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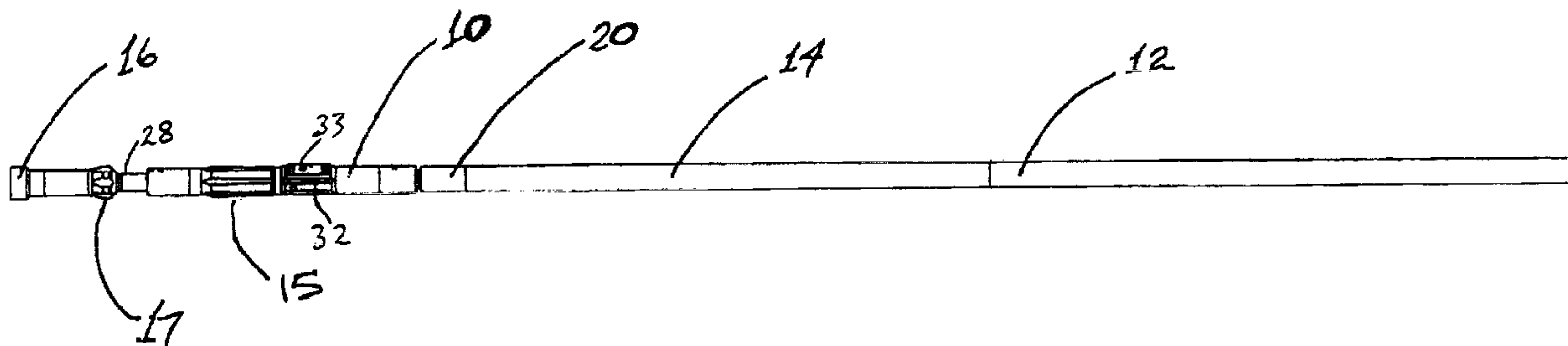
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(54) Titre : FOREUSE ROTATIVE ORIENTABLE

(54) Title: ROTARY STEERABLE DRILLING TOOL



(57) Abrégé/Abstract:

The device contemplated provides a method for positioning the drill bit in a drilling operation to achieve small changes in hole angle or azimuth as drilling proceeds. Two different positions are available to the operator. The first is a straight ahead position where the tool essentially becomes a packed hole stabilizer assembly. The second position tilts the bit across a rotating fulcrum to give a calculated offset at the bit-formation interface. The direction that the bit offset is applied in relation to current hole direction is controlled by positioning the orienting pistons prior to each drilling cycle, through the use of current MWD technology. Components of the tool comprise a MWD housing, upper steering and drive mandrel, non-rotating position housing, lower drive mandrel splined with the upper mandrel, rotating fulcrum stabilizer and drill bit.

ABSTRACT OF THE DISCLOSURE

The device contemplated provides a method for positioning the drill bit in a drilling operation to achieve small changes in hole angle or azimuth as drilling proceeds. Two different positions are available to the operator. The first is a straight ahead position where the tool essentially becomes a packed hole stabilizer assembly. The second position tilts the bit across a rotating fulcrum to give a calculated offset at the bit-formation interface. The direction that the bit offset is applied in relation to current hole direction is controlled by positioning the orienting pistons prior to each drilling cycle, through the use of current MWD technology. Components of the tool comprise a MWD housing, upper steering and drive mandrel, non-rotating position housing, lower drive mandrel splined with the upper mandrel, rotating fulcrum stabilizer and drill bit.

TITLE OF THE INVENTION**Rotary Steerable Drilling Tool****BACKGROUND OF THE INVENTION**

In the earth drilling art, it is well known to use downhole motors to rotate drill bits on the end of a non-rotating drill string. With the increasingly common use of directional drilling, where the well is drilled in an arc to produce a deliberately deviated well, bent subs have been developed for guiding the downhole motors in a desired drilling direction. The bent subs are angled, and thus cannot be used in association with rotating drill strings.

This invention is directed towards a tool that permits steered directional drilling with a rotary drilling tool.

SUMMARY OF THE INVENTION

The device contemplated provides a method for positioning the drill bit in a drilling operation to achieve small changes in hole angle or azimuth as drilling proceeds. Two different positions are available to the operator. The first is a straight ahead position where the tool essentially becomes a packed hole stabilizer assembly. The second position tilts the bit across a rotating fulcrum to give a calculated offset at the bit-formation interface. The direction that the bit offset is applied in relation to current hole direction is controlled by positioning the orienting pistons prior to each drilling cycle, through the use of current MWD technology.

In one aspect of the invention, components of the tool comprise a MWD housing, upper steering and drive mandrel, non-rotating position housing, lower drive mandrel splined with the upper mandrel, rotating fulcrum stabilizer and drill bit.

If, after surveying and orienting during a connection, it is desired to drill with the tool in the oriented position, the rig pumps are activated. The pressure differential created by the bit jets below the tool will cause pistons to open from the ID of the tool into the tool chamber. As the pistons open, they will contact wings that come out into the

path of travel of the upper mandrel as it comes down a spline, and bottoms out on the lower drive mandrel. This occurs as the drill string is being lowered to bottom. The extra length provided by the open wings moves a sliding sleeve centered over, but not attached to the upper mandrel, to a new position that in turn forces the orienting pistons to extend out into the borehole annulus. This extrusion pushes the non-rotating sleeve (outer housing) to the opposite side of the hole. When this force is applied across the rotating stabilizer, the stabilizer becomes a fulcrum point, and forces the drill bit against the side of the hole that is lined up with the orienting pistons. The calculated offset at the bit then tends to force the hole in the oriented direction as drilling proceeds. After the drilling cycle is complete, the tool will be picked up off bottom, and as the upper mandrel moves upward on the spline in the lower mandrel, a spring pushes the sliding sleeve back into its normal position, the orienting pistons retract into the outer housing, and the centering pistons come back out into the borehole annulus, thus returning the tool to its normal stabilized position. This cycle may be repeated until the desired result is achieved.

Once the desired hole angle and azimuth are achieved, the following procedure may be implemented to drill straight ahead. After making a connection and surveying, slowly lower the drill string to bottom and set a small amount of weight on the bit. Then engage the rig pumps. This time, when the activation pistons from the ID attempt to open the wings, they will be behind the sliding sleeve assembly, and the sliding sleeve will remain in its normal or centered position throughout the following drilling cycle.

Skillful alternating of the two above drilling positions will yield a borehole of minimum tortuosity, when compared to conventional steerable methods.

