle includes an associated sloped region sealing face 326 that may engage the mating nose base sealing face 328 to form the secondary MTM seal 312 when the nose 208 is driven into the recessed portion 302.

[0043] FIGS. 5A-5F illustrate example configurations that may be used with one or more embodiments, for example, in embodiments where the ATC 204 is a tieback tool. As discussed herein, one or more embodiments may be used to form a bi-directional MTM seal between the MHB 202 and the ATC 204, which may include the primary MTM 308 and the secondary MTM seal 312, and in certain embodiments, the third MTM seal 316. Various embodiments may also include a variety of features discussed herein to facilitate make up and break up of the seals, such as different differential angles for sealing interfaces, different dimensions to modify contact forces, and a variety of contact face configurations such as radii, sloped surfaces, and/or combinations thereof.

[0044] FIG. 5A illustrates a sectional side view of an embodiment of a sealing area 500, which may be similar to the sealing area 300 discussed herein. In this example, the MHB 202 receives

the ATC 204 at the recessed portion 302, which further includes the void 332 to collect debris or the like. The illustrated nose 208 extends into the recessed portion 302 and engages the MHB 202 to from the primary MTM seal 308. In the configuration of FIG. 5A, the primary MTM seal 308 is axially higher than the configuration shown, for example, in FIG. 3, but the nose 208 still contacts the outer region 310, as discussed here. In one or more embodiments, the nose 208 includes the differential angle that may contact the sloped outer region 310 in order to form the MTM seal.

[0045] Further illustrated in the secondary MTM seal 312 formed by contact between the nose base sealing face 328 and the sloped region seal face 326, as discussed herein. The example nose 208 includes a flat 402 that engages the sloped region 324. However, as discussed herein, the nose 208 may also include the radius 404, bump 406, and/or combinations thereof. Accordingly, systems and methods may be used with a variety of different downhole tools in order to form the primary MTM seal 308 at one or more desired locations while maintaining bi-directional sealing capability with the secondary MTM seal 312.

[0046] FIG. 5B illustrates a sectional view of the sealing area 500 illustrating the flat 402 extending toward the sloped region 324 of the recessed portion 302. The flat 402 in this example is on the inner portion of the ATC 204 (e.g., closer to the skirt 330 than to the outer region 310). In operation, as the nose 208 is driven into the recessed portion 302, the flat 402 may engage the sloped region 324 to form the secondary metal to metal seal.

[0047] FIG. 5C illustrates a sectional view of the seal area 500 illustrating the primary MTM seal 308 at the outer region 310. As discussed herein, the primary MTM seal 308 may be formed at a variety of different locations along the outer region 310 and may, in various embodiments, be located axially higher than the recessed portion 302 (FIG. 5B).

[0048] FIG. 5D illustrates a sectional view of the seal area 500 illustrating the primary MTM seal 308 at the outer region 310 and the nose 208 being driven into the recessed portion 302. As discussed herein, the illustrated outer region 310 extends above the recessed portion 302, and as a result, the primary MTM seal 308 is positioned radially upward and away from the recessed portion 302.

[0049] FIG. 5E illustrates a sectional view of the seal area 500 illustrating the primary MTM seal 308 at the outer region 310 and the nose 208 being driven into the recessed portion 302 to form the secondary MTM seal 312. As discussed herein, the illustrated outer region 310 extends above the recessed portion 302, and as a result, the primary MTM seal 308 is positioned radially upward and away from the recessed portion 302. Further illustrated is the formation of the secondary MTM seal 312 at the sealing faces 326, 328. Accordingly, multiple locations may be used to form the primary MTM seal 308 while still forming the secondary MTM seal 312 to provide bi-directional sealing capabilities.

[0050] FIG. 5F illustrates a sectional view of the seal area 500 illustrating the primary MTM seal 308 at the outer region 310 and the nose 208 being driven into the recessed portion 302 to form the secondary MTM seal 312. As discussed herein, the illustrated outer region 310 is now axially closer to the recessed portion 302, when compared to the configuration in FIG. 5E. Further illustrated is the formation of the secondary MTM seal 312 at the sealing faces 326, 328. Accordingly, multiple locations may be used to form the primary MTM seal 308 while still forming the secondary MTM seal 312 to provide bi-directional sealing capabilities.

[0051] Embodiments may also be described in view of the following clauses:

1. A wellbore system, comprising:

a mandrel hanger body, comprising:

a recessed portion;

a primary sealing surface;

a secondary sealing surface forming at least a part of the recessed portion; and

a retaining skirt; and

an associated tool component configured to couple to the mandrel hanger body, comprising:

a nose including a first nose sealing surface and a second nose sealing surface;

wherein the nose is configured to be positioned, at least in part, within the recessed portion such that the primary sealing surface engages the first nose sealing surface to form a first metal to metal seal and the secondary sealing surface engages the second nose sealing surface to form a second metal to metal seal.

2. The wellbore system of clause 1, wherein the secondary sealing surface is a sloped surface.

3. The wellbore system of clause 2, wherein the sloped surface is a reverse rake.

4. The wellbore system of clause 1, wherein the nose is a flexible metallic component that elastically deforms to form the first metal to metal seal and the second metal to metal seal.

5. The wellbore system of clause 1, wherein the retaining skirt is configured to block radial inward collapse of the nose responsive to a radially inward force.

6. The wellbore system of clause 1, wherein the first metal to metal seal is configured to resist pressure from a first direction and the second metal to metal seal is configured to resist pressure from a second direction, the first direction being opposite the second direction.

7. The wellbore system of clause 1, wherein the second nose sealing surface includes at least one of a flat, a bump, or a radius.

8. The wellbore system of clause 1, wherein the recessed portion further comprises a void extending, at least in part, axially lower than the secondary sealing surface.

9. The wellbore system of clause 1, further comprising:

a third metal to metal seal formed between a third nose sealing surface and a third sealing surface of the recessed portion positioned, at least in part, on the retaining skirt.

10. The wellbore system of clause 1, wherein the associated tool component is at least one of a running tool or a tieback tool.

11. The wellbore system of clause 10, wherein the nose forms a portion of the running tool and the first metal to metal seal is formed proximate the recessed portion.

12. The wellbore system of clause 10, wherein the nose forms a portion of the tieback tool and the first metal to metal seal is formed axially higher than the recessed portion.

13. A sealing system, comprising:

a first sealing surface associated with a first wellbore component, the first sealing surface arranged along an outer region of the first wellbore component;

a second sealing surface associated with the first wellbore component, the second sealing surface arranged within a recess formed in the first wellbore component;

a third sealing surface associated with a second wellbore component, the third sealing surface arranged along an outer diameter of the second wellbore component; and

a fourth sealing surface associated with the second wellbore component, the fourth sealing surface arranged along a base region of the second wellbore component;

wherein the second wellbore component is coupled to the first wellbore component to drive the third sealing surface against the first sealing surface to establish a first seal and to drive the fourth sealing surface against the second sealing surface to establish a second seal, and wherein the first seal is configured to resist a bore pressure and the second seal is configured to resist a tubing and casing annulus pressure.

14. The sealing system of clause 13, wherein each of the first seal and the second seal are metal to metal seals.

15. The sealing system of clause 13, wherein the fourth sealing surface includes at least one of a flat, a bump, or a radius.

16. The sealing system of clause 13, wherein the second sealing surface is a sloped surface in a reverse rake configuration.

17. The sealing system of clause 13, further comprising a void space axially lower than the second sealing surface.

18. A system for establishing a bi-directional metal to metal seal between a first downhole component and a second downhole component, comprising:

a first metal to metal seal between the first downhole component and the second downhole component, the first metal to metal seal formed at a first contact location between a first sealing surface along an outer region of the first downhole component and a second sealing surface along an outer diameter of the second downhole component; and

a second metal to metal seal between the first downhole component and the second downhole component, the second metal to metal seal formed at a second contact location between a third sealing surface within a recessed portion of the first downhole component and a fourth sealing surface along a base region of the second downhole component;

wherein each of the first metal to metal seal and the second metal to metal seal are configured to resist pressure from an opposite radial direction.

