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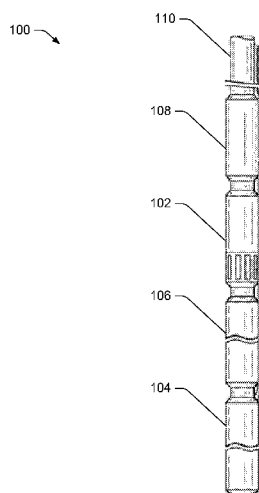
(54) **Title:** DIAMOND SURFACES FOR ELECTRIC SUBMERSIBLE PUMP COMPONENTS

FIG. 1

(57) **Abstract:** Diamond surfaces for electric submersible pump (ESP) components are provided. A layer of diamond is deposited, adhered, or sintered directly or indirectly to component surfaces subject to wear, erosion, or abrasion to form at least a partial coating. The diamond surfaces increase longevity and reliability of the ESP by reducing friction, wear, and operating temperature. The diamond surfaces may take several forms, such as an amorphous diamond layer, a polycrystalline diamond (PCD) layer, or a thermally stable polycrystalline (TSP) diamond layer. Diamond surfaces may be used to protect bearings, thrust washers, shafts, sliding surfaces, wet areas, hydraulic flow surfaces in cavities, fluid intake ports, downthrust and upthrust pads, bearing runners, shaft seals, face-seals, hydraulic seals, clearance seals, and other surfaces susceptible to erosion or abrasion in the ESP.



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DIAMOND SURFACES FOR ELECTRIC SUBMERSIBLE PUMP COMPONENTS

RELATED APPLICATIONS

[0001] This patent application claims the benefit of priority to U.S. Provisional Patent No. 61/835,528 to Camacho et al., filed June 14, 2013 and incorporated by reference herein in its entirety.

BACKGROUND

[0002] Abrasives, such as sand and particulates, are often present during oil production and result in abrasive well fluid to the detriment of the pumping equipment, valves, seals, transport pipes, and vessels that come in contact with the abrasive well fluid. The solid particles, whether frank or in fluid suspension, large or microscopic, create abrasive and erosive wear problems on sliding surfaces and flow passages. The extent of the wear can be mitigated somewhat by hydraulic design and material selection. Materials for constructing the equipment can be enhanced by surface layers of a distinct material that provides additional protection against wear.

[0003] Conventionally, several types of surface layers, coatings, platings, and treatments exist that increase the durability of the base material used in the construction of an electric submersible pump (ESP) component. For example, ESP's conventionally have used boronizing on pump stages to

increase wear resistance. Or, the conventional ESP component may use a solid piece of material that has desirable wear properties (e.g., silicon carbide). There are also industry-available coatings that can improve wear resistance, such as high velocity oxy-fuel (HVOF) coatings, conforma clad, and so forth, but these are not used on surfaces of ESP components that are vulnerable to abrasive wear, because of the extreme conditions within an operating ESP.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] For this discussion, the devices and systems illustrated in the figures are shown as having a multiplicity of components. Various implementations of devices and systems, as described herein, may include fewer components and remain within the scope of the disclosure. Alternately, other implementations of devices and systems may include additional components, or various combinations of the described components, and remain within the scope of the disclosure.

[0005] Fig. 1 is a diagram of an example electric submersible pump (ESP) with some surfaces in each section protected by a layer or coating of diamond.

[0006] Fig. 2 is a diagram of an example centrifugal pump stage with components and surfaces protected by a layer or coating of diamond.

[0007] Fig. 3 is a diagram of an example radial bearing of an ESP with surfaces protected by a layer or coating of diamond.

[0008] Fig. 4 is a diagram of example thrust pads and a runner with surfaces protected by a layer or coating of diamond.

[0009] Fig. 5 is a diagram of an example shaft seal with face seal surfaces protected by a layer or coating of diamond.

[0010] Fig. 6 is a diagram of an example shaft seal with face seal surfaces protected by a layer or coating of diamond sintered onto carbide.

[0011] Fig. 7 is another diagram of the example shaft seal of Fig. 6 with face seal surfaces protected by a layer or coating of diamond sintered onto carbide.

[0012] Fig. 8 is a diagram of an example shaft seal with face seal surfaces protected by a layer or coating of diamond sintered onto carbide, and the carbide brazed onto steel.

[0013] Fig. 9 is a diagram of example hydraulic clearance seals in an ESP, with surfaces of the hydraulic clearance seals protected by a layer or coating of diamond.

[0014] Fig. 10 is a diagram of example components and surfaces in an ESP protected by a layer or coating of diamond.

[0015] Fig. 11 is another diagram of example components and surfaces in an ESP protected by a layer or coating of diamond.

[0016] Fig. 12 is a diagram of an example pump intake with ports and flow surfaces protected by a layer or coating of diamond.

[0017] Fig. 13 is a flow diagram of an example method of protecting areas of wear in an ESP with a layer of diamond.

DETAILED DESCRIPTION

Overview

[0018] This disclosure describes diamond surfaces for ESP components. The diamond surfaces can be a layer or coating of diamond deposited or otherwise sintered, attached, or adhered directly or indirectly to an ESP component. Different types of diamond layers can be used depending on the shape and function of the component to be protected. For example, a diamond coating can be an amorphous diamond layer, a polycrystalline diamond (PCD) layer, or a thermally stable polycrystalline (TSP) diamond layer. The diamond-coated ESP components can be used on land, offshore, and in subsea locations where ESP installations of high durability are needed.

[0019] An example system uses ESP components that have one or more surfaces consisting of diamond, or at least partially coated or layered with diamond. A small ESP component may be composed entirely of diamond composite. Surfaces of relatively large components may be given a layer or coating of diamond instead. In this description, the term “coating” will be used representatively to include diamond coatings, diamond layers, diamond matrices with binders, diamond tiles, and diamond layers backed with metallic support, such as a tungsten carbide (WC) backing support. The term “diamond” is used herein in its usual sense and according to usual meaning, that is, carbon atoms in a (face-centered cubic) crystal lattice ubiquitously known as diamond. Within the diamond crystal system, however, slightly

different variations of diamond may exist. For example, lonsdaleite diamond may be utilized herein, which is also called hexagonal diamond in reference to the distinctive crystal structure. Lonsdaleite diamond is an allotrope of carbon with a hexagonal lattice, with a hardness that is theoretically superior to that of cubic diamond (up to 58% harder than cubic diamond).

[0020] The diamond “pieces” within a diamond layer or diamond coating may be of nano-size, nanostructured, a nanocomposite, or microscopic (or even larger) in size: that is, may be “nanocrystalline” or “microcrystalline” diamond. The diamond may be composited with other hard materials, such as carbides, cubic boron nitride (CBN), wurtzite boron nitride (WBN), and so forth.

[0021] In an example configuration, a diamond coating on the surface of an ESP component reduces the amount of wear experienced during equipment operation. The example diamond elements and layers for ESP components, as described herein, are used to improve the wear resistance of many surfaces that are conventionally left unprotected. For example, an unmoving hydraulic flow surface within an ESP may be layered with diamond to prevent erosion or abrasion from well fluid containing abrasive sand. Likewise, moving parts and sliding surfaces, such as surfaces of bearings, shafts, and seals may also be layered with diamond to reduce friction, wear, and operating temperature.

Example System

[0022] Fig. 1 shows an example electric submersible pump (ESP) 100. The example ESP 100 may include a variety of functional sections and components depending on the particular application or environment in which the ESP 100 is used. Component sections of the example ESP 100 may include, for example, at least one pump 102, at least one motor 104, and at least one motor protector section 106 between each pump 102 and associated motor 104. Instances of these component sections may be coupled together to form repeating stages or segments of the example ESP 100, referred to as an ESP string.

[0023] Power is provided to the example ESP 100 via a power cable connected between a pump controller, such as a variable speed drive, and the motor 104. The motor 104 drives the pump 102, which draws in production (well) fluid from the surrounding well. Within each pump 102 (for example a centrifugal pump), one or more impellers rotate in relation to one or more fixed diffusers to impel the production fluid through a connector section 108 and through production tubing 110 to a desired collection destination on the ground surface above.

