



(51) International Patent Classification:

E21B 47/12 (2012.01) *E21B 17/10* (2006.01)
E21B 17/00 (2006.01)

(21) International Application Number:

PCT/US2019/045159

(22) International Filing Date:

05 August 2019 (05.08.2019)

(25) Filing Language:

English

(26) Publication Language:

English

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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.

(54) Title: DATA TRANSMISSION SYSTEM

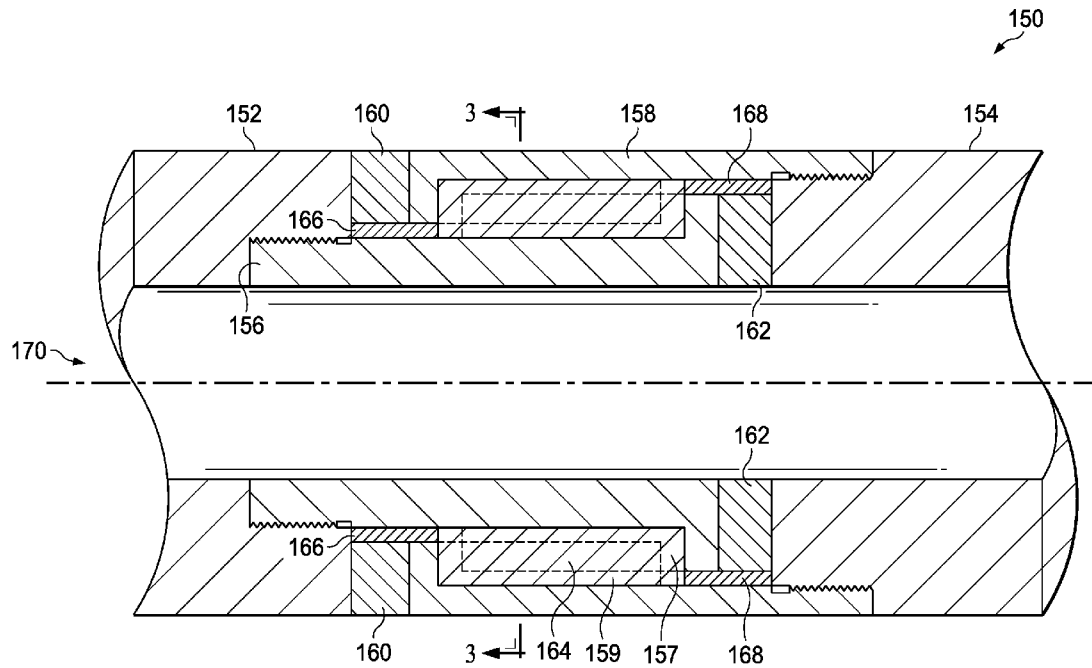


FIG. 2

(57) Abstract: A gap sub uses a plurality of insulating members in conjunction with at least two metallic members to effect a mechanically and electrically robust configuration. The gap sub includes an upper end portion, a lower end portion, an outer sleeve, an inner sleeve, an insulating outer washer, an insulating inner washer, and an insulating spider. The insulating outer washer is configured to transfer a first axial load between the upper end portion and the outer sleeve. The insulating inner washer is configured to transfer a second axial load between the inner sleeve and the lower end portion. The insulating spider is configured to transfer a torsional load between outer sleeve and the inner sleeve. Because the insulating washers are utilized to transfer axial loads and the insulating spider is utilized to transfer torsional loads, each insulator may be manufactured so that the strongest axis of the material can be optimally and advantageously oriented to be coincident with the forces applied to each insulator, thereby making the gap sub more mechanically



(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, 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).

Published:

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

DATA TRANSMISSION SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates generally to data transmission systems, and more particularly, to electromagnetic (EM) data transmission systems for use within wellbores.

BACKGROUND

[0002] Wells are drilled to facilitate the extraction of hydrocarbons from a formation. During the drilling of a well, various drilling parameters can be monitored to adjust and optimize drilling operations. For example, sensors may be utilized to monitor parameters for steering a drill bit, measurements for the optimization of drilling efficiency, formation electrical resistivity, downhole pressure, direction and inclination of the drill bit, torque on bit, weight on bit, etc. During operation, sensor readings or data from the downhole sensors can be transmitted to the surface for monitoring, analysis, decision-making, and otherwise controlling drilling operations.

[0003] Drilling systems can transmit data from downhole sensors to a surface location for the above-mentioned purposes. For example, a drilling system can transmit data from a downhole location by introducing an electrical gap between the two ends of the drill string and emitting an electric field from the gap to transmit data to the surface. However, one drawback of conventional EM data transmission systems is that introducing an electrical gap into the drill string mechanically weakens the drill string, as the electrical gap is often created by sandwiching insulating materials between two separate metallic sections of one or more drill collars. During operation, the insulating material may be subject to torsional, compressional, and cyclical bending stresses under load. In some applications, low modulus insulating materials can plastically deform over time, while high modulus insulating materials may fracture, with both failures causing mechanical and/or electrical failure of the gap.

[0004] Further, EM data transmission systems may transmit at a low broadcast signal strength when operated on batteries, causing susceptibility to electrical noise that interferes with the detection and demodulation of the surface signal. Compounded with mechanical and/or electrical failure of the gap, as described above, battery operation can result in a severe reduction in transmitted signal strength. Therefore, what is needed is an apparatus, system or method that addresses one or more of the foregoing issues, among one or more other issues.

