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(54) **RECIPROCATION-DAMPENING DRIVE SHAFT ASSEMBLY**

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(51) **Int. Cl.**

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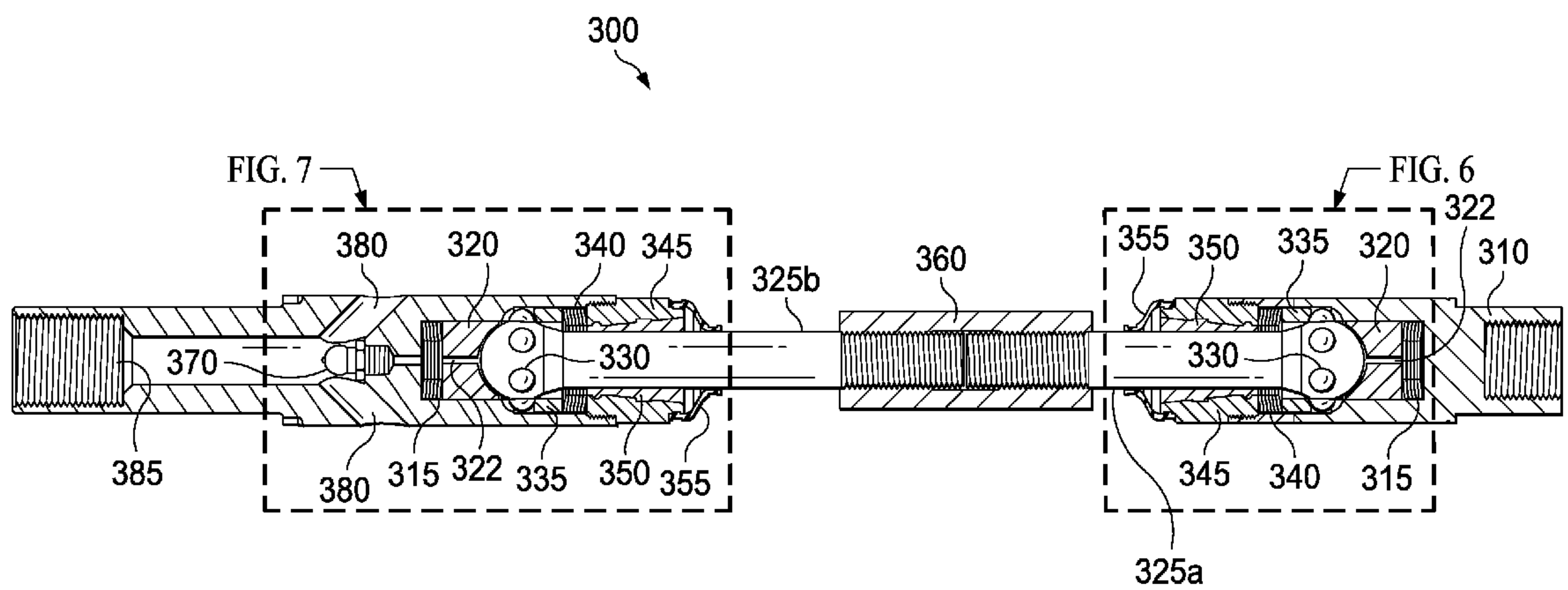
E21B 4/00	(2006.01)
F16C 3/02	(2006.01)

(52) **U.S. Cl.**

CPC ***F16D 3/22*** (2013.01); ***F16D 3/065*** (2013.01); *F16F 1/3605* (2013.01); ***F16C 3/02*** (2013.01); *E21B 4/00* (2013.01); ***E21B 4/003*** (2013.01)

(57) **ABSTRACT**

Mechanical stresses caused by jarring axial loads reduce the operational life of conventional drive shaft assemblies, increase non-productive downtime, and increase costs. A reciprocation-dampening drive shaft assembly is disclosed that allows the drive shaft to rotate and withstand axial loads, as well as vibration, without slippage or damage to the adapters of the drive shaft assembly, thereby extending productive uptime of drilling operations. The reciprocation-dampening drive shaft assembly includes first and second reciprocation-dampening adapters, first and second floating seats, first and second drive shaft portions, first and second floating rings, first and second reciprocation-dampening adapter caps with dampener inserts, and first and second boots. The spheroidal ends of the first and second drive shaft portions have limited axial freedom of motion while rotating without damaging the adapters. In addition, the dampener insert included with the first and second reciprocation-dampening adapter caps reduce vibration.



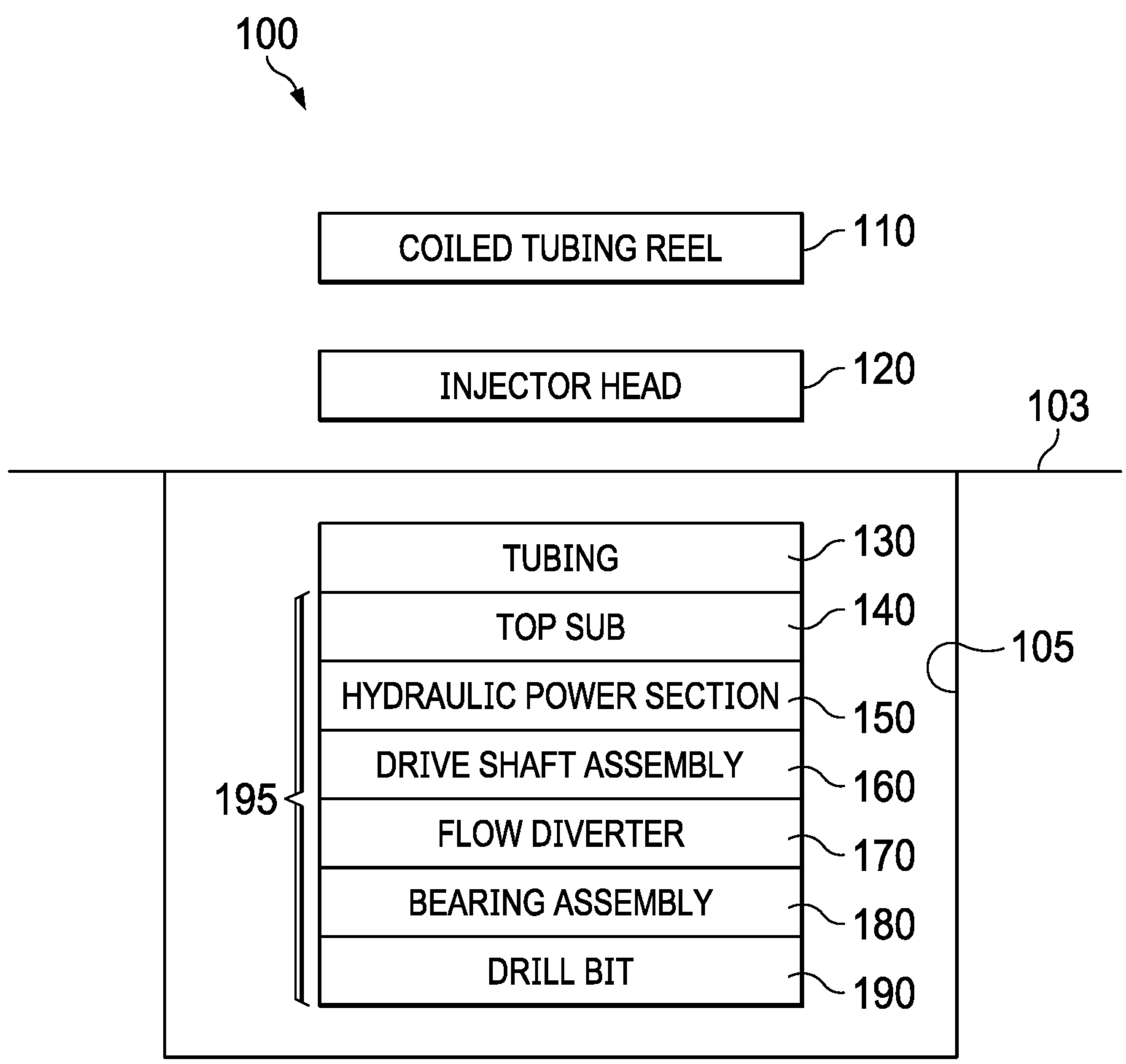


FIG. 1
PRIOR ART

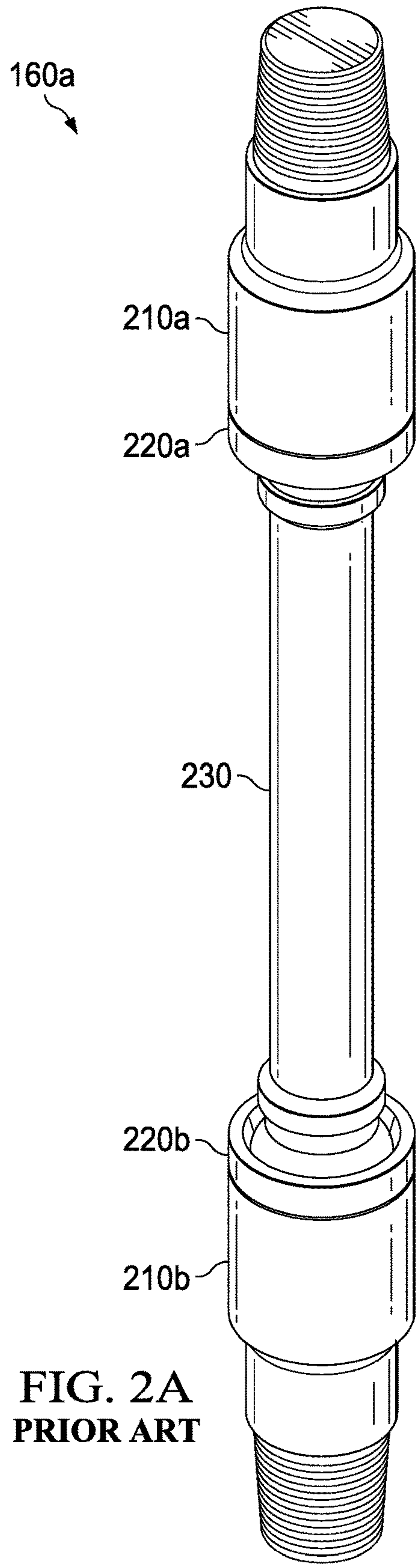


FIG. 2A
PRIOR ART

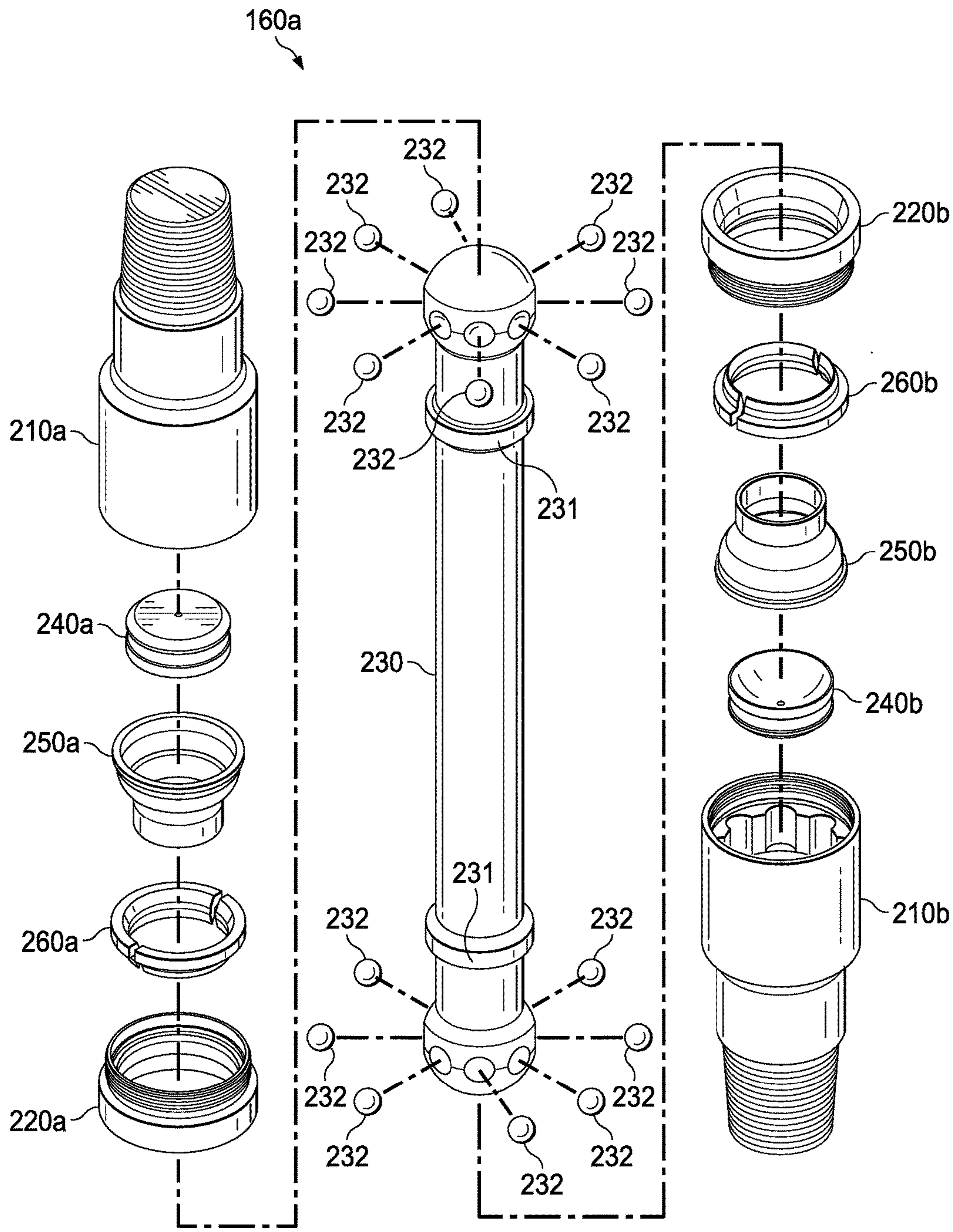


FIG. 2B
PRIOR ART

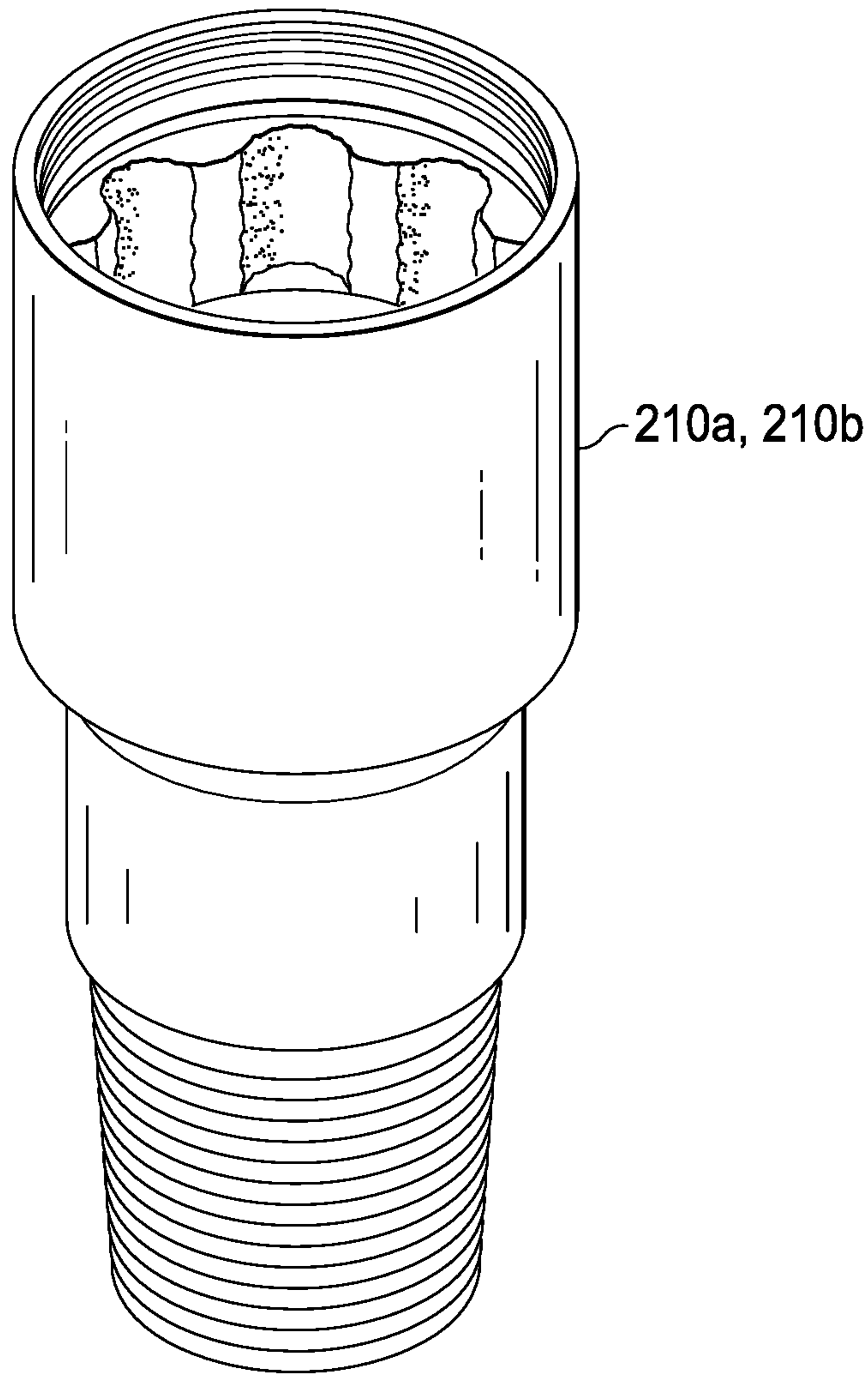


FIG. 2C
PRIOR ART

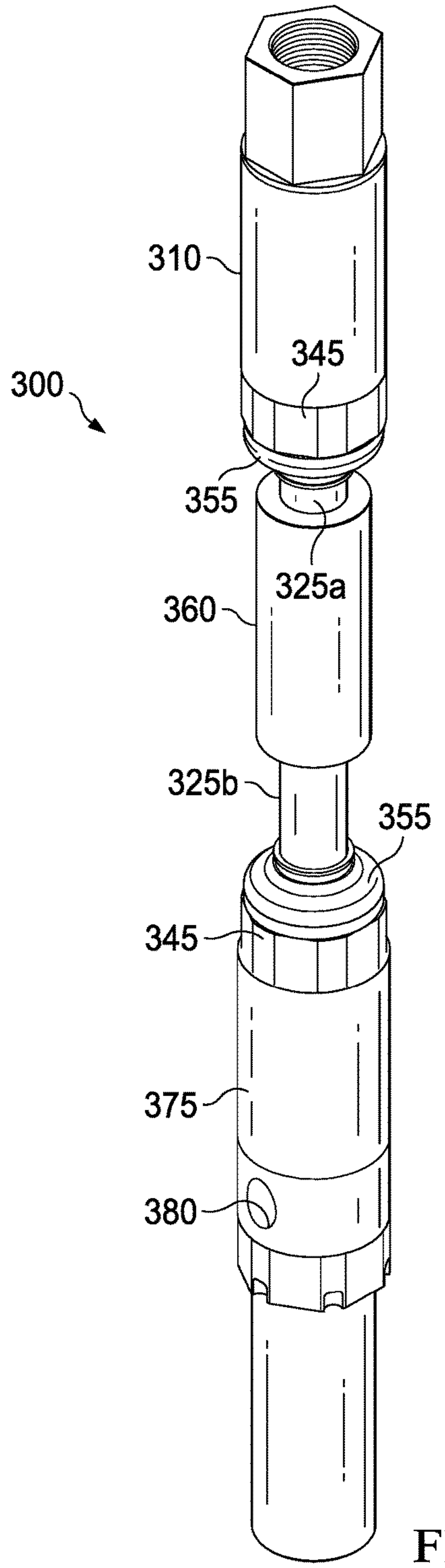


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FIG. 3A

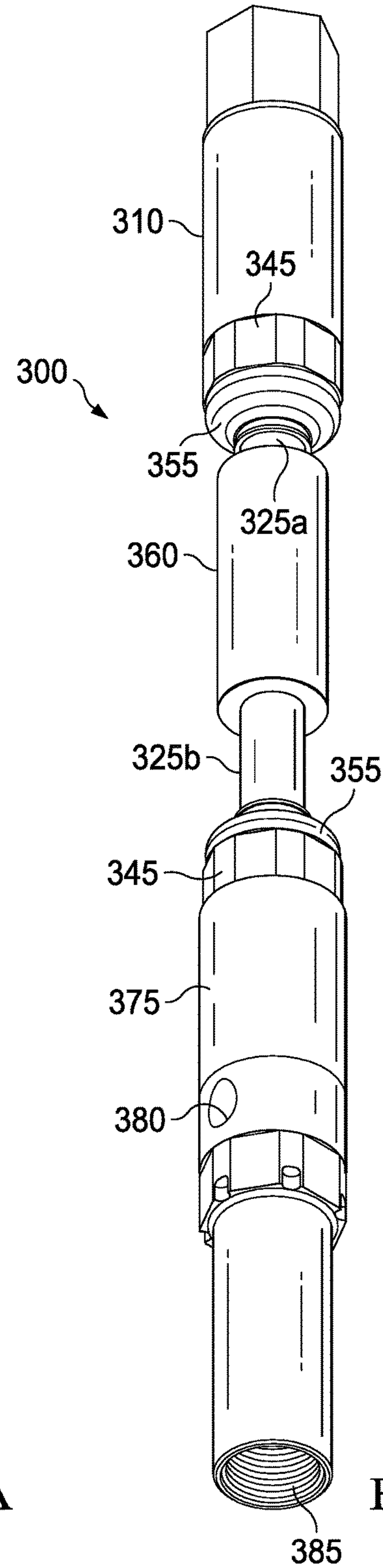

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FIG. 3B

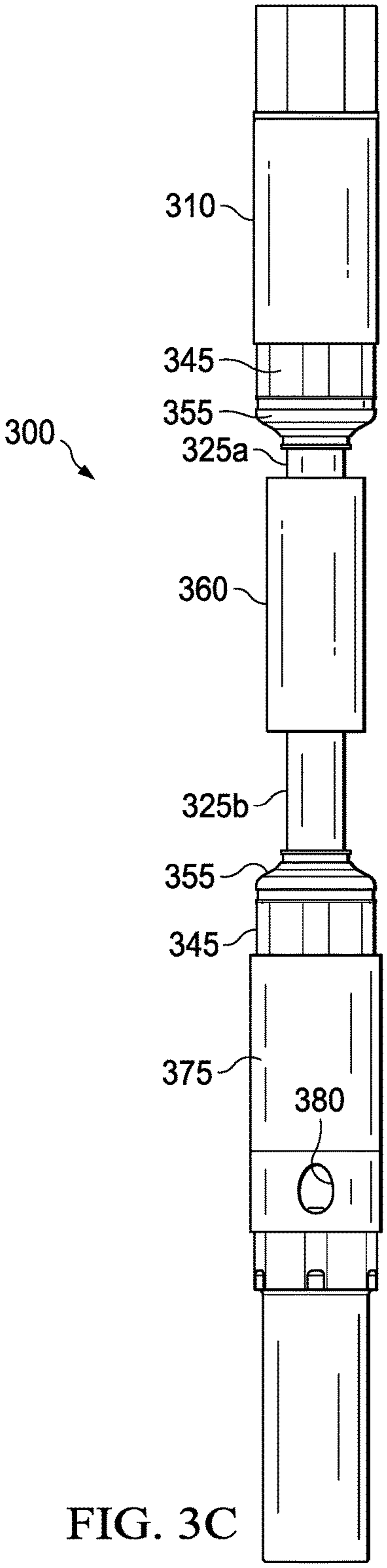
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FIG. 3C

