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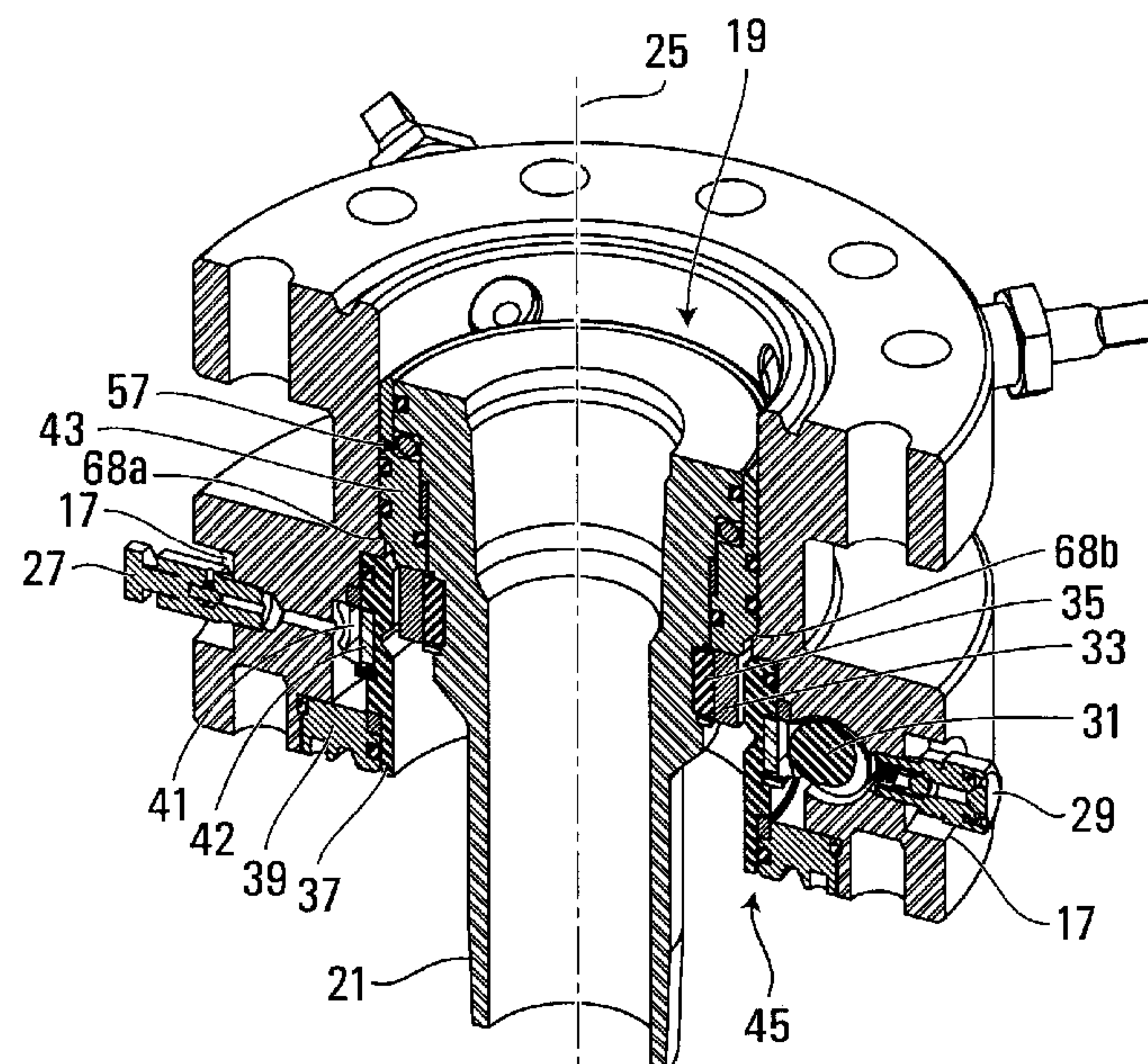
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(54) Title: WELLHEAD TUBING ROTATORS AND RELATED METHODS



(57) Abrégé/Abstract:

Wellhead tubing rotators and related methods are disclosed. A hanger assembly, to be coupled to production tubing, is supported by an internal shoulder of a housing. The hanger assembly is coupled to a drive sub assembly. The drive sub assembly is coupled to a drive mechanism in the housing. The drive sub assembly seals against the housing to create a sealed cavity containing the drive mechanism. The hanger assembly may also have a removable upper sub assembly.

54846-20

ABSTRACT

Wellhead tubing rotators and related methods are disclosed. A hanger assembly, to be coupled to production tubing, is supported by an internal shoulder of a housing. The hanger assembly is coupled to a drive sub assembly. The drive sub assembly is coupled to a drive mechanism in the housing. The drive sub assembly seals against the housing to create a sealed cavity containing the drive mechanism. The hanger assembly may also have a removable upper sub assembly.

54846-20

WELLHEAD TUBING ROTATORS AND RELATED METHODS

FIELD

The present disclosure relates generally to wellhead equipment and, in particular, to wellhead tubing rotators.

BACKGROUND

Tubing rotators are used to prolong the service life of oilfield production tubing. A wellhead tubing rotator is a particular type of tubing rotator that is coupled to a wellhead or to other oilfield equipment at the surface of a production well. The purpose of a wellhead tubing rotator, like a downhole tubing rotator, is to prevent excessive wear of a production tubing string by slowly rotating the tubing string. This allows wear, from contact with a sucker rod string, for example, to be distributed around the inside circumference of the tubing string instead of the wear being concentrated at a point of contact.

In some conventional wellhead tubing rotators, a drive sub or other component that is driven to rotate production tubing also bears the weight of the tubing string. In order to support this weight while allowing rotation of the tubing string, a large bearing is typically installed between the drive sub and a housing of the tubing rotator, and the housing remains stationary during tubing rotation. A large bearing reduces the amount of available space inside the housing. This limits the outside diameter of the drive sub and therefore also limits the internal diameter of the drive sub.

In addition, the drive shaft and a gear mechanism with which the drive shaft meshes are often exposed to well fluids. This may necessitate the usage of corrosion-resistant materials for these components. Components that are exposed to well fluids may also require more frequent cleaning or servicing than other components that are not in contact with well fluids.

SUMMARY

In some embodiments, the weight of the tubing string is supported by a hanger assembly resting against an inner shoulder inside the housing. A drive sub assembly

54846-20

therefore does not support the full weight of the tubing string and does not require as large a bearing in order to be free to rotate the hanger assembly.

The drive sub assembly may also seal against an interior of the housing to form a cavity between the drive sub assembly and the housing. The drive sub assembly is engaged with the drive shaft inside the sealed housing.

According to one aspect of the present invention, a wellhead tubing rotator includes: a housing comprising an internal shoulder; a drive mechanism located in the housing; a drive sub assembly engaged with the drive mechanism and sealed against an interior of the housing to define a sealed cavity that isolates the drive mechanism between the housing and the drive sub assembly; and a hanger assembly, supported by the internal shoulder of the housing and engaged with the drive sub assembly, to be coupled to production tubing in a production well.

The hanger assembly may include: a hanger assembly housing, supported by the internal shoulder of the housing; a hanger assembly bearing, supported by the hanger assembly housing; a hanger assembly gear, engaged with the drive sub assembly; and a mandrel, supported by the hanger assembly bearing and engaged with the hanger assembly gear, to be coupled to the production tubing.

The mandrel may seal against the hanger assembly housing, and the hanger assembly housing may seal against the housing.

The mandrel may engage with the hanger assembly gear by a hanger key that fits into slots in the mandrel and in the hanger assembly gear.

Alternatively, the hanger assembly may include: a hanger assembly housing, supported by the internal shoulder of the housing; a hanger assembly bearing, supported by the hanger assembly housing; a hanger assembly gear, engaged with the drive sub assembly; an upper sub assembly, supported by the hanger assembly bearing and engaged with the hanger assembly gear; and a mandrel, connected to the upper sub assembly, to be coupled to the production tubing.

54846-20

In this case, the mandrel may seal against the upper sub assembly, the upper sub assembly may seal against the hanger assembly housing, and the hanger assembly housing may seal against the housing.

The upper sub assembly may engage with the hanger assembly gear by a hanger key that fits into slots in the upper sub assembly and in the hanger assembly gear.

The upper sub assembly may include: an upper sub; and a fastener coupling the upper sub to the mandrel.

The hanger assembly gear is engaged with the drive sub assembly through lugs on the hanger assembly gear and on the drive sub assembly, in an embodiment.

The lugs of the hanger assembly gear and the lugs of the drive sub assembly may be tapered in a direction axial to the hanger assembly. The lugs of the hanger assembly gear and the lugs of the drive sub assembly may be tapered in a direction radial to the hanger assembly.

The drive sub assembly may include: a drive sub, engaged with the hanger assembly; a drive sub retainer, engaged with the housing and the drive sub; and a drive sub gear, engaged with the drive sub and the drive mechanism.

The drive sub retainer may seal against both the drive sub and a first portion of the interior of the housing, and the drive sub may seal against a second portion of the interior of the housing, the sealed cavity being defined between the housing, the drive sub retainer, and the drive sub.

The drive sub gear may be engaged with the drive sub by a drive sub key that fits into slots in the drive sub gear and in the drive sub.

The wellhead tubing rotator may include a pipe plug to prevent fluid communication via a channel between the sealed cavity and an exterior of the housing.

The wellhead tubing rotator may also include a locking pin installed in a bore in the housing to limit axial movement of the hanger assembly relative to the housing.

54846-20

The locking pin may include: a locking bolt; and a first washer, packing, a second washer, and a locking nut arranged on the locking bolt.

The hanger assembly may further include: an auxiliary sub, engaged with the mandrel and the hanger assembly housing.

Alternatively, the hanger assembly may further include: an auxiliary sub, engaged with the upper sub assembly and the hanger assembly housing.

The wellhead tubing rotator may further include a locking pin installed in a bore in the housing to limit axial movement of the hanger assembly relative to the housing, wherein the locking pin is engaged with the auxiliary sub, in an embodiment.

According to another aspect of the present invention, a production assembly for producing a well includes: production tubing to be placed in the well; and the wellhead tubing rotator described herein, coupled to the production tubing.

According to still another aspect of the present invention, a method of using the wellhead tubing rotator described herein includes: securing the housing to a wellhead; coupling the hanger assembly to the production tubing; lowering the hanger assembly into the housing; and providing a force to the drive mechanism to rotate the hanger assembly.

According to still another aspect of the present invention, a kit includes: a housing, a drive mechanism, a drive sub assembly, and a hanger assembly as described herein; and instructions for assembling the housing, the drive mechanism, the drive sub assembly, and the hanger assembly to form the wellhead tubing rotator.

According to still another aspect of the present invention, a method of manufacturing a wellhead tubing rotator includes: providing a housing that includes an internal shoulder; sealing a drive mechanism in a sealed cavity between the housing and a drive sub assembly that is engaged with the drive mechanism and sealed against an interior of the housing; and placing a hanger assembly, which is to be coupled to production

54846-20

tubing in a production well, on the internal shoulder of the housing and into engagement with the drive sub.

Other aspects and features of embodiments of the present disclosure will become apparent to those ordinarily skilled in the art upon review of the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of embodiments of the invention will now be described in greater detail with reference to the accompanying drawings.

FIG. 1 is an isometric view of a wellhead tubing rotator according to a first embodiment.

FIG. 2 is a cross-section view of the wellhead tubing rotator of FIG. 1, along line 2—2 shown in FIG. 1.

FIG. 3 is a side view of the wellhead tubing rotator of FIG. 1, with a hanger assembly shown above a housing.

FIG. 4 includes cross-section views of the hanger assembly and the housing of FIG. 3, and a drive sub assembly in the housing.

FIG. 5 is an exploded, isometric view of the hanger assembly of FIG. 3.

FIG. 6 is an isometric view of the wellhead tubing rotator of FIG. 1, with a drive sub assembly and a locking pin exploded therefrom.

FIG. 7 is an exploded, isometric view of the drive sub assembly shown in FIG. 6.

FIG. 8A is a side view of the wellhead tubing rotator of FIG. 1.

FIG. 8B is a cross-section view along line 8B—8B shown in FIG. 8A.

FIG. 8C is a cross-section view along line 8C—8C shown in FIG. 8A.

FIG. 8D is a cross-section view along line 8D—8D shown in FIG. 8A.

FIG. 8E is a detail view of window 8E shown in FIG. 8B.

54846-20

FIG. 8F is an isometric view of the wellhead tubing rotator of FIG. 1, with a drive mechanism exploded therefrom.

FIG. 9 is a cross-section view of the locking pin shown in FIG. 6, installed in the housing.

FIG. 10 is an exploded view of the locking pin shown in FIG. 6.

FIG. 11 is an isometric view of a wellhead tubing rotator according to a second embodiment, with a shear sub exploded therefrom.

FIG. 12 is a cross-section view of the wellhead tubing rotator of FIG. 11, along line 12—12 shown in FIG. 11.

FIG. 13 is a cross-section view of the hanger assembly shown in FIG. 12.

FIG. 14 is an exploded, isometric view of the hanger assembly of FIG. 13.

FIG. 15 is a cross-section view of a hanger assembly according to another embodiment.

FIG. 16 is a cross-section view of a hanger assembly according to a further embodiment.

FIGS. 17A-E show cross-section views of the wellhead tubing rotator of FIG. 11 at different stages of removing portions of the hanger assembly of FIG. 13.

FIG. 18 is a flow chart of a method of manufacturing a wellhead tubing rotator.

FIG. 19 is a flow chart of a method of using a wellhead tubing rotator.

DETAILED DESCRIPTION

It should be appreciated that the drawings are intended solely for illustrative purposes, and that the present invention is in no way limited to the particular example embodiments explicitly shown in the drawings and described herein.

Many of the features of the wellhead tubing rotators discussed below are cylindrical or ring-shaped, and therefore these features have both inner and outer surfaces. For

54846-20

example, an axis 25 is shown in FIG. 2 along a centerline of a mandrel 21. An “inner surface” would be a surface that faces toward the axis 25 and an “outer surface” would be a surface that faces away from the axis 25. This also applies to other embodiments, including embodiments with other shapes that are not entirely cylindrical.

Many of the features also have first and second ends, and reference may also be made to certain directions, with respect to a typical operating orientation of the wellhead tubing rotators disclosed herein. For example, there could be “top” or “upper” ends and/or “bottom” or “lower” ends, and upward and/or downward directions. However, wellhead tubing rotators could be shipped, stored, serviced, or assembled, and possibly even operated, in non-vertical orientations or in orientations opposite to those described herein.

FIG. 1 is an isometric view of a wellhead tubing rotator according to a first embodiment.

A wellhead tubing rotator 1 has a housing 3, which is shaped for being placed on a wellhead. The housing 3 has an upper face 11, which may have one or more axial bores or holes 13, such that the housing 3 may be coupled to other wellhead equipment using bolts and nuts or other types of fasteners, for example. There are multiple bores 13 in the example shown.

The housing 3 may also have one or more radial bores or holes 15 on its side, to accommodate one or more locking pins 7, four in the example shown. The housing 3 also has one or more radial bores or holes 17 to allow access to the interior of the housing. For example, the radial bores 17 may provide access to different internal components of the wellhead tubing rotator 1. The radial bores 17 could also or instead be used to inject grease into the housing 3. A plug 9 may be used to seal each of the radial bores 17 after each greasing operation.

The housing 3 is configured to receive a drive mechanism 5a, which may be coupled to a manual drive, or to an electric or hydraulic motor. A drive shaft 5, which is a part of the drive mechanism 5a, is coupled to a hanger assembly 19, which is shown in more detail in FIG. 2 and described below. A mandrel 21, which is also part of the hanger assembly

54846-20

19, is located inside the housing 3 as shown during operation of the wellhead tubing rotator 1.

The wellhead tubing rotator 1 may be coupled to production tubing 23 via the mandrel 21. The production tubing 23 is not part of the wellhead tubing rotator 1, but is shown in FIG. 1 to illustrate how the wellhead tubing rotator is coupled to a production tubing string in an embodiment.

The housing 3 may be made of any material(s) sufficiently rigid to withstand the weight of the production tubing 23, to withstand wellbore pressures, and to support any other wellhead equipment that rests on the housing upper face 11. Rigid materials that are resistant to corrosion or deterioration when exposed to well fluids, and possibly also industrial chemicals, may be preferred. In an embodiment, the housing 3 is constructed using 4130 steel in conformance with specifications from The National Association of Corrosion Engineers (NACE) for H₂S corrosive environments and having a Rockwell C Hardness between 18 and 22, stainless steel, or other alloys.

The drive shaft 5 may be made of any material(s) with sufficient torsional strength to resist breakage or significant buckling when a force is used to turn the drive shaft 5. The drive shaft 5 may be made of, for example, NACE-compliant 4130 steel or stainless steel. The drive shaft 5 could be made of the same material as the housing 3, or of a different material. For example, corrosion or deterioration from well fluids or industrial chemicals used in well operations might not be as much of a concern for the drive shaft 5 as for the housing 3.

The mandrel 21 may be made of any rigid material(s) that may be coupled to the production tubing 23, such as NACE-compliant 4130 steel or stainless steel. In an embodiment, the mandrel 21 is made of material(s) resistant to corrosion or deterioration from well fluids and/or industrial chemicals used in well operations.

Most of the components of the wellhead tubing rotator 1 are housed in the housing 3. The radial bores 15 allow the locking pins 7 to pass through the housing 3 as noted above, and the locking pins 7 limit axial movement of the hanger assembly 19, as described in further detail below.

54846-20

Rotation of the drive shaft 5 causes the mandrel 21 to turn, thereby rotating the production tubing 23. The coupling between the mandrel 21 and the production tubing 23 could be a threaded connection, for example. Tubing rotators typically turn the tubing string to the right (right hand rotation), and right hand threading is also used for threaded connections so that rotation of the production tubing 23 does not loosen the threaded connections. There could also or instead be threaded connections elsewhere, between segments of the production tubing 23, for example.

Further details of the wellhead tubing rotator 1 are shown in FIGS. 2 to 10 and described below.

With reference to FIGS. 2 to 4, FIG. 2 is a cross-section view of the wellhead tubing rotator of FIG. 1, along line 2—2 shown in FIG. 1, FIG. 3 is a side view of the wellhead tubing rotator 1 with the hanger assembly 19 shown above the housing 3, and FIG. 4 includes cross-section views of the hanger assembly 19 and the housing of FIG. 3. A section line is not shown in FIG. 3, but FIG. 4 is a cross-section in the plane of the drawing sheet of FIG. 3, through the center of the hanger assembly 19 and the housing 3.

The hanger assembly 19 includes the mandrel 21, a hanger assembly housing 43 and a hanger assembly gear 33. The mandrel 21 is supported by a bearing assembly 57. The bearing assembly 57 is supported by the hanger assembly housing 43, which rests against a housing internal shoulder 68a of the housing 3. As shown perhaps most clearly in FIG. 4, the hanger assembly housing 43 includes a shoulder 68b, which engages the housing internal shoulder 68a when the hanger assembly 19 is installed in the housing 3. Although these shoulders are flat and sloped in the example shown, different surface shapes and/or slope angles may be used in other embodiments.

The hanger assembly housing 43 may be made of any material(s) sufficiently rigid to support the weight of the tubing string. Rigid material(s) resistant to corrosion or deterioration when exposed to well fluids, and possibly also industrial chemicals, may be preferred. In an embodiment, the hanger assembly housing 43 is constructed of NACE-compliant 4130 steel or stainless steel.

54846-20

The hanger assembly 19 is coupled to a drive sub assembly 45 via the hanger assembly gear 33. The hanger assembly gear 33 is connected to the mandrel 21 by one or more hanger keys 35.

The components of the hanger assembly 19 are held in place on the mandrel 21 by a retainer 53.

As shown in FIGS. 2 and 4, the drive sub assembly 45 includes a drive sub 37, a drive sub retainer 39 and a drive sub gear 41. The drive sub retainer 39 is connected to the housing 3 and also engages the drive sub 37. The drive sub retainer 39 is rotatively coupled to the drive sub 37. The drive sub gear 41 is connected to the drive sub 37 by one or more drive sub keys 42. The drive sub gear 41 is coupled to a worm gear 31, which is connected to, and could be formed as part of, the drive shaft 5.

The hanger assembly gear 33, the hanger keys 35, the drive sub 37 and the drive sub retainer 39 may be made of any material(s) sufficiently rigid to handle expected loads. Material(s) resistant to corrosion or deterioration from well fluids and/or industrial chemicals used in well operations may be preferred. For example, NACE-compliant 4130 steel or stainless steel could be used.

The worm gear 31, the drive sub gear 41 and the drive sub keys 42 may similarly be made of any rigid material(s) capable of handling expected loads, and may be made of the same material(s) as the hanger assembly gear 33, the hanger keys 35, and/or the drive sub 37, or of different material(s). For example, corrosion deterioration from well fluids and industrial chemicals used in well operations might not be as much of a concern for the worm gear 31, the drive sub gear 41 and the drive sub keys 42 as these parts are not exposed to well fluids.