SUMMARY OF THE INVENTION

[0005] A gap sub is disclosed that uses a plurality of insulating members in conjunction with at least two metallic members to effect a mechanically and electrically robust configuration. The gap sub includes an upper end portion, a lower end portion, an outer sleeve, an inner sleeve, an insulating outer washer, an insulating inner washer, and an insulating spider. The outer sleeve includes a plurality of outer blades extending radially inward from an inner diameter of the outer sleeve. The inner sleeve includes a plurality of inner blades extending radially outward from an outer diameter of the inner sleeve and disposed at least partially between the plurality of outer blades. The insulating outer washer is configured to transfer a first axial load between the upper end portion and the outer sleeve. The insulating inner washer is configured to transfer a second axial load between the inner sleeve and the lower end portion. The insulating spider is configured to transfer a torsional load between the plurality of outer blades and the plurality of inner blades. Further, the upper end portion is electrically insulated from the lower end portion. Because the insulating washers are utilized to transfer axial loads and the insulating spider is utilized to transfer torsional loads, each insulator may be manufactured so that the strongest axis of the material can be optimally and advantageously oriented to be coincident with the forces applied to each insulator, thereby making the gap sub more mechanically robust than a conventional insulated gap collar while permitting reliable and fast transmission of sensor data to the surface. It should be understood that the terms upper and lower as used in this description are used for convenience and may be swapped without loss of performance or functionality.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various embodiments of the present disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. In the drawings, like reference numbers may indicate identical or functionally similar elements.

[0007] FIG. 1 is a schematic view of a drilling system.

[0008] FIG. 2 is a cross-sectional view of a gap sub for use with the drilling system of FIG. 1.

[0009] FIG. 3 is a cross-sectional view of the gap sub of FIG. 2 at section line 3–3.

[0010] FIG. 4 is a cross-sectional view of a gap sub for use with the drilling system of FIG. 1.

DETAILED DESCRIPTION

[0011] FIG. 1 is a schematic view of a drilling system 100. In the depicted example, the drilling system 100 can be utilized to drill a wellbore 106 through a formation 102 and can facilitate the transmission of telemetry information from a downhole location 108 to a surface location 104 for logging and real-time control of drilling operations.

[0012] As illustrated, a drill bit 130 coupled to a downhole end of a drill string 110 can be rotated within the formation 102 to form the wellbore 106. During the drilling operation, the drill string 110 can extend within the wellbore 106 from the surface location 104 to the downhole location 108. As can be appreciated, the drilling system 100 can form vertical wells, horizontal wells, lateral wells, and/or utilize directional drilling techniques.

[0013] In some embodiments, various sensors disposed within or along the drill string 110 can be used to measure and observe parameters at the drill bit 130 or generally at the downhole location 108. In the depicted example, the drill string 110 can include sensors and other electronics within a bottom hole assembly (BHA) 120 disposed at a downhole end of the drill string 110. In some embodiments, the bottom hole assembly 120 is coupled to the drill string 110 and/or the drill bit 130.

[0014] In some applications, the sensors can be configured to detect drilling parameters related to directional drilling systems, such as rotary steerable collars, measurements for the optimization of drilling efficiency, electrical resistivity of the formation 102, etc. Optionally, sensors can be configured to detect torque on bit, weight on bit, or other drilling parameters. In some applications, the sensors can be located near the drill bit 130, allowing for the sensors more accurately determine the conditions at the drill bit 130.

[0015] During operation, a gap sub 150 can transmit sensor information from the sensors disposed within the bottom hole assembly 120 (and other locations within the drill string 110) to a remote location. In the depicted example, the gap sub 150 can be disposed within the drill string 110 and offset from the bottom hole assembly 120. In some embodiments, the gap sub 150 can be integrated with or otherwise included within the bottom hole assembly 120.

[0016] As illustrated, the gap sub 150 can be disposed near the downhole end of the drill string 110. For example, the gap sub 150 can be as disposed between a mud motor and the bottom hole assembly 120. In some embodiments, the gap sub 150 can be disposed below the mud motor. During operation, the mud motor can rotate an output shaft relative to a mud motor stator to rotate the drill bit 130. Advantageously, by positioning the gap sub 150 downhole of the mud motor, the drilling system 100 can eliminate the need for transmitting data across the

mud motor using short hop telemetry systems. As can be appreciated, the gap sub 150 can be disposed uphole of the mud motor in some configurations.

[0017] As described herein, the gap sub 150 can transmit sensor information using electro-magnetic signals or fields (EM telemetry). To facilitate EM telemetry, the gap sub 150 electrically isolates the top portion of the drill string 110 from the bottom portion of the drill string 110. During transmission, the gap sub 150 can emit a modulated electro-magnetic signal corresponding to the sensor data, creating an electric and magnetic field from the gap sub 150. In some embodiments, the gap sub 150 can include and/or be operatively coupled to a transmitter and a power source such as batteries or a turbine driven downhole alternator and power supply.

[0018] Optionally, the top portion of the drill string 110 can be electrically connected to a ground stake 140 to form an antenna, allowing a receiver electrode 194 spaced some distance from the ground stake to receive the signal from the gap sub 150, which is then decoded and/or demodulated. In some embodiments, the gap sub 150 can transmit sensor information to a pair of receiver electrodes 192, and 194, disposed at the surface location 104.

[0019] FIG. 2 is a cross-sectional view of a gap sub 150 for use with the drilling system 100 of FIG. 1. In the depicted example, the gap sub 150 creates an insulating gap for electrical isolation while permitting the effective transfer of compressional and torsional loads across the drill string 110. As can be appreciated, the insulating gap of the gap sub 150 can electrically isolate an upper end 152 from a lower end 154.

[0020] As described herein, the upper end 152 and the lower end 154 of the gap sub 150 can be coupled to other components of the drill string 110. The upper end 152 and the lower end 154 of the gap sub 150 may be a continuation of longer drill collar elements or may be collars coupled using threaded joints, box connections, pin connections, or other suitable connections. As illustrated, the gap sub 150 includes an outer sleeve 158 and an inner sleeve 156, wherein the upper end 152, the lower end 154, the outer sleeve 158, and the inner sleeve 156 collectively define the mud bore 170 therethrough. In some embodiments, the inner sleeve 156 at least partially axially overlaps with the outer sleeve 158. In some applications, the upper end 152, the lower end 154, the inner sleeve 156, and the outer sleeve 158 of the gap sub 150, along with other components of the drill string 110 can be formed from conductive materials such as steels, other metals, or other metal alloys. It should be clear from FIG. 2 that outer sleeve 158 and inner sleeve 156 form “a catch” and will not pass through each other

should spider 164 mechanically fail. In that case, outer sleeve 158 would be pulled by the BHA above 154 in an uphole direction and inner sleeve 156 would be pulled by the BHA below 152 in a downhole direction until 158 and 156 come into physical contact. This is an important safety feature to allow the BHA to be pulled out of the hole should one or more gap insulators fail mechanically.

