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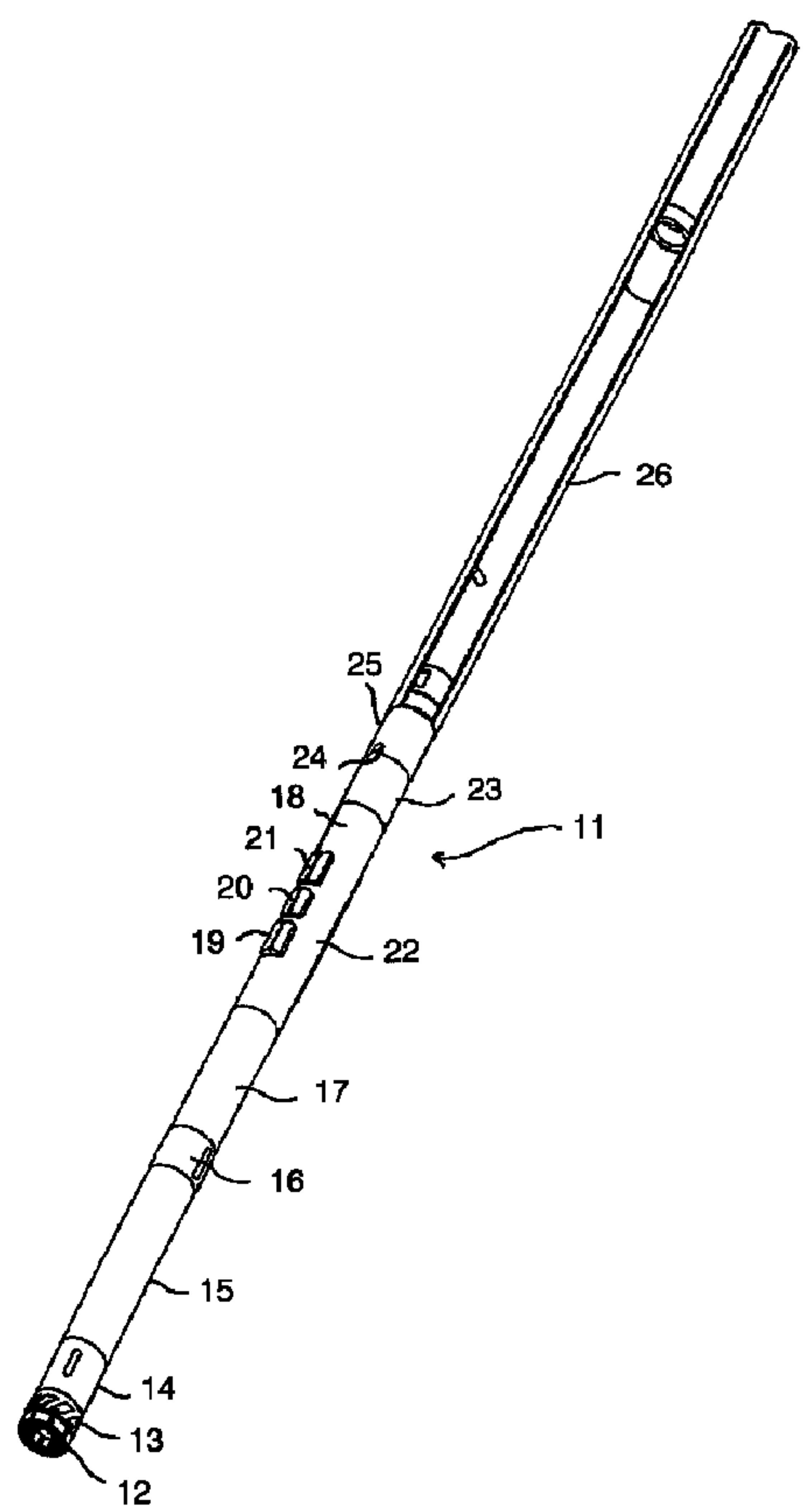
(54) **Titre :** ENSEMBLE DE PALIER DE BUTEE POUR TUBE CAROTTIER DIRECTIONNEL ACTIONNE PAR UN CABLE DE FORAGE
(54) **Title:** THRUST BEARING ASSEMBLY FOR A WIRELINE-OPERATED DIRECTIONAL CORE BARREL DRILL



(57) **Abrégé/Abstract:**
Thrust bearing assembly (40) for a wireline-operated directional core barrel drill, especially for rock drilling of curved holes with a predetermined path, where all sliding or rolling surfaces of the thrust bearing assembly (40) are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), and wherein the thrust bearing assembly (40) has an inner diameter large enough to allow the drive shaft (35) to pass through.

Abstract

Thrust bearing assembly (40) for a wireline-operated directional core barrel drill, especially for rock drilling of curved holes with a predetermined path, where all sliding or rolling surfaces of the thrust bearing assembly (40) are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), and wherein the thrust bearing assembly (40) has an inner diameter large enough to allow the drive shaft (35) to pass through.

Thrust bearing assembly for a wireline-operated directional core barrel drill

The present invention relates to a thrust bearing assembly for a wireline-operated directional core barrel drill, and especially to a thrust bearing. The invention provides a thrust bearing assembly with improved operational lifetime and reliability in relation to prior art solutions in wireline-operated directional core barrel drills.

Background

A directional core drill is described in NO 168962 which is provided with a locking device or packer which is supplied with drilling fluid under pressure in order to push out locking elements or pressure pads which can be brought in contact with the borehole wall and lock the main body of the directional core drill head and its eccentric bushing relative to the wall. Such pressure pads may be utilised for locking the high side of an eccentric housing in a certain position or be used to bring upon the drill bit a skewed position, for thereby performing directional drilling.

It is known to make directional core drills with a rotary core barrel extending through an eccentric bushing arranged in a non-rotatable outer tube. A packer is also described in NO 308552, where drilling fluid is used to press pressure pads against the borehole wall. Directional core drill heads may also carry navigational instruments, such as geotechnical instruments, as well as magnetometers, accelerometers, etc.

From NO 305713 it is known a rock drill where several pressure pads are arranged in at least two ring sections, so that the pressure pads become oriented in axial rows with projecting guiding bars oriented in a row. This solution is intended to reduce the frictional forces, which are effective in the axial direction when the drill is moved forward and shall at the same time ensure a frictional force against rotation sufficient to avoid a rotational movement. The guidance is in this case ensured by a permanent eccentric bushing positioned between the packer and the drill bit, known from the patent publication mentioned above.

A publication which improves the above presented solutions is patent publication NO 316286. In NO316286 it is known a wireline-operated directional core barrel drill for rock drilling, especially for rock drilling of curved holes with a predetermined path, having an outer drilling tube with a foremost rotatable drill bit and a part connected behind arranged for being locked against rotation. The outer body of the directional core drill is provided with pressure pads which can be pressed against the borehole by means of pressure from supplied drilling fluid. In the front section of the main body it is arranged an eccentric bushing for bending the front part of the rotating internal drive shaft, so that the shaft and the drill bit are provided with a rotational axis deviating from the existing borehole and the non-rotatable central section of the main body. In the drive shaft it is arranged an inner tube for receiving core samples when drilling, as the upper end is provided with space for a survey instrument to be able to measure and log data, such as inclination, direction and angle of rotation of central section of the main body, incl. high side of the eccentric bushing.

The operational lifetime of thrust bearings made of conventional bearing steel, if used in a wireline-operated directional core drill, is shortened due to lack of good lubrication and the high loads in relation to the space available for the bearing (both issues are connected to dimensioning and design), more specifically because of the fact that the drive shaft with its inner tube has to pass through the centre of the thrust bearing, in order to provide wireline-operation of the inner tube.

As a result of the short lifetime of the bearing, the drill needs to be retrieved to the surface for inspection and/or maintenance of the bearing in order to avoid bearing collapse downhole or even a possible loss of the tool. This rod tripping is cost expensive, time consuming as well as a hazard for both the people working there and the borehole.

It is thus identified a need for a thrust bearing having longer operational lifetime and reliability than prior art thrust bearings for wireline-operated directional core drills.

It is further identified a need for a thrust bearing which reduces the need for maintenance and/or inspection cycles, and accordingly reduce the costs and time for performing a drilling operation. By that one need to retrieve the directional core drill from the borehole to inspect the thrust bearing this result in unfavourable costs of exploitation, including drilling, service, inspection and maintenance costs, as an unnecessary workload of rod handling/tripping.

Prior art thrust bearings for wireline-operated directional core drills also suffer from that they are sensitive for bearing lubricant pollution, often resulting in that the bearing is wrecked and needs to be replaced.

A considerable drawback with prior art thrust bearing solutions for wireline-operated directional core drills is also that they need to have the lubricant replaced often to obtain sufficient lubrication and cooling of the bearing, due to lack of space for a lubricant reservoir as well as possible intrusion of drilling fluid.

Another considerable drawback with prior art is that the thrust bearings for wireline-operated directional core drills are very temperature sensitive, and consequently the operational lifetime is reduced due to the above mentioned problems with cooling and circulation of the lubricant.

Object

The main object of the invention is to provide a thrust bearing assembly for a wireline-operated directional core drill solving the above mentioned drawbacks and disadvantages of prior art.

It is further an object of the invention to provide a thrust bearing assembly for a wireline-operated directional core drill which has improved operational lifetime and reliability in relation to prior art solutions, consisting of standard roller or ball thrust bearing assemblies made of different hardened steel qualities.

It is further an object of the invention to provide a thrust bearing assembly for a wireline-operated directional core drill that reduce the need for maintenance and/or inspection cycles.

It is further an object of the invention to provide a thrust bearing assembly for a wireline-operated directional core drill which will result in reduced costs of exploration, including drilling, service, inspection and maintenance costs, in comparison with traditional core drilling tools and systems, as well as a minimizing the need for rod handling/tripping.

Yet another object of the present invention is to provide a thrust bearing assembly for a wireline-operated directional core drill being less sensitive for bearing lubricant pollution, dirt, water, and poor lubrication.

Another object of the present invention is to provide a thrust bearing assembly alternative for a wireline-operated directional core drill which does not need a lubricant other than return water from drilling fluid.

Another object of the present invention is to provide a thrust bearing assembly for a wireline-operated directional core drill that is less sensitive to oscillating rotational speed of the drive shaft.

Another object of the present invention is to provide a trust bearing assembly for a wireline-operated directional core drill that is less sensitive to misalignment of bearing plates relative to each other, due to the fact that it is used in a drill unit that makes curved holes, consequently the drill it selves including the bearing house might be affected.

Finally it is an object of the present invention to provide a thrust bearing assembly for a wireline-operated directional core drill which can operate within higher and/or broader temperature ranges than prior art thrust bearings for a wireline-operated directional core drill.

Further objects of the invention will be disclosed by the more detailed description below.

The invention

In accordance with an aspect of the present invention, there is provided a thrust bearing assembly for a wireline-operated directional core barrel drill, wherein the directional core barrel drill comprises a main body comprising a drill bit with a reamer, a reamer connection, a distance pipe, an eccentric bushing assembly, an extension pipe, a packer tubing with pressure pads or packer elements, a packer guide bar, a sleeve-shaped piston carrier and a drilling tube rear body, wherein an inner barrel bundle is arranged within the main body and the drilling tube rear body, the inner barrel bundle comprising a core catcher sleeve, an inner barrel, a bearing sleeve and a snap connection for connection to a mule shoe connection sleeve and an instrumentation pipe, wherein the inner barrel bundle is provided with a spear head for connection to a wire line, wherein the thrust bearing assembly comprises:

a stator assembly comprising a stator ring comprising a contact surface provided with sliders or slider bits, wherein the stator ring is provided, at the opposite side of where the sliders or slider bits are arranged, with a concave or convex shaped surface which is adapted to and resting against a corresponding concave or convex stator support plate resting on a stuffing box; and

a rotor assembly comprising a rotor ring comprising a contact surface provided with sliders or slider bits, wherein the rotor ring is provided with a widened inner diameter on its rear end dimensioned to fit a front end of an inner thrust rod of the thrust bearing assembly; or

a stator bearing plate, a rotor bearing plate and a bearing cage comprising free rolling balls or roller elements extending to both sides of the bearing cage, arranged between the stator bearing plate and the rotor bearing plate,

wherein all sliding or rolling contact surfaces of the thrust bearing assembly are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), and

wherein the thrust bearing assembly has an enlarged inner diameter to provide space for a drive shaft large enough to allow the inner barrel and the core catcher sleeve to pass through.

The invention relates to a wireline-operated directional core drill for rock drilling, especially a directional core drill with high accuracy, where one desires to retrieve core samples without retrieving the drill string.

The invention relates to a wireline-operated directional core drill for rock drilling, especially a directional core drill with high accuracy, where one desires to retrieve core samples without retrieving the drill string.

The wireline-operated directional core drill according to the invention is significantly more reliable, and thereby more sturdy in use, than those previously known. This also gives the possibility to ensure a stable directional core drilling by means of simple adjustment steps.

The thrust bearing assembly for a wireline-operated directional core drill according to the present invention is a thrust bearing assembly specially designed to fit the wireline-operated directional core drill, wherein rollers, balls or sliders (or slider bits) provide a contact surface that is made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD).

The invention relates to two different types of thrust bearing assembly designs or embodiments for a wireline-operated directional core drill where the above mentioned materials are used, wherein both thrust bearing assembly designs/embodiments are able to take high load on a narrow contact surface and provide a large enough bearing inner diameter to fit a drive shaft of the directional core drill. Furthermore, the thrust bearing assembly designs/embodiments provide a thrust bearing for a wireline-operated directional core drill that is less sensitive to pollutions in the lubricant (water, dirt, etc.) or which does not need lubricant other than water (return water from drilling fluid).

