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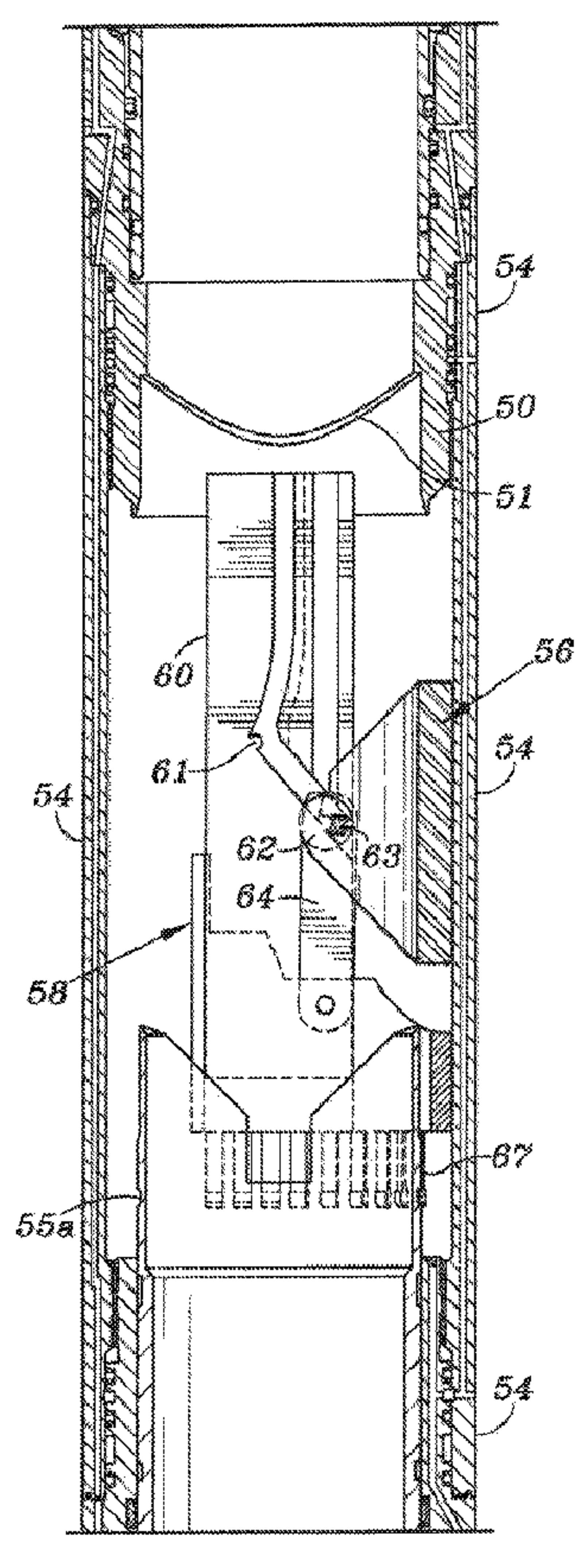
(54) **Titre :** VANNE D'ISOLEMENT ROTATIVE BIDIRECTIONNELLE HYDRAULIQUE
(54) **Title:** HYDRAULIC BI-DIRECTIONAL ROTARY ISOLATION VALVE



(57) **Abrégé/Abstract:**
A valve (156) having a sealing surface that is rotated 90 degrees on trunnions (62) that move along a track is provided. A sleeve (42) that moves into position to protect the valve mechanism (56) when the valve is in an open position is provided. A second (74)

(57) Abrégé(suite)/Abstract(continued):
sleeve locks the sealing element of the valve in place in the closed position. The valve may be used during drilling of wells to prevent flow in casing when the drill pipe and bit are raised above the valve.

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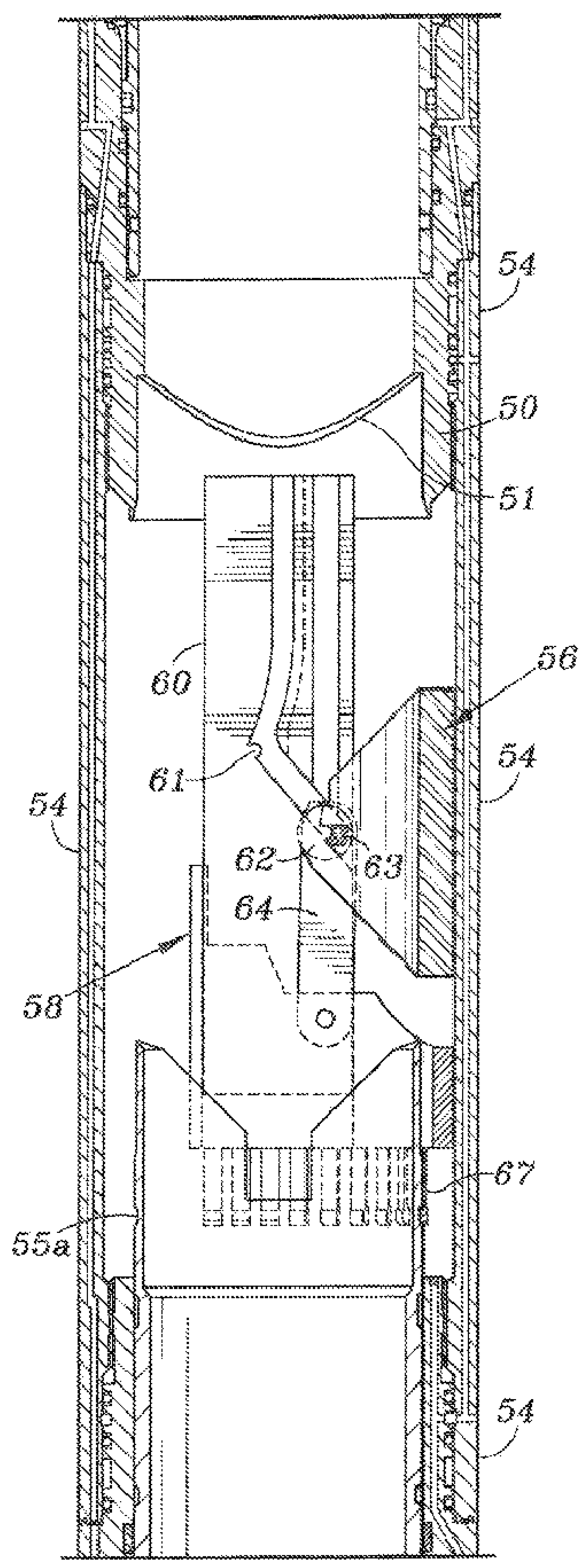

FIG. 4

(57) Abstract: A valve (156) having a sealing surface that is rotated 90 degrees on trunnions (62) that move along a track is provided. A sleeve (42) that moves into position to protect the valve mechanism (56) when the valve is in an open position is provided. A second (74) sleeve locks the sealing element of the valve in place in the closed position. The valve may be used during drilling of wells to prevent flow in casing when the drill pipe and bit are raised above the valve.

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HYDRAULIC BI-DIRECTIONAL ROTARY ISOLATION VALVE

This invention relates to a valve that may be used in wells during drilling operations or may be used in any application requiring a valve having a large bore compared with its outside diameter. More particularly, a hydraulically operated valve having a sleeve to protect the valve element when open and a mechanism for locking the valve closed is provided.

Drilling of wells in an underbalanced or balanced pressure condition has well-known advantages. In this condition, pressure in the formation being drilled is equal to or greater than pressure in the wellbore. When there is a need to withdraw the drill pipe from the well, pressure in the wellbore must be controlled to prevent influx of fluids from a formation into the wellbore. The usual remedy of preventing influx of fluid from a formation---by increasing fluid density in the wellbore---may negate the advantages of balanced or underbalanced drilling. Therefore, downhole valves have been developed to isolate fluid pressure below the valve. They have been variously called “Downhole Deployment Valves” (DDV) or “Downhole Isolation Valves” (DIV). Technical literature includes reports of the usage of such valves in Under-Balanced Drilling (UBD) For example, SPE 77240-MS, “Downhole Deployment Valve Addresses Problems Associated with Tripping Drill Pipe During Underbalanced Drilling Operations,” S. Herbal et al, 2002, described uses of such valves in industry. The DDV or DIV as a tool in the broad area of “Managed Pressure Drilling” can be generally surmised from the survey lecture “Managed Pressure Drilling,” by D. Hannagan, SPE 112803, 2007. There it is listed under “Other Tools” and called a “Downhole Casing Isolation Valve – (DCIV)” or “Downhole Deployment Valve.” Services and products for providing Managed Pressure Drilling have been commercialized by AtBalance of Houston, Texas, Weatherford International, Inc. of Houston, Texas and other companies.

A DCIV is placed in a casing at a selected depth, considering conditions that may be encountered in drilling the well. The valve is normally placed in an intermediate casing string, and the effective Outside Diameter (OD) of the valve is limited by the Inside Diameter (ID) of the surface casing through which it must pass. For example, in a 7-inch (178 mm) intermediate casing, the valve preferably will be a full-opening (have a bore at least equal to the ID of the 7-inch (178 mm) casing, about 6.276 inch (159 mm), or at least be as large as the drill bit to be used) and must pass through the drift diameter of the surface casing, which may be 8.5 inches (216 mm). Therefore, the valve must be designed to severely limit the thickness of the valve body while being large enough for a bit to pass through.

A DCIV is disclosed in U.S. Pat. No. 6,209,663. A flapper valve is illustrated, but other types of valves, such as ball valves or other rotary valves are disclosed. The valves may be operated hydraulically or by biasing means (e.g., springs). U.S. Pat. No. 6,167,974 discloses a flapper-type DCIV valve that is operated by a shifting device that is carried on a drill bit and deposited in the valve when the drill string is tripped out of the well.

Prior art valves relying on a flapper mechanism have been commercially successful, but improvements in reliability and absence of leakage are needed. A rotary valve having minimum difference between outside diameter and inside diameter is needed. The ability of the valve to seal with differential pressure in two directions is also preferred.

It should be understood that valves designed for downhole isolation may also be used for a variety of purposes. In wells, there may be a need to open or close a valve to control pressure near the bottom of the well when the hydrostatic pressure of fluid in the well is higher than desired, or there may be a need to isolate pressure in a well bore drilled from another well bore. In industry, valves requiring a minimum of wall thickness between the interior passage through the valve and the exterior surface of the valve may be needed for a variety of applications, such as: conventional products pipelines; piping in plants such as power plants, refineries or chemical plants; marine installations; biomedical devices and other devices where a thin-wall, stemless valve that can be operated by remote hydraulic pressure is needed.

The present invention provides a valve as set out in the accompanying claims.

The present invention (at least in preferred embodiments) provides a hydraulically activated, bi-directional (will isolate fluid pressure in either direction), rotary- and linear-motion valve, referred to herein as the HBRL Valve. The valve element is mounted on trunnions. As the trunnions move along a track, the valve element is rotated from a position parallel to the axis of the bore of the valve (open) to a position perpendicular to the axis of the bore (closing). Further motion along the track seats the valve element. The trunnions are moved by force from a sleeve moving in response to hydraulic pressure. A second sleeve is moved to protect the valve mechanism when the valve is open. After closing, the valve is locked into position to isolate fluid pressure differential across the valve in either direction.

In one aspect, the invention provides a bi-directional valve for use as a downhole casing isolation valve comprising:

a housing having a longitudinal axis, a fluid flow path and a stationary valve seat;

a moveable valve element having an outer cylindrical surface;

the stationary valve seat having a cylindrical, axially extending valve seating surface; and

the valve element having a valve seating area on the outer periphery of the cylindrical surface engaging the cylindrical, axially extending valve seating surface on the valve seat in a closed position so as to seal the valve in both directions, and an annular cylindrical locking sleeve.

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the stationary valve seat having a cylindrical, axially extending valve seating surface; and

the valve element having a valve seating area on the outer periphery of the cylindrical surface engaging the cylindrical, axially extending valve seating surface on the valve seat in a closed position so as to seal the valve in both directions, and an annular cylindrical locking sleeve for locking the valve closed.

