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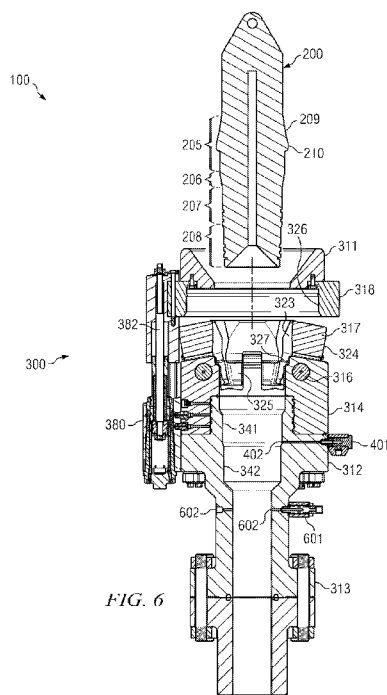
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(54) Title: REMOTELY OPERATED FLUID CONNECTION AND SEAL



(57) Abstract: A remotely-operated fluid connection assembly to hold higher internal pressures in larger diameters. Disclosed embodiments gain advantage from the internal work pressure to provide improved seal performance. The assembly comprises a fluid connection adapter and a fluid connection housing assembly. When the adapter enters the housing assembly: (A) locking elements on the housing assembly constrict about the adapter; and (B) at least a first seal section on the adapter sealingly contacts a first seal bore on the housing assembly. Progressive engagement of a locking ring upon the locking elements urges the locking elements to tighten against the adapter. Internal pressure encourages adapter displacement, which then further tightens the adapter against the locking elements as now restrained by the locking ring. Internal pressure further encourages the first seal section on the adapter to expand radially to tighten the contact with the first seal bore in the housing assembly.

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of such existing fluid connections. FIGURES 1A and 1B in this disclosure illustrate examples of such existing fluid connections, and are based upon Figure 2 in U.S. Patents 9,644,443 and 9,670,745.

Embodiments of the fluid connections described in U.S. Patents 9,644,443 and  
5 9,670,745 may be rated up to 15,000 psi MAWP (maximum allowable working pressure), with diameters ranging from about 2" to about 7" ID. In practice, however, even though serviceable, embodiments rated over about 10,000 psi MAWP in over about 5" ID have proven difficult to manufacture with consistent performance. Additionally, 10,000 psi MAWP in 5" ID is generally recognized as a satisfactory service rating in wellhead pressure  
10 control applications.

Hydraulic fracturing has become an increasingly important technique used in the extraction of hydrocarbons from subterranean formations. Fluid connections are needed in hydraulic fracturing in order, for example, to facilitate flow of fracturing fluid into and out of wells via a wellhead. However, the fracturing process often calls for hydraulic fluid  
15 pressures and flow rates exceeding those typically seen in conventional wellhead pressure control applications. In some applications, hydraulic fracturing may call for 15,000 psi MAWP pressures in wellheads up to 8" ID. This in turn translates into a requirement for fluid connections that are rated for such correspondingly higher hydraulic pressures and wellhead diameters. A need exists for a fluid connection design that is capable of  
20 consistently retaining higher pressures in larger diameter wellheads, in order to accommodate higher fluid flows at such fluid pressures. At the same time, such a fluid connection design should also be remotely operable in order to address personnel safety considerations near wellheads as described above.

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#### SUMMARY AND TECHNICAL ADVANTAGES

These and other needs in the prior art are addressed by a remotely-operated fluid connection and seal whose designs gain advantage from internal operational working pressure (e.g. ambient well pressure) to tighten the connection and seal against leakage.

According to disclosed and illustrated embodiments, a fluid connection assembly  
30 comprises a fluid connection adapter and a fluid connection housing assembly. The fluid connection adapter is received into a fluid connection housing assembly in an "open" position. The fluid connection housing assembly provides a plurality of locking elements rotating about pivot pins. A locking element actuating section on the fluid connection

adapter engages locking element rocking faces on the locking elements as the fluid connection assembly enters the fluid connection housing assembly. Engagement of the locking element rocking faces causes the locking elements to rotate, in turn causing locking element inner surfaces to contact a tapered lock engagement surface on the fluid connection adapter. In some embodiments, the fluid connection adapter's entry into the fluid connection housing assembly is stopped as a rib on the fluid connection adapter abuts housing notches within the fluid connection housing assembly. At this point, at least a first seal section on the fluid connection adapter sealingly contacts a first seal bore within the fluid connection housing assembly.

10 A locking ring is then brought onto the locking elements. A locking ring inner surface contacts locking element outer surfaces. Progressive engagement of the locking ring inner surface on the locking element outer surfaces causes the locking elements to constrict radially about the fluid connection adapter. Constriction of the locking elements urges the locking element inner surfaces to tighten against the tapered lock engagement surface on the fluid connection adapter. At this point, the fluid connection assembly is in the "closed" position.

Internal working pressure may then be introduced into the "closed" fluid connection assembly. For example, such internal working pressure may be from ambient well pressure in pressure and flow communication with the fluid connection assembly. Responsive to such internal pressure, the rib on the fluid connection adapter displaces from abutment with the housing notches on the fluid connection housing assembly, urging the tapered lock engagement surface on the fluid connection adapter even tighter onto the locking element inner surfaces, and urging the locking element outer surfaces even tighter onto the locking ring inner surface. At this point, the fluid connection assembly is in the "closed and locked" position. The presence of internal pressure further urges the first seal section on the fluid connection adapter to expand radially to make tighter contact with the first seal bore (within the fluid connection housing assembly), thereby enhancing the seal formed therebetween.

Alternative disclosed embodiments strengthen the first seal section on the fluid connection adapter with a high strength sleeve. Additional disclosed embodiments provide a quick test fitting and port to control fluid pressure in between at least the first seal section and the first seal bore.

It is therefore a technical advantage of the disclosed fluid connection assembly to hold higher internal pressures in larger diameters than currently available from existing

pressure seals. The disclosed fluid connection designs gain advantage from the internal work pressure to provide improved seal performance.

5 A further technical advantage of the disclosed fluid connection assembly is that, in currently preferred embodiments, the fluid connection adapter forms its pressure seal with the fluid connection housing assembly “deeper” or “further into” the fluid connection housing assembly than with other known connections. More specifically, the sealing contact between first seal section (on the fluid connection adapter) and first seal bore (on the fluid connection housing assembly) is located further away from the entry point into the fluid connection housing assembly than has typically been seen in other known connections. This  
10 “deeper connection” feature enhances the robustness of the seal, and gives the disclosed fluid connection assembly a greater capacity to retain high pressures in high flow / high volume service applications such as hydraulic fracturing. It is known in fracturing operations that the part corresponding to the fluid connection adapter may be exposed to high loads (bending, torsion, compression) as fracturing fluid piping is connected thereto. These loads may be even higher in deployments where coil tubing apparatus, for example,  
15 is also planned to be connected to the part corresponding to the fluid connection adapter. Provision of sealing contact “deeper” into the fluid connection housing assembly, as in embodiments of the disclosed fluid connection assembly, mitigates the effect of such high loads to stress or weaken the seal contact.

20 A further technical advantage of the disclosed fluid connection assembly is that its design favors robustness and dependability. Embodiments of the disclosed fluid connection assembly minimize moving parts and hydraulics in order to enhance robustness at high pressures in larger diameters.

25 A further technical advantage of the disclosed fluid assembly is that may be remotely operable. According to illustrated embodiments, the locking ring is brought onto the locking elements via retraction of an actuation assembly including a hydraulically-actuated piston. In some deployments, the piston may be actuated remotely. Remote actuation addresses the personnel safety concerns described in the Background section above.

30 A further technical advantage of the disclosed fluid connection assembly is that, in embodiments in which a high strength sleeve is provided, the high strength sleeve strengthens and may provide wear protection to seal sections on the fluid connection adapter.

A further technical advantage of the disclosed fluid connection assembly is that, in embodiments in which a quick test fitting is provided, a hand pump can conveniently deliver

high pressure fluid to a portion of the pressure connection, especially when such portion is sealed between two sets of sealing rings. Such sealing rings may be o-rings in some embodiments, for example, although throughout this disclosure, the term “sealing ring”, wherever used, is not limited to any type of suitable seal that may be deployed as a sealing ring.

5 It will be appreciated that the sealing rings may limit or impede high pressure fluid flow into or out of the portion of the pressure connection between the two sets of sealing rings. Embodiments of this disclosure provide a quick test port into the flow-limited portion of the pressure connection between seal sections and seal bores. A hand pump may then be used to deliver fluid to a quick test fitting allowing flow through the quick test port to the flow-  
10 limited portion. This allows the pressure integrity of the seals provided by the sealing rings to be tested prior to applying high fluid pressures from an operational pressure source (such as a well). In other applications, the quick test port may be used to equalize pressure in the flow-limited portion of the pressure connection during service engagement and disengagement of the fluid connection assembly.

15 In accordance with a first aspect, therefore, this disclosure describes a fluid connection assembly, comprising: a fluid connection adapter having first and second adapter ends, the fluid connection adapter providing in order towards the second adapter end: (a) a tapered lock engagement surface, (b) a locking element actuating section, and (c) at least a first seal section; a fluid connection housing assembly having first and second housing ends,  
20 the fluid connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of locking elements, and (iii) at least a first seal bore; wherein each locking element is disposed to constrict radially via rotation about a corresponding pivot pin provided in the fluid connection housing assembly; wherein each locking element has a locking element inner surface, a locking element outer surface and a locking element rocking surface;  
25 wherein, during entry of the second adapter end into the first housing end: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore; such that when the locking ring is retracted, progressive engagement of a locking ring inner  
30 surface on the locking element outer surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface.

According to a second aspect, this disclosure describes a fluid connection assembly, comprising: a fluid connection adapter having first and second adapter ends, the fluid connection adapter providing in order towards the second adapter end: (a) a tapered lock

engagement surface, (b) a locking element actuating section, and (c) at least a first seal section; the fluid connection adapter further providing a rib; a fluid connection housing assembly having first and second housing ends, the fluid connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of locking elements, (iii) at least a  
5 first seal bore, and (iv) a housing notch; wherein each locking element is disposed to constrict radially via rotation about a corresponding pivot pin provided in the fluid connection housing assembly; wherein each locking element has a locking element inner surface, a locking element outer surface and a locking element rocking surface; wherein, during entry of the second adapter end into the first housing end until the rib abuts the  
10 housing notch: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore; such that when the locking ring is retracted, progressive engagement of a locking ring inner surface on the locking element outer  
15 surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface.

In some embodiments according to the first or second aspects, the locking element inner surfaces are disposed to further tighten against the tapered lock engagement surface responsive to displacement of the second adapter end towards the first housing end during  
20 engagement of the locking ring inner surface on the locking element outer surfaces.

In some embodiments according to the first or second aspects, the first seal section is disposed to expand radially and further tighten sealing contact against the first seal bore responsive to introduction of internal pressure within the second adapter end.

In some embodiments according to the first or second aspects, spring bias ordains a  
25 default rotational position for the locking elements about their corresponding pivot pins.

In some embodiments according to the first or second aspects, the fluid connection housing assembly further provides a quick test port, the quick test port comprising a fluid passageway from a fluid connection housing assembly exterior through to the first seal bore.

In some embodiments according to the first or second aspects, the second adapter  
30 end further includes a high strength sleeve.

In some embodiments according to the first or second aspects, at least one actuator assembly energizes retraction of the locking ring. In some such embodiments, the at least one actuator assembly is remotely operable.

The foregoing has outlined rather broadly some of the features and technical advantages of the technology embodied in the disclosed fluid connection designs, in order that the detailed description that follows may be better understood. Additional features and advantages of the disclosed technology may be described. It should be appreciated by those skilled in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same inventive purposes of the disclosed technology, and that these equivalent constructions do not depart from the spirit and scope of the technology as described and as set forth in the appended claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of embodiments described in detail below, and the advantages thereof, reference is now made to the following drawings, in which:

FIGURES 1A and 1B depict a prior art fluid connection;

FIGURES 2, 3 and 4 depict exemplary fluid connection adapter embodiments 200, 200A and 200B respectively;

FIGURE 5 is an exploded view of fluid connection assembly 100, in which fluid connection assembly 100 is a first embodiment thereof in accordance with this disclosure;

FIGURE 6 is a section through fluid connection assembly 100 in an “open” position;

FIGURES 7A through 7D are sequential “freeze frame” views illustrating engagement of fluid connection assembly 100 to form a fluid connection and seal;

FIGURES 8A, 8B and 8C are additional, enlarged “freeze frame” views further illustrating engagement of fluid connection assembly 100 to form a fluid connection and seal;

FIGURE 9 is a partial section through fluid connection assembly 100 in a “closed and locked” position;

FIGURE 10 is a general perspective view of fluid connection housing 300 in isolation, with actuator assemblies 380 and locking ring 318 removed to reveal locking elements 317;

FIGURE 11 is a general elevation view of fluid connection assembly 100;

FIGURE 12 is a general plan (or “top”) view of fluid connection assembly 100;

FIGURE 13 is a general perspective view of fluid connection assembly 100;

FIGURE 14 illustrates one embodiment of an actuator assembly 380 in isolation;

FIGURE 15 is a section as shown on FIGURE 14;

FIGURE 16 is a section through high strength fluid connection assembly 150, in which high strength fluid connection assembly 150 is a second embodiment thereof in accordance with this disclosure; and

FIGURE 17 is an enlargement as shown on FIGURE 16.