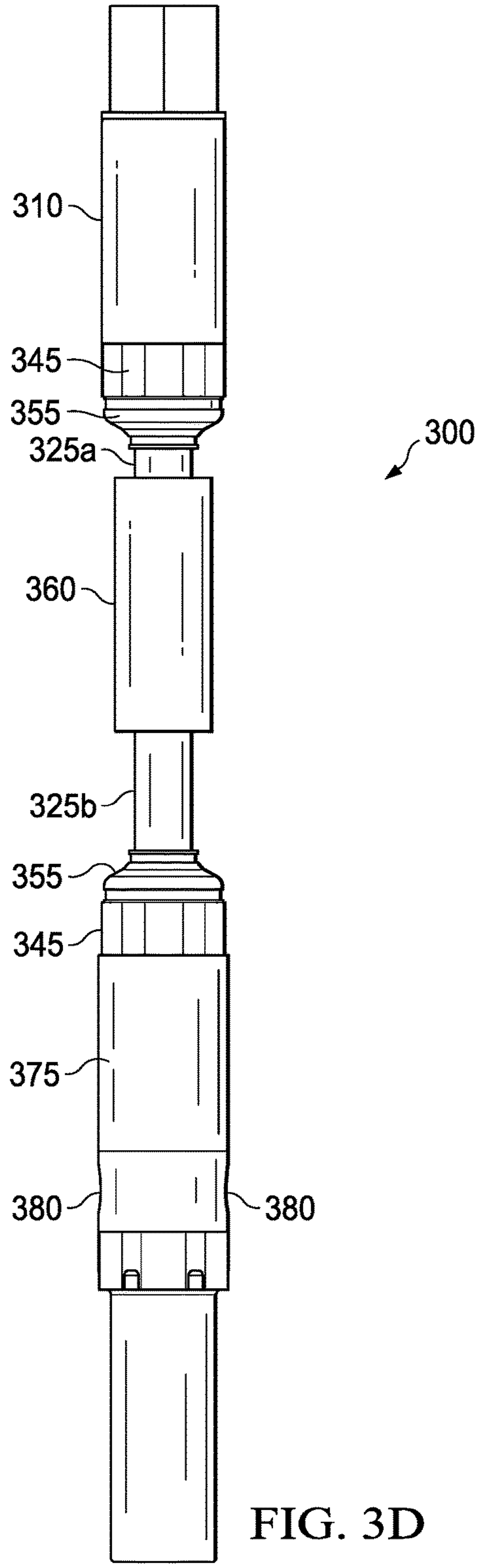
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FIG. 3D

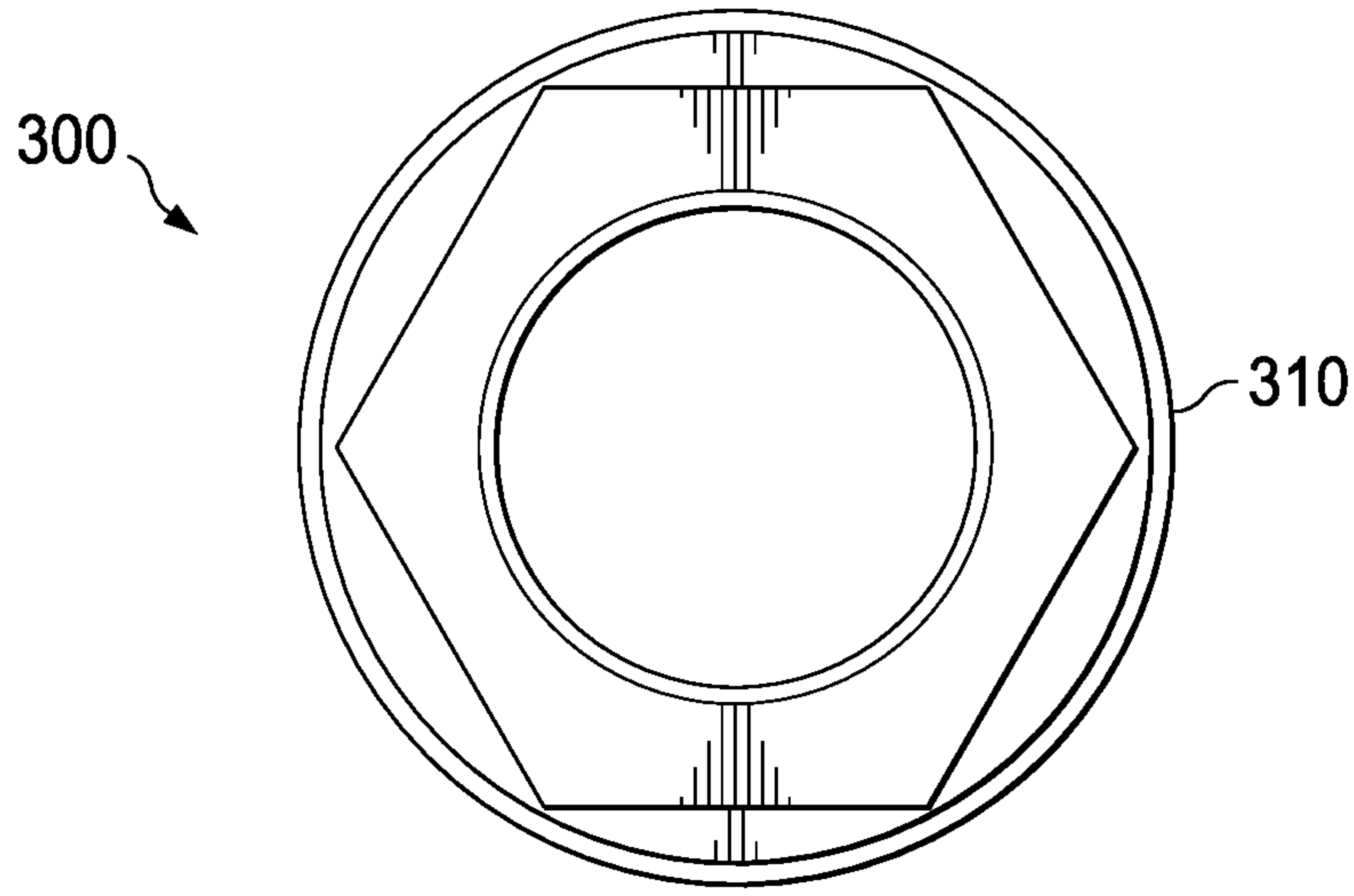

FIG. 3E

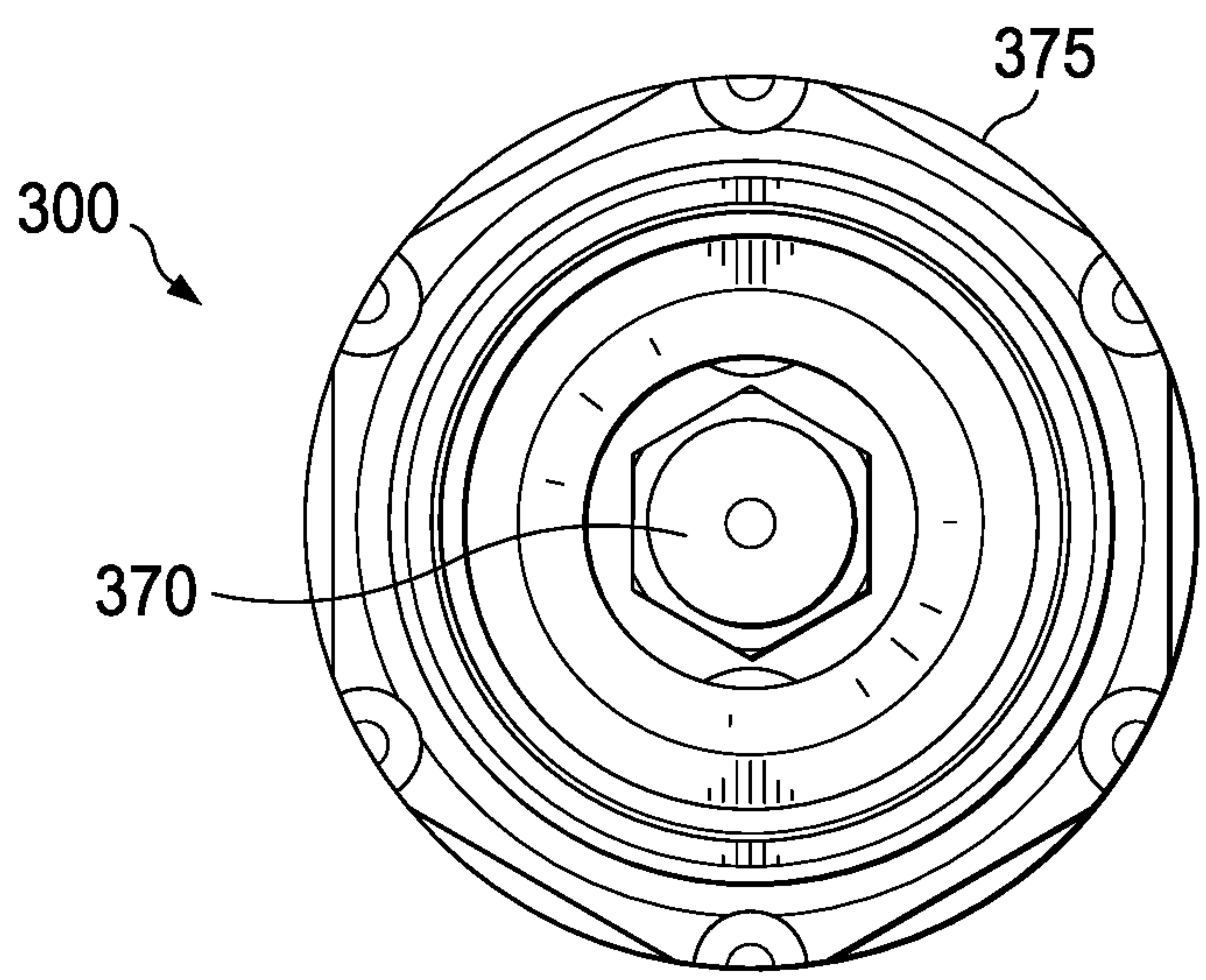

FIG. 3F

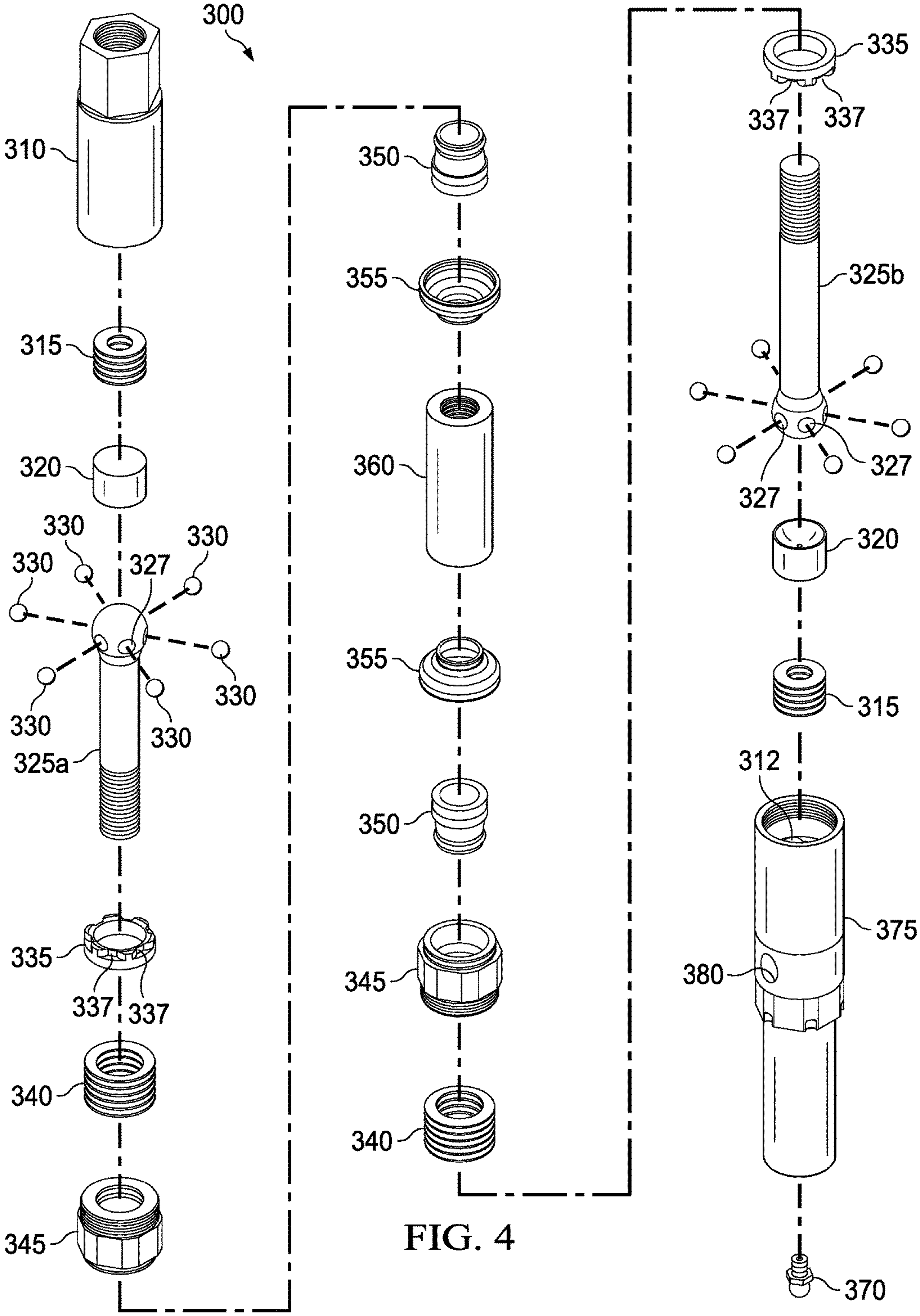
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FIG. 4

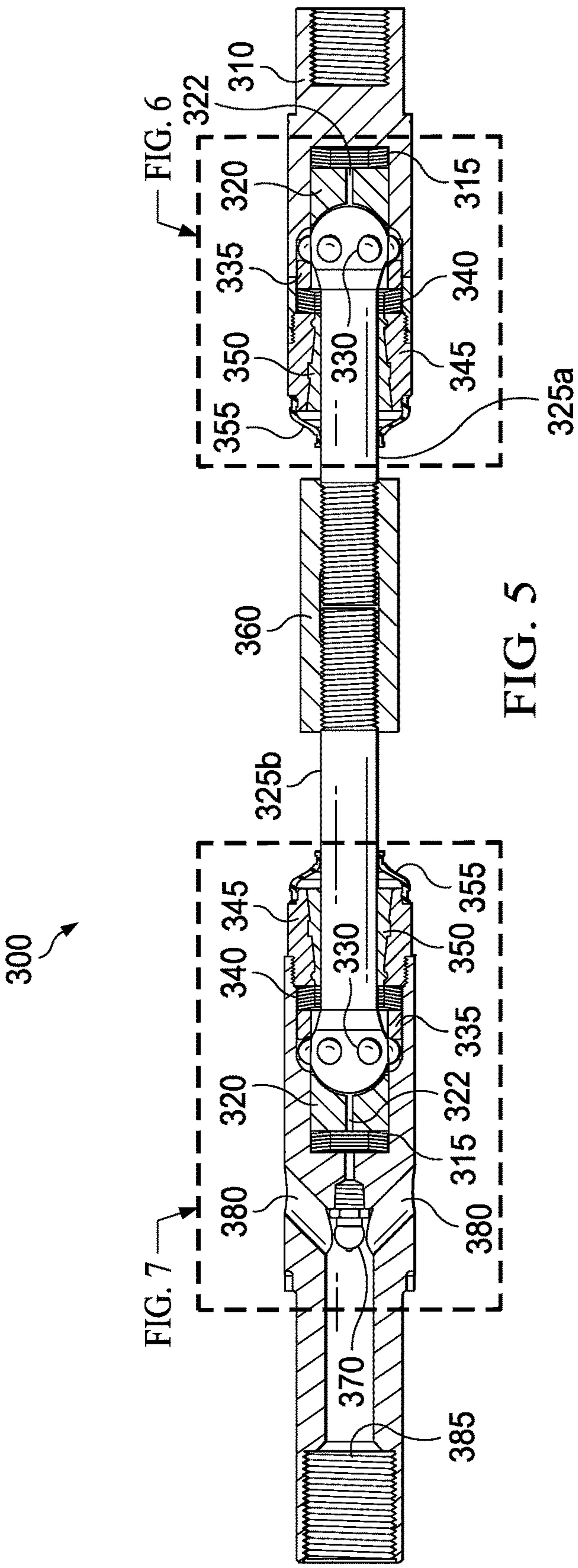
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FIG. 6
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FIG. 7
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FIG. 5

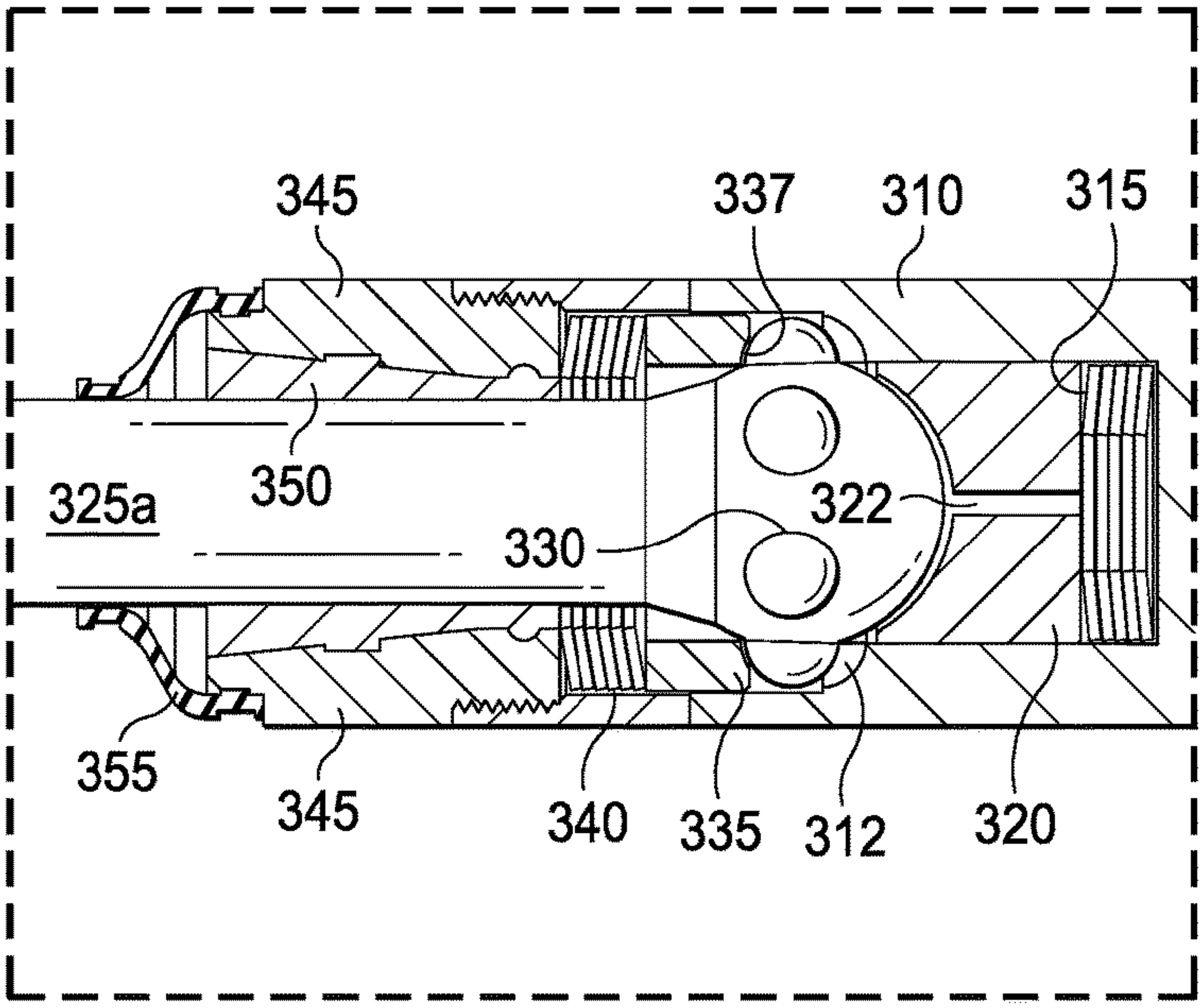
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FIG. 6