In one aspect, the invention provides a bi-directional valve for use as a downhole casing isolation valve comprising:

a housing having a fluid flow path, a valve seat and a distal end;

a valve element having an outer cylindrical surface;

the valve seat having a valve seating surface; and

the valve element having a valve seating area on the outer cylindrical surface adapted to engage the valve seating surface on the valve seat in a closed position so as to seal the valve in both directions, the valve seating surface being spaced from a distal end of the housing, and an annular cylindrical locking sleeve for locking the valve closed.

Some preferred embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

FIG. 1 is a sketch of a well having a hydraulically operated HBRL valve used as a DCIV in an intermediate casing;

FIGS. 2a - 2f illustrate the valve in the open position;

FIGS. 3a - 3f illustrate the valve in the closed position;

FIG. 4 is a detailed view of a "Wedgelock" valve assembly in the open position;

FIG. 5 is a detailed view of the Wedgelock valve assembly when the "Wedgelock" is moved toward the closed position but is not rotated;

FIG. 6 is a detailed view of the Wedgelock assembly when the Wedgelock has partially rotated into a closing position;

FIG. 7 is a detailed view of the Wedgelock assembly when the valve is in the closed position;

FIG. 8 is an end-view of a guide rail for the trunnion of the Wedgelock;

FIG. 9 is an elevation view of a guide rail for the trunnion of the Wedgelock;

FIG. 10 is an elevation view of a trunnion for the valve from a first direction;

FIG. 11 is a side view of a trunnion adapted to move in a guide rail;

FIG. 12 is a cross-section view of a trunnion as indicated in FIG. 11;

FIG. 13 is an isometric view of the control arm of the Wedgelock assembly;

FIG. 14 is an elevation view of the Wedgelock with the trunnion;

FIG. 15 is a cross-sectional view along the axis of the Wedgelock valve assembly as indicated in FIG. 3d; and

FIG. 16 is an isometric view of a split ring of the valve assembly.

FIG. 1 illustrates a well 10 that is being drilled. Surface casing 12 has been placed in the well. Intermediate casing 14, containing a HBRL (Hydraulic Bidirectional Rotary-Linear) valve 20, used as a Downhole Casing Isolation Valve (DCIV), has also been placed in the well. The inside diameter 21 of HBRL valve 20 must be large enough to allow passage of bit 16 on drill pipe 15. The HBRL valve disclosed here is adapted to allow less difference in diameter between the inside diameter of valve 20 and the inside diameter of casing 14 than is allowed by downhole isolation valves cited in the references disclosed above. Hydraulic lines in bundle 19 are connected between HBRL valve 20 and a hydraulic pressure control system at a selected location (not shown).

The elongated HBRL valve assembly is illustrated in sectional views 2a - 2f and 3a - 3f. In FIG. 2, the valve is in the open position and in FIG. 3 it is in the closed position. Lines dividing the tools into segments from uphole to downhole are labelled as lines A to E at the bottom and top of each figure a to f. Because some parts of the valve assembly extend over multiple drawings, operation of the valve may be better understood if drawings of FIGS. 2a - f and FIGS. 3a – f are laid end-to-end according to the dividing lines.

Referring to FIG. 2a, upper connection housing 40 is shown. Threads on upper connection housing 40 are adapted for joining to casing in which the HBRL valve 20 is to be employed. When the HBRL valve 20 is in a closed position, the top of protective sleeve 42 moves to within the upper connection housing, as shown in FIG. 3a.

In FIGS 2b and. 3b, upper connection housing 40 is joined to hydraulic connection housing 44. This joining may be by a threaded connection, as shown. Hydraulic connection housing 44 contains port A and port B. These ports are adapted for connection to hydraulic lines shown bundled together as 19 in FIG. 1. Protective sleeve 42 is disposed toward the lower or downhole end of the valve assembly in FIG. 2b. Protective sleeve 42 covers the "Wedgelock" valve element when in the open position, as will be shown in more detail below. (Wedgelock is used to identify the valve element. It may be formed by machining two curved surfaces from round stock, the surfaces being separated by the selected thickness of the valve element to form a "saddle-like" shape. The thickness is selected according to differential pressure expected across the valve.) In FIG. 3b, protective sleeve 42 is disposed toward the uphole direction. Sleeve 42 may be moved downhole by application of hydraulic pressure through port B across o-ring seal 42A, as shown in FIG. 3b.

Referring to FIGS. 2c and 3c, the joining of hydraulic connection housing 44 and coupling housing 48 is shown. This joining may be by a threaded connection. Hydraulic conduits from port A and port B extend through these housings. In FIG. 3c, showing the valve in the closed position, protective sleeve 42 extends to just uphole from the Wedgelock assembly, which will be shown below, and in FIG. 2c protective sleeve 42 extends through the figure and into the lower segment of the tool, so as to cover the Wedgelock assembly when it is in the open position. Also in FIGS. 2c and 3c, coupling housing 48 is shown joined to valve seat housing 50. Valve seat housing 50 also provides hydraulic conduits connected to port A and port B. Relief valve 52 may be provided in valve seat housing 50. The function of relief valve 52 is to allow fluid to pass through HBRL valve 20 if pressure below the HBRL valve exceeds a selected value.

Upper split ring 46 is also provided in coupling housing 48. The function of split ring 46 will be described below.

Referring to FIGS. 2d and 3d, the joining of valve seat housing 50 and Wedgelock assembly housing 54, the joining of Wedgelock assembly housing 54 and coupling housing 68, and the joining of coupling housing 68 and lower housing 72 are shown. These joinings may be by a threaded connection. Wedgelock assembly housing 54 and coupling housing 68 also provide hydraulic conduits through the housings, as shown. FIG. 2d shows that protective sleeve 42 extends through to a downhole location covering cam assembly 58 when the valve is in an open position. Protective sleeve 42 is displaced to an uphole position when the valve is closed, as shown by its absence in FIG. 3d. Valve seat 51, shown in FIG. 2d, is adapted for sealing on the Wedgelock valve element and may provide for a bi-directional metal-to-metal seal.

Alternatively, valve seat 51 may provide polymeric sealing material, as is known in the art. Cam assembly 58 will be described in more detail below. Wedgelock locking sleeve 74 is displaced uphole in FIG. 3d, compared with FIG. 2d, by hydraulic pressure as described below. Cam locking fingers 67 are provided on cam assembly 58, which is engaged with cam finger unlocking grooves 55a on Wedgelock locking sleeve 74, as shown in FIG. 2d. Wedgelock locking sleeve 74 is displaced uphole in FIG.. 3d by hydraulic pressure until cam locking fingers 67 engage with cam finger locking groove 55b on Wedgelock locking sleeve 74. Lower split ring 66 is provided in a groove in locking coupling housing 68. The function of lower split ring 66 will be described below.

Referring to FIGS. 2e and 3e, Wedgelock locking sleeve 74 is driven uphole by hydraulic pressure across o-ring 75. Finger locking sleeve 70 is displaced with Wedgelock locking sleeve 74. Movement uphole continues until o-ring 75 reaches by-pass groove 76. At this time movement of Wedgelock locking sleeve 74 ceases and movement of finger locking sleeve 70 continues upward, driven by hydraulic pressure, until the uphole end of finger locking sleeve 70 locks over locking fingers 71 of coupling housing 68 as shown in FIG. 2e and 3e. The distance from the initial position of o-ring 75 to by-pass groove 76 may be the same as the distance from finger locking groove 77 on Wedgelock locking sleeve 74 to the lower end of locking fingers 71.

FIGS. 2f and 3f show lower housing 72 with threads adapted to joining with the casing. Wedgelock locking sleeve 74 is shown in FIG. 2f in its downhole position when the valve assembly is open.

FIG. 4 shows a detail drawing of cam assembly 58 when the valve is open. Cam assembly 58 comprises control arm 64, trunnions 62, guide rails 60 and pivot point 61. To close the valve, trunnion 62 is moved uphole by cam assembly 58, causing control arm 64 to pivot as trunnion 62 moves along guide rails 60. Wedgelock 56 is still in a completely open position, oriented parallel to the axis to the valve. In FIG. 5, trunnion 62 has moved along guide rails 60 to pivot point 61. Trunnion 62 is designed to interact with pivot point 61 so as to cause rotation of Wedgelock 56. In FIG. 6 partial rotation of Wedgelock 56 has occurred and in FIG. 7 a 90° rotation of Wedgelock 56 has occurred and it is now in an orientation to seat on valve seat 51. Continued movement of Wedgelock 56 towards the seating position is made possible by linear movement of trunnion 62 along guide rails 60.

FIG. 8 is a cross-section view of guide rail 60. It is adapted to be welded or otherwise fastened to the inside diameter of Wedgelock assembly housing 54. Alternately, guide rail 60 can be an intrinsic part of the Wedgelock assembly housing 54. Guide rails 60 are adapted to receive trunnions 62. One embodiment of interlocking surfaces is illustrated in FIG. 15, which is the cross-section view identified in FIG. 3d. It should be understood that alternative guide rail and cam assemblies may be used. Trunnions 62 are attached to Wedgelock 56, which is the valve seating element as shown in FIG. 14. When Wedgelock 56 is used in casing, it is preferably designed to withstand differential pressure expected in a well in both directions. Preferably the sealing surface of Wedgelock 56 is metal, but, alternatively, polymeric valve seats such as known in industry may be used.

FIG. 8 shows a cross-section view of guide rails 60. FIG. 9 shows an elevation view of guide rails 60, which includes pivot point 61, adapted to interact with a trunnion to cause rotation. FIG. 10 shows a view of one embodiment of a trunnion and guide. FIG. 11 shows a side view of trunnion 62 and guide 63. The cross-section indicated in FIG. 11 is shown in FIG. 12. Pivot point contact 63a on guide 63 is adapted to contact guide rail 60 at pivot point 61 so as to rotate Wedgelock 56 into an orientation for seating.

FIG. 13 shows an isometric view of control arm 64, having opening 64a adapted to receive trunnion 62.

FIG. 14 shows Wedgelock 56 having trunnions 62 and valve seating area 57. Alternatively, Wedgelock 56 can be comprised of one or multiple sectional parts mounted on a plurality of trunnions around the outer shell of the valve element. Such arrangement and others will not change the functionality of HBRL valve 20.

FIG. 16 shows an isometric view of upper split ring 46. Upper and lower split rings are used for functions to be described below.

To move HBRL valve 20 from an open position to a closed position after drill bit 16 (FIG. 1) is raised to a location above the valve, hydraulic pressure is applied to port A through a hydraulic line in bundle 19 as shown in FIG. 1. The first operation in the sequence of closing is application of hydraulic pressure to port A, which shifts protective sleeve 42 until it shoulder limits on hydraulic connection housing 44 at shoulder 43. This movement of protective sleeve 42 causes engagement with upper split ring 46, which is positioned in a groove on coupling housing 48. Hydraulic pressure at port A is then further increased until it overcomes the force of lower split ring 66 in locking coupling housing 68. When lower split ring 66 disengages, Wedgelock locking sleeve 74 moves uphole. Continuing uphole, Wedgelock locking sleeve 74 engages cam assembly 58 at cam finger unlocking groove 55A with locking fingers 67. Cam assembly 58 moves Wedgelock 56 uphole until it has seated in valve seat 51. Rotation of Wedgelock 56 by 90° occurs as cam assembly 58 moves uphole, as described in FIGS. 4 to 7. At this point the valve is seated but not locked in position. Hydraulic pressure is then increased again at port A and it begins to push Wedgelock locking sleeve 74 uphole locking finger 67 disengaging the cam finger unlocking groove 55A causing linear movement at the Wedgelock locking sleeve 74 until it is seated against the back side of Wedgelock 56, at which time locking fingers 67 engage cam finger locking groove 55B At this location, o-ring 75 on Wedgelock locking sleeve 74 will be located at fluid by-pass grooves 76 of lower housing 72. Fluid will flow around o-ring 75 and shift finger locking sleeve 70 onto locking fingers 71 of coupling housing 68. At this point the valve is fully seated and locked.