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#### DETAILED DESCRIPTION

Reference is now made to FIGURES 1A through 17 in describing embodiments of the disclosed fluid connections. For the purposes of the following disclosure, FIGURES 1A and 1B depict prior art devices. FIGURES 2 through 17 depict embodiments of new fluid connection designs, and should be viewed together. Any part, item, or feature that is identified by part number on one of FIGURES 1A through 17 will have the same part number when illustrated on another of FIGURES 1A through 17. It will be understood that the embodiments as illustrated and described with respect to FIGURES 2 through 17 are exemplary, and the scope of this disclosure is not limited to such illustrated and described  
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FIGURES 1A and 1B illustrate examples of existing fluid connections, and are based upon Figure 2 in U.S. Patents 9,644,443 and 9,670,745. FIGURES 1A and 1B should be viewed together. In FIGURES 1A and 1B, pressure control equipment ("PCE") is labeled generally as P, and wellhead is labeled generally as W. Pressure control assembly 10 is secured to wellhead W via a conventional bolted flange, although not limited in such regard. The wellhead end of pressure control assembly 10 advantageously provides a customized fitting F to connect to wellhead W. Adapter 12 is secured to PCE P via conventional threading, although not limited to a threaded connection between PCE P and adapter 12. In operation, adapter 12 enters pressure control assembly 10 via tulip 14. Adapter 12 and pressure control assembly 10 thereupon combine to form a fluid connection and seal according to the disclosure of U.S. Patents 9,644,443 and 9,670,745.  
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FIGURES 2, 5 and 6 should now be viewed together. FIGURES 2, 5 and 6 illustrate one embodiment of the remotely-operated fluid connection and seal technology described in this disclosure. Referring first to FIGURE 6, fluid connection assembly 100 comprises fluid connection adapter 200 and fluid connection housing assembly 300. Fluid connection adapter 200 has first and second adapter ends, in which the first adapter end is blank (or closed off) and the second adapter end is configured to be inserted into fluid connection housing assembly 300. Fluid connection housing assembly 300 has first and second housing ends, in which the first housing end is configured to receive the second adapter end. Fluid  
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connection housing assembly 300 may provide a wellhead adapter 312 with a flanged connection 313 at the second housing end to enable ultimate connection to a pressurized source of fluids (such as, for example, a wellhead). Stated generally with reference to FIGURE 6, fluid connection housing assembly 300 provides: (i) a retractable locking ring 5 318; (ii) a plurality of locking elements 317, and (iii) at least a first seal bore 341.

As noted, the embodiments illustrated on FIGURES 2, 5 and 6 include fluid connection adapter 200 having a blank (or closed off) first adapter end. As such, fluid connection adapter 200 is suitable for use as a nightcap, or when operators wish to close off a wellhead temporarily. Fluid connection adapter is not limited in its deployments.

10 FIGURES 3 and 4 illustrate alternative embodiments to fluid connection adapter 200 on FIGURES 2, 5 and 6. For example, flanged fluid connection adapter 200A on FIGURE 3 provides a flange at its first adapter end thereof for further connection to other equipment (such as pressure control equipment in wellhead pressure control applications. By way of further example, goat head fluid connection adapter 200B on FIGURE 4 provides a “goat 15 head”-style manifold at its first adapter end thereof for connection to multiple fracturing fluid lines during hydraulic fracturing service. The scope of this disclosure is not limited to the examples of FIGURES 2, 3 and 4.

It will nonetheless be noted from FIGURES 2, 3 and 4 that each of the illustrated alternative adapter embodiments 200, 200A, 200B each share a common configuration at 20 their second adapter ends, to be described in more detail immediately below with reference to FIGURE 2. In this way, and with reference now to FIGURE 6, such common configuration allows alternative adapter embodiments 200, 200A, 200B to be interchangeable when inserted into fluid connection housing assembly 300.

With reference now to FIGURE 2, fluid connection adapter 200 generally provides 25 in order towards the second adapter end: (a) a tapered lock engagement surface 209, (b) a locking element actuating section 206, and (c) at least a first seal section 207. In more detail, fluid connection adapter 200 provides an enlarged outer diameter (OD) section 205. Enlarged OD section 205 includes tapered lock engagement surface 209 and rib 210. As will be described, enlarged OD section 205 acts as a positive stop to enable fluid connection 30 adapter 200 to enter fluid connection housing assembly 300 to only a predetermined longitudinal position.

Fluid connection adapter 200 also provides locking element actuating section 206. Fluid connection adapter 200 further provides first and second seal sections 207, 208. Locking element actuating section 206 and first and second seal sections 207, 208 are

described in more detail below with reference to interaction with cooperating parts within fluid connection housing assembly 300. However, it will be seen on FIGURE 2 that first and second seal sections 207, 208 also preferably each provide one or more grooves in which sealing rings may be located, in order to further facilitate seals between cooperating machined surfaces. Sealing rings (such as o-rings, for example) have been omitted for clarity in this disclosure.

FIGURES 5 and 6 should now be viewed together. FIGURE 5 is an exploded view and FIGURE 6 is a section view of the illustrated embodiments of fluid connection assembly 100. FIGURE 6 shows fluid connection assembly 100 in an “open” position. Fluid connection adapter 200 is described in detail above with reference to FIGURE 2.

Fluid connection housing assembly 300 includes wellhead adapter 312 at a second housing end thereof, per earlier disclosure. Fluid connection housing 314 is connected to wellhead adapter 312 by a flange/bolted connection. In other embodiments (not illustrated), fluid connection housing 314 and wellhead adapter 312 may be integrally formed, or connected by a threaded connection, and the scope of the disclosure is not limited in this regard.

Wellhead adapter 312 provides first and second seal bores 341, 342 formed therein. First and second seal bores 341, 342 are shaped to receive and form seals with first and second seal sections 207, 208 respectively on fluid connection adapter 200. Note first and second seal bores 341, 342 and first and second seal sections 207, 208 may preferably further include sealing rings to enhance sealing. Such sealing rings (such as o-rings, for example) are omitted for clarity on FIGURES 5 and 6.

Fluid connection housing 314 provides housing notches 327. When fluid connection adapter 200 is received into fluid connection housing assembly 300, rib 210 on fluid connection adapter 200 eventually abuts housing notches 327, thereby limiting the travel of fluid connection adapter 200 into fluid connection housing assembly 300.

A plurality of locking elements 317 rotate within fluid connection housing 314. In the embodiments illustrated on FIGURES 5 and 6, four (4) locking elements 317 are provided. The scope of this disclosure is not limited to any specific number of locking elements 317 that may be provided in other embodiments. Stated generally, each locking element 317 is disposed to constrict radially via rotation about a corresponding pivot pin 316 provided in the fluid connection housing assembly 300. In more detail, locking elements 317 rotate about pivot pins 316 received into pin bores 332 on locking elements 317 and housing bores 334 on fluid connection housing 314. Pivot pins 316 preferably

provide pin grooves 331 for sealing cooperation with pin rotation gaskets 333 deployed within pin bores 332 in locking elements 317. In the embodiments illustrated on FIGURES 5 and 6, rotation stops 322 on locking elements 317 limit rotation of locking elements 317 about pivot pins 316 to a user-selected angular displacement. In other embodiments (not illustrated), rotation stops 322 may not be provided. Locking elements 317 also have straps 319 rigidly affixed (e.g. via bolting) to the exterior thereof in illustrated embodiments. Referring now to FIGURE 9, tension springs 321 connect locking elements 317 to fluid connection housing 314 via straps 319. Generally stated, spring bias ordains a default rotational position for locking elements 317 about their corresponding pivot pins 316. In more detail, tension springs 321 create spring bias to ordain and hold a default rotational position for locking elements 317 against rotation stops 322 in an “open” position. This disclosure is not limited to the manner in which such spring bias is created. Other non-illustrated embodiments may, for example, use torsion springs to create the spring bias. Alternatively, other non-illustrated embodiments may, for example, use hydraulic or pneumatic arrangements to create bias to hold locking elements 317 in a default position. Other non-illustrated embodiments may provide no bias holding locking elements 317 in a default position.

FIGURES 5 and 6 illustrate locking elements 317 having locking element inner and outer surfaces 323, 324. Locking elements 317 also have locking element rocking surfaces 325. Locking element rocking surfaces 325, and locking element inner and outer surfaces 323, 324 are all described in more detail below with reference to interaction with cooperating parts within fluid connection housing assembly 300.

Generally stated, at least one actuator assembly 380 energizes retraction of locking ring 318. In some embodiments, actuator assemblies 380 may be remotely operable. In more detail, at least one actuator assembly 380 is rigidly affixed (e.g. via bolting) to fluid connection housing 314. In the embodiments illustrated on FIGURES 5 and 6, three (3) circumferentially spaced-apart actuator assemblies 380 are provided. The scope of this disclosure is not limited to any specific number of actuator assemblies 380 that may be provided in other embodiments. Actuator assemblies 380 are also rigidly affixed (e.g. via bolting) to locking ring 318. In illustrated embodiments, actuator assemblies 380 are hydraulically-actuated piston assemblies in which pistons 382 extend and retract locking ring 318 away from and towards locking elements 317. The scope of this disclosure is not limited, however, to any particular design of actuator assemblies 380. Actuator assemblies

380 further preferably provide guide rods 381 running parallel to the travel of pistons 382 to keep such piston travel rigid and straight under operational loads.

Locking ring 318 has locking ring inner surface 326. Locking ring inner surface 326 is described in more detail below with reference to interaction with cooperating parts within  
5 fluid connection housing assembly 300. Locking ring 318 is rigidly affixed (e.g. via bolting) to guide funnel 311. Guide funnel 311 assists directing fluid connection adapter 200 into fluid connection housing assembly 300.

FIGURE 6 shows wellhead adapter 312 providing quick test fitting 401 received into quick test port 402, preferably by threaded engagement. It will be appreciated that  
10 although FIGURE 6 illustrates an embodiment in which one quick test fitting and port 401, 402 are provided, the scope of this disclosure is not limited in this regard, and any number quick test ports 402 may be provided (or none at all). However, in most deployments only one will be in operation at any time. Quick test ports 402 that are not in operation may be sealed with threaded plugs for future use. One purpose of providing redundant quick test  
15 ports 402 is in case one or more become damaged during service, and have to be permanently sealed. In presently preferred embodiments, quick test ports 402 are preferably 3/16" in diameter, although the scope of this disclosure is not limited in this regard.

Generally stated, fluid connection housing assembly 300 further provides quick test port 402. Quick test port 402 comprises a fluid passageway from the exterior of fluid  
20 connection housing assembly 300 through to first seal bore 341, for example. In more detail, quick test fitting 401 and quick test port 402 provide a fluid passageway through wellhead adapter 312 into the space between first and second seal sections 207, 208 and first and second seal bores 341 and 342 when fluid connection adapter 200 is fully received into fluid connection housing assembly 300. Fluid may be introduced through quick test fitting 401  
25 into the space between first and second seal sections 207, 208 and first and second seal bores 341 and 342 (via, for example, hand pumping). Pressure in the space between first and second seal sections 207, 208 and first and second seal bores 341 and 342 may thus be equalized (and in particular, pressure between sealing rings in such space may be equalized) after the introduction of operational high pressure fluid (e.g. from a well) into wellhead  
30 adapter 312.

Conversely, it will be appreciated that upon removal of operational pressure within wellhead adapter 312, the seals created between first and second seal sections 207, 208 and first and second seal bores 341 and 342 (and in particular, between sealing rings in such seals) may not immediately release by themselves. Quick test fitting 401 enables fluid

trapped at pressure in the space between first and second seal sections 207, 208 and first and second seal bores 341 and 342 to be relieved. In other applications, fluid delivered through quick test fitting 401 enables the integrity of the seals created between first and second seal sections 207, 208 and first and second seal bores 341 and 342 (and in particular, between  
5 sealing rings in such seals) to be checked prior to introducing high pressure fluid into a connection between fluid connection adapter 200 and fluid connection housing assembly 300.

FIGURES 5 and 6 also illustrate transducer ports 602. It will be appreciated that although FIGURE 6 illustrates an embodiment in which two transducer ports 602 are  
10 provided, the scope of this disclosure is not limited in this regard, and any number of transducer ports 602 may be provided (or none at all). It will be understood that various suitable equipment may be deployed into transducer ports 602, including (without limitation) pressure sensors / transducers to monitor internal pressure IP such as shown and described below with reference to FIGURE 7D, for example. In illustrated embodiments  
15 (such as in FIGURE 6, for example), needle valve 601 is deployed in one of transducer ports 602. In such embodiments, needle valve 601 may be used to drain / equalize pressure within wellhead adapter 312 during service operations when, for example, fluid connection adapter 200 is being removed and fluid connection housing assembly 300 is being exposed to atmospheric pressure. The scope of this disclosure is not limited to particular uses for  
20 transducer ports 602 or equipment deployed therein.

FIGURES 6, 7A through 7D, 8A through 8C, and 9 should now be viewed together for an understanding of the operation of embodiments of the disclosed remotely-operated fluid connection and seal technology. FIGURES 7A through 7D are sequential “freeze frame” views illustrating engagement of fluid connection assembly 100 to form a fluid  
25 connection and seal. FIGURES 8A, 8B and 8C are additional, enlarged “freeze frame” views further illustrating engagement of fluid connection assembly 100 to form a fluid connection and seal. FIGURE 9 is a partial section through fluid connection assembly 100 in a “closed and locked” position. FIGURE 7A is a simplified rendering of FIGURE 6 depicting fluid connection assembly in an “open” position. FIGURE 7D is a simplified  
30 rendering of FIGURE 9 depicting fluid connection assembly 100 in a “closed and locked” position.