A plug 27 and a plug 29 are received in radial bores 17, and are illustrative examples of types of plugs generally designated at 9 in FIGS. 1 and 3. The plug 27 is located in a radial bore 17 that connects the exterior of the housing 3 with a generally annular cavity 70 formed between the housing 3 and the drive sub assembly 45. In FIGS. 2 and 4, the plug 27 is a bleeder. The plug 29 is located in a radial bore 17 that connects the exterior of the housing 3 with a part of the cavity 70 that contains the worm gear 31. In FIGS. 2

54846-20

and 4, the plug 29 is a grease-fitting vent cap. As shown, the radial bores 17 may have different shapes and sizes, and a single bore may have different diameters. Plugs, such as the plugs 27, 29, or other components such as fittings, could instead be installed in the radial bores 17, and could similarly have different shapes, sizes, and/or purposes.

The plugs 27, 29 may be any plugs that permanently or temporarily prevent fluid communication between the exterior of the housing 3 and the interior of the housing 3. For example, the plugs 27, 29 could be pipe plugs instead of a bleeder and a grease fitting vent cap as shown.

In operation, the worm gear 31 indirectly drives the mandrel 21. The worm gear 31 meshes with the drive sub gear 41, which as noted above is connected to the drive sub 37. The drive sub 37 is engaged with the hanger assembly gear 33, which is connected to the mandrel 21 by the hanger keys 35. Rotation of the worm gear 31, by driving the drive shaft 5 (FIG. 1), thus rotates the mandrel 21 and any production tubing coupled thereto.

The engagement between the hanger assembly 19 and the drive sub 37 can perhaps best be seen with reference to the side view of the hanger assembly 19 in FIG. 3 and the cross-section view of the housing in FIG. 4. As shown in FIG. 3, the hanger assembly gear 33 has one or more tapered lugs 33a. The tapered lugs 33a could be formed on the hanger assembly gear 33 by machining such as turning, milling or broaching, for example. Other processes could also or instead be used to provide the tapered lugs 33a on the hanger assembly gear 33. As shown in the cross-section of the housing in FIG. 4, tapered lugs 37a, facing inwards, are also formed or otherwise provided on an inner surface of the drive sub 37. In the embodiment shown, both the hanger assembly gear 33 and the drive sub 37 have multiple lugs 33a, 37a and the lugs fully mesh, with each lug being received in each slot between adjacent lugs when the wellhead tubing rotator 1 is assembled. In other embodiments, more or fewer lugs could be provided on one of the hanger assembly gear 33 and the drive sub 37, to mesh with slots that are provided on the other.

54846-20

Each of the lugs 33a on the hanger assembly gear 33 has tapered corners 33b, 33c at its lower end, to aid the meshing or inter-locking of the lugs 33a of the hanger assembly gear 33 with the lugs 37a of the drive sub 37 when the hanger assembly 19 is lowered or otherwise placed inside the drive sub 37. Each of the lugs 37a on the drive sub 37 similarly has tapered corners 37b, 37c at its upper end, which may further aid in meshing or interlocking the lugs 37a with the lugs 33a. FIGS. 3 and 4 also show tapered ends 33d, 37d on the lugs 33a, 37a, respectively, which may also aid in meshing or interlocking the lugs. In other embodiments, lugs 33a, 37a may have different shapes than those shown.

The tapered corners 33b, 33c, 37b, 37c taper the lugs 33, 37 along an axial direction. Without the tapered ends 33d, 37d, a width of the lugs 33 tapers along the downward axial direction in FIG. 3 and a width of the lugs 37 tapers along the upward axial direction in FIG. 4. The tapered ends 33d, 37d could be considered a form of radial tapering in that a radial thickness of the lugs 33d, 37d is tapered. Thus, the lugs 33 of the hanger assembly gear 33 and the lugs 37a of the drive sub assembly 45 may be tapered in an axial direction and/or a radial direction.

Force that is applied to the hanger assembly gear 33 is transferred to the mandrel 21 through the hanger keys 35. In an embodiment shown in the exploded, isometric view of the hanger assembly 19 in FIG. 5, the hanger keys 35 are placed into respective key slots 35a in the mandrel 21, and engage with slots 35b in an inner surface of the hanger assembly gear 33. The slots 35a, 35b could be machined or otherwise provided in the outer surface of the mandrel 21 and the inner surface of the hanger assembly gear 33.

In the example shown, three hanger keys 35 are visible in FIG. 5, but there may be more or fewer keys in other embodiments. For instance, a fourth hanger key and key slot, which are not visible in FIG. 5, could be provided, such that each of the four keys engages one of the slots 35b in the inner surface of the hanger assembly gear 33. Hanger keys and slots could be symmetrically distributed or otherwise arranged around the mandrel 21 and the hanger assembly gear 33.

54846-20

A key structure could also or instead be used in transferring force from the drive sub gear 41 to the drive sub 37. As shown in the exploded, isometric view of the drive sub assembly in FIG. 7, for example, drive sub keys 42 are placed into respective key slots 42a in the drive sub 37, and engage with slots 42b in an inner surface of the drive sub gear 41. The slots 42a, 42b could be machined or otherwise provided in the outer surface of the drive sub 37 and the inner surface of the drive sub gear 41.

Although three drive sub keys 42 are visible in FIG. 7, there may be more or fewer keys in other embodiments. The drive sub gear 41 includes four slots 42b, for example, and a fourth drive sub key could be provided. There would then be one drive sub key to engage each of the four slots 42b in the inner surface of the drive sub gear 41. Like the hanger keys and slots described above, drive keys and slots could be symmetrically or otherwise distributed, around the drive sub 37 and the drive sub gear 41.

The key-based connection structures between the hanger assembly gear 33 and the mandrel 21, and between the drive sub gear 41 and the drive sub 37 are illustrative examples. Other structures such as fasteners, or techniques such as welding, could be used to connect these components together in other embodiments. The hanger assembly gear 33 and/or the drive sub gear 41 could instead be machined or otherwise provided in a surface of the mandrel 21 or a surface of the drive sub 37. For example, the lugs 33a (FIG. 3) could be machined into the outer surface of the mandrel 21, and/or the lugs 37a could be machined into the inner surface of the drive sub 37.

When the wellhead tubing rotator 1 is installed and coupled to the production tubing 23 (FIG. 1), the housing internal shoulder 68a (most clearly visible in FIG. 4) bears the weight of the production tubing string via the corresponding shoulder 68b cut or milled into the hanger assembly housing 43. Therefore, the drive sub assembly 45 does not bear the weight of the production tubing 23.

The bearing assembly 57 allows the mandrel 21 to rotate relative to the hanger assembly housing 43, which remains stationary relative to the housing 3 during tubing rotation. The bearing assembly 57 not only supports the mandrel 21, but also carries side loading between the mandrel 21 and the hanger assembly housing 43. Side

54846-20

loading between the mandrel 21 and the hanger assembly housing 43 may be created, for example, in slant wells and deviated wells.

The bearing assembly 57, in an example shown in more detail in FIG. 5, includes ball bearings in a bearing race 59. The bearing race 59 may be made of any material(s) sufficiently rigid to support the expected weight of the tubing string. For example, in one embodiment the ball bearings and the bearing race 59 are made of stainless steel.

The drive sub 37 is similarly supported by a bearing ring 69, which as shown in FIG. 4 is supported by the drive sub retainer 39 that is coupled to the housing 3. The drive sub 37 abuts a shoulder 3b on the inner surface of the housing 3. Another bearing ring 67 may be provided between the drive sub gear 41, the drive sub 37 and the housing 3, since the drive sub gear 41 and the drive sub 37 rotate relative to the housing 3 during tubing rotation. The bearing rings 67, 69 are made of material(s) sufficiently rigid to withstand expected loading. For example the bearing rings 67, 69 may be made of bearing bronze. Since the bearing rings 67, 69 are isolated from well fluids as described below, resistance to corrosion might not be of concern in material selection.

The bearing rings 67, 69 are illustrative of a type of bearing that could be used between components that move relative to each other, and other types of bearings, fewer bearings, or additional bearings may be provided in other embodiments. For example, a single bearing such as the bearing ring 69 could be used between the drive sub 37 and the drive sub retainer 39 to support vertical loads and still permit rotation of the drive sub 37. The bearing ring 67 or another type of bearing between the drive sub gear 41, the drive sub 37 and the housing 3 may be provided for additional side load support, but need not be provided in all embodiments.

A bushing 55 located between the hanger assembly housing 43 and the mandrel 21 could be used in some embodiments to provide additional load support, for side loading of the mandrel 21 for instance. The bushing 55 allows the mandrel 21 to rotate inside the hanger assembly housing 43, even under significant side loading. Side loading may occur when the wellhead is employed in a slant well application, in particular with a slant wellhead at the surface. The bushing 55, like other load carrying components, is made

54846-20

of material(s) such as bearing bronze, having sufficient rigidity to withstand expected loads.

Various seals are also shown in FIGS. 2 to 5 and 7. The purposes or effects of these seals can perhaps best be understood with reference to FIGS. 2 and 4.

Seals 47, 49, 51, 61, 65 may be exposed to wellbore pressures, and therefore are made of material(s) that can withstand such pressures. A seal 63 may be made of the same material(s) as the seals 47, 49, 51, 61, 65, but the seal 63 may be exposed to lower pressures and therefore may be made of different materials. Seal materials may also or instead be selected based on whether the seals are between parts that are stationary or movable relative to each other. The seals 49, 51, 61, 65 are moveable seals, whereas the seals 47, 63 are stationary. Another factor that may be used in seal material selection is expected fluid exposure. For example, the seals 47, 49, 61, 65 may have the greatest exposure to well fluids, and material(s) resistant to corrosion or deterioration from well fluids and/or industrial chemicals used in well operations may be preferred for at least these seals. In an embodiment, all of the seals 47, 49, 51, 61, 63, 65 are rubber O-Rings. In another embodiment, at least the movable seals 49, 51, 61, 65 are PolypakTM rings.

The seals 47 allow the hanger assembly 19 to seal against the housing 3. The seals 49, 51 allow the mandrel 21 to seal against the hanger assembly housing 43. The seals 61, 65 seal the cavity 70 from well fluids. The seal 63 is a backup or safety seal to seal the drive sub retainer 39 against the housing 3, to help prevent leakage of well fluids to the atmosphere if either or both of the seals 61, 65 are leaking.

There may also be other seals in a complete wellhead equipment installation. For example, a groove 73 (FIG. 7) may be formed in the drive sub retainer 39 to accommodate an additional seal to permit the wellhead tubing rotator 1 to be sealed to other wellhead equipment. In an embodiment, a metal ring gasket may be placed in the groove 73.

The drive sub assembly 45, with its seals 61, 65 defines the sealed cavity 70 (FIG. 4) that isolates the worm gear 31, the drive sub gear 41 and other components such as the

54846-20

drive sub keys 42 in the example shown, from well fluids. Removal of the hanger assembly 19 from the housing 3 does not affect the sealed cavity 70. The sealed cavity 70 could be accessible through the radial bores 17 to apply grease into the cavity, for example, but remains sealed from well fluids. Pipe plugs could be used instead of the plug 27, which is shown as a bleeder (FIG. 2), and the plug 29, which is shown as a grease-fitting vent cap (FIG. 2), to seal the cavity 70 from the exterior of the housing 3, between grease applications and/or other servicing for instance.

Holes 75 (FIG. 4) allow the drive sub retainer 39 to be coupled to the drive sub 37 as described with reference to FIG. 7, herein.

The housing 3 may also have one or more axial bores or holes 77 (FIG. 4) that may allow the wellhead tubing rotator 1 to be coupled to other wellhead equipment using, for example, bolts and nuts. Other means of connecting the wellhead tubing rotator 1 to other wellhead equipment, such as a clamping system, could also or instead be used.

Most of the components of the wellhead tubing rotator 1 that are involved in rotation of production tubing are described above. Other components may also be provided.

FIG. 5 is an exploded, isometric view of the hanger assembly 19. With reference to FIG. 5, the following operations are performed to assemble the hanger assembly 19 in an embodiment:

the seal 49 is positioned in a groove 21a in the mandrel 21;

the bearing assembly 57 is slid onto the mandrel 21 to abut a bottom surface of a top flange 21d of the mandrel;

the bushing 55 is slid onto the mandrel 21 to abut a shoulder 21b on the mandrel;

the hanger keys 35 are placed into the key slots 35a;

the seals 47 are placed into grooves 43a, 43b in the outer surface of the hanger assembly housing 43;

54846-20

the seal 51 is placed into a groove in the inner surface of the hanger assembly housing 43;

the hanger assembly housing 43 is slid onto the mandrel 21 to position the bearing assembly 57 between an internal shoulder 43c of the hanger assembly housing 43 and the bottom surface of the top flange 21d of the mandrel;

the hanger assembly gear 33 is slid onto the mandrel 21;

the slots 35b in the inner surface of the hanger assembly gear 33 are aligned with the hanger keys 35;

the hanger assembly gear 33 is slid further along the mandrel 21 to abut the hanger assembly housing 43; and

the retainer 53, illustratively a stainless steel snap ring, is installed into the groove 21c on the mandrel 21 to hold components of the hanger assembly 19 on the mandrel 21.

These operations may be performed in a different order in other embodiments. There could also be additional operations, such as applying lubricants and/or sealing compounds during assembly. Fewer operations could be involved in embodiments that have fewer components, such as embodiments in which the lugs 33a on the hanger assembly gear 33 are machined into the mandrel 21.

The housing 3 may also have components assembled or installed therein. With reference to the isometric view of the wellhead tubing rotator 1 in FIG. 6, components such as the locking pins 7 (four in the example shown) and the plugs 9 could be installed before or after the hanger assembly 19 is installed in the housing 3. The drive sub assembly 45 is installed in the housing 3, before or possibly after the hanger assembly 19 is installed.

FIG. 7 is an exploded, isometric view of the drive sub assembly 45. With reference to FIGS. 4 and 7, the following operations are performed to assemble the drive sub assembly 45 and install it into the housing 3 in an embodiment:

54846-20

the drive sub keys 42 are placed into the key slots 42a in the drive sub 37;

the drive sub gear 41 is slid onto the drive sub 37;

the key slots 42b in the inner surface of the drive sub gear 41 are aligned with the drive sub keys 42;

the drive sub gear 41 is slid further along the drive sub 37 to abut a shoulder 37e on the drive sub 37;

a retainer 71, illustratively a stainless steel snap ring, is installed into a groove 37f on the drive sub 37 to hold the drive sub gear 41 on the drive sub 37;

the bearing ring 67 is slid onto the drive sub 37 to abut the drive sub gear 41;

the seal 61 is placed into a groove 37g in the outer surface of the drive sub 37;

the drive sub 37 is slid into the housing 3 to abut the shoulder 3b (FIG. 4) on the inner surface of the housing 3;

the bearing ring 69 is slid onto the drive sub 37 to abut a shoulder 37h on the outer surface of the drive sub 37;

the seal 65 is placed into a groove 39a in the inner surface of the drive sub retainer 39;

the seal 63 is placed into a notch 3c (FIG. 4) in the inner surface of the housing 3 or around an outer surface of the drive sub retainer 39; and

the drive sub retainer 39 is connected to the housing 3 such that the drive sub retainer 39 abuts the bearing ring 69.

In an embodiment, the holes 75 in the drive sub retainer 39 (FIG.4) allow a C-wrench to be used in threadedly connecting the drive sub retainer 39 to the housing 3 by engaging threads on an outer surface of the drive sub retainer with threads on an inner surface of the housing.

54846-20

These operations may be performed in a different order in other embodiments. There could also be additional operations, such as applying lubricants and/or sealing compounds during assembly. Fewer operations could be involved in embodiments that have fewer components, such as embodiments in which the drive sub gear 41 is machined into the drive sub 37.

FIGS. 8A to 8E show additional internal details of the wellhead tubing rotator 1. FIG. 8A is a side view of the wellhead tubing rotator 1. FIGS. 8B to 8D are cross-section views of the wellhead tubing rotator 1 along lines 8B—8B, 8C—8C, and 8D—8D, respectively, shown in FIG. 8A, and FIG. 8E is a detail view of window 8E as shown in FIG. 8B.

Referring to FIG. 8B, this drawing shows the worm gear 31 formed as part of the drive shaft 5, but in other embodiments the worm gear 31 could be a separate component that is connected to the drive shaft 5. The worm gear 31 is held in place by a bearing 79 and a bearing 81. The bearings 79, 81 may be made of any material(s) having sufficient compressional strength to support expected loading. For example, the bearings 79, 81 are thrust bearings made of bearing bronze in an embodiment.

FIG. 8B also illustrates that the plug 29 in this embodiment provides access to the worm gear 31, for applying grease to the gear for example. The drive sub keys 42 are also shown.

FIG. 8C is a cross-section view through the bearing assembly 57, and individual ball bearings are visible in this view.

Referring now to FIG. 8D, the coupling of the drive sub 37 to the hanger assembly gear 33 and the hanger assembly gear 33 to the mandrel 21 is shown. In the example shown, four hanger keys connect the mandrel 21 to the hanger assembly gear 33, and ten lugs on the hanger assembly gear 33 mesh with ten lugs on the drive sub 37.

Referring now to FIG. 8E, a seal is created between the drive shaft 5 and the housing 3 by seals 83, 85, 87. A seal retainer 91 holds the seal 85 in place. A retainer nut 93 is held in place with a nut 89. Both the retainer nut 93 and the nut 89 are threadedly coupled to the housing 3. The seals 83, 85, 87 may be made of material(s) similar to

54846-20

the seal material(s) of the seals 47, 49, 51, 61, 63, 65. For example, the seals 83, 87 are rubber O-rings and the seal 85 is a PolypakTM ring in an embodiment. The nut 89, the seal retainer 91, and the retainer nut 93 may be made of any material(s) with sufficient strength to retain the drive shaft 5, the seals 83, 85, 87, and the bearing 81 in place, such as stainless steel.

Referring now to FIGS. 8B and 8E, when the drive shaft 5 turns the worm gear 31, a force is created on one or both of the bearings 79, 81. The bearings 79, 81 allow the drive shaft 5 to rotate, and retain the worm gear 31 in an appropriate position in which it meshes with the drive sub gear 41.

The seals 83, 85, 87 seal the cavity 70 that is formed between the housing 3 and the drive sub assembly 45 from the exterior of the housing 3.

The drive mechanism 5a is perhaps most clearly shown in FIGS. 8B, 8E and 8F. FIG. 8F is an isometric view of the wellhead tubing rotator 1, with the drive mechanism 5a exploded therefrom. The drive mechanism 5a includes the drive shaft 5, the worm gear 31 and the bearings 79, 81.

The drive mechanism 5a may be installed before or after the drive sub assembly 45 is installed in the housing 3. With reference to FIGS. 8B, 8E and 8F the following operations are performed to assemble the drive mechanism 5a in an embodiment:

the bearing 79 is placed into the housing 3 to abut a shoulder 3d on the housing 3;

the drive shaft 5 is slid into a bore 5b and the bearing 79, and may also be rotated to mesh with the drive sub gear 41;

the bearing 81 is slid onto the drive shaft 5 to abut a shoulder 3e on the housing 3;

the seal 87 is placed against a shoulder 93a on the retainer nut 93, and the retainer nut 93 is then slid onto the drive shaft 5 and threaded into the housing 3 to abut the bearing 81;

54846-20

the seal 85 is slid onto the drive shaft 5 to abut a shoulder 93b of the retainer nut 93;

the seal retainer 91 is slid onto the drive shaft 5 to abut the seal 85; and

the seal 83 is placed into a groove 89a in the nut 89 and the nut 89 is slid onto the drive shaft 5 and threaded into the housing 3 to abut the retainer nut 93 and the seal retainer 91.

These operations may be performed in a different order in other embodiments. There could also be additional operations, such as applying lubricants and/or sealing compounds during assembly. For example, Loctite™ could be placed onto threads of the nut 89 before it is threadedly connected to the housing 3. Fewer operations could be involved in embodiments that have fewer components.

FIG. 9 is a cross-section view of the locking pin shown 7 in FIG. 6, and FIG. 10 is an exploded view of the locking pin 7. As shown, washers 99, 103, packing 101, and the locking nut 97 are fitted onto the locking bolt 95. The locking bolt 95 is threaded into a threaded bore the housing 3. The washers 99, 103 and the packing 101 are then also installed into the bore, and the locking nut 97 is then threadedly coupled to the housing 3. The extent to which the locking bolt 95 protrudes from an interior surface 3a of the rotator housing is controllable by turning the locking bolt 95. The washers 99, 103 and the packing 101 are held in place against a shoulder in the bore by the locking nut 97.

In the embodiment shown in FIG. 9, the locking nut 97 is threaded into the housing 3 until the packing 101 seals between the bore and the locking bolt 95. The locking bolt 95 can then be safely moved while under pressure. The locking bolt 95 moves between a locked position, where a shoulder 95a of the locking bolt 95 protrudes from the bore and contacts a shoulder of the hanger assembly housing 43 in the embodiment shown, and an unlocked position, where the shoulder 95a of the locking bolt no longer protrudes from the bore and a second shoulder 95b of the locking bolt 95 may be in contact with the washer 103. In the locked position shown, the locking bolt 95 abuts the hanger assembly housing 43 such that further upwards movement of the hanger assembly housing 43 is limited by the locking bolt 95.