To operate HBRL valve 20 from a closed position to an open position, hydraulic pressure is applied to port B on hydraulic connection housing 44. Pressure is applied to the opposite side of finger locking sleeve 70 until it unlocks from coupling housing 68 and begins to move downhole. Finger locking sleeve 70 will continue movement until it has reached shoulder limit 78 on Wedgelock locking sleeve 74. Both pieces will then move simultaneously downhole. Still engaged with Wedgelock locking sleeve 74, cam assembly 58 disengages from its seated position and also moves downhole until cam assembly 58 reaches shoulder limit 69 on coupling housing 68. Lower snap ring 66 will reengage at this point. Pressure is increased further until protective sleeve 42 overcomes the force of upper split ring 46. Protective sleeve 42 then shifts downhole until it reaches shoulder limit 41 against the ID of coupling housing 48. At this time the valve is fully opened and Wedgelock 56 is covered by protective sleeve 42.

When the HBRL valve is used in other applications, it will normally be adapted to operate in confined spaces where the small difference between outside and inside dimensions of the valve is important. The difference achievable with the HBRL valve is dependent on pressure requirements for the valve. When used as a DCIV, as shown in FIG. 1, the valve may be constructed to withstand thousands of psi of differential pressure and still provide an inside diameter of 6.276 inches (159 mm) and an outside diameter of 8.5 inches (216 mm).

Although the present invention has been described with respect to specific details, it is not intended that such details should be regarded as limitations on the scope of the invention, except as and to the extent that they are included in the accompanying claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A bi-directional valve for use as a downhole casing isolation valve comprising:
a housing having a longitudinal axis, a fluid flow path and a stationary valve seat;
a moveable valve element having an outer cylindrical surface;
the stationary valve seat having a cylindrical, axially extending valve seating surface; and
the valve element having a valve seating area on the outer periphery of the cylindrical surface engaging the cylindrical, axially extending valve seating surface on the valve seat in a closed position so as to seal the valve in both directions, and an annular cylindrical locking sleeve for locking the valve closed.

2. The bi-directional valve of claim 1, further comprising a protective sleeve moveable to isolate the valve element from fluid flow when the valve is in the open position.

3. The bi-directional valve of claim 1 or 2, wherein the valve element is formed by machining two curved surfaces from a single piece stock, the surfaces being separated by the selected thickness of the valve element to form a saddle shape.

4. The bi-directional valve of claim 3, wherein the single piece stock is round.

5. The bi-directional valve of any one of claims 1 to 4, wherein the valve seat and valve element form a metal to metal seal.

6. The bi-directional valve of any one of claims 1 to 4, wherein one of the valve seat and valve element includes a polymeric sealing material.

7. The bi-directional valve of any one of claims 1 to 6, wherein the valve element has a curved outer seating surface that engages a complimentary surface of the valve seat.

8. The bi-directional valve of any one of claims 1 to 7, wherein the valve seating area on the valve element follows a curve on the cylindrical surface.

9. The bi-directional valve of any one of claims 1 to 8, wherein the valve seat has a complementary cylindrical surface that cooperates with the outer cylindrical surface of the valve element to form a seal.

10. A bi-directional valve for use as a downhole casing isolation valve comprising:

a housing having a fluid flow path, a valve seat and a distal end;

a valve element having an outer cylindrical surface;

the valve seat having a valve seating surface; and

the valve element having a valve seating area on the outer cylindrical surface adapted to engage the valve seating surface on the valve seat in a closed position so as to seal the valve in both directions, the valve seating surface being spaced from a distal end of the housing, and an annular cylindrical locking sleeve for locking the valve closed.