[0021] As described herein, the gap sub 150 can effectively isolate the upper portion of the drill string 110 coupled to the upper end 152 from the lower portion of the drill string 110 coupled to the lower end 154. As illustrated, the gap sub 150 utilizes insulating materials to electrically isolate the upper end 152 from the lower end 154. For example, the gap sub 150 can include isolating components such as an outer washer 160, an inner washer 162, and/or a spider 164 formed from insulating materials disposed between the upper end 152 and the lower end 154 to prevent the conduction of electricity therebetween. In conventional applications, certain insulating materials may not be able to adequately transfer the combination of axial and/or torsional loads that typically may be experienced by a conventional gap sub, limiting the performance and operation of a drill string 110 that includes a conventional arrangement of insulating materials in a conventional gap sub.

[0022] Advantageously, the gap sub 150 includes a construction and geometry that allows for the generally separate transfer of axial and torsional loads by separate insulating members, each optimized to transmit either axial or torsional forces in a specific orientation. For example, in some embodiments, the construction and geometry of the gap sub 150 allows for axial loads to generally be transferred through the gap sub 150 by the outer washer 160 and the inner washer 162, while minimizing torsional loading of the outer washer 160 and the inner washer 162. Similarly, the construction and geometry of the gap sub 150 can allow for torsional loads to generally be transferred through the gap sub 150 by the spider 164 while minimizing axial loading of the spider 164. Therefore, the combination of the outer washer 160, the inner washer 162, and the spider 164 along with the configuration of the inner sleeve 156 and the outer sleeve 158 can cooperatively transfer the combination of axial and torsional loads across the gap sub 150.

[0023] In the depicted example, the gap sub 150 includes an outer washer 160 to carry or transfer a compressional or axial load across an outer diameter of the gap sub 150. Similarly, the gap sub 150 can include an inner washer 162 to carry or transfer a compressional or axial

load across the inner diameter of the gap sub 150. The outer washer 160 and/or the inner washer 162 can be configured to transfer minimal to no torsional load across the gap sub 150.

[0024] In some embodiments, the outer washer 160 is axially disposed between the upper end 152 and the outer sleeve 158. The outer washer 160 can have a generally annular shape or any other suitable shape. During operation, the outer washer 160 can transfer an axial load between the upper end 152 and the outer sleeve 158. In some embodiments, the outer washer 160 can abut against the upper end 152 and the outer sleeve 158 without a threaded connection therebetween.

[0025] Similarly, the inner washer 162 is axially disposed between the inner sleeve 156 and the lower end 154. The inner washer 162 can have a generally annular shape or any other suitable shape. During operation, the inner washer 162 can transfer an axial load between the inner sleeve 156 and the lower end 154. In some embodiments, the inner washer 162 can abut against the inner sleeve 156 and the lower end 154 without a threaded connection therebetween.

[0026] In some applications, compressional load between the upper end 152 and the lower end 154 of the gap sub 150 can be transmitted by the outer sleeve 158 and the inner sleeve 156 in parallel. For example, an outer diameter (OD) or outer compressional path can comprise a compressional load supported by the upper end 152, the outer washer 160, the outer sleeve 158, and the lower end 154. Optionally, the outer sleeve 158 can be coupled to the lower end 154 via a threaded connection or any other suitable connection. Similarly, an inner diameter (ID) or inner compressional path can comprise a compressional load supported by the upper end 152, the inner sleeve 156, the inner washer 162, and the lower end 154. Further, the inner sleeve 156 can be coupled to the upper end 152 via a threaded connection or any other suitable connection.

[0027] In some applications, the strain experienced by both compressional paths of the gap sub 150 can be equalized to minimize any differential compressional stress (e.g. during the application of weight-on-bit), minimizing compressional loading of the spider 164 due to unequal strains. Therefore, in some embodiments, the axial cross-sectional area of the outer sleeve 158 can be the same or similar as the axial cross-sectional area of the inner sleeve 156. Similarly, the axial cross-sectional area of the outer washer 160 and the inner washer 162 can be the same or similar. Further, the axial cross-sectional area of the outer washer 160 and the inner washer 162 can be selected to withstand applied stresses (such as from excessive weight-on-bit) without exceeding the rated yield strength of the insulating washer material.

[0028] In the depicted example, the outer washer 160 and/or the inner washer 162 can be formed from any suitable insulating material, including materials suitable for withstanding axial or compressive loading. Advantageously, by separating torsional and compressional loading, the outer washer 160 and/or the inner washer 162 formed from high modulus materials are thereby less susceptible to fracturing and/or formed from low modulus materials are thereby less susceptible to plastic deformation. For example, the outer washer 160 and/or the inner washer 162 can be formed from high modulus ceramic materials, including, but not limited to, Silicon Nitride 240, etc. Further, the outer washer 160 and/or the inner washer 162 can be formed from low modulus composite materials, including, but not limited to, epoxy fiberglass, high strength fiber-loaded thermoplastics, etc. In some embodiments, low modulus materials, in addition to any fibrous materials, can include metallic structures or skeletons to provide additional mechanical strength to the outer washer 160 and/or the inner washer 162. As can be appreciated, the metallic structure within the material can be potted inside the material to maintain the insulating properties of the member. In yet another embodiment, the insulating material may be bonded directly to a thin load bearing metallic face on one side or the other or both to better distribute any uneven loads that may result from mechanical variations in the load bearing faces of the inner or outer sleeves and the upper or lower ends of the gap. Any metallic faces so used must be configured so as not to provide a parasitic electrical path that electrically bypasses any of the gap insulators, thereby destroying the operation of the gap.