54846-20

The locking nut 97 and the locking bolt 95 are made of stainless steel in an embodiment. The washers 99, 103 are also made of stainless steel and the packing 101 is rubber in an embodiment.

FIG. 11 is an isometric view of a wellhead tubing rotator according to a second embodiment, with a shear sub exploded therefrom.

A wellhead tubing rotator 105 shares many features with the wellhead tubing rotator 1 described above. However, the wellhead tubing rotator 105 also has an upper sub 109, which is a part of a hanger assembly 115.

The upper sub 109 allows for the mandrel 107 to be detached from other parts of the hanger assembly 115 as is described in more detail below with reference to FIGS. 15A to 15E.

The upper sub 109 has one or more axial bores or holes 111. For example, two bores 111 are shown in FIG. 11. The bores 111 in the upper sub 109 allow for the upper sub 109 to be assembled with or disassembled from the mandrel 107 by means of a C-wrench.

The upper sub 109 and the mandrel 107 may be made of any material(s) sufficiently rigid to support expected loading. For example, NACE-compliant 4130 steel or stainless steel is used in an embodiment.

The wellhead tubing rotator 105 may be coupled to the production tubing 23 via the mandrel 107. The production tubing 23 is not part of the wellhead tubing rotator 105, but is shown in FIG. 11 to illustrate how the wellhead tubing rotator 105 is coupled to the production tubing 23 in an embodiment.

The drive shaft 5 may be coupled to a shear sub 139. The shear sub 139 is constructed to limit force transfer such that the drive shaft 5 is not overtorqued. The shear sub 139 is also not part of the wellhead tubing rotator 105, but is shown in FIG. 11 to illustrate how the drive shaft 5 may be coupled to the shear sub 139.

54846-20

With reference to FIGS. 12 to 14, FIG. 12 is a cross-section view of the wellhead tubing rotator 105, along line 12—12 shown in FIG. 11, FIG. 13 is a cross-section view of the hanger assembly 115 shown in FIG. 12, and FIG. 14 is an exploded, isometric view of the hanger assembly 115 of FIG. 13.

The hanger assembly 115 includes the mandrel 107, an upper sub assembly 119, a hanger assembly housing 117 and a hanger assembly gear 127. The upper sub assembly 119 includes the upper sub 109 and one or more fasteners 113.

The mandrel 107 is supported by the upper sub 109. The upper sub 109 is supported by a bearing assembly 123. The bearing assembly 123 is supported by the hanger assembly housing 117, which rests against the housing internal shoulder 68a of the housing 3. As shown perhaps most clearly in FIG. 13, the hanger assembly housing 117 includes the shoulder 68b, which engages the housing internal shoulder 68a when the hanger assembly 115 is installed in the housing 3. Other embodiments of these shoulders are contemplated, as described above with reference to the housing 3 and the hanger assembly 19.

The hanger assembly 115 is coupled to the drive sub assembly 45 via the hanger assembly gear 127. The hanger assembly gear 127 is connected to the upper sub 109 by one or more hanger keys 129. The upper sub 109 is attached to the mandrel 107 by a connection between threads 114a on an inner surface of the upper sub 109 and threads 114b on an outer surface of the mandrel 107, and by the fasteners 113. Other types of connections could be used in other embodiments to connect the upper sub 109 and the mandrel 107 to each other.

The upper sub 109 has one or more radial holes or bores 109b and the mandrel 107 has one or more radial bores or holes 107a. For example, in FIG. 14, two radial bores 109b and two radial bores 107a are visible, and radial bores 109b, 107a are aligned. The fasteners 113 are threadedly engaged with a radial bore 109b, which allows the fasteners to be extended into and retracted from the radial bores 107a. The fasteners 113 could have different shapes, sizes, and/or engagements with the radial bores 109b, 107a in other embodiments.

54846-20

The fasteners 113 may be made of any material(s) sufficiently rigid to withstand expected loading between the upper sub 109 and the mandrel 107. For example, the fasteners 113 could be stainless steel bolts.

The drive sub assembly 45, the housing 3, the drive mechanism 5a, the locking pins 7 and the plugs 9, 27, 29 have similar parts, configurations and preferred materials to those identified above in association with the first embodiment.

The hanger assembly housing 117; the bearing assembly 123, illustratively including ball bearings in a bearing race 121 (FIGS. 13 and 14); the hanger assembly gear 127; and the hanger keys 129 may be made of similar materials and have similar configurations as those described above in association with the first embodiment.

Various seals are also shown in FIGS. 12 to 14. The purposes or effects of these seals can perhaps best be understood with reference to FIGS. 12 and 13. The seals 47, 133, 135, 137 may be exposed to wellbore pressure, and therefore are made of material(s) that can withstand such pressures. The seals 133, 135 are moveable seals, whereas the seals 47, 137 are stationary. In an embodiment, the seals 47, 137 are O-rings, and the seals 133, 135 are PolypakTM rings. The seals 47 allow the hanger assembly housing 117 to seal against the housing 3, as in the first embodiment described above. The seals 133, 135 allow the upper sub 109 to seal against the hanger assembly housing 117. These seals 133, 135 are similar to the seals 51, 49 (FIG. 4) in the first embodiment, but in the first embodiment the seals 51, 49 allow the mandrel 21, instead of an upper sub 109 as in FIG. 12, to seal against the hanger assembly housing 43. The seal 137 does not have a counterpart in the first embodiment, but allows the mandrel 107 to seal against the upper sub 109 in the second embodiment, as shown in FIG. 12, for example.

A bushing 125 located between the hanger assembly housing 117 and the upper sub 109 could be used in some embodiments to provide additional load support in a similar manner to the bushing 55 described herein. The bushing 125, like other load carrying components, is made of material(s) having sufficient rigidity to withstand expected loads.

54846-20

An opening 117f is provided in the hanger assembly housing 117 allows for the equalization of pressure between the seals 47 during installation or disassembly of the hanger assembly 115.

The hanger keys 129 and the hanger assembly gear 127 are held in place on the upper sub 109 by a retainer 131. Although the hanger assembly gear 127 is carried by the upper sub 109 in the second embodiment, the hanger assembly gear 127 may be the same as or substantially similar to the hanger assembly gear 33 of the first embodiment, and includes tapered lugs 127a (FIG. 14) to mesh with tapered lugs in the drive sub 37 in the housing 3.

With reference to FIGS. 13 and 14, the following operations are performed to assemble the hanger assembly 115 in an embodiment:

- the seals 47 are positioned in grooves 117e on the hanger assembly housing 117;

- the bearing assembly 123 is placed on a shoulder 117b of the hanger assembly housing 117;

- the bushing 125 is placed on a shoulder 117a on the hanger assembly housing 117;

- the seal 133 is positioned in a groove 117d in an inner surface of the hanger assembly housing 117;

- the seal 135 is positioned in a groove 109c in the upper sub 109, and the upper sub 109 is slid into the hanger assembly housing 117 to abut the bearing assembly 123 and the bushing 125;

- the hanger keys 129 are placed into hanger key slots 129a in the outer surface of the upper sub 109;

- the hanger assembly gear 127 is slid onto the upper sub 109;

54846-20

the slots 129b in the inner surface of the hanger assembly gear 127 are aligned with the hanger keys 129;

the hanger assembly gear 127 is slid further along the upper sub 109 to abut an end 117c of the hanger assembly housing 117;

the retainer 131, illustratively a stainless steel snap ring, is installed into a groove 109d on the upper sub 109 to hold the hanger keys 129 and the hanger assembly gear 127 on the upper sub 109;

the seal 137 is positioned in a groove 107b in the mandrel 107;

the mandrel 107 is inserted into the upper sub 109;

the threads 114b of the mandrel 107 are threaded into the threads 114a in the inner surface of the upper sub 109 so that a shoulder 107c on the mandrel 107 abuts the upper sub 109;

the fasteners 113 are inserted into the bores 109b in the upper sub 109; and

the fasteners 113 are threadedly tightened into the bores 109b so that the fasteners 113 extend into the bores 107a in the mandrel 107.

These operations may be performed in a different order in other embodiments. There could also be additional operations, such as applying lubricants and/or sealing compounds during assembly. Fewer operations could be involved in embodiments that have fewer components, such as embodiments in which the lugs 127a of the hanger assembly gear 127 are machined into the upper sub 109.

Threaded connections are also shown in FIG. 13 between the mandrel 107 and the upper sub 109, and the upper sub 109 and the fasteners 113. Other connection methods, such as lock-and-key connections, could also or instead be used.

The second embodiment is similar to the first embodiment in that the housing 3 bears the weight of the production tubing 23 via the housing internal shoulder 68a. Therefore, in the second embodiment the drive sub assembly 45 also does not bear the weight of

54846-20

the production tubing 23. Also like the first embodiment, in the second embodiment the drive sub gear 41 and the worm gear 31 are sealed from well fluids by the drive sub assembly 45.

The upper sub assembly 119 allows for the mandrel 107 to be released from other parts of the hanger assembly housing 117. For example, the mandrel 107 may be detached from the upper sub 109 by removing the fasteners 113 and unthreading the threads 114a, 114b. Detaching the mandrel 107 from the upper sub 109 may allow for the production tubing 23, and the mandrel 107 that is attached to the production tubing 23, to be moved further down into the well to wash or clear material that has deposited onto downhole equipment in the well. This may be especially useful in horizontal wells.

Two illustrative embodiments are shown in FIGS. 1 to 14 and described in detail above. Other embodiments are also contemplated. For example, FIG. 15 is a cross-section view of a hanger according to another embodiment.

A hanger assembly 179 shares many features with the hanger assembly 19 (FIGS. 1 to 4), and such shared features are labelled in FIG. 15 with the same reference numbers as above. However, the hanger assembly 179 also has additional components.

As shown, an upper auxiliary sub 172 is threadedly connected to a hanger assembly housing 170 and rests on a bearing 176. The bearing 176 allows the mandrel 21 to rotate relative to the upper auxiliary sub 172.

The upper auxiliary sub 172 seals against the mandrel 21 and the hanger assembly housing 170 by means of seals 178, 174, respectively.

The seal 178 is a moveable seal and the seal 174 is a stationary seal. The seals 178, 174 may be exposed to well pressure, and therefore are made of material(s) that can withstand such pressures. The seals 178, 174 may be made of similar materials to the seals 49, 47, respectively.

The bearing 176 may be made of material(s) having sufficient rigidity to withstand expected loads.

54846-20

The upper auxiliary sub 172, and the hanger assembly housing 170 may be made of any material(s) with sufficient rigidity and resistance to corrosion.

In operation, the shoulder 95a of the locking pin 7 (FIG. 9) abuts a shoulder 172a of the upper auxiliary sub 172. The larger thickness in the radial direction of the upper auxiliary sub 172 relative to that of the hanger assembly housing 43 may help reduce the likelihood that overtightening of the locking pin 7 will prevent the mandrel 21 from turning. The thicker upper auxiliary sub 172 is less likely to be deformed than the hanger assembly housing 43 by overtightening of the locking pin 7.

Further embodiments are also contemplated. FIG. 16 is a cross-section view of a hanger assembly according to a further embodiment.

A hanger assembly 180 shares many features with the hanger assembly 115 (FIGS. 11 to 14) and such shared features are labelled in FIG. 16 with the same reference numerals as above. However, similar to the hanger assembly 179 (FIG. 15), the hanger assembly 180 also has additional components.

As shown, an upper sub 152 is threadedly connected to the mandrel 107 and an upper auxiliary sub 154 is threadedly connected to a hanger assembly housing 150 and rests on a bearing 156. The bearing 156 is identical to the bearing 176 except that the bearing 156 is supported by the upper sub 152.

The upper auxiliary sub 154 seals against the hanger assembly housing 150 and the upper sub 152 by means of seals 158, 160, respectively.

The seal 160 is a moveable seal and the seal 158 is a stationary seal. The seals 160, 158 may be exposed to well pressure, and therefore are made of material(s) that can withstand such pressures. The seals 160, 158 may be made of similar materials to the seals 178, 174, respectively.

The bearing 156 may be made of material(s) having sufficient rigidity to withstand expected loads.

54846-20

The upper auxiliary sub 154, the upper sub 152 and the hanger assembly housing 150 may be made of any material(s) with sufficient rigidity and resistance to corrosion.

In operation, the shoulder 95a of the locking pin 7 (FIG. 9) abuts a shoulder 154a of the upper auxiliary sub 154. The larger thickness in the radial direction of the upper auxiliary sub 154 relative to that of the hanger assembly housing 117 (FIG. 13) may help reduce the likelihood that overtightening of the locking pin 7 will prevent the mandrel 107 from turning. The thicker upper auxiliary sub 154 is less likely to be deformed than the hanger assembly housing 117 by overtightening of the locking pin 7.

Different stages of removing portions of the hanger assembly are depicted in the cross-section views in FIGS. 17A to 17E. FIG. 17A shows the wellhead tubing rotator 105 in an assembled position in which the mandrel 107 is connected to the production tubing 23. In FIG. 17B, a connector 138, which may also be referred to as a pick up sub, is coupled to the mandrel 107, by threading the connector to the mandrel 107 for example. The connector 138 may be made of any rigid material(s) that can carry expected loads, such as a stub or section of production tubing. The locking pins 7 may be backed off or otherwise retracted from protruding inside the housing 3 before or after the connector 138 is coupled to the mandrel 107. FIG. 17C shows the connector 138 being lifted, by using wellhead equipment to apply a lifting force for example, to remove the hanger assembly 115 from the housing 3. At this stage, the drive sub assembly 45 remains in the housing 3.

Referring now to FIG. 17D, the fasteners 113 are removed, thereby partially releasing the upper sub 109 from the mandrel 107. FIG. 17E shows the mandrel 107 after it has been decoupled from the upper sub assembly 119, by unthreading the upper sub assembly from the mandrel 107 for example. At this point the mandrel 107, which is coupled to the production tubing 23, is free to be moved upwards and/or downwards.

Examples of wellhead tubing rotators are described in detail above. Wellhead tubing rotators may be implemented in conjunction with, and coupled to, the production tubing 23 that is to be placed in a well, a manual drive or an electric or hydraulic motor to drive the drive shaft 5, and other wellhead or surface production equipment.

54846-20

The embodiments described above relate primarily to examples of wellhead tubing rotators. Methods are also contemplated.

FIG. 18 is a flow chart of a method of manufacturing a wellhead tubing rotator. The example method 1800 involves providing, at 1802, a housing that includes an internal shoulder. This could involve machining or otherwise manufacturing the housing, or purchasing the housing from a manufacturer, for example. A drive mechanism is sealed in a sealed cavity between the housing and a drive sub assembly that is engaged with the drive mechanism and sealed against an interior of the housing, at 1804. At 1806, a hanger assembly, which is to be coupled to production tubing in a production well, is installed in the housing by placing the hanger assembly on the internal shoulder of the housing and into engagement with the drive sub.

FIG. 19 is a flow chart of a method of using a wellhead tubing rotator. The example method 1900 involves securing, at 1902, a housing of a wellhead tubing rotator to a wellhead of a production well. The housing has an internal shoulder. The wellhead tubing rotator also has: a drive mechanism located in the housing; a drive sub assembly engaged with the drive mechanism and sealed against an interior of the housing to define a sealed cavity that isolates the drive mechanism between the housing and the drive sub assembly; and a hanger assembly, supported by the internal shoulder of the housing and engaged with the drive sub assembly, to be coupled to production tubing in the production well, as described above. The hanger assembly is coupled to the production tubing, at 1904. The hanger assembly is lowered into the housing, at 1906. At 1908, a force is provided to the drive mechanism to rotate the hanger assembly.

The methods 1800, 1900 are illustrative embodiments. Other embodiments could involve performing the illustrated operations in a similar or different order, and/or performing additional operations. For example, other embodiments could involve providing and assembling other components of a wellhead tubing rotator. For instance, one embodiment could involve a kit including a housing, such as 3, a drive mechanism, such as 5a, a drive sub assembly, such as 45, and a hanger assembly, such as 19 or 115, along with instructions for assembling the housing, the drive mechanism, the drive

54846-20

sub assembly and the hanger assembly to form a wellhead tubing rotator, such as 1 or 105. Assembly of hanger assemblies and a housing are described above. Other variations may also be or become apparent to a skilled person.

What has been described is merely illustrative of the application of principles of embodiments of the present disclosure. Other arrangements and methods can be implemented by those skilled in the art.

For example, the hanger assembly housings 43 and 117 are described above as being supported on the housing internal shoulder 68a. However, other means for supporting the hanger assembly housings 43 and 117 are possible, such as a locking pin system.

As another example, the mandrels 21 and 107 are described above as being support by the bearing assemblies 57 and 123. However, other options to support the mandrels 21 and 107 while allowing them to rotate could also or instead be used, such as a sleeve bearing or magnetic support.

54846-20

I Claim:

1. A wellhead tubing rotator comprising:

a housing comprising an internal shoulder;

a drive mechanism located in the housing;

a drive sub assembly engaged with the drive mechanism and sealed against an interior of the housing to define a sealed cavity that isolates the drive mechanism between the housing and the drive sub assembly; and

a hanger assembly, supported by the internal shoulder of the housing and engaged with the drive sub assembly, to be coupled to production tubing in a production well.

2. The wellhead tubing rotator according to claim 1, wherein the hanger assembly comprises:

a hanger assembly housing, supported by the internal shoulder of the housing;

a hanger assembly bearing, supported by the hanger assembly housing;

a hanger assembly gear, engaged with the drive sub assembly; and

a mandrel, supported by the hanger assembly bearing and engaged with the hanger assembly gear, to be coupled to the production tubing.

3. The wellhead tubing rotator according to claim 2, wherein the mandrel is sealed against the hanger assembly housing, and the hanger assembly housing is sealed against the housing.

54846-20

4. The wellhead tubing rotator according to claim 2, wherein the mandrel is engaged with the hanger assembly gear by a hanger key that fits into slots in the mandrel and in the hanger assembly gear.

5. The wellhead tubing rotator according to claim 1, wherein the hanger assembly comprises:

a hanger assembly housing, supported by the internal shoulder of the housing;

a hanger assembly bearing, supported by the hanger assembly housing;

a hanger assembly gear, engaged with the drive sub assembly;

an upper sub assembly, supported by the hanger assembly bearing and engaged with the hanger assembly gear; and

a mandrel, connected to the upper sub assembly, to be coupled to the production tubing.

6. The wellhead tubing rotator according to claim 5, wherein the mandrel is sealed against the upper sub assembly, the upper sub assembly is sealed against the hanger assembly housing, and the hanger assembly housing is sealed against the housing.

7. The wellhead tubing rotator according to claim 5, wherein the upper sub assembly is engaged with the hanger assembly gear by a hanger key that fits into slots in the upper sub assembly and in the hanger assembly gear.

8. The wellhead tubing rotator according to claim 5, wherein the upper sub assembly comprises:

54846-20

an upper sub; and

a fastener coupling the upper sub to the mandrel.

9. The wellhead tubing rotator according to any one of claims 2 or 5, wherein the hanger assembly gear is engaged with the drive sub assembly through lugs on the hanger assembly gear and on the drive sub assembly.

10. The wellhead tubing rotator according to claim 9, wherein the lugs of the hanger assembly gear and the lugs of the drive sub assembly are tapered in a direction axial to the hanger assembly.

11. The wellhead tubing rotator according to claim 9, wherein the lugs of the hanger assembly gear and the lugs of the drive sub assembly are tapered in a direction radial to the hanger assembly.

12. The wellhead tubing rotator according to any one of claims 1 to 11, wherein the drive sub assembly comprises:

a drive sub, engaged with the hanger assembly;

a drive sub retainer, engaged with the housing and the drive sub; and

a drive sub gear, engaged with the drive sub and the drive mechanism.

13. The wellhead tubing rotator according to claim 12, wherein the drive sub retainer seals against both the drive sub and a first portion of the interior of the housing, and the

54846-20

drive sub seals against a second portion of the interior of the housing, the sealed cavity being defined between the housing, the drive sub retainer, and the drive sub.

14. The wellhead tubing rotator according to claim 13, wherein the drive sub gear is engaged with the drive sub by a drive sub key that fits into slots in the drive sub gear and in the drive sub.

15. The wellhead tubing rotator according to any one of claims 1 to 14, further comprising:

a pipe plug to prevent fluid communication via a channel between the sealed cavity and an exterior of the housing.

16. The wellhead tubing rotator according to claim 1, further comprising a locking pin installed in a bore in the housing to limit axial movement of the hanger assembly relative to the housing.

17. The wellhead tubing rotator according to claim 16, wherein the locking pin comprises:

a locking bolt; and

a first washer, packing, a second washer, and a locking nut arranged on the locking bolt.

18. The wellhead tubing rotator according to claim 2, wherein the hanger assembly further comprises:

54846-20

an auxiliary sub, engaged with the mandrel and the hanger assembly housing.

19. The wellhead tubing rotator according to claim 5, wherein the hanger assembly further comprises:

an auxiliary sub, engaged with the upper sub assembly and the hanger assembly housing.

20. The wellhead tubing rotator according to claim 18 or 19, further comprising a locking pin installed in a bore in the housing to limit axial movement of the hanger assembly relative to the housing, wherein the locking pin is engaged with the auxiliary sub.