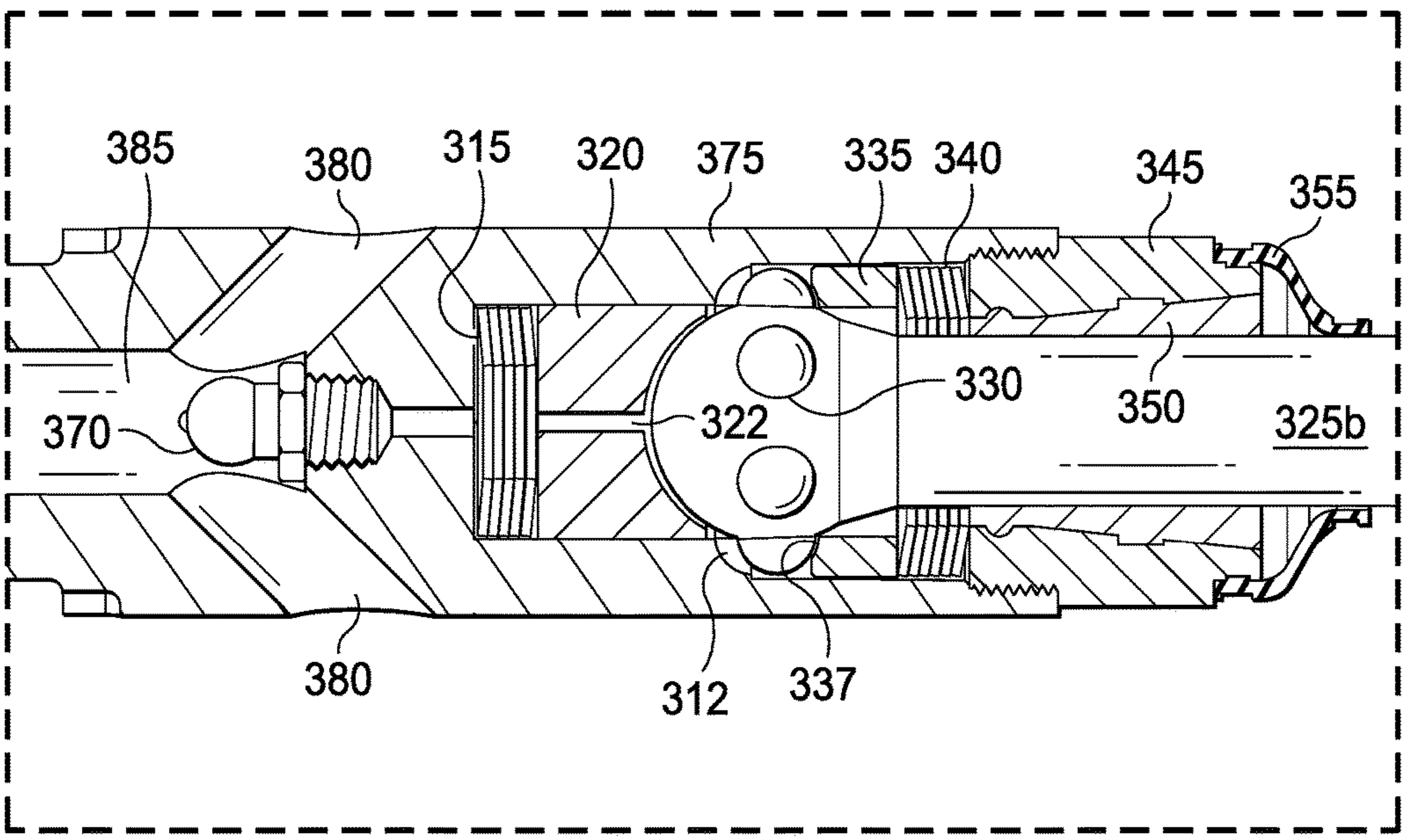
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FIG. 7