[0029] FIG. 3 is a cross-sectional view of the gap sub 150 of FIG. 2 at section line 3–3. With reference to FIGS. 2 and 3, the gap sub 150 includes a spider 164 to carry or transfer a torsional load across the gap sub 150. Advantageously, as the outer washer 160 and the inner washer 162 support the axial or compressive load through the gap sub 150, the spider 164 may not experience significant axial or compressive loading (e.g., due to weight-on-bit) during operation.

[0030] In the depicted example, the spider 164 is disposed in the annulus defined by the outer sleeve 158 and the inner sleeve 156 to transmit torque or torsional load therebetween, thereby preventing rotation of the outer sleeve 158 relative to the inner sleeve 156 and vice versa. In some embodiments, the spider material 165 can extend along a portion or all of the axial length of the outer sleeve 158 and/or the inner sleeve 156. As illustrated, the spider 164 can be axially disposed between the outer washer 160 and the inner washer 162.

[0031] As illustrated, the outer sleeve 158 engages with the spider 164 via a plurality of outer blades 159 that extend radially inward into the spider material 165. As shown, the plurality of outer blades 159 can extend from the inner diameter of the outer sleeve 158. Similarly, the inner sleeve 156 engages with the spider 164 via a plurality of inner blades 157 that extend radially outward into the spider material 165. As shown, the plurality of inner blades 157 can extend from the outer diameter of the inner sleeve 156. In some embodiments, the plurality of outer blades 159 and/or the plurality of inner blades 157 can be circumferentially spaced apart. Optionally, the plurality of inner blades 157 can extend between the space between the plurality of outer blades 159 to at least partially radially overlap (as shown in FIG. 3). As illustrated, the plurality of outer blades 159 can be spaced apart or dimensioned to avoid contact with the plurality of inner blades 157 and/or the inner sleeve 156. Similarly, the plurality of inner blades 157 can be spaced apart or dimensioned to avoid contact with the plurality of outer blades 159 and/or the outer sleeve 158.

[0032] During operation, torsional load across the gap sub 150 can be transmitted by the spider 164. For example, torsional load path can comprise a torsional load supported by the upper end 152, the inner sleeve 156, the spider 164, the outer sleeve 158, and the lower end 154. As previously described, the inner sleeve 156 and the outer sleeve 158 can be coupled to the upper end 152 and the lower end 154, respectively, via a threaded connection or any other suitable connection. As can be appreciated, the plurality of inner blades 157 and the plurality of outer blades 159 in engagement with the spider 164 allow for torsional load to be transmitted between the inner sleeve 156 and the outer sleeve 158 while minimizing shear forces on the spider material 165. Further, the area of overlap between the plurality of inner blades 157 and the plurality of outer blades 159 can be selected to withstand applied stresses (such as from excessive applied torque during drilling) without exceeding the rated yield strength of the insulating spider material 165.

[0033] In the depicted example, the spider material 165 can comprise any suitable insulating material, including materials suitable for withstanding torsional loading. Advantageously, by separating torsional and compressional loading, the spider material 165 can comprise high modulus materials that are therefore less susceptible to fracturing and/or comprise low modulus materials that are therefore less susceptible to plastic deformation. For example, the spider material 165 can comprise high modulus ceramic materials, including, but not limited to, Silicon Nitride 240, etc. Further, the spider material 165 can comprise low modulus composite materials, including, but not limited to, epoxy fiberglass, high strength fiber-loaded

thermoplastics, etc. In some embodiments, low modulus materials, in addition to any fibrous materials, can include metallic structures or skeletons to provide additional mechanical strength to the spider 164. As can be appreciated, the metallic structure within the material can be potted inside the material to maintain the insulating properties of the member. In yet another embodiment, the insulating material may be bonded directly to a thin load bearing metallic face on one side or the other or both of the spider to better distribute any uneven loads that may result from mechanical variations in the load bearing faces of the inner or outer sleeves of the gap. Any metallic faces so used must be configured so as not to provide a parasitic electrical path that electrically bypasses any of the gap insulators, thereby destroying the operation of the gap. It should be understood that to facilitate the fabrication of the spider and/or to minimize any susceptibility to fracturing or plastic deformation that it can be comprised of a single piece of insulating material or it can be comprised of several axial sections that are stacked in series with each other or it can be comprised of several azimuthal sections that together form a complete spider subassembly.

[0034] Optionally, the gap sub 150 can include sealing members, such as bushings, to prevent the migration of mud or other fluids from the mud bore 170 through the gap sub 150. For example, as shown in FIG. 2, a bushing 166 can be disposed between the outer sleeve 158, the inner sleeve 156, and/or the outer washer 160. Similarly, bushing 168 can be disposed between the outer sleeve 158, the inner sleeve 156, and/or the inner washer 162. In some embodiments, the bushings 166, 168 can comprise rubber or other elastomeric materials, including, but not limited to, Viton[®] or Calraz[®]. Further, threaded connections, such as the threaded connection between the upper end 152 and the inner sleeve 156 and/or the threaded connection between the outer sleeve 158 and the lower end 154, can utilize a thread locking and/or sealing compound to similarly prevent the migration of mud or other fluids.

[0035] In some embodiments, the gap sub 150 can be used in conjunction with downhole power generation mechanisms, such as an alternator assembly with a suitable power supply to advantageously provide significantly more power (voltage and current) and for a longer period of time (duration) relative to the power and duration available from downhole batteries. This allows for an increase in broadcast signal levels, enabling an increase in the frequency of transmission for higher data rates with good signal to noise ratios on the surface, allowing for signals transmitted from the gap sub 150 to be more robustly detected and demodulated at the surface compared with using batteries with limited capacity. Downhole power generation mechanisms provide a significant advantage over existing downhole technology, namely,

addressing the several limitations of battery powered operation, namely, signal strength, duration of operation, cost of battery replacement, and ecologically sound battery disposal.