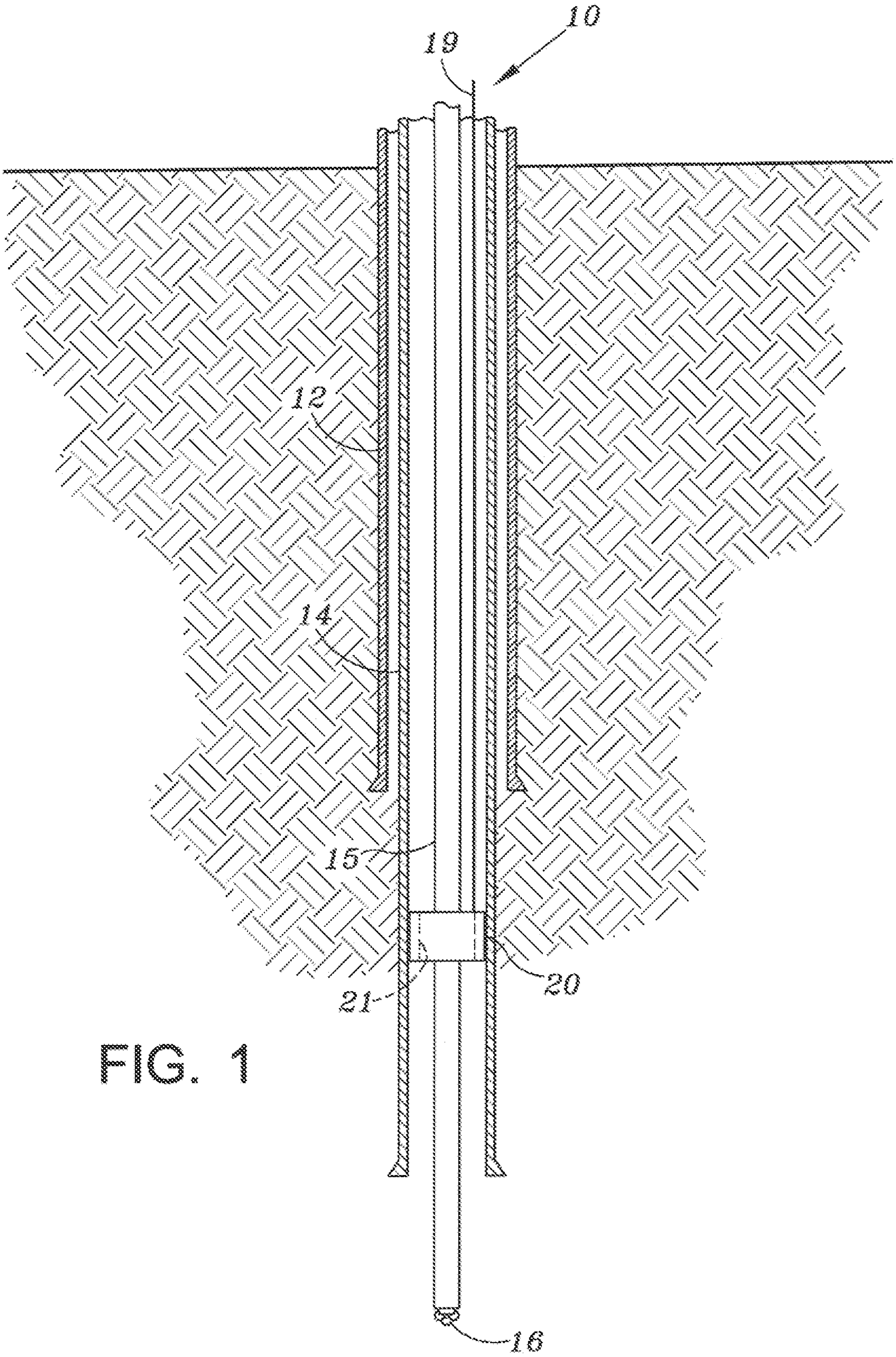

FIG. 1

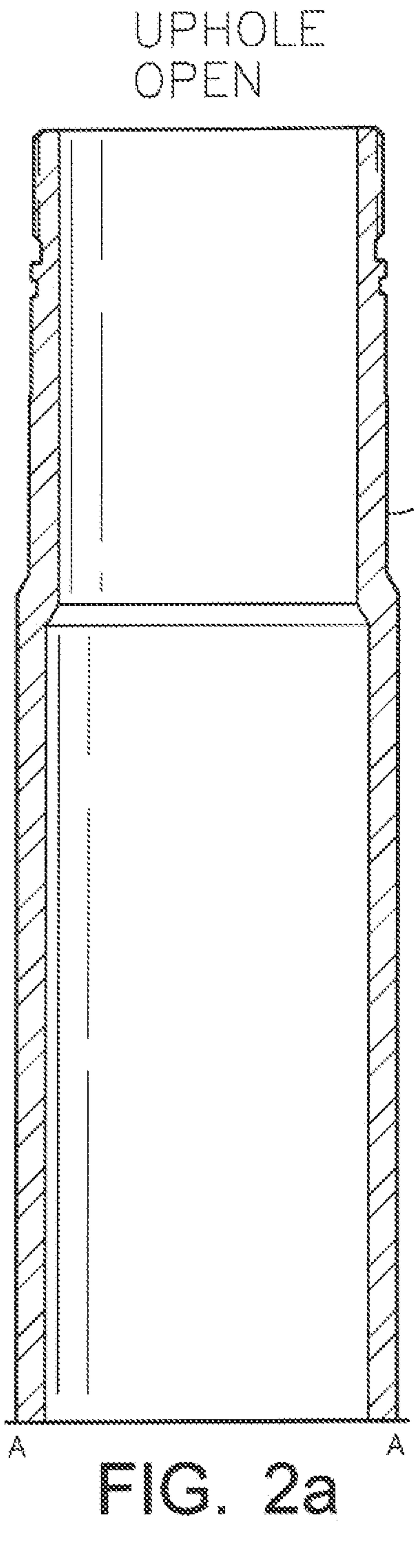

FIG. 2a

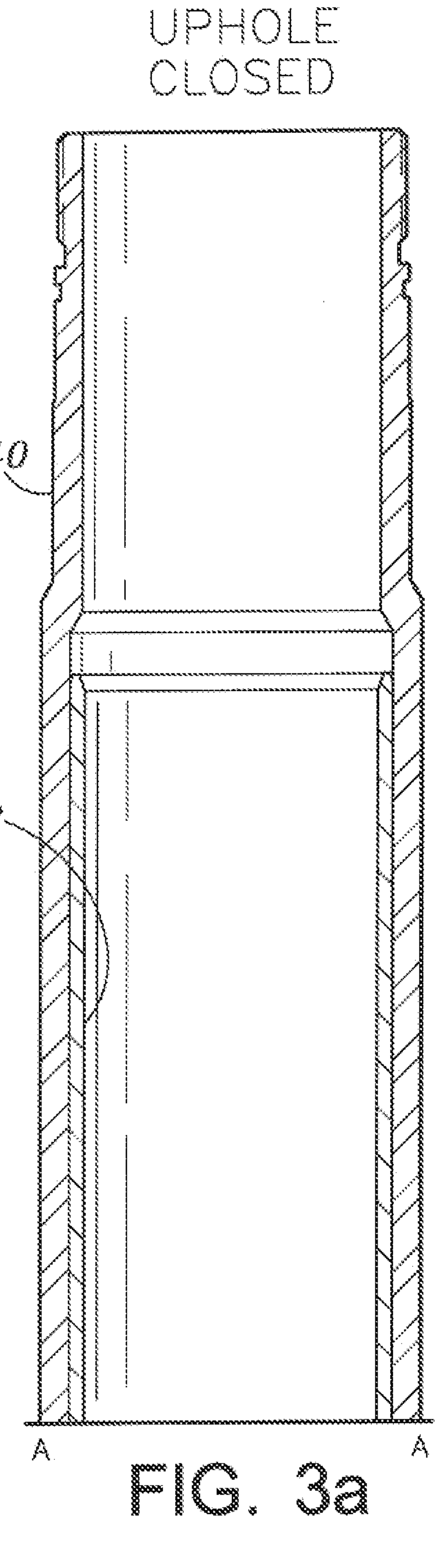

FIG. 3a

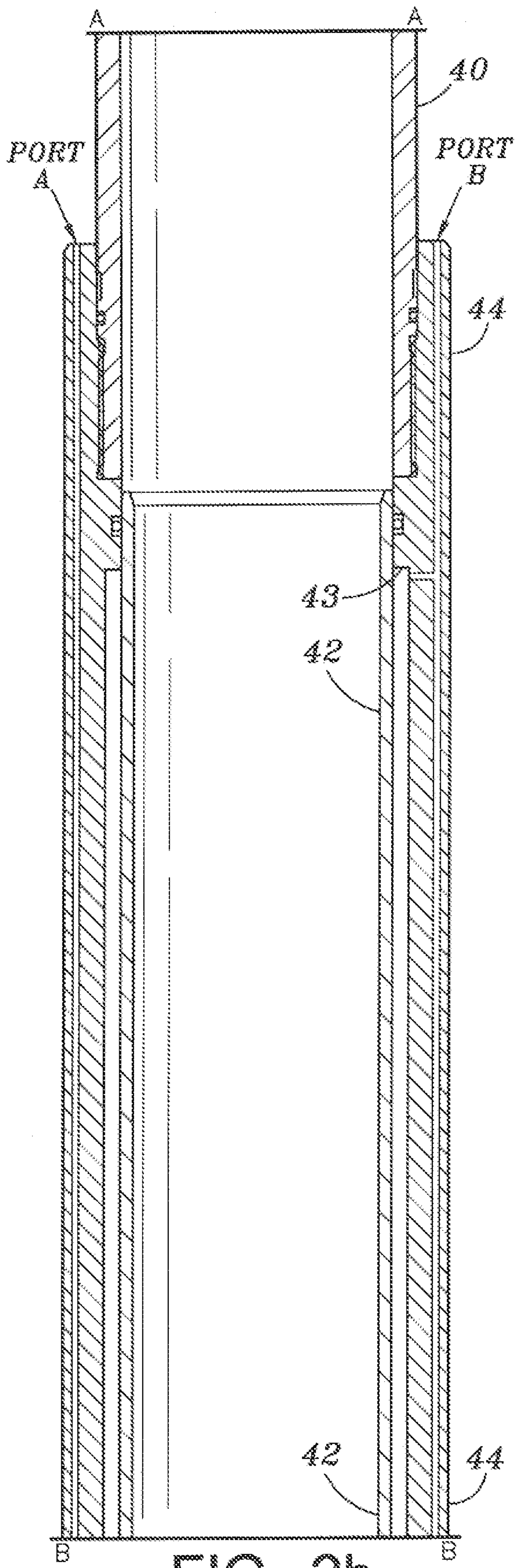
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FIG. 2b

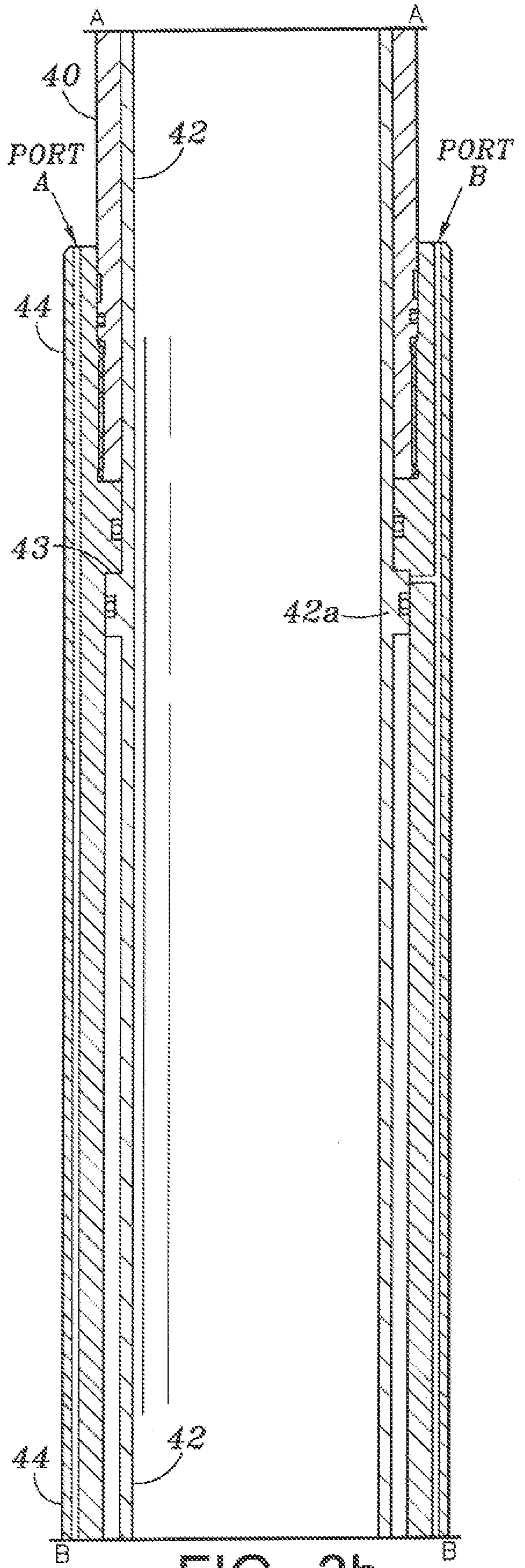
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FIG. 3b

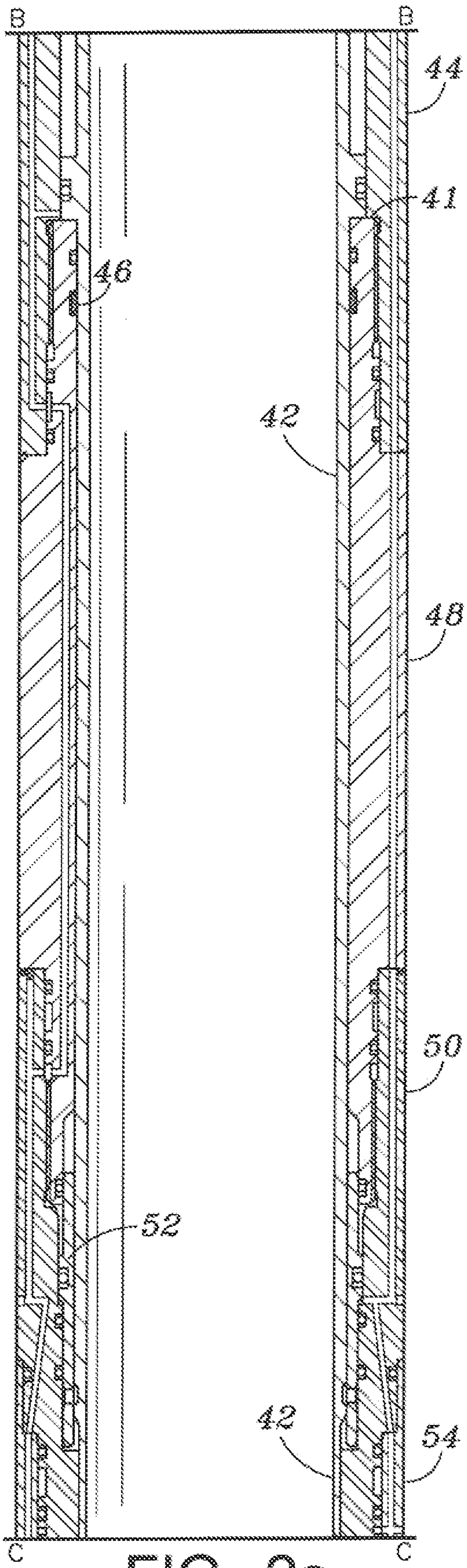


FIG. 2c

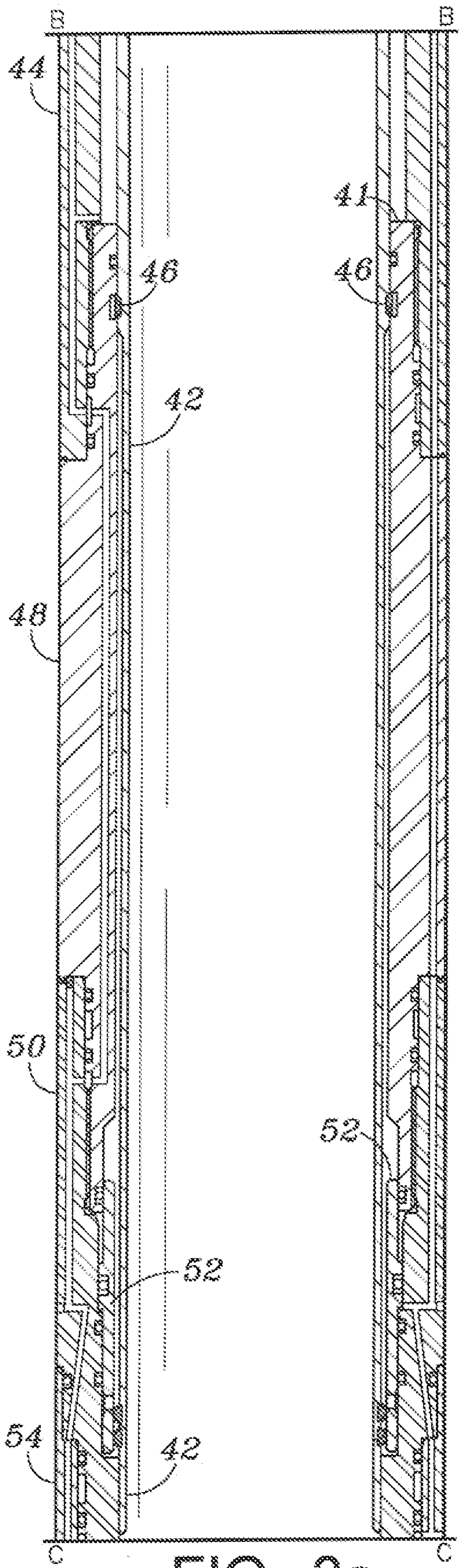
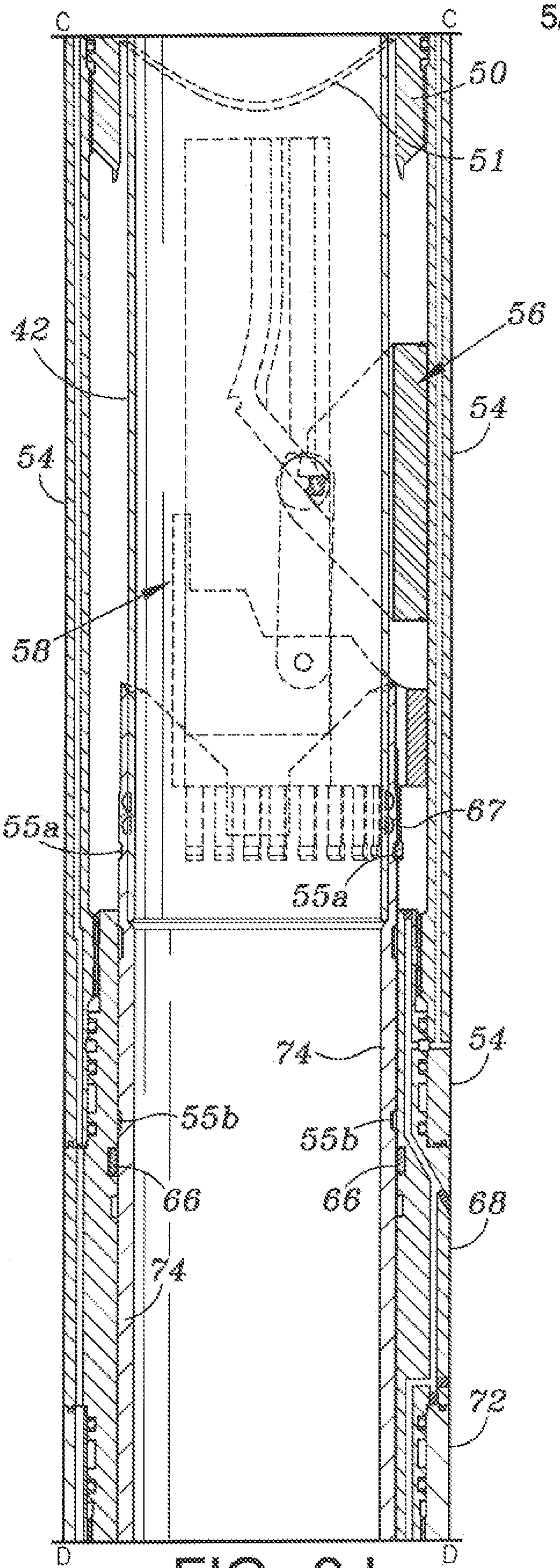


FIG. 3c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68
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D
FIG. 2d