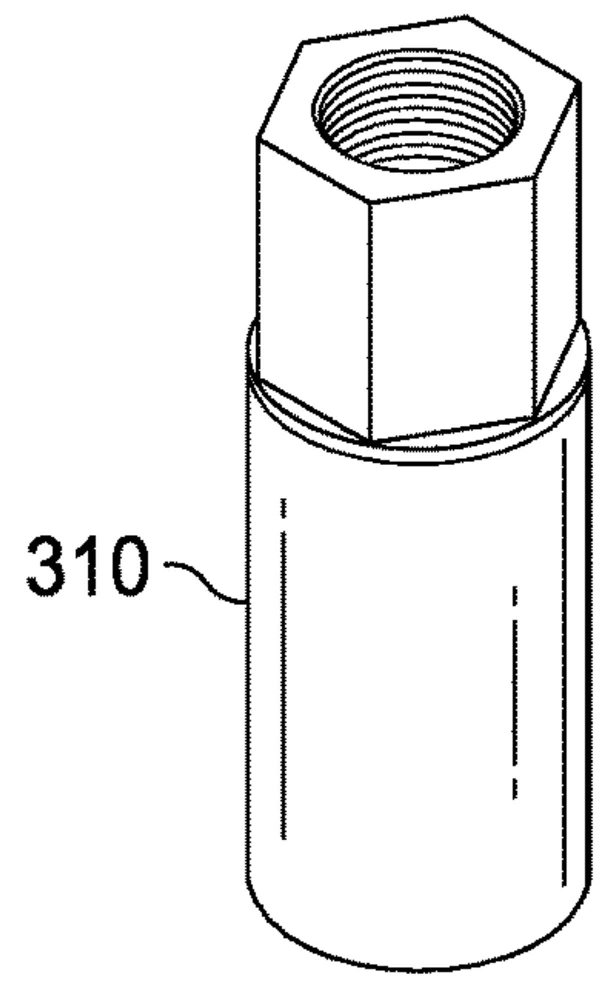

FIG. 8A

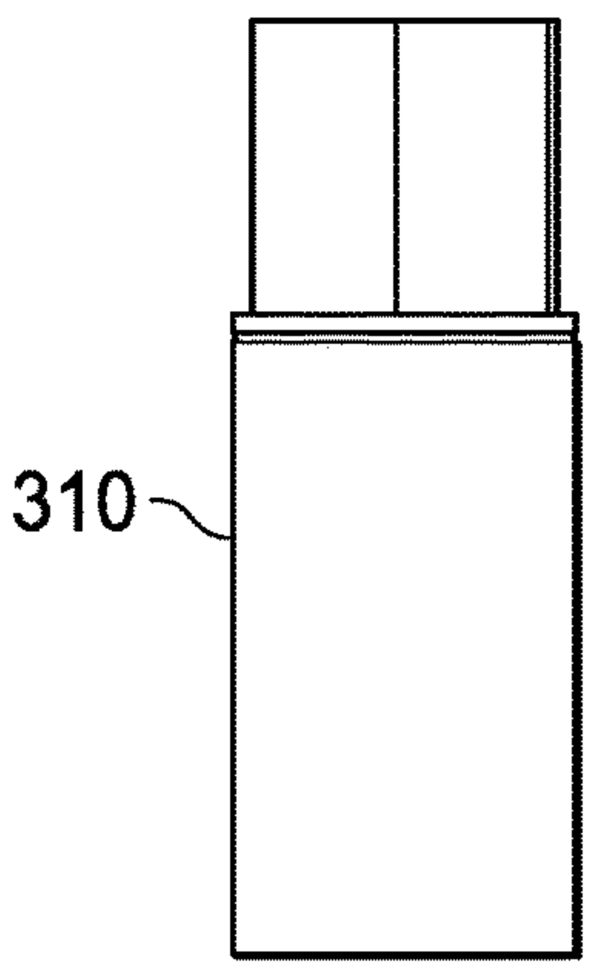

FIG. 8B

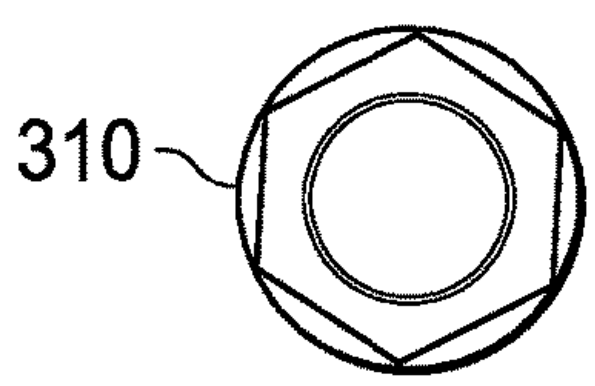

FIG. 8C

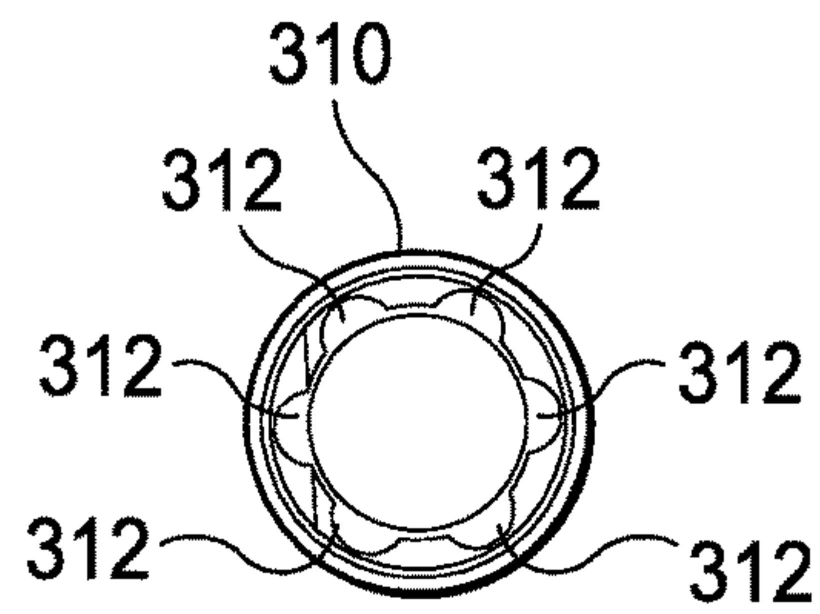

FIG. 8D

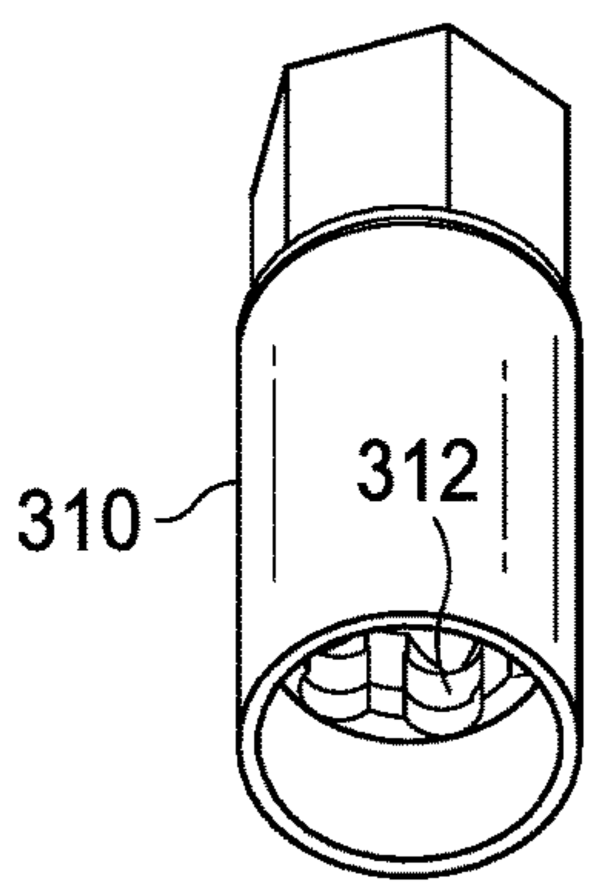

FIG. 8E

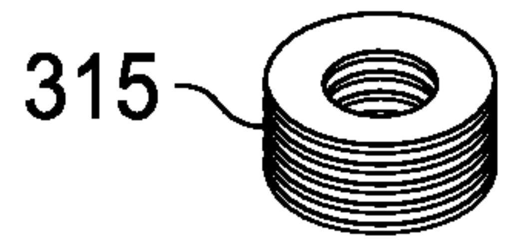

FIG. 9A

FIG. 9B

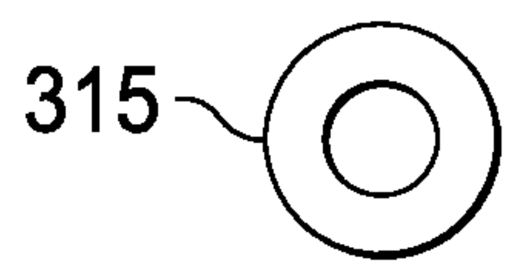

FIG. 9C

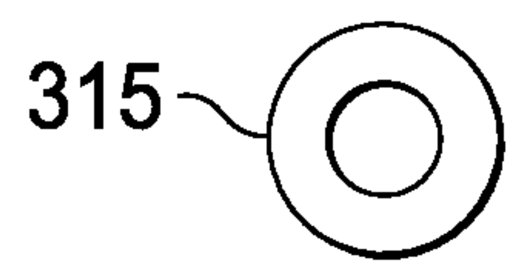

FIG. 9D

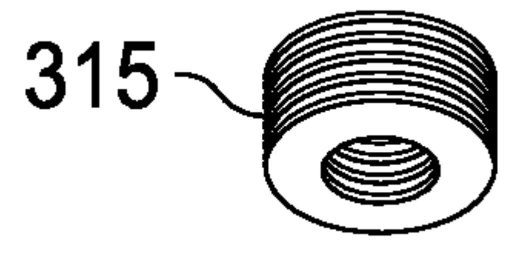

FIG. 9E

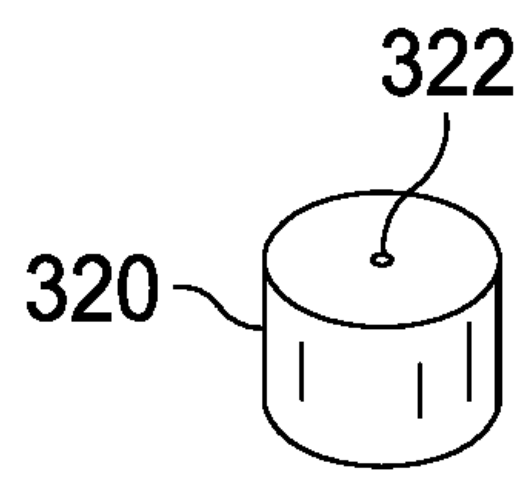

FIG. 10A

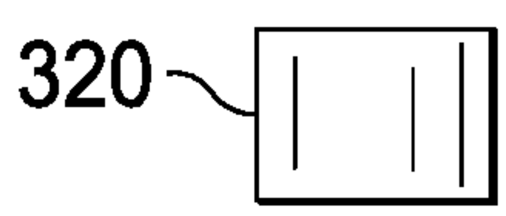

FIG. 10B

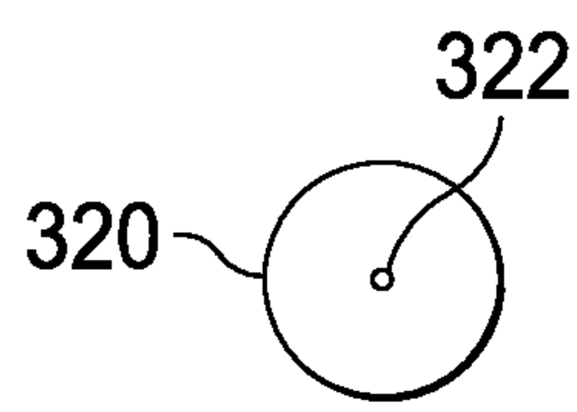

FIG. 10C

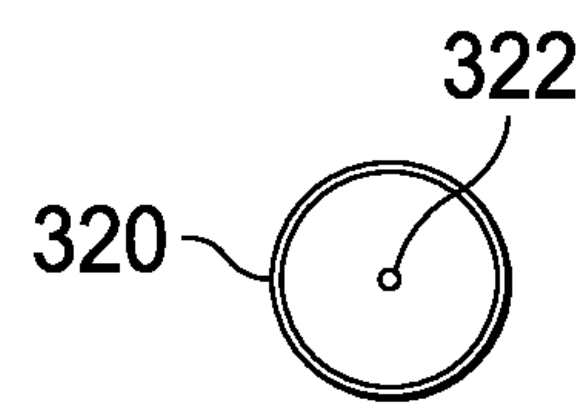

FIG. 10D

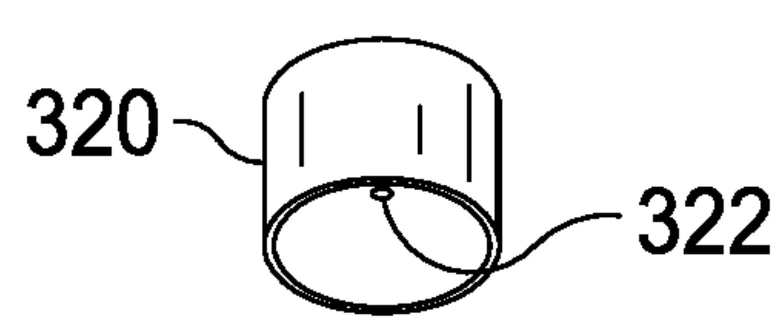

FIG. 10E

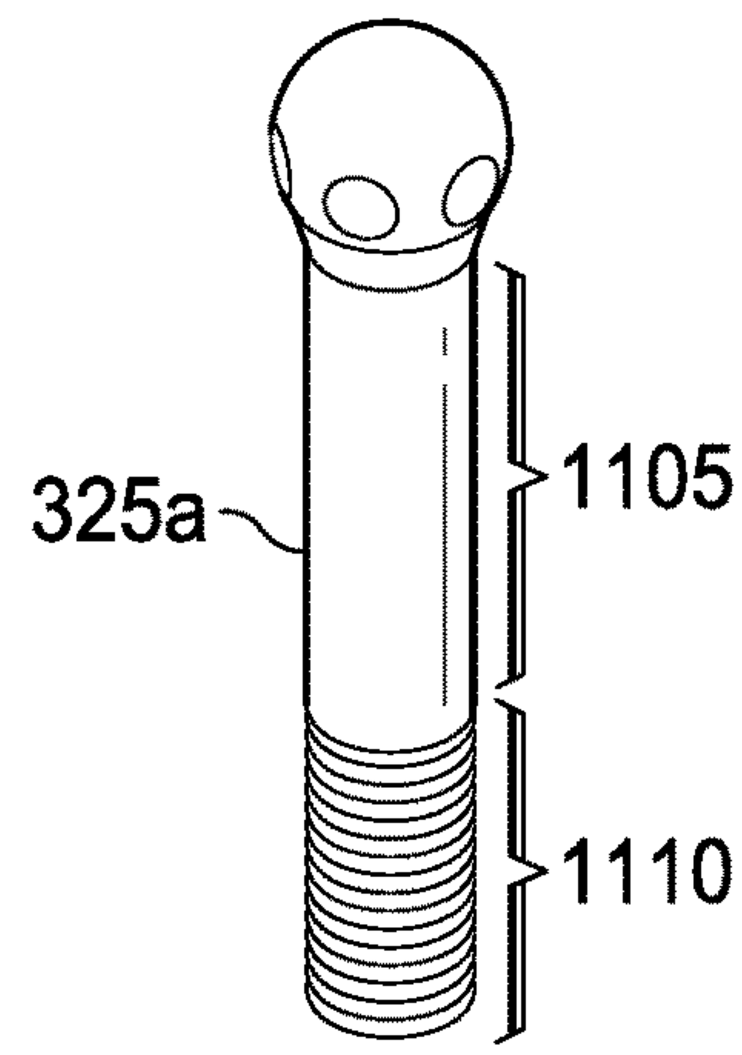

FIG. 11A

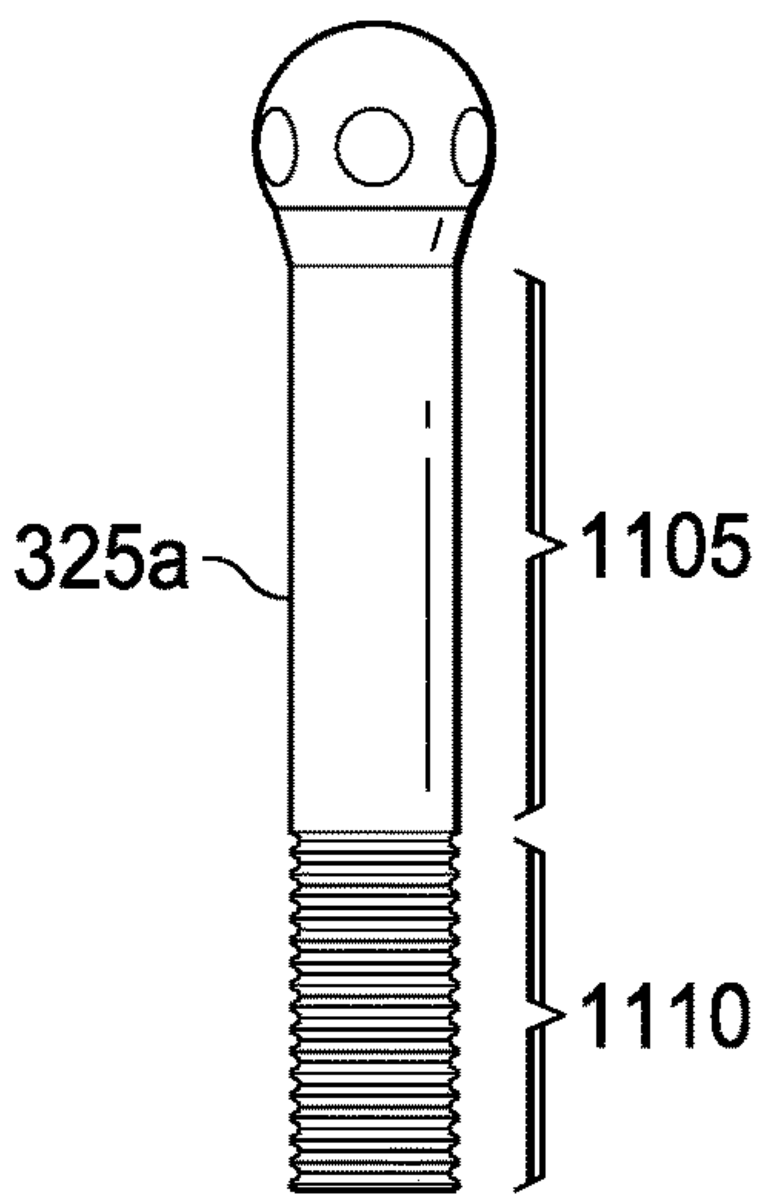

FIG. 11B

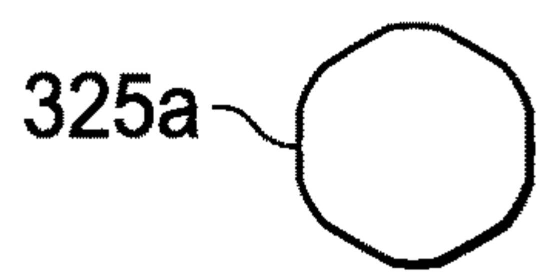

FIG. 11C

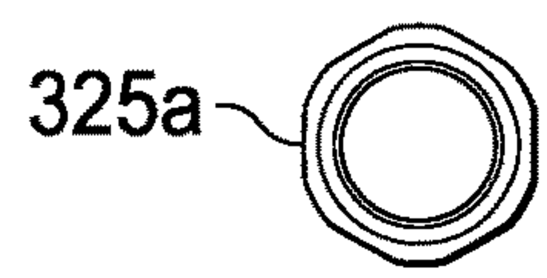

FIG. 11D

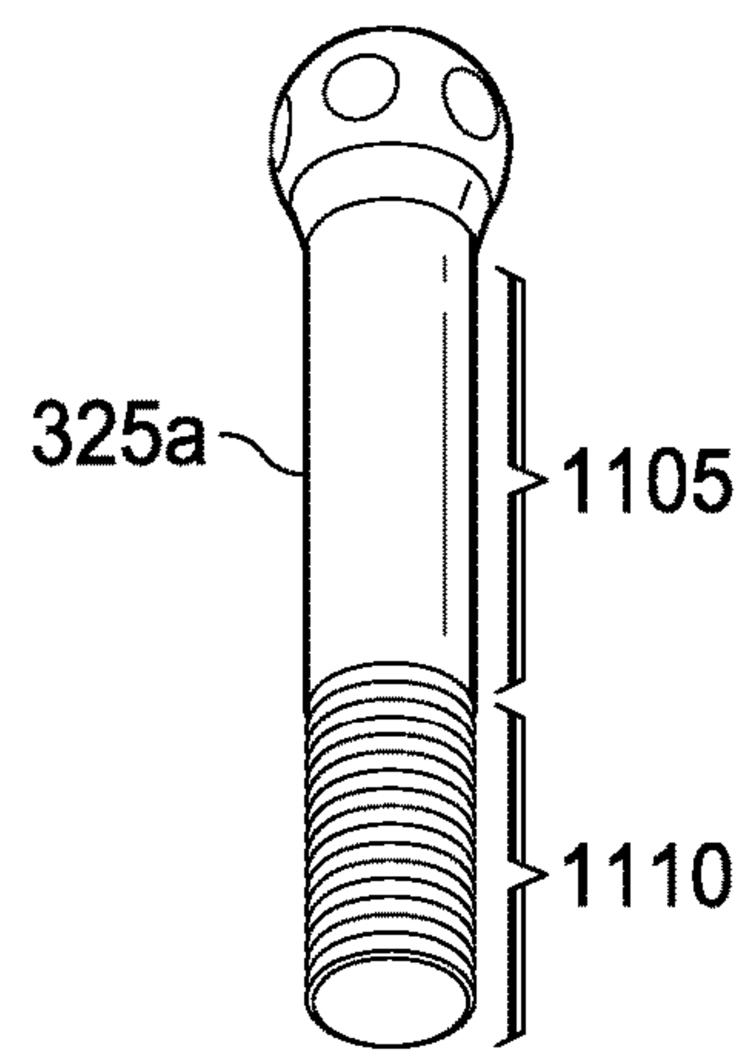

FIG. 11E

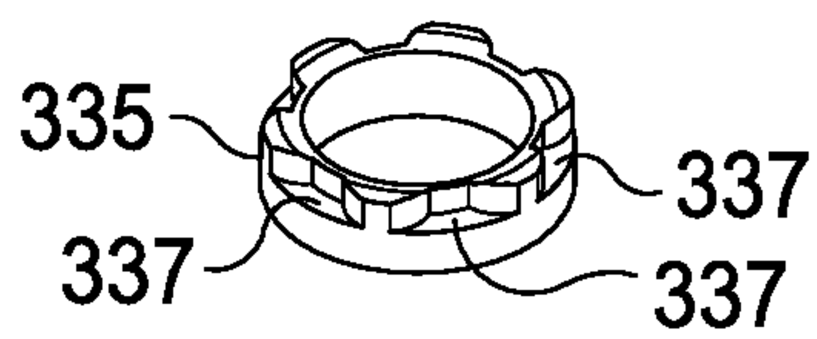

FIG. 12A

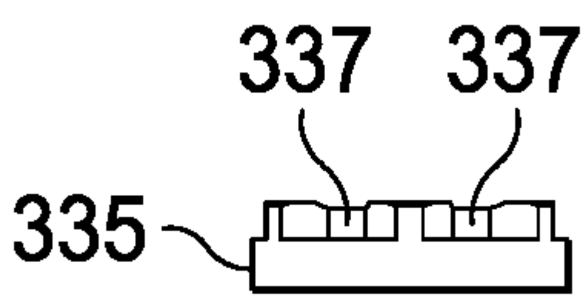

FIG. 12B

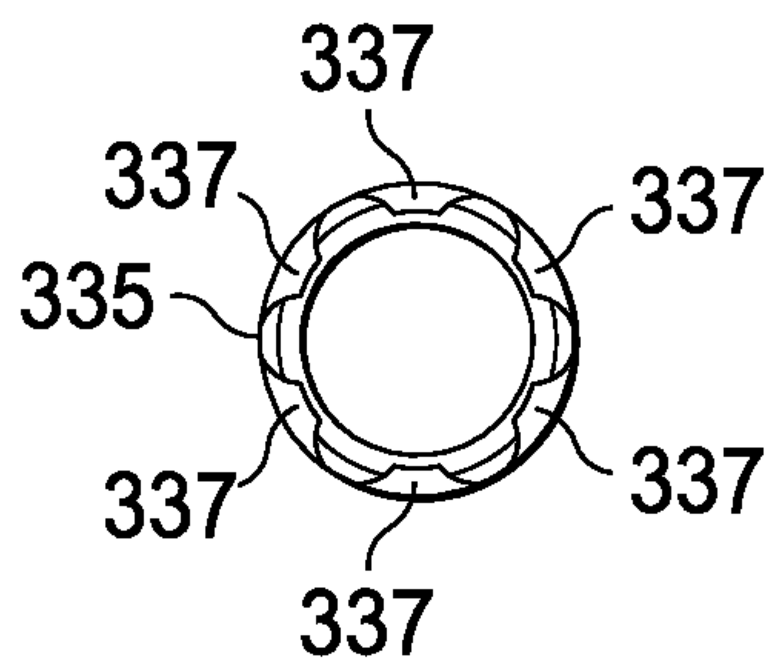

FIG. 12C

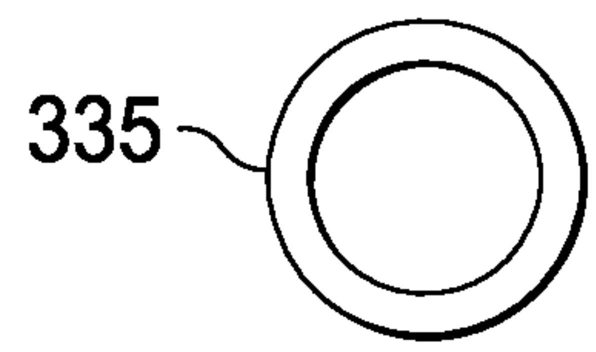

FIG. 12D

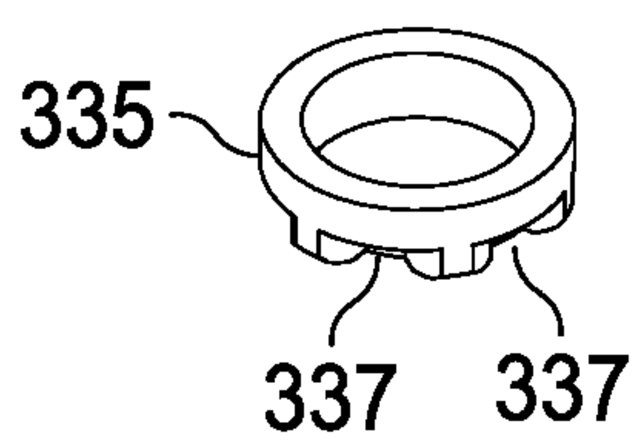

FIG. 12E

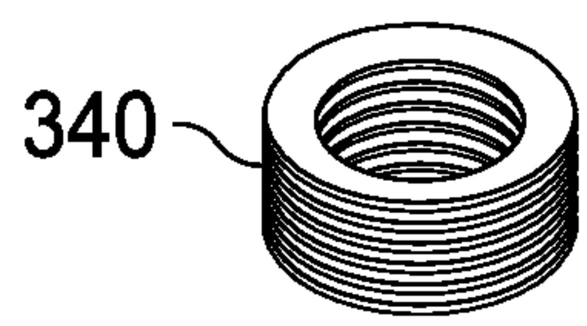

FIG. 13A

FIG. 13B

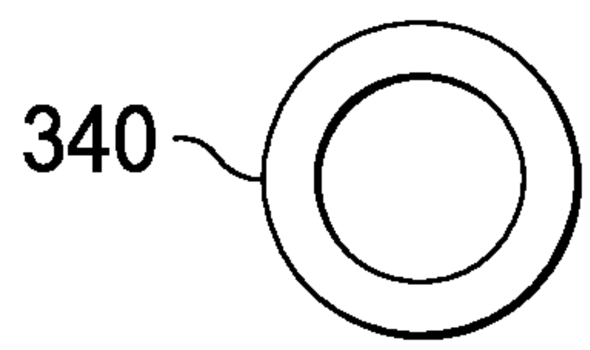

FIG. 13C

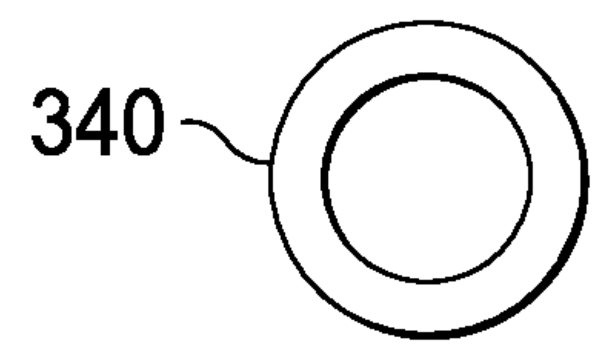

FIG. 13D

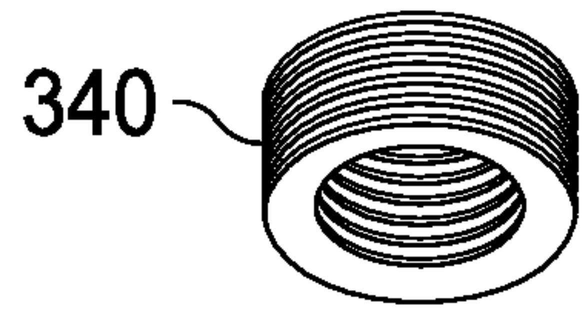

FIG. 13E

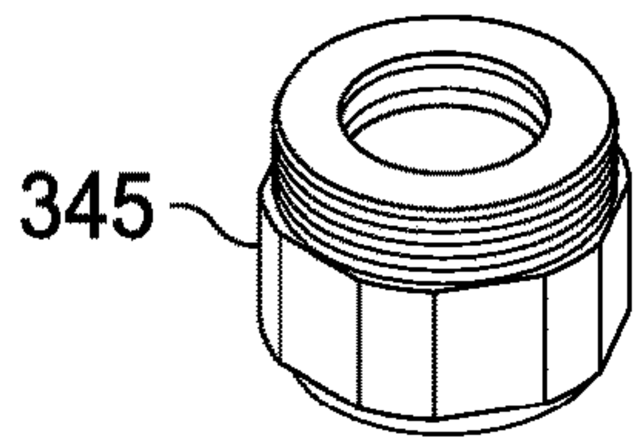

FIG. 14A

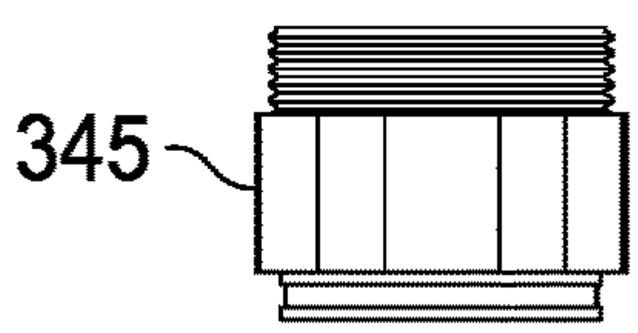

FIG. 14B

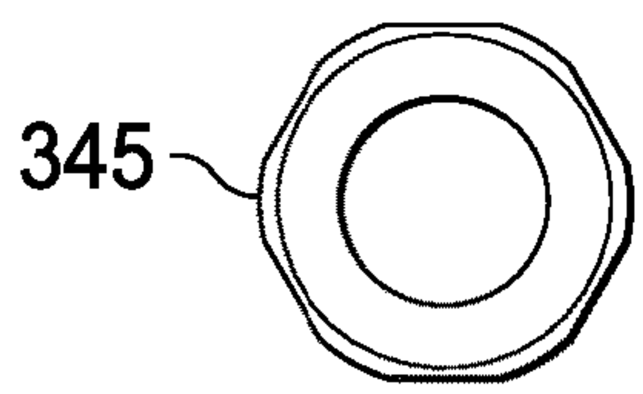

FIG. 14C

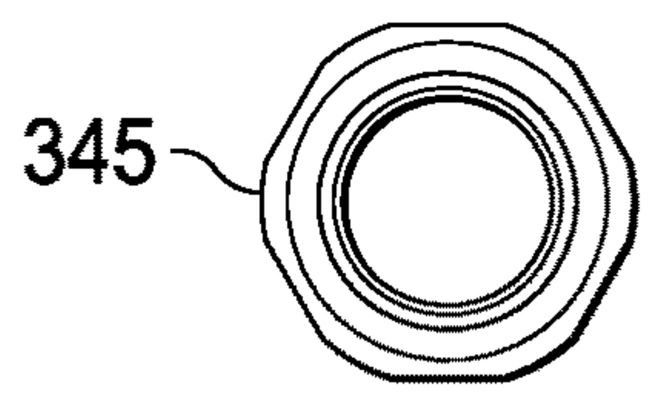

FIG. 14D

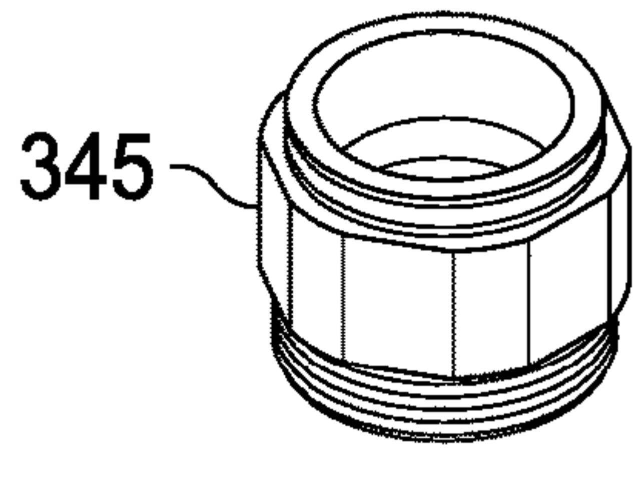

FIG. 14E

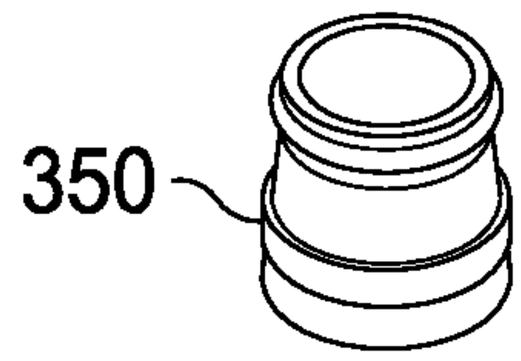

FIG. 15A

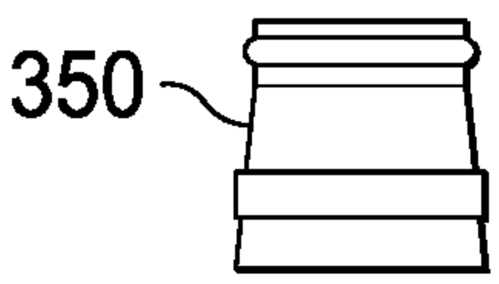

FIG. 15B

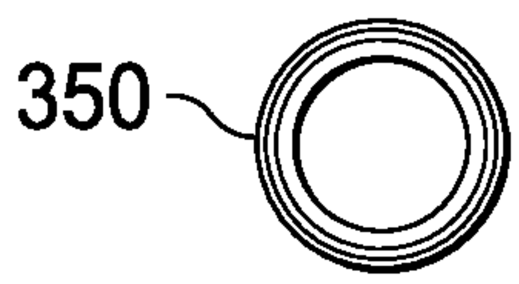

FIG. 15C

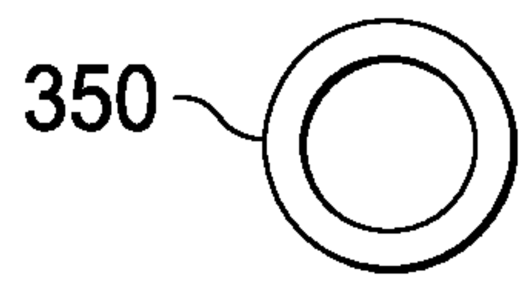

FIG. 15D

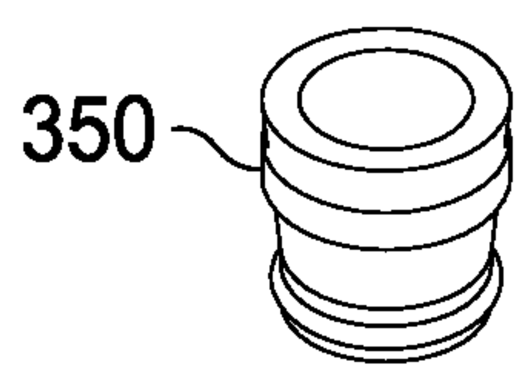

FIG. 15E

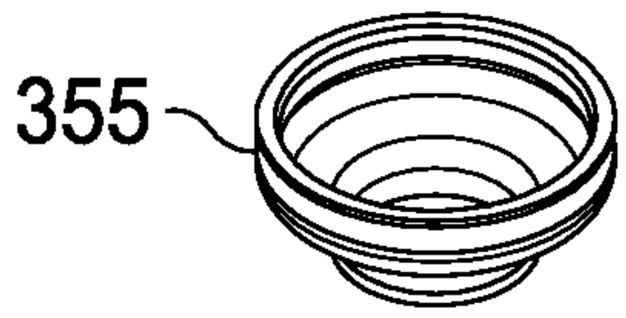

FIG. 16A

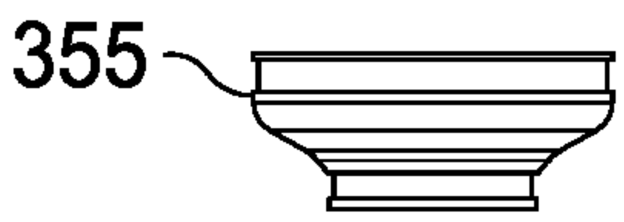

FIG. 16B

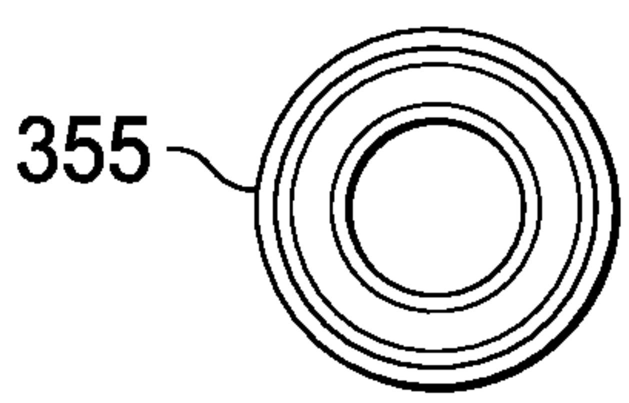

FIG. 16C

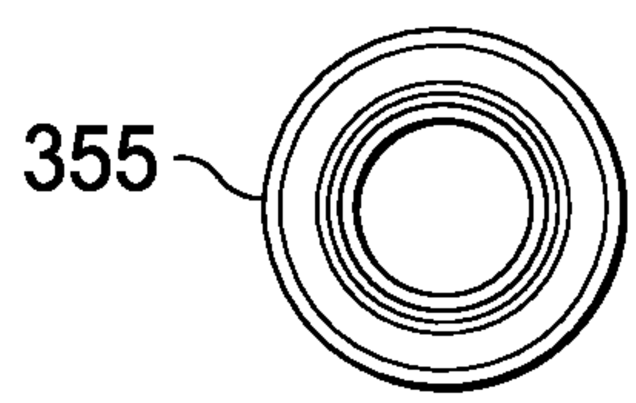

FIG. 16D

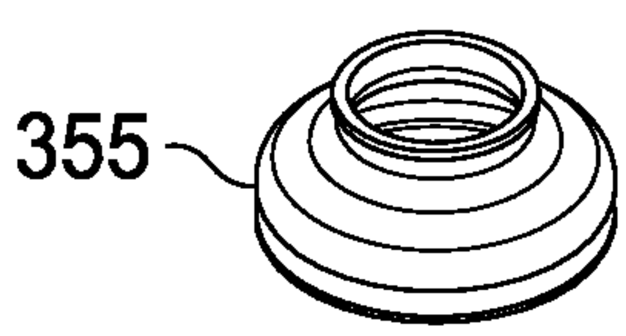

FIG. 16E

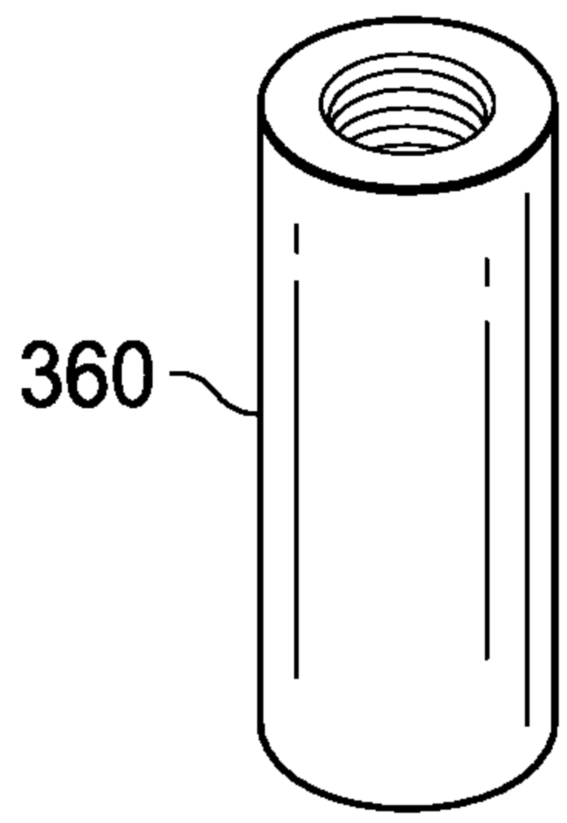

FIG. 17A

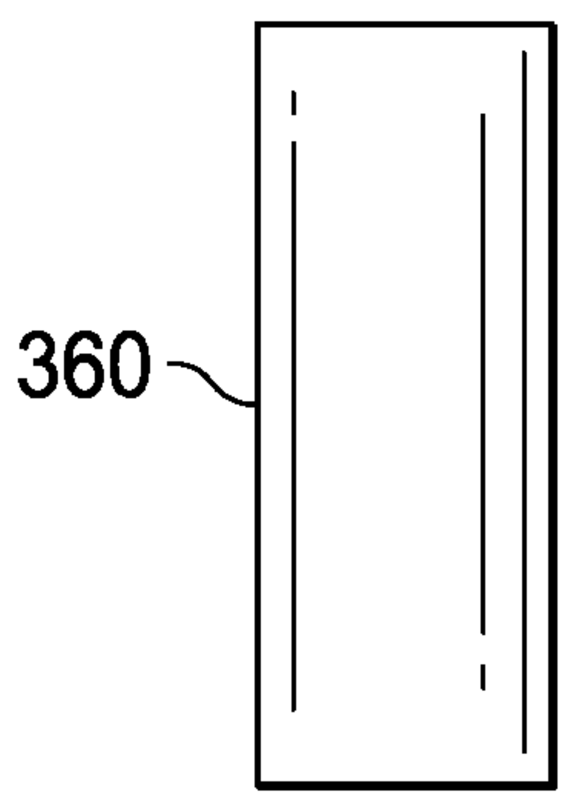

FIG. 17B

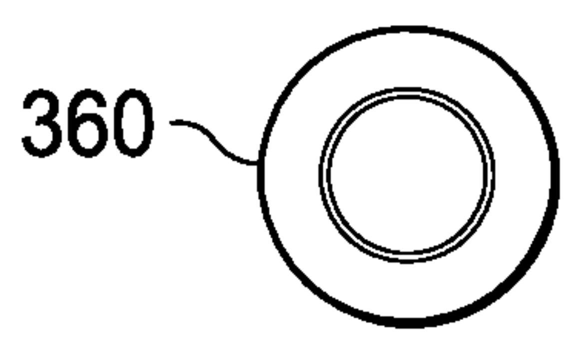

FIG. 17C

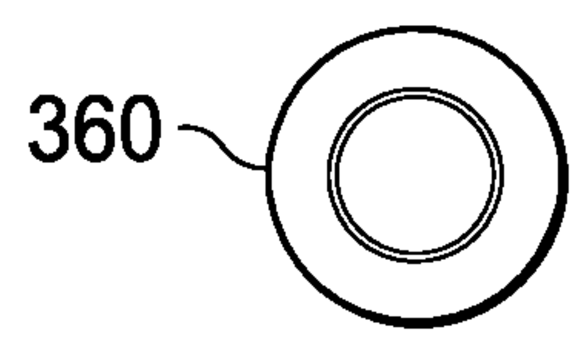

FIG. 17D

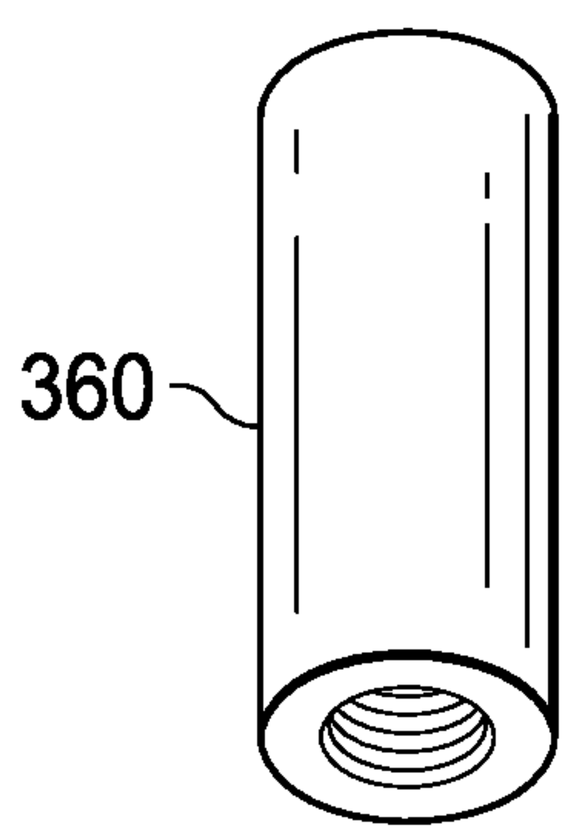

FIG. 17E

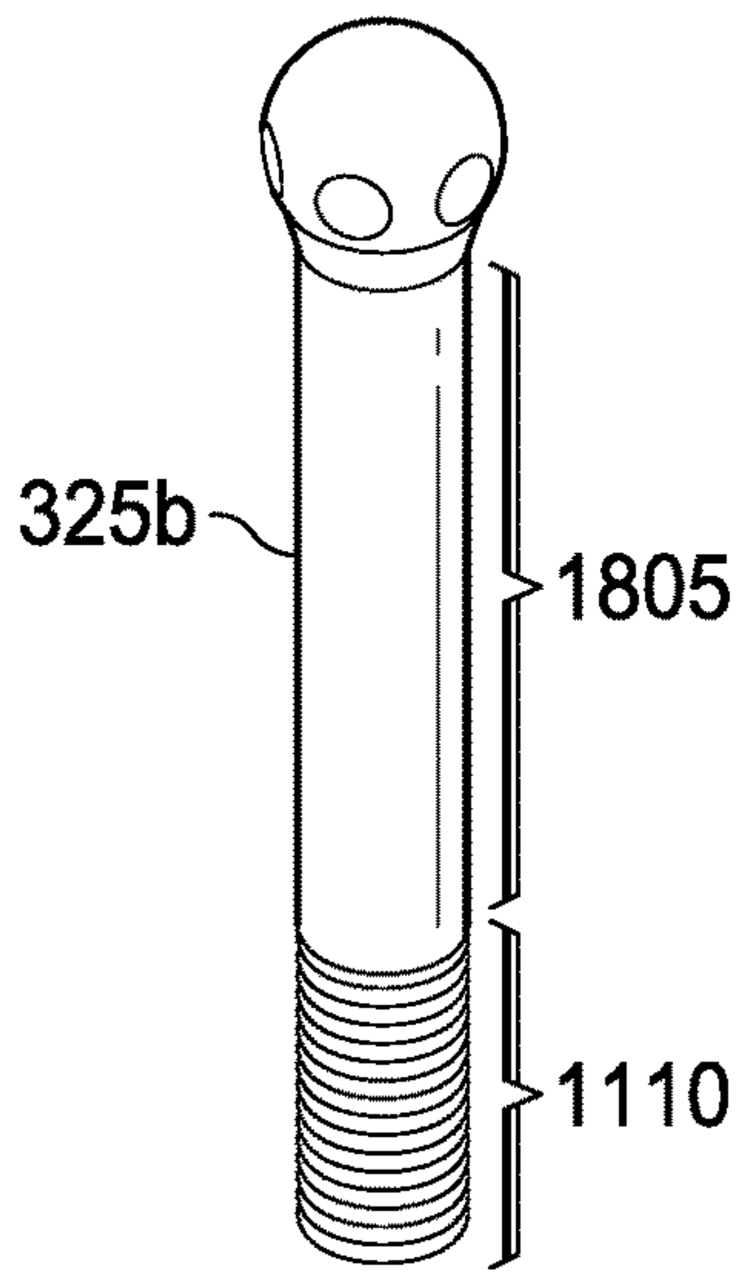

FIG. 18A

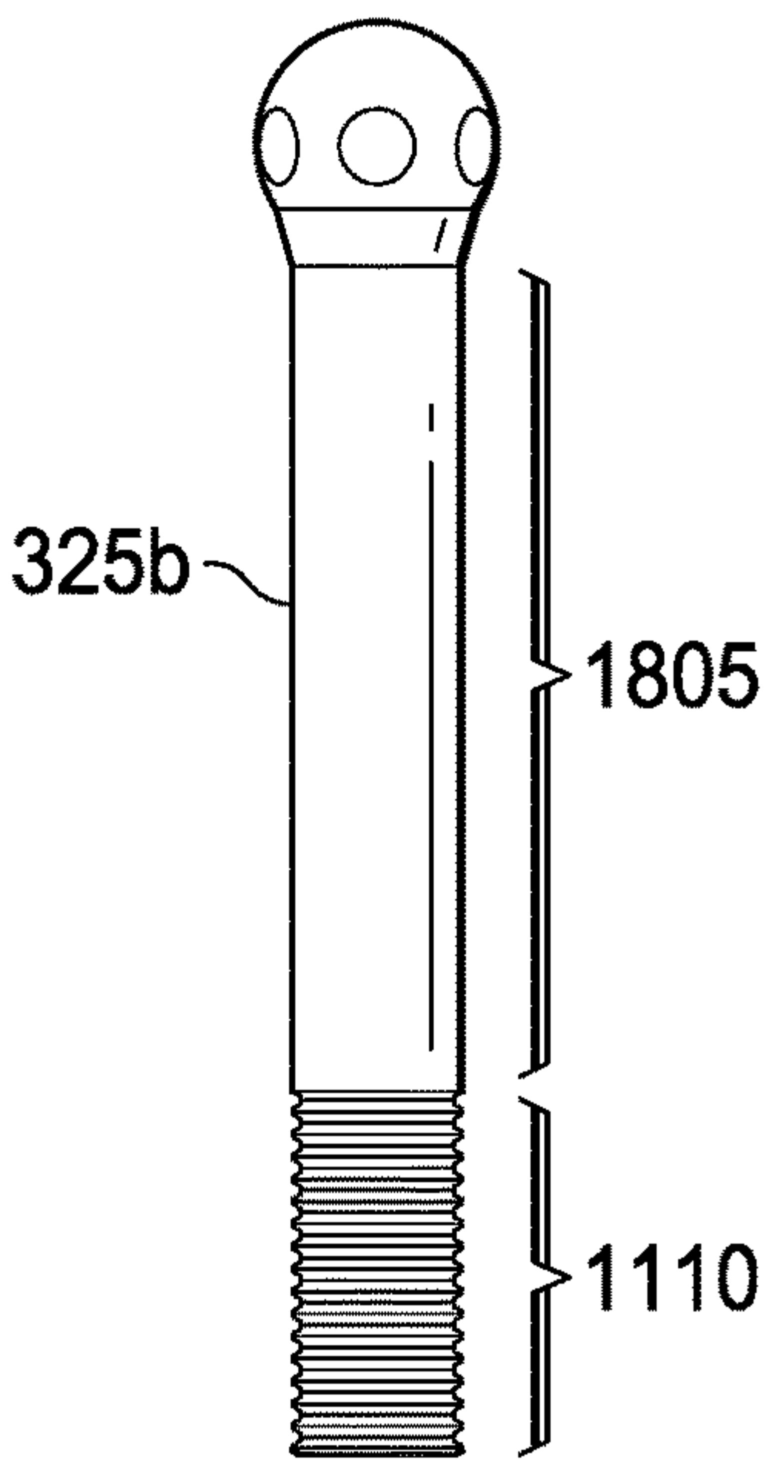

FIG. 18B

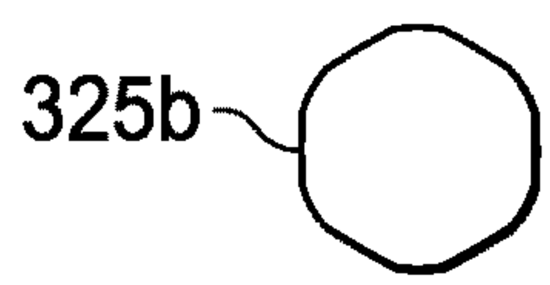

FIG. 18C

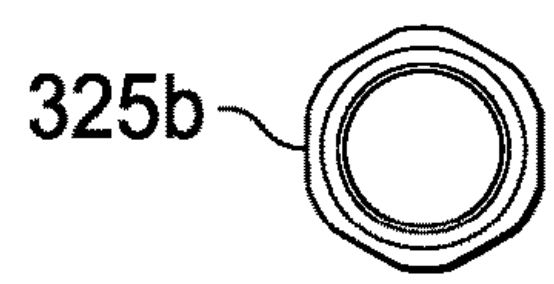

FIG. 18D

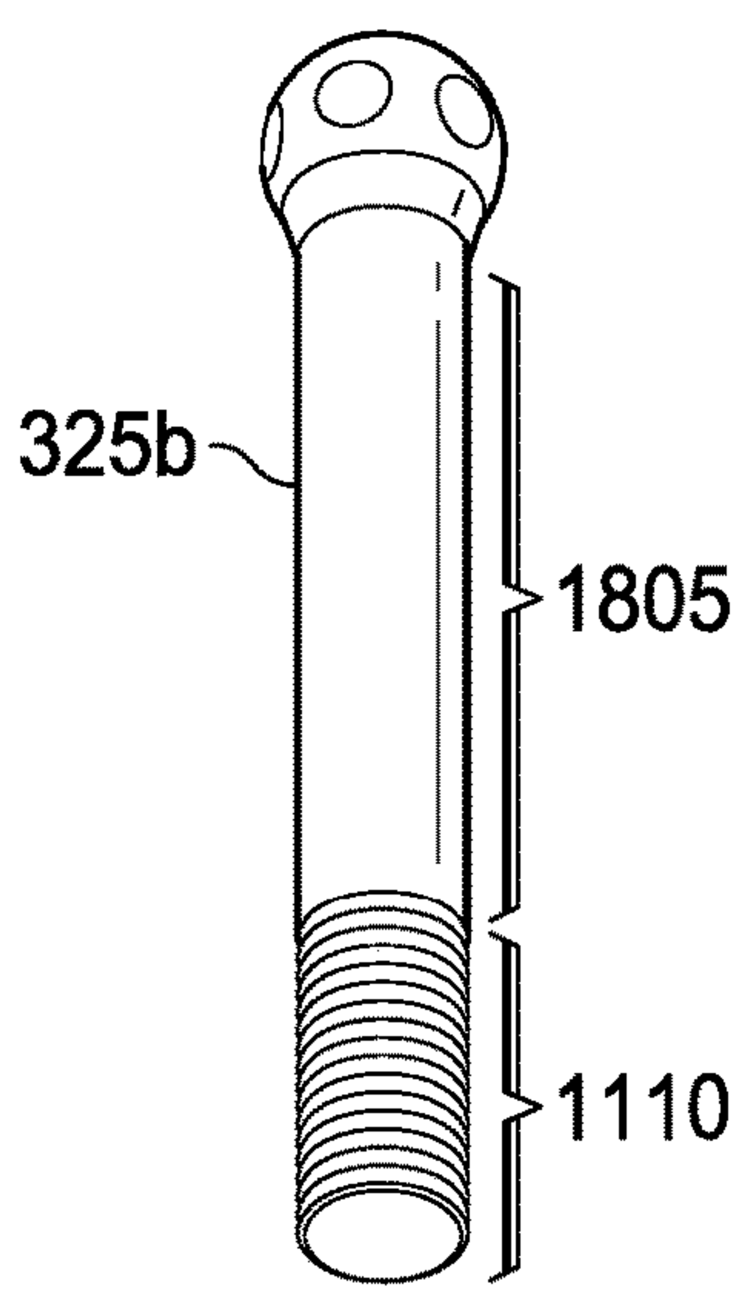

FIG. 18E

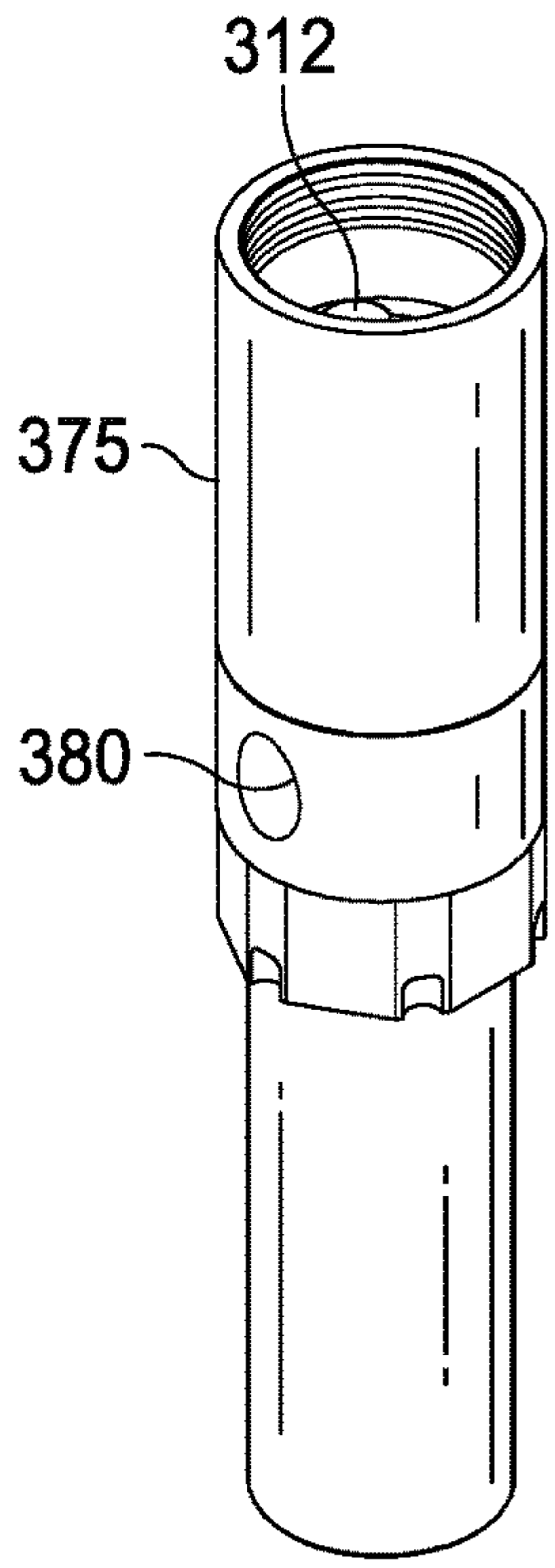

FIG. 19A

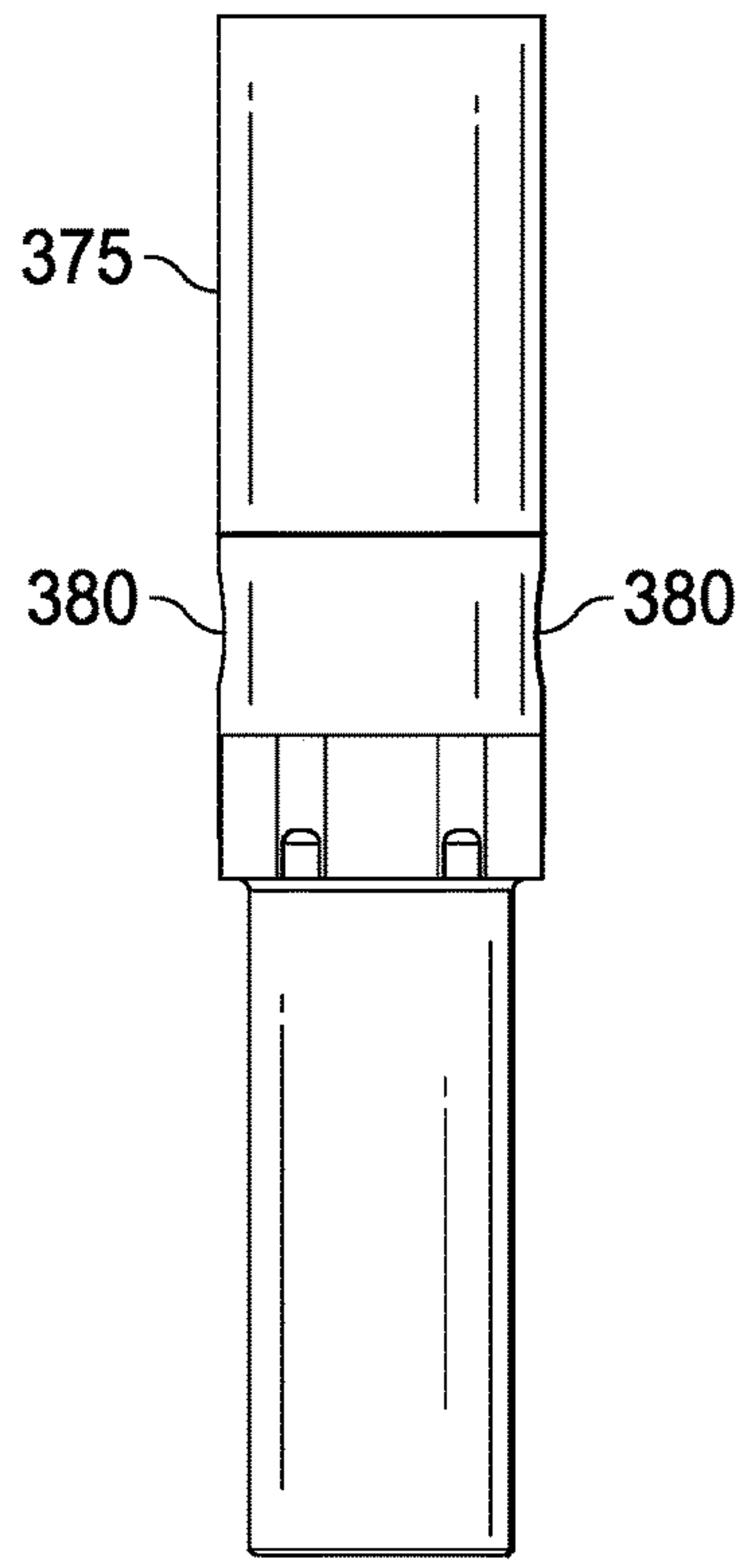

FIG. 19B

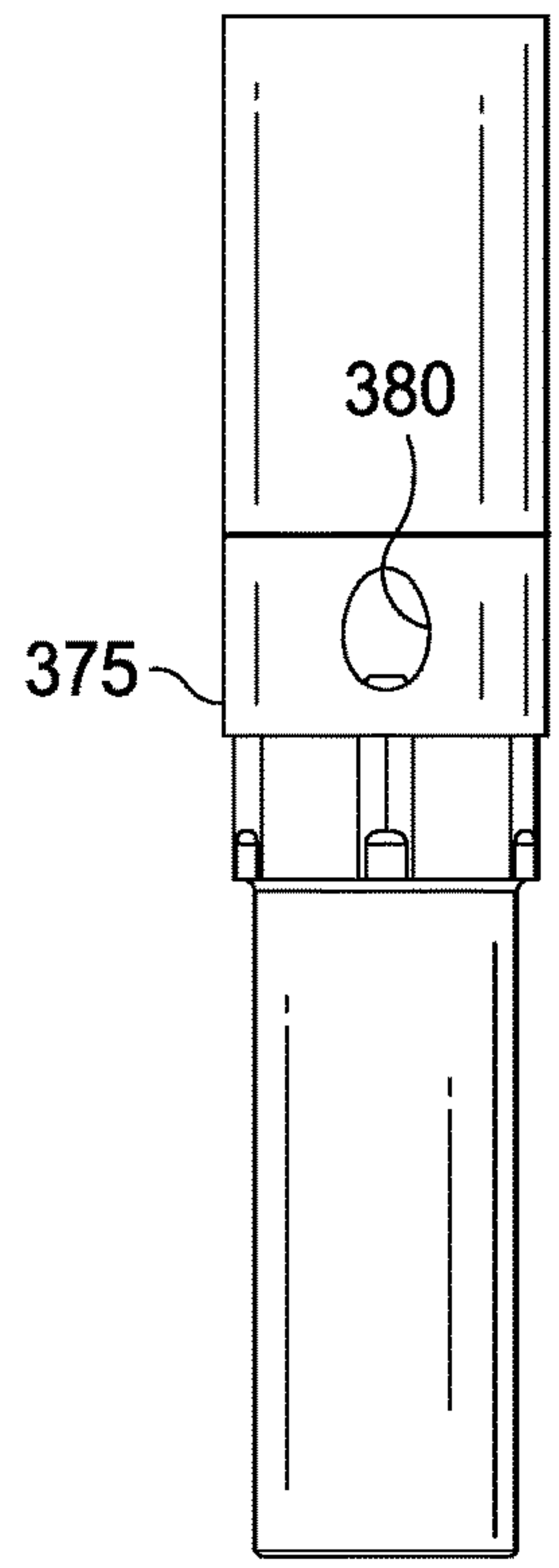

FIG. 19C

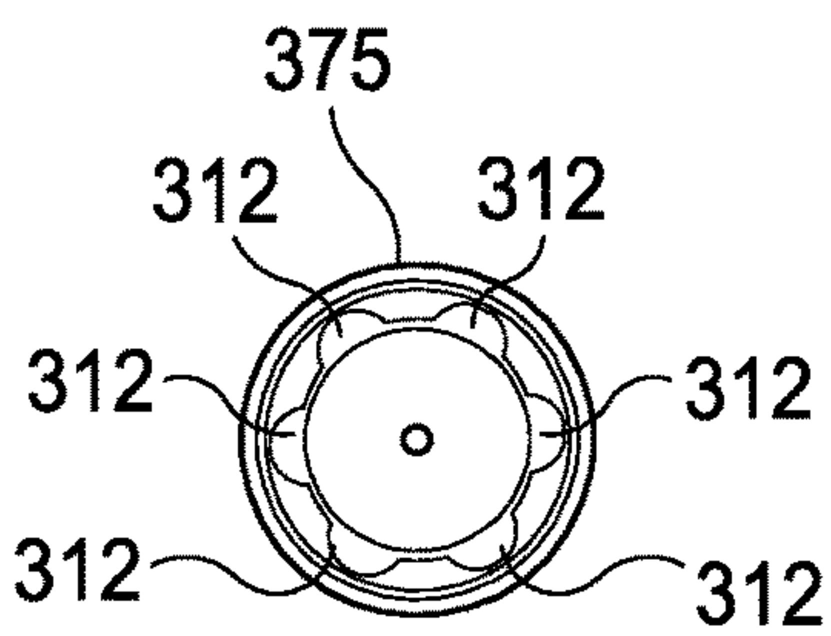

FIG. 19D

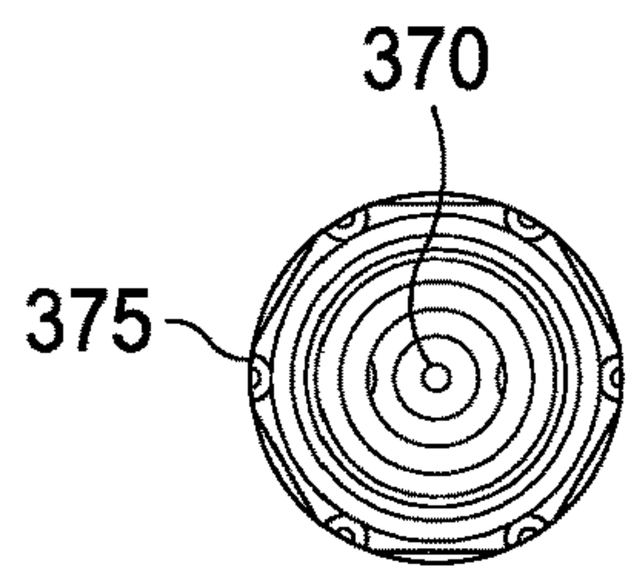

FIG. 19E

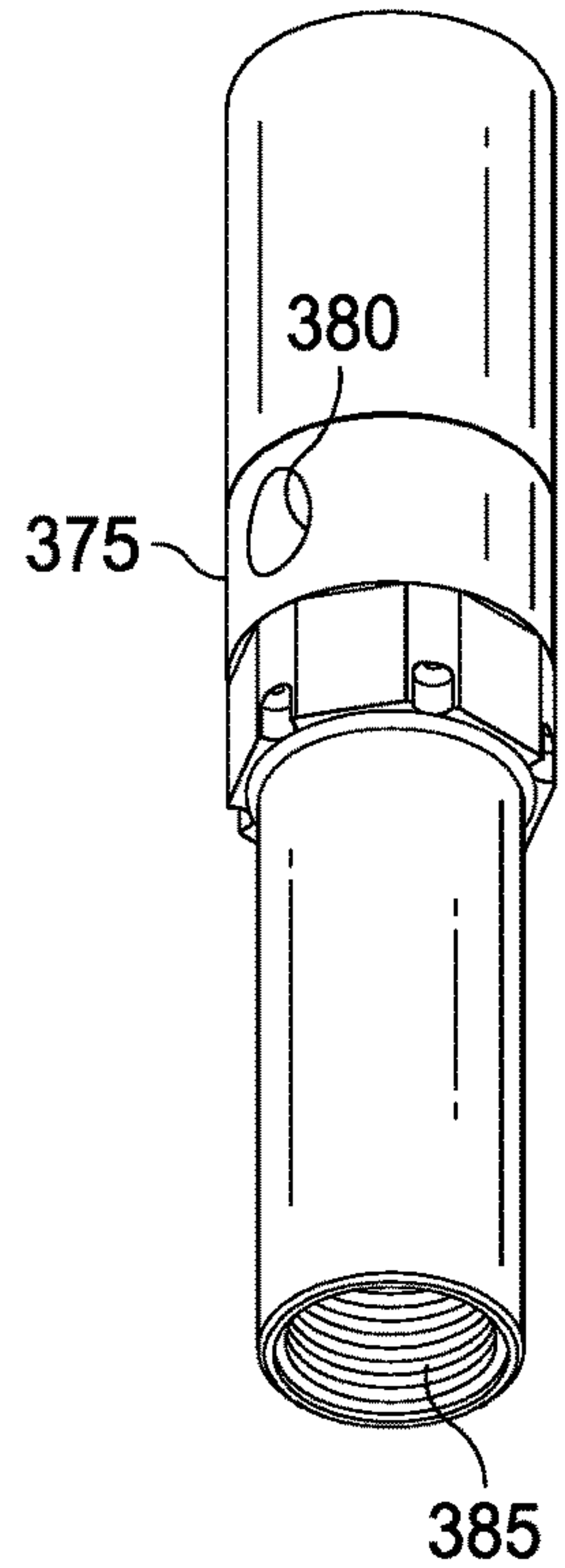

FIG. 19F

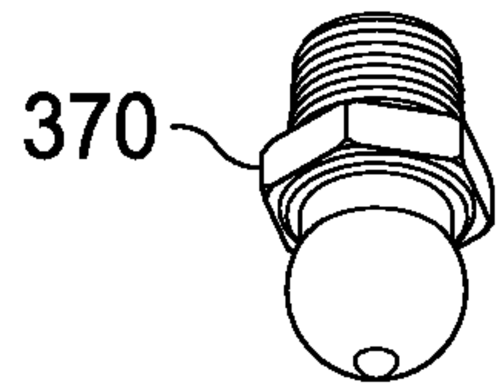

FIG. 20A

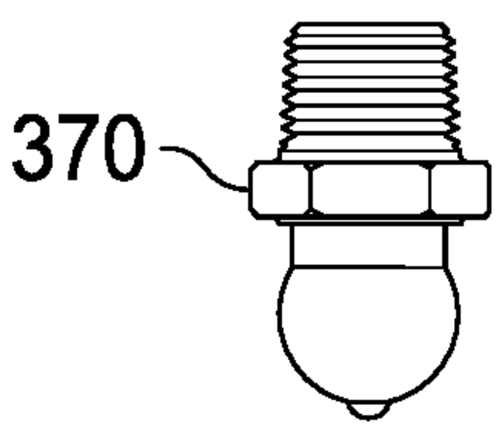

FIG. 20B

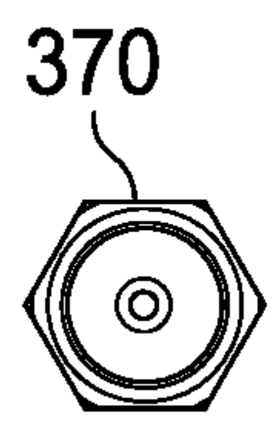

FIG. 20C

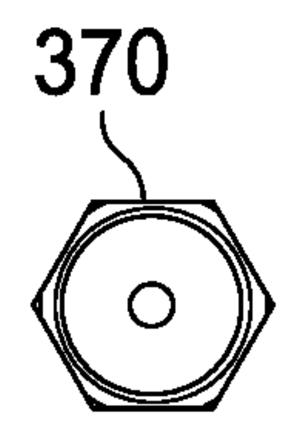

FIG. 20D

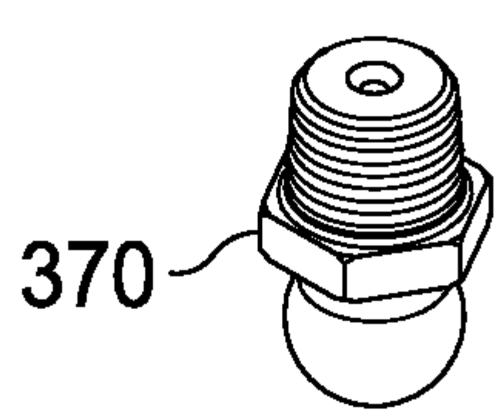

FIG. 20E

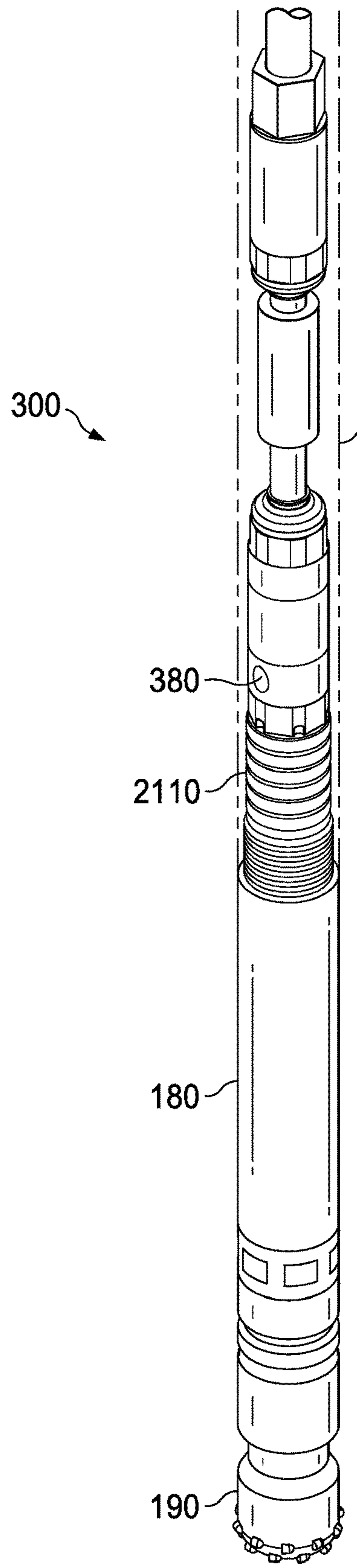

FIG. 21

RECIPROCATION-DAMPENING DRIVE SHAFT ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] A conventional drilling rig is used to drill a wellbore that provides access to a subsurface formation. The wellbore may include one or more straight and/or directional sections. In addition, a drilling rig may be used to stimulate an already existing well to gain access to more remote subsurface formations. Hydraulic fracturing is an example of an effective well-stimulation technique in which a geologic formation is hydraulically fractured by a high-pressure fluid to extract the hydrocarbon deposits disposed therein.

[0002] During conventional drilling operations, a top drive, or rotary table, system is used to rotate a drill string and a drill bit, where the rotation is provided from the surface. However, once the well plan kicks off on a directional section, where the inclination angle is non-zero, rotation typically cannot be provided from the surface. As such, a hydraulic system may be used to rotate a drill bit, where the rotation is provided downhole using hydrostatic pressure. A conventional hydraulic drilling system includes a hydraulic power section, sometimes referred to as a mud motor, which is disposed downhole to convert hydraulic energy from drilling fluid and/or drilling mud into mechanical energy that rotates a drill bit. A conventional mud motor uses a Moineau progressive cavity positive displacement pump system that typically includes a helical rotor inserted into a double helix stator. The interference fit between the rotor and the stator forms a number of sealed cavities. As fluid enters a cavity formed at an inlet, hydrostatic pressure forces the fluid through the cavities toward an outlet and rotates the rotor eccentrically within the stator. The eccentric rotation of the rotor is transferred to the drill bit by a drive shaft assembly that seeks to reduce or eliminate eccentricity while transferring torque to the drill bit.

BRIEF SUMMARY OF THE INVENTION

[0003] According to one aspect of one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly includes a first reciprocation-dampening adapter having a connection end and a cylindrical adapter portion. The cylindrical adapter portion includes a recessed inner aperture having a first diameter, a recessed inner aperture having a second diameter and a plurality of semispheroidal recessed portions, and a first adapter threaded end. A first plurality of spring washers are disposed within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter. A first floating seat is disposed within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter on a spring loaded side of the first plurality of spring washers. The first floating seat includes a spheroidal cap indentation configured to receive a portion of a spheroidal end of a first drive shaft portion. The first drive shaft portion includes the spheroidal end, a cylindrical shaft portion, and a shaft threaded end. The spheroidal end includes a plurality of ball cap indentations disposed about its outer surface. A first floating ring includes a plurality of semispheroidal recessed portions. The plurality of semispheroidal recessed portions of the first reciprocation-dampening adapter are configured to receive a portion of a first plurality of spheroidal balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the first drive shaft portion and the plurality of semispheroidal recessed portions of the first floating ring are configured to receive a portion of the first plurality of spheroidal balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the first drive shaft portion. A first plurality of spring washers are disposed within the recessed inner aperture having the second diameter of the first reciprocation-dampening adapter. A first reciprocation-dampening adapter cap includes a recessed dampener aperture configured to receive a first dampener insert and a first adapter cap threaded end configured to removably connect to the first adapter threaded end of the first reciprocation-dampening adapter. A first boot is configured to seal the first reciprocation-dampening adapter cap and the cylindrical shaft portion of the first drive shaft portion.