According to a first embodiment of a thrust bearing assembly according to the invention it is provided large ID (inner diameter) slider bearing for a wireline-operated directional core drill where sliding elements or slider bits are made of at least one of the materials mentioned above.

According to a second embodiment of a thrust bearing assembly for a wireline-operated directional core drill according to the present invention it is provided a large ID (inner diameter) roller or ball bearing where both rolling elements, as well as rotor and stator plates, are made of at least one of the materials mentioned above.

The invention also includes means for cooling of the thrust bearing assembly for a wireline-operated directional core drill.

A first embodiment for cooling of the thrust bearing assembly for a wireline-operated directional core drill according to the invention is by creating a bleeding or flow from inside of the drive shaft of the directional core drill in order to provide water to cool the thrust bearing assembly.

A second embodiment for cooling of the thrust bearing assembly for a wireline-operated directional core drill according to the invention is by making or arranging holes or perforations in the bearing housing, in order to allow return water from the drill bit to get in contact with the bearing.

A third embodiment for cooling the thrust bearing assembly for a wireline-operated directional core drill is to arrange a turbo/impeller section right behind a rotor plate, which turbo/impeller section will act as a pump when bearing plate is rotating and consequently will suck water through the slider elements and pump it out at the impeller section outer diameter. The third embodiment may be combined with the first or second embodiment of cooling.

Sufficient cooling and lubrication of the second embodiment of the thrust bearing assembly can, in contrary to bearing assemblies based on conventional bearing steel, be made with low volume of stationary grease or oil, cooled by drilling fluid passing outside an outer trust tube during drilling/flushing, due to the high temperature properties of the ultra-hard materials used.

Any working combination of the above-mentioned cooling procedures can also be considered and utilized.

To provide sufficient operation lifetime of the directional core drill in total it is also favorable that parts being in contact with the thrust bearing assembly according to the invention, such as the drive shaft, is hardened (e.g. plasma hardening) or applied spray metal/ceramic on whole or sections of the drive shaft. It is necessary that the parts being in contact with the thrust bearing assembly according to the invention also exhibits wear resistant properties, to avoid wear from the ultra-hard bearing parts.

With the present invention one will save time and costs in a drilling operation.

Further details and preferable features of the invention are disclosed by the example below.

Example

In the following the invention is described in more detail with reference to the accompanying drawings, where

Figure 1 is a perspective view of a main body and rear body of a prior art directional core barrel drill including a drill bit, packer and attachment sleeve at the upper end, for connection to the rear body,

Figure 2 is a perspective view of an inner barrel bundle of a prior art directional core barrel drill including a core case, inner tube, mule shoe, instrument housing and connection for wire line operation,

Figure 3 is an axial cut through the front end of the drill bit and its coupling in Figure 1,

Figure 4 is a perspective view of a thrust bearing assembly for a wireline-operated directional core drill according to prior art,

Figure 5a is a perspective view of a thrust bearing assembly for a wireline-operated directional core drill according to a first embodiment of the invention including slider bits,

Figure 5b shows details of the thrust bearing assembly in Figures 5a, according to the invention,

Figure 5c is a cross sectional view of the thrust bearing assembly in Figure 5a, according to the invention, with the drive shaft inserted therein,

Figure 5d and 5e show details of a stator assembly of the thrust bearing assembly in Figure 5a, according to the invention,

Figure 5f-5h show details of a rotor assembly of the thrust bearing assembly in Figure 5a, according to the invention,

Figures 6a is a perspective view of a thrust bearing assembly according to a second embodiment of the invention in the form of a roller/ball bearing,

Figure 6b shows details of the thrust bearing assembly in Figure 6a, according to the invention,

Figure 6c is a cross sectional view of the thrust bearing assembly in Figure 6b, according to the invention,

Figure 6d is a perspective view of a stator bearing plate or a rotor bearing plate,

Figure 6e shows details of a concave stator support plate for the thrust bearing assembly in Figure 6b, according to the invention,

Figures 6f and 6g show details of a convex stator support plate for the thrust bearing assembly in Figure 6a, according to the invention, and

Figure 6h shows details of a bearing cage provided with ultra-hard rollers for the thrust bearing assembly in Figure 6b, according to the invention.

Reference is now made to Figure 1 which shows a wireline-operated directional core barrel drill according to prior art. In Figure 1 it is shown a steering tool main body 11 which is assembled of several parts in the longitudinal direction. The main body 11 includes in order from below and up, a drill bit 12 with a reamer 13, a front stabilizer 14, a distance pipe 15, an eccentric bushing assembly 16, extension pipe 17, a packer tubing 18 with three pressure pads or packer elements 19, 20, 21, a packer guide bar 22, a pipe 23 for a thrust and radial bearing, a locking recess 24 at the upper end of a carrier pin (driving stud), a sleeve-shaped piston carrier 25 which forms a annular piston space, and a drilling tube rear body 26. These elements will be described below.

In Figure 2 it is shown an inner barrel bundle 27 having a lower core catcher sleeve 28 attached to an inner barrel 29 having space for receiving a bore core which at the upper end is connected to a bearing sleeve and a snap connection 30 for connection to a mule shoe connection sleeve 31, which at its upper end carries an instrumentation pipe 32. The instrumentation pipe 32 has a communication port for instruments carrying measuring instruments for measuring direction and inclination, and angle of rotation, for example magnetometer and accelerometer. Further it is arranged a spear head 33 for connection of the inner barrel bundle 27 to a wire line with a quick snap connection (not shown).

In Figure 3 the lower part of the main body 11 is shown in an axial cut. The drill bit 12, having exterior water paths, is tubular and has an inner mandrel 34 provided with threads for insertion in the reamer 13, which in a corresponding way is connected at the lower end of the reamer connection 14, which again is connected together with a rotating drive shaft 35.

At the front end of the reamer connection 14 it is arranged a sleeve 36 which can retrieve the core catcher sleeve 28. When the core catcher sleeve 28 is seated inside the sleeve 36, circulating water passing through the drive shaft 35 has to pass through one or more exterior channels in the core catcher sleeve 28, which in turn acts like a nozzle for choking drilling fluid which is supplied through the drive shaft 35, so that there is provided a pressure in the drill pipe, which is sufficient for activating the packer 18 (Figure 1). The pressure upstream of the sleeve 36 can be 20-30 bars. The cross section of the channels in the core catcher sleeve 28 and thus the pressure of the packer 18 can be adjusted by replacing the core catcher sleeve 28 with a core catcher sleeve with more or less channels or with core catcher or core catcher channels having a different size. In this way it is possible in an easy way to adapt the directional core barrel drill to different kinds of rock which requires different amounts of water and different packer pressure. To achieve the highest possible wear resistance the sleeve 36 can be manufactured of a very wear resistant material.

Alternatively it can be arranged a corresponding sleeve higher up on the drive shaft 35 or the inner barrel 29, at the lower side of the packer housing 18.

The directional core drill of Figure 1-3 is so arranged that by supplying drilling fluid under pressure to the sleeve-shaped piston carrier 25, the sleeve-shaped piston carrier 25, the drill bit 12 and its couplings, drive shaft 35 and rear body 26 can rotate independent of the stationary part of the main body 11.

The above described apparatus makes it possible to retrieve core samples from a directional core barrel drill. At the same time the directional core barrel drill has a connection mechanism making it easy to monitor, make adjustments and regulate the drilling direction and borehole curvature. Further, it is easy to adapt the packer pressure after need when it is to be drilled in different kinds of rock, which requires different pressure during sliding.

Channels for conveying and chocking drilling fluid can alternatively or in addition be arranged in a sleeve surrounding the front end of the inner barrel 29.

Reference is now made to Figure 4 which shows the rear section of the main body 11 of a directional core barrel drill provided with a thrust bearing assembly 40. As shown in Figure 1 and described above the directional core barrel drill includes a pipe 23 for a thrust and radial bearing which is arranged between the sleeve-shaped piston carrier 25 and the packer tubing 18. The prior art trust bearings in wireline-operated directional core barrel drills are conventional of the shelf bearings made in hardened steel, such as SKF 511109 (ball trust bearing) or SKF 81109 (roller trust bearing) or SKF AXK4565 (needle trust bearing).

According to the present invention the prior art trust bearing assembly 40 shown in Figure 4, which is arranged in the directional core drill, between the sleeve-shaped piston carrier 25 and packer tubing 18 by means of connection tubes 41, 42, respectively, is replaced with a thrust bearing assembly 40 according to the invention, as shown in Figure 5a.

Reference is now made to Figure 5a which shows a perspective view of the thrust bearing assembly 40 according to a first embodiment the present invention. The thrust bearing assembly 40 includes an inner thrust rod 43 arranged for connection to the sleeve-shaped piston carrier 25 (Figure 1), a stuffing box 44 arranged for connection to the distance tube 42, and an outer thrust tube 45, which outer thrust tube 45 in one embodiment of the thrust bearing assembly 40 according to the invention is provided with through holes 46 or allowing flow of fluid for cooling of the thrust bearing assembly 40.

Reference is now made to Figure 5b which shows details of the thrust bearing assembly 40 in Figure 5a, according to the invention, where the outer thrust tube 45 is removed for the purpose of disclosing details of the thrust bearing assembly 40 according to the invention. The thrust bearing assembly 40 according to the invention includes a stator assembly 47 arranged to the stuffing box 44, and where a convex stator support plate 48 is arranged between the stuffing box 44 and the stator assembly 47. The thrust bearing assembly 40 according to the invention also includes a rotor assembly 49 which is arranged to the inner thrust rod 43. To the inner thrust rod 43 it is also arranged a bushing 50 and sealing means 51a, 51b at each side of the bushing 50, which bushing 50 is arranged for taking up radial forces acting on the thrust bearing assembly 40 during handling and operation of the directional core drill. The sealing means 51a, 51b are arranged for preventing cooling fluid/sludge from entering other parts of the directional core drill.

Reference is now made to Figure 5c which shows a cross sectional view of the thrust bearing assembly 40 according to the first embodiment of the invention in Figures 5a-b with the drive shaft 35 inserted therein. The thrust bearing assembly 40 according to the invention includes a bushing 52 arranged to the stuffing box 44. The thrust bearing assembly 40 according to the invention further includes a spring 53 arranged between the rotor assembly 49 and a spring stopper 54. The thrust bearing assembly 40 according to the invention also includes a thrust rod washer 55 arranged at the end of the inner thrust rod 43, facing the rotor assembly 49.

Reference is now made to Figures 5d and 5e which shows details of the stator assembly 47 in Figures 5b-c. The stator assembly 47 includes a stator ring 56, where it is arranged through holes 57 at a surface 58 forming the circumference of the stator ring 56 for allowing flow of a cooling fluid for cooling of the thrust bearing assembly 40. At a surface 59 of the stator ring 56 sliders or slider bits 60 are arranged, which sliders or slider bits 60 are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), or a combination of these materials.

The purpose of the sliders or slider bits 60 is to provide an ultra-hard and extremely wear resistant surface against the rotor assembly 49. The slider bits 60 are preferably arranged in recesses arranged in the stator ring 56, and fastened in the recesses by means of, for example, soldering or gluing.

On the opposite side of the slider bits 60 the stator ring 56 has a concave shaped surface 61, as shown in Figure 5e. The concave shaped surface 61 of the stator ring 56 is adapted to and resting against the convex stator support plate 48 resting on the stuffing box 44. The concave surface 61 is preferably provided with holes or slots that match guide pins 62 pointing out of the convex stator support plate 48, in order to prevent the convex stator support plate 48 from rotating when the drive shaft 35 is rotating, especially when the thrust bearing assembly 40 is under load.

Furthermore, the convex stator support plate 48 is provided with similar guide pins on the side that rest against the stuffing box 44 to prevent the convex stator support plate 48 from rotating when the drive shaft 35 is rotating and especially when the thrust bearing assembly 40 is under load. Consequently the stuffing box 44 is provided with slots or holes that match the guide pins of the convex stator support plate 48.

Reference is now made to Figures 5f and 5g which show details of the rotor assembly 49 in Figures 5b-c. The rotor assembly 49 includes a rotor ring 63, where it is arranged through holes 64 at a surface 65 for allowing flow of a cooling fluid for cooling of the thrust bearing assembly 40.

At a surface 66 of the rotor ring 63 sliders or slider bits 67 are arranged, which sliders or slider bits are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), or a combination of these materials. The purpose of the sliders or slider bits 67, made in the materials mentioned above, is to provide an ultra-hard and extremely wear resistant surface against the stator assembly 47, i.e. the slider bits 60 arranged on the stator ring 56. The slider bits 67 are preferably arranged in recesses arranged in the rotor ring 63, and fastened in the recesses by means of, for example, soldering or gluing.

When the rotor ring 63 rotates the holes 64 will act as an impeller pump where cooling liquid is sucked through the slider bits 67, between the slider bits 67, when water due to the centrifugal force is pumped out of the holes 64. To make the pumping force stronger the holes 64 can be replaced with impeller wings 68, as shown in Figure 5h.