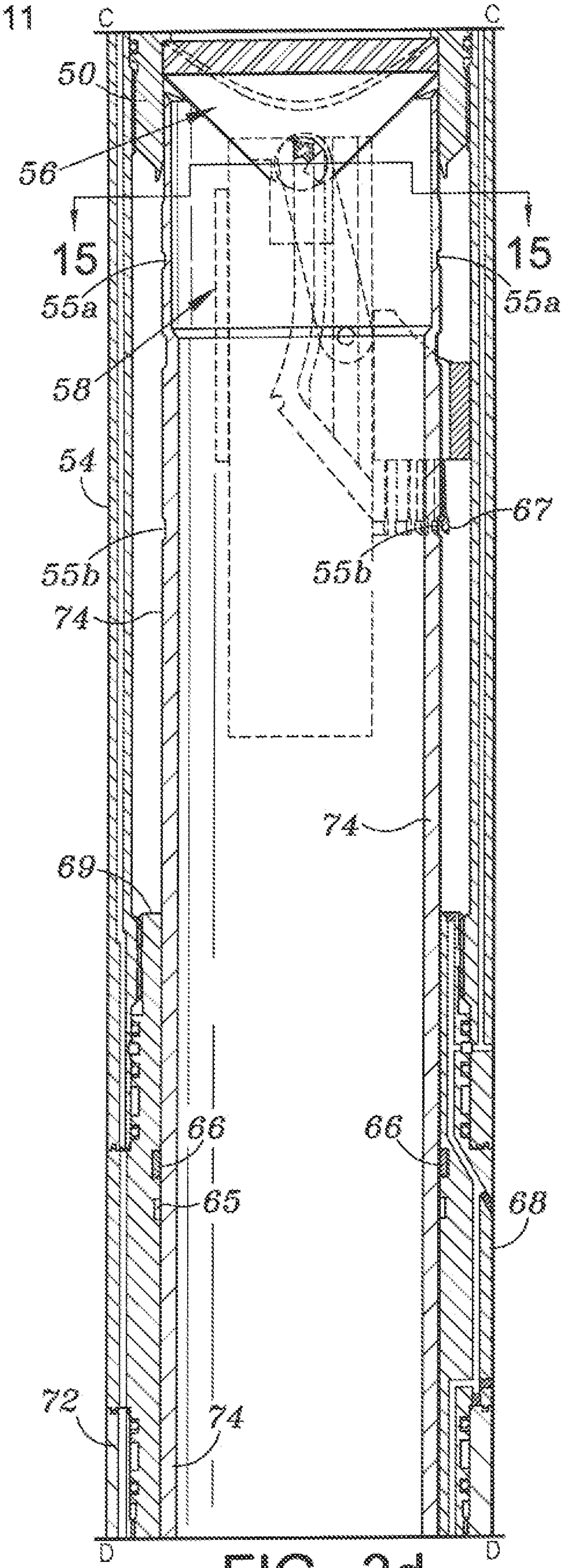
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FIG. 3d

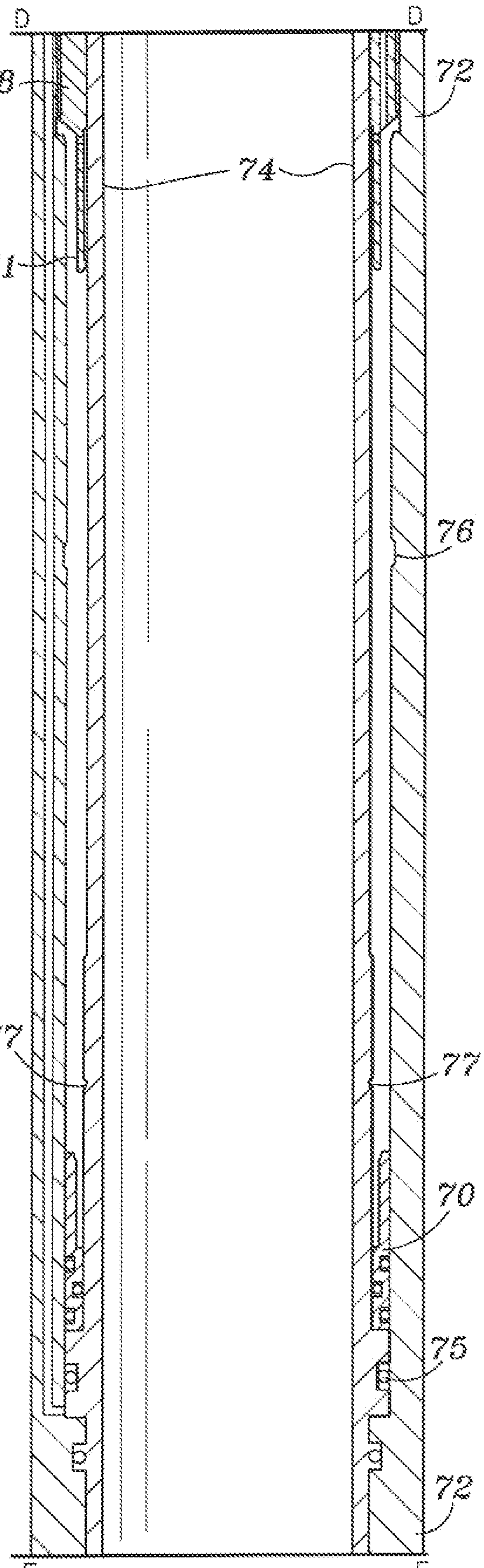
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FIG. 2e

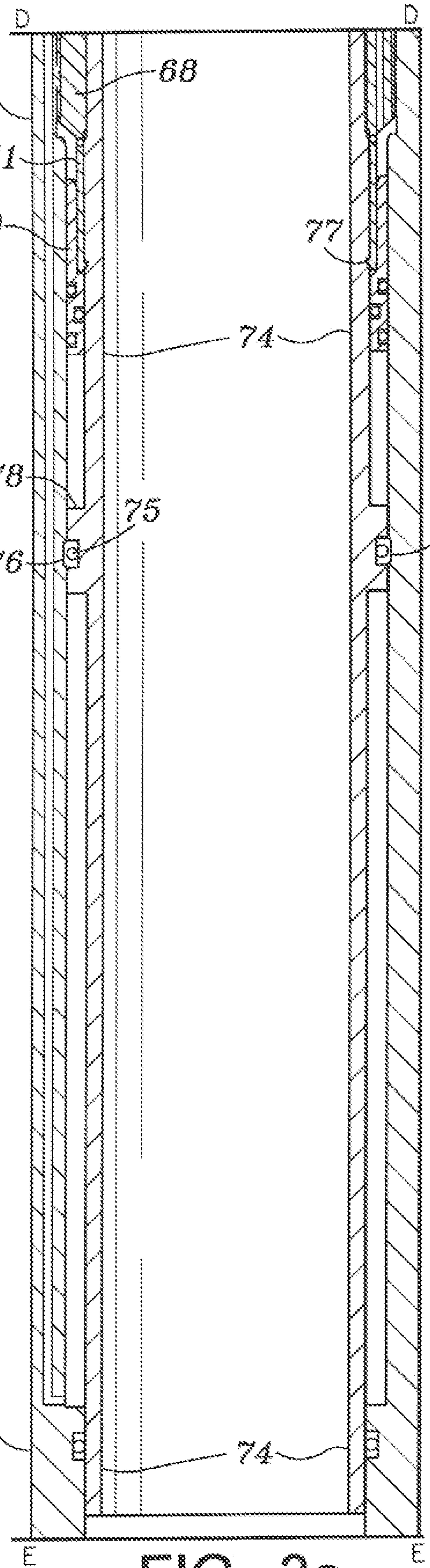
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FIG. 3e