These and other aspects of the invention are described in the detailed description of the invention and claimed in the claims that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

There will now be described preferred embodiments of the invention, with reference to the drawings, by way of illustration only and not with the intention of

limiting the scope of the invention, in which like numerals denote like elements and in which:

Fig. 1 is a side view of a drill string with rotary steerable tool according to the invention;

Fig. 2 is a perspective view of a rotary steerable tool according to the invention showing wings in the extended position with the housing partly broken away to show the mandrel;

Fig. 3 is a perspective view of a rotary steerable tool according to the invention with the housing broken away to show wings in the retracted position;

Fig. 4 is a close up view of mating dog clutch faces for use in orienting the rotary steerable tool according to the invention;

Fig. 5 is an end view of a rotary steerable tool according to the invention showing pistons set in the offset drilling position;

Fig. 6 is an end view of a rotary steerable tool according to the invention showing pistons set in the straight ahead drilling position;

Figs. 7A-7D are lengthwise connected sections (with some overlap) through a rotary steerable tool according to the invention showing the tool in pulled back position ready to extend the wings used to move the pistons into the offset drilling position;

Fig. 8 is a cross-section along the line 8-8 in Fig. 7C;

Fig. 9 is a cross-section along the line 9-9 in Fig. 7C and 13C;

Fig. 10 is a cross-section along the line 10-10 in Fig. 7C and 13C;

Fig. 11 is a cross-section along the line 11-11 in Fig. 7C and 13C;

Fig. 12 is a cross-section along the line 12-12 in Fig. 7B, 13B and 15;

Figs. 13A-13D are lengthwise connected sections (with some overlap) through a rotary steerable tool according to the invention showing the tool in straight ahead drilling position;

Fig. 14 is a cross-section along the line 14-14 in Fig. 13B;

Fig. 15 is a lengthwise section through a rotary steerable tool according to the invention showing the tool in offset drilling position;

Fig. 16 is a cross-section along the line 16-16 in Fig. 15;

Fig. 17 is a cross-section along the line 17-17 in Fig. 15;

Fig. 18 is a cross-section along the line 18-18 in Fig. 15; and

Fig. 19 is a cross-section along the line 19-19 in Fig. 15.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In this patent document, "comprising" is used in its inclusive sense and does not exclude other elements being present in the device. In addition, a reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present. "MWD" means measurement-while-drilling. All seals and bearings described herein and shown in the drawings are conventional seals and bearings.

Referring to Fig. 1, which shows the overall assembly of a drill string according to the invention, a rotary steerable drilling tool 10 is shown located on a conventional drill string 12 between a conventional MWD tool 14 and a conventional drill bit 16. As shown more particularly in Figs. 7A and 7D, the rotary steerable drilling tool 10 includes a mandrel 20 having a conventional box connection 22 at an uphole end for connection into the drill string 12 and a conventional box connection 24 at a downhole end for connection to a pin connection 26 of a drilling sub 28. The sub 28 is configured as a rotating stabilizer 17 provided on the drill string between the rotary steerable drilling tool 10 and the drill bit 16, and operates as a fulcrum for the rotary steerable drilling tool 10 and the drill bit 16 to pivot around. The drill bit 16 will conventionally have jets in the bit for egress of fluid from the drill string. At the surface, a conventional rig will include conventional pumps (not shown) for pumping fluid down the drill string 12 to the drill bit 16 and out the jets in the drill bit.

The components of the rotary steerable drilling tool 10 are best seen in Figs. 7A-7D, which show the tool in the pulled back off-bottom position, ready to set the tool into either a straight ahead drilling position or an offset drilling position. Figs. 8-12 are sections corresponding to the section lines on Figs. 7A-7D. Figs. 2-6 provide perspective views of the tool broken away to show the internal workings. Figs. 8-12 are sections

corresponding to the section lines on Figs. 7A-7D. Figs. 13A-13D show the rotary steerable drilling tool 10 in a straight ahead on-bottom drilling position. Fig. 14 is a section corresponding to the section line 14-14 on Fig. 13C. The other sections shown on Figs. 13A-13D correspond to Figs. 9-12 as well, since the sections do not change in those positions. Fig. 15 shows the rotary steerable drilling tool 10 in position for offset drilling, in so far as it is different from the position shown in Figs. 13A-13D. Figs. 16-19 are sections corresponding to the section lines on Fig. 15.

Referring to Figs. 2-13, and particularly to Figs 7A-7D, a bore 30 is provided within the mandrel 20 for communication of fluid from surface to the drill bit 16. A housing 32 is mounted on the mandrel 20 for rotation in relation to the mandrel 20. During drilling, the housing 32 is held against rotation by frictional engagement with the wellbore and the mandrel rotates, typically at about 120 rpm. The housing 32 is provided with an adjustable offset mechanism that can be adjusted from the surface so that the rotary steerable drilling tool 10 can be operated in and changed between a straight ahead drilling position and an offset drilling position. In the straight ahead drilling position, asymmetry of the housing 32, namely thickening 33 of the housing 32 on one side, in combination with pistons on the other side of the housing 32 yields a tool that is centered in the hole. In an offset drilling position, pistons on the thickened side of the housing 32 drive the tool 10 to one side of the wellbore, and thus provide a stationary fulcrum in which the mandrel 20 rotates, to force the drill bit in a chosen direction. Three hole grippers 15 are provided on the exterior surface of the housing 32 downhole of the thickened section 33. One of the hole grippers 15 is on the opposite side of the thickened section, and the other two are at about 90° to the thickened section 33. The hole grippers 15 are oriented such that when the rotary steerable tool 10 is offset in the hole by 1/2 degrees by operation of the adjustable offset mechanism described below, the hole grippers 15 will lie parallel to the hole wall, so that the hole grippers 15 make maximum contact with the hole wall. The hole grippers 15 grip the wall of the hole and prevent the housing 32 from rotation, as well as preventing premature wear of the housing 32 against the wellbore.

The housing 32 has threaded on its uphole end an end cap 34 holding a piston 36, and on its downhole end another end cap 40 holding a floating piston seal 42 within chamber 44. The floating piston 42 accommodates pressure changes caused by movement of the housing on the mandrel 20. The housing 32 rotates on the mandrel 20 on seven bearings 46. The mandrel 20 is formed from an upper mandrel 50 and lower mandrel 52 connected by splines 54. A sleeve 55, is held in the bore of the lower mandrel 52, and in the downhole end of the upper mandrel 50, by a pin on sub 28. Appropriate seals are provided as shown to prevent fluid from the mandrel bore from entering between the upper mandrel 50 and the lower mandrel 52 at 57. Downhole movement of the upper mandrel 50 in lower mandrel 52 is limited by the respective shoulders 59 and 61. The housing 32 is supported on the lower mandrel 52 by thrust bearings 56 on either side of a shoulder 58 on the lower mandrel 52.