[0036] As can be appreciated, the gap sub 150 can be assembled utilizing any suitable procedure and/or sequence. By way of non-limiting example, steps of assembly can include first mounting the spider 164 onto the inner sleeve 156. Then, a bushing 168 can be positioned onto a lower portion of the inner sleeve 156, and a bushing 166 positioned around an upper portion of the inner sleeve 156, proximate to the spider 164. Next, the outer sleeve 158 is positioned over the spider 164 and the bushing 166. Then, the inner washer 162 and the outer washer 160 are mounted onto the gap sub 150 and the lower end 154 and the upper end 152 are threadedly coupled to the outer sleeve 158 and the inner sleeve 156, respectively.

[0037] The upper end 152 and the lower end 154 are then torqued to a preselected torque specification, preloading the internal mating surfaces of the gap sub 150. As a result of the preloading procedure, the spider 164, the outer washer 160, and the inner washer 162 may be axially preloaded. As can be appreciated, the axial (compressional) cross-sectional area of the spider 164 can be selected to withstand the relatively small axial preload imparted during assembly.

[0038] FIG. 4 is a cross-sectional view of a gap sub 250 for use with the drilling system of FIG. 1. The gap sub 250 is similar to gap sub 150 illustrated and described with respect to FIG. 2. Unless noted, similar elements are referred to with similar reference numerals.

[0039] Optionally, the gap sub 250 includes O-rings 280, 282 to prevent the migration of mud or other fluids from the mud bore 170 through the gap sub 150. In the depicted example, the O-ring 280 is disposed at the threaded connection between the upper end 252 and the inner sleeve 256. Similarly, the O-ring 282 can be disposed at the threaded connection between the outer sleeve 258 and the lower end 254. In some embodiments, the O-rings 280, 282 can comprise rubber or other elastomeric materials, including, but not limited to, Viton or Calraz.

[0040] It is understood that variations may be made in the foregoing without departing from the scope of the present disclosure. In several exemplary embodiments, the elements and teachings of the various illustrative exemplary embodiments may be combined in whole or in part in some or all of the illustrative exemplary embodiments. In addition, one or more of the elements and teachings of the various illustrative exemplary embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various illustrative embodiments. It is to be understood that mechanical design

best practices require the use of generous radii on the sharp corners and edges of both metallic and insulating members to reduce stress concentrations to minimize susceptibility to fracturing, plastic deformation, and metal fatigue. These features do not affect the functional description of the gap are not included in the figures in the interest of clarity.

[0041] Any spatial references, such as, for example, “upper,” “lower,” “above,” “below,” “between,” “bottom,” “vertical,” “horizontal,” “angular,” “upwards,” “downwards,” “side-to-side,” “left-to-right,” “right-to-left,” “top-to-bottom,” “bottom-to-top,” “top,” “bottom,” “bottom-up,” “top-down,” etc., are for the purpose of illustration only and do not limit the specific orientation or location of the structure described above.

[0042] In several exemplary embodiments, while different steps, processes, and procedures are described as appearing as distinct acts, one or more of the steps, one or more of the processes, and/or one or more of the procedures may also be performed in different orders, simultaneously and/or sequentially. In several exemplary embodiments, the steps, processes, and/or procedures may be merged into one or more steps, processes and/or procedures.

[0043] In several exemplary embodiments, one or more of the operational steps in each embodiment may be omitted. Moreover, in some instances, some features of the present disclosure may be employed without a corresponding use of the other features. Moreover, one or more of the above-described embodiments and/or variations may be combined in whole or in part with any one or more of the other above-described embodiments and/or variations.

[0044] Although several exemplary embodiments have been described in detail above, the embodiments described are exemplary only and are not limiting, and those skilled in the art will readily appreciate that many other modifications, changes and/or substitutions are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of the present disclosure. Accordingly, all such modifications, changes, and/or substitutions are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, any means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Moreover, it is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the word “means” together with an associated function.

CLAIMS

1. A gap sub, comprising:

an outer sleeve axially disposed between an upper end portion of a drill string and a lower end portion of a drill string, the outer sleeve comprising a plurality of outer blades extending radially inward from an inner diameter of the outer sleeve;

an inner sleeve axially disposed between the upper end portion of the drill string and the lower end portion of the drill string, and at least partially axially overlapping with the outer sleeve, the inner sleeve comprising a plurality of inner blades extending radially outward from an outer diameter of the inner sleeve and radially overlapping at least partially with the plurality of outer blades;

an insulating outer washer axially disposed between the upper end portion of the drill string and the outer sleeve, wherein the insulating outer washer is configured to transfer a first axial load between the upper end portion of the drill string and the outer sleeve;

an insulating inner washer axially disposed between the inner sleeve and the lower end portion of the drill string, wherein the insulating inner washer is configured to transfer a second axial load between the inner sleeve and the lower end portion of the drill string; and

an insulating spider disposed axially between the insulating outer washer and the insulating inner washer and disposed radially between the inner sleeve and the outer sleeve, wherein one or more of the plurality of inner blades and one or more of the plurality of outer blades radially overlap with portions of the insulating spider, such that the insulating spider is configured to transfer a torsional load between the plurality of outer blades and the plurality of inner blades and the upper end portion of the drill string is electrically insulated from the lower end portion of the drill string.

2. The gap sub of Claim 1, wherein the inner sleeve is configured to connect to the upper end portion of the drill string.

3. The gap sub of Claim 2, wherein the outer sleeve is configured to connect to the lower end portion of the drill string.