Referring first to FIGURE 7A, the second adapter end of fluid connection adapter 200 enters the first housing end of the fluid connection housing assembly 300 through guide funnel 311 and past locking ring 318. Stated generally with reference to FIGURES 6, 7A

and 7B, during entry of the second adapter end into the first housing end: (A) locking element actuating section 206 contacts locking element rocking surfaces 325, thereby causing locking elements 317 to rotate such that locking element inner surfaces 323 contact the tapered lock engagement surface 209; and (B) first seal section 207 sealingly contacts first seal bore 208. Transitioning from FIGURE 7A to FIGURE 7B in more detail, locking element actuating section 206 on fluid connection adapter makes contact with locking element rocking surfaces 325, causing locking elements 317 to “close” via rotation as shown on FIGURE 7B, whereupon locking element inner surfaces 323 begin to engage enlarged OD section 205 on fluid connection adapter 200. Figure 8A illustrates such “closing” of locking elements 317 in enlarged format. The rotation of locking elements 317 as shown on FIGURE 7B also restrains fluid connection adapter 200 from unintended reverse longitudinal movement (i.e. from accidentally “exiting” fluid connection housing assembly 300).

Stated generally with reference to FIGURES 6, 7B and 7C, when locking ring 318 is retracted, progressive engagement of locking ring inner surface 326 on locking element outer surfaces 324 urges locking element inner surfaces 323 to tighten against tapered lock engagement surface 209. Transitioning now from FIGURE 7B to FIGURE 7C in more detail, fluid connection adapter 200 ends its travel into fluid connection housing assembly 300 as rib 210 abuts housing notches 327. Locking element inner surfaces 323 make full contact with tapered lock engagement surface 209 on fluid connection adapter 200. Actuator assemblies 380 retract to bring locking ring 318 onto locking elements 317. Retraction of actuator assemblies 380 causes locking ring inner surface 326 to make contact with locking element outer surfaces 324. Locking element outer surfaces 324 have a taper. Progressive engagement of locking ring inner surface 326 on locking element outer surfaces 324 causes locking elements 317 to constrict radially. As locking ring inner surface 326 tightens its contact with locking element outer surfaces 324, locking ring 318 urges locking element inner surfaces 323 tighter onto tapered lock engagement surface 209. Preferably, tapered lock engagement surface 209 has a taper selected to cooperate with locking element inner surfaces 323 such that a full tightening action and force translation is enabled as locking elements 317 constrict radially, while still allowing relatively easy disengagement in reverse when releasing fluid connection adapter 200 from fluid connection housing assembly 300. This disclosure is not limited to any specific cooperating tapers selected, and may include curved tapers as well as straight tapers. FIGURE 8B illustrates in enlarged

format the above-described movement of locking ring 318 onto locking elements 317 to place locking elements 317 into a “closed” position.

Additionally, as illustrated on FIGURE 7C, when fluid connection adapter 200 ends its travel into fluid connection housing assembly 300: (1) first seal section 207 on fluid connection adapter 200 sealingly engages first seal bore 341 inside wellhead adapter 312, and (2) second seal section 208 on fluid connection adapter 200 sealingly engages second seal bore 342 also inside wellhead adapter 312.

Stated generally with reference to FIGURES 6, 7C and 7D, the locking element inner surfaces 323 are disposed to further tighten against the tapered lock engagement surface 209 responsive to displacement of the second adapter end towards the first housing end during engagement of the locking ring inner surface 326 on the locking element outer surfaces 324. Transitioning now from FIGURE 7C to FIGURE 7D in more detail, operational internal pressure IP is introduced inside fluid connection housing assembly 300. Well pressure may be the source of internal pressure IP, for example. Internal pressure IP displaces fluid connection adapter 200 into tighter restraint by locking elements 317. Specifically, responsive to internal pressure IP, rib 210 displaces from abutment with housing notches 327, urging tapered lock engagement surface 209 even tighter onto locking element inner surfaces 323, and urging locking element outer surfaces 324 even tighter onto locking ring inner surface 326.

FIGURE 7D also depicts first seal section 207 still sealingly engaged with first seal bore 341, and second seal section 208 still sealingly engaged with second seal bore 342. It will be understood that when internal pressure IP displaces fluid connection adapter 200, first and second seal sections 207, 208 also slidingly displace within first and second seal bores 341, 342 but nonetheless maintain sealing contact and engagement. Further, with additional reference to FIGURE 9, it will be understood that, generally stated, first seal section 207 is disposed to expand radially and further tighten sealing contact against first seal bore 341 responsive to introduction of internal pressure IP within the second adapter end. In more detail, the presence of internal pressure IP urges first and second seal sections 207, 208 to expand radially to make tighter contact with first and second seal bores 341, 342, thereby enhancing the seals formed therebetween. FIGURE 8C illustrates in enlarged format the displacement of fluid connection adapter 200 into tighter restraint by locking elements 317 wherein locking elements 317 are now in a “closed and locked” position.

Disengagement of fluid connection adapter 200 from fluid connection housing assembly 300 is essentially the reverse operation of the one described immediately above

with reference to FIGURES 7A through 7D. Internal pressure IP is removed. Actuator assemblies 380 extend, causing locking ring 318 to release locking elements 317 from radial constriction. Fluid connection adapter 200 may be removed. As enlarged OD section 205 on fluid connection adapter 200 withdraws, tapered lock engagement surface 209 and rib  
5 210 cause locking elements 317 to rotate about pivot pins 316 back into an “open” position.

FIGURE 9 is similar to FIGURES 7D and 8C, in that FIGURE 9 also illustrates locking elements 317 in a “closed and locked” position. In FIGURE 9, however, the illustrated embodiment depicts additional features, some of which may be considered optional in other embodiments. As described above with reference to FIGURES 5 and 6,  
10 FIGURE 9 shows rotation stops 322 on locking elements 317 to limit rotation of locking elements 317 about pivot pins 316 to a user-selected angular displacement. As also described above with reference to FIGURES 5 and 6, FIGURE 9 shows straps 319 and tension springs 321. Tension springs 321 create spring bias to ordain and hold a default rotational position for locking elements 317 against rotation stops 322 in an “open” position.

FIGURE 9 further illustrates locking ring ridge 328 on locking ring 318 matched with locking element groove 329 on locking elements 317. Locking ring ridge 318 is preferably a geometrically inverted ridge shaped to fit within locking element groove 329. Locking ring ridge 328 cooperates with locking element groove 329 to provide an additional locking feature, strengthening the contact between locking ring inner surface 326 and  
20 locking element outer surfaces 324 against sliding displacement. Further, the additional locking feature provided by locking ring ridge 328 and locking element groove 329 may prevent inadvertent movement of locking ring 318 during operational service. Such inadvertent movement might arise by erroneous actuation of an actuator assembly 380 during operational service while the disclosed fluid connection is in the “closed and locked”  
25 position. The additional locking feature, although optional, may thereby enhance operational safety of the disclosed fluid connection when operational pressure is introduced.

FIGURE 10 is a general perspective view of fluid connection housing 300, with actuator assemblies 380 and locking ring 318 removed to reveal locking elements 317. FIGURE 10 also illustrates other features described above with reference to other Figures  
30 in this disclosure.

FIGURES 11 through 13 show various views of fluid connection assembly 100. FIGURE 11 is a general elevation view of fluid connection assembly 100. FIGURE 12 is a general plan (or “top”) view of fluid connection assembly 100. FIGURE 13 is a general perspective view of fluid connection assembly 100. FIGURES 11 through 13 illustrate

features and aspects of fluid connection assembly 100 also described above with reference to other Figures in this disclosure. FIGURES 11 through 13 are intended to aid further understanding of such features and aspects by providing additional views.

FIGURE 14 illustrates one embodiment of an actuator assembly 380 in a fully retracted position, and FIGURE 15 is a section as shown on FIGURE 14. As noted in the description above with reference to FIGURES 5 and 6, actuator assemblies 380 may be hydraulically-actuated piston assemblies in which pistons 382 extend and retract. Pistons 382 are hidden on FIGURE 14 and 15 in order to better view guide rods 381. As shown on FIGURES 14 and 15, guide rods 381 preferably run parallel to the travel of pistons 382 to keep such piston travel rigid and straight under operational loads. In illustrated embodiments, two (2) guide rods 381 are provided for each actuator assembly 380, although the scope of this disclosure is not limited in this regard.

FIGURE 16 is a section view through high strength fluid connection assembly 150. FIGURE 17 is an enlargement as shown on FIGURE 16. High strength fluid connection assembly 150 presents additional embodiments. In contrast to previously-described embodiments, FIGURES 16 and 17 depict high strength fluid connection assembly 150 providing high strength sleeve 501.

It will be noted that the illustrated embodiments of FIGURE 16 also include depiction of flanged fluid connection adapter 200A from FIGURE 3. It will nonetheless be understood that the following description of high strength sleeve 501 is independent of the style of fluid connection adapter deployed. High strength sleeve 501 may be provided on any style of fluid connection adapter (including as depicted on FIGURES 2, 3 and 4) and the scope of this disclosure is not limited in this regard.

Generally stated, and as shown on FIGURES 16 and 17, the second adapter end further includes high strength sleeve 501, wherein high strength sleeve 501 provides wall thickness strengthening to a selected portion of the second adapter end. In more detail, high strength sleeve 501 strengthens the material on flanged fluid connection adapter 200A in the region of second seal section 208, and further provides a high strength sleeve extended portion 503 on the second adapter end that sealingly engages with high strength sleeve bore 343 provided in wellhead adapter 312. Advantageously, high strength sleeve 501 is made from a high strength metal such as titanium, although the scope of this disclosure is not limited to any particular material selection for high strength sleeve 501. FIGURE 17 shows that the presence of high strength sleeve 501 is operative to reduce the effective internal diameter at which a seal is formed to coincide with high strength sleeve bore 343, either via

direct contact between high strength sleeve 501 and high strength sleeve bore 343, or via contact between high strength sleeve 501 and second seal section 208.

It will be understood that in some embodiments, flanged fluid connection adapter 200A has a wall thickness that is thinnest at the second adapter end, in the region of second seal section 208. This thinning of wall thickness is inevitable given a geometry that requires (1) keeping external diameter towards the second adapter end small (to pass through locking elements 317 in the “open” position), and (2) keeping internal diameter large throughout so as not to affect internal flow or pressure. Especially at higher working pressures, it will be appreciated that when internal pressure IP on FIGURE 16 urges second seal section 208 to expand radially onto second seal bore 342, the thinner wall thickness of flanged fluid connection adapter 200A in the regions of second seal section 208 may be susceptible to deformation or cracking, possibly leading to failure.

In other embodiments, such as illustrated on FIGURES 16 and 17, high strength sleeve 501 may be operative to act as a substitute “effective internal wall” of the second adapter end at the location where a pressure seal is formed. In this way, the internal diameter at which the seal is formed may be reduced (the seal now being formed on the exterior of the sleeve). The overall circumferential wall cross-sectional area at such reduced internal diameter is now also reduced (by virtue of a reduced diameter), thereby reducing the force exerted by internal pressure IP on the internal wall. Since the wall material itself in the sleeve is preferably high strength material, such as titanium, the wall thickness of high strength sleeve 501 may be thin to retain the force exerted by internal pressure IP.

Thus, as shown on FIGURES 16 and 17, high strength sleeve 501 is provided as an insert on the second adapter end of flanged fluid connection adapter 200A. In the illustrated embodiments, high strength sleeve 501 strengthens second seal section 208 by providing high strength sleeve insert portion 502 received into second seal section 208. In illustrated embodiments (to which the scope of this disclosure is not limited), high strength sleeve 501 further provides high strength sleeve extended portion 503 protruding from the second adapter end. As shown on FIGURE 17, high strength sleeve extended portion 503 sealingly engages directly with high strength sleeve bore 343 provided within wellhead adapter 312.

It will be appreciated that the foregoing description of illustrated embodiments of high strength sleeve 501 are exemplary only. The scope of this disclosure contemplates embodiments in which a high strength insert or sleeve may be deployed as required to provide wall thickness strengthening to a selected portion of the second adapter end.

Further, in addition to providing strengthening, some embodiments of high strength sleeve 501 may also provide wear protection to the inside of second adapter end via wear coatings such as, for example, tungsten carbide coatings.

5 Earlier description made clear that the scope of this disclosure in no way limits the described fluid connection design embodiments and associated seal embodiments to specific sizes or models. Currently envisaged embodiments make the disclosed technology available in several sizes, shapes, and pressure ratings to adapt to desired applications. Proprietary connections may require specialized adapters. It will be nonetheless understood that the scope of this disclosure is not limited to any particular sizes, shapes, and pressure ratings  
10 for various embodiments thereof, and that the embodiments described in this disclosure and in U.S. provisional patent application serial no. 62/649,008 (incorporated herein by reference) are exemplary only.

Currently envisaged embodiments of the fluid connection designs (and associated seals) provide pressure ratings up to and including at least 15,000 psi MAWP. Currently  
15 envisaged sizes include internal diameters up to and including at least 8" ID. The foregoing sizes and performance metrics are exemplary only, and the scope of this disclosure is not limited in such regards.

Although fluid connection embodiments and associated seal embodiments have been described in this disclosure with reference to an exemplary application in hydraulic  
20 fracturing, pressure control at a wellhead, alternative applications could include, for example, areas such as subsea connections, deep core drilling, offshore drilling, methane drilling, open hole applications, well pressure control, wireline operations, coil tubing operations, mining operations, and various operations where connections are needed under a suspended or inaccessible load (i.e., underwater, hazardous area). The scope of this  
25 disclosure is not limited to any particular application in which the described fluid connections may be deployed.