The adjustable offset mechanism may for example be formed using plural pistons 60, 62 and 64 radially mounted in openings in the housing 32. The pistons 60 and 62 are mounted in openings on the thickened side 33 of the sleeve, while the pistons 64 are mounted on the opposed side. The thickened side 33 has a larger radius than the opposed side, and the pistons 64 are extendable outward to that radius. Pistons 62 are at 120° on either side of the piston 60 and extend outward at their maximum extension less than the extension of piston 60 when measured from the center of the mandrel 50. The pistons 60 and 62 extend outward to a radius of a circle that is centered on a point offset from the center of the mandrel 50, as shown in Fig. 5. As shown in Figs. 9-11 and 17-19, hole grippers 65 are also embedded on either side of housing 32 at 90° to the piston 60. The hole grippers 65 are about 5 inches long, and are oriented, as with hole grippers 15, so that one edge lies furthest outward. Thus, the hole grippers 65 assist in preventing the housing 32 from rotating by engaging the hole wall with their outermost edge. The hole grippers 15 and 65 should be made of a suitably hard material, and may for example be power tong dies since these are readily available and may be easily removed for replacement. The pistons 60, 62 and 64 should also be made of a similar hard material.

The pistons 60, 62 and 64 are radially adjustable by actuation of the mandrel 20 as follows. Dog clutch 66 is pinned by pins 68 to the mandrel 32 to form a chamber 70 between the housing 32 and upper mandrel 50. Dog clutch 66 has a dog face 67 that bears against dog face 69 on the end cap 34 when the upper mandrel 50 is raised in the hole. Wings 72 secured on pins 76 in the upper mandrel 50 are operable by fluid pressure in the bore 30 of the upper mandrel 50 through opening 74. Fluid pressure in the bore 30 urges pistons 71 radially outward and causes the wings 72 to swing outward on pins 76 into the chamber 70. Upon reduction of fluid pressure in the bore 30, wave springs 73 surrounding the pistons 71 draw the pistons 71 back into the upper mandrel 50. A spring (not shown) is also placed around the wings 72 seated in groove 77. The groove 77 is also formed in the outer surface of the wings 72 and extends around the upper mandrel 50. The spring retracts the wings 72 when the pressure in the bore 30 is reduced and the wings 72 are not held by frictional engagement with collar 84.

The chamber 70 is bounded on its housing side by a sleeve 78, which acts as a retainer for a piston actuation mechanism held between shoulder 80 on end cap 34 and shoulder 82 on the housing 32. The piston actuation mechanism includes thrust bearing 86 held between collars 84 and 88, cam sleeve 90 and spring 92, all mounted in that order on the mandrel 32. The cam sleeve 90 is mounted over a brass bearing sleeve 91 that provides a bearing surface for cam sleeve 90. The spring 92 provides a sufficient force, for example 1200 lbs, to force the cam sleeve 90 uphole to its uphole limit determined by the length of sleeve 78, yet not so great that downhole pressure on the upper mandrel 50 cannot overcome the spring 92. The spring 92 may be held in place by screws in holes 93 after the spring 92 is compressed into position during manufacture, and then the screws can be removed and the holes 93 sealed, after the remaining parts are in place.

The cam sleeve 90 is provided with an annular ramped depression in its central portion 94 and thickens uphole to cam surface 96 and downhole to cam surface 98, with greater thickening uphole. Piston 60 is offset uphole from the pistons 64 by an amount L, for example 3 1/2 inches. The cam surface 96 is long enough and spaced from the center of the depression 94 sufficiently, that when the cam sleeve 90 moves a distance L

downward to the position shown in Fig. 15, the piston 60 rides on the cam surface 96, while the pistons 64 ride in the center of the depression 94. The cam surface 98 is long enough and spaced from the center of the depression 94 sufficiently, that when the cam sleeve 90 is urged uphole by the spring 92 to the position shown in Fig. 7C or 13C, the pistons 64 ride on the cam surface 98, while the piston 60 rides in the center of the depression 94. Thus, when cam sleeve 90 is forced downhole in relation to the housing 32, the pistons 60 ride on the uphole cam surface 96, and are pressed outward into the well bore beyond the outer diameter of the housing 32, while the pistons 64 may retract into the annular depression 94. When the cam sleeve 90 is in the uphole position, the pistons 60 are in the annular depression 94, while pistons 64 ride on the downhole cam surface 98. The pistons 62 will also ride on the cam sleeve 90, but are slightly offset downhole from the piston 60 and so do not extend as far outward. Since the cam surface 98 has a smaller diameter than the cam surface 96, the tool may move more readily in the hole when the pistons 64 are extended for the straight ahead drilling position, and the piston 64 and housing 32 act as a stabilizer. The stabilizer position or straight ahead drilling position of the pistons is shown in the end view Fig. 6 and the cross-sections 10 and 11. The offset drilling position of the pistons is shown in end view in Fig. 5 and in cross-section in Figs. 17-19.

An orientation system is also provided on the rotary steerable drilling tool 10. A sensor 102, for example a magnetic switch, is set in an opening in the upper mandrel 50. A trigger 104, for example a magnet, is set in the end cap 34 at a location where the trigger 104 will trip the sensor 102 when the mandrel 20 rotates in an on-bottom drilling position (either offset or straight). Snap ring 105 should be non-magnetic. A further sensor 106 is set in the upper mandrel 50 at a distance below the sensor 102 about equal to the amount the upper mandrel 50 is pulled back as shown in Figs. 7A-7D, which will be slightly greater than the distance L, for example 4 inches when L is 3 1/2 inches. The trigger 104 will therefore trip the sensor 106 when the mandrel 20 is pulled back, and the jaw clutch faces 67, 69 are engaged. This position allows the tool to be oriented with the MWD tool face. The sensors 104 and 106 communicate through a communication link,

eg a conductor, in channel 105 with a MWD package in the MWD tool 14. The sensors 102 and 106 are thus sensitive to the rotary orientation of the housing 32 in relation the mandrel 20, and when the trigger 104 trips one of the sensors 102, 106, sends a signal to the MWD tool 14 that is indicative of the rotary orientation of the housing 32 on the mandrel 20.

For drilling in the straight ahead position shown in Figs. 13A-13D and 14, the mandrel 50 is set down on the lower mandrel 52 so that the shoulders 59 and 61 abut. Wings 72 are held in the mandrel 50, and the spring 92 urges the cam sleeve 90 to the position shown in Fig. 13B, so that the pistons 64 are forced outward by the cam surface 98, and piston 60 lies in the annular depression 94. In this position, the pistons 64 and thickened portion of the housing 32 form a circular stabilizer and the mandrel 20 rotates within the housing 32 centrally located in the hole.