[0004] Other aspects of the present invention will be apparent from the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** shows a schematic view of a hydraulic drilling system.

[0006] FIG. **2**A shows a top-facing perspective view of a conventional drive shaft assembly used as part of a hydraulic drilling system.

[0007] FIG. **2**B shows an exploded view of the conventional drive shaft assembly.

[0008] FIG. **2**C shows a perspective view of a worn-out adapter of a conventional drive shaft assembly.

[0009] FIG. **3**A shows a top-facing perspective view of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0010] FIG. **3**B shows a bottom-facing perspective view of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0011] FIG. **3**C shows a front elevation view of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0012] FIG. **3**D shows a side elevation view of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0013] FIG. **3**E shows a top plan view of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0014] FIG. **3**F shows a bottom plan view of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0015] FIG. **4** shows an exploded view of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0016] FIG. **5** shows a cross-sectional view of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0017] FIG. **6** shows a detailed cross-sectional view of an assembled portion of a first reciprocation-dampening adapter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0018] FIG. **7** shows a detailed cross-sectional view of an assembled portion of a second reciprocation-dampening adapter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0019] FIG. **8**A shows a top-facing perspective view of a first reciprocation-dampening adapter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0020] FIG. **8**B shows a side elevation view of the first reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0021] FIG. **8**C shows a top plan view of the first reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0022] FIG. **8**D shows a bottom plan view of the first reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0023] FIG. **8**E shows a bottom-facing perspective view of the first reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0024] FIG. **9**A shows a top-facing perspective view of a plurality of spring washers with a first inner diameter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0025] FIG. **9**B shows a side elevation view of the plurality of spring washers with the first inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0026] FIG. **9**C shows a top plan view of the plurality of spring washers with the first inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0027] FIG. **9**D shows a bottom plan view of the plurality of spring washers with the first inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0028] FIG. **9**E shows a bottom-facing perspective view of the plurality of spring washers with the first inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0029] FIG. **10**A shows a top-facing perspective view of a floating seat of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0030] FIG. **10**B shows a side elevation view of the floating seat of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0031] FIG. **10**C shows a top plan view of the floating seat of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0032] FIG. **10**D shows a bottom plan view of the floating seat of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0033] FIG. **10**E shows a bottom-facing perspective view of the floating seat of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0034] FIG. **11**A shows a top-facing perspective view of a first drive shaft portion of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0035] FIG. **11**B shows a side elevation view of the first drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0036] FIG. **11**C shows a top plan view of the first drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0037] FIG. **11**D shows a bottom plan view of the first drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0038] FIG. **11**E shows a bottom-facing perspective view of the first drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0039] FIG. **12**A shows a top-facing perspective view of a floating ring of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0040] FIG. **12**B shows a side elevation view of the floating ring of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0041] FIG. **12**C shows a top plan view of the floating ring of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0042] FIG. **12**D shows a bottom plan view of the floating ring of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0043] FIG. **12**E shows a bottom-facing perspective view of the floating ring of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0044] FIG. **13**A shows a top-facing perspective view of a plurality of spring washers with a second inner diameter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0045] FIG. **13**B shows a side elevation view of the plurality of spring washers with the second inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0046] FIG. **13**C shows a top plan view of the plurality of spring washers with the second inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0047] FIG. **13**D shows a bottom plan view of the plurality of spring washers with the second inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0048] FIG. **13**E shows a bottom-facing perspective view of the plurality of spring washers with the second inner diameter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0049] FIG. **14**A shows a top-facing perspective view of a reciprocation-dampening adapter cap of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0050] FIG. **14**B shows a side elevation view of the reciprocation-dampening adapter cap of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0051] FIG. **14**C shows a top plan view of the reciprocation-dampening adapter cap of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0052] FIG. **14**D shows a bottom plan view of the reciprocation-dampening adapter cap of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0053] FIG. **14**E shows a bottom-facing perspective view of the reciprocation-dampening adapter cap of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0054] FIG. **15**A shows a top-facing perspective view of a dampener insert of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0055] FIG. **15**B shows a side elevation view of the dampener insert of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0056] FIG. **15**C shows a top plan view of the dampener insert of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0057] FIG. **15**D shows a bottom plan view of the dampener insert of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0058] FIG. **15**E shows a bottom-facing perspective view of the dampener insert of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0059] FIG. **16**A