21. A production assembly for producing a well comprising:

production tubing to be placed in the well; and

the wellhead tubing rotator as claimed in any one of claims 1 to 20, coupled to the production tubing.

22. A method of using the wellhead tubing rotator as claimed in any one of claims 1 to 20, the method comprising:

securing the housing to a wellhead;

coupling the hanger assembly to the production tubing;

lowering the hanger assembly into the housing; and

providing a force to the drive mechanism to rotate the hanger assembly.

54846-20

23. A kit comprising:

a housing, a drive mechanism, a drive sub assembly, and a hanger assembly as defined in any one of claims 1 to 20; and

instructions for assembling the housing, the drive mechanism, the drive sub assembly, and the hanger assembly to form the wellhead tubing rotator.

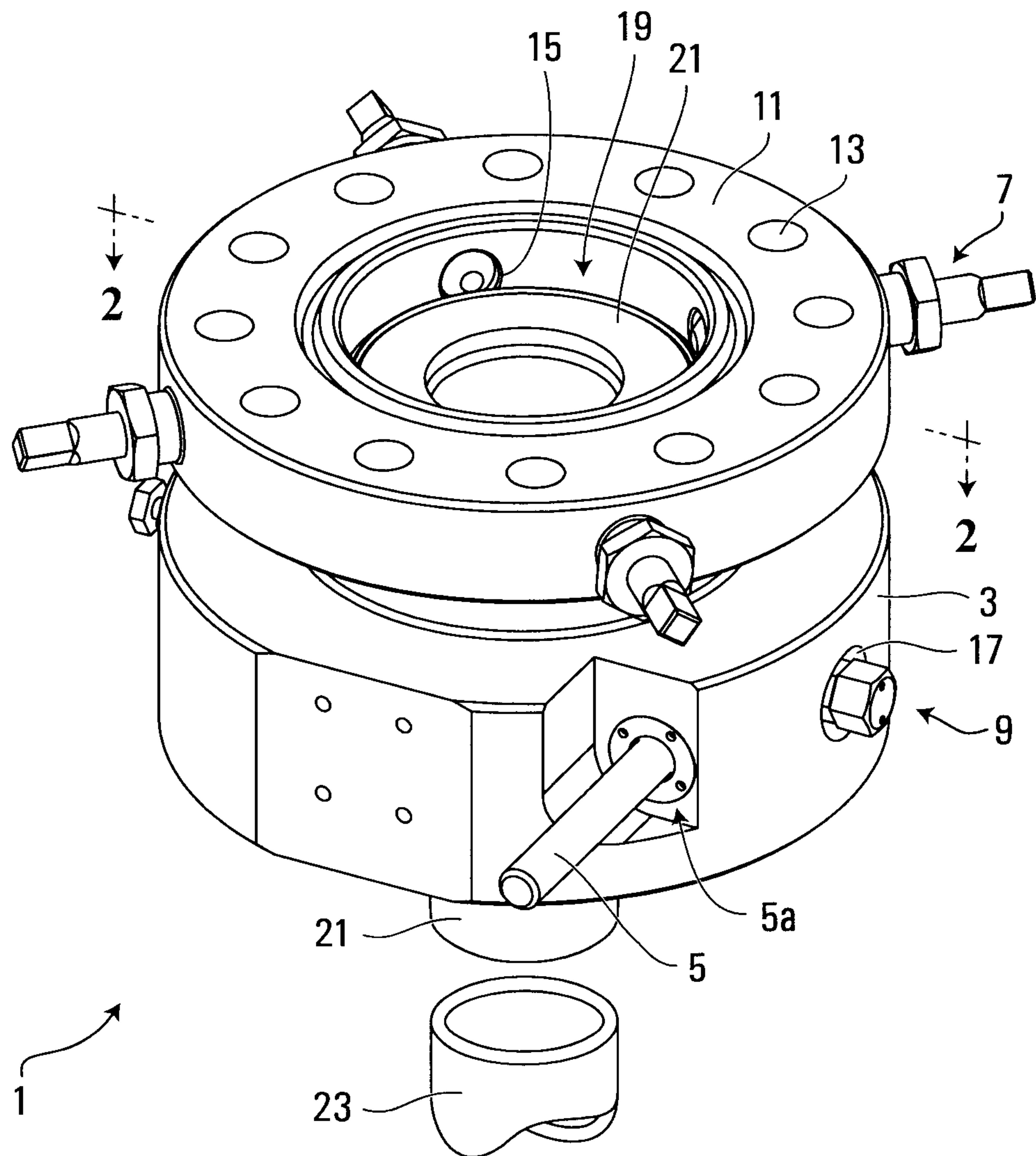
24. A method of manufacturing a wellhead tubing rotator, the method comprising:

providing a housing that comprises an internal shoulder;

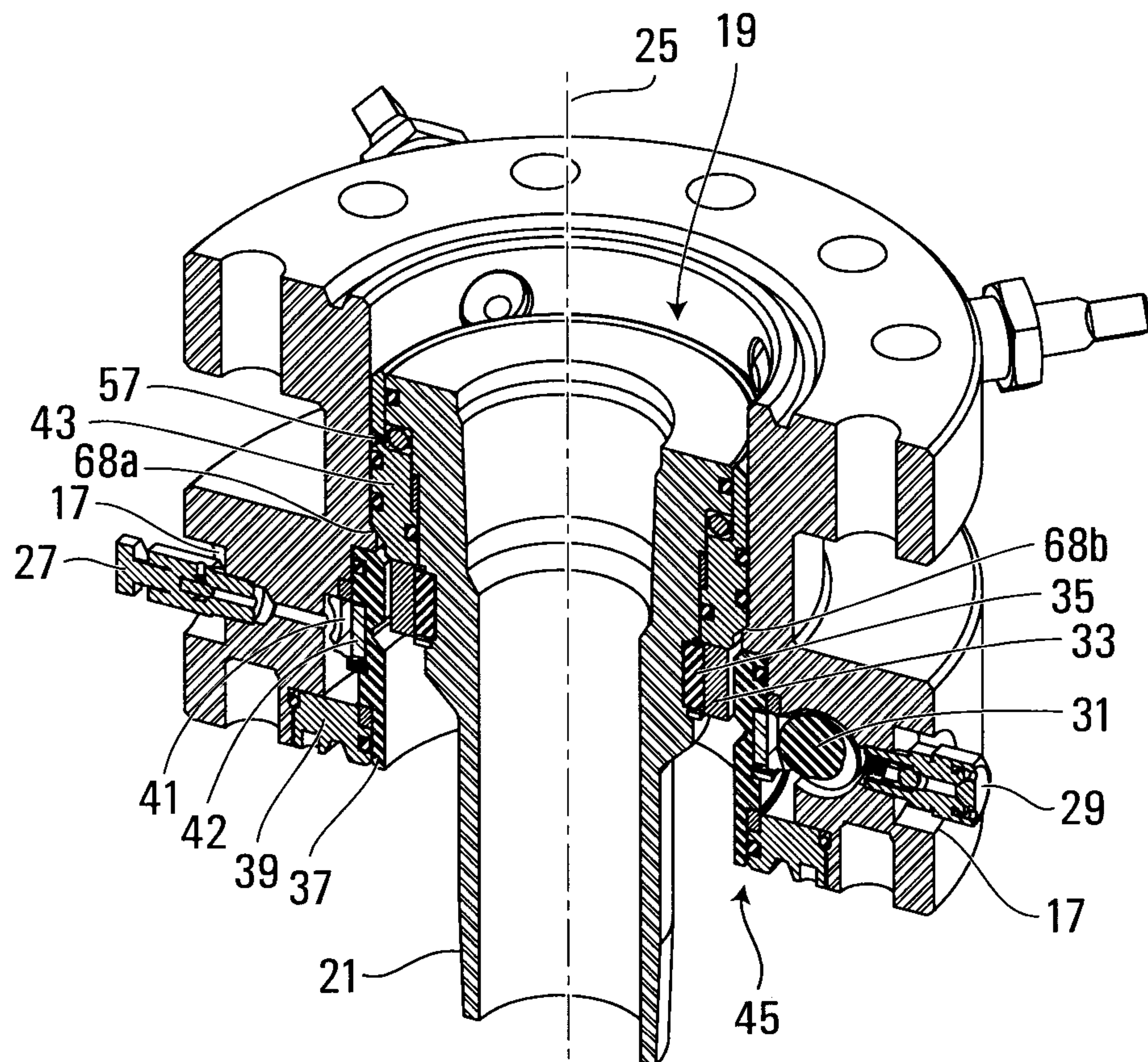
sealing a drive mechanism in a sealed cavity between the housing and a drive sub assembly that is engaged with the drive mechanism and sealed against an interior of the housing; and

placing a hanger assembly, which is to be coupled to production tubing in a production well, on the internal shoulder of the housing and into engagement with the drive sub.

1/24

**FIG. 1**

2/24

**FIG. 2**

3/24

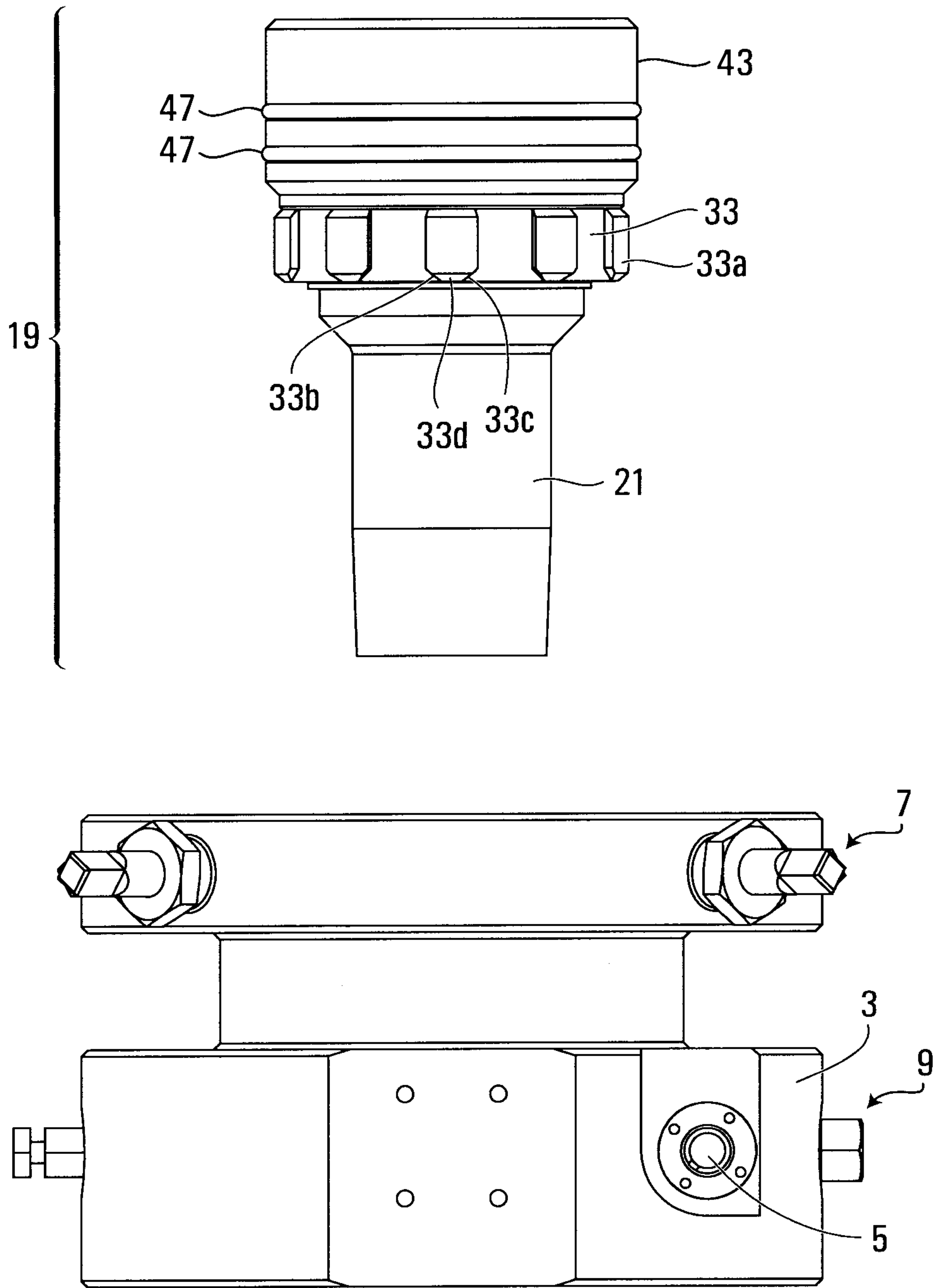
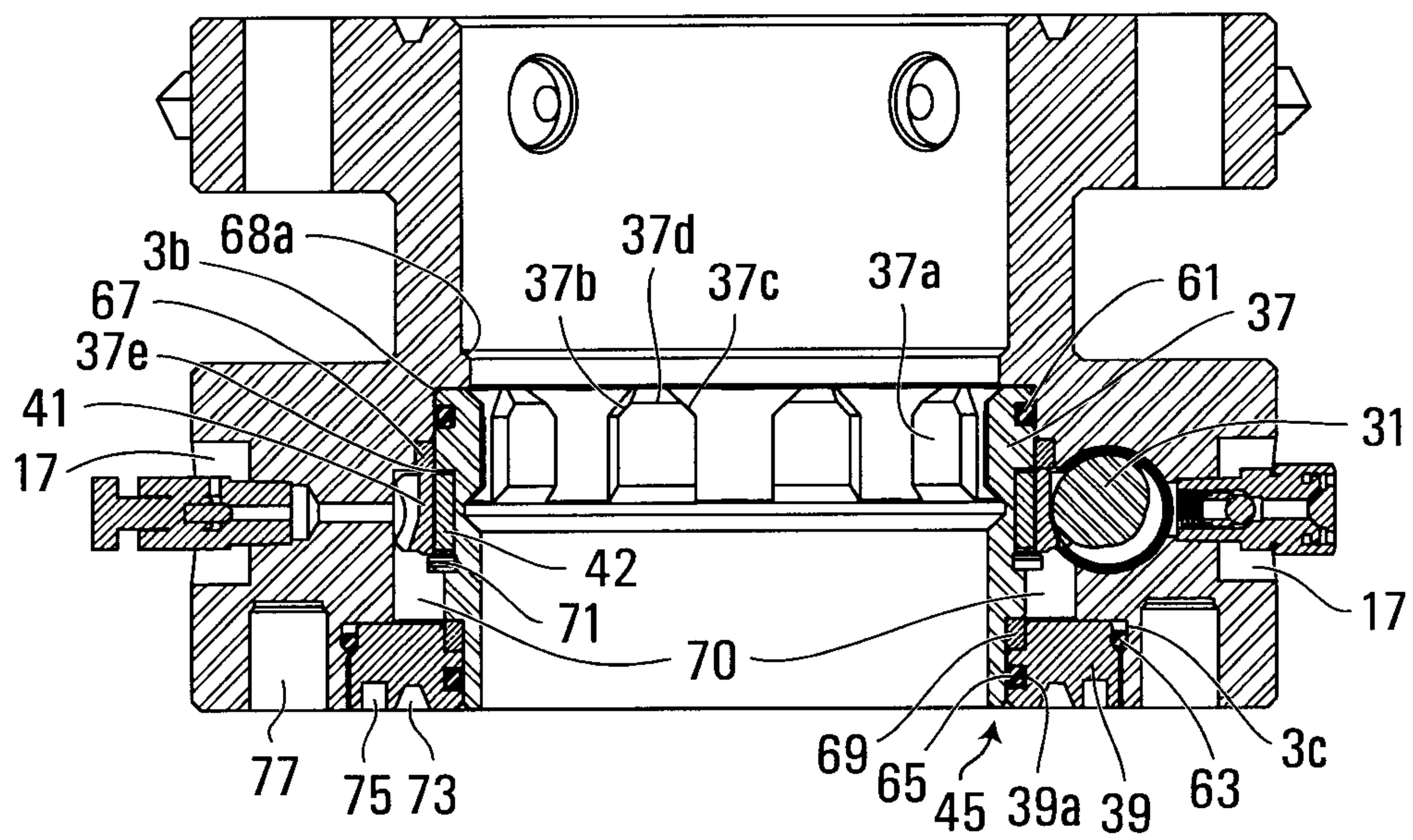
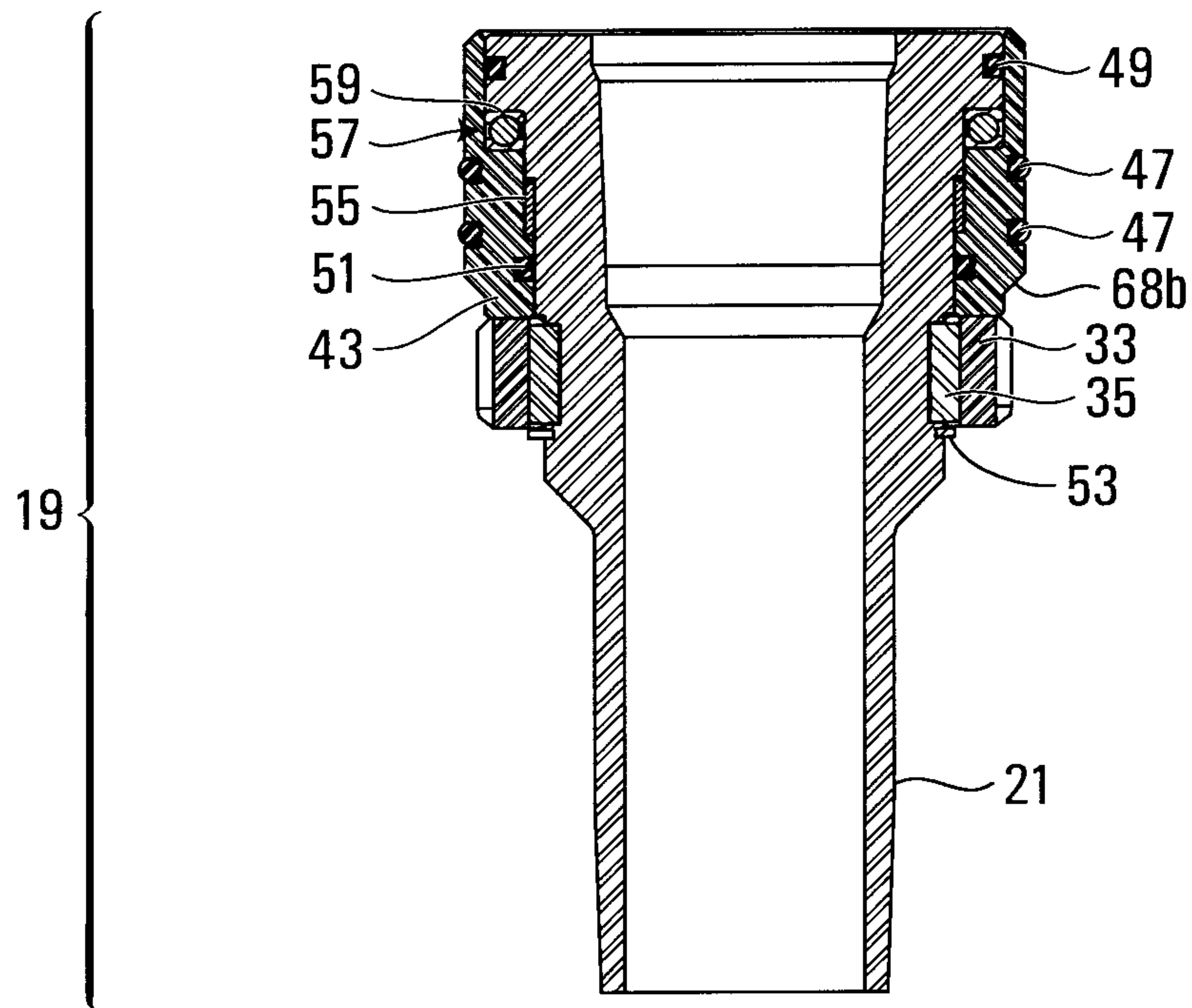
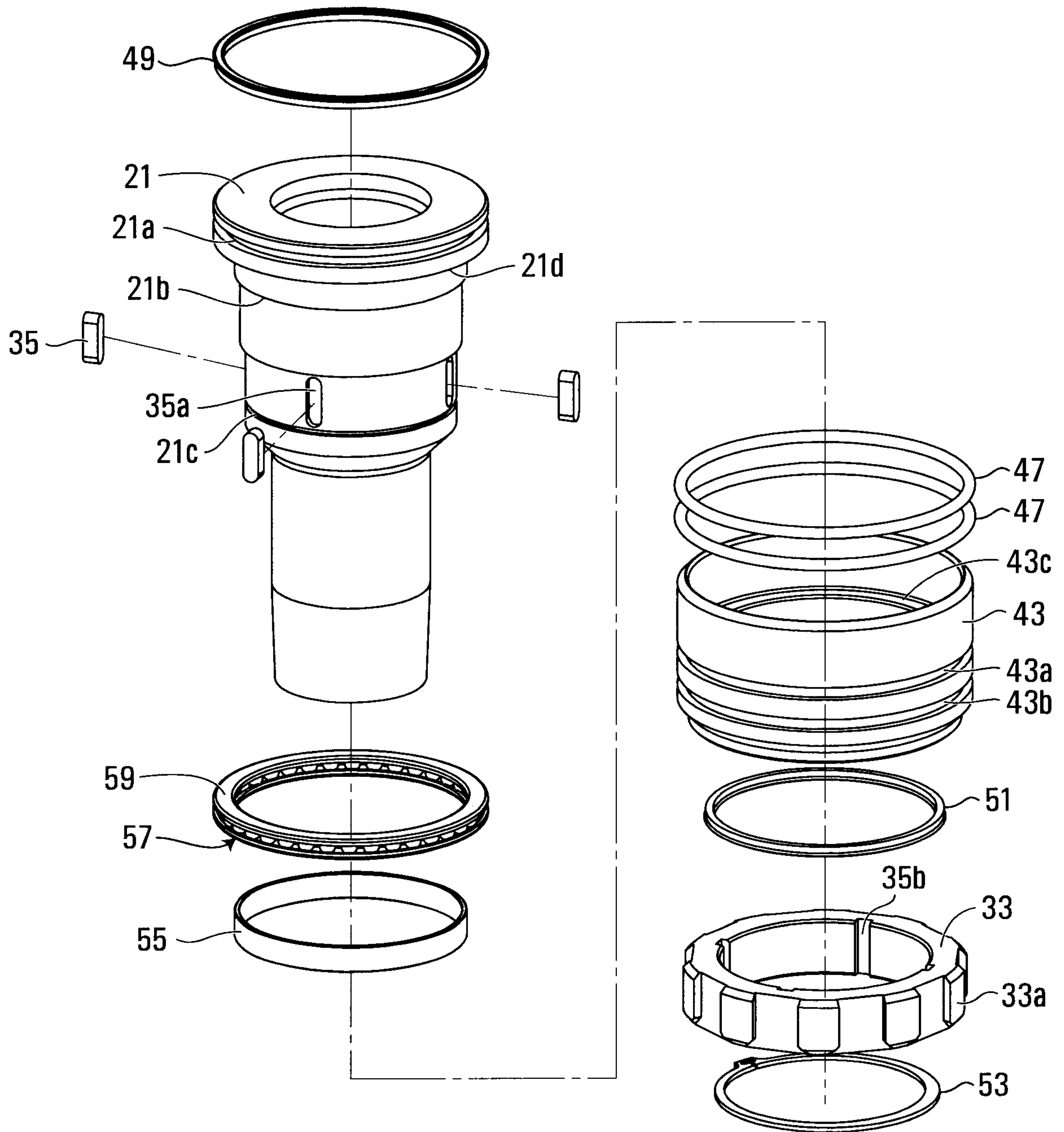