For drilling in the offset position, the rotary steerable drilling tool 10 is altered in position as shown in Figs. 15-19. The upper mandrel 50 is lifted off the lower mandrel 52 until dog face 67 engages dog face 69, and rotated at least 360° to ensure engagement of the faces 67 and 69. The orientation of the housing 32 in the hole can then be determined by the MWD tool 14 if the engaging position of the dog faces 67, 69 is programmed in the MWD package. The housing 32 may then be rotated from surface using the mandrel 20 into the desired direction of drilling in the offset drilling position. The drilling direction will conveniently coincide with the direction that the piston 60 points. With the dog faces 67, 69 engaged, fluid pressure is applied from surface to the bore 30 of the mandrel 20 to force the wings 72 into a radially extended position. The mandrel 20, or more specifically the upper mandrel 50, since the lower mandrel 52 does not move in this operation, is then moved downward. Upon downward motion of the mandrel 20, the wings 72 drive the cam sleeve 90 downward and lift the piston 60 onto the cam surface 96, thus extending the piston 60 outward, while pistons 64 move into the annular depression 94. The action of the piston 60 bearing against the wellbore places the rotary steerable tool 10 in an offset drilling position using the rotary stabilizer 17 as a rotating fulcrum. The ratio of the offset caused by the pistons 60, 62 to the offset at the drill bit

16 is equal to the ratio of the distance of the pistons 60,62 from the rotary stabilizer 17 to the distance of the drill bit 16 from the rotary stabilizer 17.

During straight ahead drilling, the location of the housing 32 may also be determined by rotating the mandrel 20 in the housing 32 and taking readings from the sensors 106. The timing of the readings from the sensor 106 may be used by the MWD package to indicate the location of the housing 32.

Immaterial modifications may be made to the invention described here without departing from the essence of the invention.

We claim :

1. A rotary steerable drilling tool, comprising :
 - (a) a mandrel;
 - (b) a housing mounted on the mandrel for rotation in relation to the mandrel;
 - (c) an adjustable offset mechanism on the housing, the adjustable offset mechanism being surface adjustable to move the rotary steerable drilling tool to and from a straight ahead drilling position and an offset drilling position, wherein the adjustable offset mechanism comprises plural pistons radially mounted in the housing, the plural pistons being radially adjustable by actuation of the mandrel, wherein the plural pistons comprise first and second pistons located on opposed sides of the housing, the first piston being extended and the second piston being retracted in the straight ahead drilling position, and the first piston being retracted and the second piston being extended in the offset drilling position, and wherein the pistons are actuated by a cam sleeve mounted on the mandrel;
 - (d) wings mounted on the mandrel and operable by fluid pressure within the mandrel into a radially extended position; and
 - (e) the wings cooperating with the cam sleeve to drive the second piston outward and retract the first piston when the wings are in the extended position.
2. The rotary steerable drilling tool of claim 1 in which the mandrel comprises an upper mandrel splined with a lower mandrel, the wings are mounted on the upper mandrel, and movement of the upper mandrel with the wings extending radially outward operates the cam sleeve.

3. A drill string, comprising:

- (a) a mandrel;
- (b) a housing mounted on the mandrel for rotation in relation to the mandrel;
- (c) an adjustable offset mechanism on the housing, the adjustable offset mechanism being surface adjustable to move the drill string to and from a straight ahead drilling position and an offset drilling position;
- (d) first piston and second piston radially mounted in the housing, the first piston and second piston being radially adjustable by actuation of the mandrel; the first piston being extended and the second piston being retracted in the straight ahead drilling position, and the first piston being retracted and the second piston being extended in the offset drilling position;
- (e) a cam sleeve mounted on the mandrel for actuating the first piston and second piston;
- (f) wings mounted on the mandrel and operable by fluid pressure within the mandrel into a radially extended position;
- (g) the wings cooperating with the cam sleeve to drive the second piston outward and retract the first piston when the wings are in the extended position;
- (h) a drill bit terminating the drill string; and
- (i) a stabilizer on the drill string between the drill bit and mandrel.

4. A drill string, comprising:
 - (a) an upper mandrel;
 - (b) a lower mandrel slidably connected to the upper mandrel by splines;
 - (c) a housing mounted on the upper mandrel for rotation in relation to the upper mandrel;
 - (d) an adjustable offset mechanism on the housing, the adjustable offset mechanism being surface adjustable to move the drill string to and from a straight ahead drilling position and an offset drilling position;
 - (e) a drill bit terminating the drill string; and
 - (f) a stabilizer on the drill string between the drill bit and lower mandrel.
5. The drill string of claim 4 in which the adjustable offset mechanism comprises plural pistons radially mounted in the housing, the plural pistons being radially adjustable by actuation of the upper mandrel.
6. The drill string of claim 5 in which the plural pistons comprise first and second pistons located on opposed sides of the housing, the first piston being extended and the second piston being retracted in the straight ahead drilling position, and the first piston being retracted and the second piston being extended in the offset drilling position.
7. The drill string of claim 6 in which the pistons are actuated by a cam sleeve mounted on the upper mandrel.
8. The drill string of claim 7, further comprising:
 - (a) wings mounted on the upper mandrel and operable by fluid pressure within the upper mandrel into a radially extended position; and

- (b) the wings cooperating with the cam sleeve to drive the second piston outward and retract the first piston when the wings are in the extended position.
- 9. The drill string of claim 8 in which the wings are mounted on the upper mandrel, and movement of the upper mandrel with the wings extending radially outward operates the cam sleeve.
- 10. The drill string of claim 4, further comprising a MWD tool on the drill string.