shows a top-facing perspective view of a boot of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0060] FIG. **16**B shows a side elevation view of the boot of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0061] FIG. **16**C shows a top plan view of the boot of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0062] FIG. **16**D shows a bottom plan view of the boot of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0063] FIG. **16**E shows a bottom-facing perspective view of the boot of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0064] FIG. **17**A shows a top-facing perspective view of a drive shaft joint of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0065] FIG. **17**B shows a side elevation view of the drive shaft joint of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0066] FIG. **17**C shows a top plan view of the drive shaft joint of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0067] FIG. **17**D shows a bottom plan view of the drive shaft joint of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0068] FIG. **17**E shows a bottom-facing perspective view of the drive shaft joint of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0069] FIG. **18**A shows a top-facing perspective view of a second drive shaft portion of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0070] FIG. **18**B shows a side elevation view of the second drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0071] FIG. **18**C shows a top plan view of the second drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0072] FIG. **18**D shows a bottom plan view of the second drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0073] FIG. **18**E shows a bottom-facing perspective view of the second drive shaft portion of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0074] FIG. **19**A shows a top-facing perspective view of a second reciprocation-dampening adapter of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0075] FIG. **19**B shows a front elevation view of the second reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0076] FIG. **19**C shows a side elevation view of the second reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0077] FIG. **19**D shows a top plan view of the second reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0078] FIG. **19**E shows a bottom plan view of the second reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0079] FIG. **19**F shows a bottom-facing perspective view of the second reciprocation-dampening adapter of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0080] FIG. **20**A shows a top-facing perspective view of a grease injection nipple of a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0081] FIG. **20**B shows a side elevation view of the grease injection nipple of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0082] FIG. **20**C shows a top plan view of the grease injection nipple of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0083] FIG. **20**D shows a bottom plan view of the grease injection nipple of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0084] FIG. **20**E shows a bottom-facing perspective view of the grease injection nipple of the reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

[0085] FIG. **21** shows a bottomhole assembly including a reciprocation-dampening drive shaft assembly in accordance with one or more embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0086] One or more embodiments of the present invention are described in detail with reference to the accompanying figures. For consistency, like elements in the various figures are denoted by like reference numerals. In the following detailed description of the present invention, specific details are set forth in order to provide a thorough understanding of the present invention. In other instances, well-known features to one of ordinary skill in the art are not described to avoid obscuring the description of the present invention.

[0087] For the purpose of this disclosure, spheroid (or spheroidal) means spherical or approximately spherical, semispheroid (or semispheroidal) means a portion of a spheroid, and cap means a portion of a spheroid cut off by a bisecting plane.

[0088] FIG. **1** shows a schematic view of a hydraulic drilling system, or rig, **100**. For purposes of illustration only, a coiled tubing rig **100** is depicted in FIG. **1**. Coiled tubing rig **100** may be used in various applications including, for example, drilling operations, well stimulation including hydraulic fracturing, well intervention, and repair and remediation work. One of ordinary skill in the art will recognize that other types of hydraulic drilling systems (not shown) may be used for such purposes.

[0089] Coiled tubing rig **100** includes a sufficient length of tubing **130** spooled on a coiled tubing reel **110** that is disposed above the surface **103**. A first end (not shown) of tubing **130** remains disposed above the surface **103** and is in fluid communication with a fluid source (not shown) that provides drilling fluid and/or drilling mud (not shown) under pressure. A second end (not shown) of tubing **130** is disposed downhole **105** and is in fluid communication with a bottom hole assembly ("BHA") **195** that receives the drilling fluid and/or drilling mud (not shown) provided from the surface **103**. An injector head **120** may be used to push and/or pull tubing **130** into or out of wellbore **105** or position BHA **195** in a desired location.

[0090] BHA **195** typically includes a top sub **140**, a hydraulic power section **150**, a drive shaft assembly **160**, a flow diverter **170**, a bearing assembly **180**, and a drill bit **190**. Top sub **140** is a tubular connector that provides a fluid connection between tubing **130** and hydraulic power section **150**. Hydraulic power section, or mud motor, **150** uses the hydrostatic pressure of the drilling fluid and/or drilling mud (not shown) to provide eccentric rotation to drive shaft assembly **160**. One of ordinary skill in the art will recognize that hydraulic power section **150** may vary based on one or more design characteristics such as, for example, the number of stages (not shown), the lobe ratio (not shown), the external diameter (not shown), the design of the rotor, and the design of the stator. In addition, one of ordinary skill in the art will also recognize that hydraulic power section **150** may vary in the rotational speed, torque, or amount of eccentricity it produces. Drive shaft assembly **160** reduces or eliminates the eccentricity of hydraulic power section **150** and provides substantially concentric rotation to drill bit **190** via bearing assembly **180** and flow diverter **170**. In this way, drive shaft assembly **160** transfers torque from hydraulic power section **150** to the mandrel (not shown) of bearing assembly **180** and, ultimately, drill bit **190**. Flow diverter **170** is disposed between drive shaft assembly **160** and bearing assembly **180** and provides an inlet for drilling fluid and/or drilling mud (not shown) to lubricate and cool the bearings (not shown) and the mandrel (not shown) of bearing assembly **180** as well as the drill bit **190** during drilling operations.