4. The gap sub of Claim 1, wherein the insulating outer washer, insulating inner washer, and insulating spider is each comprised of an insulating material comprising silicon nitride, zirconia, epoxy fiberglass, or fiber-loaded thermoplastic.
5. The gap sub of Claim 4, wherein the insulating material of at least one of the insulating outer washer, insulating inner washer, and insulating spider comprises a metallic structure potted within the insulating material.
6. The gap sub of Claim 4, wherein the insulating material is bonded to a metallic face.
7. A method comprising:
 - drilling a wellbore within a formation via a drill string, wherein the drill string comprises a gap sub;
 - transferring an axial load across the gap sub via an insulating washer;
 - transferring a torsional load across the gap sub via an insulating spider;
 - sensing a drilling parameter via a sensor disposed within a bottom hole assembly of the drill string; and
 - transmitting an electromagnetic signal corresponding to sensor data from the sensor.
8. The method of Claim 7, further comprising:
 - transferring a first portion of the axial load across the gap sub via an insulating outer washer axially disposed between an upper end portion of the drill string and an outer sleeve.
9. The method of Claim 8, further comprising:
 - transferring a second portion of the axial load across the gap sub via an insulating inner washer axially disposed between an inner sleeve and a lower end portion of the drill string.
10. The method of Claim 7, further comprising:
 - transferring the torsional load between an outer sleeve and an inner sleeve of the gap sub via the insulating spider.

11. The method of Claim 10, further comprising:
transferring the torsional load between a plurality of outer blades extending from the outer sleeve and a plurality of inner blades extending from the inner sleeve via the insulating spider.
12. The method of Claim 7, further comprising:
transmitting the electromagnetic signal using a downhole power generation mechanism.
13. The method of Claim 12, where the downhole power generation mechanism is an alternator assembly.
14. A drilling system comprising:
a drill string configured to form a wellbore within a formation, the drill string comprising:
a drill pipe extending from a surface location to a downhole location within the wellbore;
a bottom hole assembly coupled to a downhole end of the drill pipe, wherein the bottom hole assembly comprises:
a drill collar;
at least one sensor operatively coupled to a transmitter; and
a drill bit coupled to the drill collar; and
a gap sub disposed along the drill string, the gap sub comprising:
an outer sleeve disposed between an upper end portion of the drill string and a lower end portion of the drill string, the outer sleeve comprising a plurality of outer blades extending radially inward from an inner diameter of the outer sleeve;
an inner sleeve axially disposed between the upper end portion of the drill string and the lower end portion of the drill string, and at least partially axially overlapping with the outer sleeve, the inner sleeve comprising a plurality of inner blades extending radially outward from an outer diameter of the inner sleeve and radially overlapping at least partially with the plurality of outer blades;

an insulating outer washer axially disposed between the upper end portion of the drill string and the outer sleeve, wherein the insulating outer washer is configured to transfer a first axial load between the upper end portion of the drill string and the outer sleeve;

an insulating inner washer axially disposed between the inner sleeve and the lower end portion of the drill string, wherein the insulating inner washer is configured to transfer a second axial load between the inner sleeve and the lower end portion of the drill string; and

an insulating spider disposed axially between the insulating outer washer and the insulating inner washer and disposed radially between the inner sleeve and the outer sleeve, wherein one or more of the plurality of inner blades and one or more of the plurality of outer blades radially overlap with portions of the insulating spider, such that the insulating spider is configured to transfer a torsional load between the plurality of outer blades and the plurality of inner blades and the upper end portion of the drill string is electrically insulated from the lower end portion of the drill string; and

wherein the gap sub is configured to allow transmission from a transmitter of an electromagnetic signal corresponding to sensor data.

15. The drilling system of Claim 14, further comprising a downhole power generation mechanism operatively coupled to the gap sub.
16. The drilling system of Claim 14, wherein the downhole power generation mechanism is an alternator assembly.
17. The drilling system of Claim 14, further comprising a mud motor, wherein the gap sub is disposed downhole of the mud motor.
18. The drilling system of Claim 14, wherein a first end portion of the drill string is coupled to the inner sleeve.
19. The drilling system of Claim 18, wherein a second end portion of the drill string is coupled to the outer sleeve.

20. The drilling system of Claim 14, wherein the insulating outer washer, insulating inner washer, and insulating spider is each comprised of an insulating material comprising silicon nitride, zirconia, epoxy fiberglass, or fiber-loaded thermoplastic.
21. The drilling system of Claim 20, wherein the insulating material of at least one of the insulating outer washer, insulating inner washer, and insulating spider comprises a metallic structure potted within the insulating material.
22. The drilling system of Claim 20, wherein the insulating material is bonded to a metallic face.