The rotor ring 63 has a widened inner diameter on its rear end large enough to fit the front end of the inner thrust rod 43. The surface of the widened inner diameter is preferably provided with guide pins 69 pointing towards center of the drive shaft 35. The inner thrust rod 43 will in this case be provided with axial slots (not shown) that fit the guide pins 69 and consequently it will allow the rotor ring 63 to move axially, but prevent rotational movement of the rotor ring 63 relative to the inner thrust rod 43. The above mentioned spring 53 will make sure that there is no gap between the sliding or rolling surfaces of the stator assembly 47 and rotor assembly 49 when the thrust bearing assembly 40 is unloaded and through that protect the thrust bearing assembly 40 from damage.

Cooling of the above described thrust bearing assembly 40 is achieved by the through holes 46 in the outer thrust tube 45, the through holes 57 of the stator ring 56 and the through holes 64 or impellers 68 of the rotor ring 63. It should be mentioned that the holes 46 in the outer thrust tube 45 are arranged so that they cover both the stator assembly 47 and rotor assembly 49, so that fluid both can enter the interior of the bearing assembly 40 and escape from the bearing assembly 40. By means of these holes 46, 57, 64 or impellers 68 return water from the drill bit 12 can access the bearing surfaces and thereby cool the bearing assembly 40.

Alternative cooling options for the thrust bearing assembly 40 is by a bleeding or flow from inside of the drive shaft 35 for providing a flow of cooling fluid for the thrust bearing assembly 40. In such a solution the outer thrust tube 45 will be solid.

Reference is now made to Figures 6a-6h which show a second embodiment of a thrust bearing assembly 40 according to the present invention. This embodiment provides a large ID (inner diameter) roller or ball bearing where both rolling elements, as well as rotor and stator plates, are made of at least one of the materials mentioned above, i.e. tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), or a combination of these materials.

The thrust bearing assembly 40 according to the second embodiment in Figures 6a-6g includes as in the first embodiment presented above (Figures 5a-h), an inner thrust rod 43, a stuffing box 44, outer thrust tube 45, stator bearing plate 70 (corresponds to the stator ring 56 in the first embodiment), rotor bearing plate 71 (corresponds to the rotor ring 58 in the first embodiment), bushing 50 and bushing 53 which are all well described above. For taking up impacts and vibrations, it can be arranged a plate 72 of soft metal, such as cobber, next to the bushing 53. The stator side of the bearing assembly 40 in this embodiment includes a concave stator support plate 73 (shown in detail in Figure 6e), i.e. a plate with a concave side and a planar side, which stator support plate 73 is resting on the stuffing box 44 at the planar side. The stator side of assembly 40 further includes a convex stator support plate 74 (shown in detail in Figure 6f and 6g), i.e. a plate with a convex side and a planar side, which convex side is adapted to the concave stator support plate 73, i.e. the concave side of the stator support plate 73, and is resting against the concave stator support plate 73. The convex stator support plate 74 is preferably at the planar side provided with a rim for stabilization of the stator bearing plate 70. The stator bearing plate 70 (shown in Figure 6b-c and shown in detail in Figure 6d) is made out one of the above mentioned ultra-hard materials.

The rotor side of assembly 40 in this embodiment includes a bearing cage 75 (shown in detail in Figure 6h) preferably of hardened metal, where balls or rollers 76 made of one of the above mentioned ultra-hard materials are arranged inside, and a rotor bearing plate 71 (shown in Figure 6b-c and shown in detail in Figure 6d) made of one of the above mentioned ultra-hard materials, a rotor cup 77, which rotor cup 77 is arranged to the inner thrust rod 43.

The bearing cage 75 is arranged between the stator bearing plate 70 and the rotor bearing plate 71, as shown in Figures 6b and 6c. The balls or rollers 76 inside the bearing cage 75 are preferably arranged so that they extend to both sides of the bearing cage 75.

Sufficient cooling and lubrication of the latter described embodiment of the thrust bearing assembly 40 can, in contrary to bearing assemblies based on conventional bearing steel, be made with low volume of stationary grease or oil, cooled by drilling fluid passing outside the outer trust tube 45 during drilling/flushing, due to the high temperature properties of the ultra-hard materials used.

It should also be mentioned that all embodiments where it is necessary are provided with means for applying grease to parts of the bearing requiring this.

Any of the above described embodiments can med modified and possibly combined to form new embodiments of the thrust bearing assembly 40.

Claims

1. A thrust bearing assembly for a wireline-operated directional core barrel drill, wherein the directional core barrel drill comprises a main body comprising a drill bit with a reamer, a reamer connection, a distance pipe, an eccentric bushing assembly, an extension pipe, a packer tubing with pressure pads or packer elements, a packer guide bar, a sleeve-shaped piston carrier and a drilling tube rear body, wherein an inner barrel bundle is arranged within the main body and the drilling tube rear body, the inner barrel bundle comprising a core catcher sleeve, an inner barrel, a bearing sleeve and a snap connection for connection to a mule shoe connection sleeve and an instrumentation pipe, wherein the inner barrel bundle is provided with a spear head for connection to a wire line, wherein the thrust bearing assembly comprises:

a stator assembly comprising a stator ring comprising a contact surface provided with sliders or slider bits, wherein the stator ring is provided, at the opposite side of where the sliders or slider bits are arranged, with a concave or convex shaped surface which is adapted to and resting against a corresponding concave or convex stator support plate resting on a stuffing box; and

a rotor assembly comprising a rotor ring comprising a contact surface provided with sliders or slider bits, wherein the rotor ring is provided with a widened inner diameter on its rear end dimensioned to fit a front end of an inner thrust rod of the thrust bearing assembly; or

a stator bearing plate, a rotor bearing plate and a bearing cage comprising free rolling balls or roller elements extending to both sides of the bearing cage, arranged between the stator bearing plate and the rotor bearing plate,

wherein all sliding or rolling contact surfaces of the thrust bearing assembly are made of tungsten (wolfram carbide), titanium carbide, ceramic or Polycrystalline Diamond (PCD), and

wherein the thrust bearing assembly has an enlarged inner diameter to provide space for a drive shaft large enough to allow the inner barrel and the core catcher sleeve to pass through.

2. The thrust bearing assembly according to claim 1, wherein the drive shaft is hardened on whole or sections of the drive shaft being in contact with the thrust bearing assembly.

3. The thrust bearing assembly according to claim 2, wherein the drive shaft is hardened by means of plasma hardening or applied spray metal/ceramic.

4. The thrust bearing assembly according to claim 1, wherein the stator ring of the stator assembly is provided with holes for allowing a flow of cooling fluid for cooling of the thrust bearing assembly.

5. The thrust bearing assembly according to claim 1, wherein a surface of the widened inner diameter of the rotor ring comprises guide pins pointing towards the center of the drive shaft, and the inner thrust rod comprises axial slots that fit the guide pins to allow the rotor ring to move axially, but prevent rotational movement of the rotor ring relative to the inner thrust rod.

6. The thrust bearing assembly according to claim 1, wherein the convex or concave stator support plate comprises guide pins on a side facing the convex or concave shaped surface, the concave or convex shaped surface comprising matching holes or slots and a second set of guide pins on a side that is resting against the stuffing box, and wherein the stuffing box comprises a second set of matching slots or holes that prevents the convex or concave stator support plate from rotating when the drive shaft is rotating while preserving alignment of the convex or concave shaped surface.

7. The thrust bearing assembly according to claim 1, wherein the rotor ring of the rotor assembly comprises holes or impellers that provide pumping of cooling fluid for cooling of the thrust bearing assembly.

8. The thrust bearing assembly according to claim 1, further comprising an outer thrust tube comprising a solid outer surface or through holes for allowing a flow of cooling fluid to access and escape from the interior of the thrust bearing assembly.

9. The thrust bearing assembly according to any one of claims 1 to 8, further comprising sealing means for preventing cooling fluid/sludge from entering other parts of the directional core drill.

10. The thrust bearing assembly according to any one of claims 1 to 9, wherein a bleeding or flow is arranged from inside of the drive shaft for providing a flow of cooling fluid for the thrust bearing assembly.

11. The thrust bearing assembly according to claim 1, wherein the stator bearing plate is resting against a first stator support plate comprising a convex or concave surface opposite the

stator bearing plate, the convex or concave surface resting against a second stator support plate having a corresponding shape.

12. The thrust bearing assembly according to any one of claims 1 to 11, wherein the bearing assembly further comprises a rotor cup.

13. The thrust bearing assembly according to claim 12, further comprising a spring arranged between the rotor cup/rotor ring and a spring stopper to make sure that there is no gap between sliding or rolling contact surfaces when the thrust bearing assembly is unloaded.

14. The thrust bearing assembly according to any one of claims 1 to 13, further comprising a bushing arranged to contact the inner thrust rod for taking up radial forces acting on the thrust bearing assembly.

15. The thrust bearing assembly according to any one of claims 1 to 14, wherein the wireline-operated directional core barrel drill is used for rock drilling.

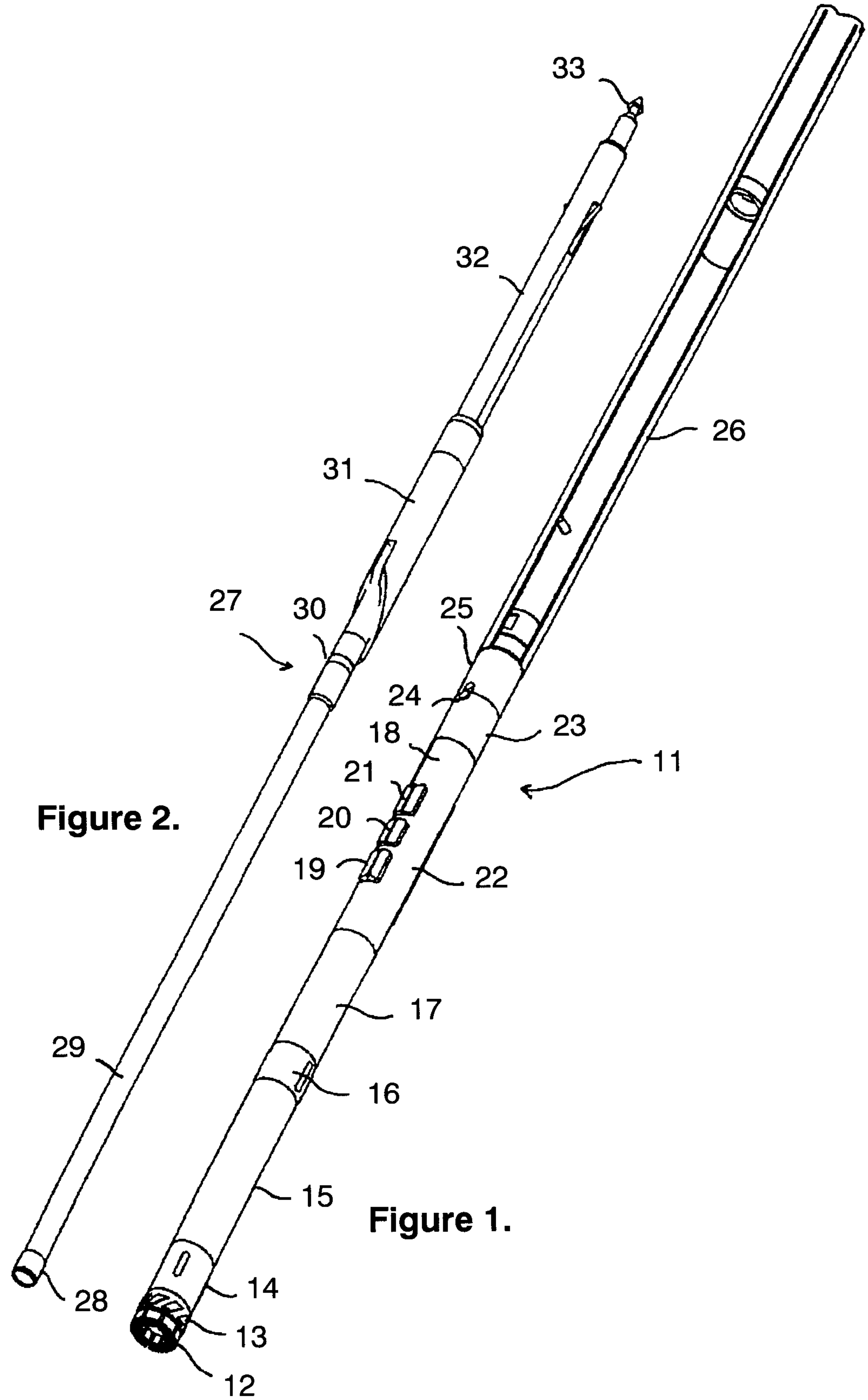


Figure 2.

Figure 1.