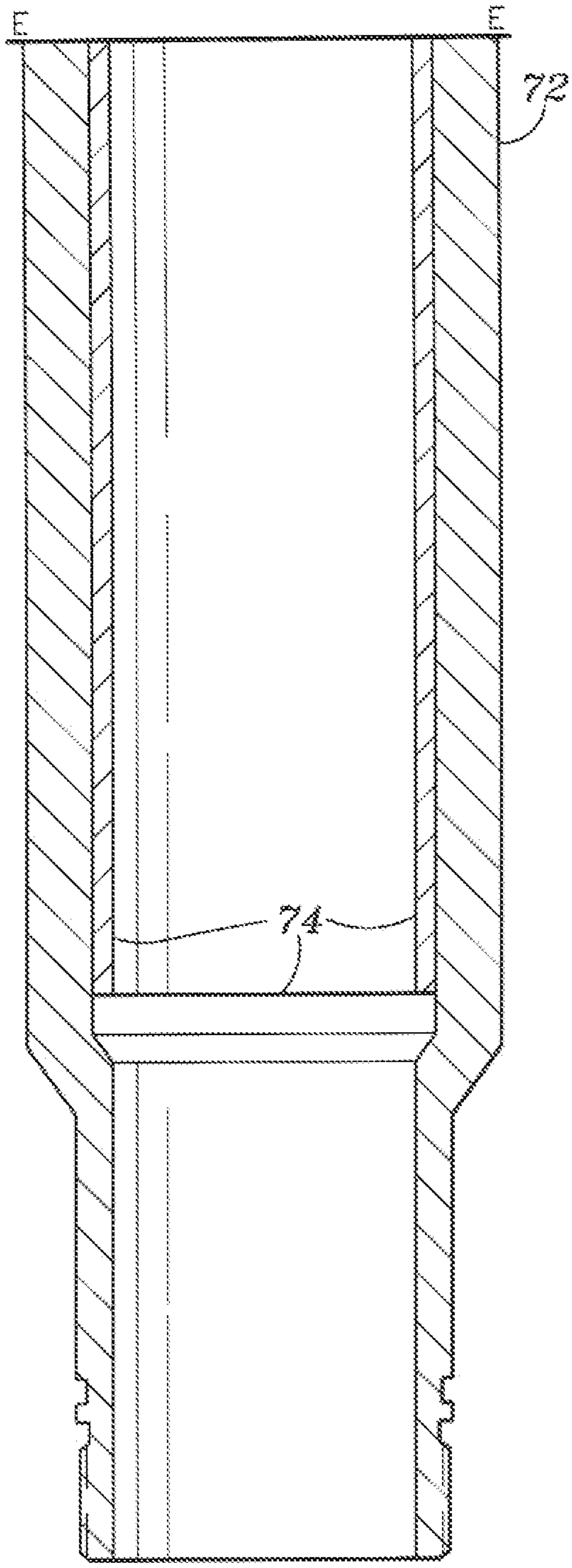

FIG. 2f
DOWNHOLE
OPEN

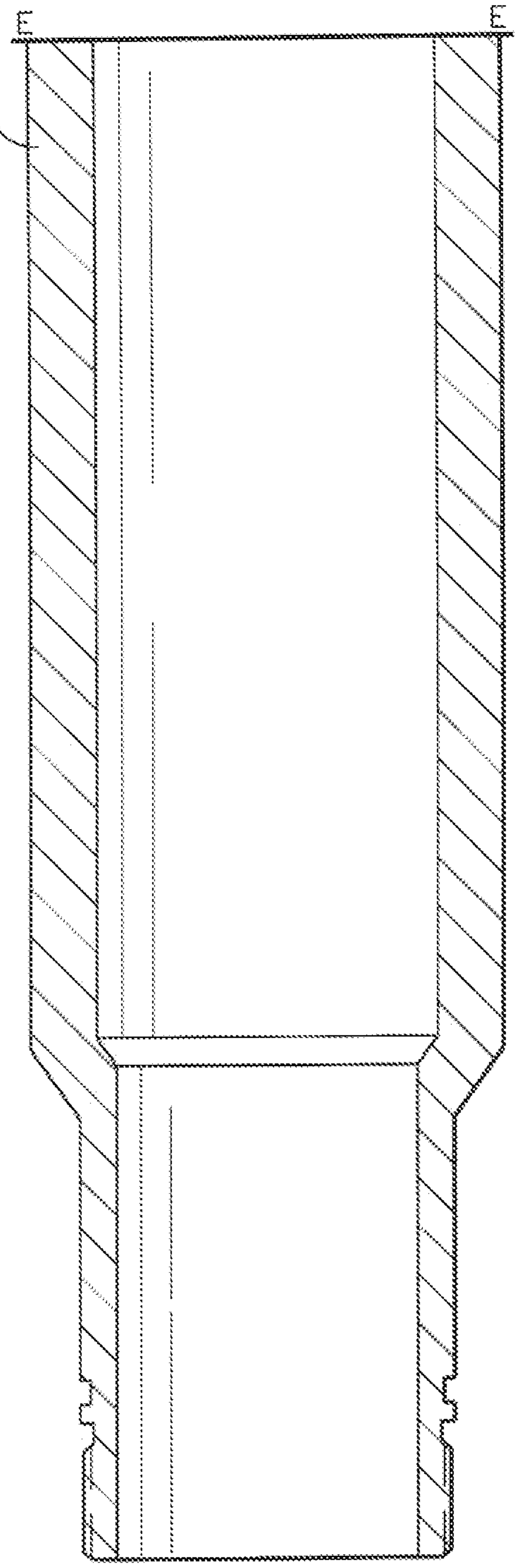

FIG. 3f
DOWNHOLE
CLOSED

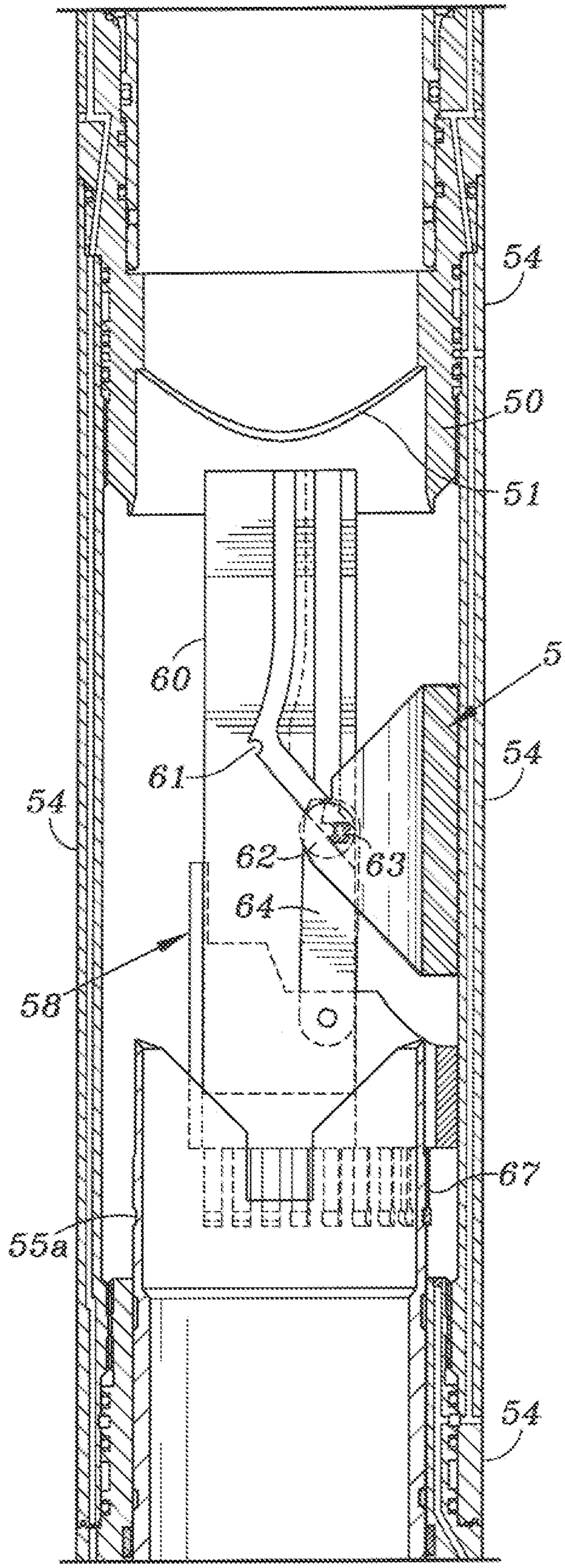
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FIG. 4

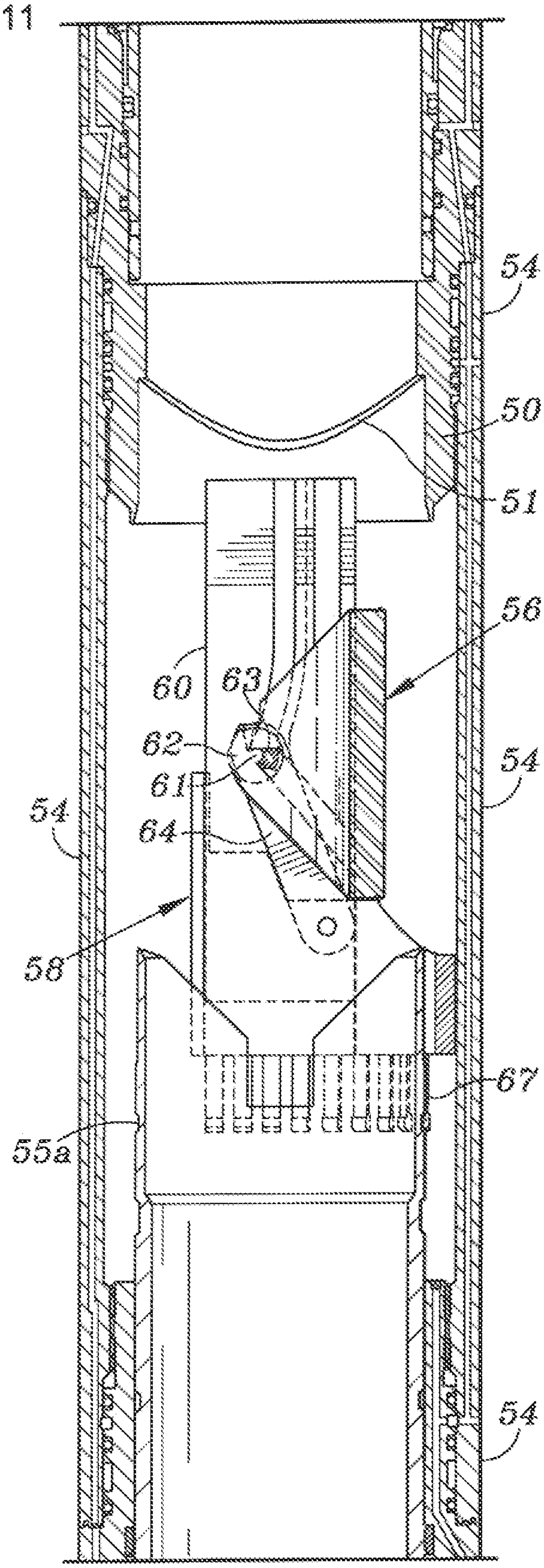
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FIG. 5

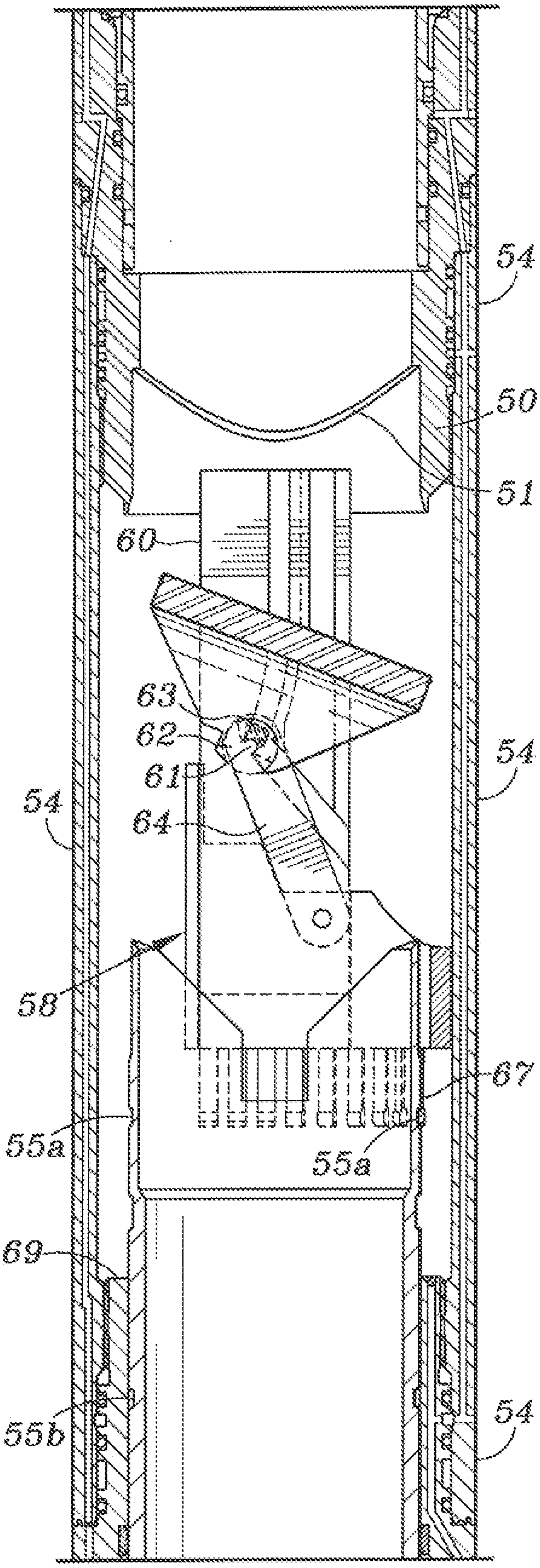
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FIG. 6

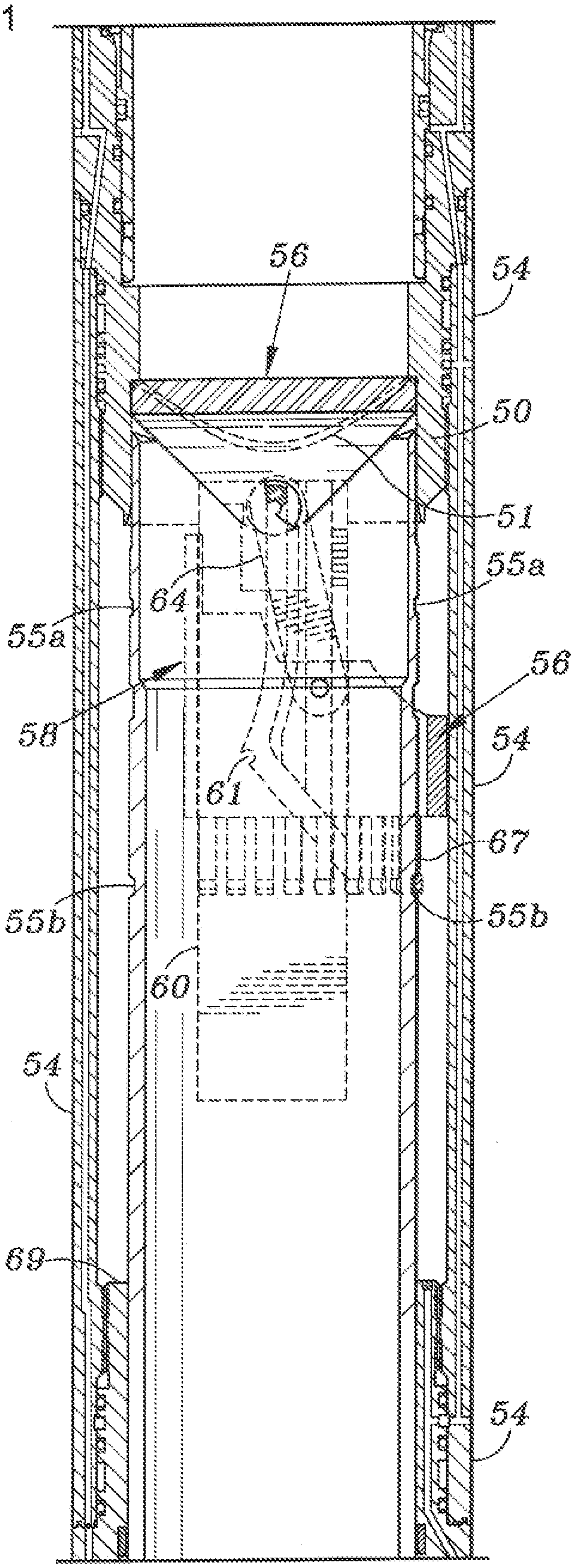
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FIG. 7