19. The system of clause 18, wherein the fourth sealing surface includes at least one of a flat, a bump, or a radius.

20. The system of clause 18, wherein the third sealing surface is a sloped surface.

21. A wellbore system, comprising:

a mandrel hanger body, comprising:

a recessed portion;

a primary sealing surface;

a secondary sealing surface forming at least a part of the recessed portion; and

a retaining skirt; and

an associated tool component configured to couple to the mandrel hanger body, comprising:

a nose including a first nose sealing surface and a second nose sealing surface;

wherein the nose is configured to be positioned, at least in part, within the recessed portion such that the primary sealing surface engages the first nose sealing surface to form a first metal to metal seal and the secondary sealing surface engages the second nose sealing surface to form a second metal to metal seal.

22. The wellbore system of clause 21, wherein the secondary sealing surface is a sloped surface.

23. The wellbore system of clause 22, wherein the sloped surface is a reverse rake.

24. The wellbore system of any of clauses 21-23, wherein the nose is a flexible metallic component that elastically deforms to form the first metal to metal seal and the second metal to metal seal.

25. The wellbore system of any of clauses 21-24, wherein the retaining skirt is configured to block radial inward collapse of the nose responsive to a radially inward force.

26. The wellbore system of any of clauses 21-25, wherein the first metal to metal seal is configured to resist pressure from a first direction and the second metal to metal seal is configured to resist pressure from a second direction, the first direction being opposite the second direction.

27. The wellbore system of any of clauses 21-26, wherein the second nose sealing surface includes at least one of a flat, a bump, or a radius.

28. The wellbore system of any of clauses 21-27, wherein the recessed portion further comprises a void extending, at least in part, axially lower than the secondary sealing surface.

29. The wellbore system of any of clauses 21-28, further comprising:

a third metal to metal seal formed between a third nose sealing surface and a third sealing surface of the recessed portion positioned, at least in part, on the retaining skirt.

30. The wellbore system of any of clauses 21-29, wherein the associated tool component is at least one of a running tool or a tieback tool.

31. The wellbore system of clause 30, wherein the nose forms a portion of the running tool and the first metal to metal seal is formed proximate the recessed portion.

32. The wellbore system of clause 30, wherein the nose forms a portion of the tieback tool and the first metal to metal seal is formed axially higher than the recessed portion.

33. A sealing system, comprising:

a first sealing surface associated with a first wellbore component, the first sealing surface arranged along an outer region of the first wellbore component;

a second sealing surface associated with the first wellbore component, the second sealing surface arranged within a recess formed in the first wellbore component;

a third sealing surface associated with a second wellbore component, the third sealing surface arranged along an outer diameter of the second wellbore component; and

a fourth sealing surface associated with the second wellbore component, the fourth sealing surface arranged along a base region of the second wellbore component;

wherein the second wellbore component is coupled to the first wellbore component to drive the third sealing surface against the first sealing surface to establish a first seal and to drive the fourth sealing surface against the second sealing surface to establish a second seal, and

wherein the first seal is configured to resist a bore pressure and the second seal is configured to resist a tubing and casing annulus pressure.

34. The sealing system of clause 33, wherein each of the first seal and the second seal are metal to metal seals.

35. The sealing system of any of clauses 33 or 34, wherein the fourth sealing surface includes at least one of a flat, a bump, or a radius.

36. The sealing system of any of clauses 33-35, wherein the second sealing surface is a sloped surface in a reverse rake configuration.

37. The sealing system of any of clauses 33-36, further comprising a void space axially lower than the second sealing surface.

38. A system for establishing a bi-directional metal to metal seal between a first downhole component and a second downhole component, comprising:

a first metal to metal seal between the first downhole component and the second downhole component, the first metal to metal seal formed at a first contact location between a first sealing surface along an outer region of the first downhole component and a second sealing surface along an outer diameter of the second downhole component; and

a second metal to metal seal between the first downhole component and the second downhole component, the second metal to metal seal formed at a second contact location between a third sealing surface within a recessed portion of the first downhole component and a fourth sealing surface along a base region of the second downhole component;

wherein each of the first metal to metal seal and the second metal to metal seal are configured to resist pressure from an opposite radial direction.

39. The system of clause 38, wherein the fourth sealing surface includes at least one of a flat, a bump, or a radius.

40. The system of any of clauses 38 or 39, wherein the third sealing surface is a sloped surface.

[0052] The foregoing disclosure and description of the disclosed embodiments is illustrative and explanatory of the embodiments of the disclosure. Various changes in the details of the illustrated embodiments can be made within the scope of the appended claims without departing from the true spirit of the disclosure. The embodiments of the present disclosure should only be limited by the following claims and their legal equivalents.

CLAIMS

1. A wellbore system, comprising:

a mandrel hanger body (202), comprising:

a recessed portion (302);

a primary sealing surface (322);

a secondary sealing surface (326) forming at least a part of the recessed portion (302); and

a retaining skirt (330); and

an associated tool component (204) configured to couple to the mandrel hanger body (202), comprising:

a nose (208) including a first nose sealing surface (320) and a second nose sealing surface (328);

wherein the nose (308) is configured to be positioned, at least in part, within the recessed portion (302) such that the primary sealing surface (322) engages the first nose sealing surface (320) to form a first metal to metal seal (308) and the secondary sealing surface (326) engages the second nose sealing surface (328) to form a second metal to metal seal (312).

2. The wellbore system of claim 1, wherein the secondary sealing surface (326) is a sloped surface.

3. The wellbore system of claim 2, wherein the sloped surface is a reverse rake.

4. The wellbore system of claim 1, wherein the nose (308) is a flexible metallic component that elastically deforms to form the first metal to metal seal (308) and the second metal to metal seal (312).

5. The wellbore system of claim 1, wherein the retaining skirt (330) is configured to block radial inward collapse of the nose (208) responsive to a radially inward force.

6. The wellbore system of claim 1, wherein the first metal to metal seal (308) is configured to resist pressure from a first direction and the second metal to metal seal (312) is

configured to resist pressure from a second direction, the first direction being opposite the second direction.

7. The wellbore system of claim 1, wherein the second nose sealing surface (328) includes at least one of a flat (402), a bump (406), or a radius (404).

8. The wellbore system of claim 1, wherein the recessed portion (302) further comprises a void (332) extending, at least in part, axially lower than the secondary sealing surface (326).

9. The wellbore system of claim 1, further comprising:

a third metal to metal seal (316) formed between a third nose sealing surface and a third sealing surface of the recessed portion positioned, at least in part, on the retaining skirt (330).

10. The wellbore system of claim 1, wherein the associated tool component (204) is at least one of a running tool or a tieback tool.

11. The wellbore system of claim 10, wherein the nose (208) forms a portion of the running tool and the first metal to metal seal (308) is formed proximate the recessed portion (302).

12. The wellbore system of claim 10, wherein the nose (208) forms a portion of the tieback tool and the first metal to metal seal (308) is formed axially higher than the recessed portion (302).

13. A sealing system, comprising:

a first sealing surface (322) associated with a first wellbore component (202), the first sealing surface (322) arranged along an outer region (310) of the first wellbore component (202);

a second sealing surface (326) associated with the first wellbore component (202), the second sealing surface (326) arranged within a recess (302) formed in the first wellbore component (202);

a third sealing surface (320) associated with a second wellbore component (204), the third sealing surface (320) arranged along an outer diameter of the second wellbore component (204); and

a fourth sealing surface (328) associated with the second wellbore component (204), the fourth sealing surface arranged (328) along a base region (314) of the second wellbore component (204);

wherein the second wellbore component (204) is coupled to the first wellbore component (202) to drive the third sealing surface (320) against the first sealing surface (322) to establish a first seal (308) and to drive the fourth sealing surface (328) against the second sealing surface (326) to establish a second seal (312), and wherein the first seal (308) is configured to resist a bore pressure and the second seal (312) is configured to resist a tubing and casing annulus pressure.

14. The sealing system of claim 13, wherein each of the first seal (308) and the second seal (312) are metal to metal seals.

15. The sealing system of claim 13, wherein the fourth sealing surface (328) includes at least one of a flat (402), a bump (406), or a radius (404).