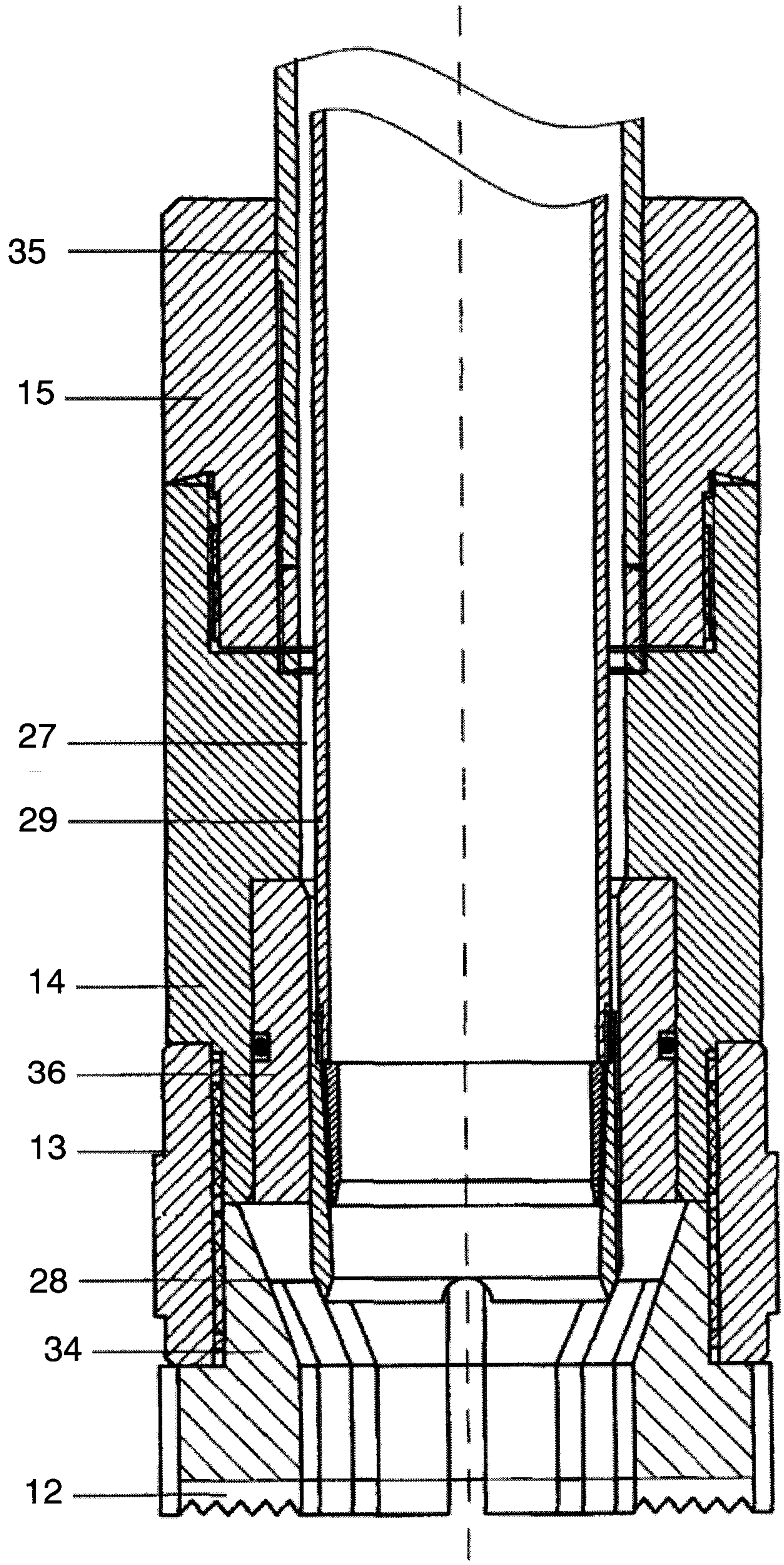
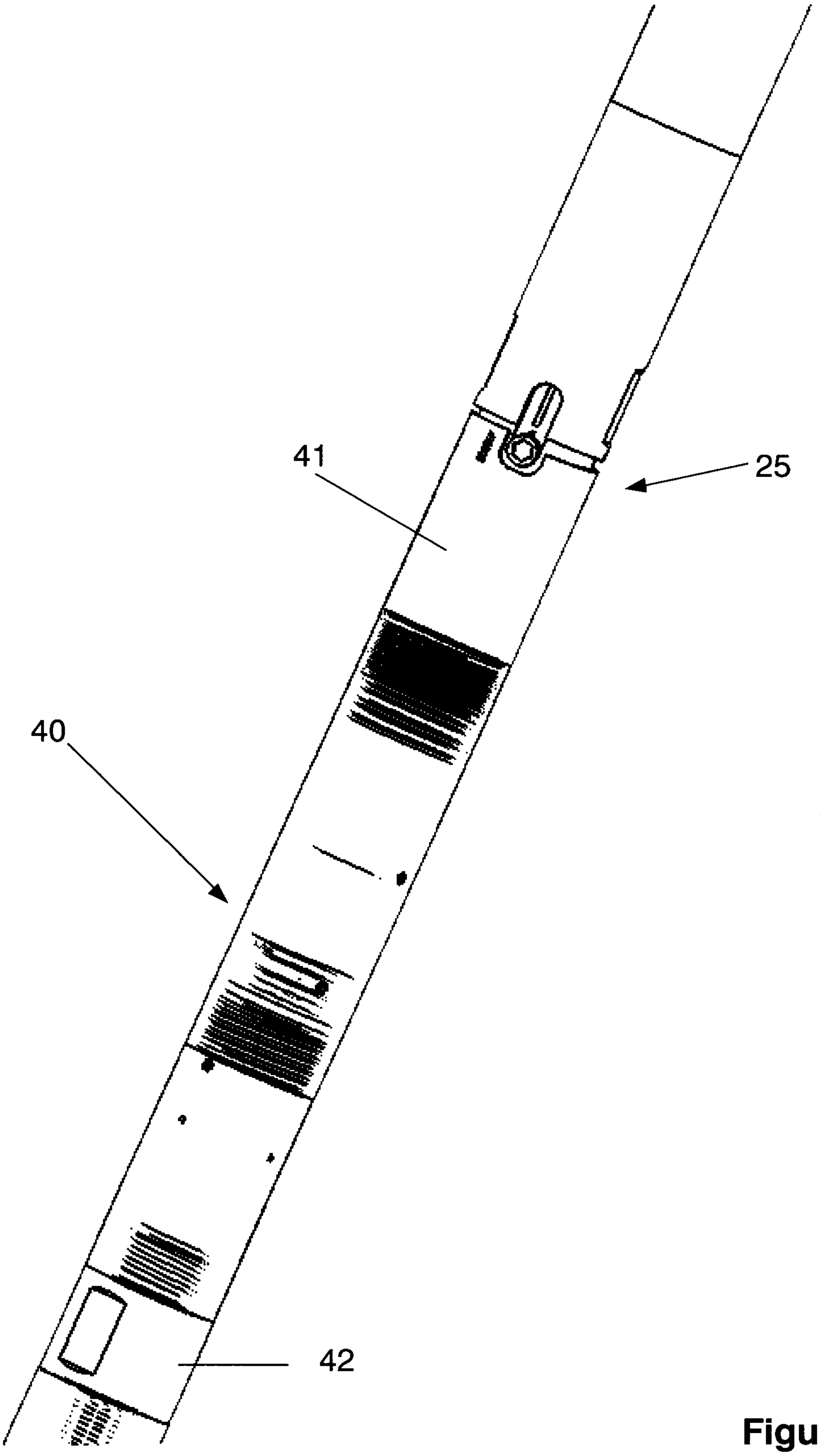


Figure 3.



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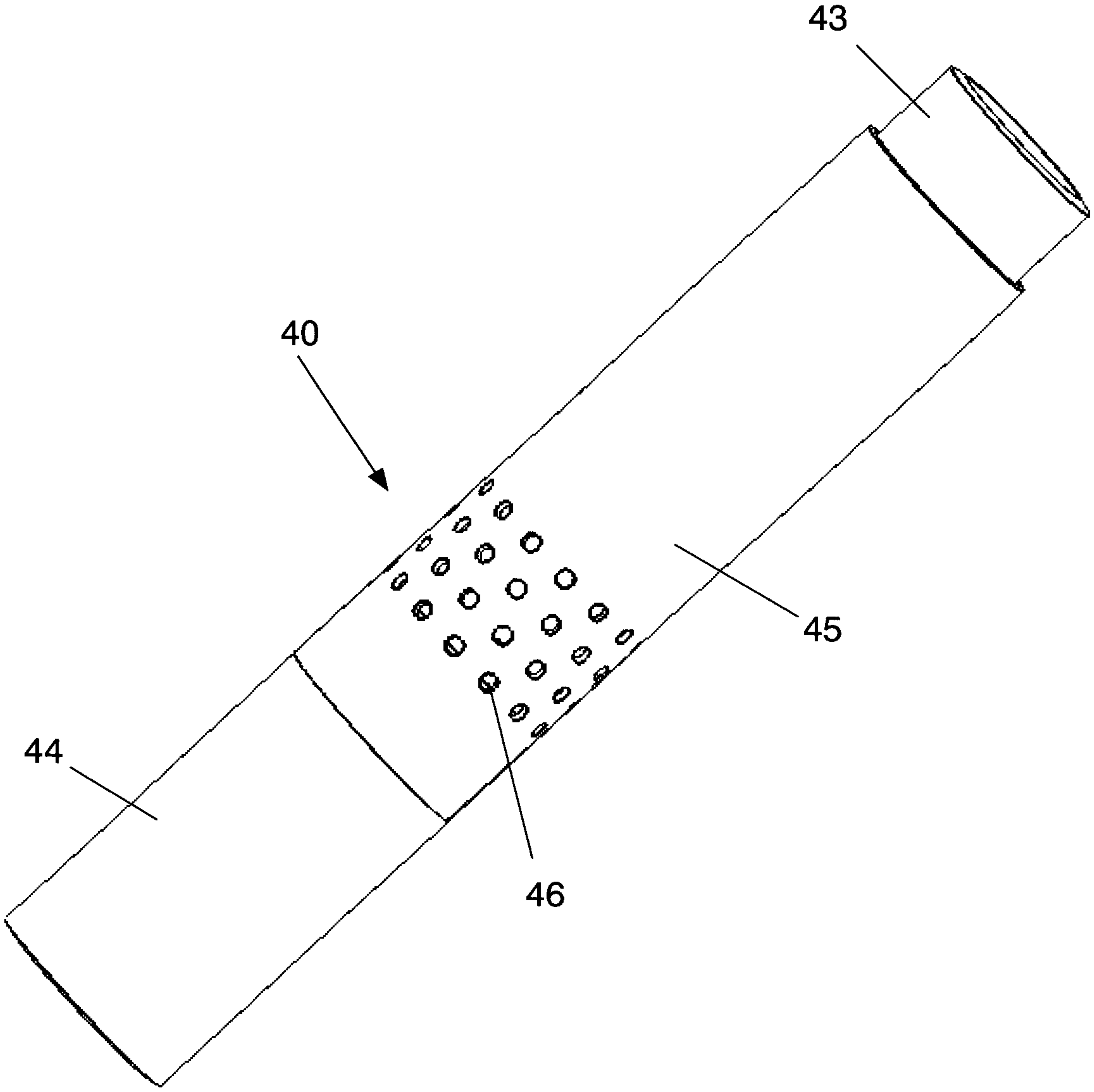


Figure 5a.

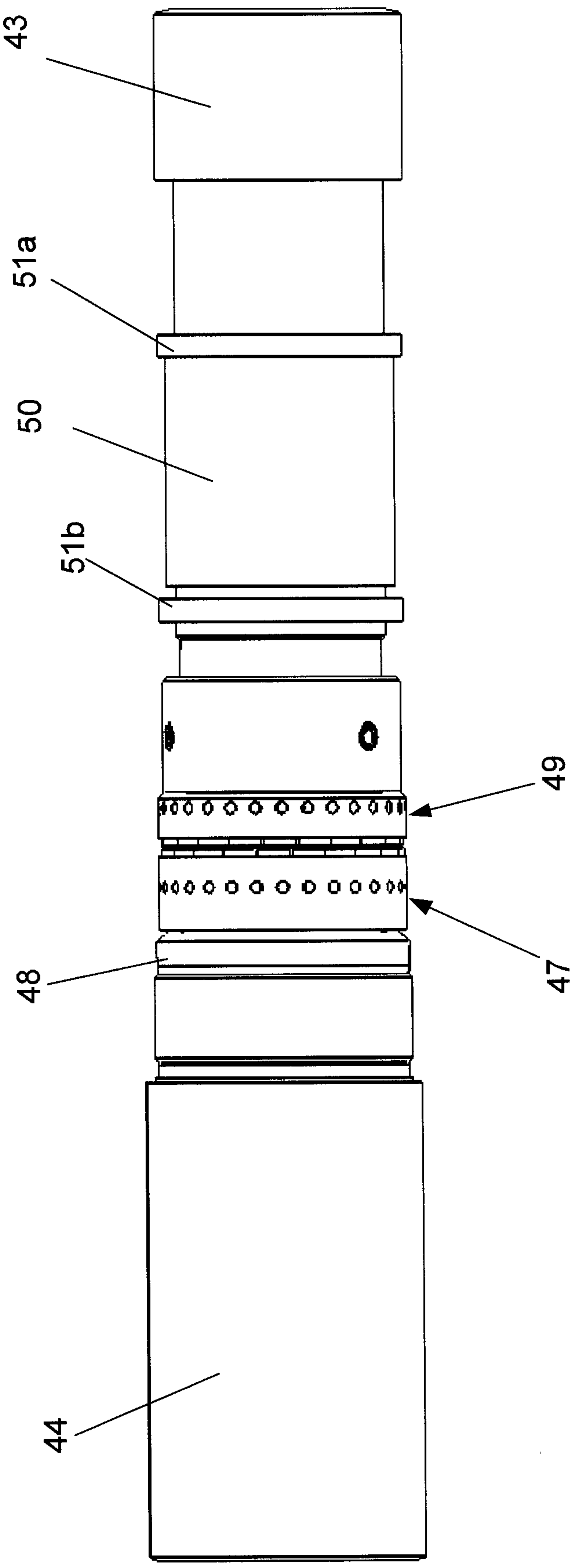


Figure 5b.