FIG. 3

4/24

**FIG. 4**

5/24

**FIG. 5**

6/24

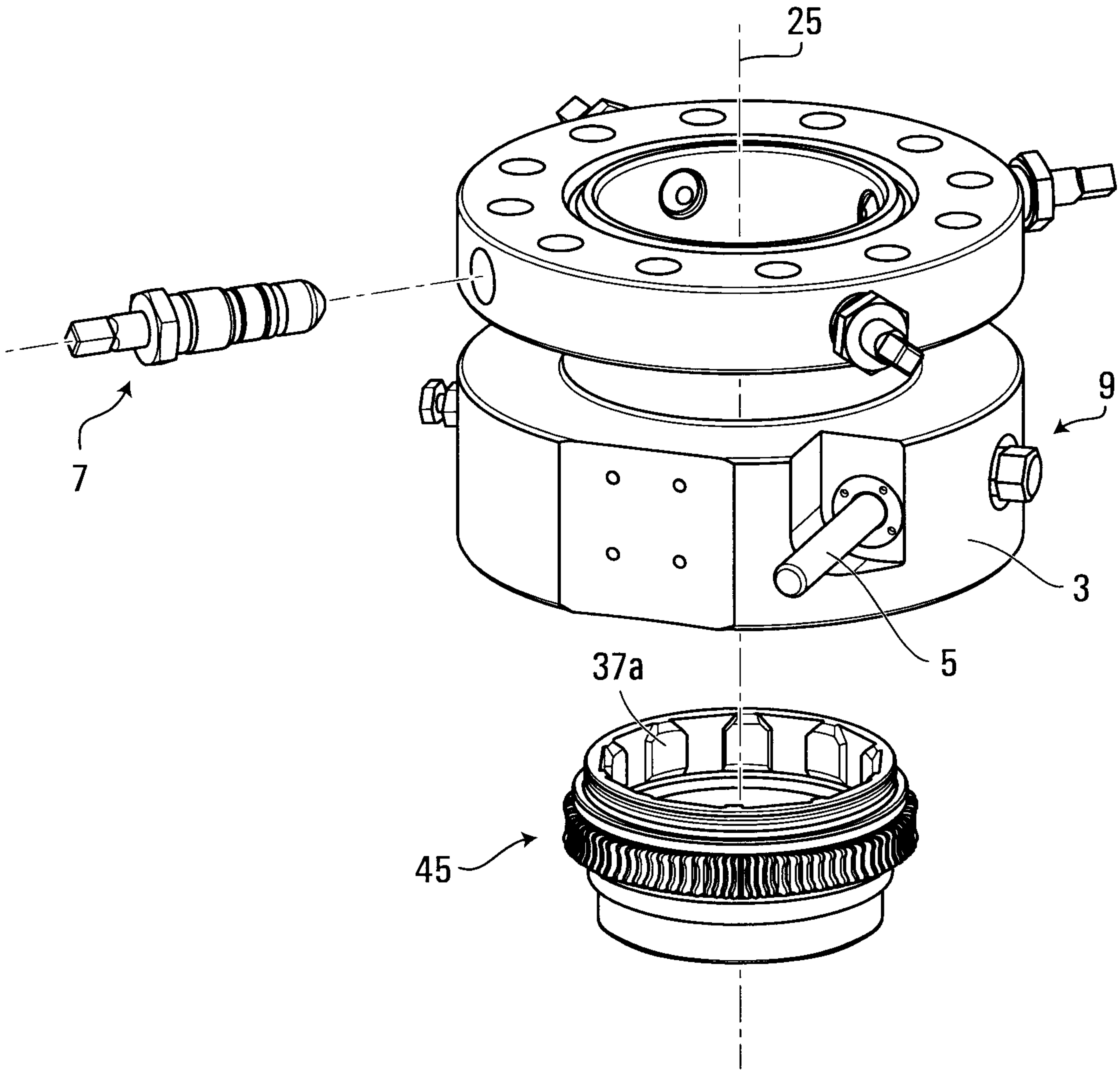
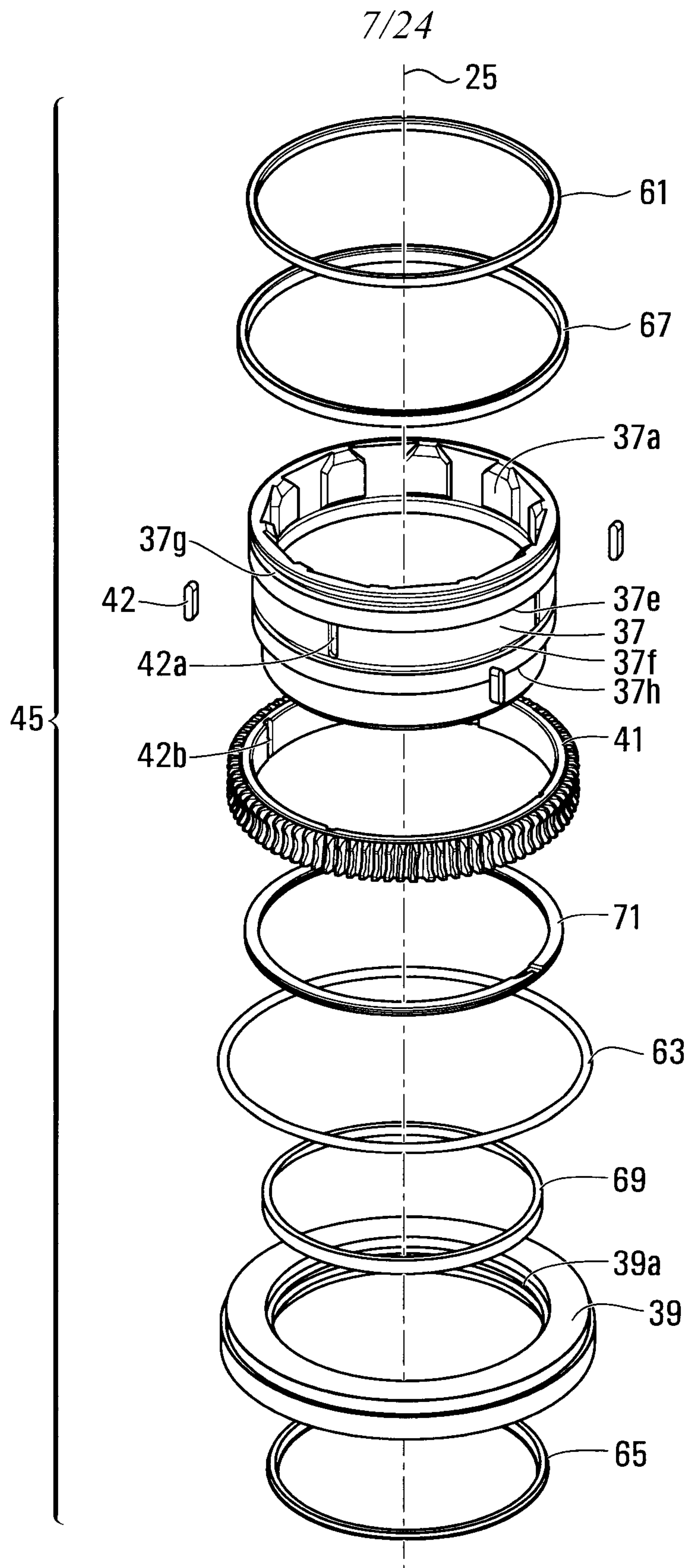