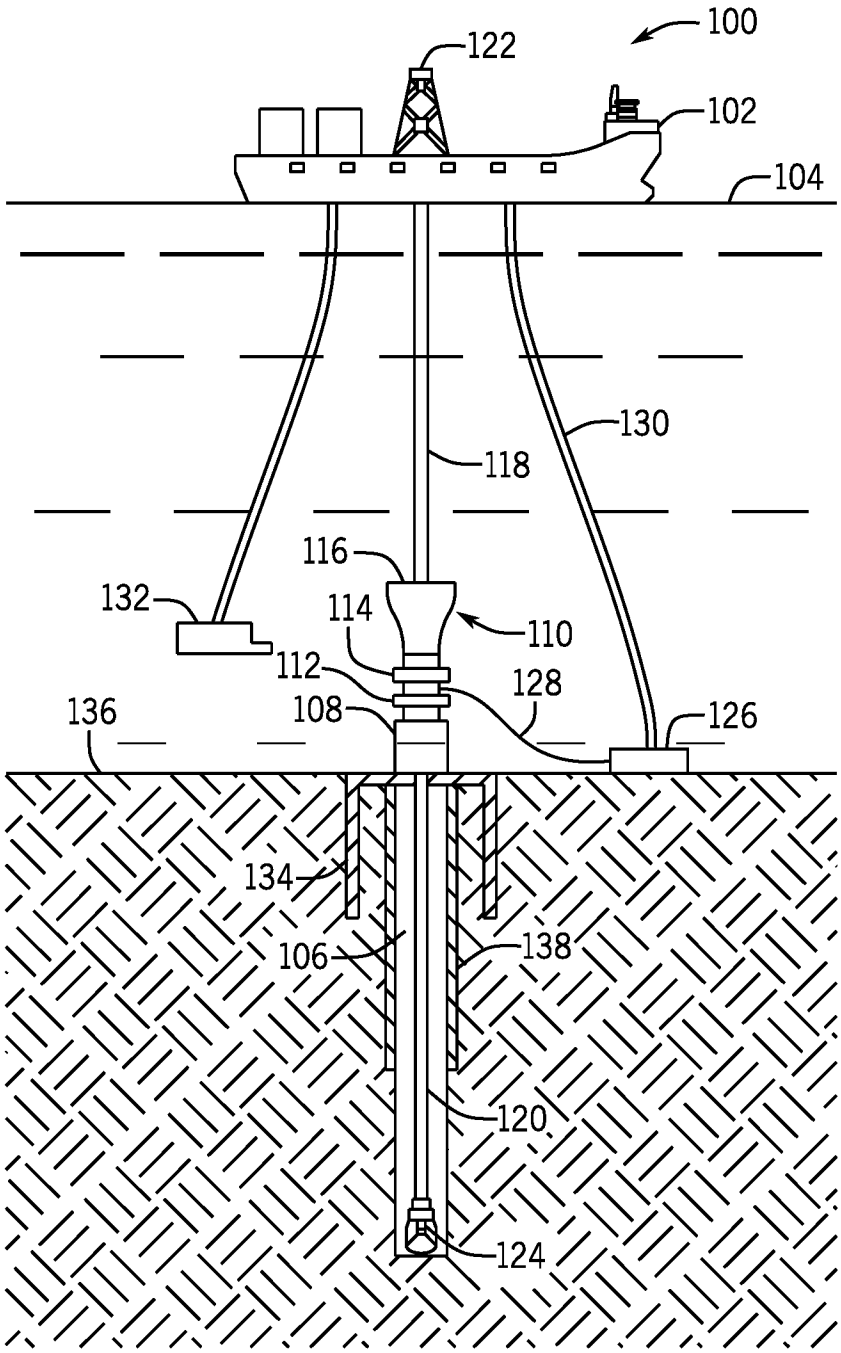

100
122
102
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136
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126
134
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138
120
124