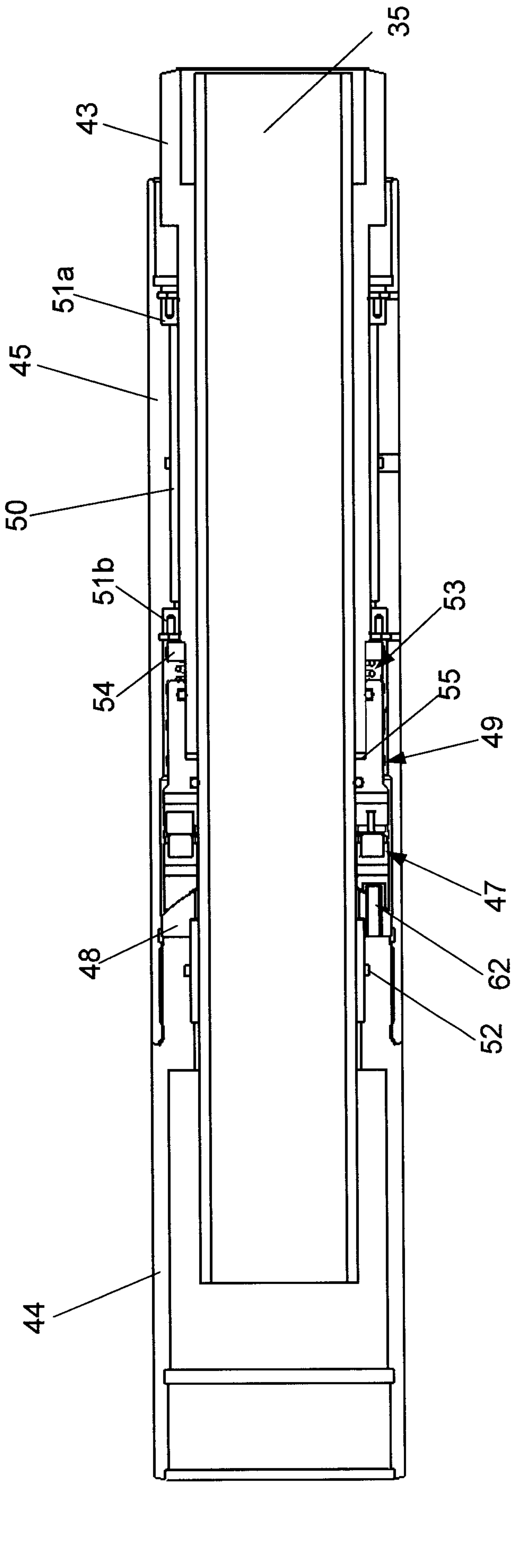


Figure 5c.

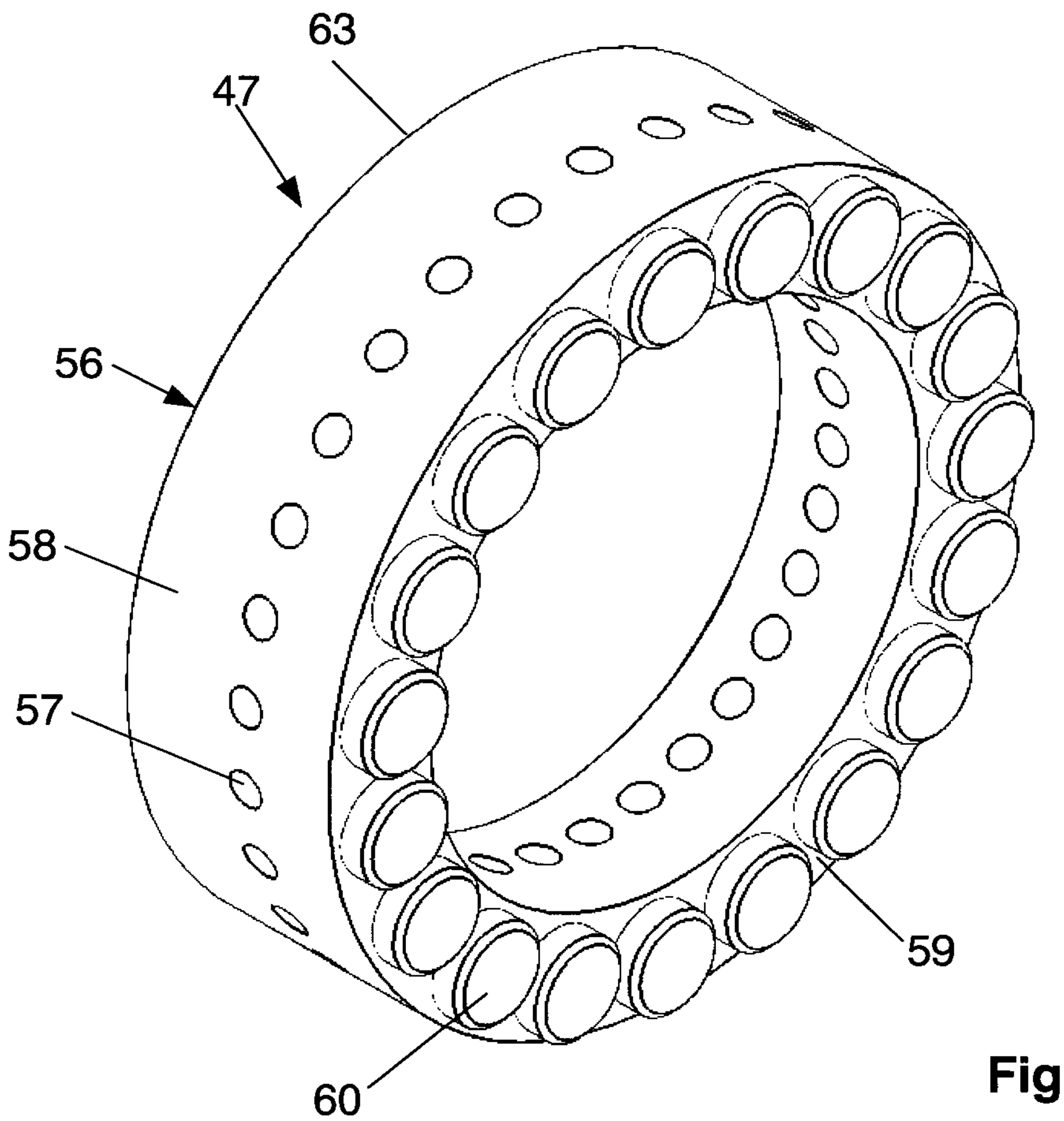


Figure 5d.

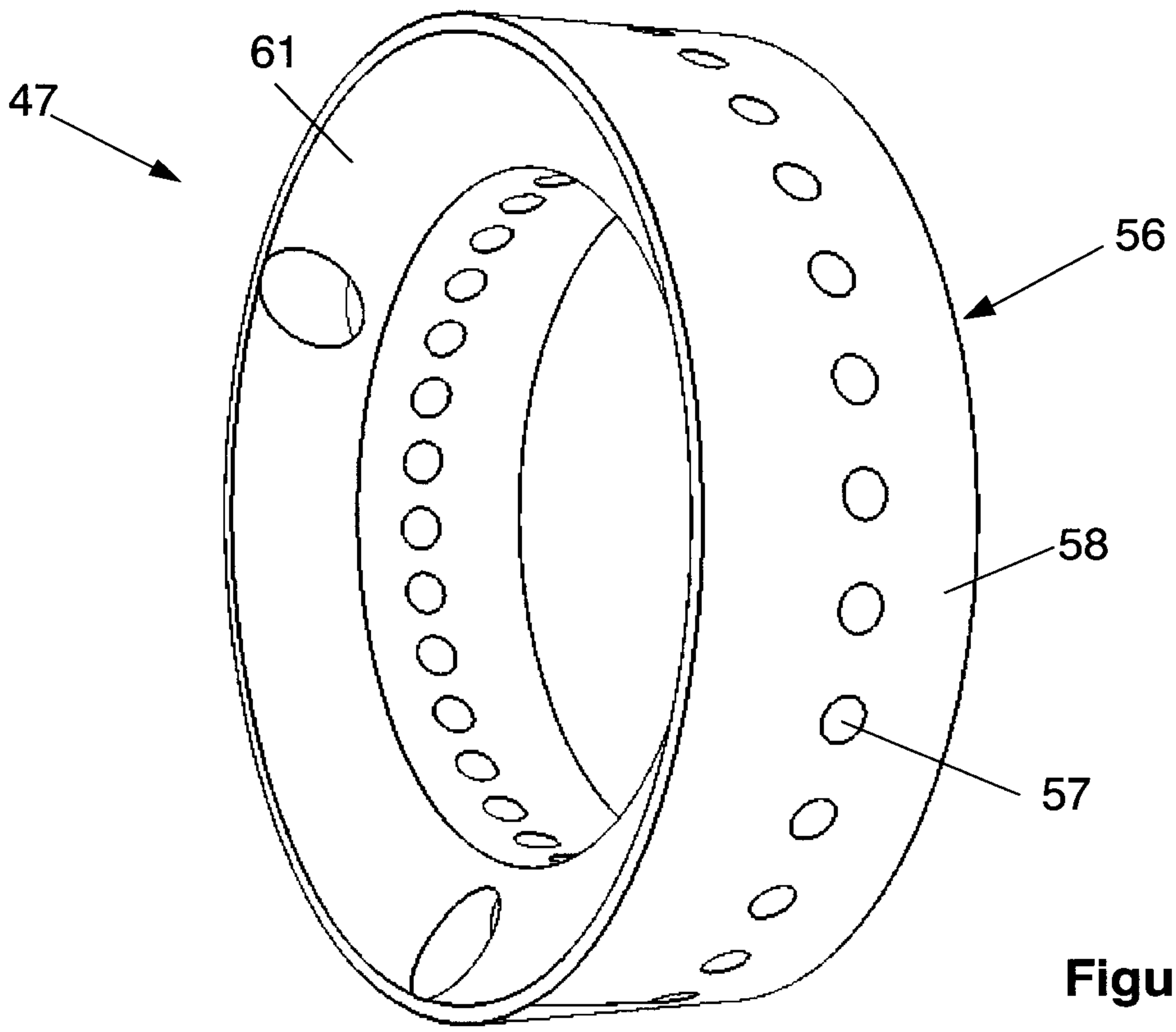
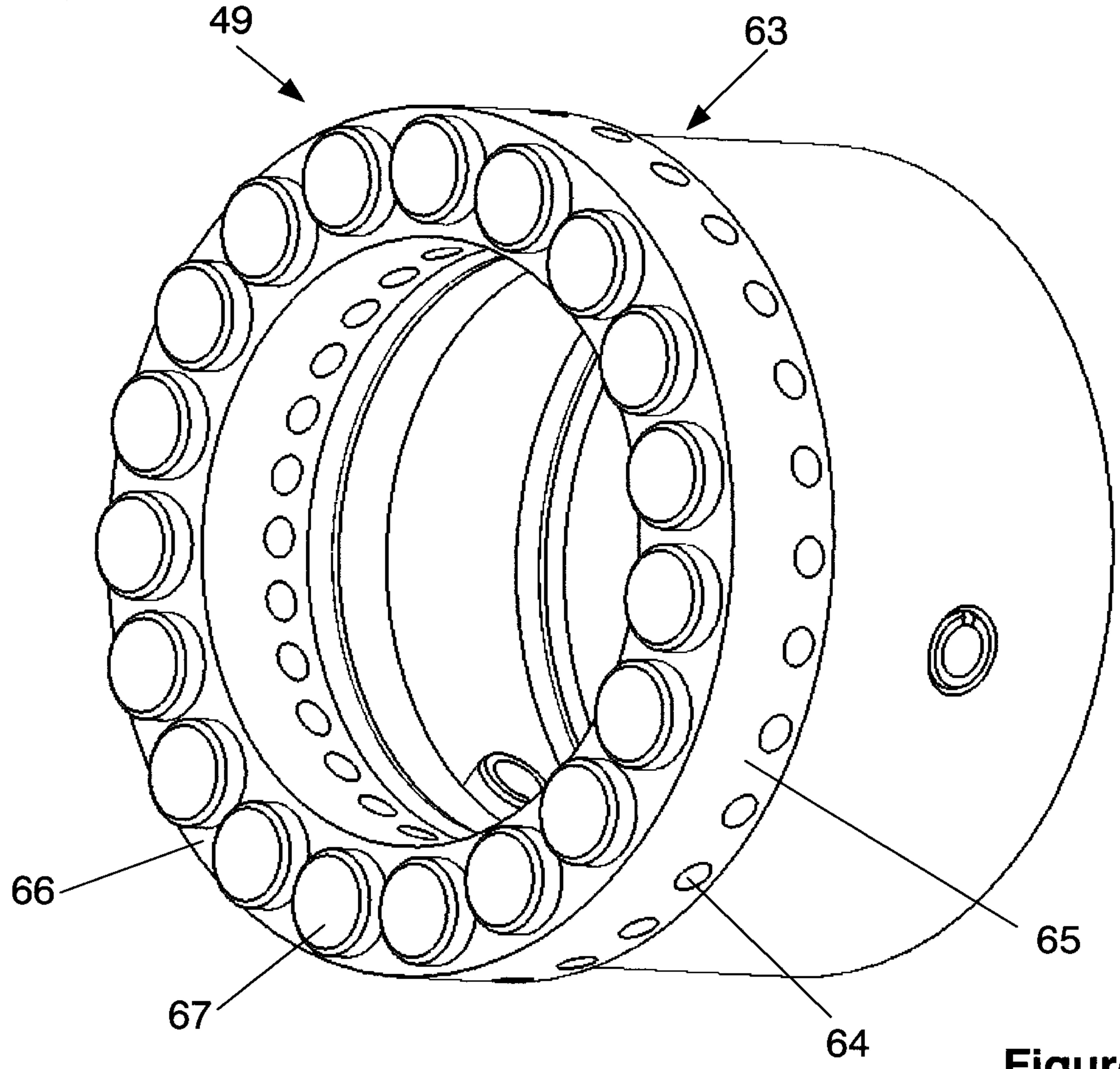


Figure 5e.