[0024] The example ESP 100 is only one example of many types of electric submersible pumps or pumping systems that can benefit from the diamond surface protection features described herein. Multiple pump stages having multiple pumps 102 and multiple motors 104 can be added to the ESP

lineup to make a longer string. Additionally, the production fluids may be pumped to a collection location partly through an annulus space around the ESP 100 that is also subject to abrasion and wear when the production fluid contains abrasive components. The example ESP 100 can use different types of pump stages, such as centrifugal, mixed flow, radial flow stages, and so forth.

Example Diamond Coatings

[0025] Example techniques for coating or layering diamond over component parts can be performed in many ways. Example processes can deposit diamond in either an amorphous form or a more crystalline layer. For the crystalline layers, some industry-employed processes can be used to treat ESP components that have never been conventionally coated with a diamond surface before. Processes for conventional non-ESP components include a diamond-like coating (DLC) process, crystalline diamond coating, and so forth. Such conventional coating techniques are already well-known in the art, but not applied to ESP components, and are not described herein in their technical detail.

[0026] Polycrystalline diamond (PCD) components are conventionally used for cutters (e.g., drill-bits). These may be obtained by sintering a powder of small diamonds (e.g., 10 to 50 microns diamonds) and other forms of carbons in a large mono-block of PCD. The operation may use pressure in

the range of 1.2 to 1.5 million PSI and a temperature in the range of 1500 degrees Celsius. In an example process, the PCD element is sintered with a backing block of tungsten carbide (chemical symbol: WC) for shear strength. The WC backing can be removed after the sintering process. A high-pressure high-temperature (HPHT) pressing process may obtain diamond blocks of large size (e.g., a nearly one inch dimension). For example, polycrystalline diamond cutters employed on drill bits are obtained by this process. By using a belt press, a WC plate covered with several hundred microns of PCD material can be obtained (such plate can have a width or diameter in the range of two inches). A lower-strength block of diamond can be obtained by a thermally stable polycrystalline (TSP) process in which the completed structure is closer to that of ceramic, with a high concentration of large diamond particles. Conventionally, TSP diamond elements are primarily used on the gauge pad of drill-bits.

[0027] Polycrystalline diamond (PCD) may consist of numerous small grains, which are easily seen by the naked eye through strong light absorption and scattering. Polycrystalline diamond (PCD) is often described by the average size (or grain size) of the crystals that make it up. Grain sizes range from nanometers to hundreds of micrometers, usually referred to as “nanocrystalline” and “microcrystalline” diamond, respectively.

[0028] Tungsten carbide (WC), as a backing material, is approximately two times stiffer than steel, with a Young's modulus of approximately 550 GPa

and is much denser than steel or titanium. Tungsten carbide is like corundum ($\alpha\text{-Al}_2\text{O}_3$) or sapphire/ruby in hardness and can only be polished and finished with abrasives of superior hardness such as cubic boron nitride and diamond.

Example Diamond Surfaces for ESP Components

[0029] The example diamond elements and layers for ESP components, as described herein, are used to improve the wear resistance of many surfaces that are conventionally left unprotected.

[0030] Fig. 2 shows an example centrifugal pump stage 200 of an ESP 100. The centrifugal pump stage 200 has stationary diffuser parts 202 and rotating impeller parts 204. A diamond surface may be applied at numerous places in the example centrifugal pump stage 200. For example, unmoving hydraulic flow surfaces 206 & 208, which are part of the stationary diffuser 202 within the centrifugal pump stage 200, may be layered with diamond to prevent erosion or abrasion from abrasive well fluid containing sand and particulates. The stage impellers 204 and diffusers 202 are subjected to abrasion from high velocity fluid flow containing particulates. An example ESP 100 may have a partial or a total diamond layering on all wet surfaces of each diffuser 202 and impeller 204.

[0031] A diamond surface may also be used on sliding surfaces of a central shaft 210 and on bearing surfaces 212 that support the central shaft 210. A diamond surface may be used on both sides of a thrust bearing or

thrust washer interface 214 to reduce friction, wear, and operating temperature of the thrust washer interface 214. The thrust washer bears the axial counter-load of the fluid thrust generated by the centrifugal pump stage 200. The thrust washer itself may be attached to the stationary diffuser 202 or to the rotating impeller 204, depending on implementation. The thrust washer interface 214 can be made up of a diamond surface on the stationary surface and a second diamond surface on the running surface of the thrust washer interface 214. Diamond surfaces may also be applied to each side of a hydraulic clearance seal 216 to prevent wear (more in Fig. 9).

[0032] The illustrated locations for using a diamond surface in an example ESP 100 and centrifugal pump stage 200 are only examples. Many more surfaces in a pump stage or ESP 100 can be protected by incorporating diamond surfaces to reduce friction, wear, and operating temperature. Thus, an example diamond component (whether solid diamond composite or a diamond-coated component) can be located in many places in an example ESP 100. The example ESP 100 includes locations and surfaces that are strategically coated with diamond to reduce abrasive wear and increase the life of the component or equipment.

Example Bearing Protection with Diamond Surfaces

[0033] A common failure mechanism in radial bearings of ESPs 100 is due to wear. Abrasives in the well fluid environment can induce accelerated

abrasive wear on the sliding surfaces of the bearings. In addition, friction and heat can reduce the ability of the fluid medium to lubricate the bearings.

[0034] In Fig. 3, the sliding surfaces of radial bearings can greatly benefit from a diamond layer. For example, a bearing bushing 300 may be coated with a diamond layer on the surface that faces a bearing sleeve 302, attached to a pump shaft 304. These two surfaces move with respect to each other, and only the diamond surfaces wear on each other. Since diamond is one of the hardest substances known, the lifespan of the bearing is greatly increased as the durability of the interface between the sliding surfaces of the bearing is greatly increased.

[0035] For a small shaft 304 in an ESP 100, for example a shaft 304 with a diameter no larger than approximately 0.8 inch in diameter, the two parts of a journal bearing, for example, can be made of solid PCD materials. For a larger shaft 304, in an implementation, the radial bearing(s) can also be constructed of PCD or TSP diamond tiles attached to a metallic support, such as tungsten carbide (WC). This example scheme can be applied to most or all radial bearings inside an example ESP 100, including radial bearings in the pump 102, pump fluid intake, gas handler, gas separator, protector 106, shaft seal modules, motor 104, and so forth.

Example Thrust Bearing Protection with Diamond Surfaces

[0036] As described above for Fig. 2, a diamond surface may be used on both sides of a thrust bearing or thrust washer interface 214 to reduce friction, wear, and operating temperature of the thrust washer interface 214.

[0037] In Fig. 4, pump load is often transferred to different types of axial thrust bearings. There may be bearing downthrust pads 402, bearing upthrust pads 404, and a bearing runner 406 in-between. The axial load on the pump impeller may reverse, thereby bringing the upthrust pads 404 into play when the direction of rotation of the impeller reverses, or when there is inherent pressure in a reservoir that pushes fluid into a pump intake. Heavy-load thrust bearings 402 are usually of the hydro-dynamic type with tilting pads, while low-load versions may be non-tilting. In both varieties, wear can be an issue especially when the lubricity between the sliding surfaces is lost. Having a diamond layer on the surfaces of the sliding parts reduces wear, friction and heat. The diamond layer can be applied on the running surfaces of the downthrust 402 and upthrust pads 404, as well as on the surfaces of the bearing runner 406. Depending on the size of the sliding parts, these parts can be fabricated from solid PCD or TSP diamond materials supported by tungsten carbide (WC) backing. The thrust bearing 402 can also be fabricated by multiple flat PCD (over WC) elements sliding onto other similar elements. Such a bearing can operate in abrasive well-fluid.

Shaft Seals

[0038] As shown in Fig. 5, shaft seals feature a rotating face 502 and a static face 504 that slide against each other, not necessarily to bear a load, but to achieve a hydraulic seal. The faces of the sliding surfaces 502 & 504 are often precision-lapped to achieve the best possible seal. These surfaces can be subject to sand particles in the lubricating environment that add to the sliding wear.

[0039] In Fig. 5, the use of diamond layers on ESP shaft seals can greatly improve their sealing capacity in terms of reduced wear, friction and temperature. In an implementation, the face-seals 502 & 504 can be made of PCD or TSP diamond material. For small shaft diameter, each entire face seal can be made of PDC material. For larger shaft, the face seal 502 or 504 can be made of a plate, such as PCD over tungsten carbide (WC) cut into a ring shape for the seal.

[0040] Fig. 6 shows an example shaft seal 600 that uses a face seal 602. In an implementation, the shaft seal 600 has face seal components that are made, at least in part, from a carbide, such as silicon carbide. These face seal surfaces are coated with diamond.