FIG. 1A

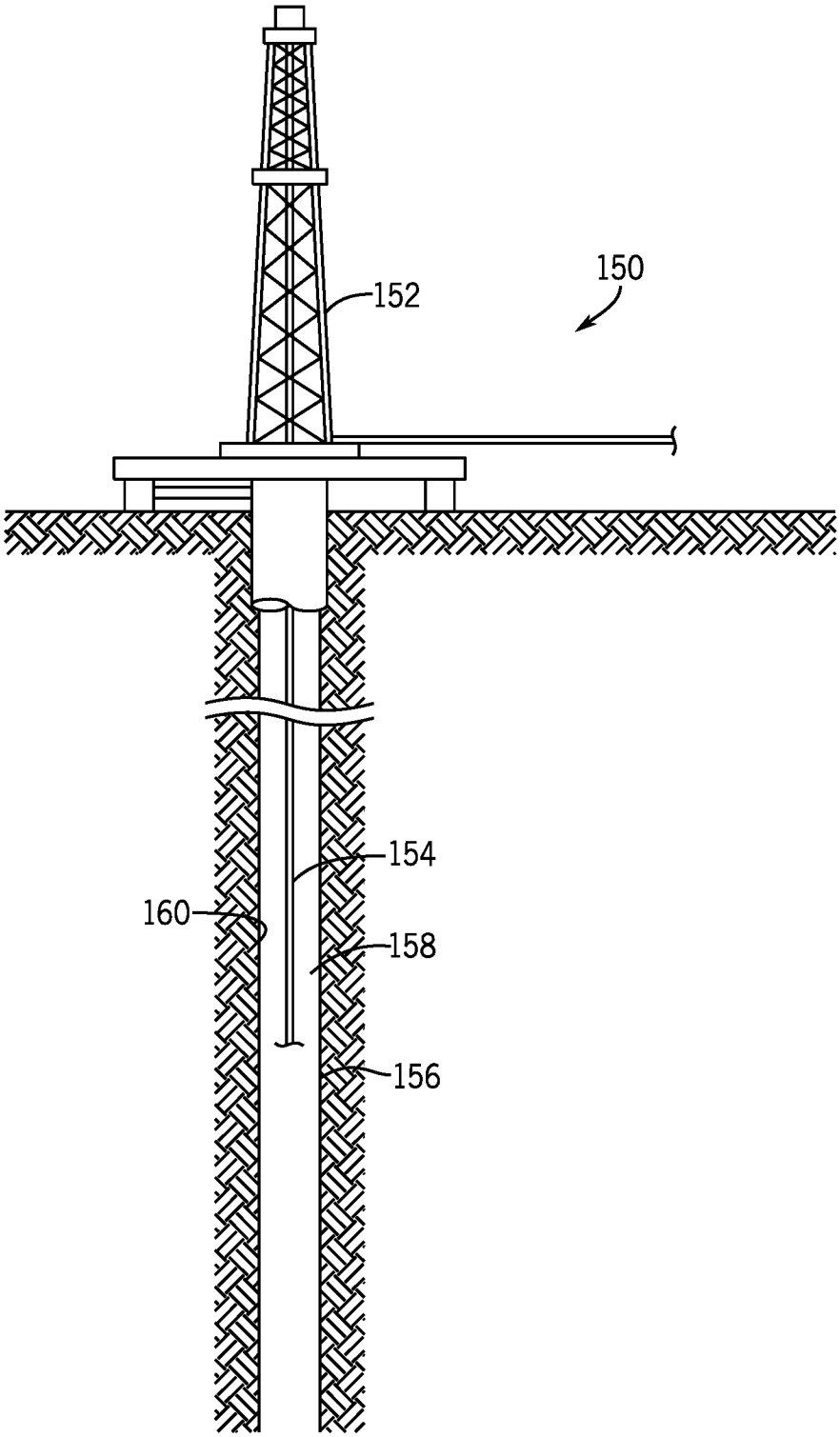


FIG. 1B

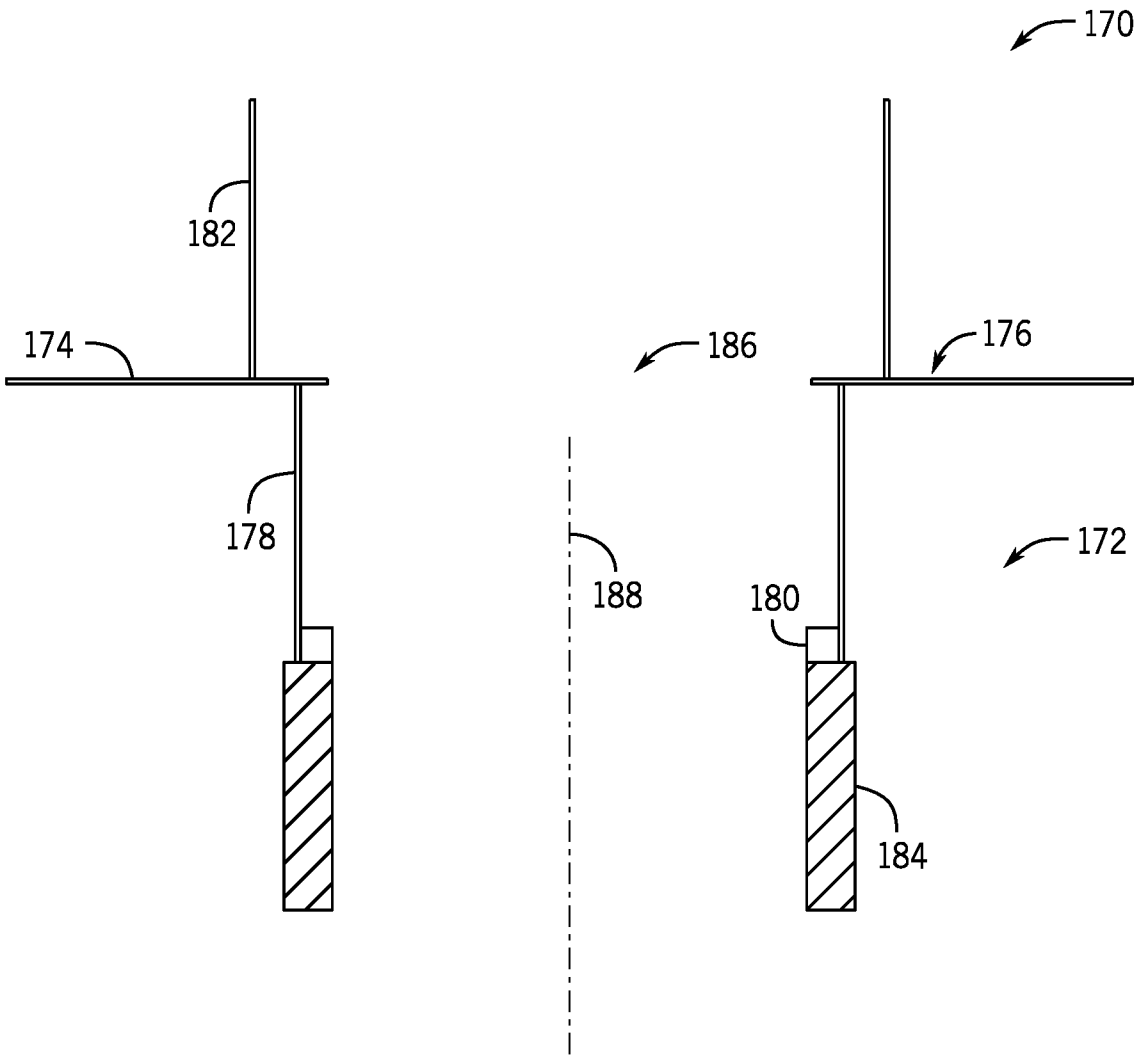


FIG. 1C

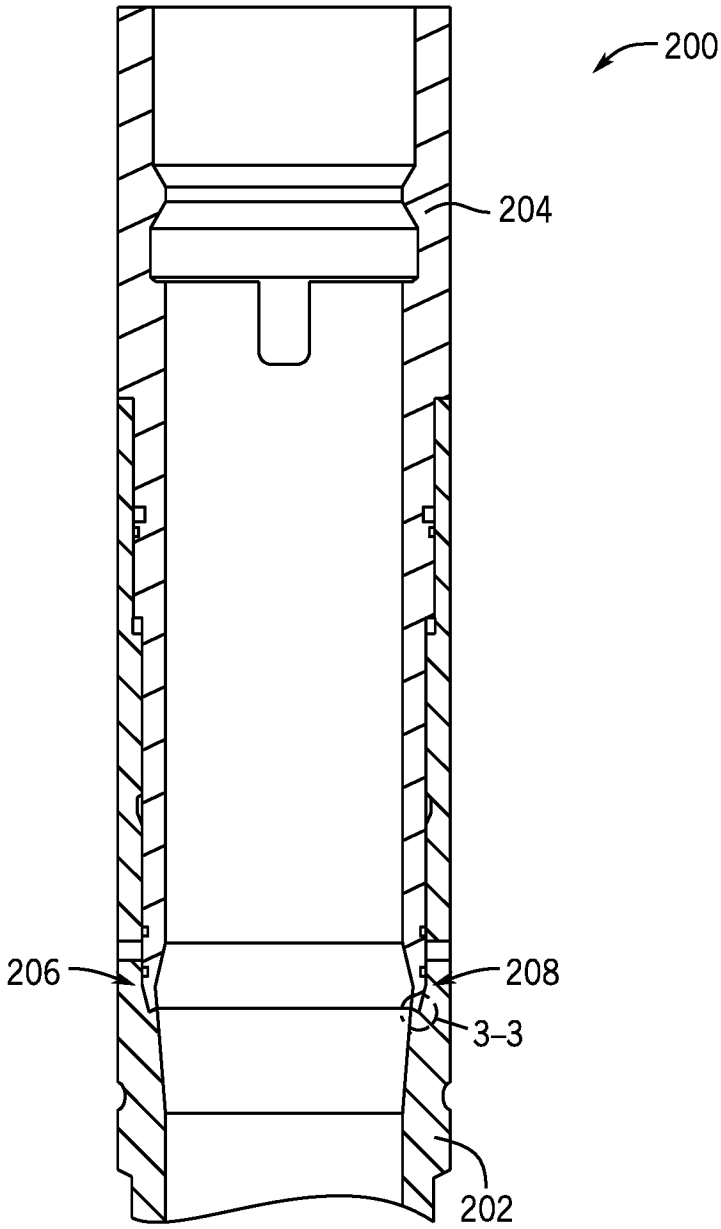


FIG. 2