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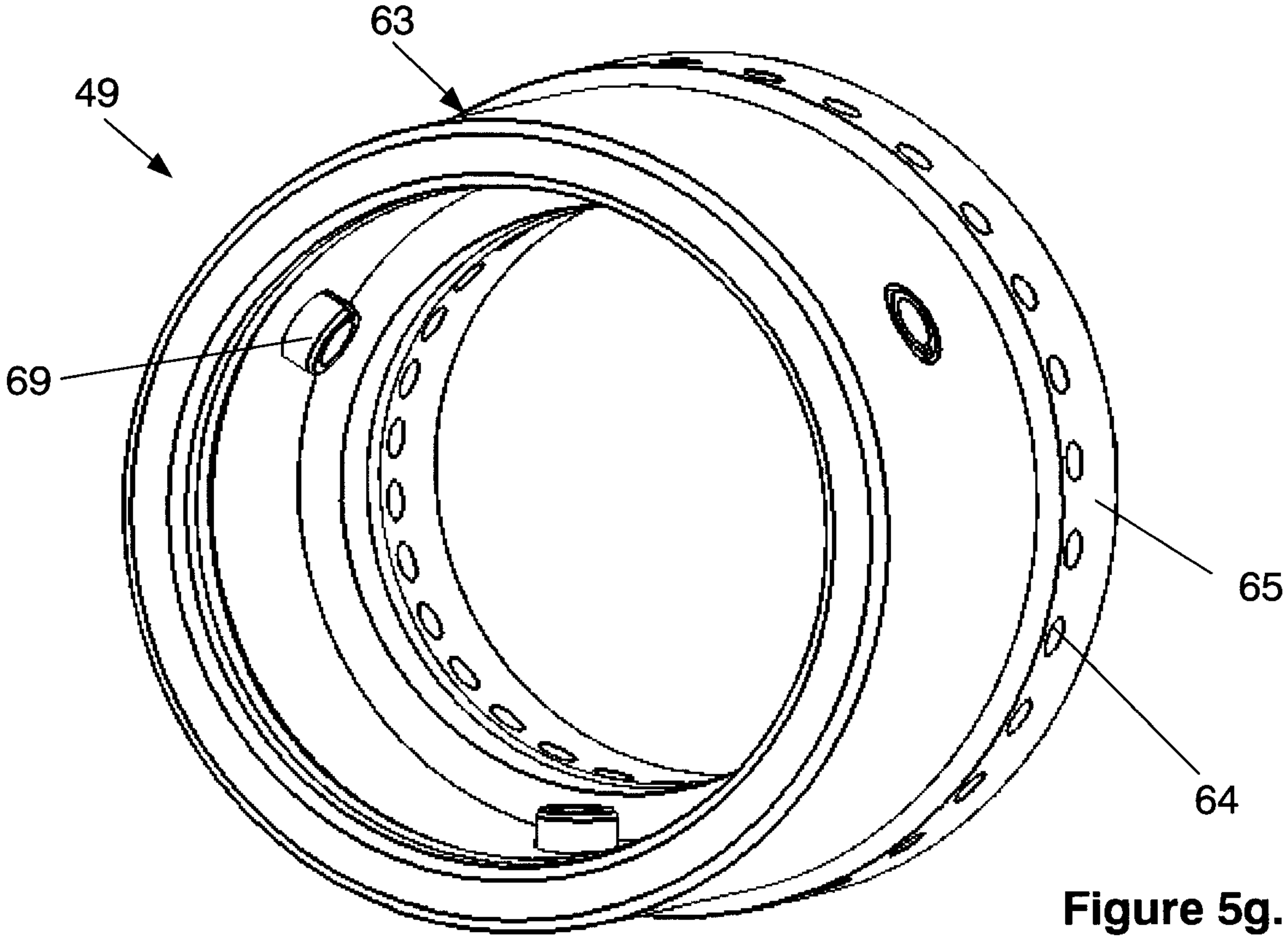


Figure 5g.

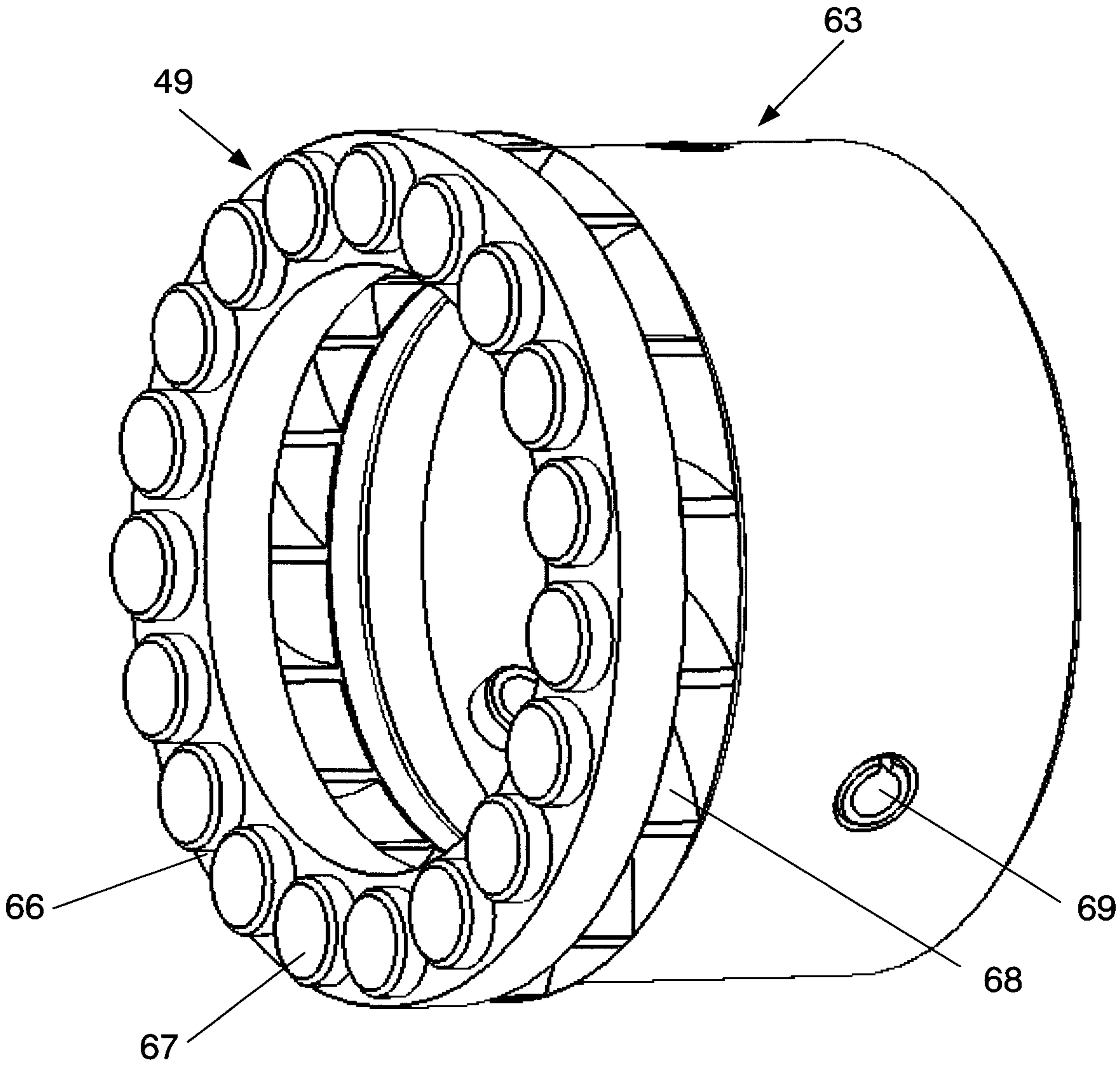


Figure 5h.

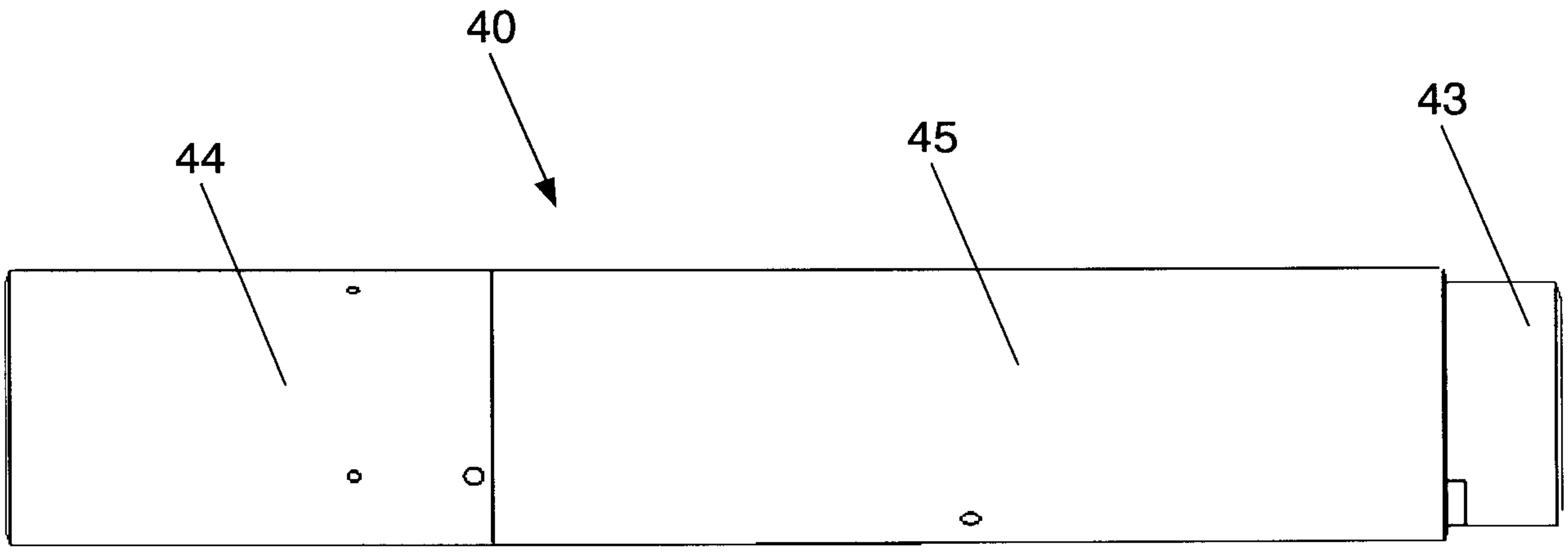
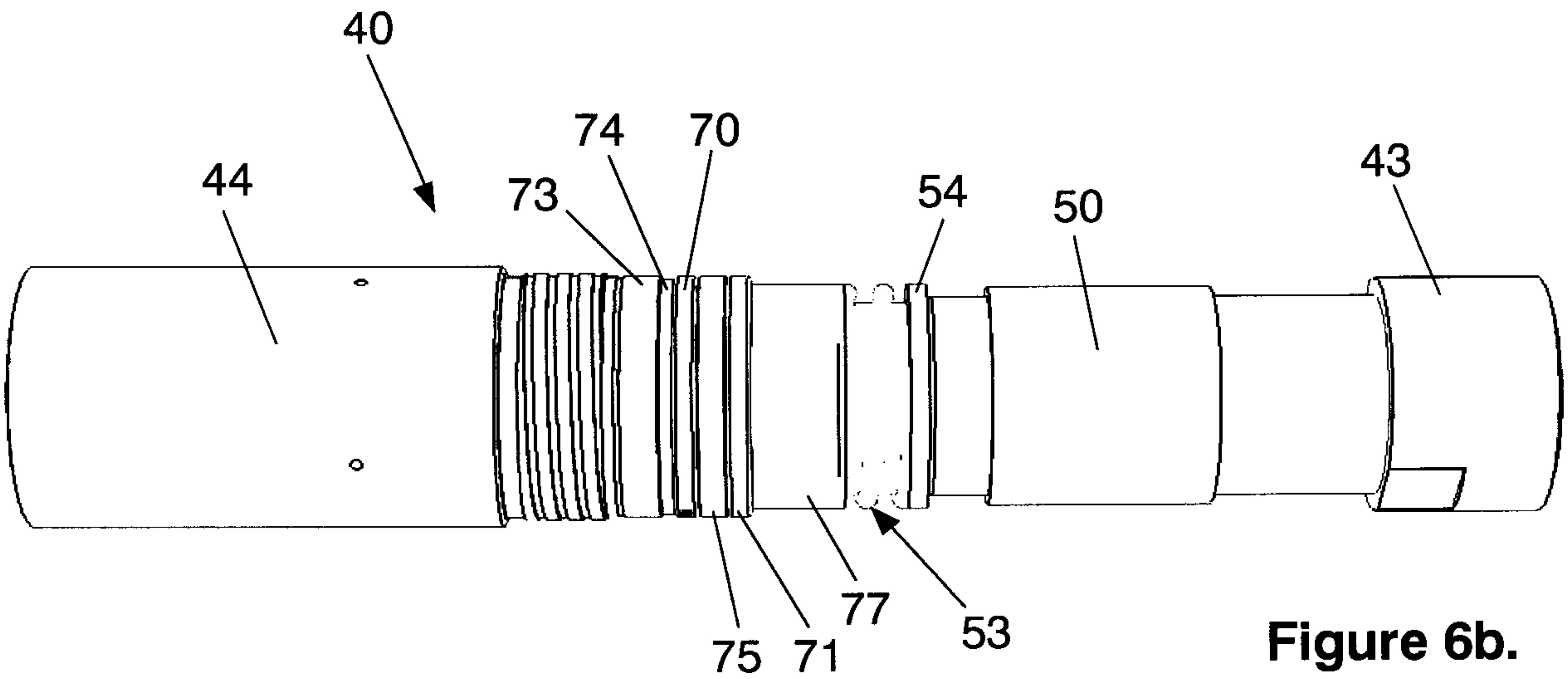


Figure 6a.