FIG. 6

**FIG. 7**

8/24

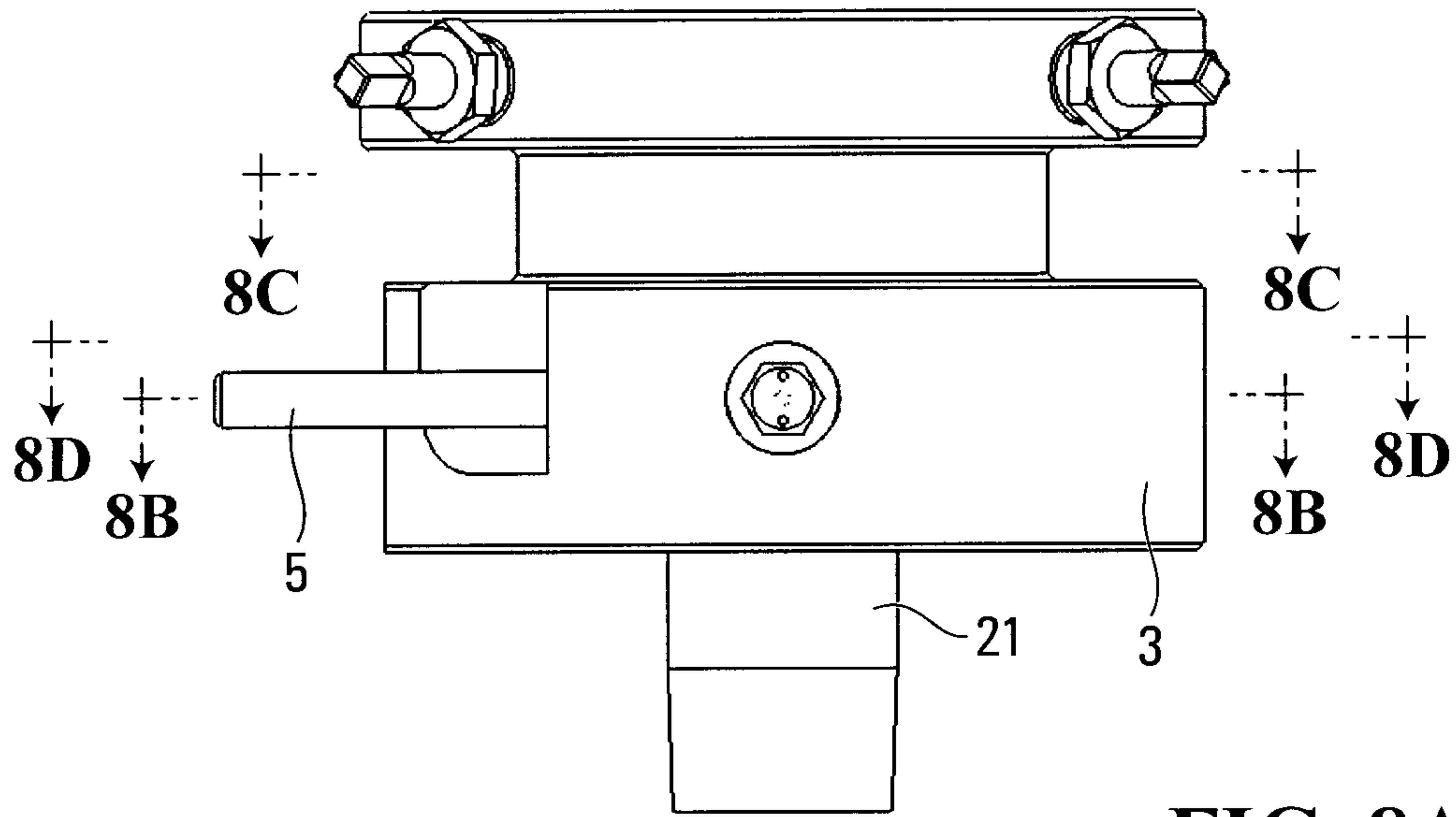


FIG. 8A

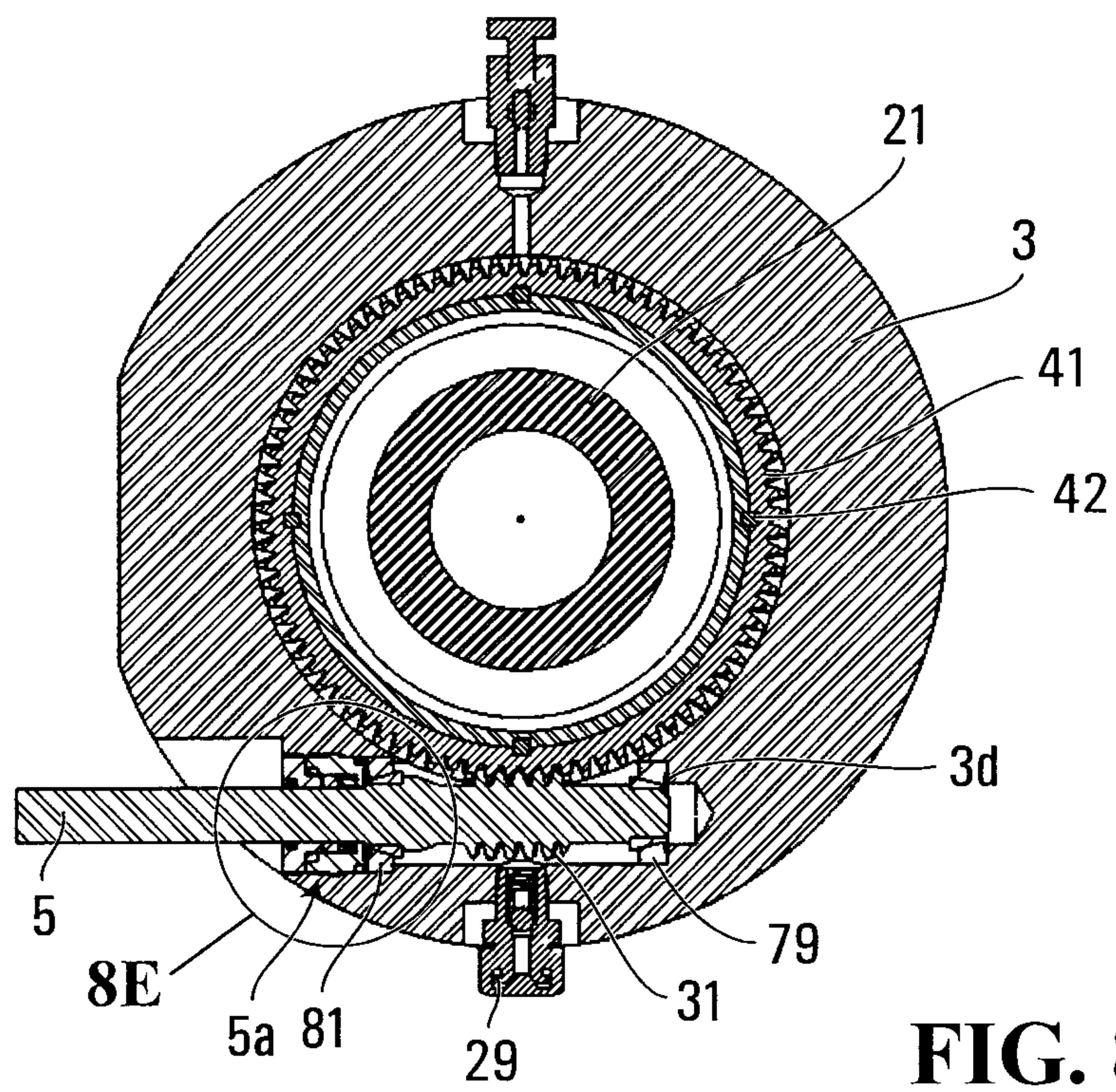


FIG. 8B

9/24

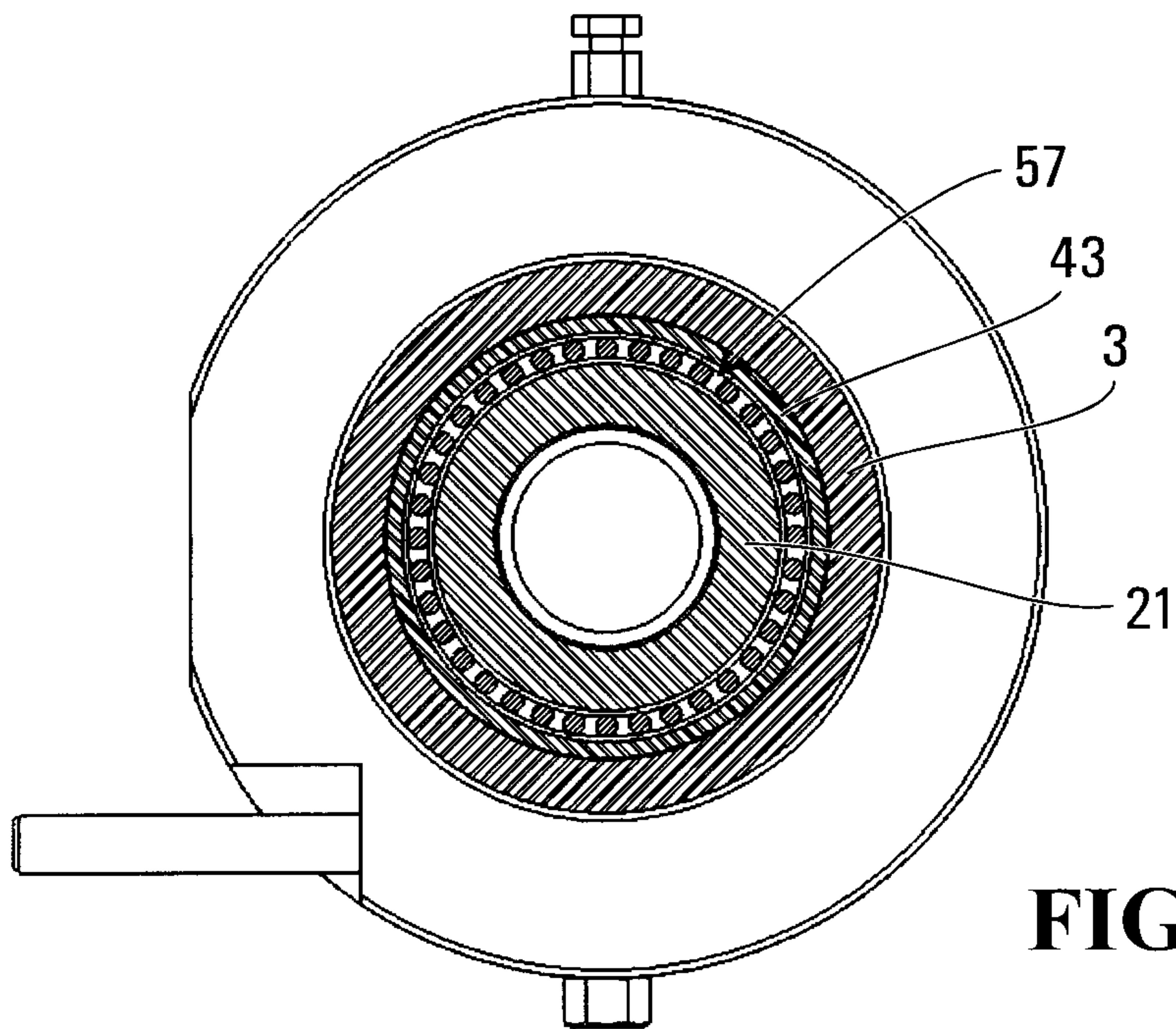


FIG. 8C

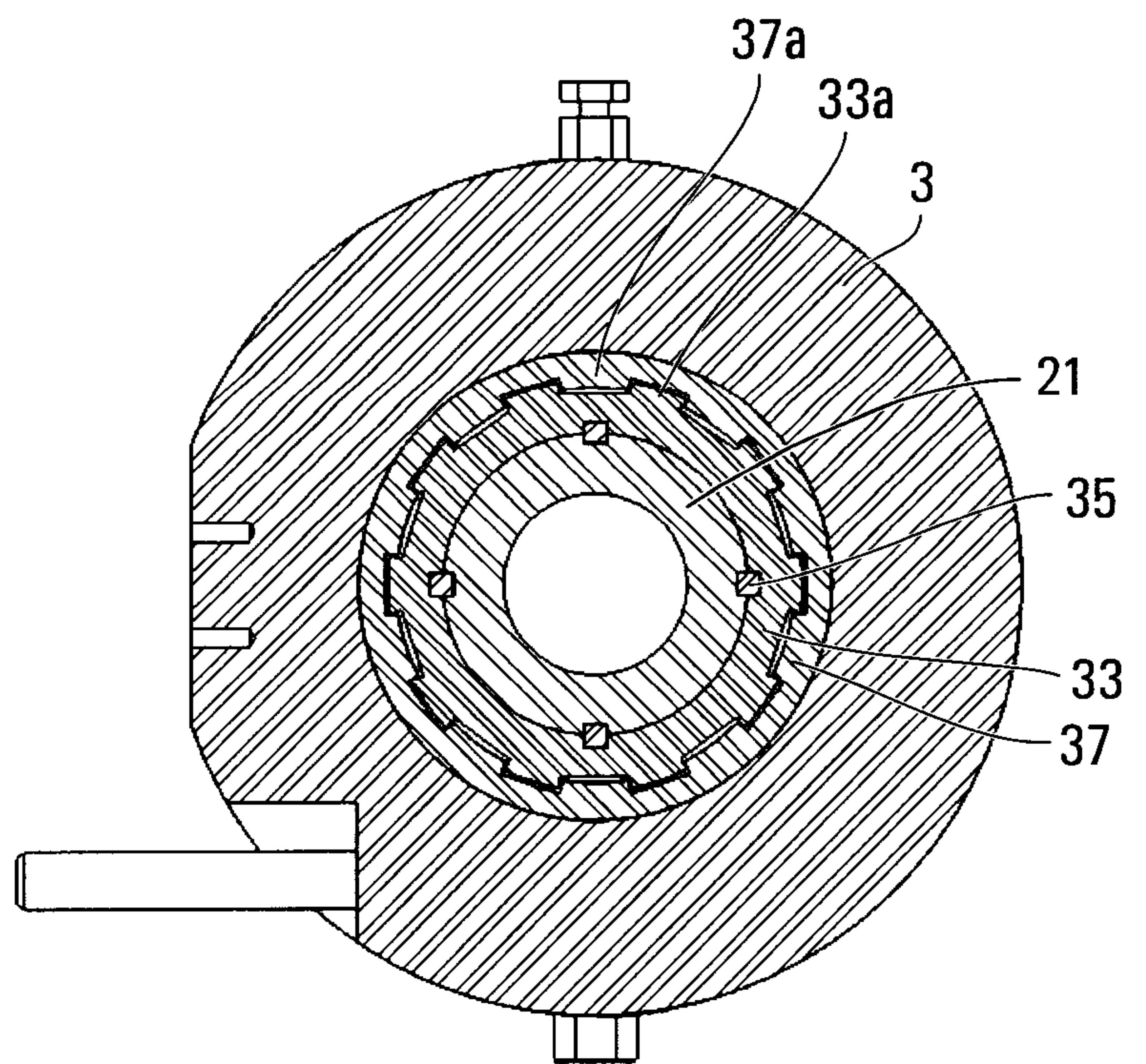
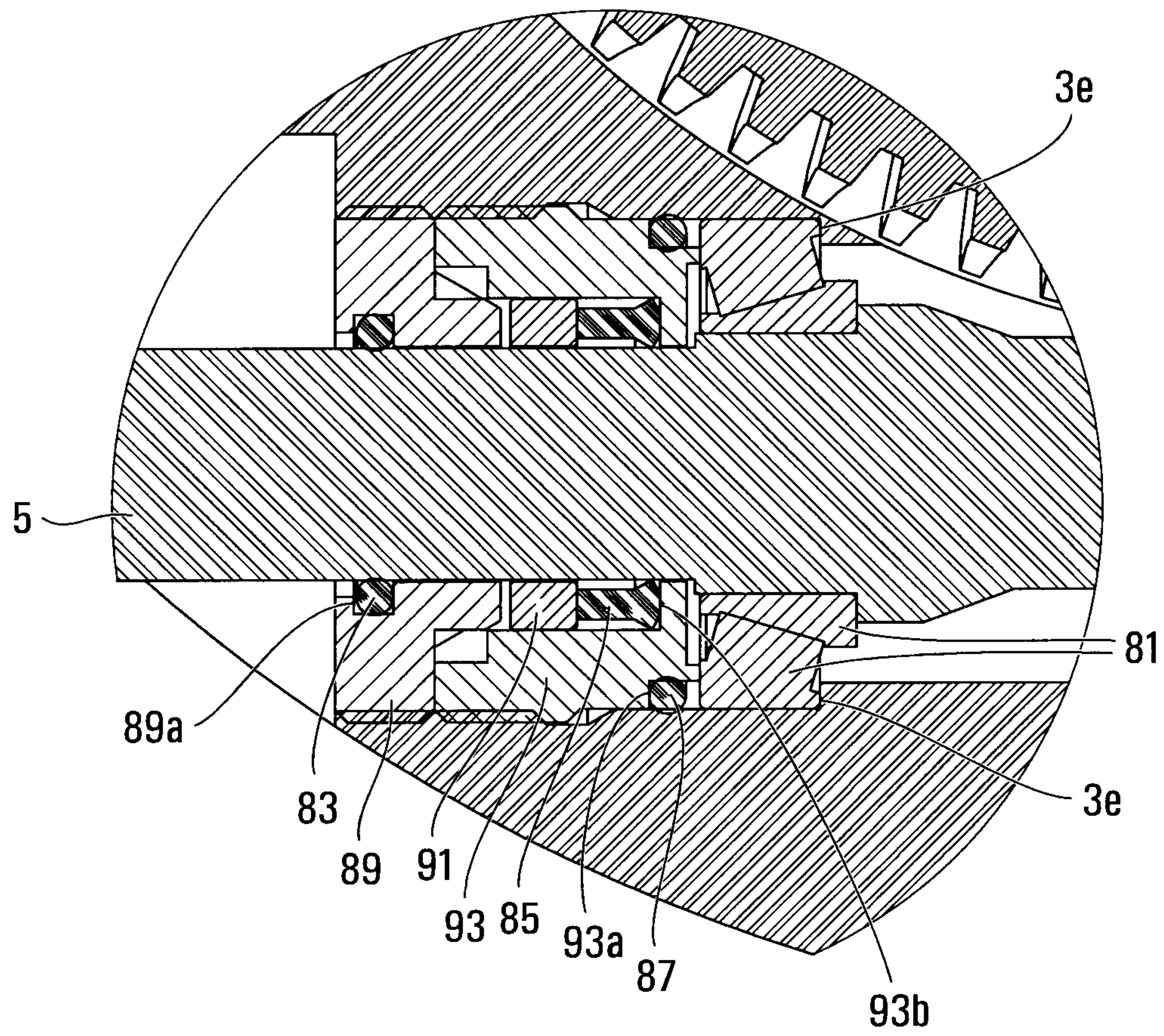


FIG. 8D

10/24

**FIG. 8E**

11/24

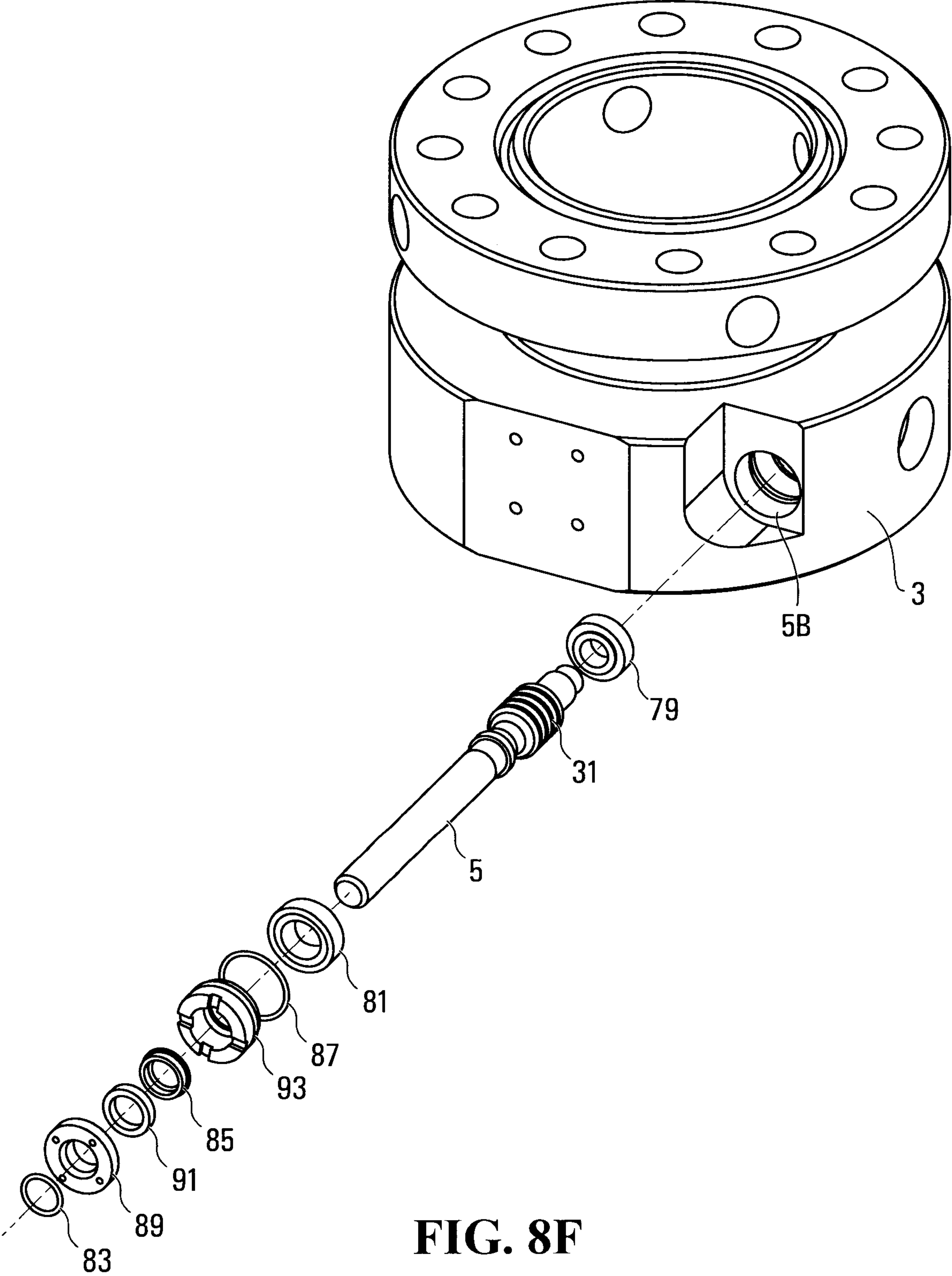
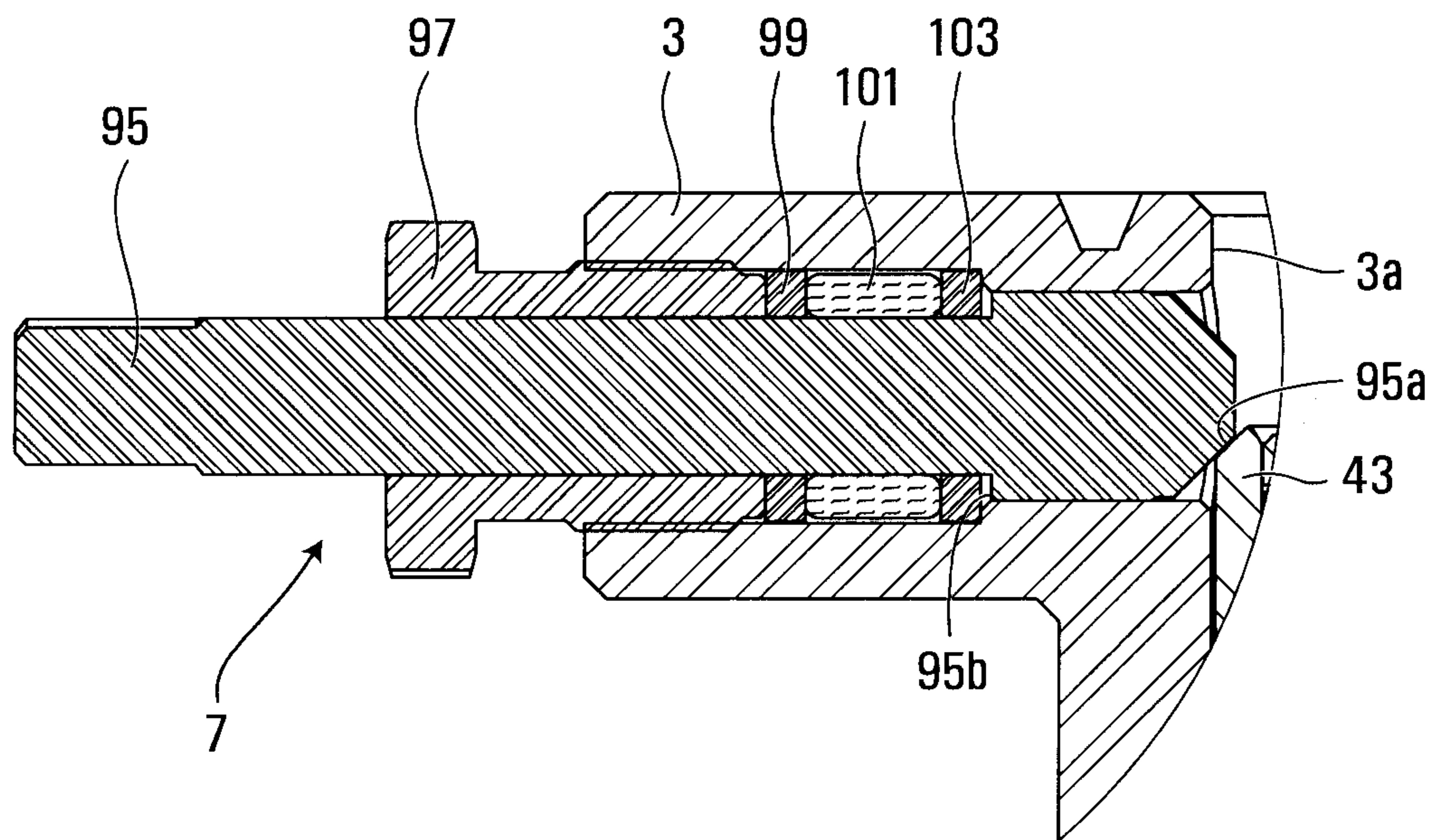
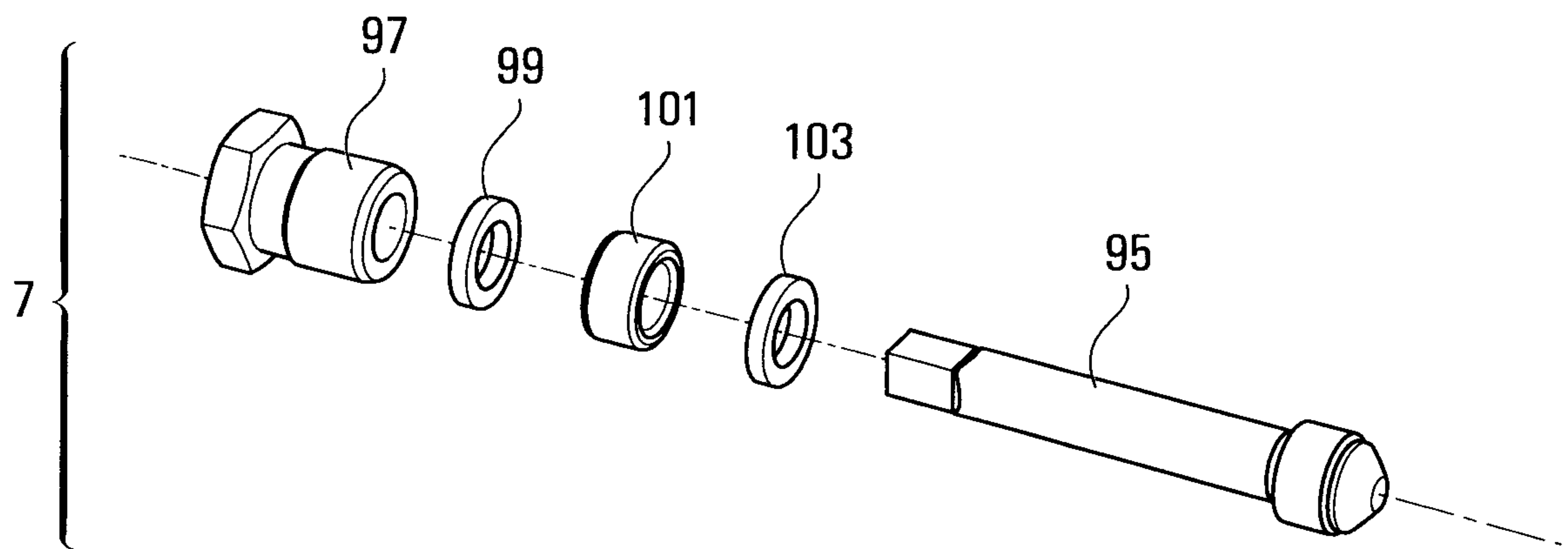
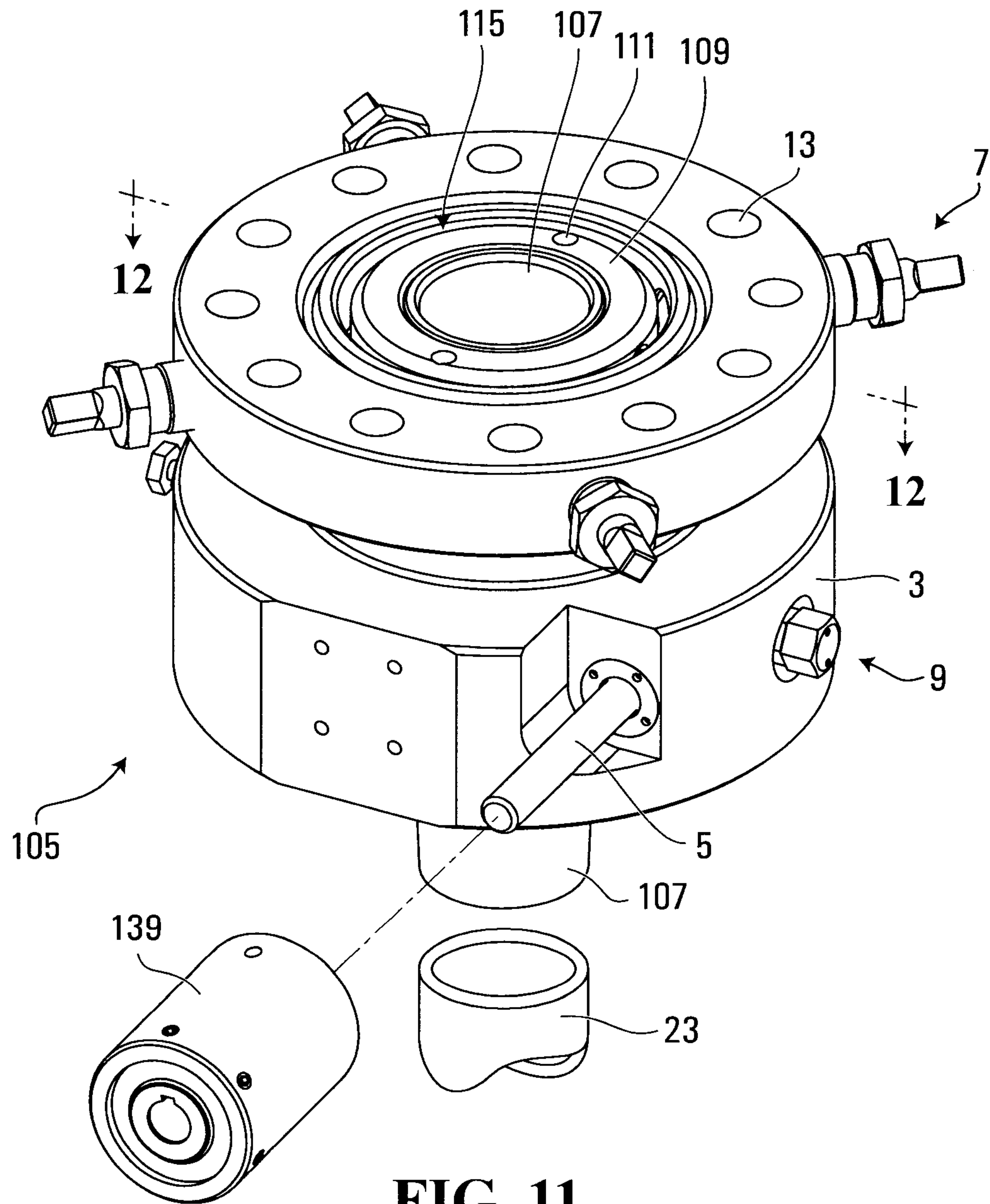