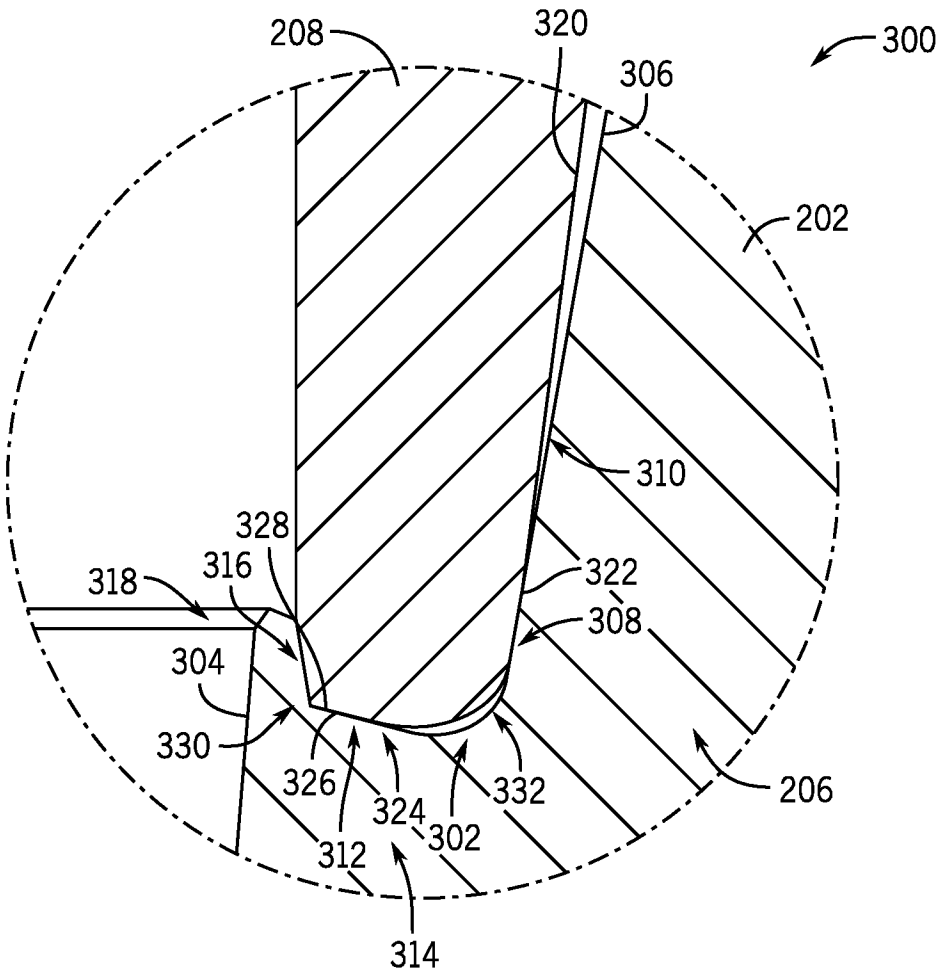

208
320
300
306
202
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328
316
318
322
308
304
330
326
324
332
206
312
302
314