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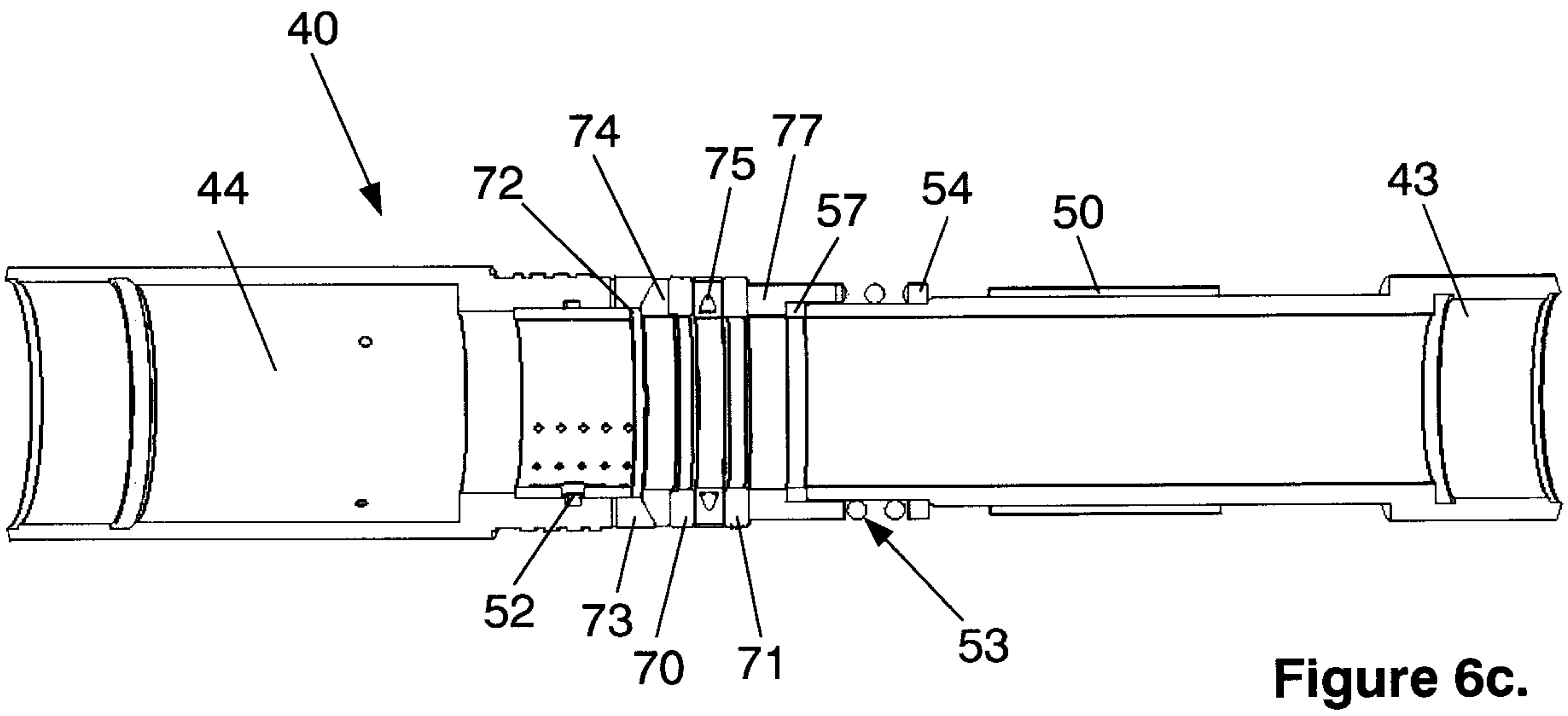


Figure 6c.

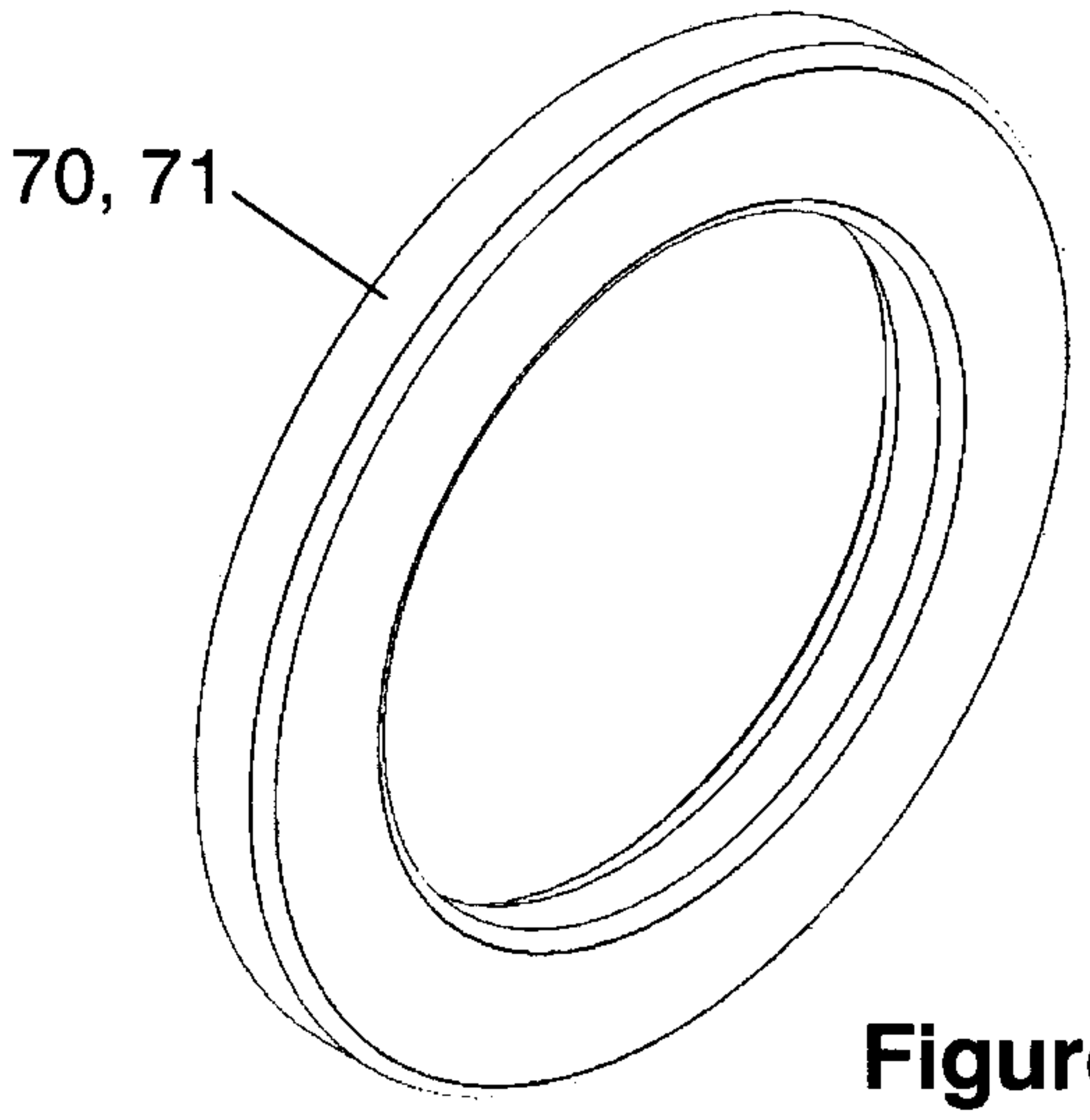
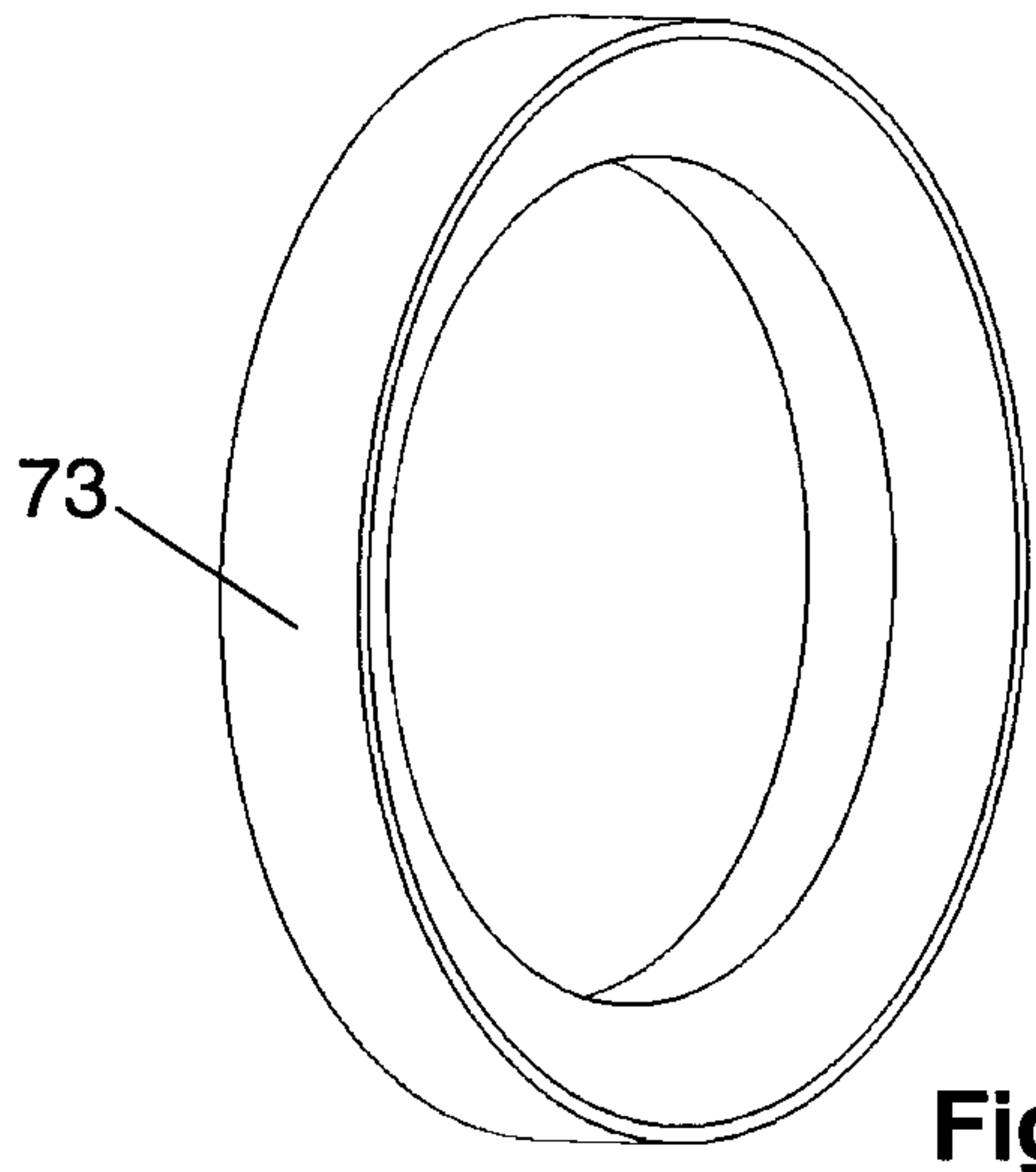


Figure 6d.