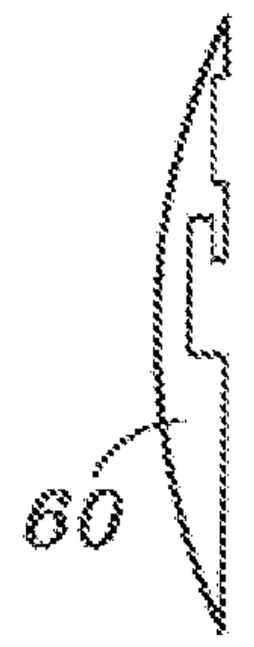


FIG. 8

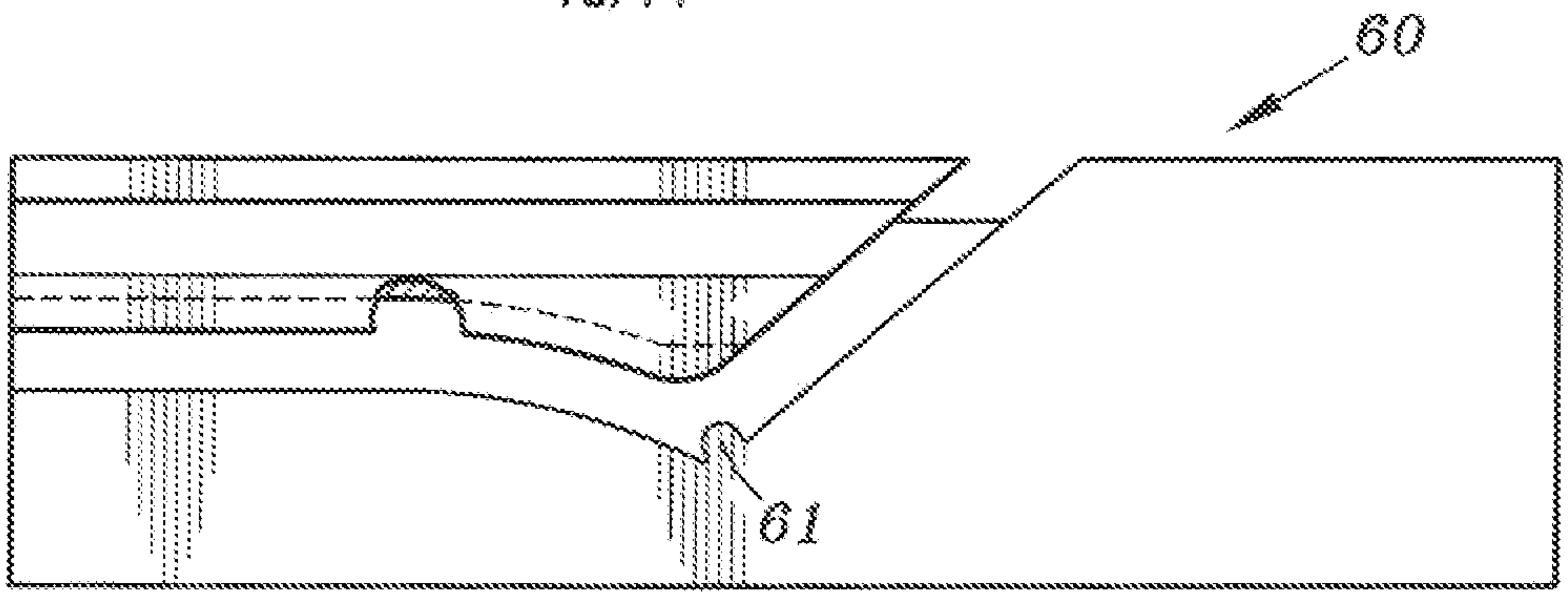


FIG. 9

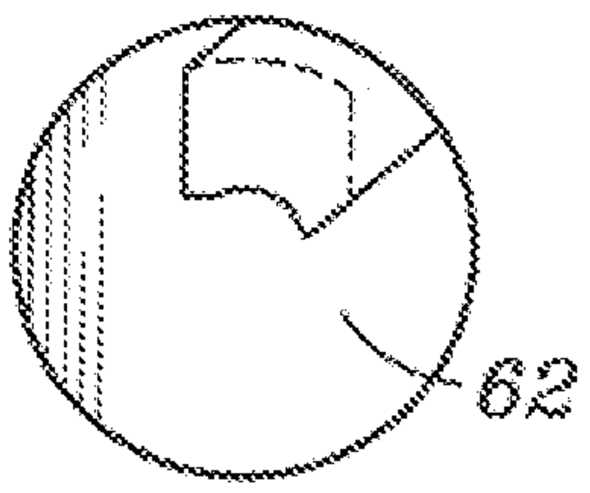


FIG. 10

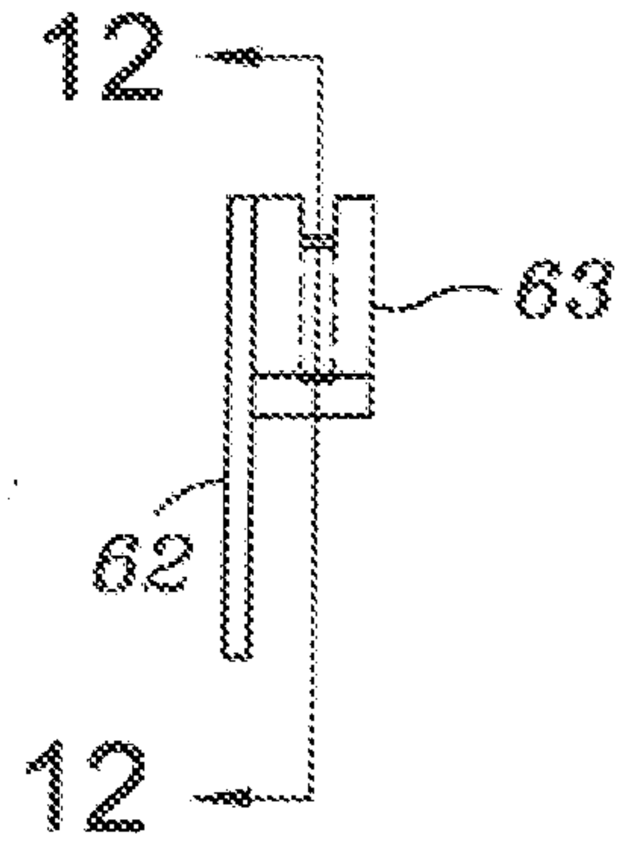


FIG. 11

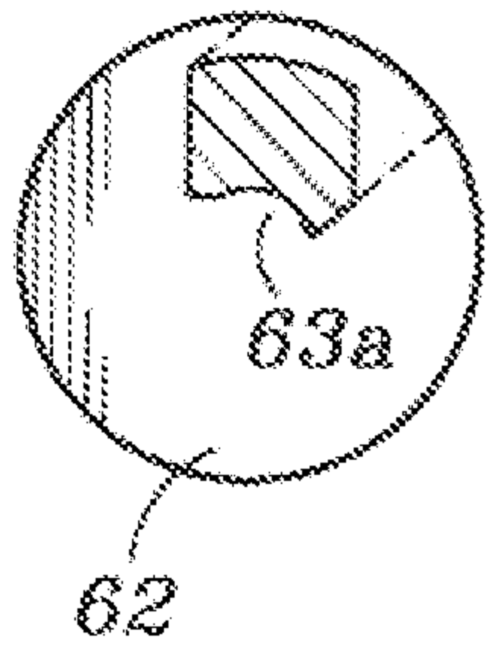


FIG. 12

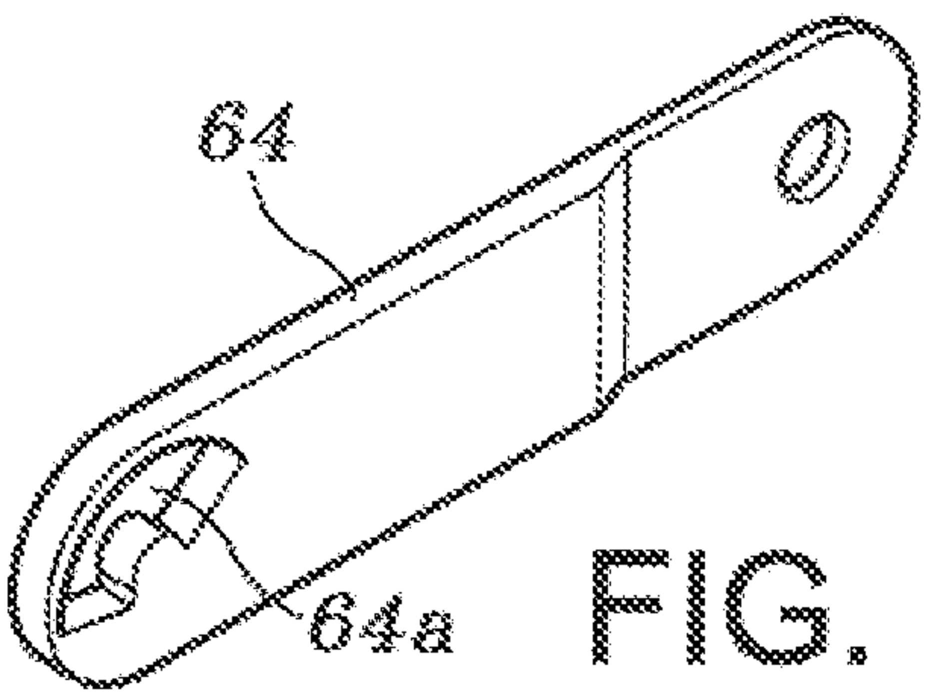