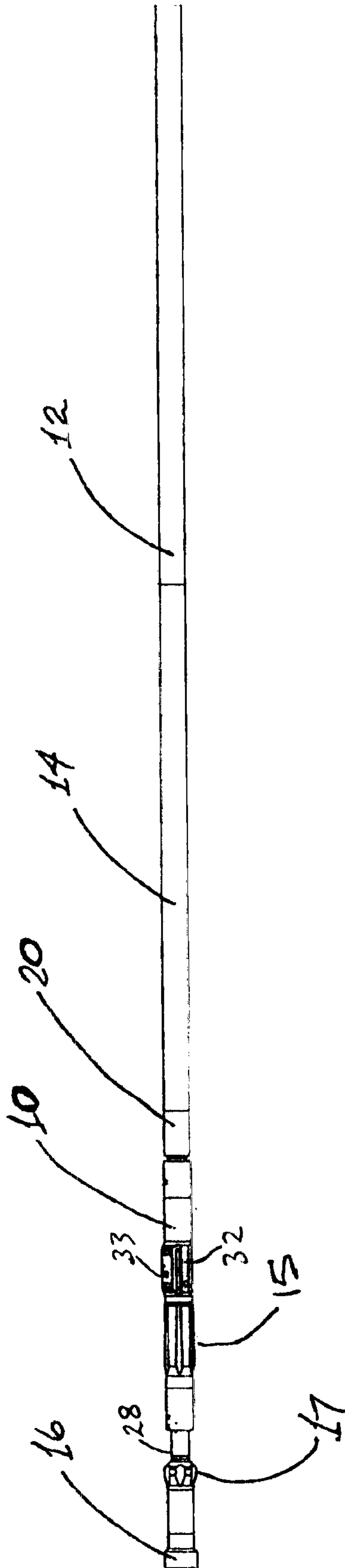


Fig. #1

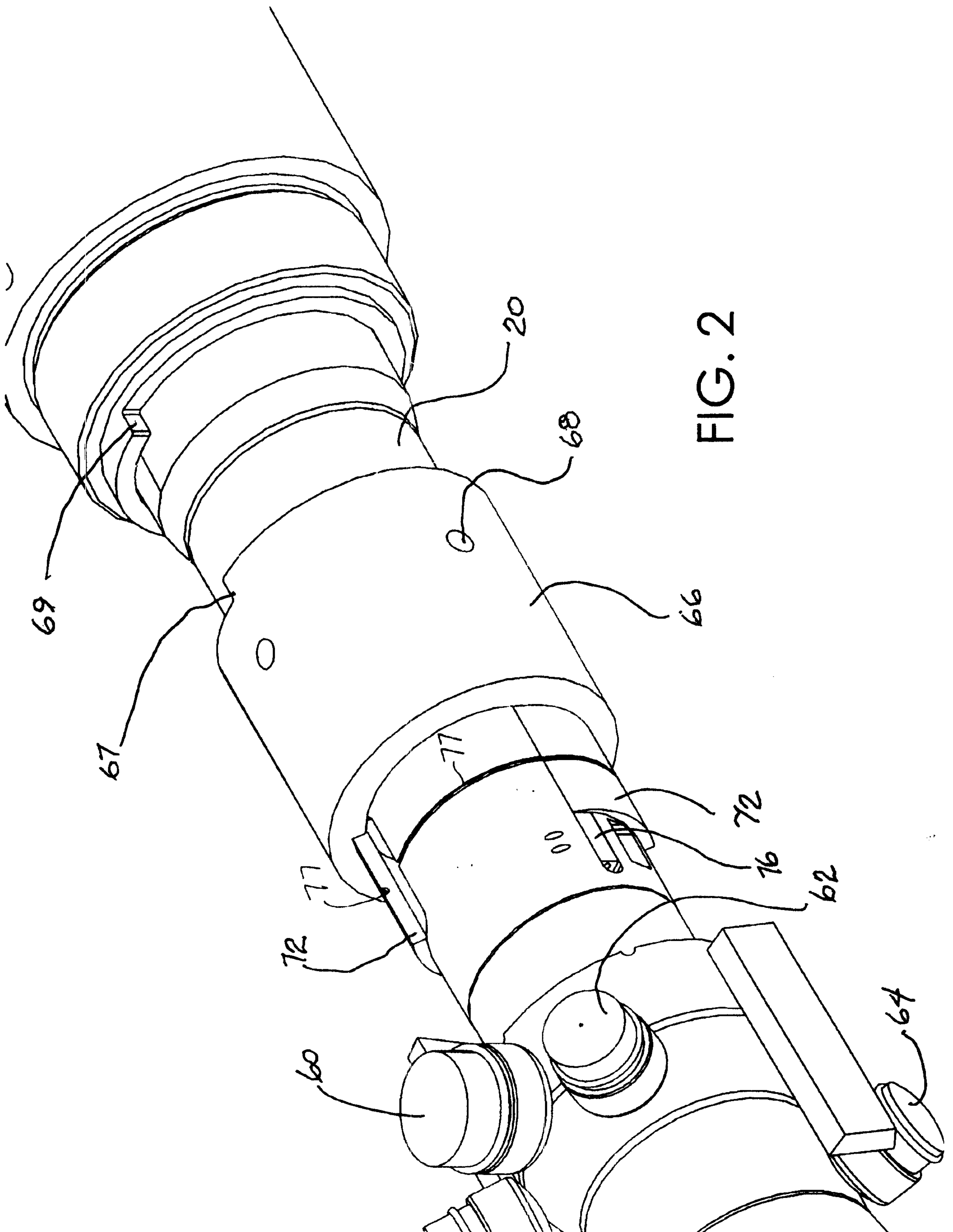