Exemplary materials used in the construction of the disclosed embodiments include high strength alloy steels, high strength polymers, and various grades of elastomers.

Although the material in this disclosure has been described in detail along with some  
30 of its technical advantages, it will be understood that various changes, substitutions and alternations may be made to the detailed embodiments without departing from the broader spirit and scope of such material as set forth in the following claims.

CLAIMS

We claim:

1. A fluid connection assembly, comprising:

5 a fluid connection adapter having first and second adapter ends, the fluid connection adapter providing in order towards the second adapter end: (a) a tapered lock engagement surface, (b) a locking element actuating section, and (c) at least a first seal section;

a fluid connection housing assembly having first and second housing ends, the fluid connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of locking elements, and (iii) at least a first seal bore;

10 wherein each locking element is disposed to constrict radially via rotation about a corresponding pivot pin provided in the fluid connection housing assembly;

wherein each locking element has a locking element inner surface, a locking element outer surface and a locking element rocking surface;

15 wherein, during entry of the second adapter end into the first housing end: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore;

20 such that when the locking ring is retracted, progressive engagement of a locking ring inner surface on the locking element outer surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface.

2. The fluid connection assembly of claim 1, in which the locking element inner surfaces are disposed to further tighten against the tapered lock engagement surface responsive to displacement of the second adapter end towards the first housing end during engagement of the locking ring inner surface on the locking element outer surfaces.

3. The fluid connection assembly of claim 1, in which the first seal section is disposed to expand radially and further tighten sealing contact against the first seal bore responsive to introduction of internal pressure within the second adapter end.

4. The fluid connection assembly of claim 1, in which a spring bias ordains a default rotational position for the locking elements about their corresponding pivot pins.

5. The fluid connection assembly of claim 1, in which the fluid connection housing assembly further provides a quick test port, the quick test port comprising a fluid passageway from a fluid connection housing assembly exterior through to the first seal bore.

5 6. The fluid connection assembly of claim 1, in which the second adapter end further includes a strengthening sleeve.

7. The fluid connection assembly of claim 1, in which at least one actuator assembly energizes retraction of the locking ring.

10

8. The fluid connection assembly of claim 7, in which the at least one actuator assembly is remotely operable.

9. A fluid connection assembly, comprising:

15

a fluid connection adapter having first and second adapter ends, the fluid connection adapter providing in order towards the second adapter end: (a) a tapered lock engagement surface, (b) a locking element actuating section, and (c) at least a first seal section;

20

a fluid connection housing assembly having first and second housing ends, the fluid connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of locking elements, and (iii) at least a first seal bore;

wherein each locking element is disposed to constrict radially via rotation about a corresponding pivot pin provided in the fluid connection housing assembly;

wherein each locking element has a locking element inner surface, a locking element outer surface and a locking element rocking surface;

25

wherein, during entry of the second adapter end into the first housing end: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore;

30

such that when the locking ring is retracted, progressive engagement of a locking ring inner surface on the locking element outer surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface; and

wherein the locking element inner surfaces are disposed to further tighten against the tapered lock engagement surface responsive to displacement of the second adapter end

towards the first housing end during engagement of the locking ring inner surface on the locking element outer surfaces.

10           10.     The fluid connection assembly of claim 9, in which the first seal section is  
5 disposed to expand radially and further tighten sealing contact against the first seal bore responsive to introduction of internal pressure within the second adapter end.

10           11.     The fluid connection assembly of claim 9, in which a spring bias ordains a  
default rotational position for the locking elements about their corresponding pivot pins.

12.     The fluid connection assembly of claim 9, in which the fluid connection  
housing assembly further provides a quick test port, the quick test port comprising a fluid  
passageway from a fluid connection housing assembly exterior through to the first seal bore.

15           13.     The fluid connection assembly of claim 9, in which the second adapter end  
further includes a strengthening sleeve.

14.     The fluid connection assembly of claim 9, in which at least one actuator  
assembly energizes retraction of the locking ring.

20           15.     The fluid connection assembly of claim 14, in which the at least one actuator  
assembly is remotely operable.

25           16.     A fluid connection assembly, comprising:  
a fluid connection adapter having first and second adapter ends, the fluid connection  
adapter providing in order towards the second adapter end: (a) a tapered lock engagement  
surface, (b) a locking element actuating section, and (c) at least a first seal section;

30           a fluid connection housing assembly having first and second housing ends, the fluid  
connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of  
locking elements, and (iii) at least a first seal bore;

wherein each locking element is disposed to constrict radially via rotation about a  
corresponding pivot pin provided in the fluid connection housing assembly;

wherein each locking element has a locking element inner surface, a locking element  
outer surface and a locking element rocking surface;

wherein, during entry of the second adapter end into the first housing end: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore;

such that when the locking ring is retracted, progressive engagement of a locking ring inner surface on the locking element outer surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface;

wherein the locking element inner surfaces are disposed to further tighten against the tapered lock engagement surface responsive to displacement of the second adapter end towards the first housing end during engagement of the locking ring inner surface on the locking element outer surfaces.; and

wherein the first seal section is disposed to expand radially and further tighten sealing contact against the first seal bore responsive to introduction of internal pressure within the second adapter end.

17. The fluid connection assembly of claim 16, in which a spring bias ordains a default rotational position for the locking elements about their corresponding pivot pins.

18. The fluid connection assembly of claim 16, in which the fluid connection housing assembly further provides a quick test port, the quick test port comprising a fluid passageway from a fluid connection housing assembly exterior through to the first seal bore.

19. The fluid connection assembly of claim 16, in which the second adapter end further includes a strengthening sleeve.

20. The fluid connection assembly of claim 16, in which at least one actuator assembly energizes retraction of the locking ring.

21. The fluid connection assembly of claim 20, in which the at least one actuator assembly is remotely operable.

22. A fluid connection assembly, comprising:

a fluid connection adapter having first and second adapter ends, the fluid connection adapter providing in order towards the second adapter end: (a) a tapered lock engagement surface, (b) a locking element actuating section, and (c) at least a first seal section;

the fluid connection adapter further providing a rib;

5 a fluid connection housing assembly having first and second housing ends, the fluid connection housing assembly providing: (i) a retractable locking ring; (ii) a plurality of locking elements, (iii) at least a first seal bore, and (iv) a housing notch;

wherein each locking element is disposed to constrict radially via rotation about a corresponding pivot pin provided in the fluid connection housing assembly;

10 wherein each locking element has a locking element inner surface, a locking element outer surface and a locking element rocking surface;

wherein, during entry of the second adapter end into the first housing end until the rib abuts the housing notch: (A) the locking element actuating section contacts the locking element rocking surfaces, thereby causing the locking elements to rotate such that the locking element inner surfaces contact the tapered lock engagement surface; and (B) the first seal section sealingly contacts the first seal bore;

such that when the locking ring is retracted, progressive engagement of a locking ring inner surface on the locking element outer surfaces urges the locking element inner surfaces to tighten against the tapered lock engagement surface.

20

23. The fluid connection assembly of claim 22, in which the locking element inner surfaces are disposed to further tighten against the tapered lock engagement surface responsive to displacement of the second adapter end towards the first housing end during engagement of the locking ring inner surface on the locking element outer surfaces.

25

24. The fluid connection assembly of claim 22, in which the first seal section is disposed to expand radially and further tighten sealing contact against the first seal bore responsive to introduction of internal pressure within the second adapter end.

30

25. The fluid connection assembly of claim 22, in which a spring bias ordains a default rotational position for the locking elements about their corresponding pivot pins.

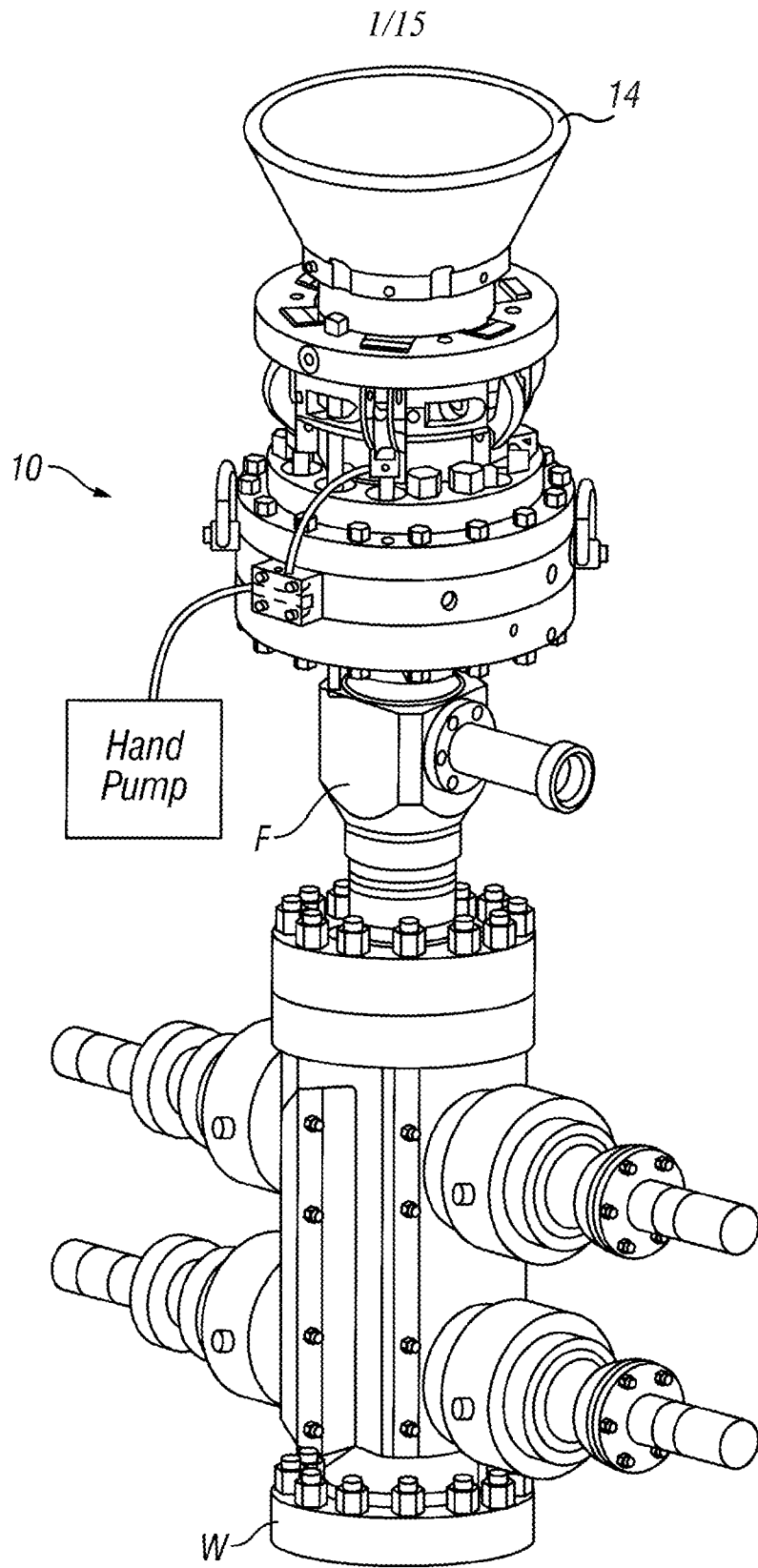
26. The fluid connection assembly of claim 22, in which the fluid connection housing assembly further provides a quick test port, the quick test port comprising a fluid passageway from a fluid connection housing assembly exterior through to the first seal bore.

5 27. The fluid connection assembly of claim 22, in which the second adapter end further includes a strengthening sleeve.

28. The fluid connection assembly of claim 22, in which at least one actuator assembly energizes retraction of the locking ring.