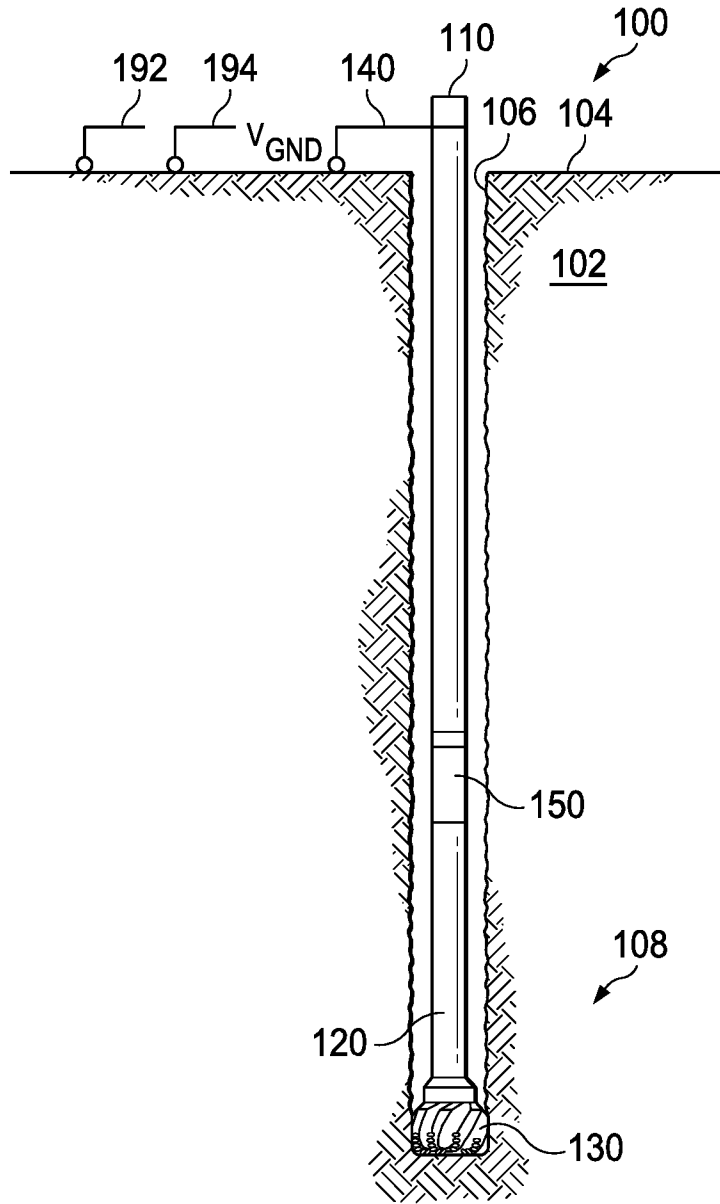
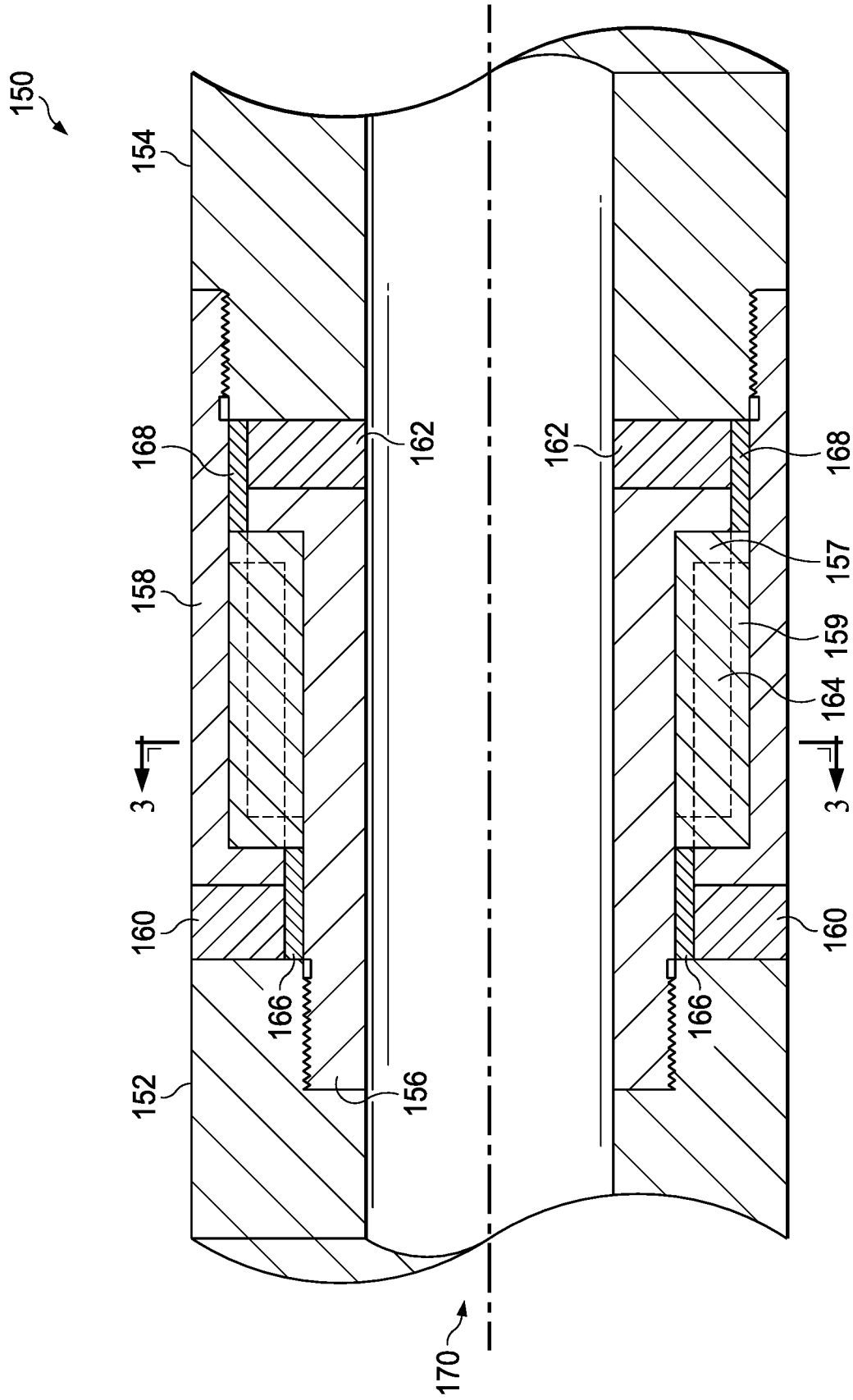