FIG. 8F

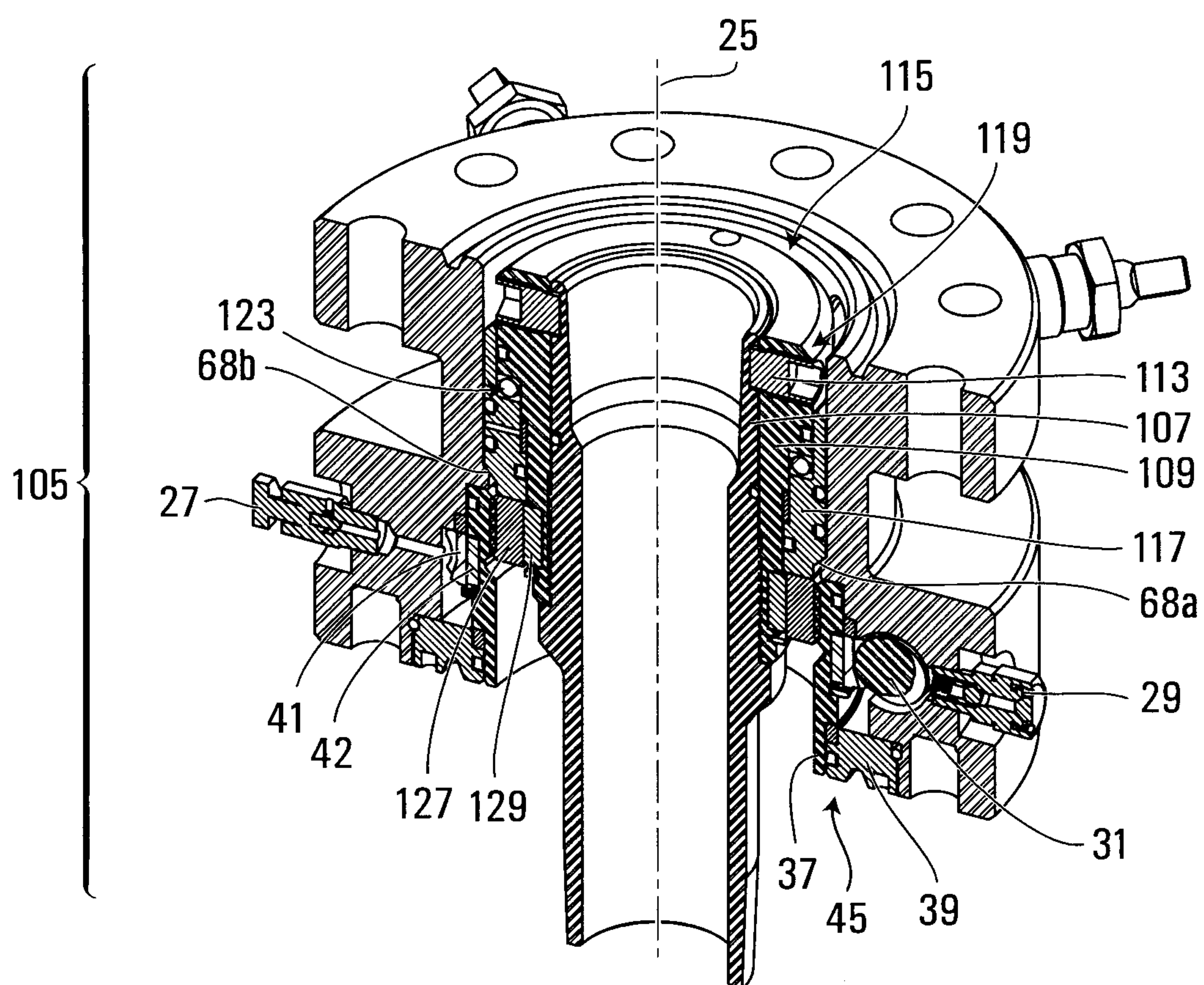
12/24

**FIG. 9****FIG. 10**

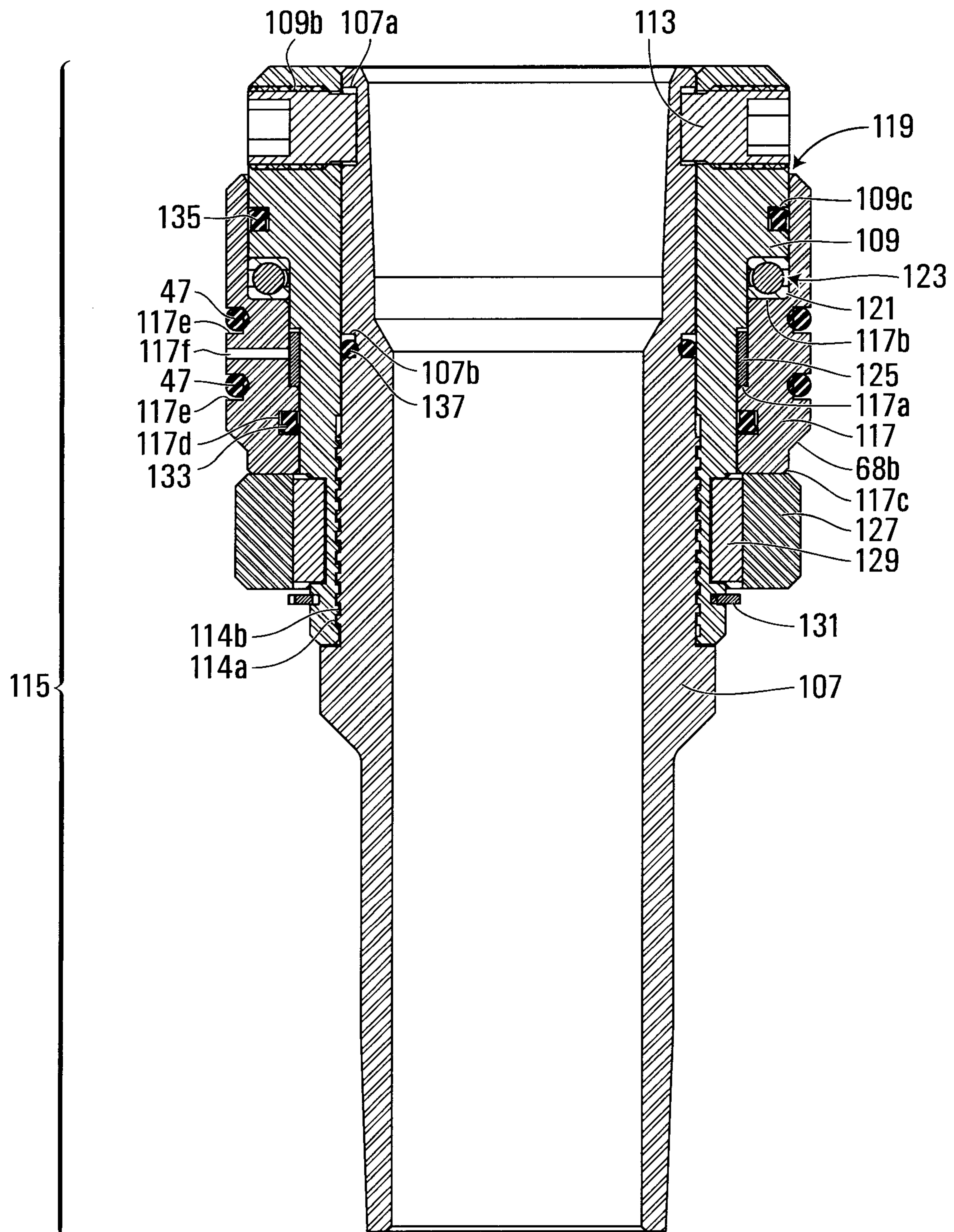
13/24

**FIG. 11**

14/24

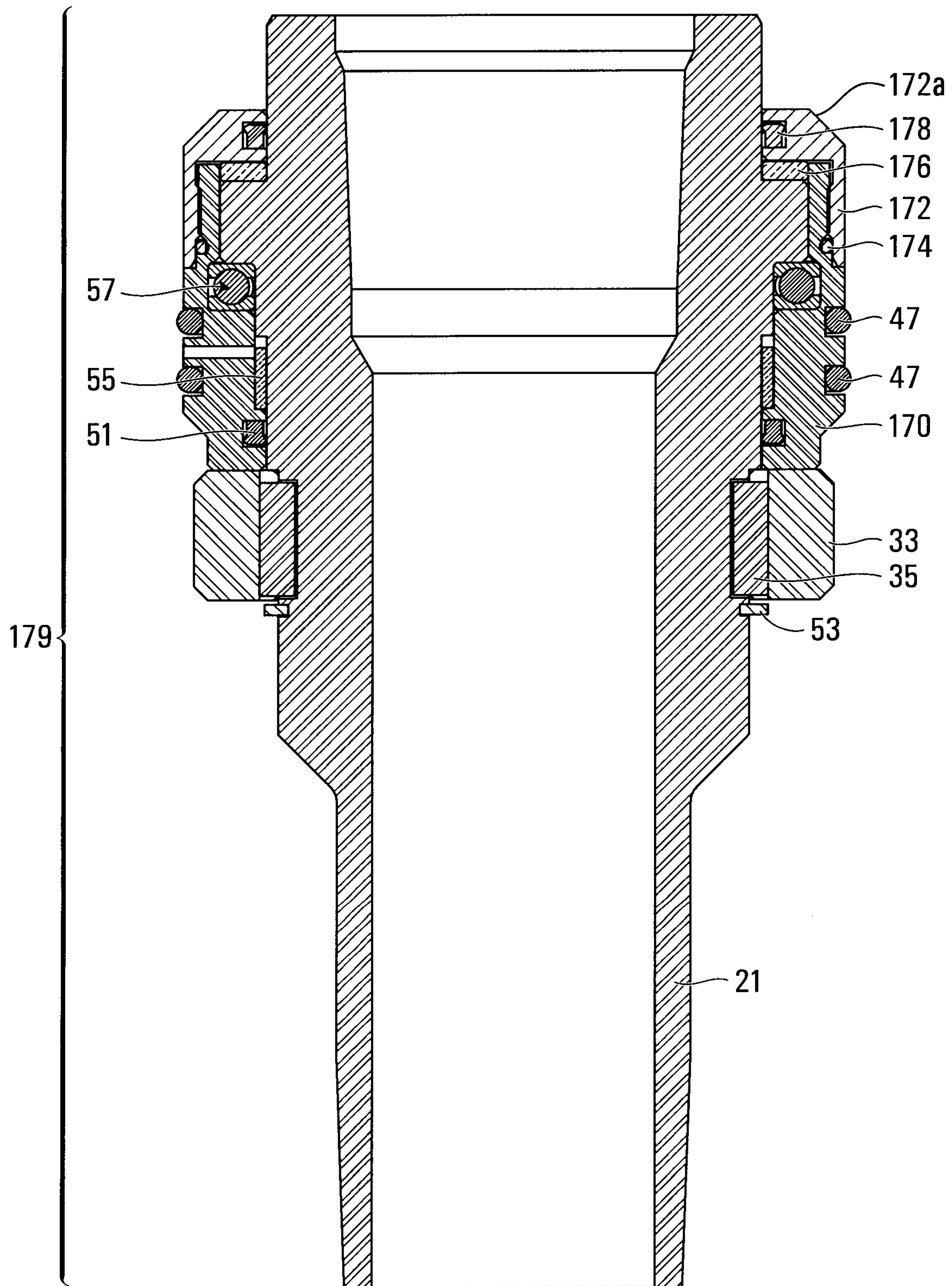
**FIG. 12**

15/24

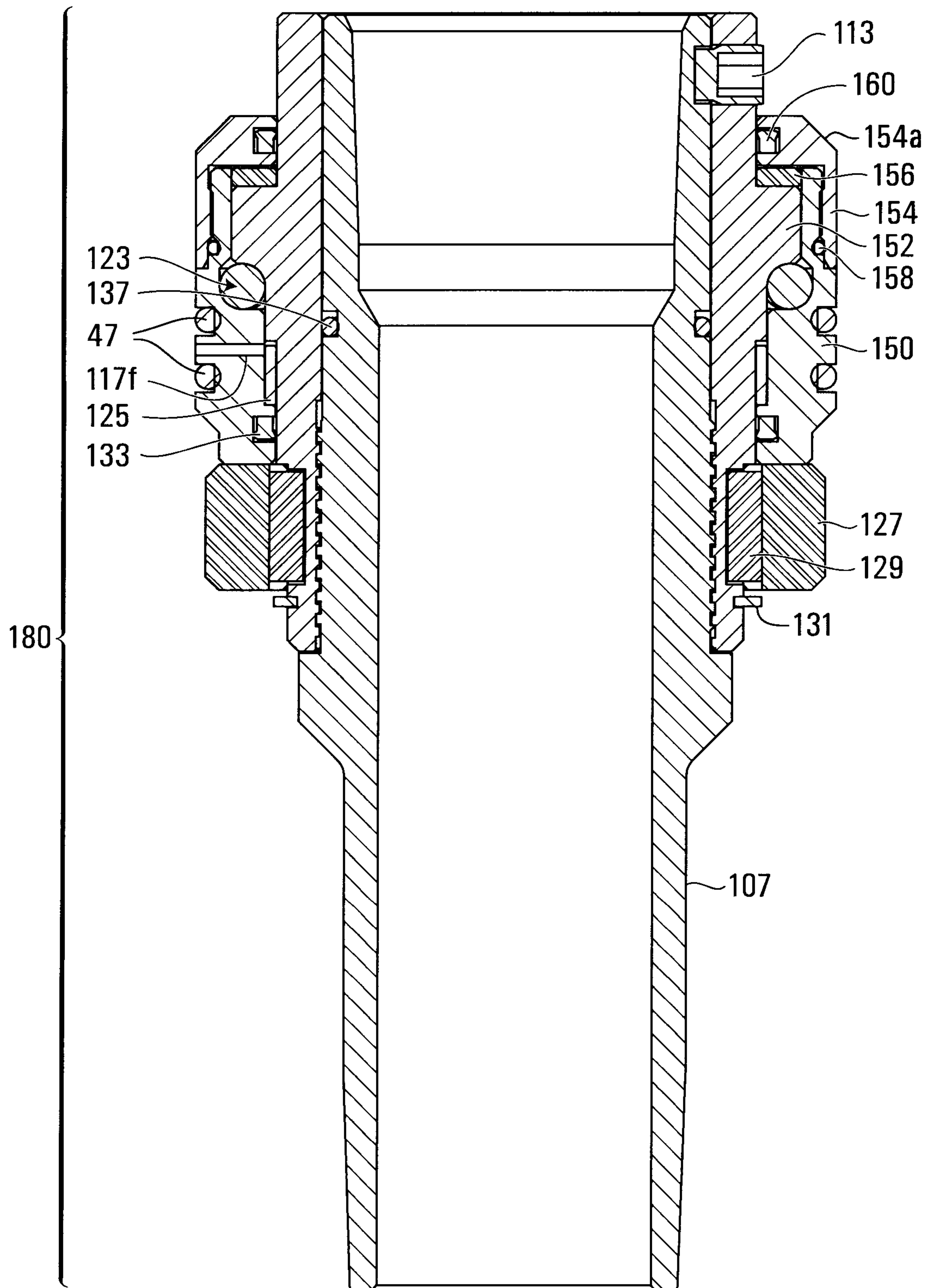
**FIG. 13**



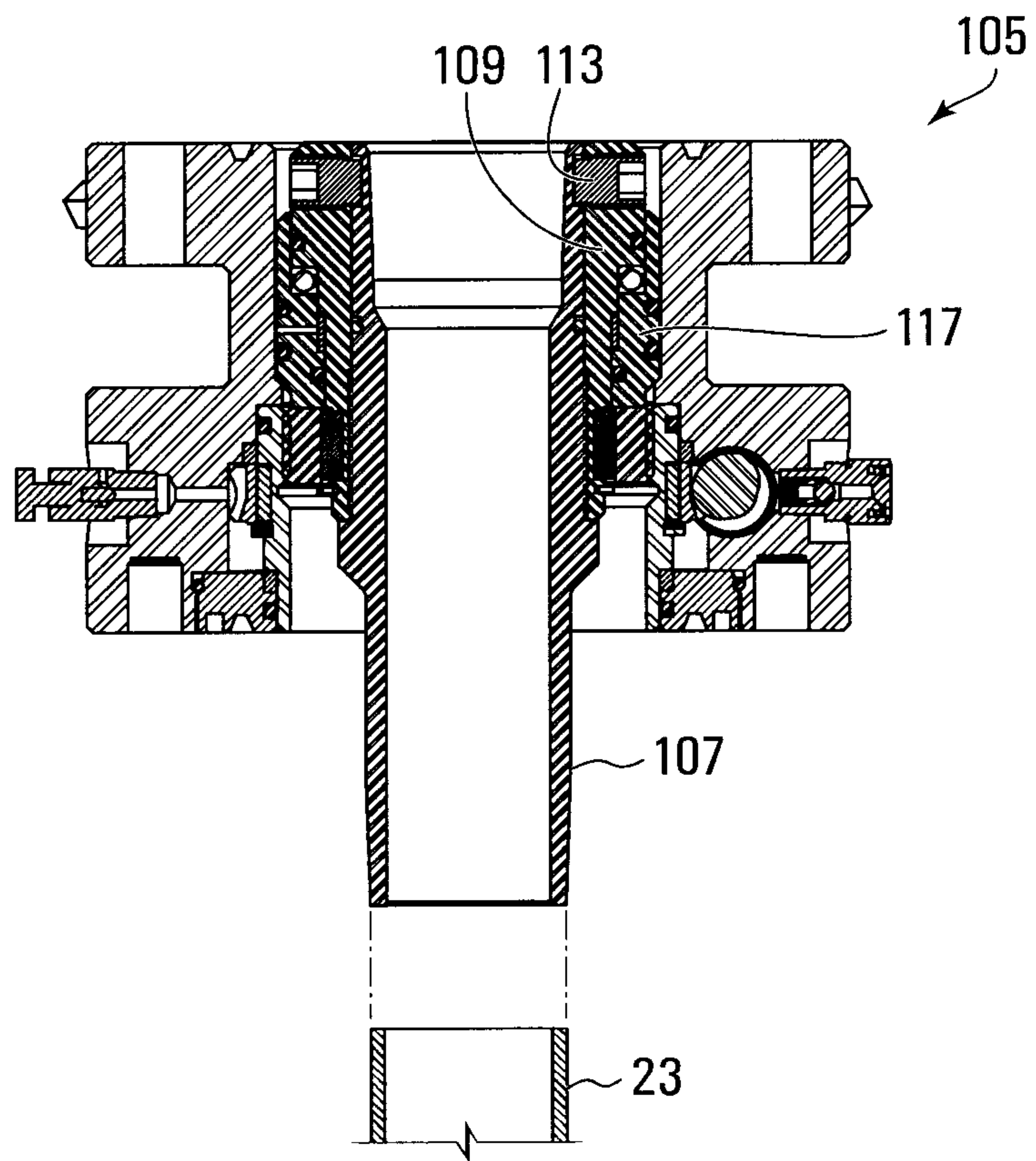
17/24

**FIG. 15**

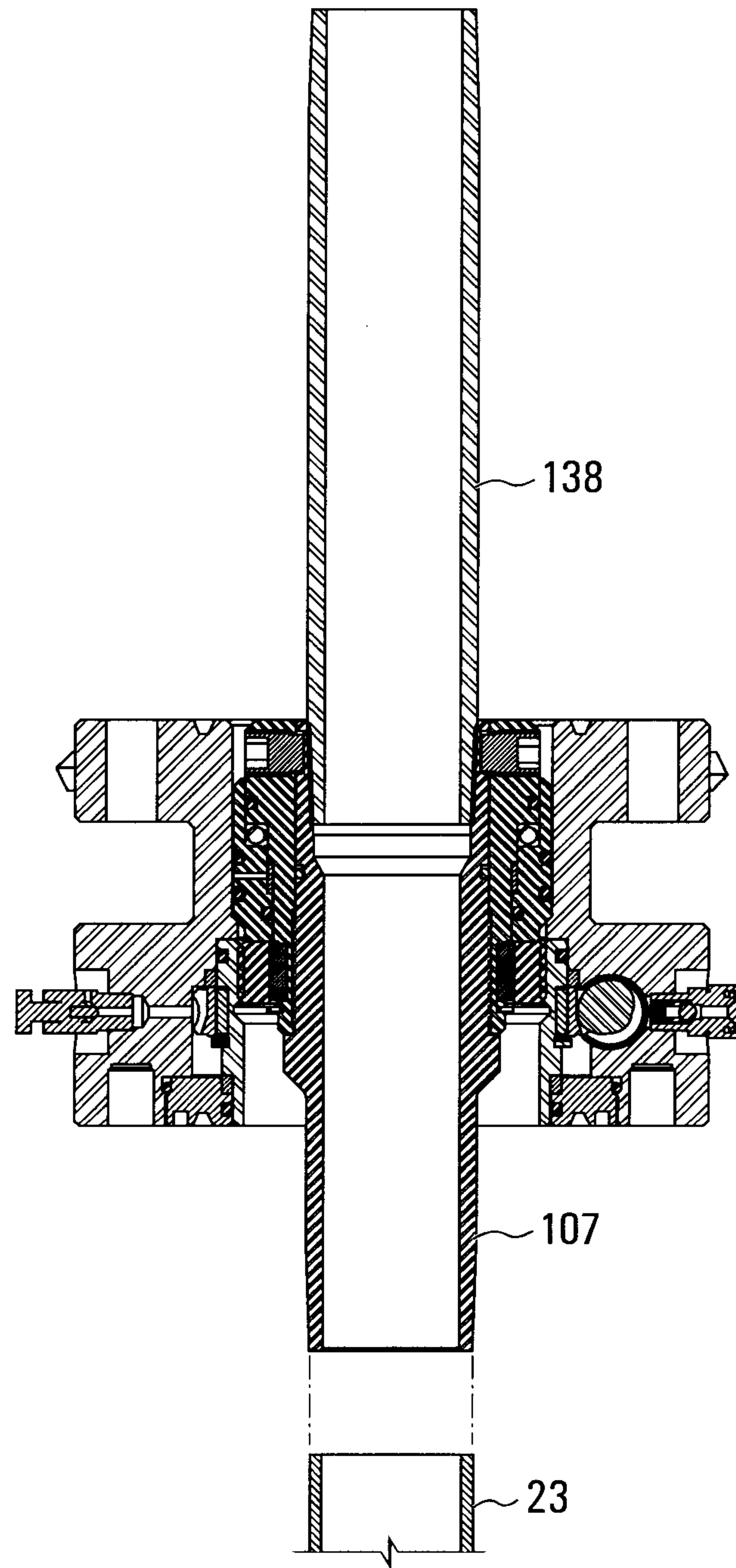