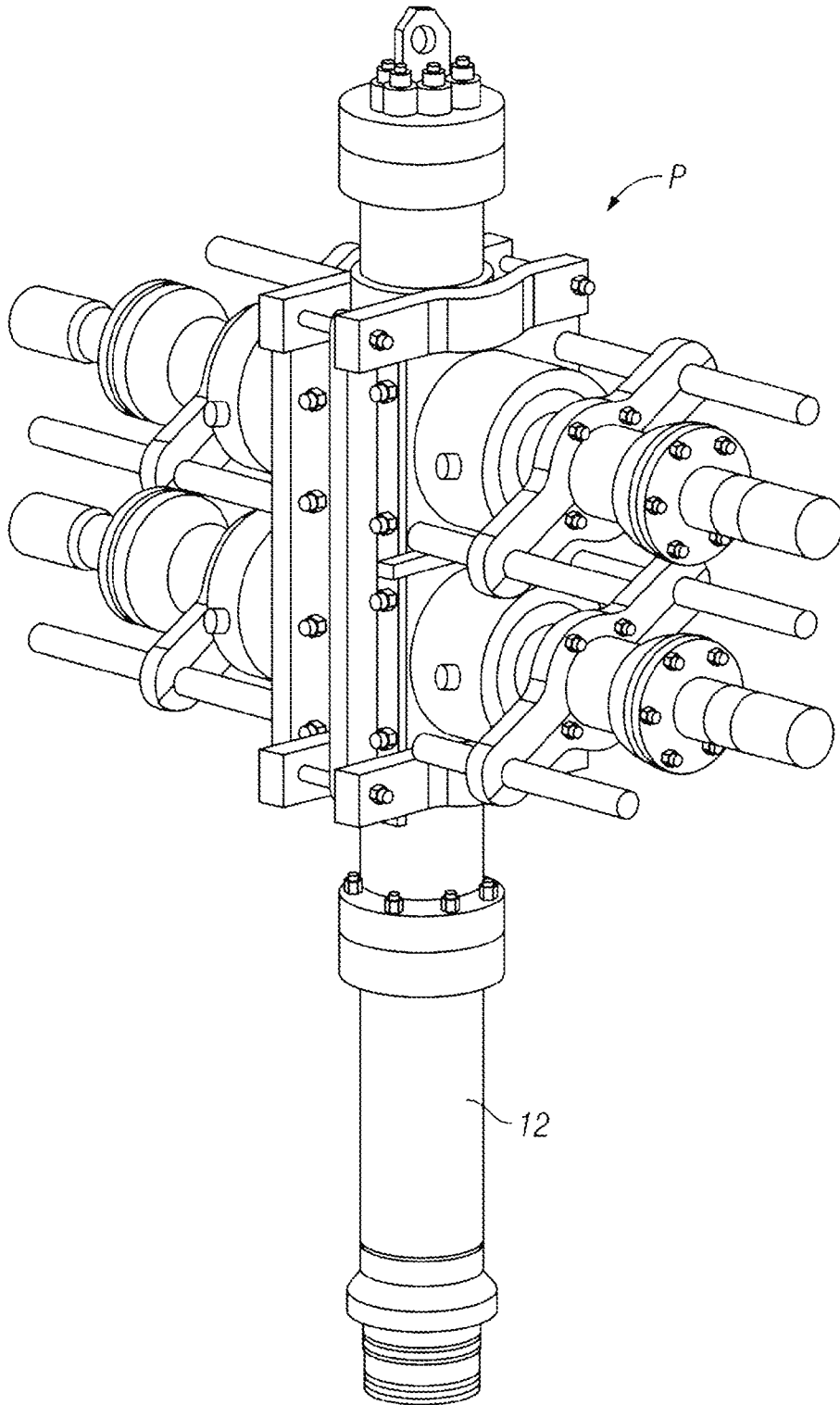
10

29. The fluid connection assembly of claim 28, in which the at least one actuator assembly is remotely operable.



**FIG. 1A**  
(Prior Art)

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**FIG. 1B**  
(Prior Art)

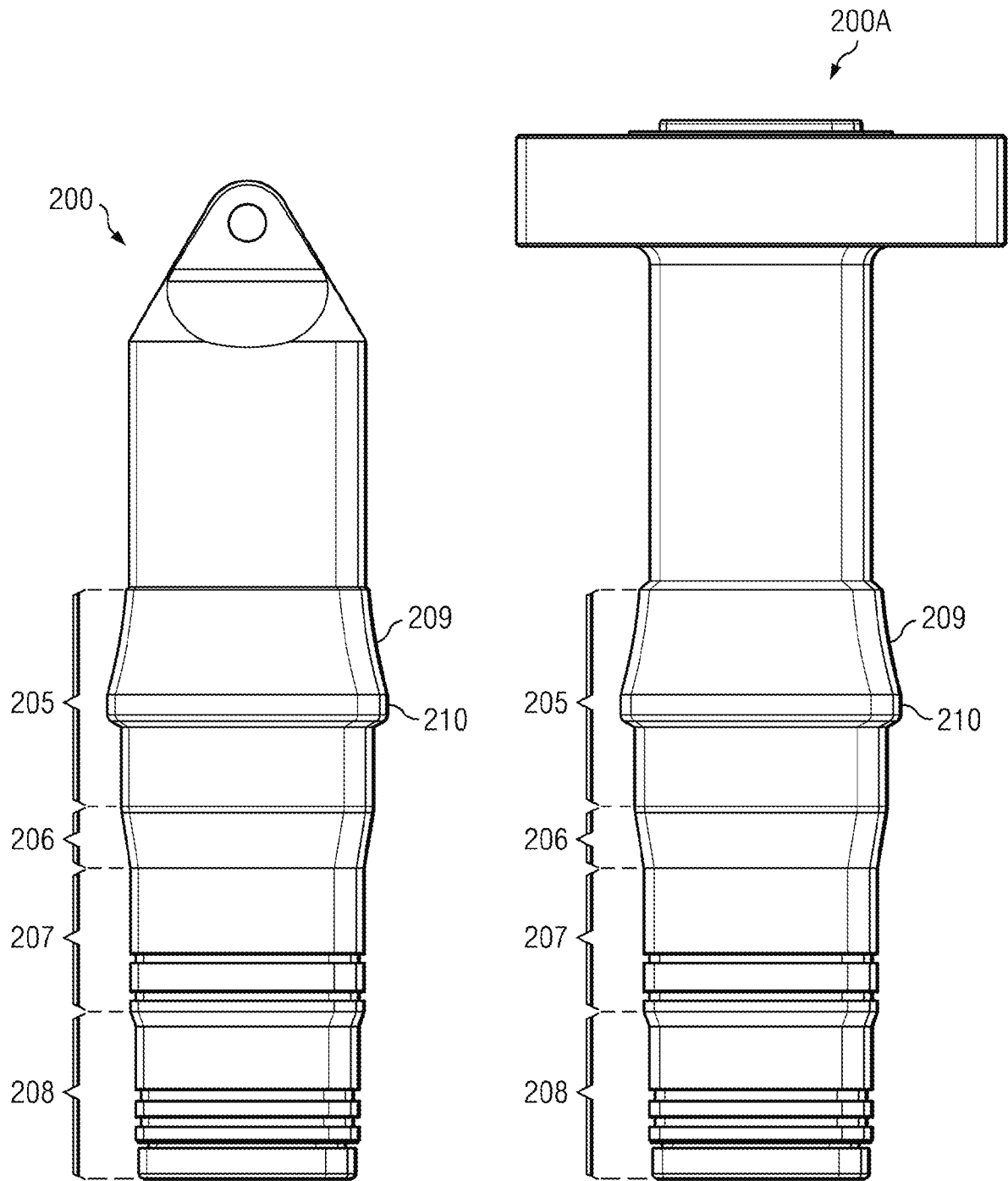


FIG. 2

FIG. 3

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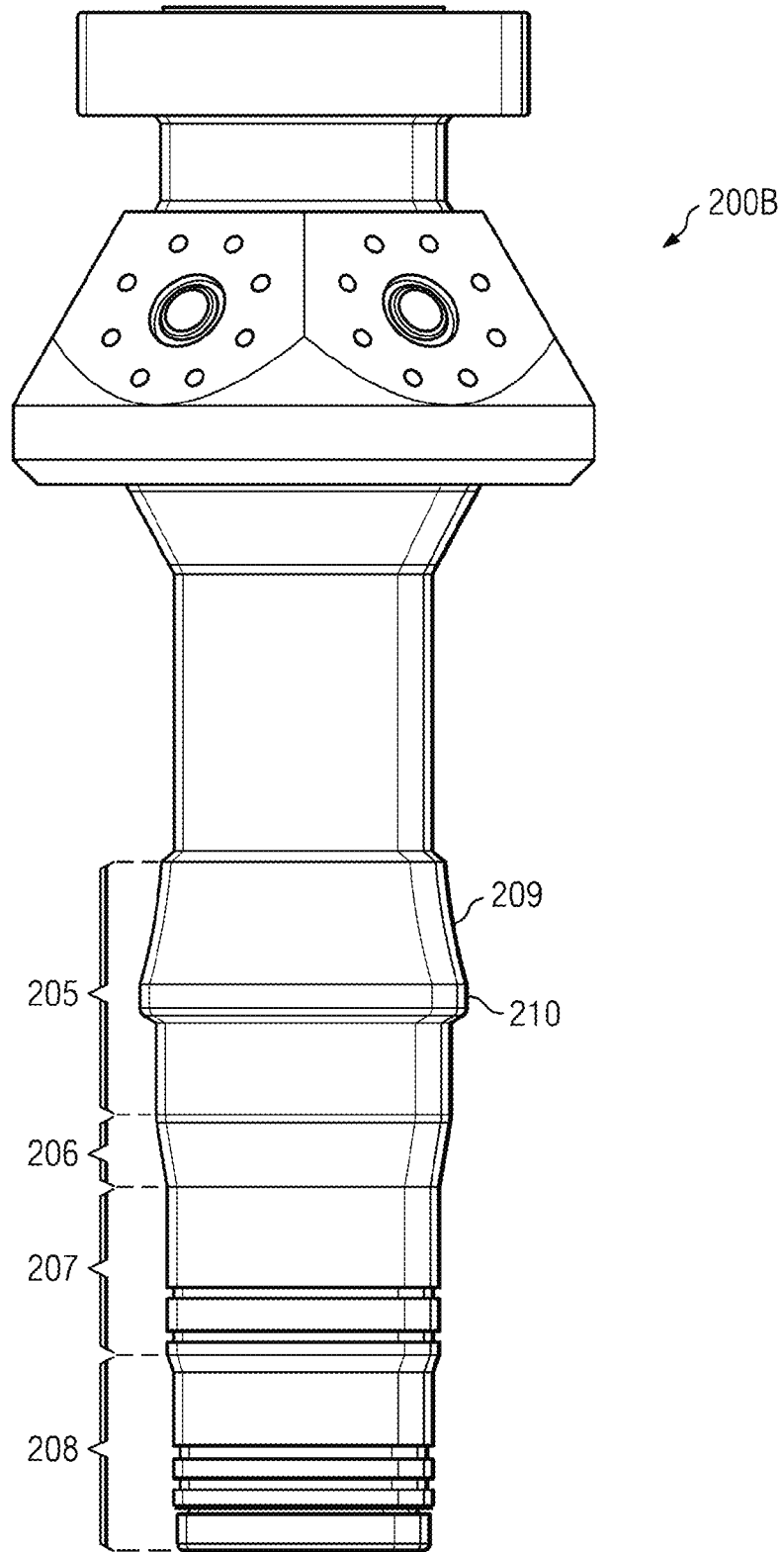