FIG. 1



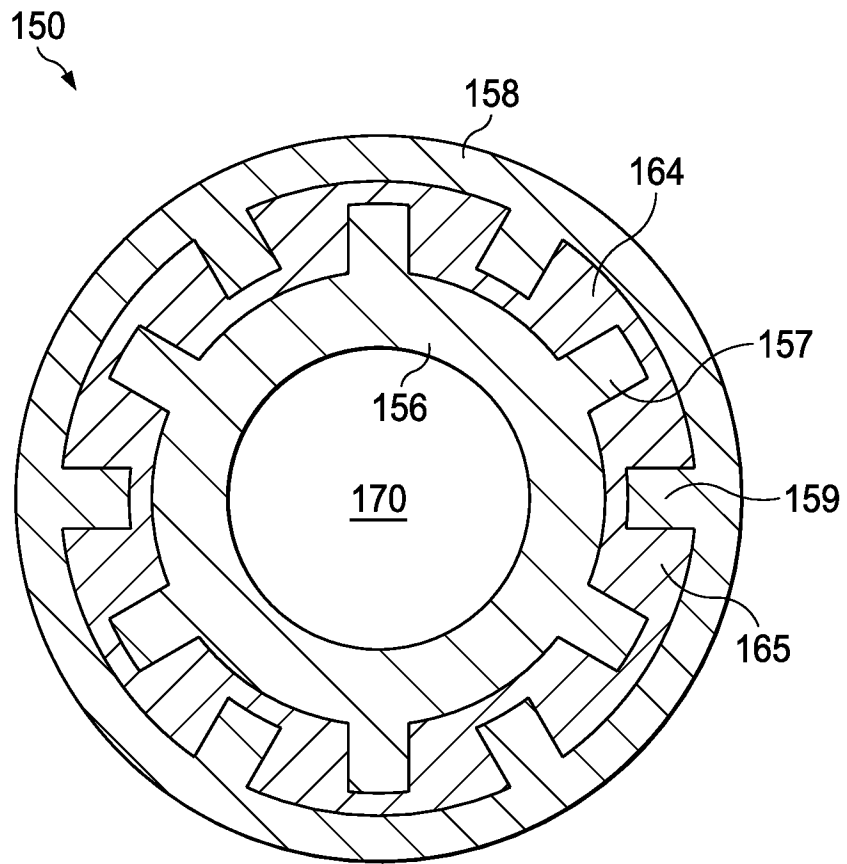


FIG. 3

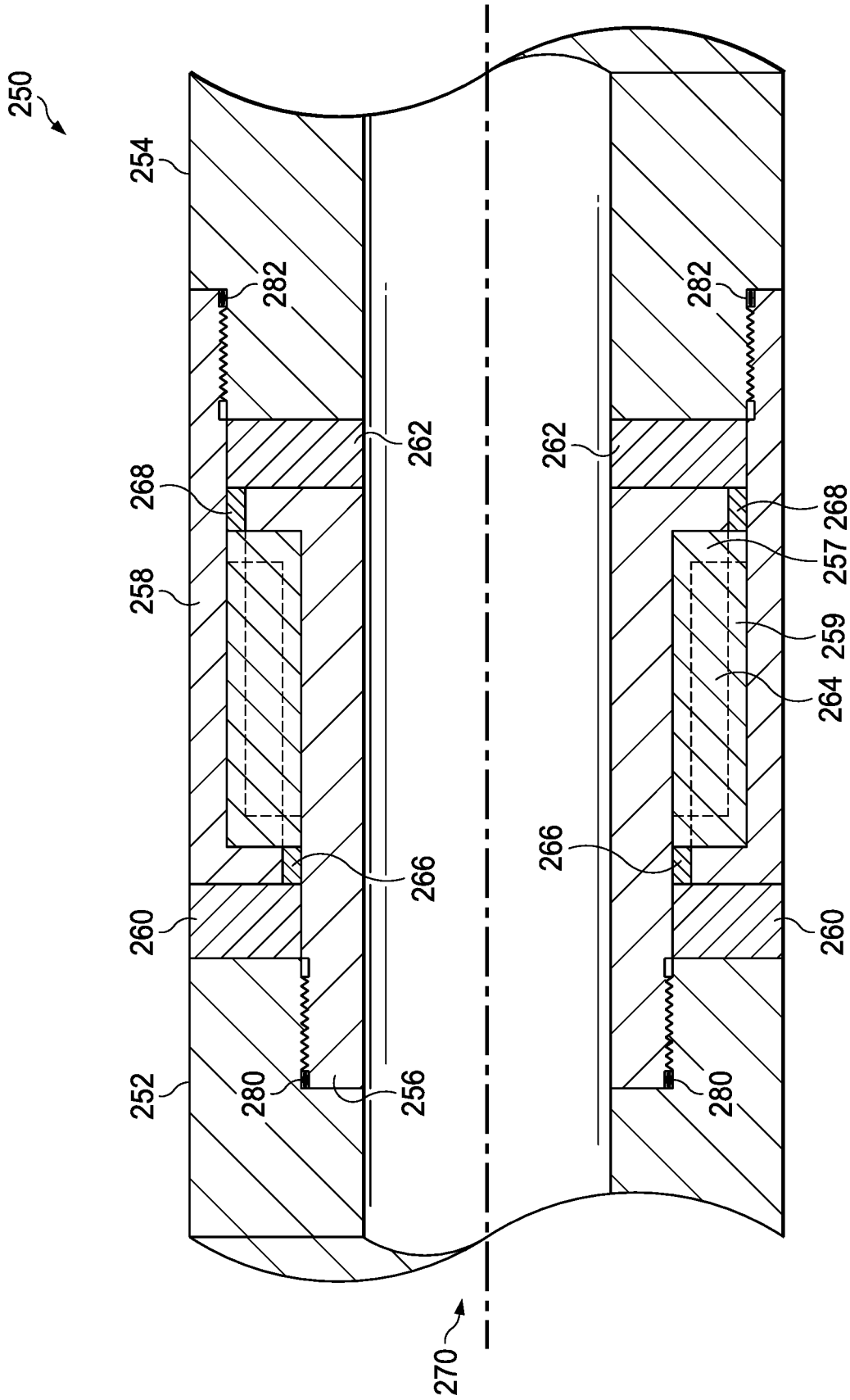


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2019/045159

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - E21B 47/12; E21B 17/00; E21B 17/10 (2019.01)
 CPC - E21B 47/12; E21B 17/003; E21B 17/1007 (2019.08)

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)
 See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 USPC - 166/66; 285/53; 340/854.8 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,496,174 A (MCDONALD et al) 29 January 1985 (29.01.1985) entire document	1-22
A	US 2018/0044999 A1 (EVOLUTION ENGINEERING INC.) 15 February 2018 (15.02.2018) entire document	1-22
A	US 2018/0135406 A1 (EVOLUTION ENGINEERING INC.) 17 May 2018 (17.05.2018) entire document	1-22
A	US 4,348,672 A (GIVLER) 07 September 1982 (07.09.1982) entire document	1-22
A	US 2007/0247329 A1 (PETROVIC et al) 25 October 2007 (25.10.2007) entire document	1-22

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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
 17 September 2019

Date of mailing of the international search report
17 OCT 2019

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