[0091] FIG. **2**A shows a top-facing perspective view of a conventional drive shaft assembly **160***a*. Conventional drive shaft assembly **160***a* includes, in part, first adapter **210***a*, first adapter cap **220***a*, drive shaft **230**, second adapter cap **220***b*, and second adapter **210***b*. First adapter **210***a* is mechanically connected to a hydraulic power section (e.g., **150** of FIG. **1**) and receives eccentric rotation from the hydraulic power section (e.g., **150** of FIG. **1**). The rotation of first adapter **210***a* rotates drive shaft **230**. The rotation of drive shaft **230** rotates second adapter **210***b*. The rotation of second adapter **210***b* rotates a flow diverter (e.g., **170** of FIG. **1**) that rotates a mandrel (not shown) of a bearing assembly (e.g., **180** of FIG. **1**) that in turn rotates a drill bit (e.g., **190** of FIG. **1**). Because of the freedom of movement between first adapter **210***a* and second adapter **210***b*, the eccentric rotation of first adapter **210***a* is converted into substantially concentric rotation at second adapter **210***b*.

[0092] Continuing in FIG. **2**B, an exploded view of the conventional drive shaft assembly **160***a* is shown. As noted above, conventional drive shaft assembly **160***a* includes first adapter **210***a*, first adapter cap **220***a*, drive shaft **230**, second adapter cap **220***b*, and second adapter **210***b*. Conventional drive shaft assembly **160***a* also includes first beryllium copper cap **240***a*, first boot **250***a*, first split ring clamp **260***a*, a first plurality of spheroidal balls **232**, a second plurality of spheroidal balls **232**, second split ring clamp **260***b*, second boot **250***b*, and second beryllium copper cap **240***b*.

[0093] First beryllium copper cap **240***a* is a consumable component typically made of beryllium copper. First beryllium copper cap **240***a* is a substantially cylindrical member that has diameter and a height that allows first beryllium copper cap **240***a* to be inserted into a corresponding cavity of first adapter **210***a* that is configured to receive it. A first side of first beryllium copper cap **240***a* includes a flat surface that is in limited moveable contact with a flat surface (not shown) of the corresponding cavity of first adapter **210***a*. A second side of first beryllium copper cap **240***a* includes a spheroidal cap indentation (not shown) configured to receive a portion of a first spheroidal end of drive shaft **230**. In operation, first beryllium copper cap **240***a* tends to wear out over time giving rise to a variety of failure modes. As such, first beryllium copper cap **240***a* must be removed and replaced at regular intervals requiring the cessation of drilling operations, removal of the BHA (e.g., **195** from FIG. **1**) from the wellbore, disassembly of the drive shaft assembly **160***a*, replacement of the first beryllium copper cap **240***a*, reassembly of the drive shaft assembly **160***a*, and redeployment of the BHA (e.g., **195** from FIG. **1**).

[0094] First boot **250***a* is another consumable component that is typically made of synthetic rubber or fluoropolymer elastomer. First boot **250***a* includes a first end having a flared aperture of a first diameter and a second end having an aperture of a second diameter. A portion of drive shaft **230** extends through the second aperture of first boot **250***a* and the first end of first boot **250***a* covers a portion of a first universal joint formed by the first adapter cap **220***a*, the first spheroidal end of drive shaft **230**, the first plurality of spheroidal balls **232**, the first beryllium copper cap **240***a*, and the first adapter **210***a* protecting the first joint from drilling fluid and/or drilling mud and other particulate matter. In this way, first boot **250***a* functions as a temporary seal that protects the first joint from contamination and retains the lubrication necessary for the functionality of the first joint. In operation, first boot **250***a* tends to deform and ultimately disintegrate allowing the first joint to become contaminated, lose lubrication, and ultimately fail. As such, first boot **250***a* must be removed and/or replaced at regular intervals requiring the cessation of drilling operations, removal of the BHA (e.g., **195** from FIG. **1**) from the wellbore, disassembly of the drive shaft assembly **160***a*, replacement of the first boot **250***a*, reassembly of the drive shaft assembly **160***a*, and redeployment of the BHA (e.g., **195** from FIG. **1**).

[0095] First split ring clamp **260***a* is a retention member that is typically made out of a metal. First split ring clamp **260***a* includes a first end having a flared aperture of a first diameter and a second end having an aperture of a second diameter. The first end of first split ring clamp **260***a* wraps around the first end of first boot **250***a* within an inner diameter of first adapter cap **210***a*. The second end of first split ring clamp **260***a* is flush with an inner diameter of first adapter cap **220***a* and closes the clamp **260***a* when first adapter cap **220***a* is removably attached to first adapter **210***a*. First adapter cap **220***a* includes a first end (male threaded) configured to mate with a second end (female threaded) of first adapter **210***a*. The first end (male threaded) of first adapter **210***a* is connected to a hydraulic power section (e.g., **150** of FIG. **1**).

[0096] Drive shaft **230** includes the first spheroidal end, a cylindrical shaft portion, and a second spheroidal end. Around the circumference of the first spheroidal end, a first plurality of ball cap indentations are disposed that are configured to receive a portion of the first plurality of spheroidal balls **232**. Around the circumference of the second spheroidal end, a second plurality of ball cap indentations are formed that are configured to receive a portion of the second plurality of spheroidal balls **232**.

[0097] Second beryllium copper cap **240***b* is a consumable component typically made of beryllium copper. Second beryllium copper cap **240***b* is a substantially cylindrical member that has diameter and a height that allows second beryllium copper cap **240***b* to be inserted into a corresponding cavity of second adapter **210***b* that is configured to receive it. A first side of second beryllium copper cap **240***b* includes a flat surface (not shown) that is in moveable contact with a flat surface of the corresponding cavity of second adapter **210***b*. A second side of second beryllium copper cap **240***b* includes a spheroidal cap indentation configured to receive a portion of a second spheroidal end of drive shaft **230**. In operation, second beryllium copper cap **240***b* tends to wear out over time giving rise to a variety of failure modes. As such, second beryllium copper cap **240***b* must be removed and replaced at regular intervals requiring the cessation of drilling operations, removal of the BHA (e.g., **195** from FIG. **1**) from the wellbore, disassembly of the drive shaft assembly **160***a*, replacement of the second beryllium copper cap **240***b*, reassembly of the drive shaft assembly **160***a*, and redeployment of the BHA (e.g., **195** from FIG. **1**).

[0098] Second boot **250***b* is another consumable component that is typically made of synthetic rubber or fluoropolymer elastomer. Second boot **250***b* includes a first end having a flared aperture of a first diameter and a second end having an aperture of a second diameter. A portion of drive shaft **230** extends through the second aperture of second boot **250***b* and the first end of second boot **250***b* covers a portion of a second universal joint formed by the second adapter cap **220***b*, the second spheroidal end of drive shaft **230**, the second plurality of spheroidal balls **232**, the second beryllium copper cap **240***b*, and the second adapter **210***b* protecting the second joint from drilling fluid and/or drilling mud and other particulate matter. In this way, second boot **250***b* functions as a temporary seal that protects the second joint from contamination and retains the lubrication necessary for the functionality of the second joint. In operation, second boot **250***b* tends to deform and ultimately disintegrate allowing the second joint to become contaminated, lose lubrication, and ultimately fail. As such, second boot **250***b* must be removed and/or replaced at regular intervals requiring the cessation of drilling operations, removal of the BHA (e.g., **195** from FIG. **1**) from the wellbore, disassembly of the drive shaft assembly **160***a*, replacement of the second boot **250***b*, reassembly of the drive shaft assembly **160***a*, and redeployment of the BHA (e.g., **195** from FIG. **1**).

[0099] Second split ring clamp **260***b* is a retention member that is typically made out of metal. Second split ring clamp **260***b* includes a first end having a flared aperture of a first diameter and a second end having an aperture of a second diameter. The first end of second split ring clamp **260***b* wraps around the first end of second boot **250***b* within an interior diameter of second adapter **210***b*. The second end of second split ring clamp **260***b* is flush with second adapter cap **220***b* and closes the clamp **260***b* when second adapter cap **220***b* is removably attached to second adapter **210***b*. Second adapter cap **220***b* includes a first end (male threaded) configured to mate with a second end (female threaded) of second adapter **210***b*. The first end (male threaded) of second adapter **210***b* is connected to a bearing assembly (e.g., **180** of FIG. **1**) by way of a flow diverter (e.g., **170** of FIG. **1**).

[0100] Continuing in FIG. **2**C, a worn-out adapter **210***a*, **210***b* of a conventional drive shaft assembly **160***a* is shown. During drilling operations, there are various actions taken by the driller that impart jarring axial loads on conventional drive shaft assembly **160***a*. These jarring axial loads may be true axial loads, semi-axial loads offset by an angle that may vary, or axial or semi-axial loads related to the precession of the axis of rotation caused by eccentric rotation or other movements. These loads may be thought of as pulling or pushing or the BHA (e.g., **195** of FIG. **1**) in a jarring manner. The result of these jarring axial loads is the premature wear out of first and/or second adapters **210***a*, **210***b* where the recessed portions configured to receive the plurality of spheroidal balls **232** become deformed or otherwise damaged or drive shaft **230** bends or breaks. As noted above, the objective of the conventional drive shaft assembly **160***a* is to transmit torque to the drill bit (e.g., **190** of FIG. **1**) by converting eccentric rotation provided by the hydraulic power section (e.g., **150** of FIG. **1**) to concentric rotation at the drill bit (e.g., **190** of FIG. **1**). As such, first adapter **210***a* must be able to rotate drive shaft **230**, which in turn must be able to rotate second adapter **210***b*. The spheroidal balls **232**, and their close fit with their respective adapters **210***a* and **210***b*, are critical to this functionality. If either adapter **210***a* or **210***b* becomes deformed or otherwise damaged due these jarring axial loads, or vibration, then conventional drive shaft assembly **160***b* will fail, potentially resulting in deformation or damage to itself or other constituent parts of the BHA (e.g., **195** of FIG. **1**). The failure modes may include slippage as the spheroidal balls **232** no longer catch in damaged recessed portions of their respective adapters **210***a* or **210***b*, and breakage of various components. This results in non-productive downtime that causes drilling operations to stop, the BHA (e.g., **195** of FIG. **1**) typically must be fished out of the hole, the damaged components must be repaired or replaced, and the BHA (e.g., **195** of FIG. **1**) must be tripped back into the hole before drilling operations can resume. As such, there is a long felt, but unsolved, need in the industry for a drive shaft assembly capable of withstanding such jarring axial loads and vibration that is easily serviced in the field.

[0101] Accordingly, in one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly can withstand jarring axial loads, including precession, as well as vibration, without slippage or damage to the adapters of the drive shaft assembly, thereby extending productive uptime of drilling operations. As such, a reciprocation-dampening drive shaft assembly may be used in place of a conventional drive shaft assembly and provide improved operational service life. Advantageously, a reciprocation-dampening drive shaft assembly reduces non-productive downtime and reduces operational costs for drilling operations. Even when consumable parts require replacement, the simplicity and elegance of the design allows the reciprocation-dampening drive shaft assembly to be easily serviced in the field.

[0102] FIG. **3**A shows a top-facing perspective view of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Reciprocation-dampening drive shaft assembly **300** may include, in part, a first reciprocation-dampening adapter **310**, a first reciprocation-dampening adapter cap **345**, a first boot **355**, a first drive shaft portion **325***a*, a drive shaft joint **360**, a second drive shaft portion **325***b*, a second boot **355**, a second reciprocation-dampening adapter cap **345**, a bottom ring **365**, and a second reciprocation-dampening adapter **375**. First reciprocation-dampening adapter **310** may mechanically connect to a hydraulic power section (e.g., **150** of FIG. **1**) that provides eccentric rotation. The rotation of first reciprocation-dampening adapter **310** may rotate first drive shaft portion **325***a* and second drive shaft portion **325***b*. The rotation of second drive shaft portion **325***b* may rotate second reciprocation-dampening adapter **375**. In certain embodiments, including the one depicted in the figure, second reciprocation-dampening adapter **375** may include an integrated flow diverter (e.g., **170** of FIG. **1**) that rotates a mandrel (not shown) of the bearing assembly (e.g., **180** of FIG. **1**) that in turn rotates a drill bit (e.g., **190** of FIG. **1**). In other embodiments, second reciprocation-dampening adapter **375** may not include an integrated flow diverter (not shown). Because of the freedom of movement between first reciprocation-dampening adapter **310** and second reciprocation-dampening adapter **375**, the eccentric rotation of first reciprocation-dampening adapter **310** is converted into substantially concentric rotation at second reciprocation-dampening adapter **375**. Continuing, FIG. **3**B shows a bottom-facing perspective view of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. As discussed in more detail herein, fluids are directed into one or more flow diverter ports **380** that are fluidly connected to an interior passageway **385** that terminates on a distal end of second reciprocation-dampening adapter **375**, thereby providing fluids to the bearing assembly (e.g., **180** of FIG. **1**) and drill bit (e.g., **190** of FIG. **1**). Continuing, FIG. **3**C shows a front elevation view, FIG. **3**D shows a side elevation view, FIG. **3**E shows a top plan view, and FIG. **3**F shows a bottom plan view of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention.

[0103] FIG. **4** shows an exploded view of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention.

[0104] A first reciprocation-dampening adapter **310** may include a connection end and a cylindrical adapter portion. The cylindrical adapter portion may include a recessed inner aperture having a first diameter (not shown), a recessed inner aperture having a second diameter (not shown) and a plurality of semispheroidal recessed portions, and an adapter threaded end (not shown).

[0105] A first plurality of spring washers **315** may be disposed within the recessed inner aperture having the first diameter (not shown) of the first reciprocation-dampening adapter **310**. The first plurality of spring washers **315** may have a first inner diameter.

[0106] A first floating seat **320** may be disposed within the recessed inner aperture having the first diameter (not shown) of the first reciprocation-dampening adapter **310** on a spring loaded side of the first plurality of spring washers **315**. The first floating seat **320** may be a substantially cylindrical member that has a flat surface on a first side that is in moveable contact with the first plurality of spring washers **315** disposed within the recessed inner aperture having the first diameter (not shown) of the first reciprocation-dampening adapter **310**. A second side of first floating seat **320** may include a spheroidal cap indentation configured to movably receive a portion of a spheroidal end of a first drive shaft portion **325***a*. The first floating seat **320** may include a central lumen that fluidly connects the spheroidal end of the first drive shaft portion **325***a* and the recessed inner aperture having the first diameter (not shown) of the first reciprocation-dampening adapter **310**, where grease or lubricant may be disposed.

[0107] A first drive shaft portion **325***a* may include the spheroidal end, a cylindrical shaft portion, and shaft threaded end. The spheroidal end may include a plurality of ball cap indentations **327** disposed about its outer surface. One of ordinary skill in the art will recognize that the number, size, and location of ball cap indentations **327** may vary based on an application or design in accordance with one or more embodiments of the present invention. A first plurality of spheroidal balls **330** may be partially disposed within the plurality of ball cap indentations **327** of first drive shaft portion **325***a*.

[0108] A first floating ring **335** may include a plurality of semispheroidal recessed portions **337** on a first side and substantially flat surface on a second side (not shown). The plurality of semispheroidal recessed portions (not shown) of first reciprocation-dampening adapter **310** may be configured to receive a portion of the first plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of first drive shaft portion **325***a* when first drive shaft portion **325***a* is inserted into first reciprocation-dampening adapter **310**. The plurality of semispheroidal recessed portions **337** of first floating ring **335** may be configured to receive another portion of the first plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of the spheroidal end of the first drive shaft portion **325***a*. First floating ring **335** may be disposed in the recessed inner aperture having a second diameter (not shown) of the first reciprocation-dampening adapter **310**. First drive shaft portion **325***a* may be disposed through a central lumen of first floating ring **335**.

[0109] A first plurality of spring washers **340**, having a second inner diameter, larger than the first inner diameter of washers **315**, may be disposed within the recessed inner aperture having the second diameter (not shown) of the first reciprocation-dampening adapter **310**. The second inner diameter may be large enough to pass the cylindrical shaft portion of the first drive shaft portion **325***a*. The first plurality of spring washers **340** may be disposed such that their spring loaded side is facing a first reciprocation-dampening adapter cap **345**.

[0110] The first reciprocation-dampening adapter cap **345** may include a recessed dampener aperture configured to receive a first dampener insert **350** and a first adapter cap threaded end configured to removably connect to the first adapter threaded end of the first reciprocation-dampening adapter **310**. The recessed dampener aperture (not shown) of the first reciprocation-dampening adapter cap **345** may be tapered in a direction toward the adapter cap threaded end and includes a plurality of ridges (not shown) configured to secure the first dampener insert **350** within the first reciprocation-dampening adapter cap **345**. When the first reciprocation-dampening adapter cap **345** is connected to the first reciprocation-dampening adapter **310**, the spheroidal end of first drive shaft portion **325***a* may be securely disposed within first reciprocation-dampening adapter **310**.

[0111] A first boot **355** may be configured to seal the first reciprocation-dampening adapter cap **345** and the cylindrical shaft portion of the first drive shaft portion **325***a*. The first reciprocation-dampening adapter cap **345** may include a recessed area disposed about its outer surface configured to secure a first end of the first boot **355** to the first reciprocation-dampening adapter cap **345**.

[0112] A drive shaft joint **360** may include a first distal end configured to receive the shaft threaded end of the first drive shaft portion **325***a* and a second distal end configured to receive the shaft threaded end of the second drive shaft portion **325***b*.

[0113] A second reciprocation-dampening adapter **375** may include a connection end, a cylindrical adapter portion, and a flow diverter portion. The cylindrical adapter portion includes a recessed inner aperture having the first diameter (partially shown), a recessed inner aperture having a second diameter (not shown) and a plurality of semispheroidal recessed portions **312**, and a second adapter threaded end (not shown). The flow diverter portion of the second reciprocation-dampening adapter **375** may include a one or more flow diverter ports **380** fluidly connected to an interior passageway (not shown) that fluidly communicates with a distal end of second reciprocation-dampening adapter **375**. A grease injection nipple **370** may be disposed within a recessed inner aperture (not shown) of the interior passageway of the distal end of second reciprocation-dampening adapter **375**. Grease injection nipple **370** may be used to inject grease or lubricant into the sealed joint of the second reciprocation-dampening adapter **375** when assembled.

[0114] A second plurality of spring washers **315** may be disposed within the recessed inner aperture having the first diameter (partially shown) of the second reciprocation-dampening adapter **375**. The second plurality of spring washers **315** may have the first inner diameter.

[0115] A second floating seat **320** may be disposed within the recessed inner aperture having the first diameter (not shown) of the second reciprocation-dampening adapter **375** on a spring loaded side of the second plurality of spring washers **315**. The second floating seat **320** may be a substantially cylindrical member that has a flat surface on a first side that is in moveable contact with the second plurality of spring washers **315** disposed within the recessed inner aperture having the first diameter (not shown) of the second reciprocation-dampening adapter **375**. A second side of second floating seat **320** may include a spheroidal cap indentation configured to movably receive a portion of a spheroidal end of the second drive shaft portion **325***b*. The second floating seat **320** may include a central lumen that fluidly connects the spheroidal end of the second drive shaft portion **325***b* and the interior passageway of the flow diverter portion of the second reciprocation-dampening adapter **310**.

[0116] A second drive shaft portion **325***b* may include the spheroidal end, a cylindrical shaft portion, and shaft threaded end. The spheroidal end may include a plurality of ball cap indentations **327** disposed about its outer surface. One of ordinary skill in the art will recognize that the number of ball cap indentations **327** may vary based on an application or design in accordance with one or more embodiments of the present invention. A second plurality of spheroidal balls **330** may be partially disposed within the plurality of ball cap indentations **327** of second drive shaft portion **325***b*. In certain embodiments, including the one depicted in the figure, the cylindrical shaft portion of second drive shaft portion **325***b* may be longer than the cylindrical shaft portion of the first drive shaft portion **325***a*. One of ordinary skill in the art will recognize that the lengths of the cylindrical drive shaft portions of the first **325***a* and second **325***b* drive shaft portions may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0117] A second floating ring **335** may include a plurality of semispheroidal recessed portions **337** on a first side (partially shown) and substantially flat surface on a second side. The plurality of semispheroidal recessed portions (partially shown) of second reciprocation-dampening adapter **375** may be configured to receive a portion of the second plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of second drive shaft portion **325***b* when second drive shaft portion **325***b* is inserted into second reciprocation-dampening adapter **375**. The plurality of semispheroidal recessed portions **337** of second floating ring **335** may be configured to receive another portion of the second plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of the spheroidal end of the second drive shaft portion **325***b*. Second floating ring **335** may be disposed in the recessed inner aperture having a second diameter (not shown) of the second reciprocation-dampening adapter **375**. Second drive shaft portion **325***b* may be disposed through a central lumen of second floating ring **335**.

[0118] A second plurality of spring washers **340**, having the second inner diameter, larger than the first inner diameter of washers **315**, may be disposed within the recessed inner aperture having the second diameter (not shown) of the second reciprocation-dampening adapter **375**. The second inner diameter may be large enough to pass the cylindrical shaft portion of the second drive shaft portion **325***b*. The second plurality of spring washers **340** may be disposed such that their spring loaded side is facing a second reciprocation-dampening adapter cap **345**.

[0119] The second reciprocation-dampening adapter cap **345** may include a recessed dampener aperture configured to receive a second dampener insert **350** and a second adapter cap threaded end configured to removably connect to the second adapter threaded end of second reciprocation-dampening adapter **375**. The recessed dampener aperture (not shown) of second reciprocation-dampening adapter cap **345** may be tapered in a direction toward the second adapter cap threaded end of second reciprocation-dampening adapter cap **345** and include a plurality of ridges (not shown) configured to secure the second dampener insert **350** within the second reciprocation-dampening adapter cap **345**. When the second reciprocation-dampening adapter cap **345** is connected to second reciprocation-dampening adapter **375**, the spheroidal end of second drive shaft portion **325***b* may be securely disposed within second reciprocation-dampening adapter **375**.

[0120] A second boot **355** may be configured to seal the second reciprocation-dampening adapter cap **345** and the cylindrical shaft portion of the second drive shaft portion **325***b*. The second reciprocation-dampening adapter cap **345** may include a recessed area disposed about its outer surface configured to secure a first end of the second boot **355** to the second reciprocation-dampening adapter cap **345**.

[0121] FIG. **5** shows a cross-sectional view of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. A detailed cross-sectional view of an assembled portion of a first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300** is shown in FIG. **6** and a detailed cross-sectional view of an assembled portion of a second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** is shown in FIG. **7**. However, in this cross-sectional view, the shaft threaded end of first drive shaft portion **325***a* and the shaft threaded end of second drive shaft portion **325***b* are shown connected to opposing distal ends of drive shaft joint **360**. Splitting the drive shaft into first **325***a* and second **325***b* portions facilitates assembly as well as decouples mechanical stresses and increases the strength of the most vulnerable portion of the drive shaft, thereby preventing or reducing breakage.