FIG. 4

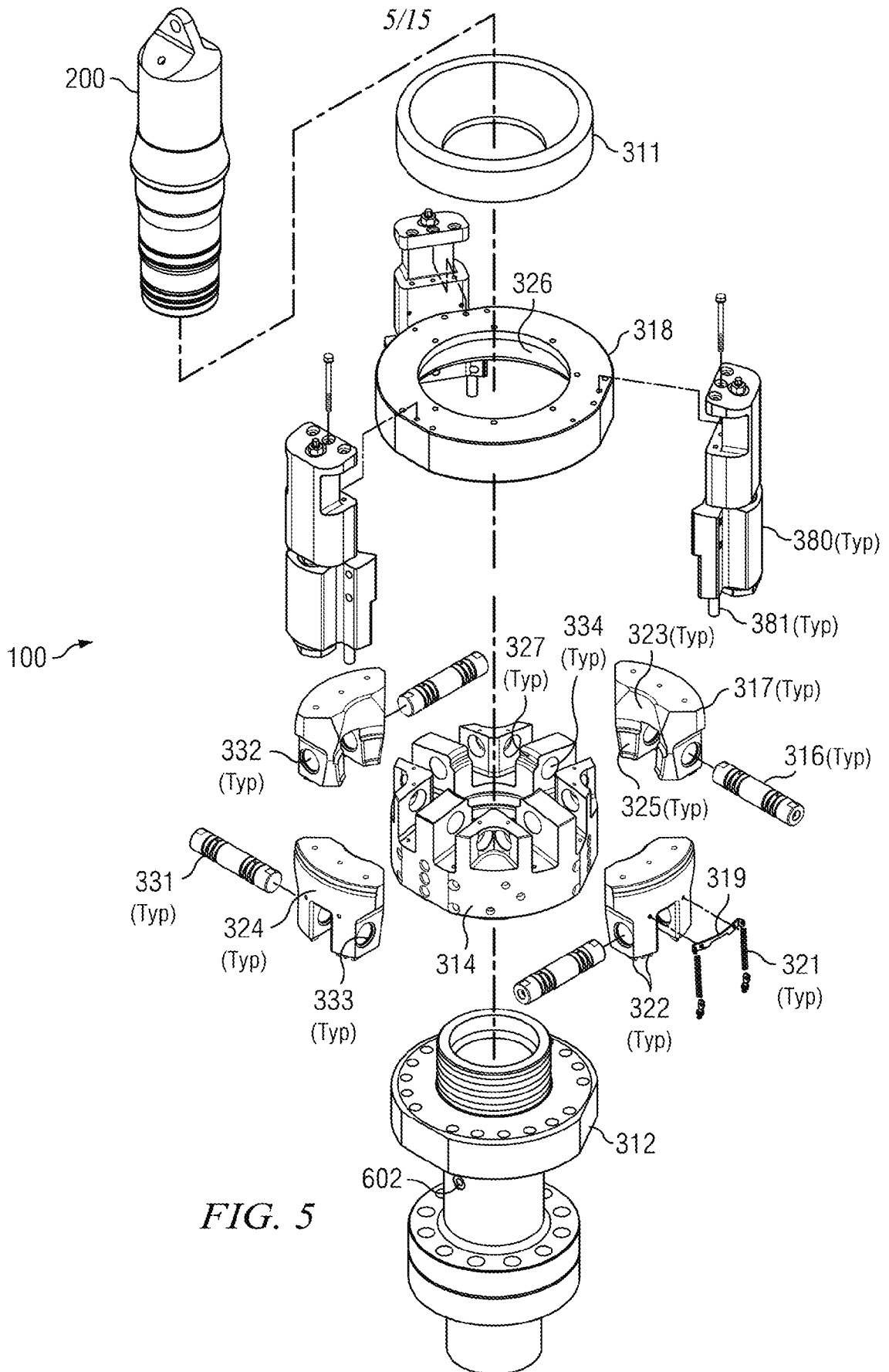
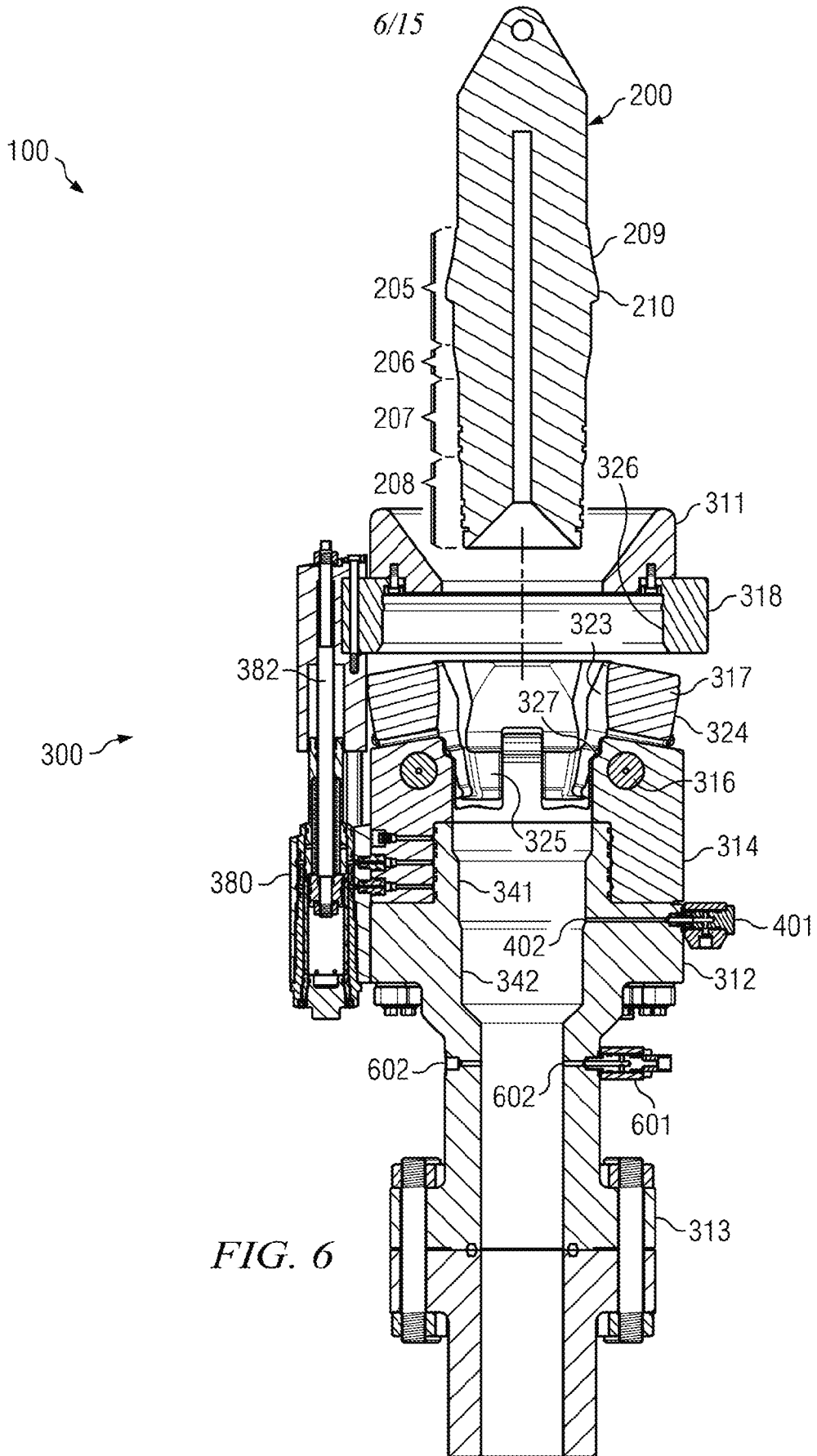