FIG. 2

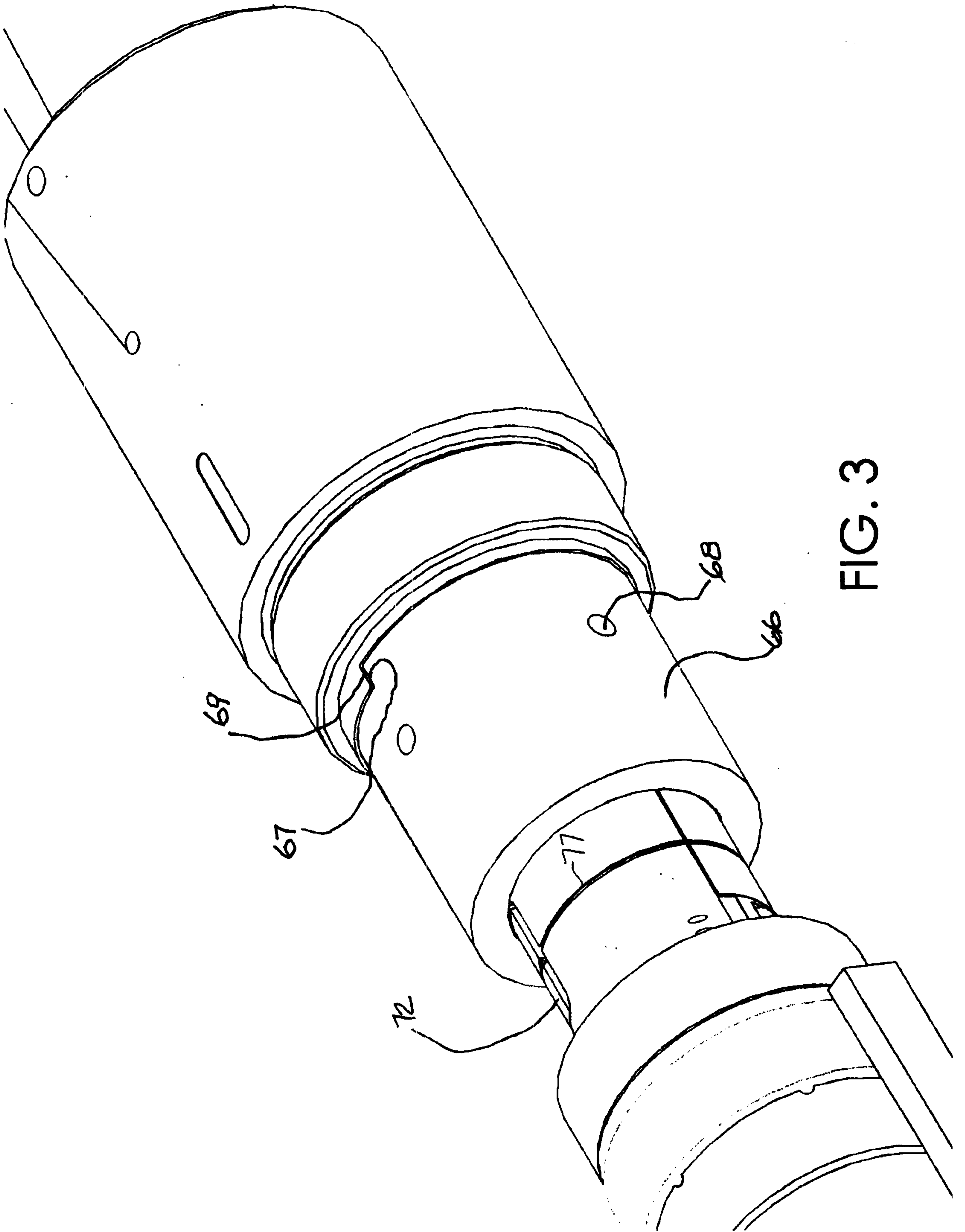
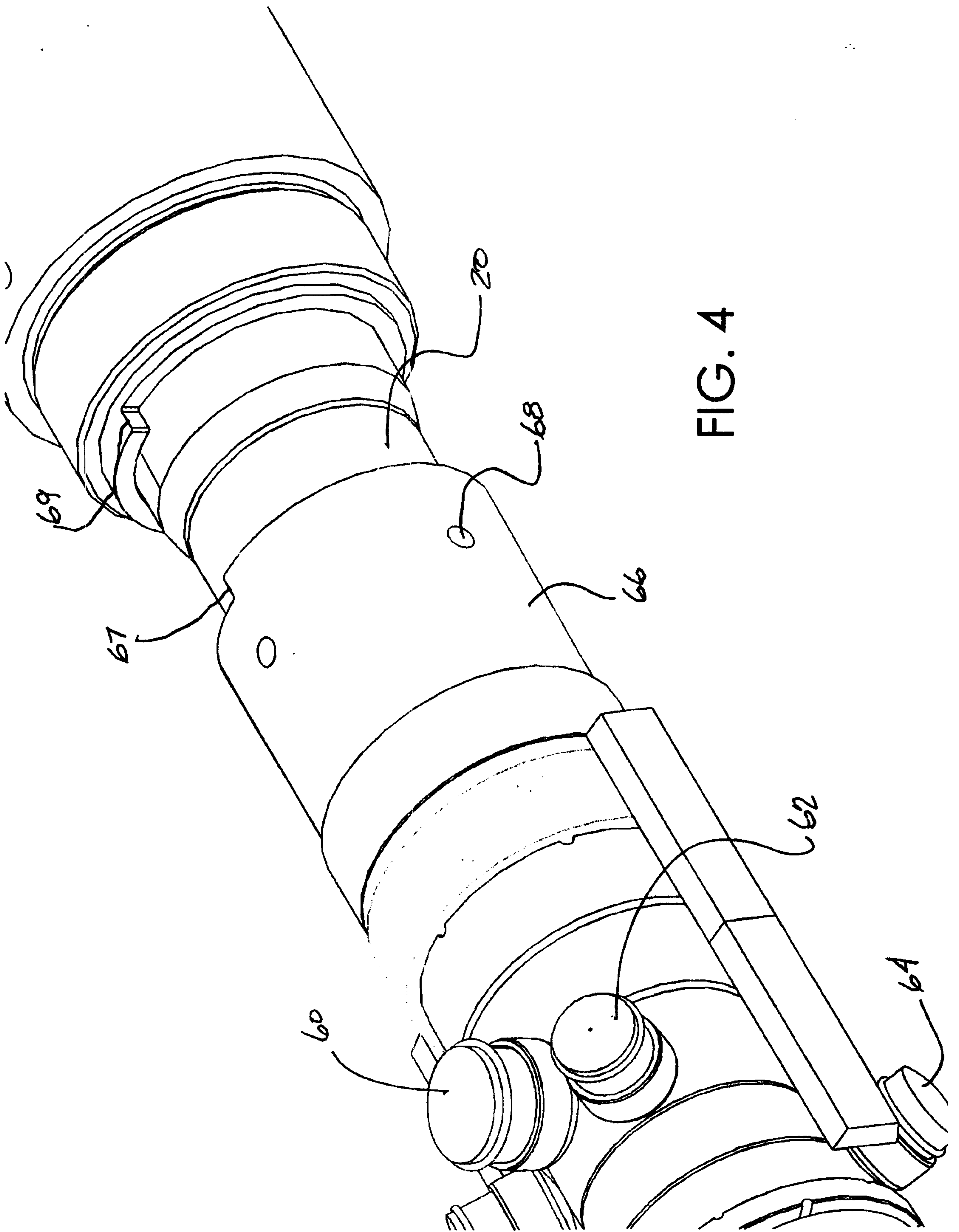