[0041] Fig. 7 shows an implementation of the example face seal 602 in Fig. 6. In an implementation, the sliding surfaces of the face seal 602 are replaced or layered with a diamond surface. In an implementation, diamond surfaces 702 and 704 are sintered directly to a carbide surface of the face

seal components, or, the face seal components themselves may be solid carbide, to which the diamond layer is sintered.

[0042] Fig. 8 shows another example implementation of the example face seal 602 in Fig. 6. In this implementation, the diamond layers 802 & 804 are sintered to respective carbide pieces or supports 806 & 808, and then these are brazed in turn onto the steel material of the face seal components 810 & 812.

Hydraulic seals

[0043] Pump stage performance depends on the ability to route fluids through the appropriate pathways. Fig. 9 shows a pump interior in which various hydraulic seals (or clearance seals) 902 & 904 & 906 between impellers and diffuser parts achieve fluid routing while controlling the amount of leak that goes through non-productive paths. In general, these hydraulic seals 902 & 904 & 906 are created by having sliding surfaces with very small clearances between the rotating impeller and the stationary diffuser. The pumped fluid together with accompanying abrasive particles can create unwanted wear in the seal surface. A diamond layer can be applied to these seal surfaces during manufacture to reduce wear.

[0044] In a “floating” stage construction, each ESP impeller slides against its own thrust support. In such a design, the impeller thrust support can also act as a seal. Using a PCD disk is beneficial for such design because the

PCD disk can operate in well fluid, where the PCD disk material provides wear resistance and low friction-torque.

Pump Internal Passages & Wet Areas

[0045] As shown in Fig. 10 and Fig. 11, there are other internal components inside a pump section 102 of an ESP 100 that are subjected to produced fluid flow and that can wear over time. Examples of these components that can be at least partly covered with a protective diamond surface are spaces and cavities in the pump, shafts 1002, pump heads 1102, pump bases 1004, flange areas 1006, bearing supports 1008 & 1104, flow directors 1010 & 1106, spacers 1012 & 1108 & 1110, and so forth.

Pump Intakes

[0046] In Fig. 12, the pump intake 1200 (or gas separator, handler) is subjected to internal flow similar to that of the pump 102 but, in addition, the intake 1200 can also have localized high-velocity flow on the inlet ports 1202. Diamond coatings throughout the inlet locations, on both the interior and exterior of the intake 1200, for example on the inlet ports 1202 and on the interior and exterior of the screen 1204, are beneficial to reduce wear of these components.

Example Method

[0047] Fig. 13 shows a representative process 1300 for protecting ESP components. The example process 1300 is shown as individual blocks.

[0048] At block 1302, an area of wear in an electric submersible pump or other downhole equipment is determined.

[0049] At block 1304, the area of wear is coated with a layer of diamond.

CONCLUSION

[0050] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from the subject matter. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, 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. 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 words 'means for' together with an associated function.

CLAIMS

1. An apparatus, comprising:
an electric submersible pump; and
a diamond coating, the diamond coating at least partially covering at least one component of the electric submersible pump to reduce one of a friction, a wear, or an operating temperature of the at least one component.
2. The apparatus of claim 1, wherein the diamond coating is selected from the group consisting of an amorphous diamond coating, a polycrystalline diamond (PCD) coating, a thermally stable polycrystalline (TSP) diamond coating, a lonsdaleite diamond coating, and a diamond-wurtzite boron nitride coating.
3. The apparatus of claim 2, further comprising one of a tungsten carbide (WC) support for the diamond coating or a silicon carbide (SiC) binder for the diamond coating.
4. The apparatus of claim 2, wherein the diamond coating at least partially covers a surface of a hydraulic flow passage or cavity of the electric submersible pump to reduce an erosion or an abrasion of the hydraulic flow passage or cavity.

5. The apparatus of claim 2, wherein the diamond coating at least partially covers a sliding surface of a radial bearing component included in a section of the electric submersible pump, wherein the section is selected from the group consisting of a pump section, a motor section, an intake section, an inlet port, a gas handler section, a gas separator section, a protector section, and a shaft seal module section.

6. The apparatus of claim 5, wherein the diamond coating covers at least part of an exterior and an interior of a fluid intake section of a pump section of the electric submersible pump.

7. The apparatus of claim 2, wherein the diamond coating at least partially covers a thrust bearing of the electric submersible pump, wherein the thrust bearing is selected from the group consisting of a hydrodynamic thrust bearing, a tilting pad thrust bearing, a non-tilting thrust bearing, downthrust thrust bearing, an upthrust thrust bearing, and a thrust bearing runner.

8. The apparatus of claim 2, wherein the diamond coating at least partially covers a rotating face or a static face of a shaft seal to improve a sealing capacity of the shaft seal by reducing a friction, a wear, or an operating temperature of the shaft seal.

9. The apparatus of claim 8, wherein a face-seal of the shaft seal is made entirely of a PCD or TSP diamond material or the face-seal is made of a plate comprising a PCD material over a tungsten carbide (WC) backing cut into a ring shape.

10. The apparatus of claim 2, wherein the diamond coating at least partially covers a wet surface of an impeller or a wet surface of a diffuser of the electric submersible pump to reduce an erosion or an abrasion of the wet surface.

11. The apparatus of claim 2, wherein the diamond coating at least partially covers a surface of a hydraulic seal or a clearance seal between an impeller and a diffuser of the electric submersible pump, to reduce a wear of the hydraulic seal or the clearance seal from an abrasive in a fluid being pumped by the electric submersible pump.

12. The apparatus of claim 2, wherein the diamond coating at least partially covers a shaft, a pump head, a pump base, a flange area, a bearing support, or a flow director of the electric submersible pump.

13. The apparatus of claim 2, wherein the diamond coating comprises a layer of diamond deposited or sintered in a crystalline form on the at least one component or on a backing support attached in turn to the at least one component.

14. The apparatus of claim 2, wherein the diamond coating comprises a layer of diamond deposited or sintered in an amorphous form on the at least one component or on a backing support attached in turn to the at least one component.

15. The apparatus of claim 2, wherein the diamond coating is supported by a tungsten carbide (WC) backing support.

16. An apparatus, comprising:
an electric submersible pump;
a bearing in the electric submersible pump; and
a bearing surface of the bearing composed at least in part of diamond.

17. The apparatus of claim 16, wherein the bearing comprises a two-part journal bearing, wherein each part of the two-part journal bearing is made of solid polycrystalline diamond (PCD).

18. The apparatus of claim 16, wherein the bearing comprises a radial bearing, wherein the radial bearing comprises at least in part PCD or TSP diamond tiles attached to a metallic support.

19. A system, comprising:
an electric submersible pump (ESP) or ESP string;
at least one component of the ESP or ESP string possessing a surface composed of diamond or coated in diamond or having a layer of diamond.

20. The system of claim 19, wherein the at least one component is selected from a group consisting of a bearing, a thrust washer, a shaft, a sliding surface, a hydraulic flow surface, a flow passage, an internal fluid passage, a fluid intake port, a downthrust pad, an upthrust pad, a bearing runner, a shaft seal, a face-seal, a hydraulic seal, a clearance seal, a wet area, and a surface susceptible to erosion or abrasion.