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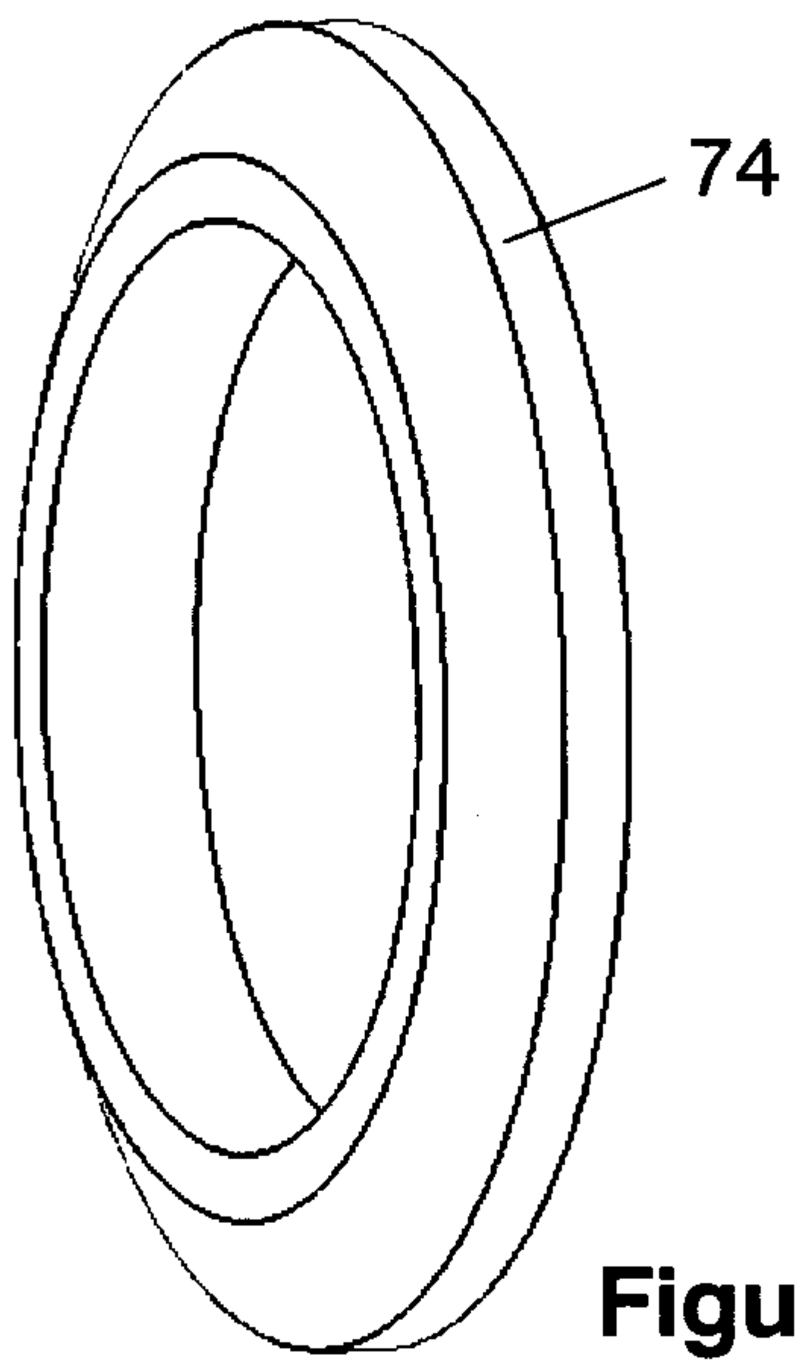

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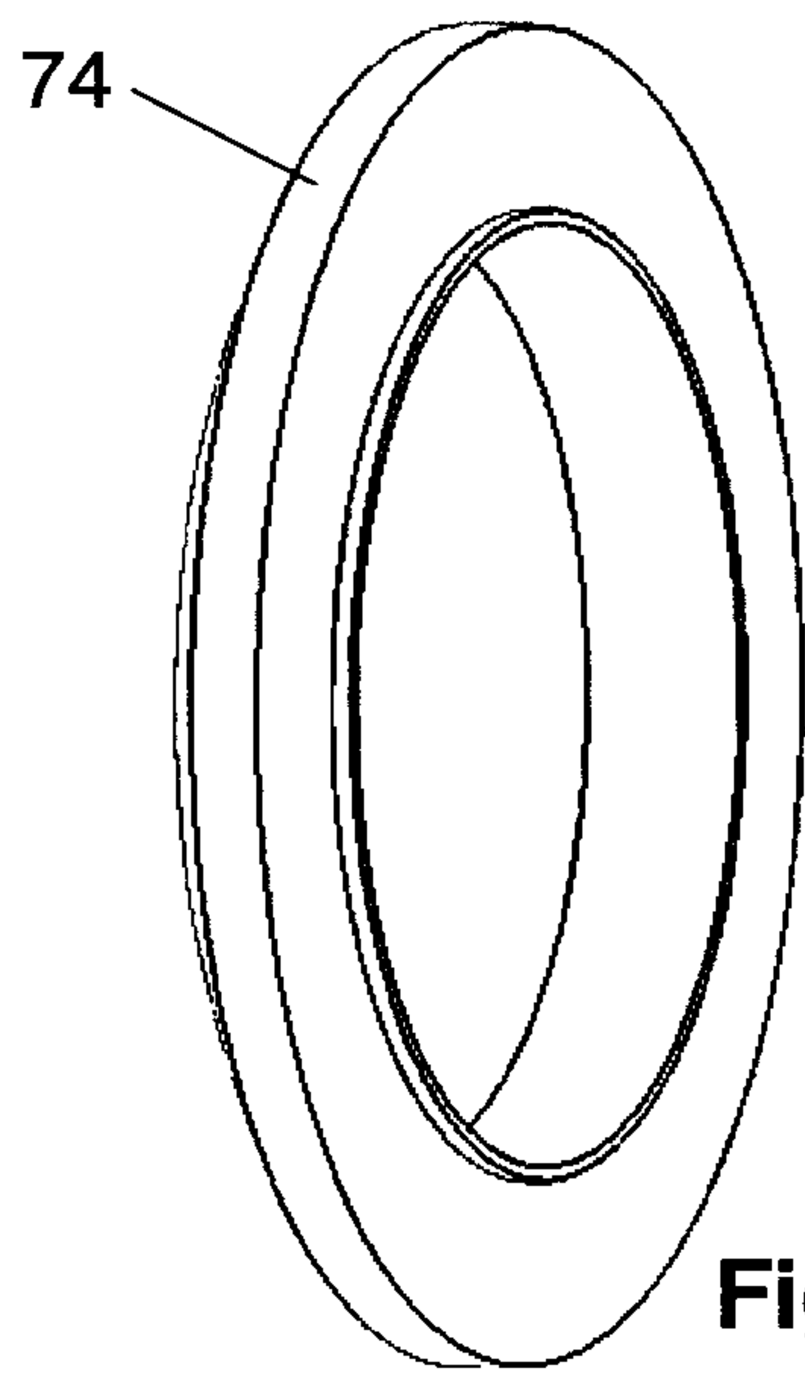


Figure 6g.

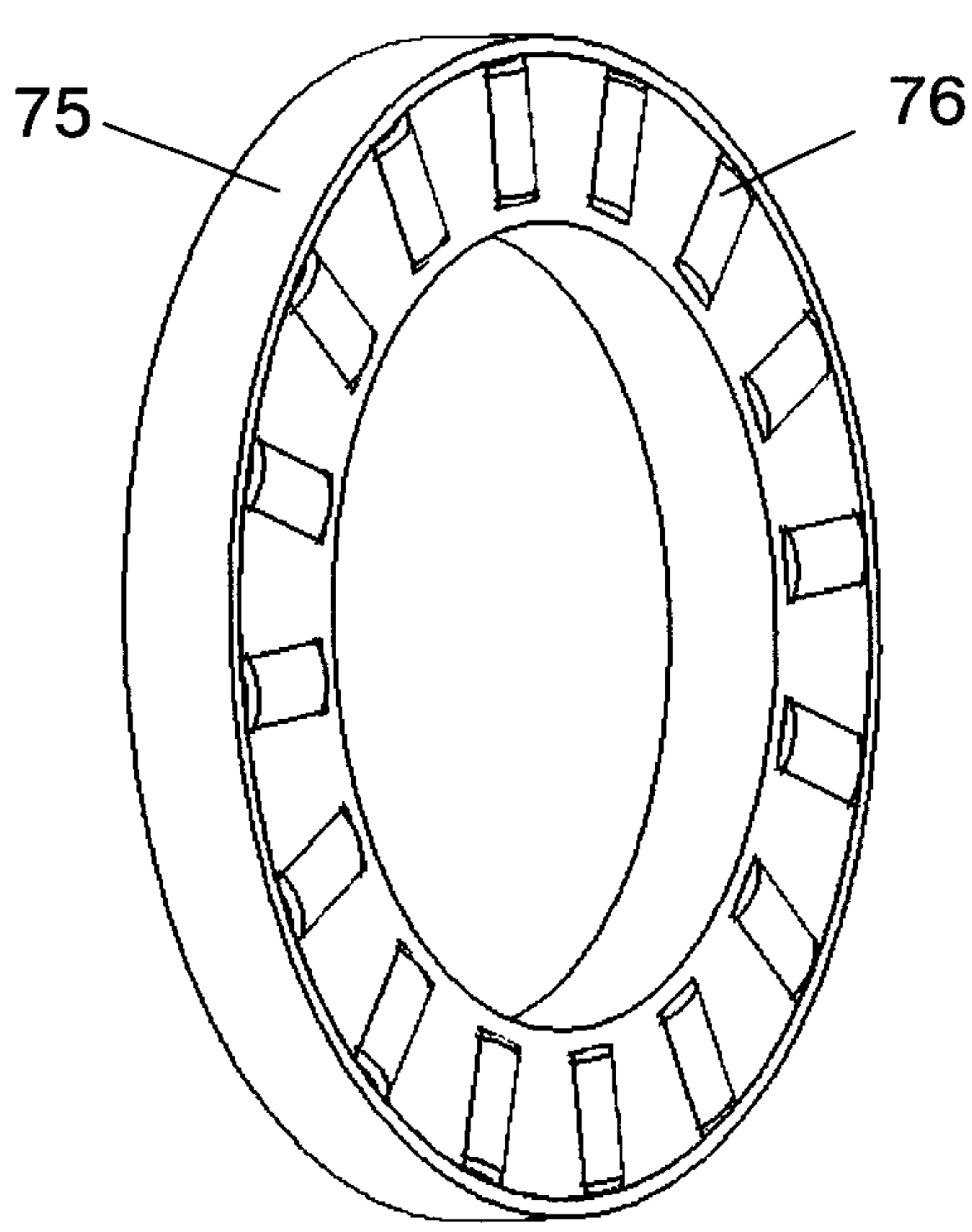
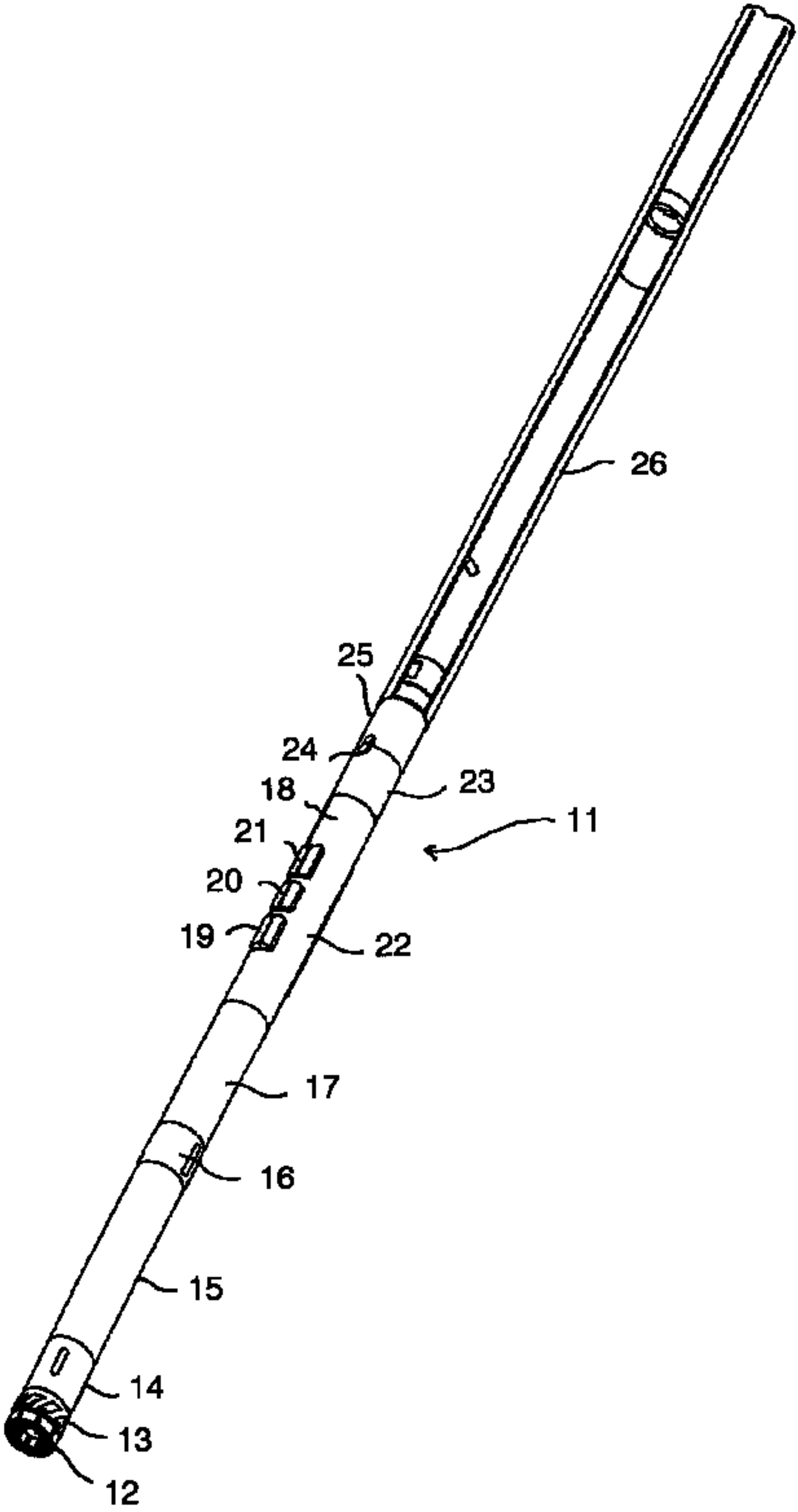


Figure 6h.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