FIG. 3



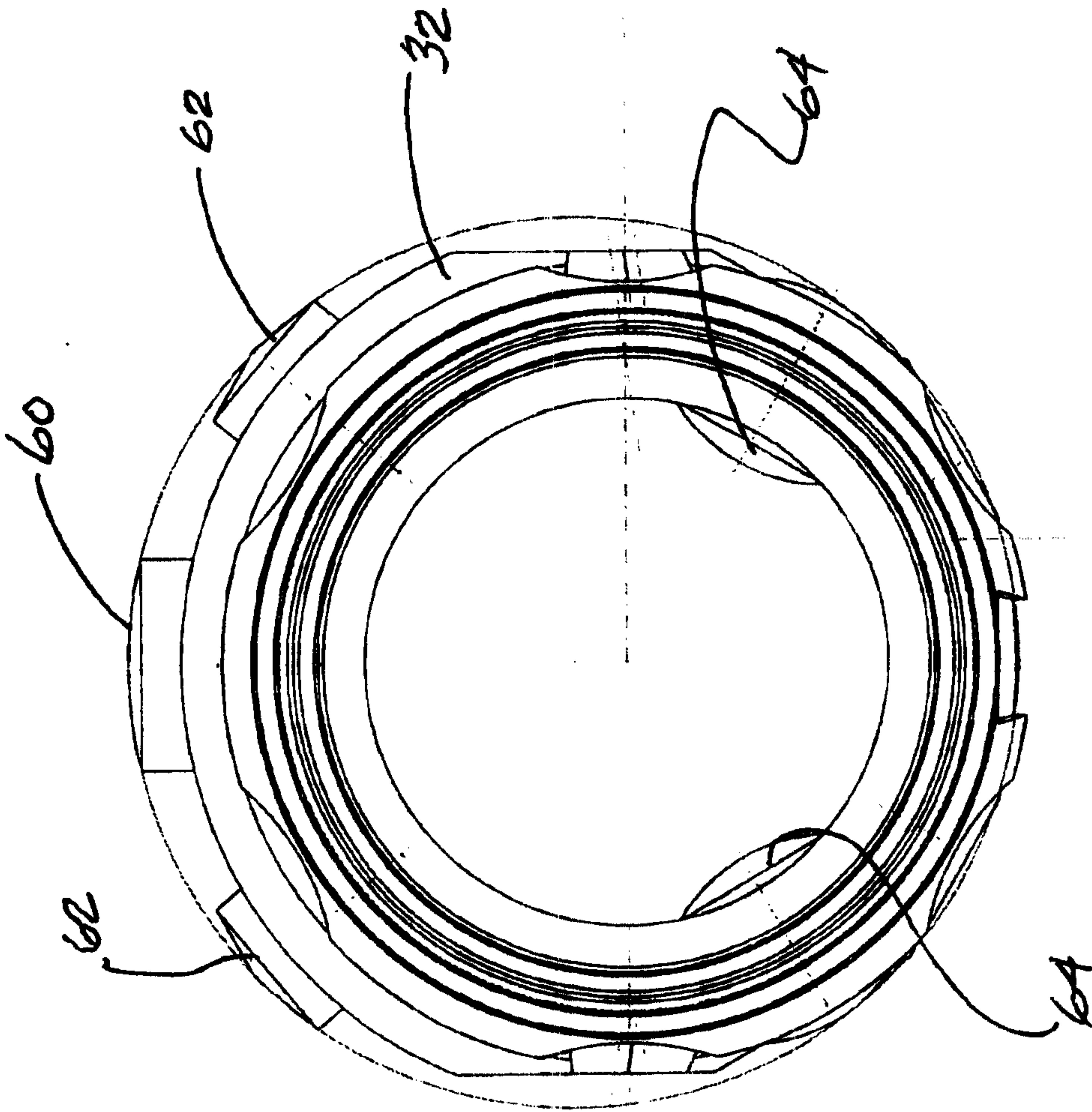


FIG. 5

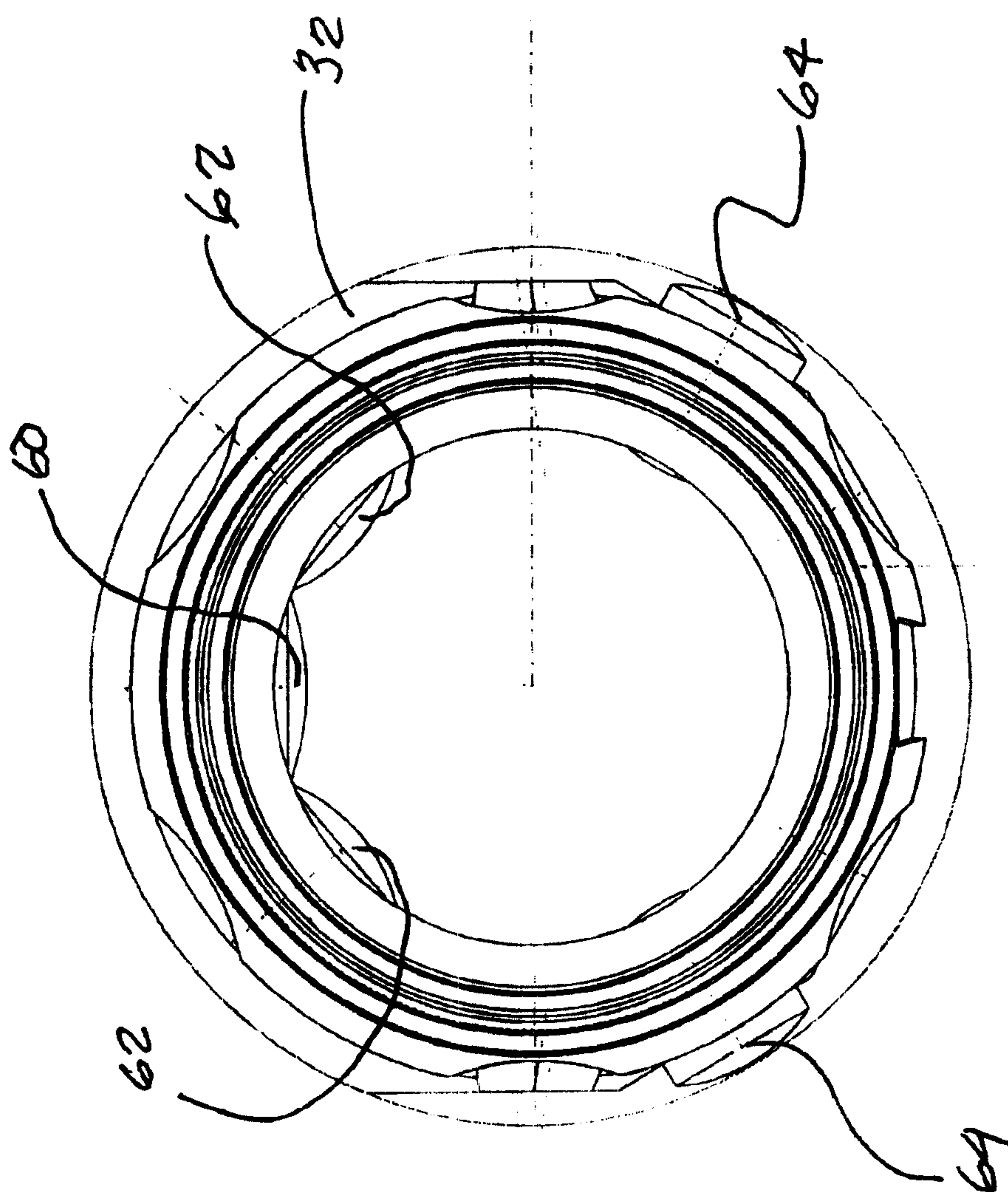


FIG. 6

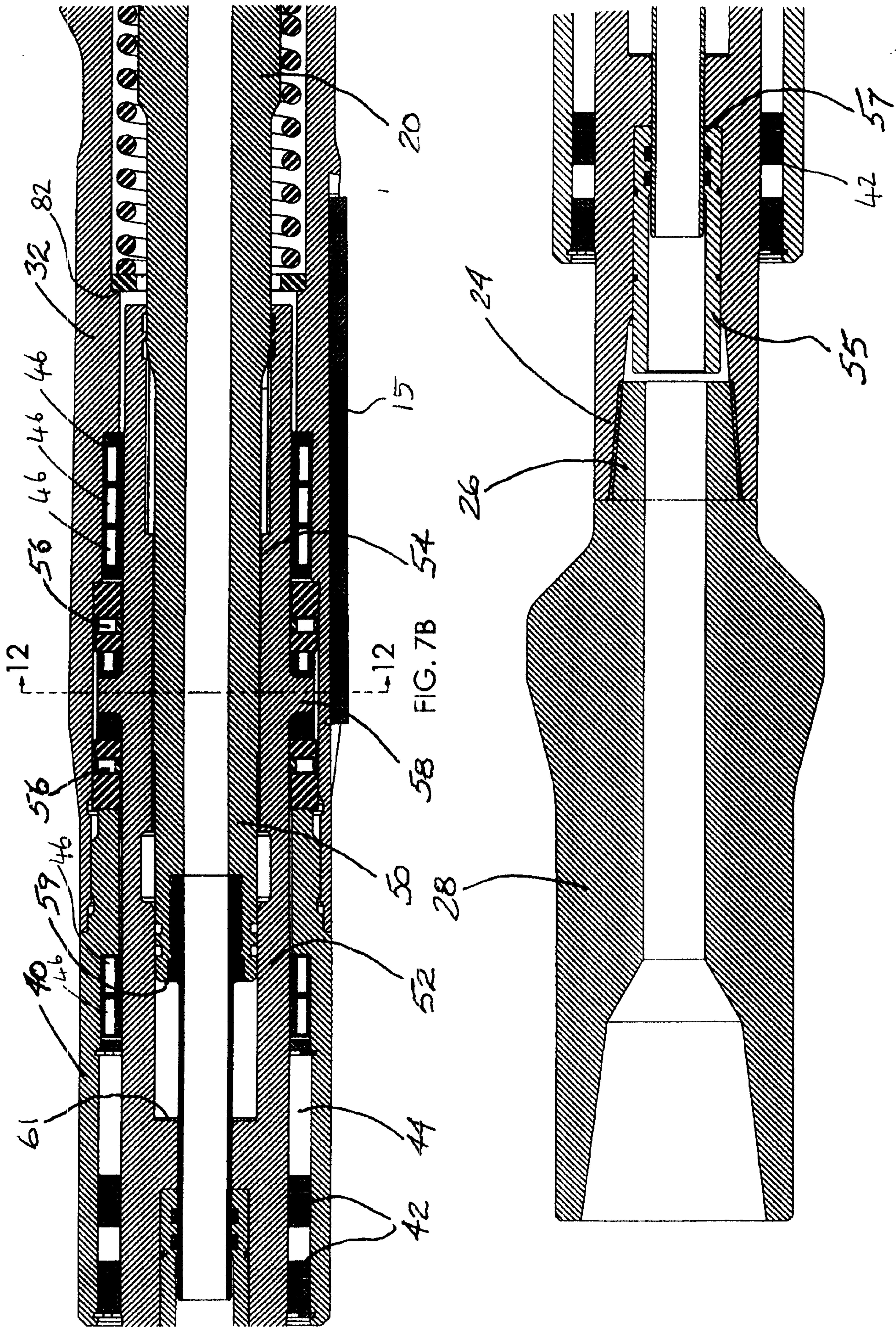