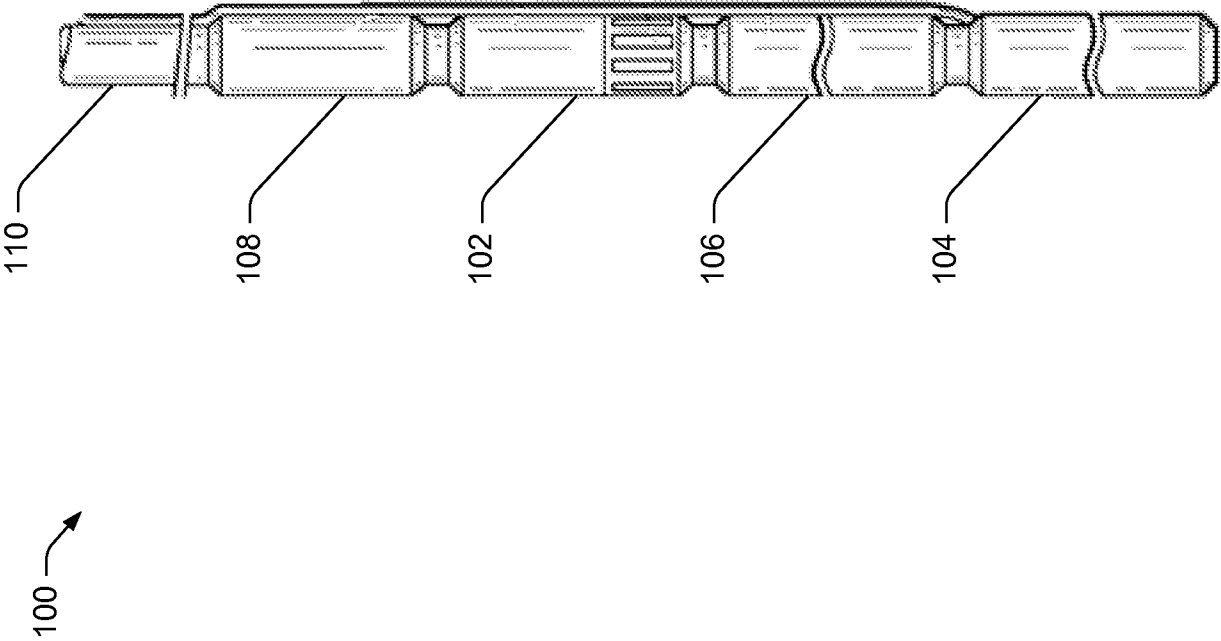


FIG. 1

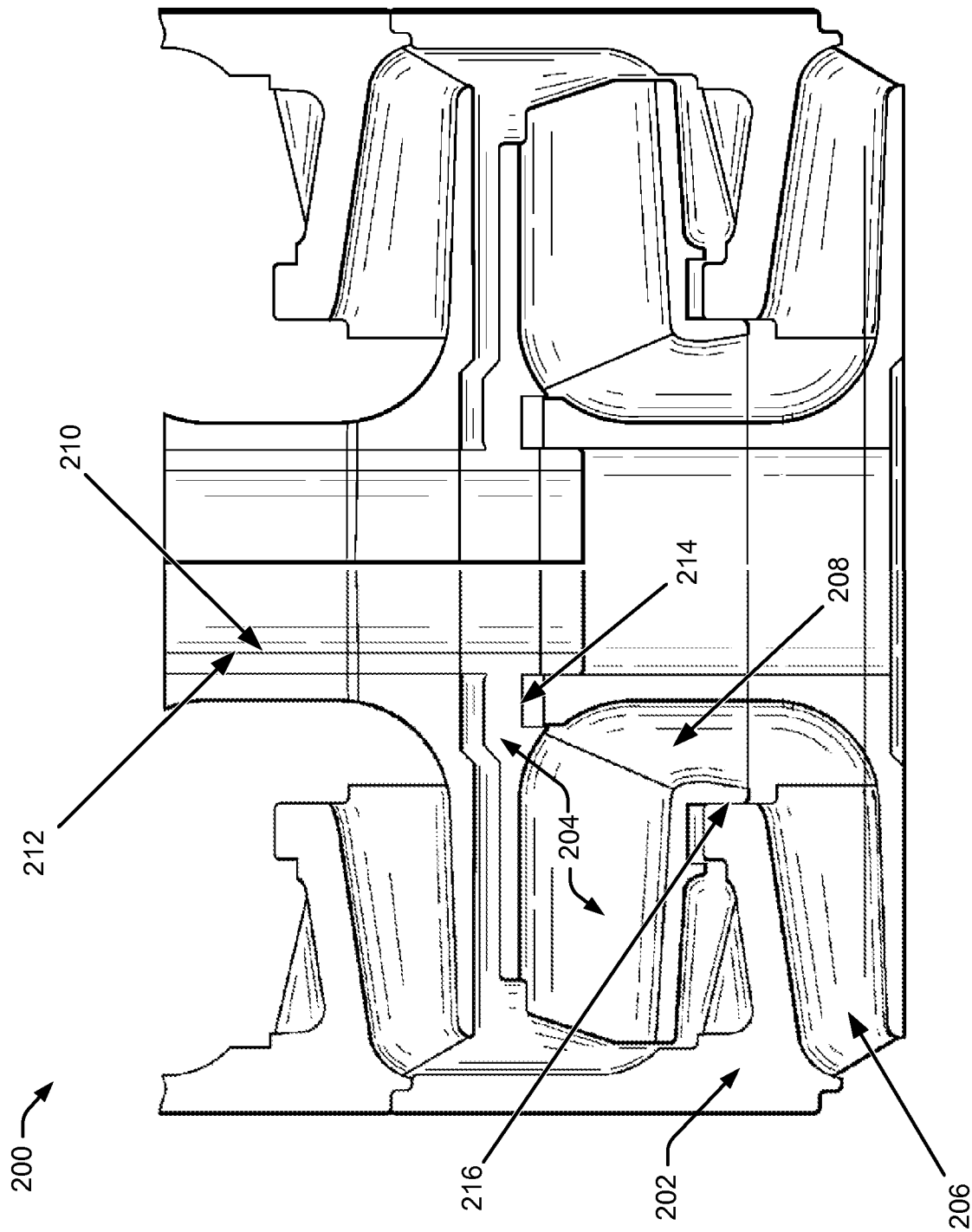


FIG. 2

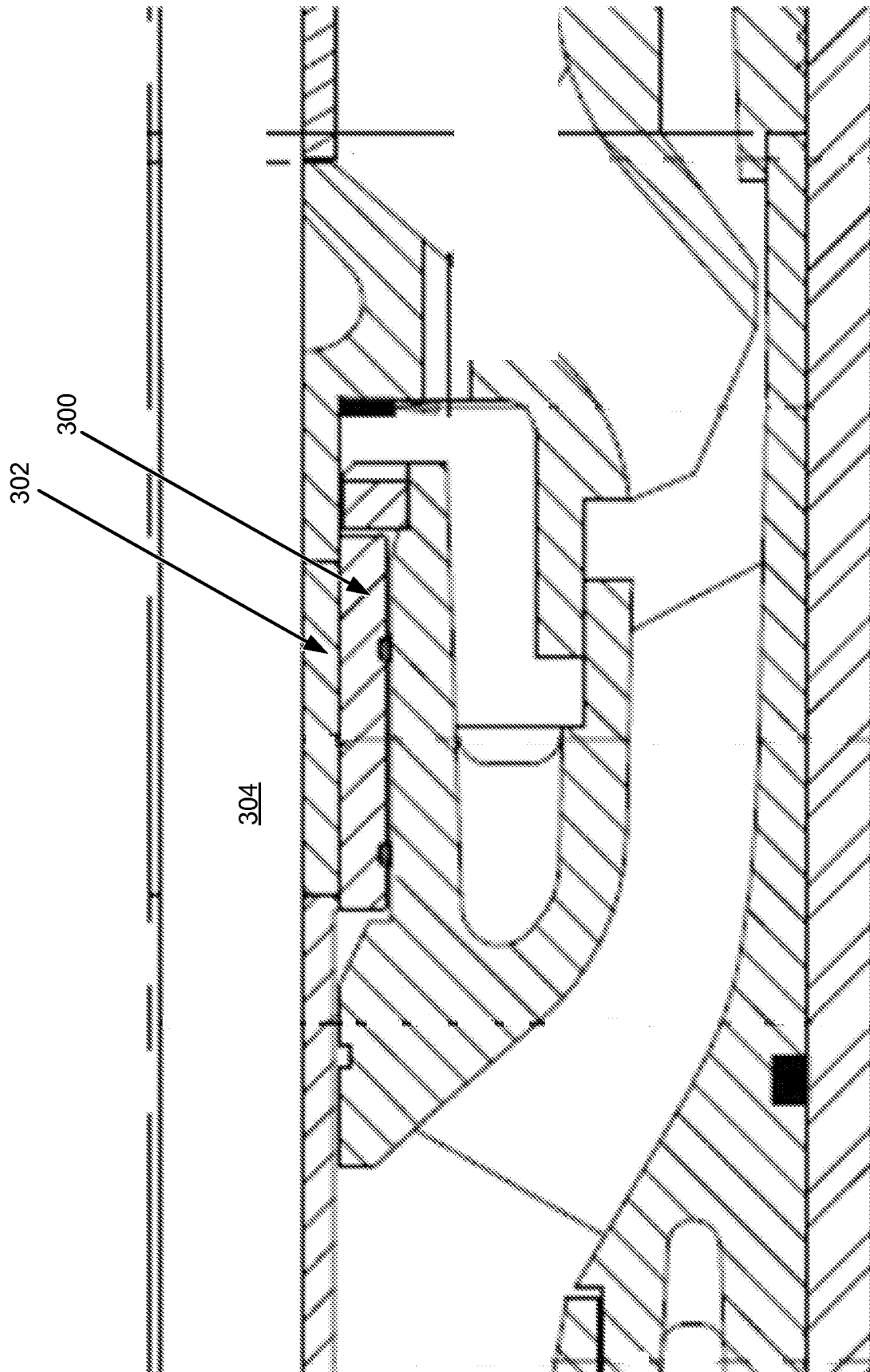


FIG. 3

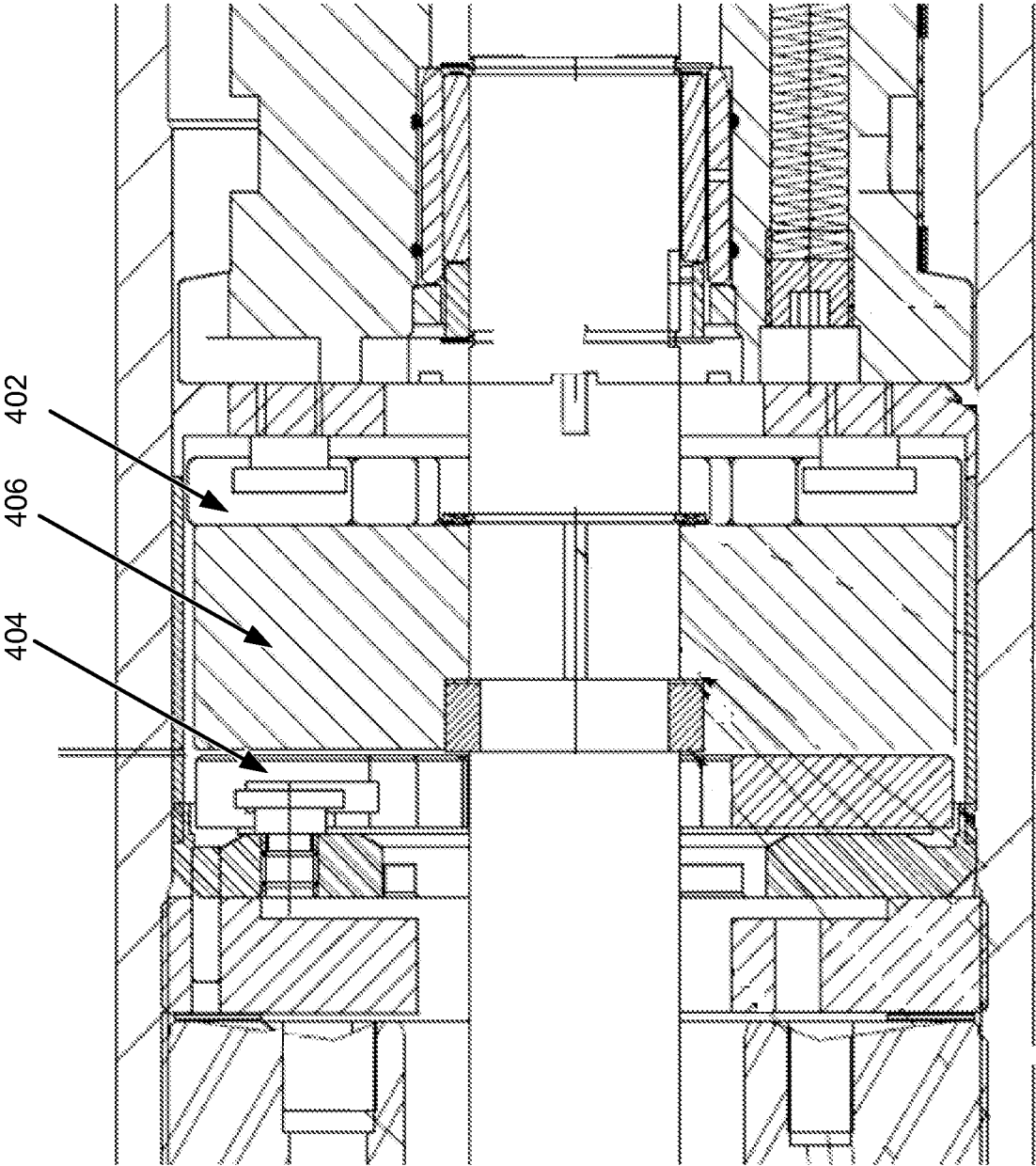


FIG. 4

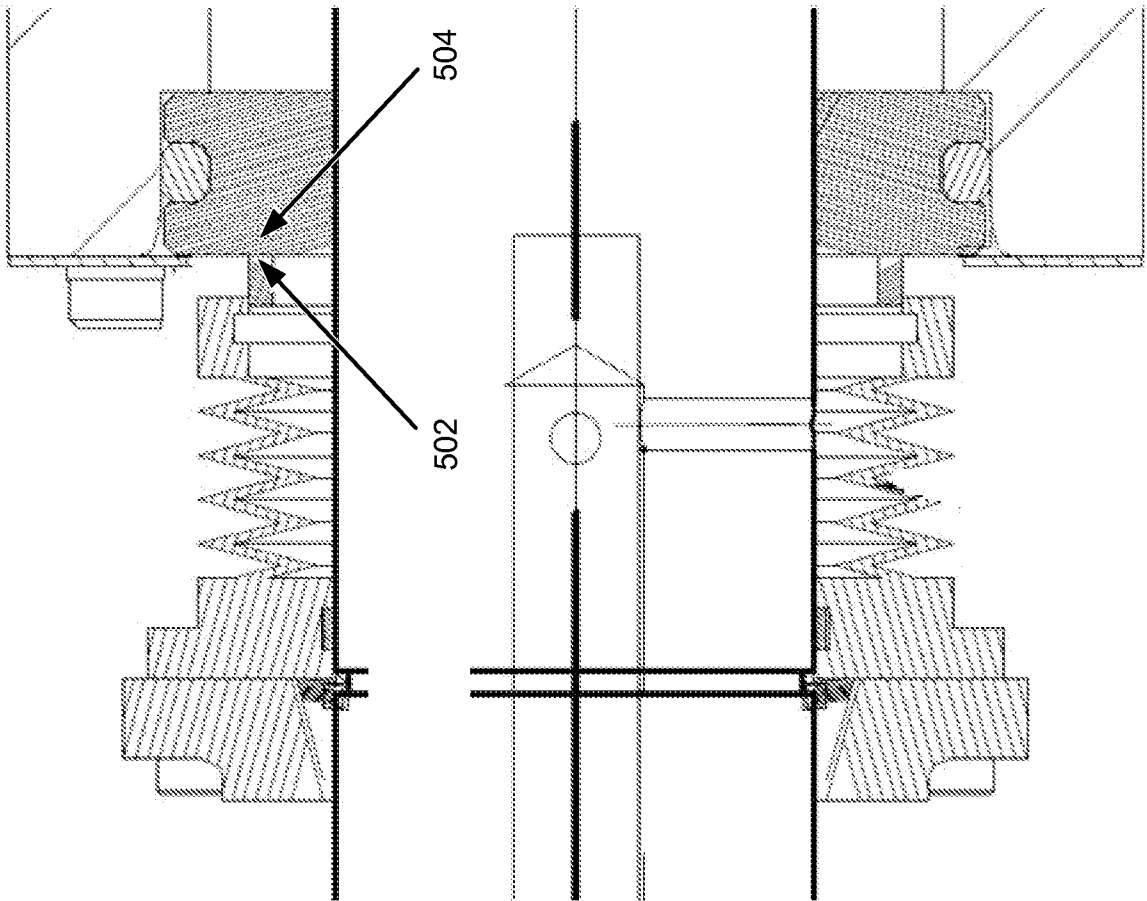


FIG. 5

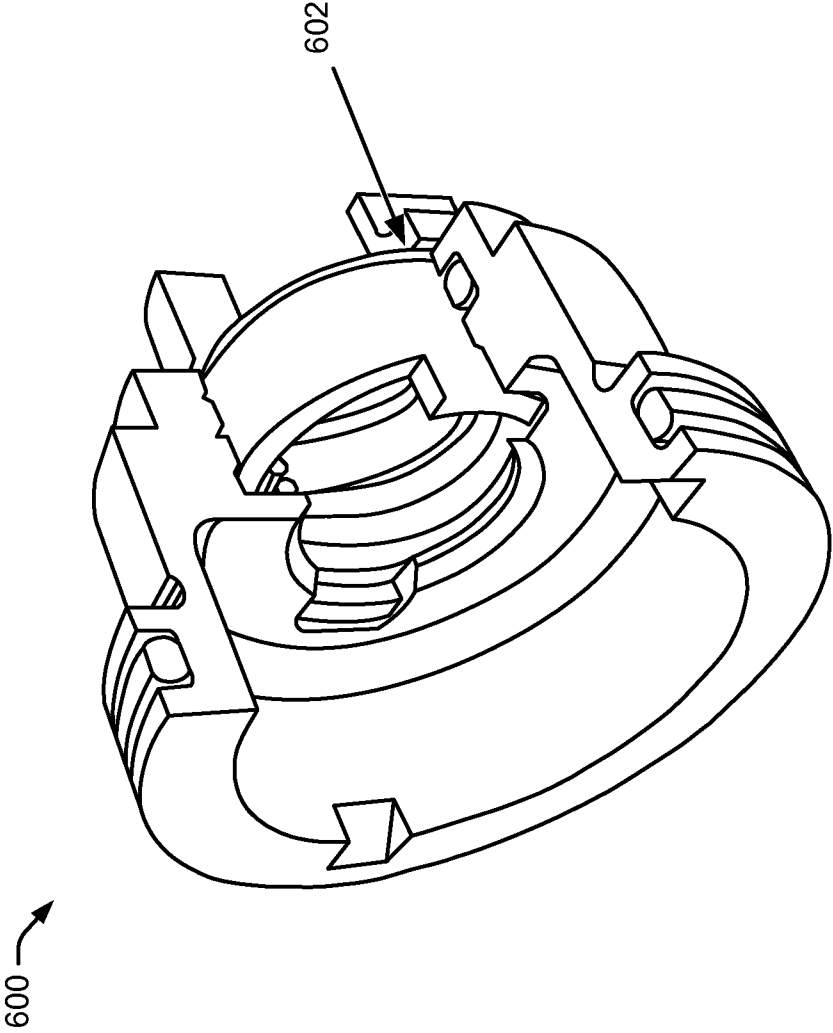


FIG. 6

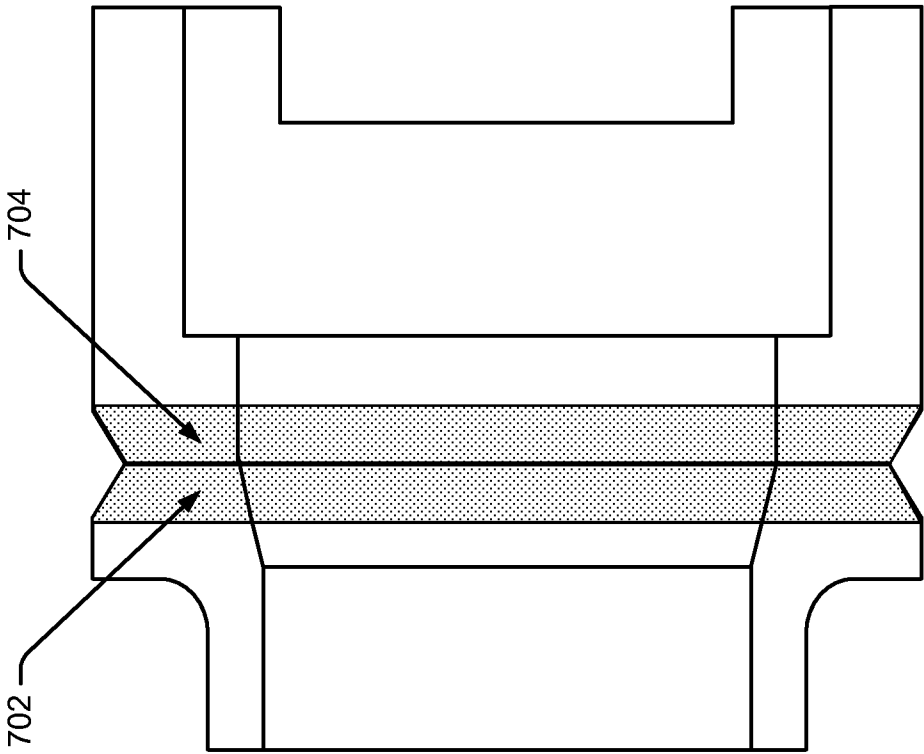