FIG. 13

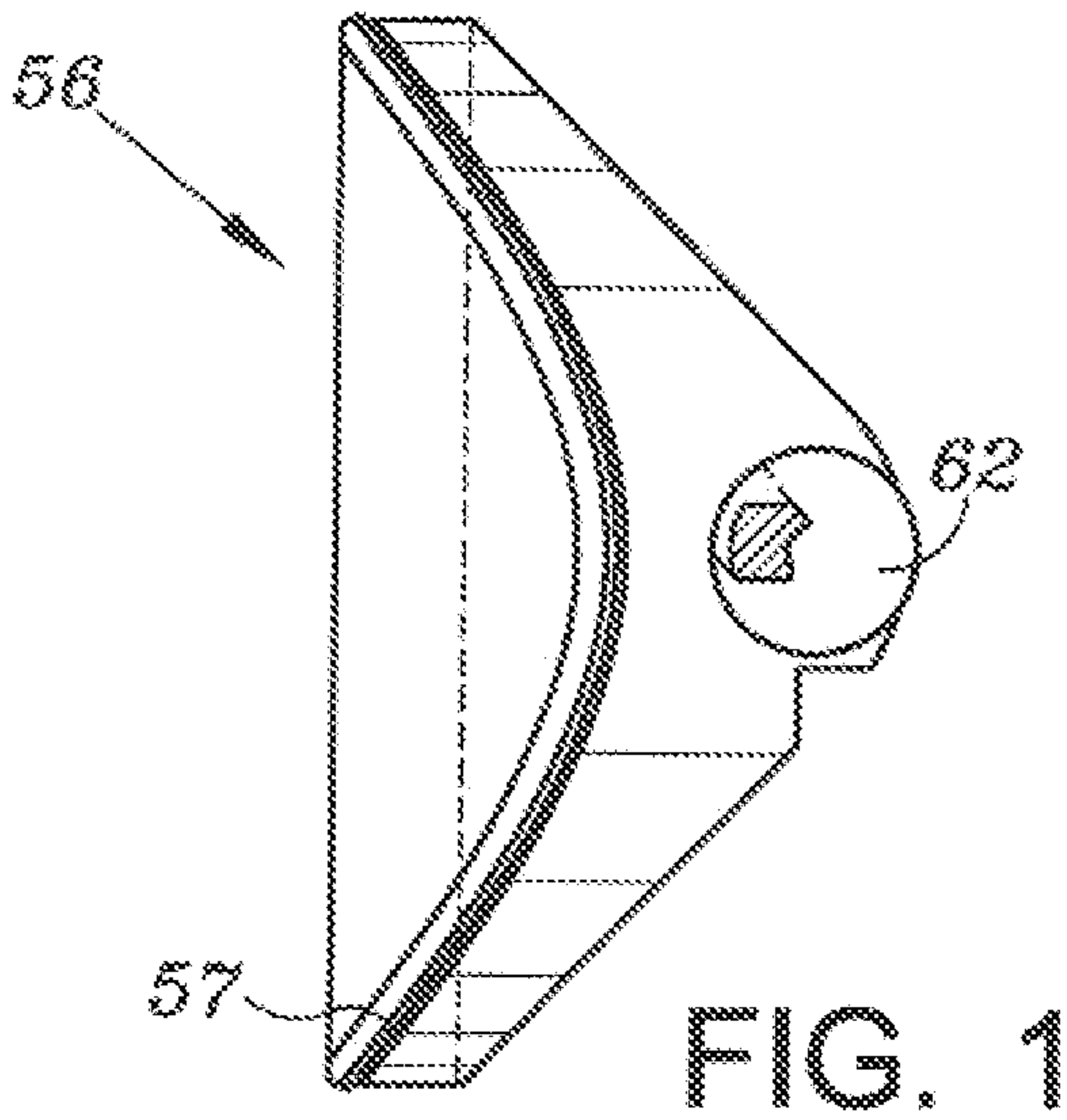


FIG. 14

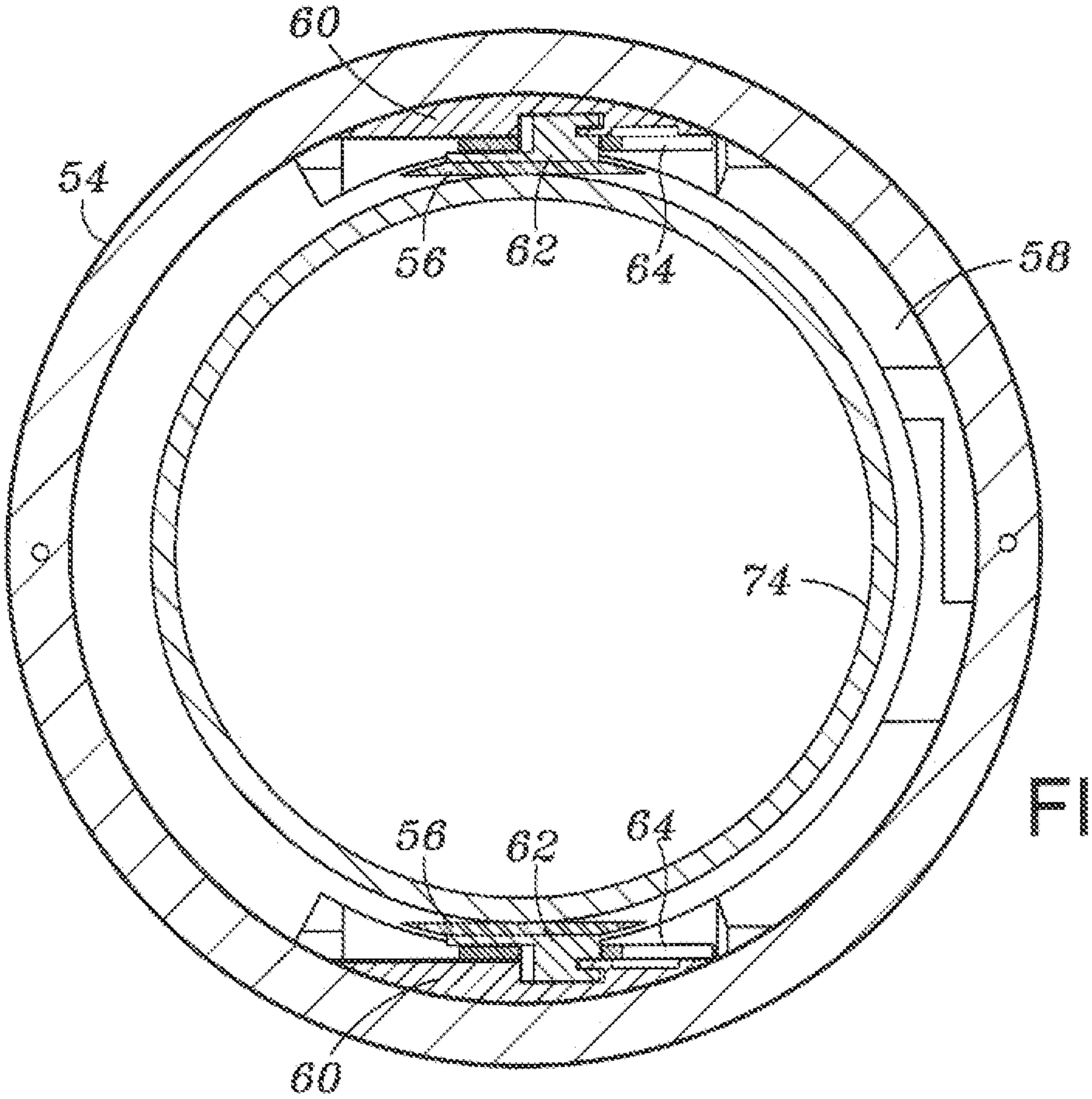


FIG. 15

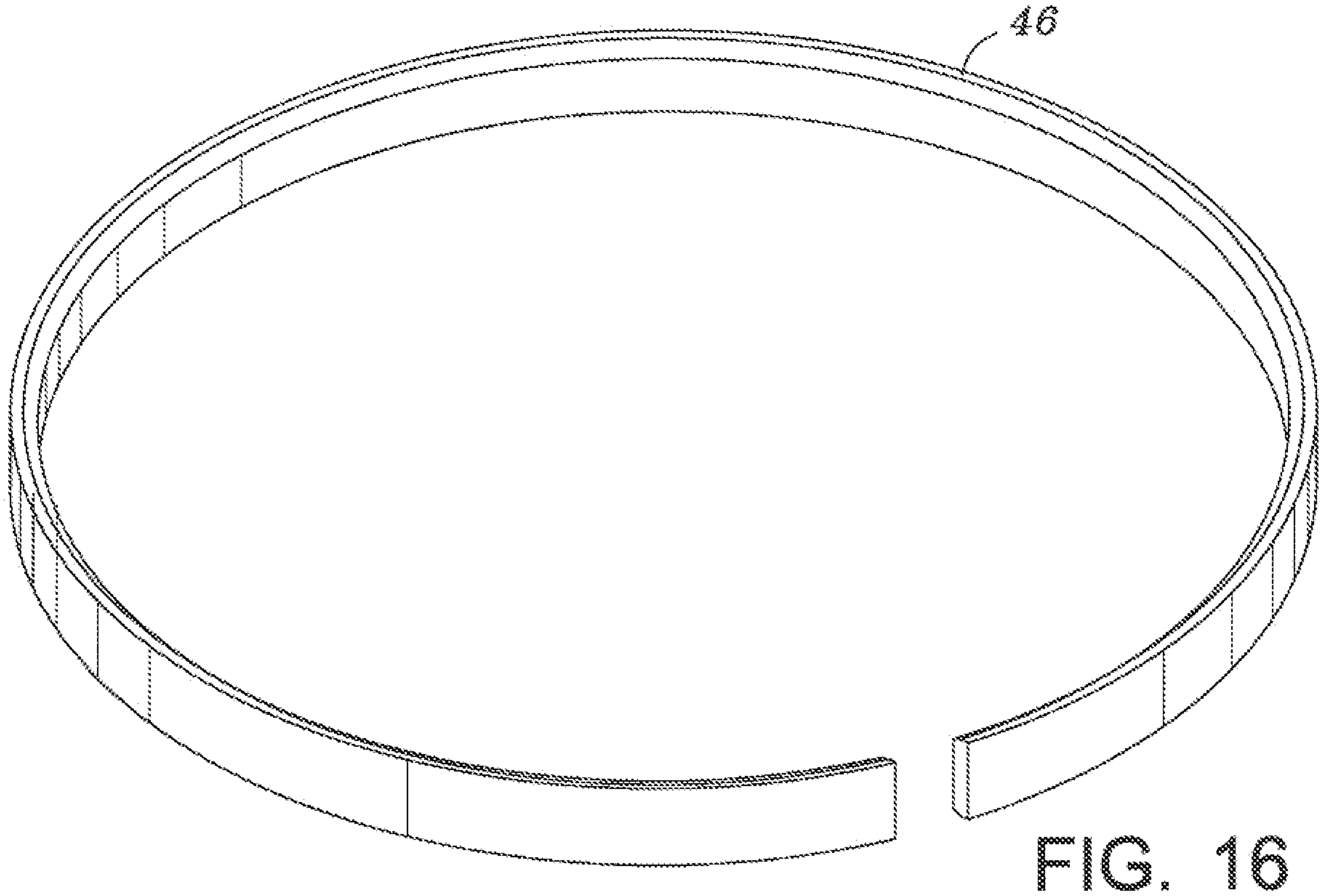
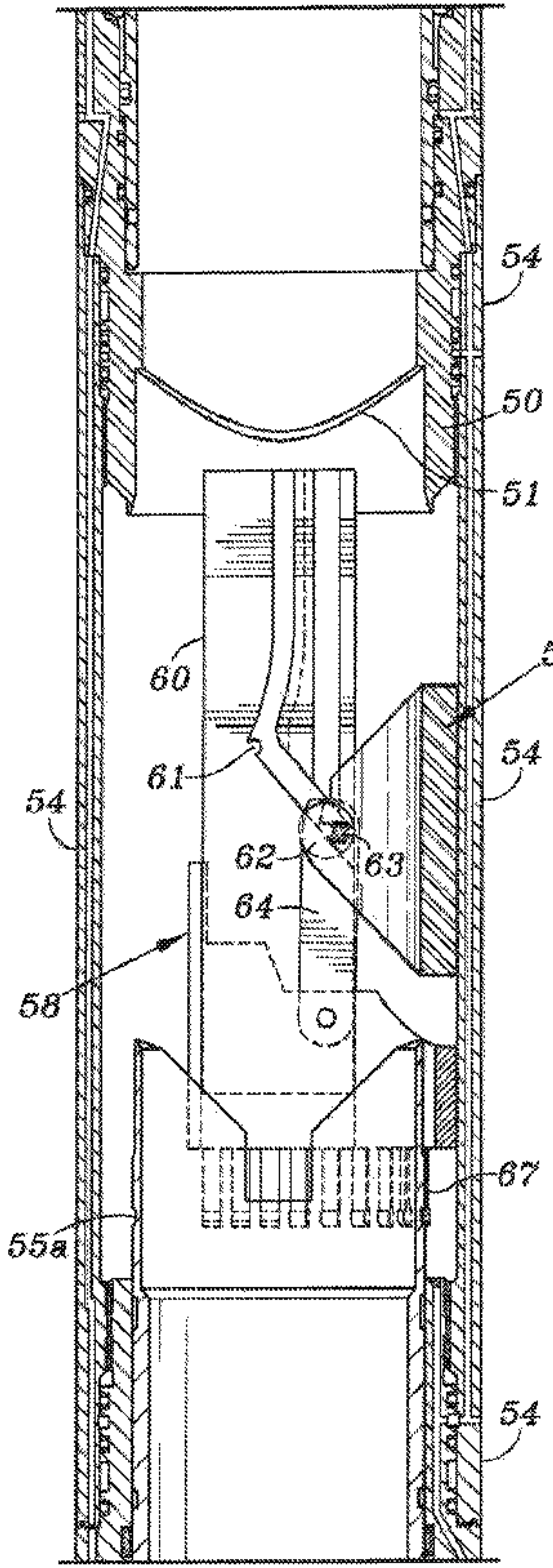


FIG. 16



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