FIG. 3

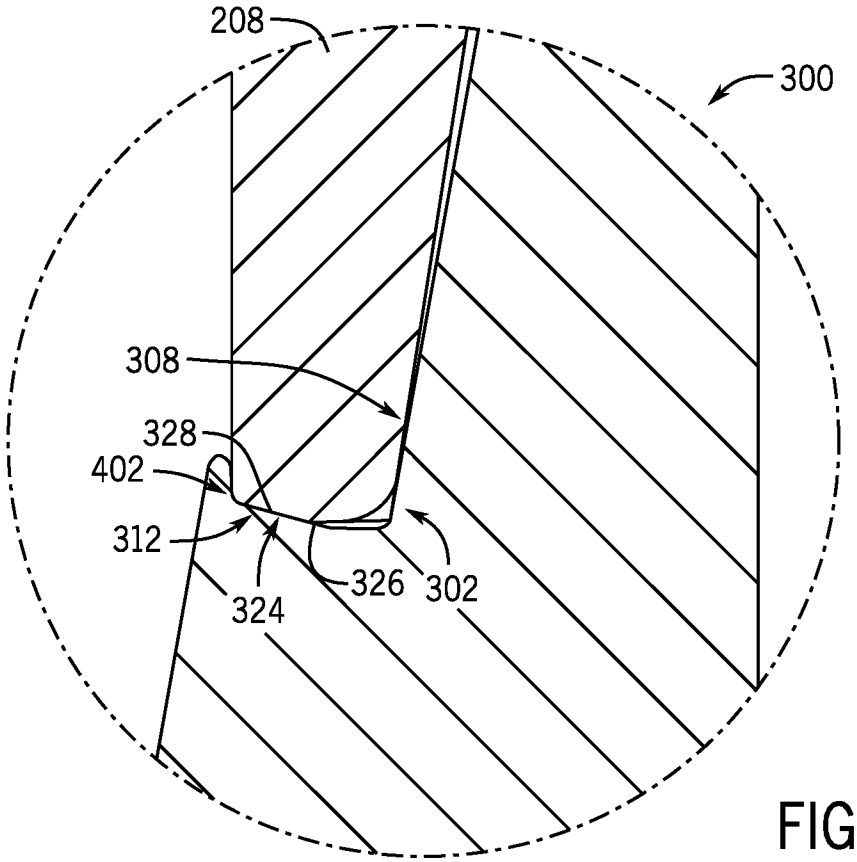

208
300
308
328
402
312
324
326
302

FIG. 4A

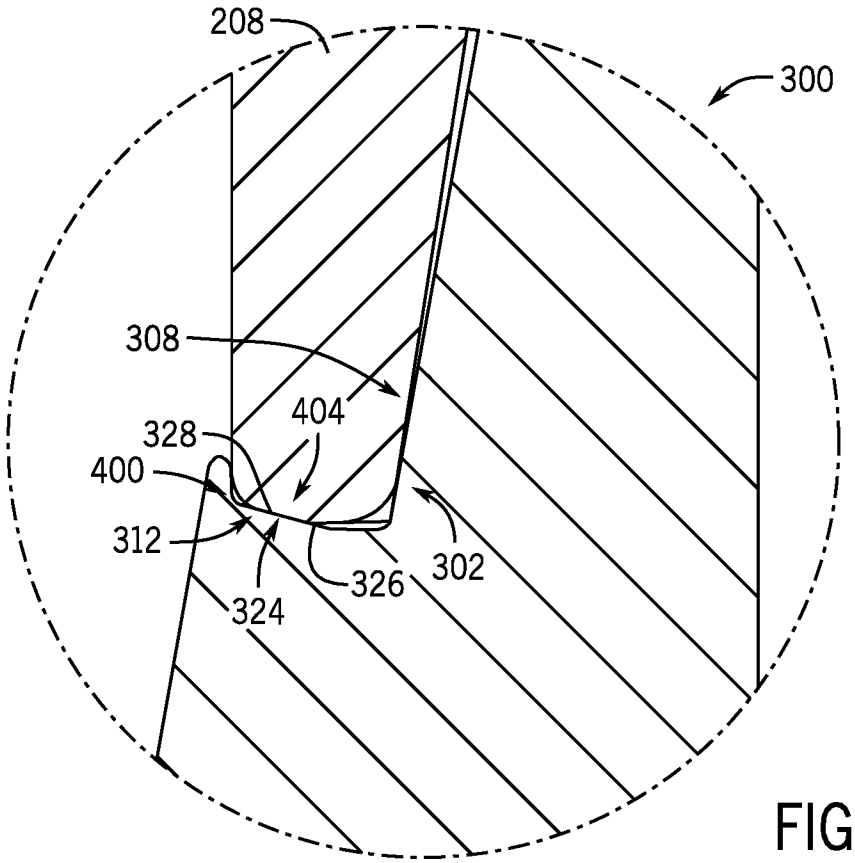

208
300
308
404
328
400
312
324
326
302

FIG. 4B

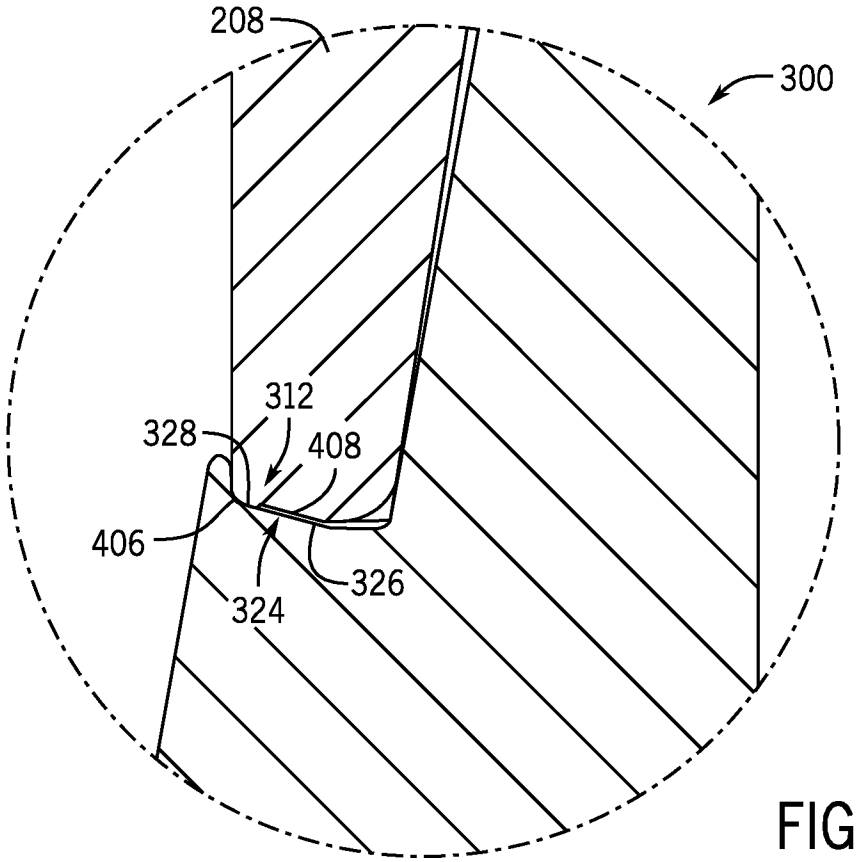


FIG. 4C

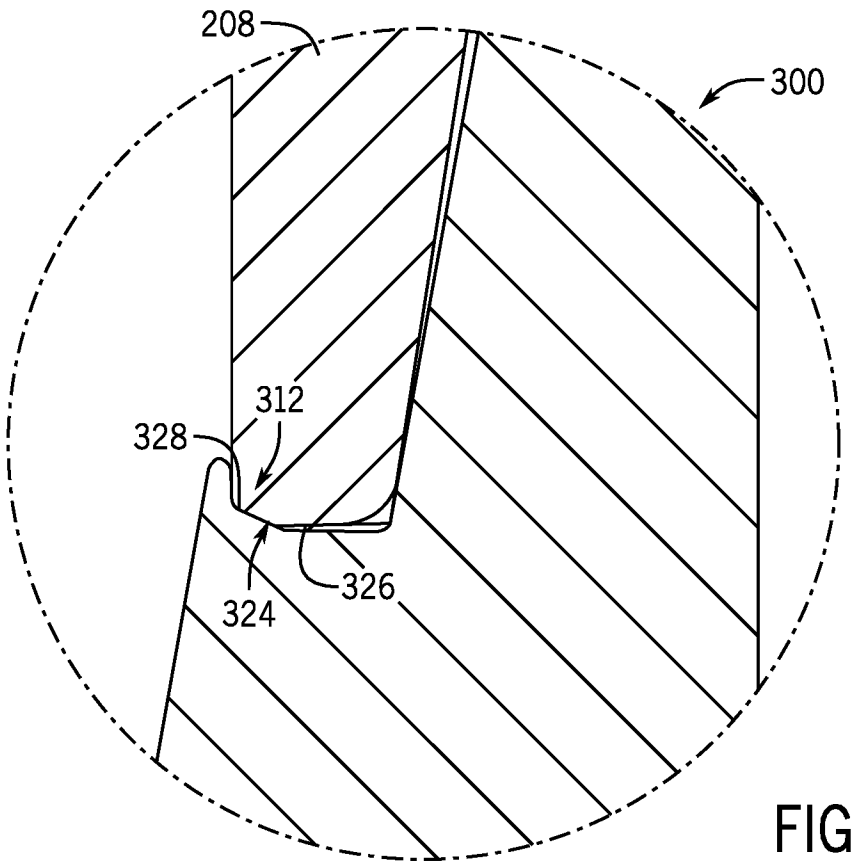
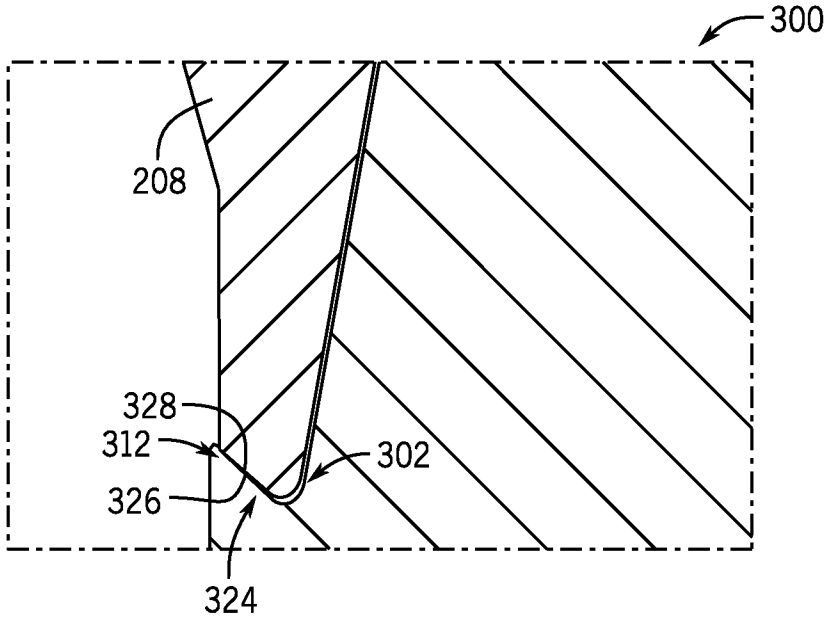