FIG. 5



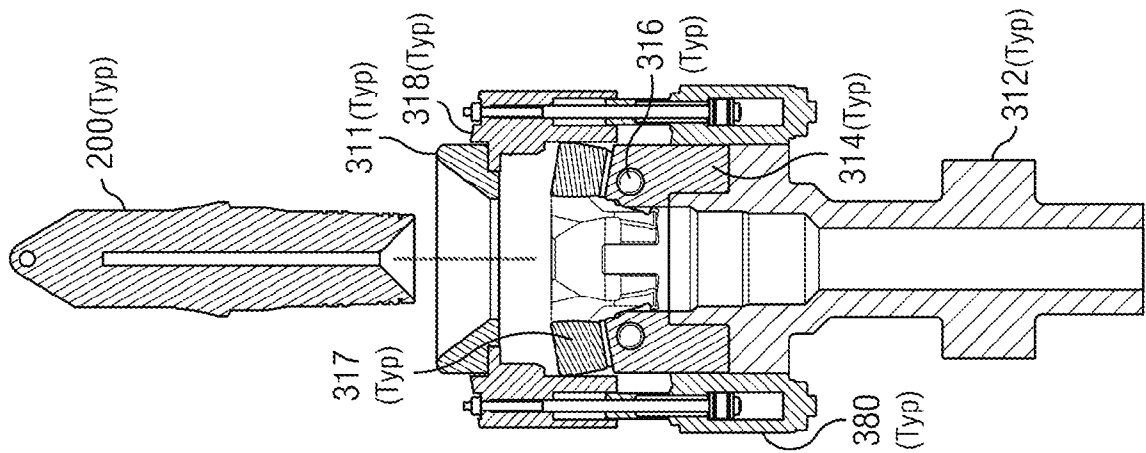


FIG. 7A

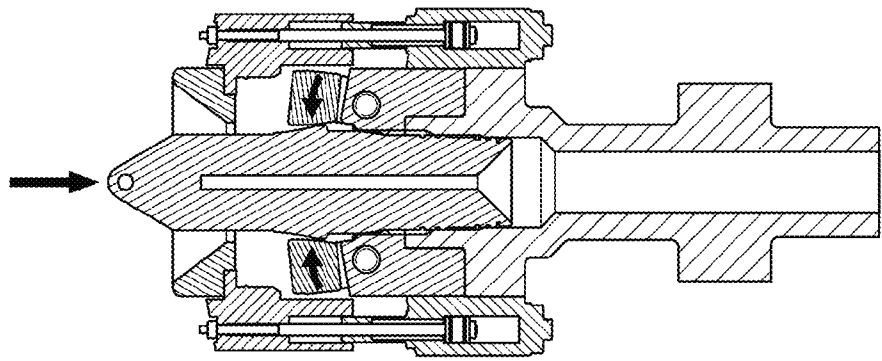


FIG. 7B

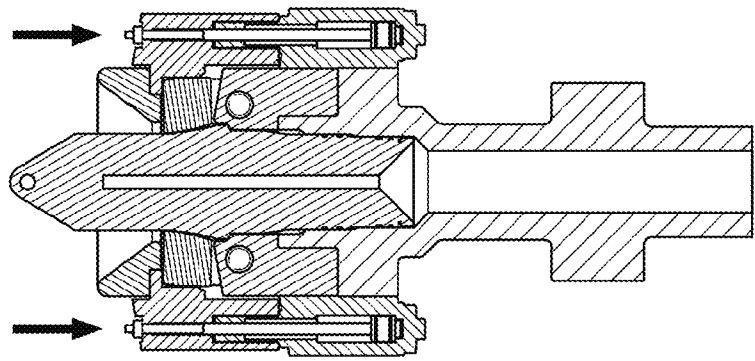


FIG. 7C

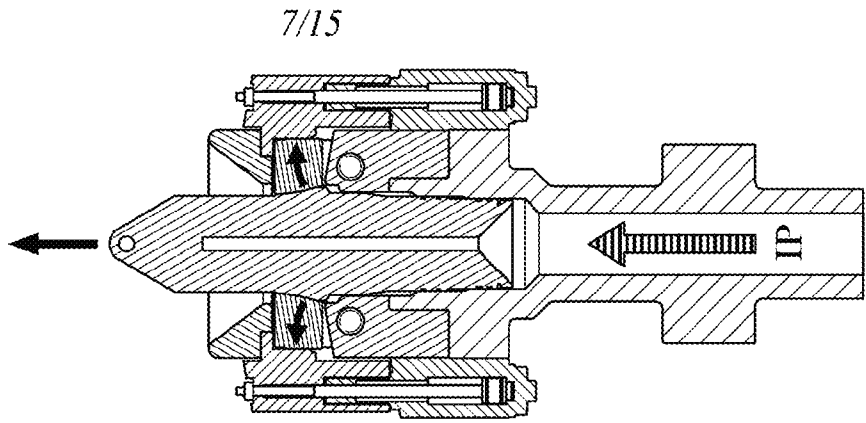


FIG. 7D

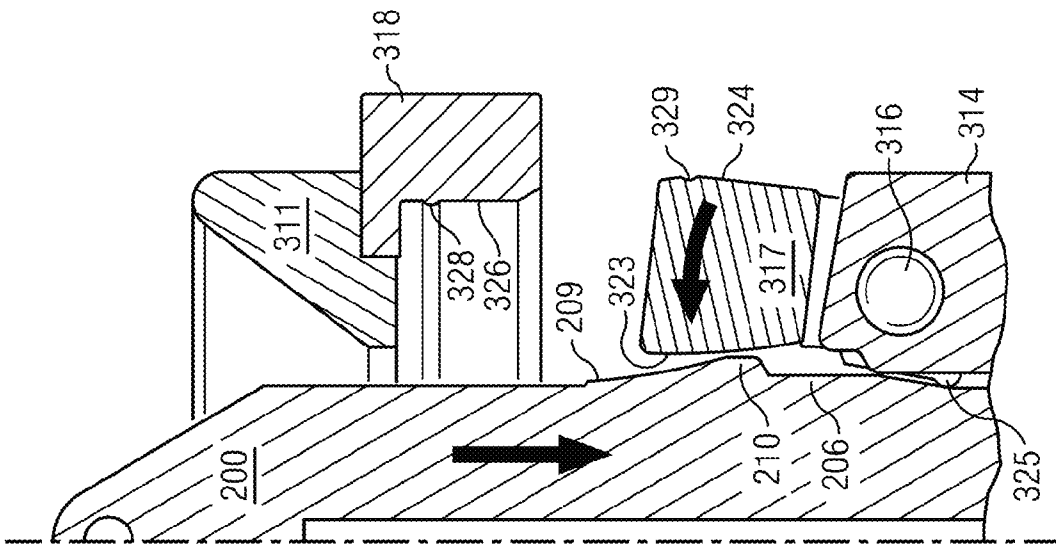


FIG. 8A

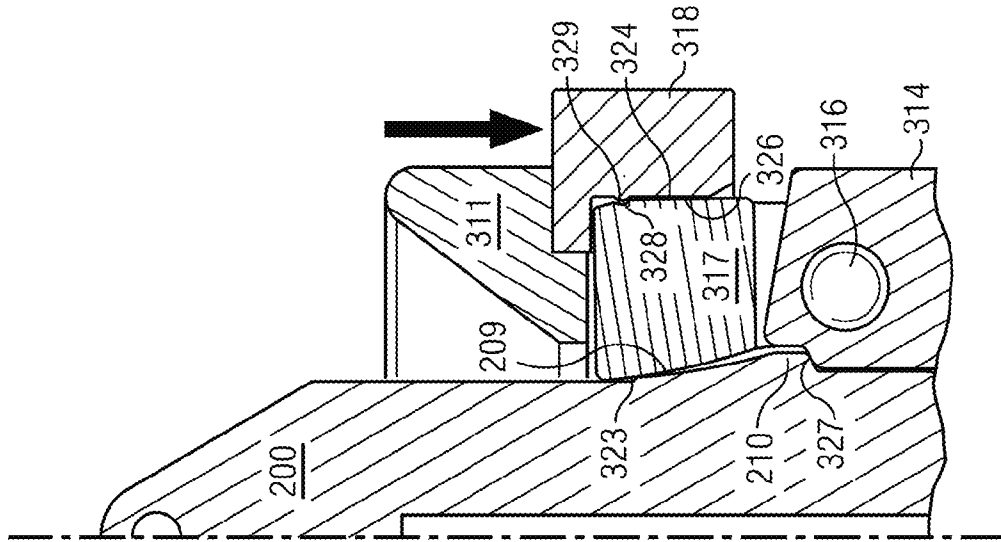


FIG. 8B

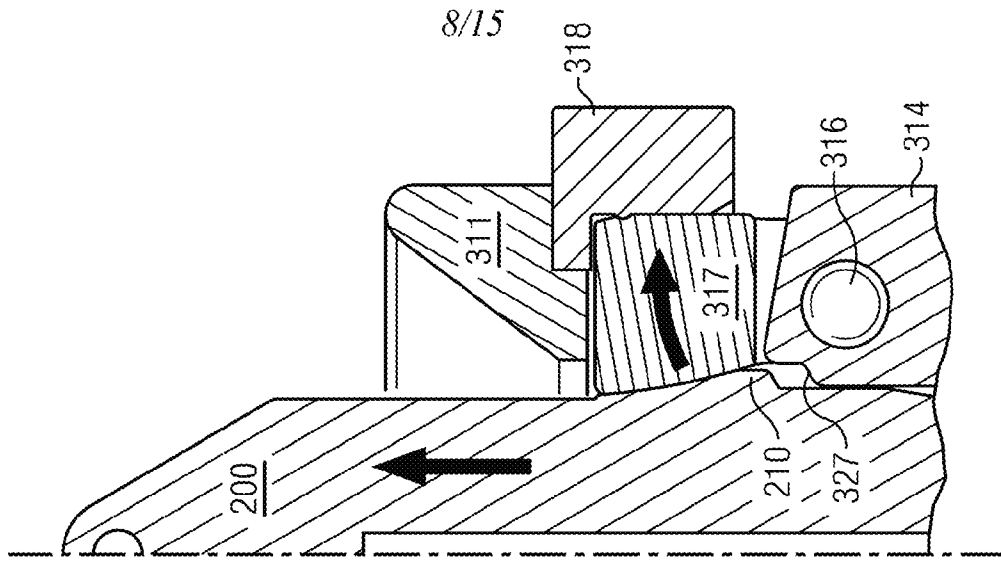


FIG. 8C

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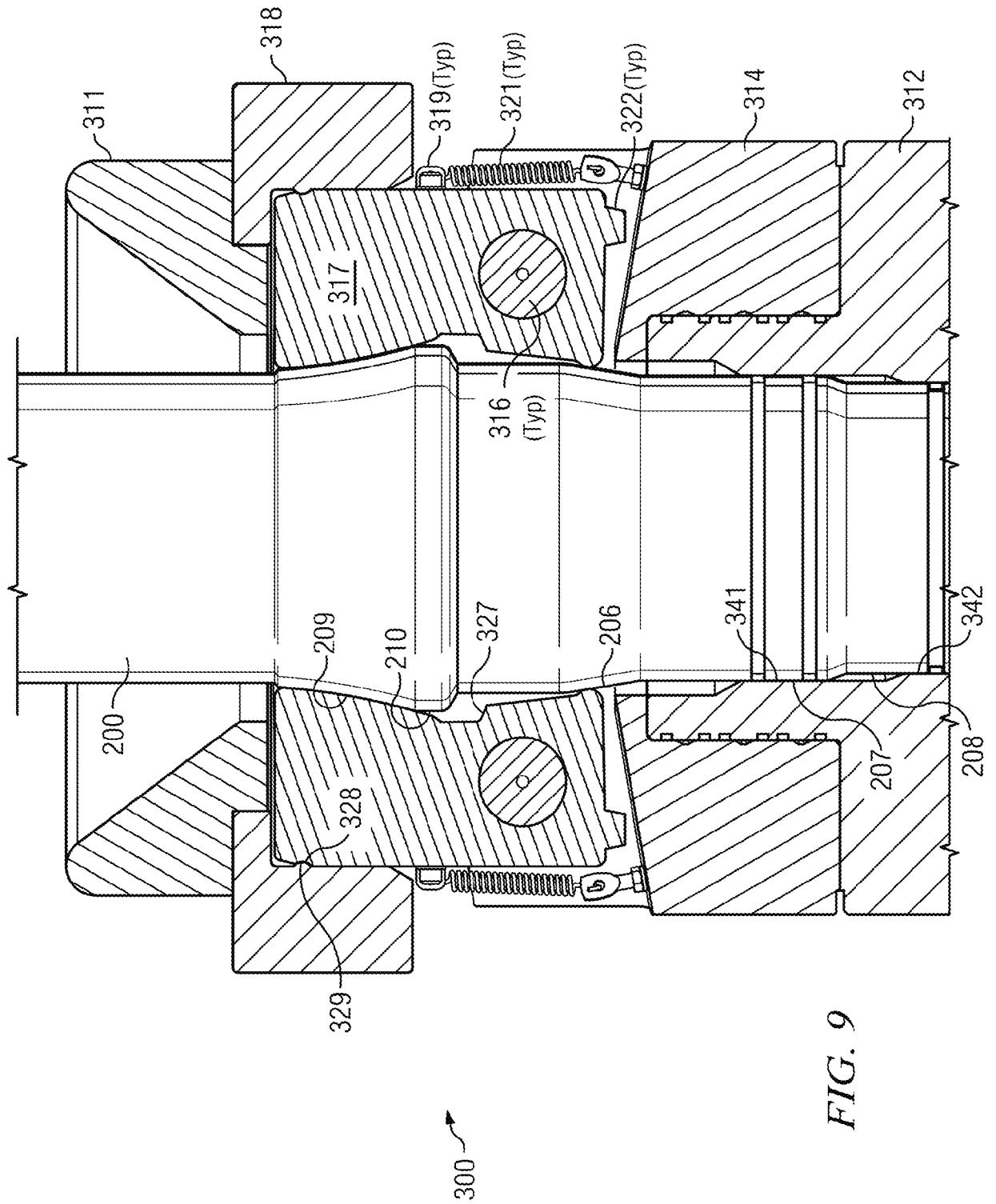


FIG. 9

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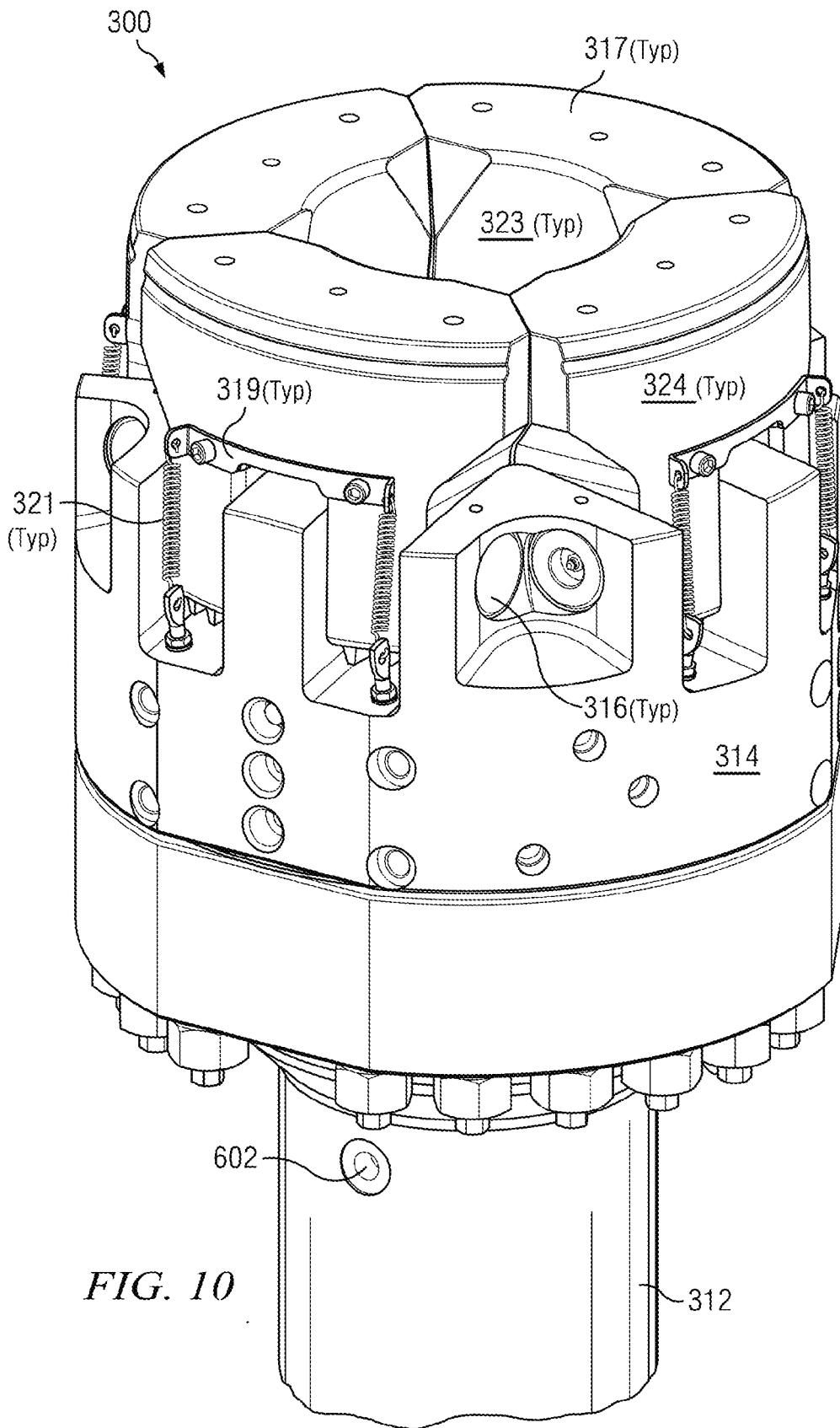


FIG. 10

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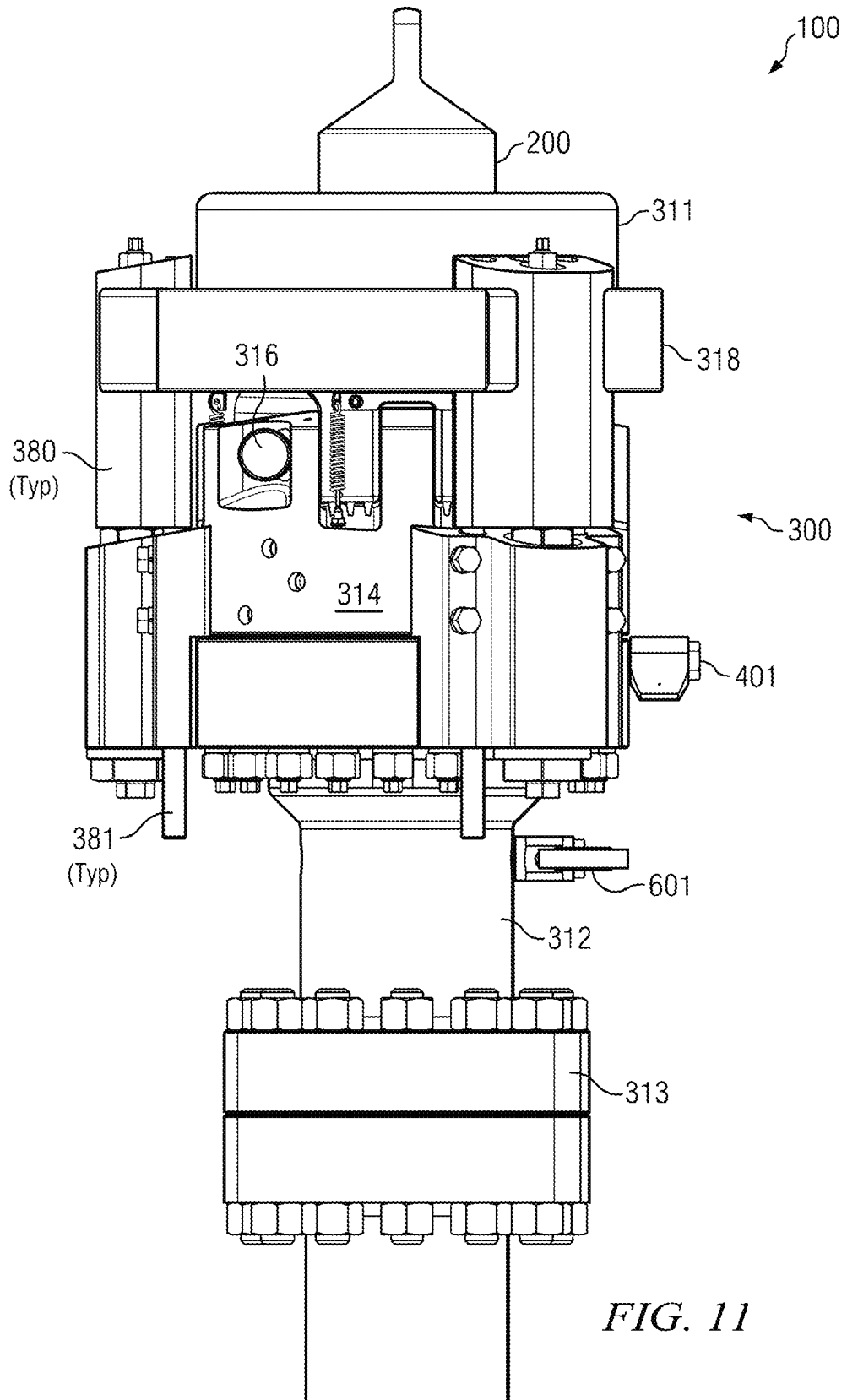