[0122] FIG. **6** shows a detailed cross-sectional view of an assembled portion of a first reciprocation-dampening adapter **310** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. In this assembled cross-sectional view, a configuration of the components and their intended functionality is more clearly shown. Within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter **310**, the first plurality of spring washers **315** are shown with the spring loaded end facing the spheroidal end of the first drive shaft portion **325***a*. Also within this same recessed inner aperture, the first floating seat **320** is shown. The flat surface on the first side of the first floating seat **320** is shown in movable contact with the spring loaded end of the first plurality of spring washers **315**. The second side of the first floating seat **320** may include a spheroidal cap indentation configured to receive a portion of a spheroidal end of the first drive shaft portion **325***a*. A central lumen **322** may fluidly connect the spheroidal end of the first drive shaft portion **325***a* and the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter **310**.

[0123] The first plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of the spheroidal end of the first drive shaft portion **325***a* are shown where a portion of the balls **330** are fitted into the plurality of semispheroidal recessed portions **312** of first reciprocation-dampening adapter **310**. Similarly, the plurality of semispheroidal recessed portions **337** of the first floating ring **335** are shown movably fitted to further support balls **330**. A first plurality of spring washers **340** are shown disposed within the recessed inner aperture having the second diameter of the first reciprocation-dampening adapter **310**. The spring loaded end of the first plurality of spring washers **340** are facing the in the direction of the first reciprocation-dampening adapter cap **345**. The adapter cap threaded end of the first reciprocation-dampening adapter cap **345** may removably connect to the adapter threaded end of the first reciprocation-dampening adapter **310**, with the cylindrical shaft portion of the first drive shaft portion **325***a* extending therethrough. The recessed dampener aperture of the first reciprocation-dampening adapter cap **345** is shown with a first dampener insert **350** installed. The first boot **355** seals the first reciprocation-dampening adapter cap **345** to the cylindrical shaft portion of the first drive shaft portion **325***a*.

[0124] When axial loads are exerted, the first plurality of spring washers **315**, the first floating seat **320**, the first floating ring **335**, the first plurality of spring washers **340**, and the first dampener insert **350**, provide improved freedom of movement, including the ability to withstand axial loads, while maintaining a protective and secure grip on the spheroidal end of the first drive shaft portion **325***a* that prevents such loads, or vibrations, from damaging the semispheroidal recessed portions **312** of the first reciprocation-dampening adapter **310** or other components of the drive shaft assembly **300**.

[0125] FIG. **7** shows a detailed cross-sectional view of an assembled portion of a second reciprocation-dampening adapter **375** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. In this assembled cross-sectional view, a configuration of the components and their intended functionality is more clearly shown. Within the recessed inner aperture having the first diameter of the second reciprocation-dampening adapter **375**, the second plurality of spring washers **315** are shown with the spring loaded end facing the spheroidal end of the second drive shaft portion **325***b*. Also within this same recessed inner aperture, the second floating seat **320** is shown. The flat surface on the first side of the second floating seat **320** is shown in movable contact with the spring loaded end of the second plurality of spring washers **315**. The second side of the second floating seat **320** may include a spheroidal cap indentation configured to receive a portion of a spheroidal end of the second drive shaft portion **325***b*. A central lumen **322** may fluidly connect the spheroidal end of the second drive shaft portion **325***b* and grease injection nipple **370** that may be used to inject grease or lubricant.

[0126] The second plurality of balls **330** partially disposed within the plurality of ball cap indentations **327** of the spheroidal end of the second drive shaft portion **325***b* are shown where a portion of the balls **330** are fitted into the plurality of semispheroidal recessed portions **312** of second reciprocation-dampening adapter **375**. Similarly, the plurality of semispheroidal recessed portions **337** of the second floating ring **335** are shown movably fitted to further support balls **330**. A second plurality of spring washers **340** are shown disposed within the recessed inner aperture having the second diameter of the second reciprocation-dampening adapter **375**. The spring loaded end of the second plurality of spring washers **340** are facing the in the direction of the second reciprocation-dampening adapter cap **345**. The second adapter cap threaded end of the second reciprocation-dampening adapter cap **345** may removably connect to the second adapter threaded end of second reciprocation-dampening adapter **375**, with the cylindrical shaft portion of the second drive shaft portion **325***b* extending therethrough. The recessed dampener aperture of the second reciprocation-dampening adapter cap **345** is shown with a second dampener insert **350** installed. The second boot **355** seals the second reciprocation-dampening adapter cap **345** to the cylindrical shaft portion of the second drive shaft portion **325***b*.

[0127] When axial loads are exerted, the second plurality of spring washers **315**, the second floating seat **320**, the second floating ring **335**, the second plurality of spring washers **340**, and the second dampener insert **350**, provide improved freedom of movement, including the ability to withstand axial loads, while maintaining a protective and secure grip on the spheroidal end of the second drive shaft portion **325***b* that prevents such loads, or vibrations, from damaging the semispheroidal recessed portions **312** of the second reciprocation-dampening adapter **375** or other components of the drive shaft assembly **300**.

[0128] FIG. **8**A shows a top-facing perspective view of a first reciprocation-dampening adapter **310** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **8**B shows a side elevation view of the first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **8**C shows a top plan view of the first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **8**D shows a bottom plan view of the first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **8**E shows a bottom-facing perspective view of the first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the connection end and the cylindrical adapter portion may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0129] FIG. **9**A shows a top-facing perspective view of a plurality of spring washers **315** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Spring washers **315** are intended to be disposed within the recessed inner aperture having the first diameter of either the first reciprocation-dampening adapter **310** or second reciprocation-dampening adapter **375** to provide for limited axial movement. Continuing, FIG. **9**B shows a side elevation view of the plurality of spring washers **315** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **9**C shows a top plan view of the plurality of spring washers **315** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **9**D shows a bottom plan view of the plurality of spring washers **315** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **9**E shows a bottom-facing perspective view of the plurality of spring washers **315** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention.

[0130] One of ordinary skill in the art will recognize that the number of spring washers **315** used may vary to adjust the spring constant based on an application or design in accordance with one or more embodiments of the present invention. In certain embodiments, the plurality of spring washers **315** may be Belleville washers. In other embodiments, one or more gas springs (not shown) may be used in place of the plurality of spring washers **315**. In still other embodiments, one or more extension springs (not shown) may be used in place of the plurality of spring washers **315**. One of ordinary skill in the art will recognize that the type or kind of spring washers **315** used may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0131] FIG. **10**A shows a top-facing perspective view of a floating seat **320** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **10**B shows a side elevation view of floating seat **320** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **10**C shows a top plan view of floating seat **320** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **10**D shows a bottom plan view of floating seat **320** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **10**E shows a bottom-facing perspective view of floating seat **320** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of floating seat **320** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0132] FIG. **11**A shows a top-facing perspective view of a first drive shaft portion **325***a* of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. First drive shaft portion **325***a* may include a spheroidal end, a cylindrical shaft portion **1105**, and a shaft threaded end **1110**. In certain embodiments, including those depicted in the figures, first drive shaft portion **325***a* may have a cylindrical shaft portion **1105** that is shorter than the cylindrical shaft portion (e.g., **1805** of FIG. **18**) of the second drive shaft portion **325***b*. Cylindrical shaft portion **1105** of the first drive shaft portion **325***a* may be shorter than, longer than, or substantially equal in length to the cylindrical shaft portion (e.g., **1805** of FIG. **18**) of the second drive shaft portion (e.g., **325***b* of FIG. **18**). One of ordinary skill in the art will recognize that the length and diameter of the cylindrical shaft portion **1805** may vary based on an application or design in accordance with one or more embodiments of the present invention. Continuing, FIG. **11**B shows a side elevation view of the first drive shaft portion **325***a* of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **11**C shows a top plan view of the first drive shaft portion **325***a* of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **11**D shows a bottom plan view of the first drive shaft portion **325***a* of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **11**E shows a bottom-facing perspective view of the first drive shaft portion **325***a* of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of first drive shaft portion **325***a* may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0133] FIG. **12**A shows a top-facing perspective view of a floating ring **335** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **12**B shows a side elevation view of the floating ring **335** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **12**C shows a top plan view of the floating ring **335** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **12**D shows a bottom plan view of the floating ring **335** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **12**E shows a bottom-facing perspective view of the floating ring **335** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of floating ring **335**, including the shape, size, configuration and number of semispheroidal recessed portions **337**, may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0134] FIG. **13**A shows a top-facing perspective view of a plurality of spring washers **340** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **13**B shows a side elevation view of the plurality of spring washers **340** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **13**C shows a top plan view of the plurality of spring washers **340** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **13**D shows a bottom plan view of the plurality of spring washers **340** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **13**E shows a bottom-facing perspective view of the plurality of spring washers **340** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention.

[0135] One of ordinary skill in the art will recognize that the number of spring washers **340** used may vary to adjust the spring constant based on an application or design in accordance with one or more embodiments of the present invention. In certain embodiments, the plurality of spring washers **340** may be Belleville washers. In other embodiments, one or more extension springs (not shown) may be used in place of the plurality of spring washers **340**. One of ordinary skill in the art will recognize that the type or kind of spring washers **340** used may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0136] FIG. **14**A shows a top-facing perspective view of a reciprocation-dampening adapter cap **345** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **14**B shows a side elevation view of the reciprocation-dampening adapter cap **345** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. In this view, the adapter cap threaded end as well as the recessed area disposed about its outer surface configured to secure a first end of a boot **355** to the reciprocation-dampening adapter cap **345** is shown. Continuing, FIG. **14**C shows a top plan view of the reciprocation-dampening adapter cap **345** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **14**D shows a bottom plan view of the reciprocation-dampening adapter cap **345** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **14**E shows a bottom-facing perspective view of the reciprocation-dampening adapter cap **345** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of reciprocation-dampening adapter cap **345**, including the shape of the recessed dampener aperture, may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0137] FIG. **15**A shows a top-facing perspective view of a dampener insert **350** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **15**B shows a side elevation view of the dampener insert **350** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **15**C shows a top plan view of the dampener insert **350** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **15**D shows a bottom plan view of the dampener insert **350** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **15**E shows a bottom-facing perspective view of the dampener insert **350** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention.

[0138] In certain embodiments, dampener insert **350** may be composed of urethane, nitrile, fluorocarbons, butadiene, polymers, elastomers, synthetic rubbers, or combinations thereof. One of ordinary skill in the art will recognize that any other suitable material may be used in in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will also recognize that the shape, size, and configuration of dampener insert **350** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0139] FIG. **16**A shows a top-facing perspective view of a boot **355** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **16**B shows a side elevation view of the boot **355** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **16**C shows a top plan view of the boot **355** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **16**D shows a bottom plan view of the boot **355** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **16**E shows a bottom-facing perspective view of the boot **355** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. In certain embodiments, boot **355** may be composed of hydrogenated nitrile butadiene rubber ("H-NBR"). One of ordinary skill in the art will recognize that the material composition of boot **355** may vary based on an application or design in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of boot **355** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0140] FIG. **17**A shows a top-facing perspective view of a drive shaft joint **360** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **17**B shows a side elevation view of the drive shaft joint **360** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **17**C shows a top plan view of the drive shaft joint **360** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **17**D shows a bottom plan view of the drive shaft joint **360** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **17**E shows a bottom-facing perspective view of the drive shaft joint **360** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of boot **355** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0141] FIG. **18**A shows a top-facing perspective view of a second drive shaft portion **325*b*** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Second drive shaft portion **325*b*** may include a spheroidal end, a cylindrical shaft portion **1805**, and a shaft threaded end **1110**. Cylindrical shaft portion **1805** of the second drive shaft portion **325*b*** may be shorter than, longer than, or substantially equal in length to the cylindrical shaft portion (e.g., **1105** of FIG. **11**) of the first drive shaft portion (e.g., **325*a*** of FIG. **1**). One of ordinary skill in the art will recognize that the length and diameter of the cylindrical shaft portion **1805** may vary based on an application or design in accordance with one or more embodiments of the present invention. Continuing, FIG. **18**B shows a side elevation view of the second drive shaft portion **325*b*** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **18**C shows a top plan view of the second drive shaft portion **325*b*** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **18**D shows a bottom plan view of the second drive shaft portion **325*b*** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **18**E shows a bottom-facing perspective view of the second drive shaft portion **325*b*** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of second drive shaft portion **325*b*** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0142] FIG. **19**A shows a top-facing perspective view of a second reciprocation-dampening adapter **375** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **19**B shows a front elevation view of the second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **19**C shows a side elevation view of the second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **19**D shows a top plan view of the second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **19**E shows a bottom plan view of the second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **19**F shows a bottom-facing perspective view of the second reciprocation-dampening adapter **375** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. In certain embodiments, second reciprocation-dampening adapter **375** may include an integrated flow diverter **380**. In other embodiments, second reciprocation-dampening adapter **375** may connect to a discrete flow diverter (not shown). One of ordinary skill in the art will recognize that the shape, size, and configuration of second reciprocation-dampening adapter **375** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0143] FIG. **20**A shows a top-facing perspective view of a grease injection nipple **370** of a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **20**B shows a side elevation view of the grease injection nipple **370** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **20**C shows a top plan view of the grease injection nipple **370** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **20**D shows a bottom plan view of the grease injection nipple **370** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. Continuing, FIG. **20**E shows a bottom-facing perspective view of the grease injection nipple **370** of the reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. One of ordinary skill in the art will recognize that the shape, size, and configuration of grease injection nipple **370** may vary based on an application or design in accordance with one or more embodiments of the present invention.

[0144] FIG. **21** shows a BHA (e.g., similar to **195** of FIG. **1**) including a reciprocation-dampening drive shaft assembly **300** in accordance with one or more embodiments of the present invention. A top portion of reciprocation-dampening drive shaft assembly **300** may be connected to a hydraulic power section (e.g., **150** of FIG. **1**) that provides eccentric rotation to the first reciprocation-dampening adapter **310** of the reciprocation-dampening drive shaft assembly **300**. The first reciprocation-dampening adapter **310** provides rotation to the first drive shaft portion **325***a,* which in turn provides rotation to the second drive shaft portion **325***b*. The second drive shaft portion **325***b* provides substantially concentric rotation to second reciprocation-dampening adapter **375**. For scale, the above-noted components are not independently labeled in this view, but their use is consistent with prior figures. The second reciprocation-dampening adapter **375** may be connected to a bearing assembly **180** and rotate a bearing mandrel (not shown) disposed therein. The bearing assembly **180** may provide rotation to drill bit **190**. A cover **2105**, shown in ghostline for clarity of disclosure, may be disposed over reciprocation-dampening drive assembly **300** to show that, when fluids are injected downhole, they traverse outside reciprocation-dampening drive shaft assembly **300**, but enter fluid injector ports **380** of the second reciprocation-dampening adapter **375**. The fluids then pass through an interior passageway **385** of the second reciprocation-dampening adapter **375** and lubricate and cool the bearing assembly **180** and the drill bit **190** during drilling operations.

[0145] One of ordinary skill in the art will recognize that the shape, size, and configuration of the various components of reciprocation-dampening drive shaft assembly **300**, or its constituent components, may vary based on an application or design in accordance with one or more embodiments of the present invention. Additionally, one of ordinary skill in the art will also recognize that the scale of reciprocation-dampening drive shaft assembly **300**, or its constituent components, may also vary based on an application or design in accordance with one or more embodiments of the present invention.

[0146] Advantages of one or more embodiments of the present invention may include one or more of the following:

[0147] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly can withstand jarring axial loads, as well as vibration, without slippage or damage to the adapters of the drive shaft assembly, thereby extending productive uptime of drilling operations.

[0148] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly provides improved operational service life as compared to a conventional drive shaft assembly.

[0149] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly may be used in place of a conventional drive shaft assembly.

[0150] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly provides at least the same level of performance as that of a conventional drive shaft assembly and in many instances improved performance.

[0151] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly reduces the operating cost of a hydraulic drilling system. Conventional drive shaft assemblies are prone to failure. When a conventional drive shaft assembly fails, drilling operations must cease, the BHA must be removed from the wellbore, the drive shaft assembly must be disassembled and consumable parts must be repaired or replaced before it is reassembled and the BHA is redeployed. Because the reciprocation-dampening drive shaft assembly is capable of withstanding jarring axial loads, as well as vibration, the operational service life is increased, nonproductive downtime is reduced, and costs are reduced.

[0152] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly provides improved reliability over a conventional drive shaft assembly.

[0153] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly is easier to assemble than a conventional drive shaft assembly.

[0154] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly is at or near cost parity with a conventional drive shaft assembly.

[0155] In one or more embodiments of the present invention, a size of the various components of a reciprocation-dampening drive shaft assembly may vary based on an application or design.

[0156] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly may be compatible with hydraulic drilling systems including, for example, a coiled tubing rig.

[0157] In one or more embodiments of the present invention, a reciprocation-dampening drive shaft assembly may be compatible with top drive drilling systems.

[0158] While the present invention has been described with respect to the above-noted embodiments, those skilled in the art, having the benefit of this disclosure, will recognize that other embodiments may be devised that are within the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the appended claims.

What is claimed is:

1. A reciprocation-dampening drive shaft assembly comprising:

a first reciprocation-dampening adapter comprising a connection end and a cylindrical adapter portion, wherein the cylindrical adapter portion comprises a recessed inner aperture having a first diameter, a recessed inner aperture having a second diameter and a plurality of semispheroidal recessed portions, and a first adapter threaded end;

a first plurality of spring washers disposed within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter;

a first floating seat disposed within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter on a spring loaded side of the first plurality of spring washers, wherein the first floating seat comprises a spheroidal cap indentation configured to receive a portion of a spheroidal end of a first drive shaft portion;

the first drive shaft portion comprising the spheroidal end, a cylindrical shaft portion, and a shaft threaded end, wherein the spheroidal end comprises a plurality of ball cap indentations disposed about its outer surface;

a first floating ring comprising a plurality of semispheroidal recessed portions, wherein the plurality of semispheroidal recessed portions of the first dampening adapter are configured to receive a portion of a first plurality of balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the first drive shaft portion and the plurality of semispheroidal recessed portions of the first floating ring are configured to receive a portion of the first plurality of balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the first drive shaft portion;

a first plurality of spring washers disposed within the recessed inner aperture having the second diameter of the first reciprocation-dampening adapter;

a first reciprocation-dampening adapter cap comprising a recessed dampener aperture configured to receive a first dampener insert and a first adapter cap threaded end configured to removably connect to the first adapter threaded end of the first dampening adapter; and

a first boot configured to seal the first reciprocation-dampening adapter cap and the cylindrical shaft portion of the first drive shaft portion.

2. The reciprocation-dampening drive shaft assembly of claim **1**, further comprising:

a second reciprocation-dampening adapter comprising a connection end, a cylindrical adapter portion, and a flow diverter portion, wherein the cylindrical adapter portion comprises a recessed inner aperture having the first diameter, a recessed inner aperture having the second diameter and a plurality of semispheroidal recessed portions, and a second adapter threaded end;

a second plurality of spring washers disposed within the recessed inner aperture having the first diameter of the second reciprocation-dampening adapter;

a second floating seat disposed within the recessed inner aperture having the first diameter of the second reciprocation-dampening adapter on a spring loaded side of the second plurality of spring washers, wherein the second floating seat comprises a spheroidal cap indentation configured to receive a portion of a spheroidal end of a second drive shaft portion;

the second drive shaft portion comprising the spheroidal end, a cylindrical shaft portion, and a shaft threaded end, wherein the spheroidal end comprises a plurality of ball cap indentations disposed about its outer surface;

a second floating ring comprising a plurality of semispheroidal recessed portions, wherein the plurality of semispheroidal recessed portions of the second dampening adapter are configured to receive a portion of a second plurality of balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the second drive shaft portion and the plurality of semispheroidal recessed portions of the second floating ring are configured to receive a portion of the second plurality of balls partially disposed within the plurality of ball cap indentations of the spheroidal end of the second drive shaft portion;

a second plurality of spring washers disposed within the recessed inner aperture having the second diameter of the second reciprocation-dampening adapter;

a second reciprocation-dampening adapter cap comprising a recessed dampener aperture configured to receive a second dampener insert and a second adapter cap threaded end configured to removably connect to the second adapter threaded end of the second dampening adapter;

a second boot configured to seal the second reciprocation-dampening adapter cap and the cylindrical shaft portion of the second drive shaft portion.

3. The reciprocation-dampening drive shaft assembly of claim **2**, further comprising:

a drive shaft joint having a first distal end configured to receive the shaft threaded end of the first drive shaft portion and a second distal end configured to receive the shaft threaded end of the second drive shaft portion.

4. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the cylindrical shaft portion of the second drive shaft portion is longer than the cylindrical shaft portion of the first drive shaft portion.

5. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the flow diverter portion comprises a plurality of flow diverter ports configured to divert fluid flow into an interior passageway of the second reciprocation-dampening adapter.

6. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the flow diverter portion comprises a grease injection nipple used to inject lubricant into an interior area surrounding the spheroidal end of the second drive shaft portion.

7. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the first floating seat comprises a central lumen that fluidly connects the spheroidal end of the first drive shaft portion and the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter.

8. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the second floating seat comprises a central lumen that fluidly connects the spheroidal end of the second drive shaft portion and the recessed inner aperture having the first diameter of the second reciprocation-dampening adapter.

9. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the recessed dampener aperture of the first reciprocation-dampening adapter cap is tapered toward the first adapter cap threaded end and includes a plurality of ridges configured to secure the first dampener insert within the first reciprocation-dampening adapter cap.

10. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the recessed dampener aperture of the second reciprocation-dampening adapter cap is tapered toward the second adapter cap threaded end and includes a plurality of ridges configured to secure the second dampener insert within the second reciprocation-dampening adapter cap.

11. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the first dampener insert is composed of urethane, nitrile, fluorocarbons, butadiene, polymers, elastomers, synthetic rubbers, or combinations thereof.

12. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the second dampener insert is composed of urethane, nitrile, fluorocarbons, butadiene, polymers, elastomers, synthetic rubbers, or combinations thereof.

13. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the first reciprocation-dampening adapter cap comprises a recessed area disposed about its outer surface configured to secure a first end of the first boot to the first reciprocation-dampening adapter cap.

14. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the second reciprocation-dampening adapter cap comprises a recessed area disposed about its outer surface configured to secure a first end of the second boot to the second reciprocation-dampening adapter cap.

15. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the connection end of the first reciprocation-dampening adapter cap connects to a hydraulic power section.

16. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the connection end of the second reciprocation-dampening adapter cap connects to a bearing assembly.

17. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the first plurality of spring washers disposed within the recessed inner aperture having the first diameter of the first reciprocation-dampening adapter are Belleville washers.

18. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the second plurality of spring washers disposed within the recessed inner aperture having the first diameter of the second reciprocation-dampening adapter are Belleville washers.

19. The reciprocation-dampening drive shaft assembly of claim **1**, wherein the first plurality of spring washers disposed within the recessed inner aperture having the second diameter of the first reciprocation-dampening adapter are Belleville washers.

20. The reciprocation-dampening drive shaft assembly of claim **2**, wherein the second plurality of spring washers disposed within the recessed inner aperture having the second diameter of the second reciprocation-dampening adapter are Belleville washers.

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