FIG. 4D

FIG. 4E


300
208
328
312
326
302
324

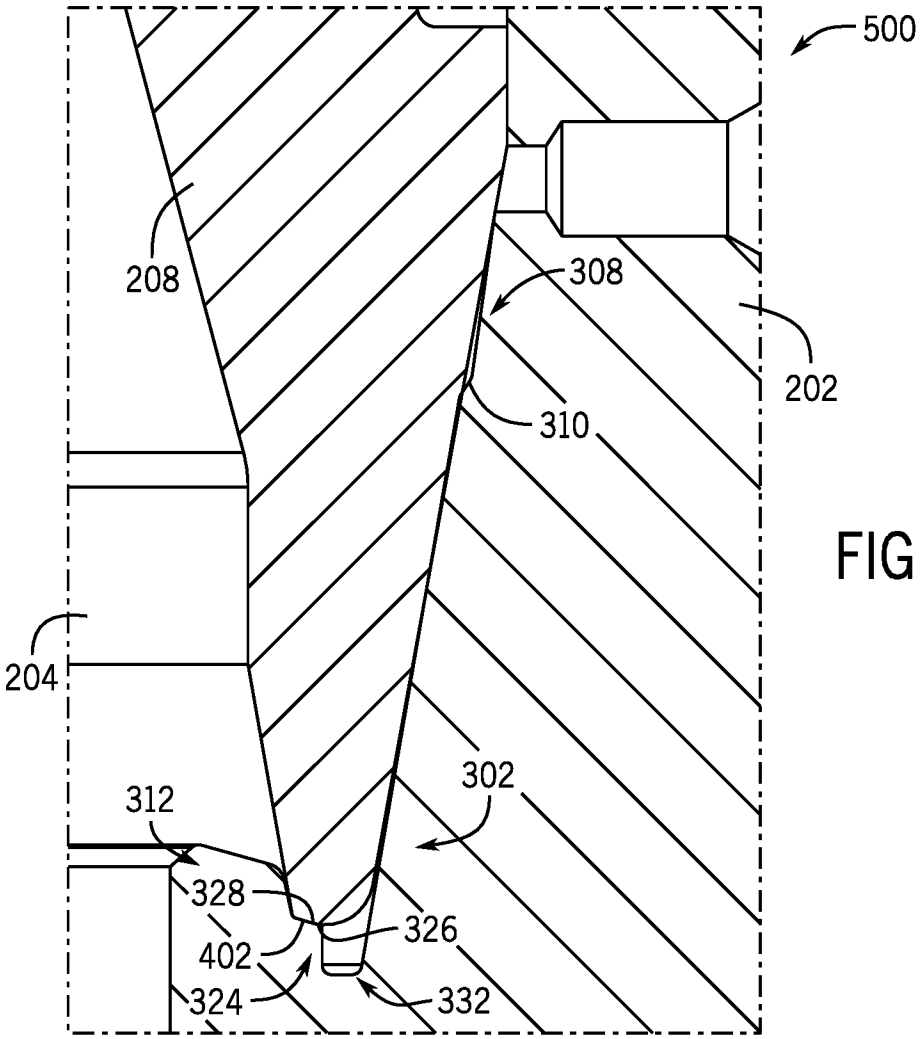

500
208
308
202
310
204
302
312
328
326
402
324
332

FIG. 5A

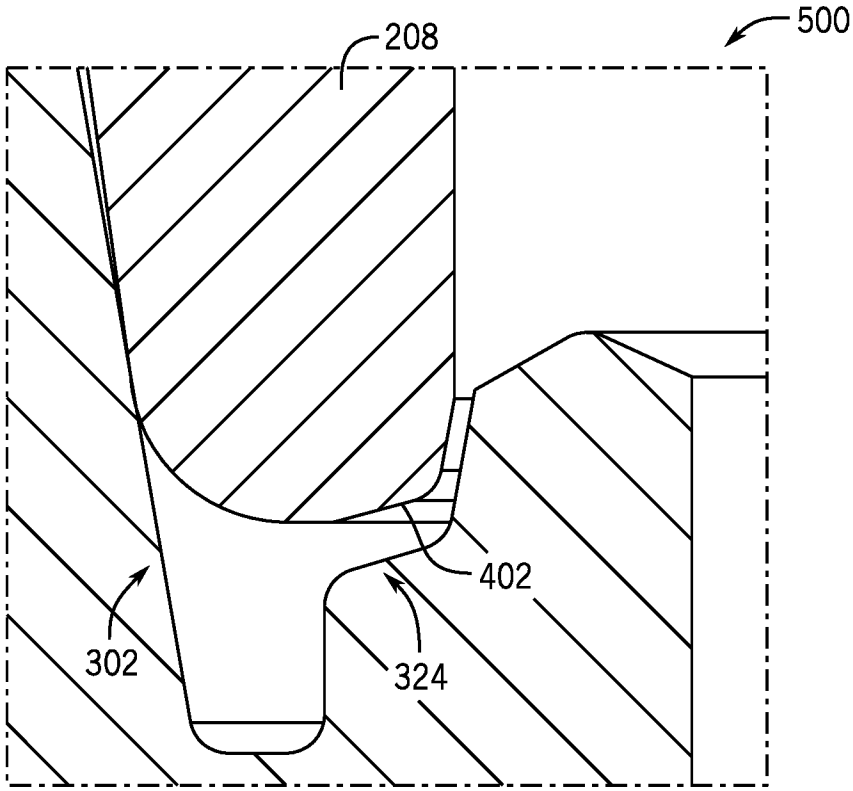


FIG. 5B

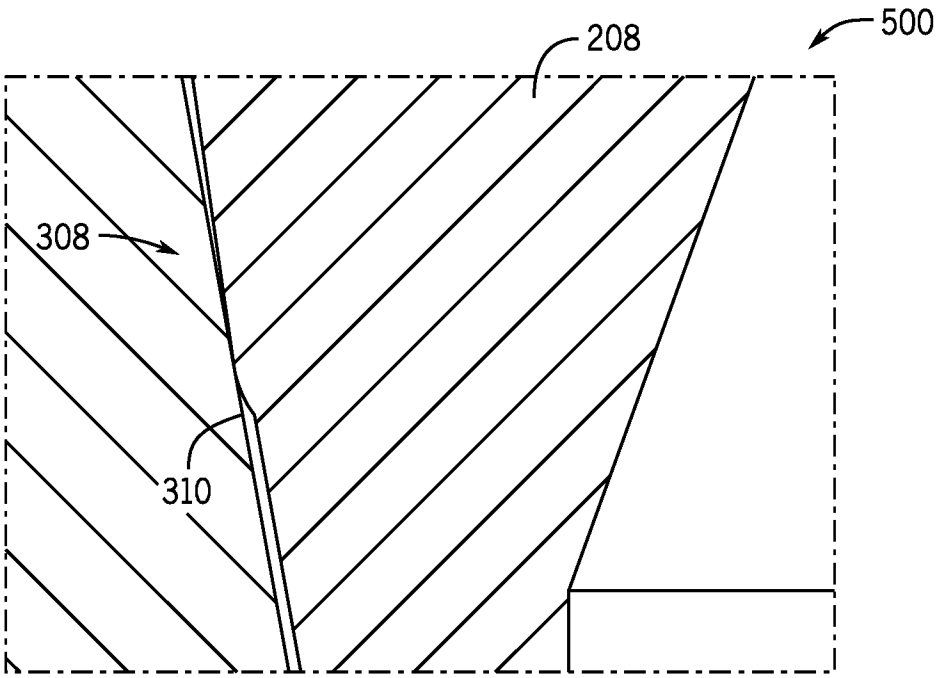


FIG. 5C

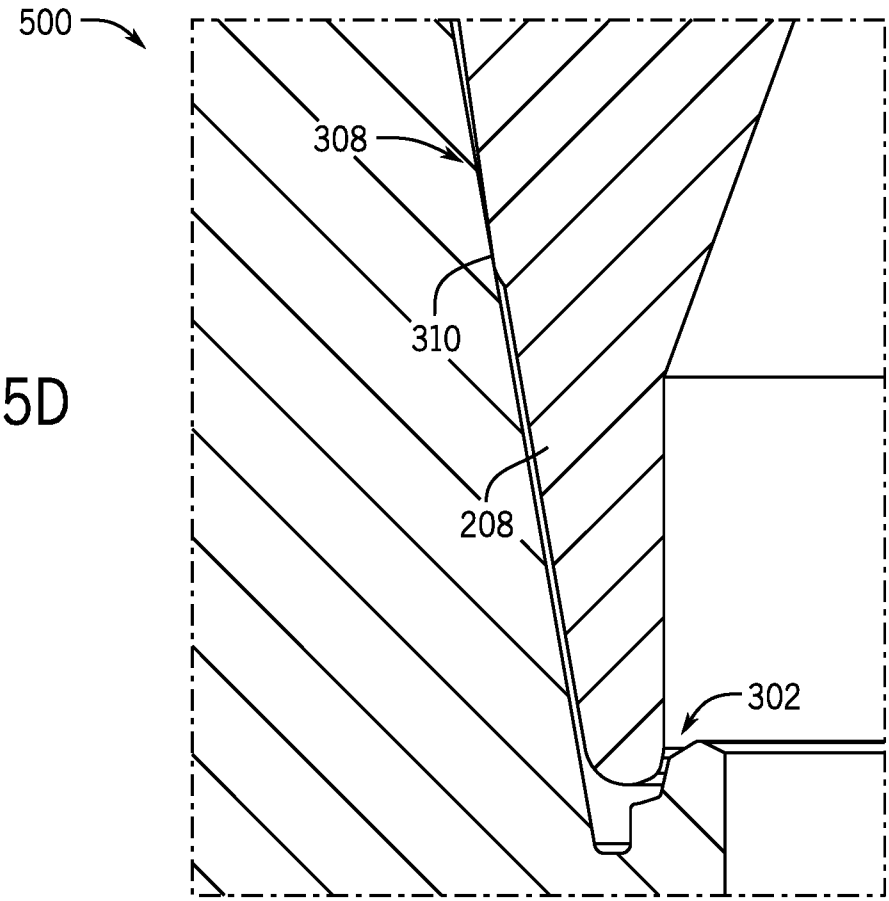


FIG. 5D

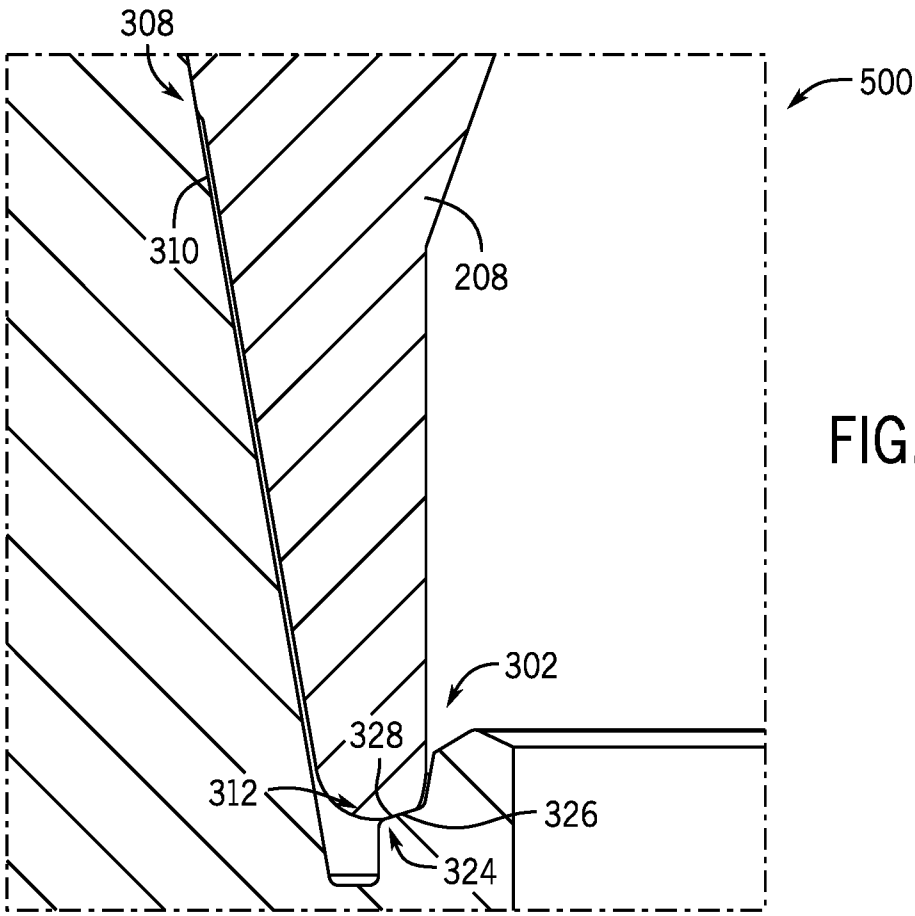


FIG. 5E

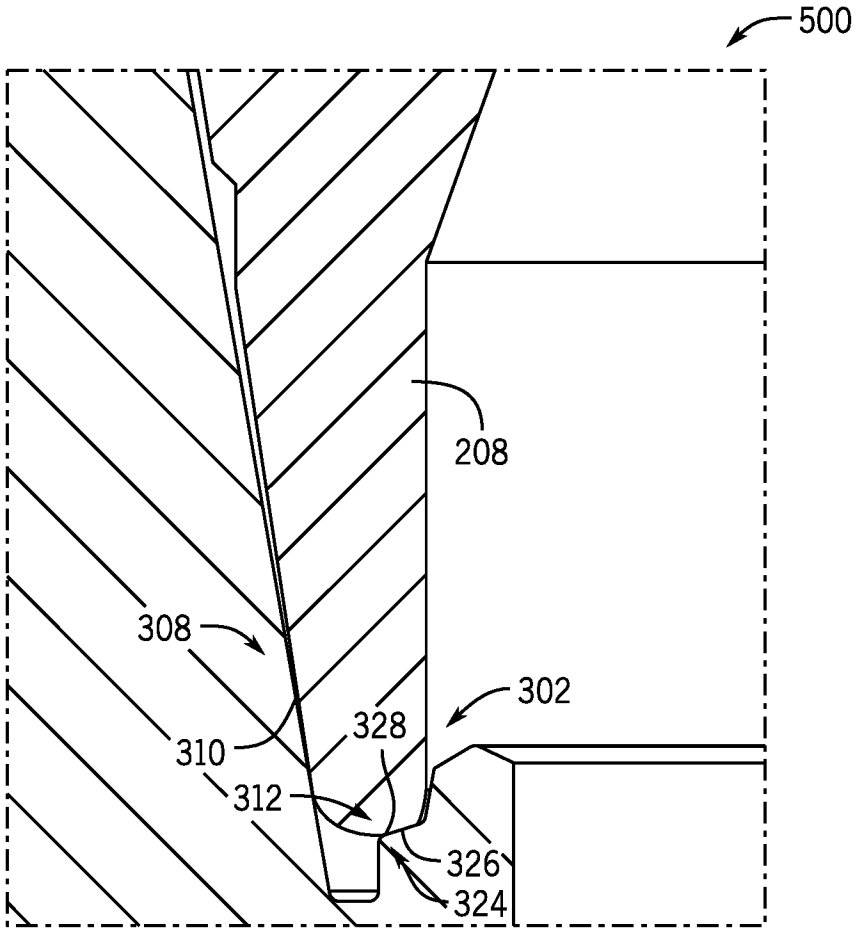


FIG. 5F

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/054969

A. CLASSIFICATION OF SUBJECT MATTER

E21B 33/12(2006.01)i; **E21B 17/04**(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)

E21B 33/12(2006.01); E21B 17/042(2006.01); E21B 17/08(2006.01); E21B 33/038(2006.01); E21B 33/04(2006.01); E21B 33/043(2006.01); E21B 33/10(2006.01); F16L 15/00(2006.01)

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: wellbore system, mandrel hanger body, recessed portion, sealing surface, retaining skirt, running tool, tieback tool, nose, metal to metal seal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015-0260001 A1 (KUO et al.) 17 September 2015 (2015-09-17) paragraphs [0050], [0071], [0076], [0081]-[0082] and figures 5A-5E	1-10,12-15
Y		11
Y	US 2016-0069150 A1 (CAMERON INTERNATIONAL CORPORATION) 10 March 2016 (2016-03-10) paragraph [0048] and figures 9-10	11
A	US 2016-0281441 A1 (ULTRA PREMIUM OILFIELD SERVICES, LTD.) 29 September 2016 (2016-09-29) paragraphs [0039]-[0042] and figure 5	1-15
A	US 2009-0322030 A1 (PALLINI, JR. et al.) 31 December 2009 (2009-12-31) paragraphs [0021]-[0028] and figures 3-4	1-15

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
19 February 2025	**19 February 2025**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/054969

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2015-0145247 A1 (VETCO GRAY INC.) 28 May 2015 (2015-05-28) paragraphs [0030]-[0035] and figures 5-7	1-15

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/054969

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2015-0260001 A1	17 September 2015	BR 112014032720 A2	27 June 2017
		BR 112014032720 B1	17 February 2021
		CA 2877921 A1	03 January 2014
		CA 2877921 C	30 May 2017
		EP 2867444 A1	06 May 2015
		MX 2015000228 A	10 April 2015
		MX 350502 B	07 September 2017
		US 9580986 B2	28 February 2017
		WO 2014-003745 A1	03 January 2014
US 2016-0069150 A1	10 March 2016	BR 112012020158 A2	24 September 2019
		EP 2357315 A1	17 August 2011
		EP 2357315 B1	02 April 2014
		EP 2690250 A1	29 January 2014