FIG. 11

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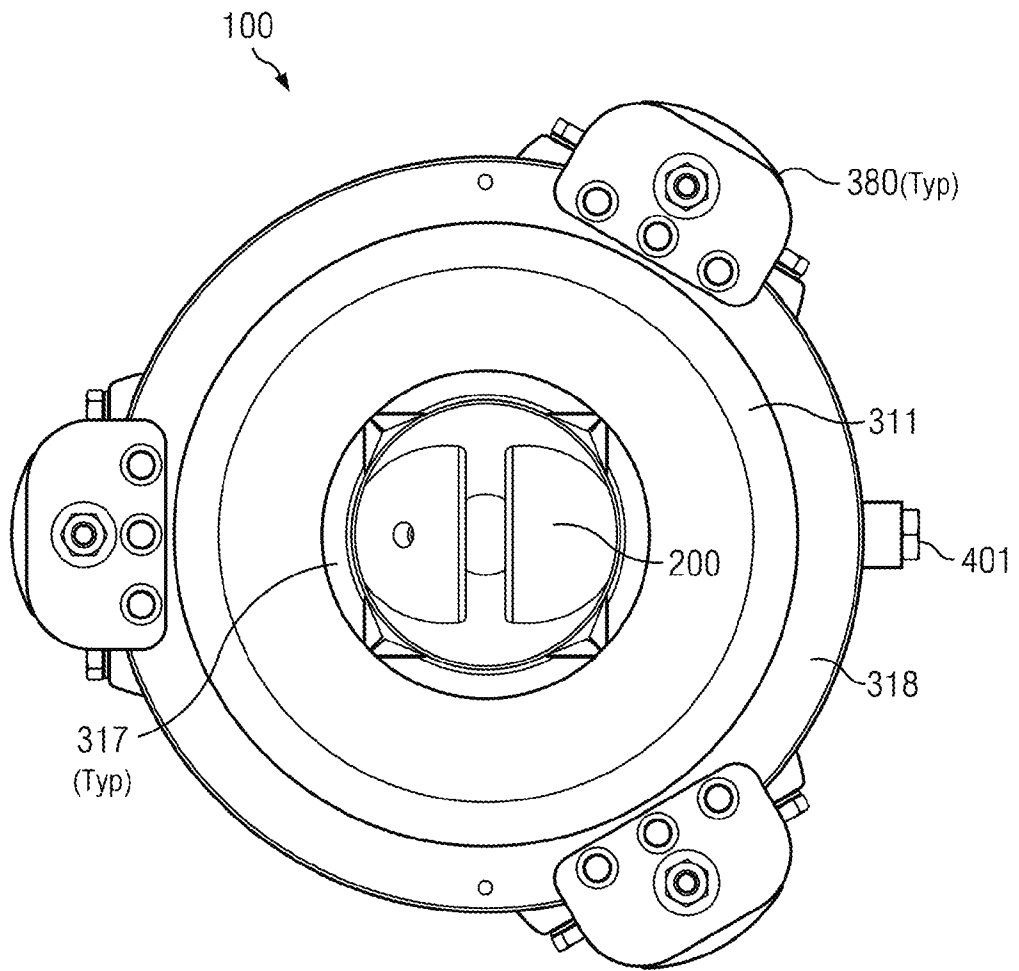


FIG. 12

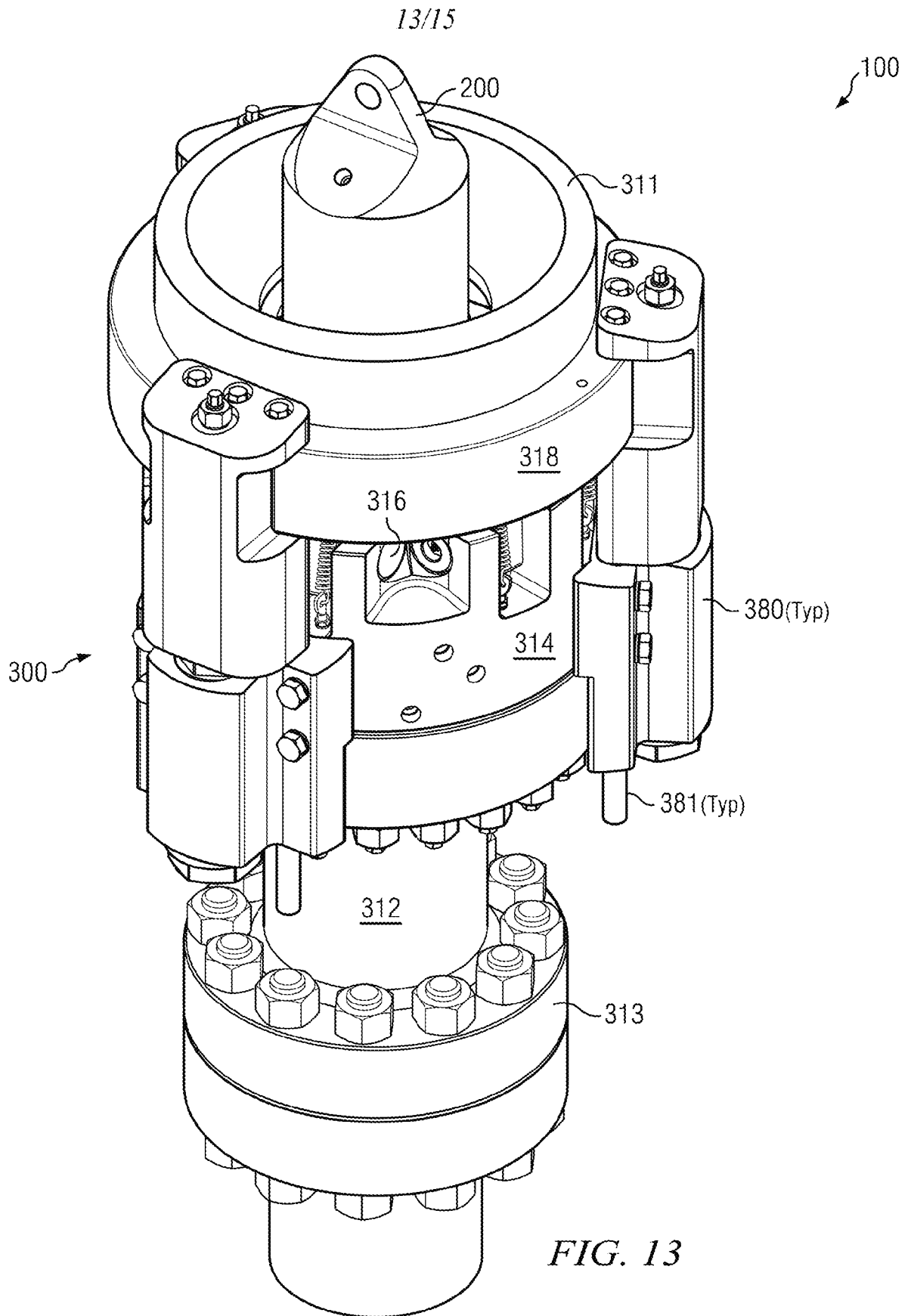


FIG. 13

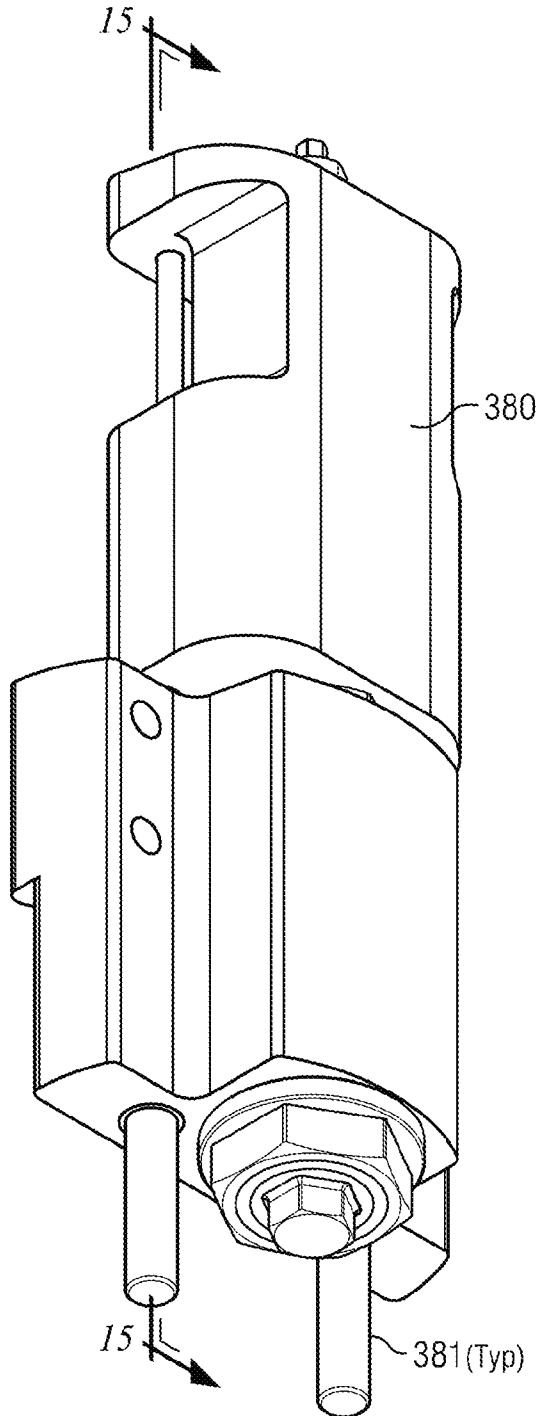


FIG. 14

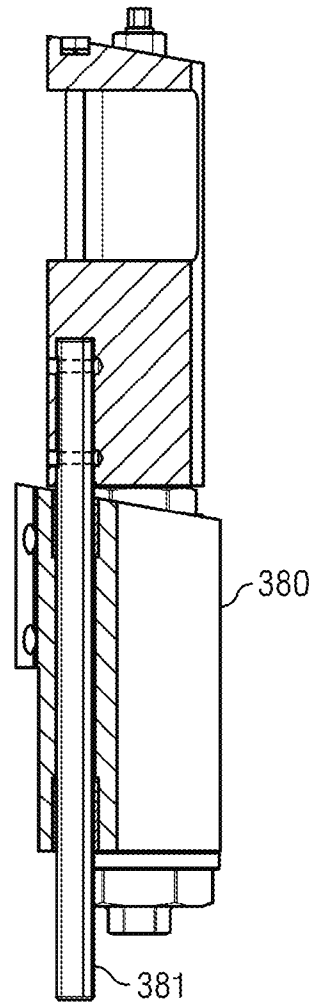


FIG. 15

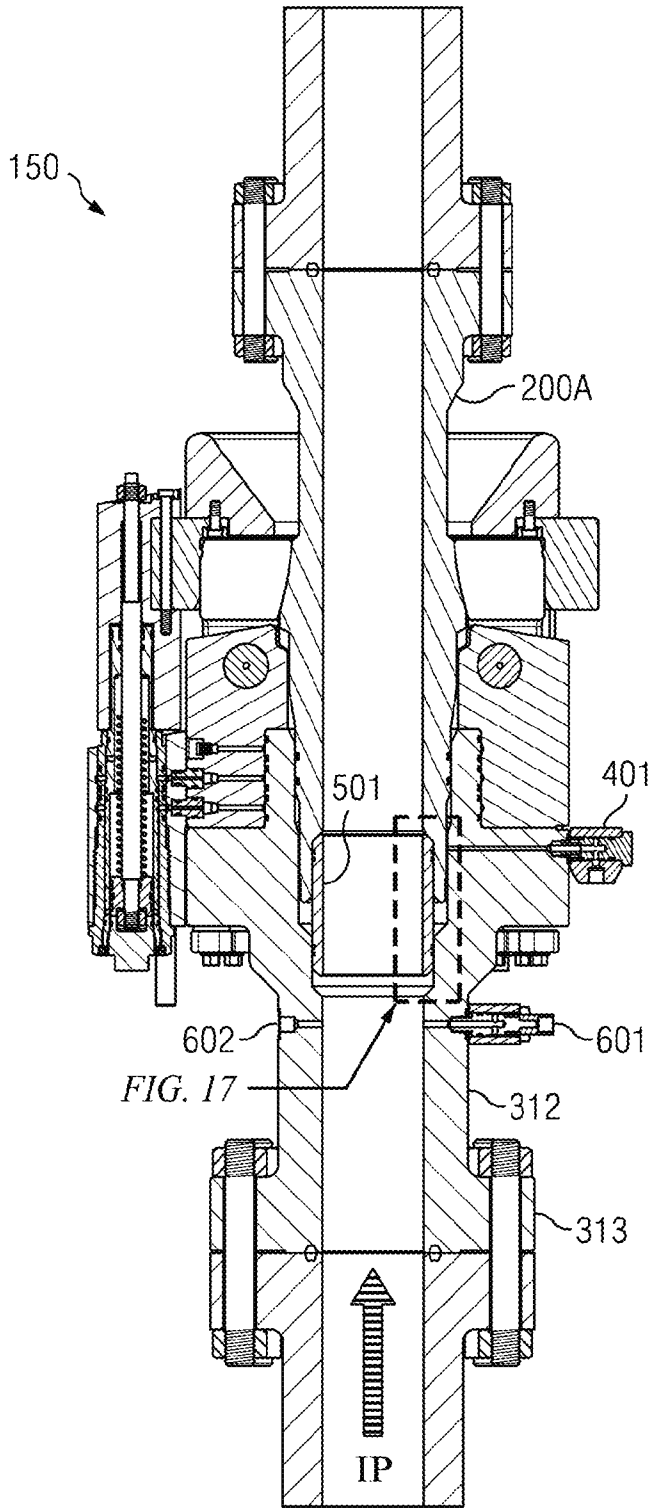


FIG. 16

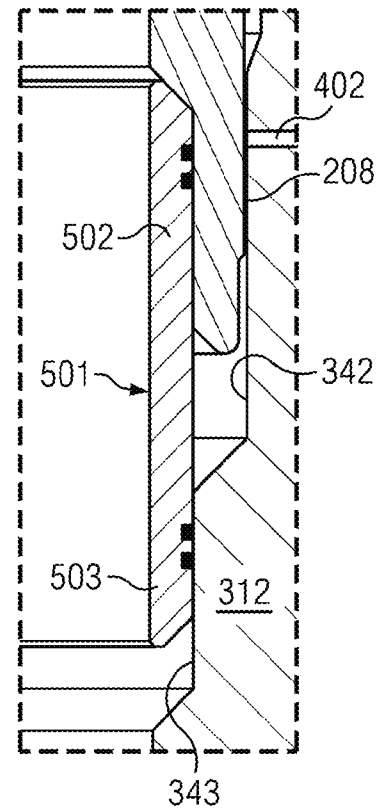


FIG. 17