18/24

**FIG. 16**

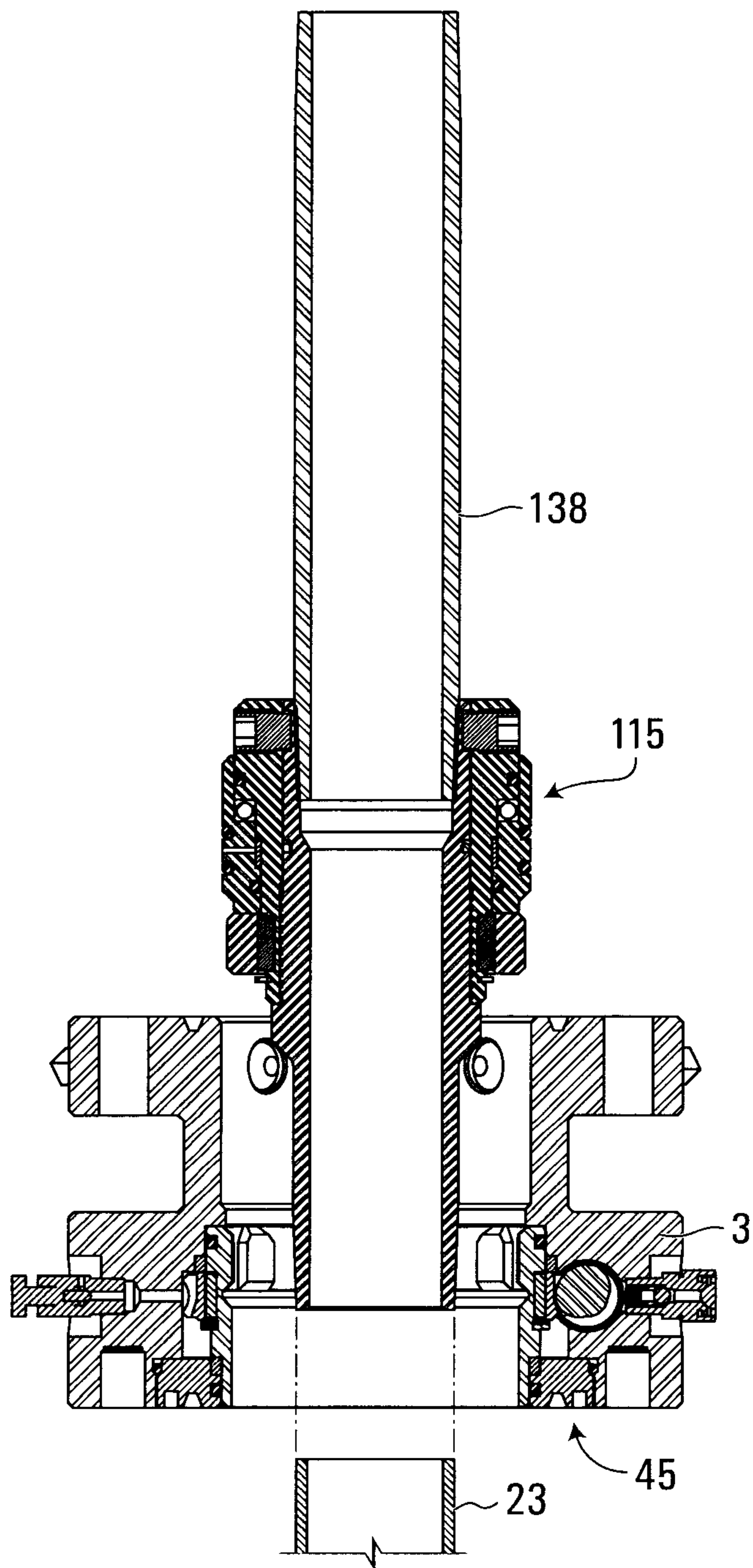
19/24

**FIG. 17A**

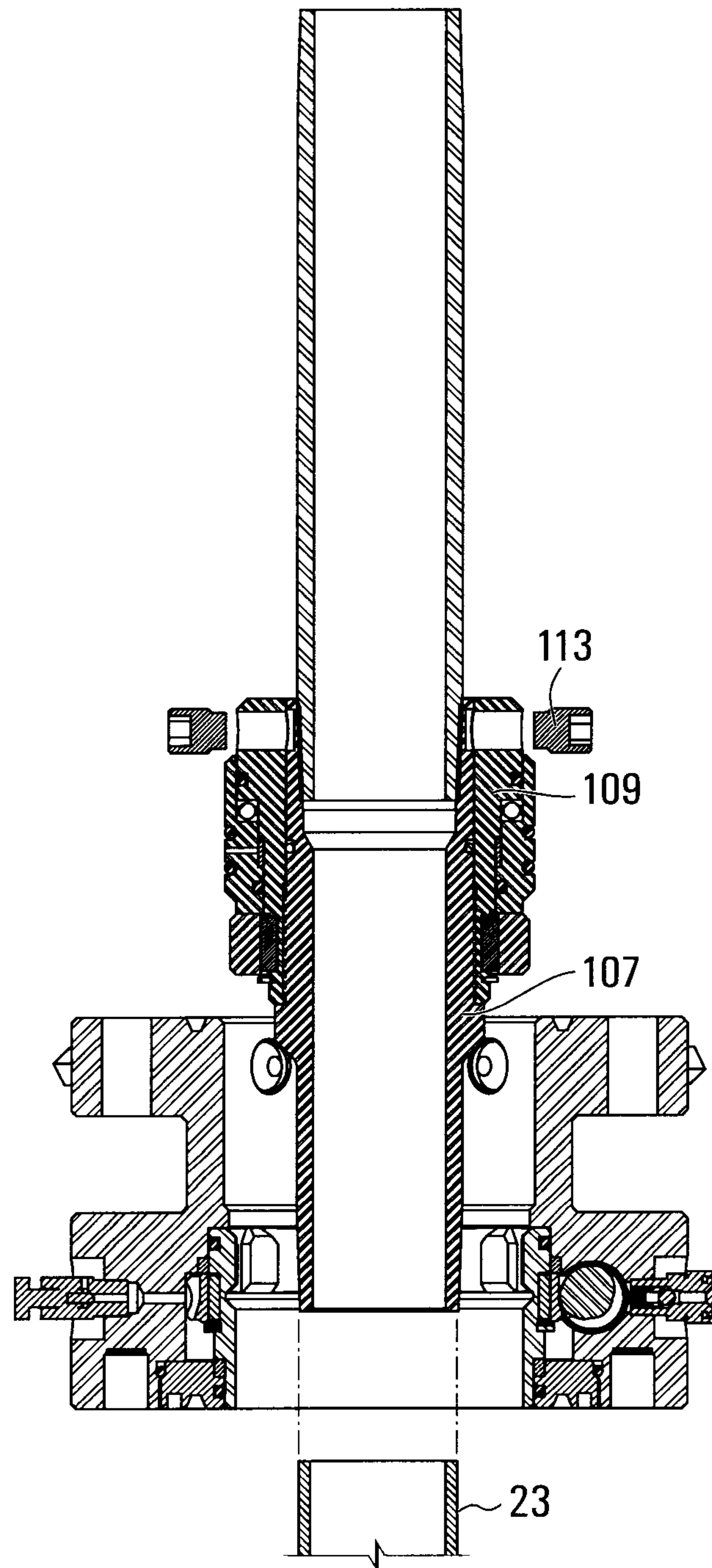
20/24

**FIG. 17B**

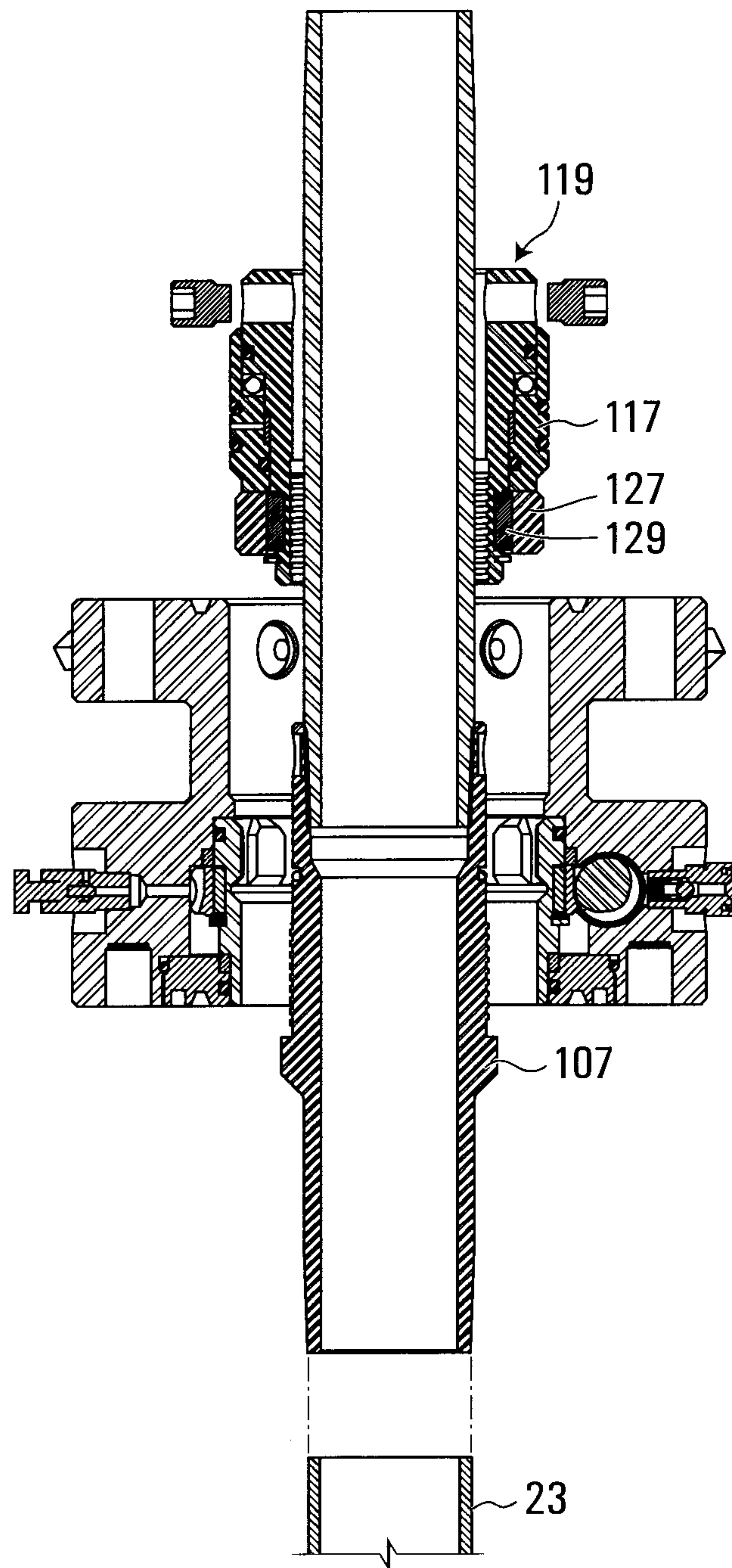
21/24

**FIG. 17C**

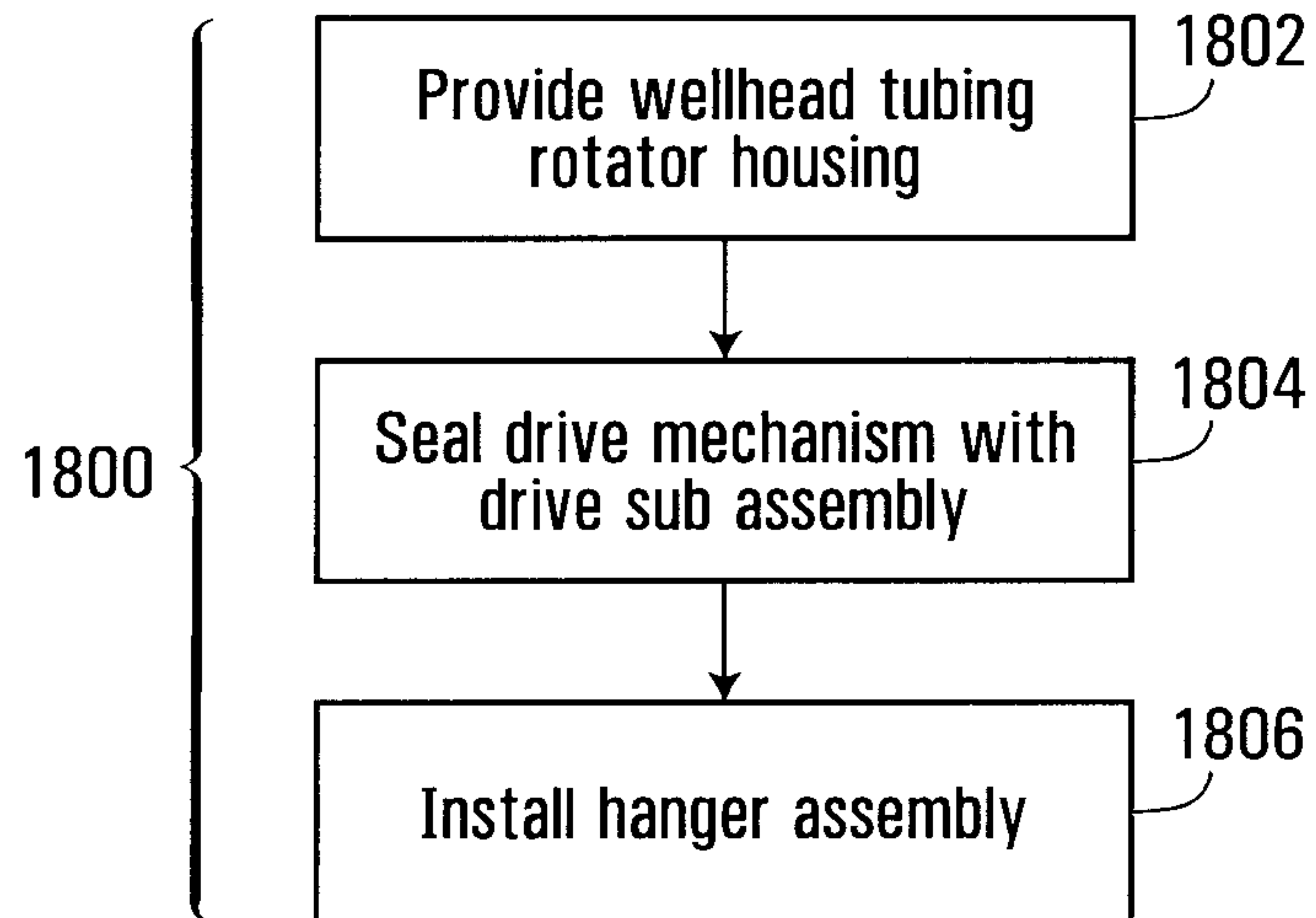
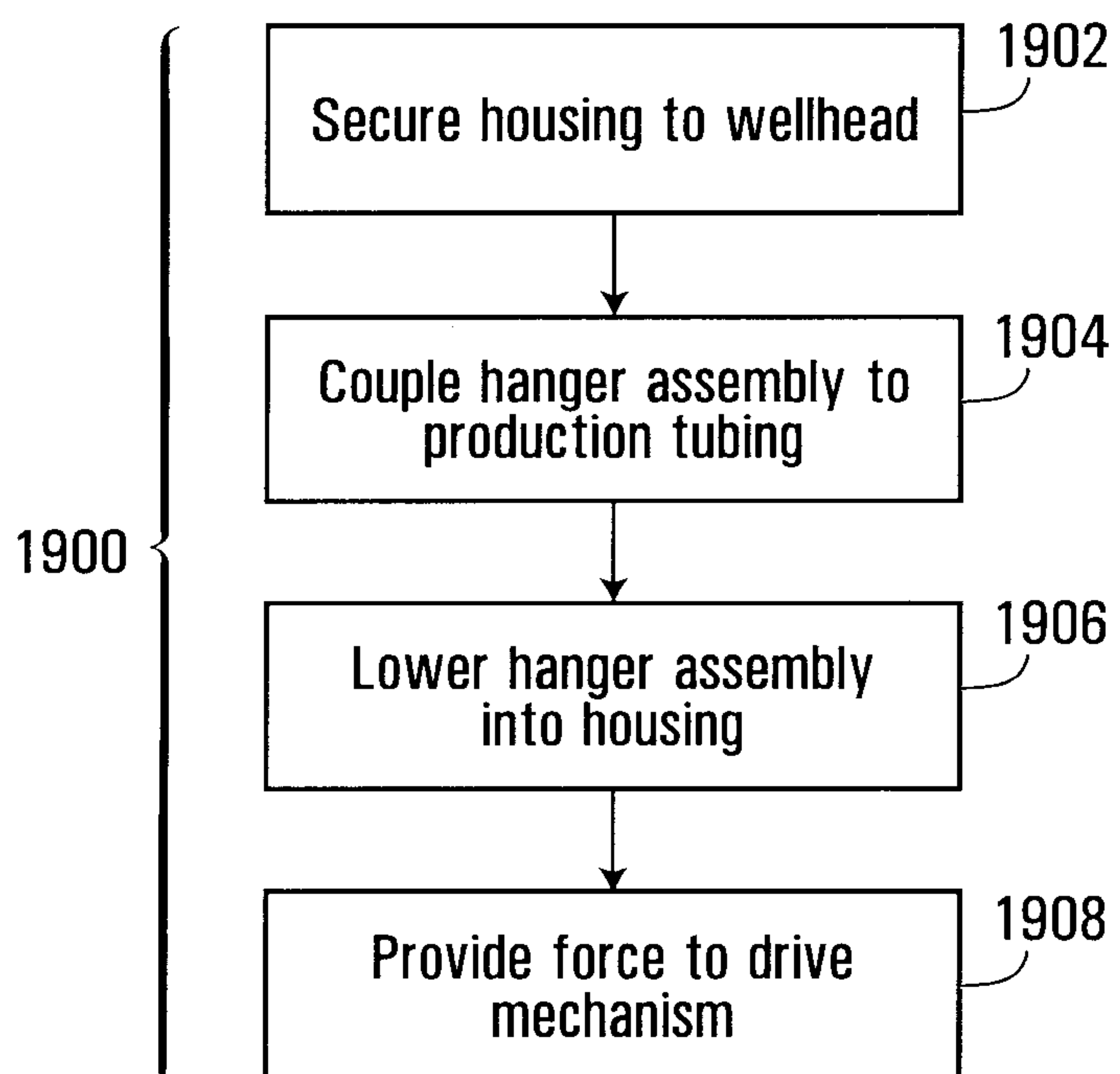
22/24

**FIG. 17D**

23/24

**FIG. 17E**

24/24

**FIG. 18****FIG. 19**