FIG. 7

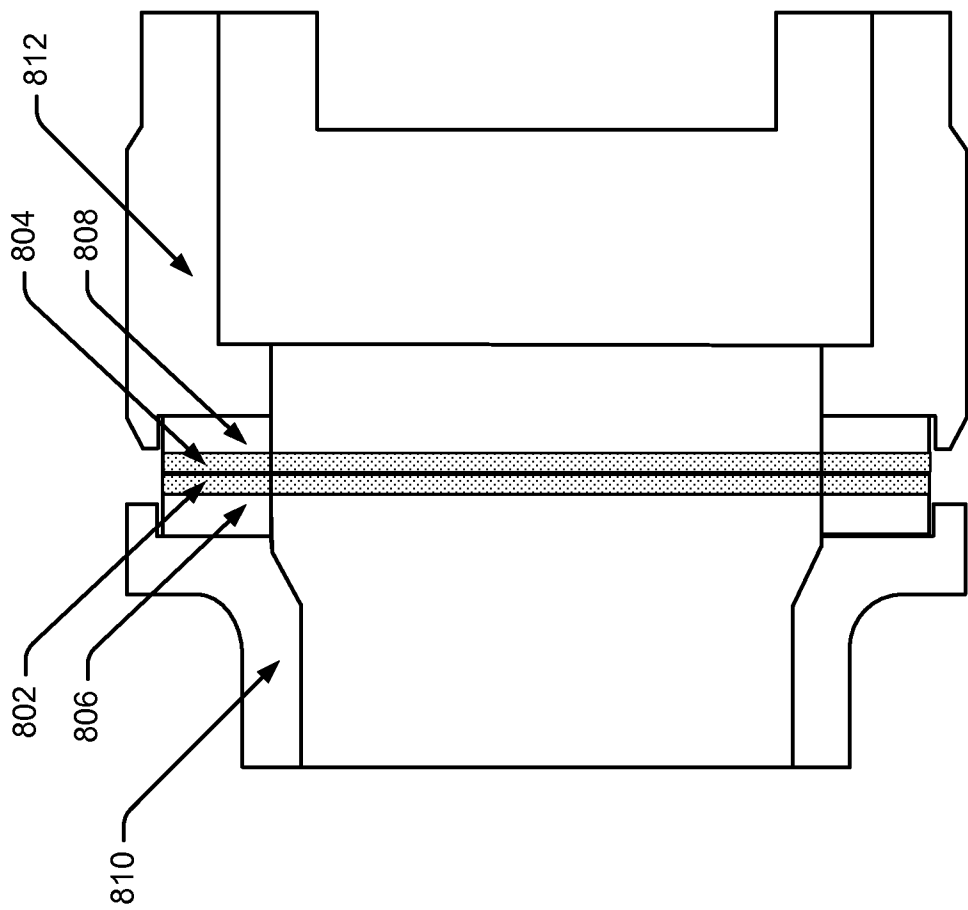


FIG. 8

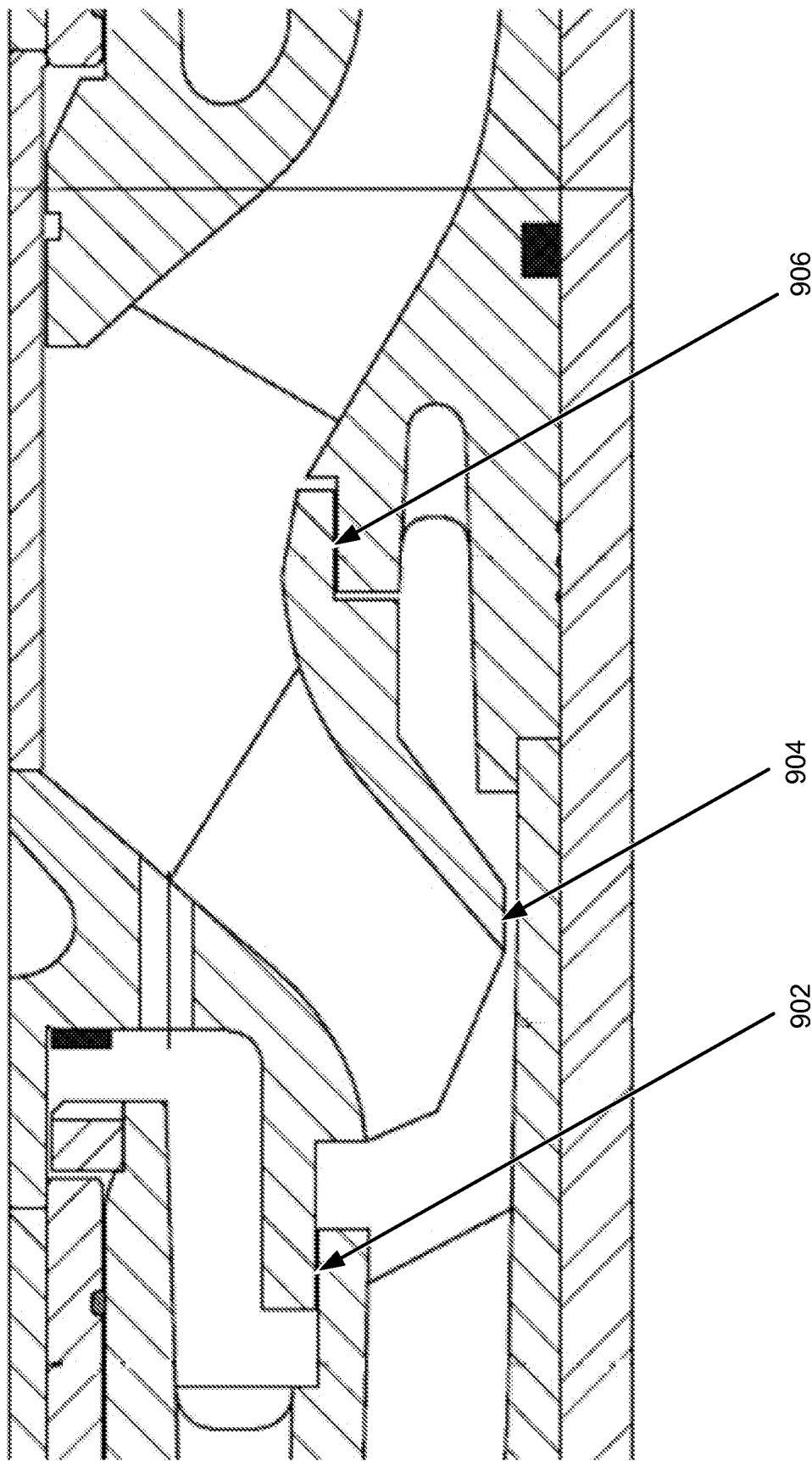


FIG. 9

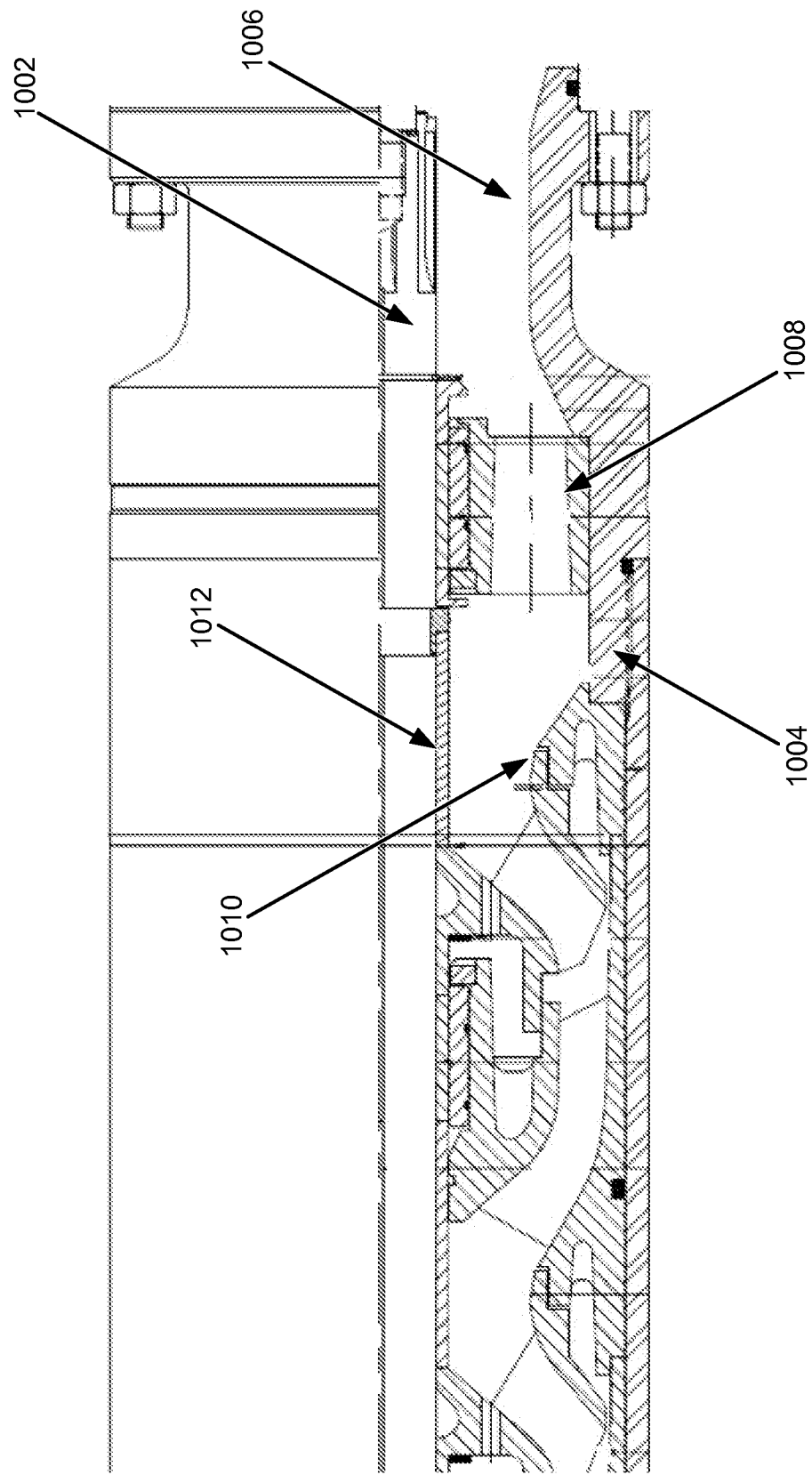


FIG. 10

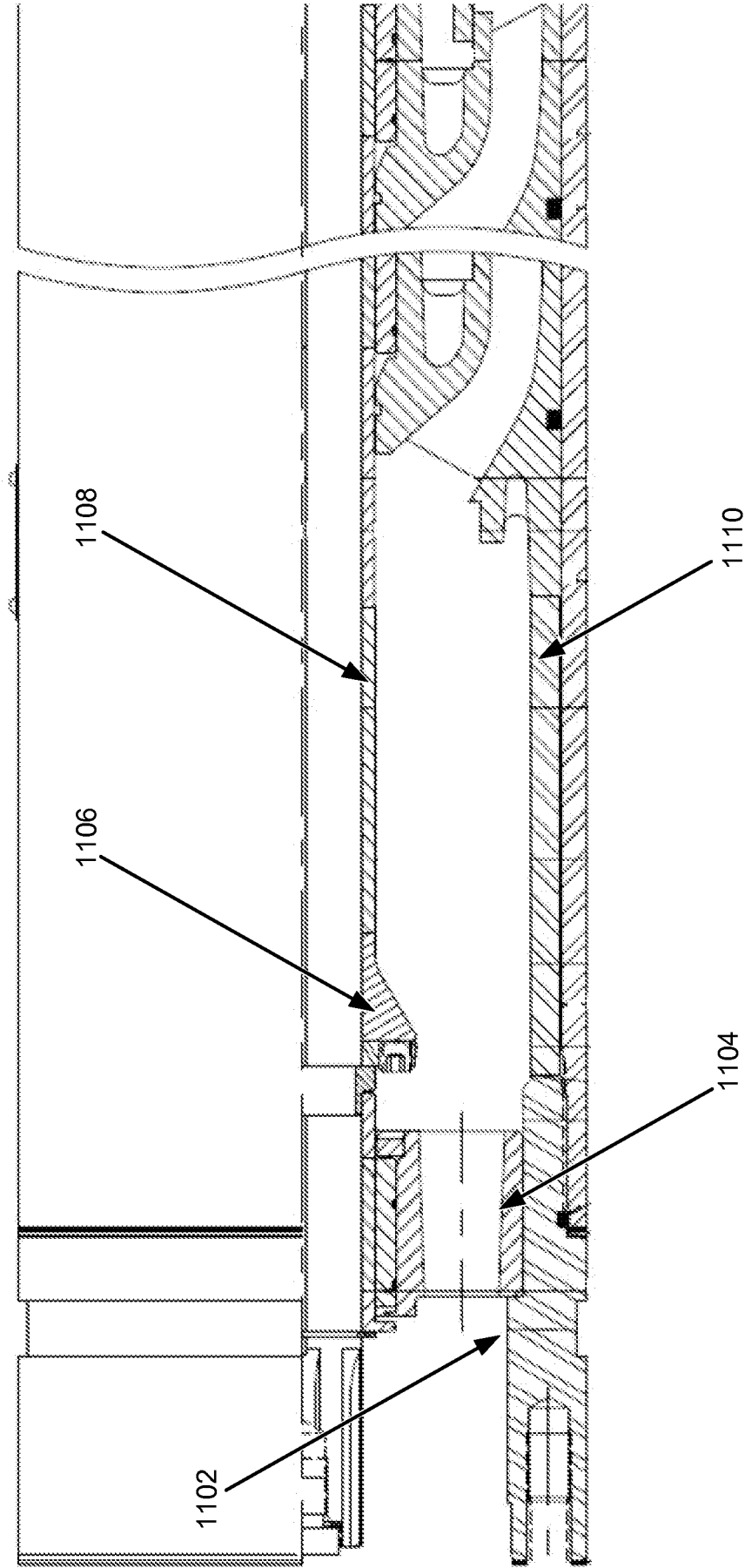


FIG. 11

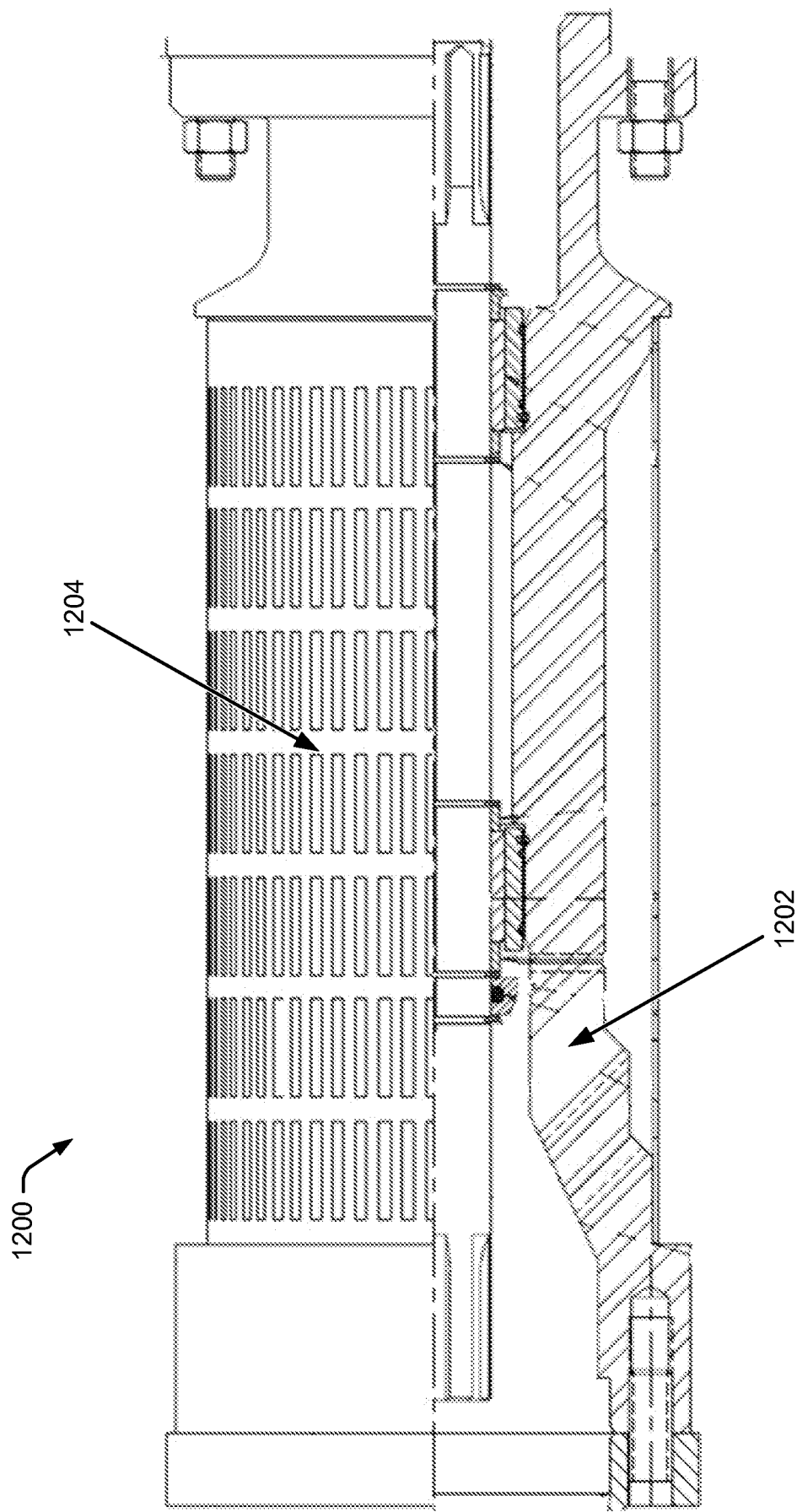


FIG. 12

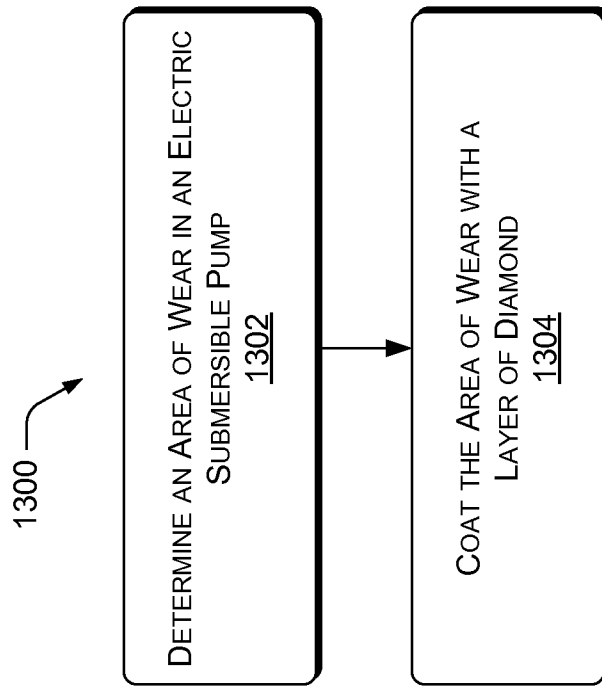


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/042510**A. CLASSIFICATION OF SUBJECT MATTER****F04D 13/10(2006.01)i, E21B 43/12(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)

F04D 13/10; E21B 7/00; E21B 10/36; E21B 10/00; H02K 5/12; F16C 17/04; F01D 3/00; F16C 32/00; F16C 17/02; F16C 33/12; E21B 43/12

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: electric submersible pump, diamond, coating, friction, wear, and temperature

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0024198 A1 (DICK, AARON J. et al.) 03 February 2011 See paragraphs [0042], [0046]–[0049] and figures 6–8.	1–20
A	JP 2006-275286 A (EBARA CORP.) 12 October 2006 See abstract, paragraph [0010], and figures 1,2.	1–20
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A	US 2005-0269885 A1 (KNOX, DICK L. et al.) 08 December 2005 See paragraph [0016] and figure 3.	1–20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

08 October 2014 (08.10.2014)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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