		SG 182727 A1	30 August 2012
		SG 193781 A1	30 October 2013
		US 10132132 B2	20 November 2018
		US 2013-0056282 A1	07 March 2013
		US 9133679 B2	15 September 2015
		WO 2011-102877 A1	25 August 2011
US 2016-0281441 A1	29 September 2016	AR 094616 A1	12 August 2015
		AU 2014-215661 A1	10 September 2015
		AU 2014-215661 B2	05 January 2017
		AU 2017-202254 A1	27 April 2017
		AU 2017-202254 B2	17 May 2018
		BR 112015018602 A2	24 January 2017
		BR 112015018602 B1	10 April 2018
		CA 2900152 A1	14 August 2014
		CA 2900152 C	07 March 2017
		CN 104968883 A	07 October 2015
		CN 104968883 B	07 December 2018
		GB 2526963 A	09 December 2015
		GB 2526963 B	05 April 2017
		GB 2545578 A	21 June 2017
		GB 2545578 B	06 December 2017
		HK 1215878 A1	23 September 2016
		JP 2016-513216 A	12 May 2016
		JP 6267236 B2	24 January 2018
		KR 10-2015-0114493 A	12 October 2015
		KR 10-2217604 B1	18 February 2021
		MX 2015009814 A	30 October 2015
		MX 345933 B	24 February 2017
		PL 413905 A1	16 August 2016
		RU 2015137167 A	13 March 2017
		RU 2628356 C2	16 August 2017
		SA 515360848 B1	23 December 2018
		SG 10201604647 A	28 July 2016
		SG 11201506085 A	29 September 2015
		UA 114741 C2	25 July 2017
		US 10053924 B2	21 August 2018
		US 2014-0217725 A1	07 August 2014

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/054969

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
		US 9388925 B2	12 July 2016
		UY 35303 A	29 August 2014
		WO 2014-123718 A1	14 August 2014
US 2009-0322030 A1	31 December 2009	AU 2009-267242 A1	07 January 2010
		AU 2009-267242 B2	16 July 2015
		BR PI0910135 A2	29 December 2015
		BR PI0910135 B1	11 December 2018
		GB 2473387 A	09 March 2011
		GB 2473387 B	27 June 2012
		GB 2485720 A	23 May 2012
		GB 2485720 B	09 January 2013
		GB 2485721 A	23 May 2012
		GB 2485721 B	05 September 2012
		MY 156038 A	31 December 2015
		NO 20110016 A1	17 January 2011
		NO 344329 B1	04 November 2019
		US 2009-0322029 A1	31 December 2009
		US 8096560 B2	17 January 2012
		US 8226089 B2	24 July 2012
		WO 2010-002686 A1	07 January 2010
US 2015-0145247 A1	28 May 2015	BR 112016011465 A8	05 May 2020
		BR 112016011465 B1	19 October 2021
		CN 105980755 A	28 September 2016
		CN 105980755 B	22 January 2019
		GB 2535078 A	10 August 2016
		GB 2535078 B	11 April 2018
		SG 11201603474 A	30 May 2016
		US 10428594 B2	01 October 2019
		WO 2015-077464 A2	28 May 2015
		WO 2015-077464 A3	01 October 2015
		WO 2015-077464 A8	23 June 2016