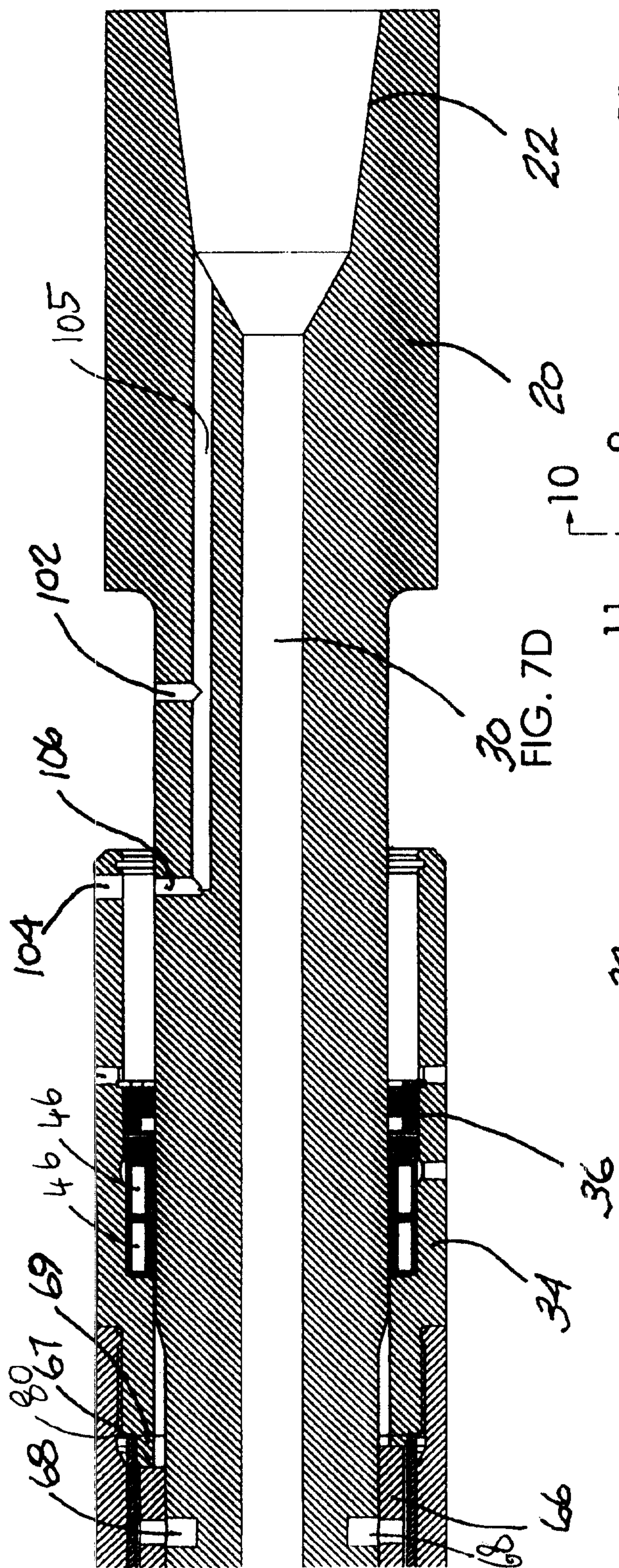


FIG. 7A



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FIG. 7D

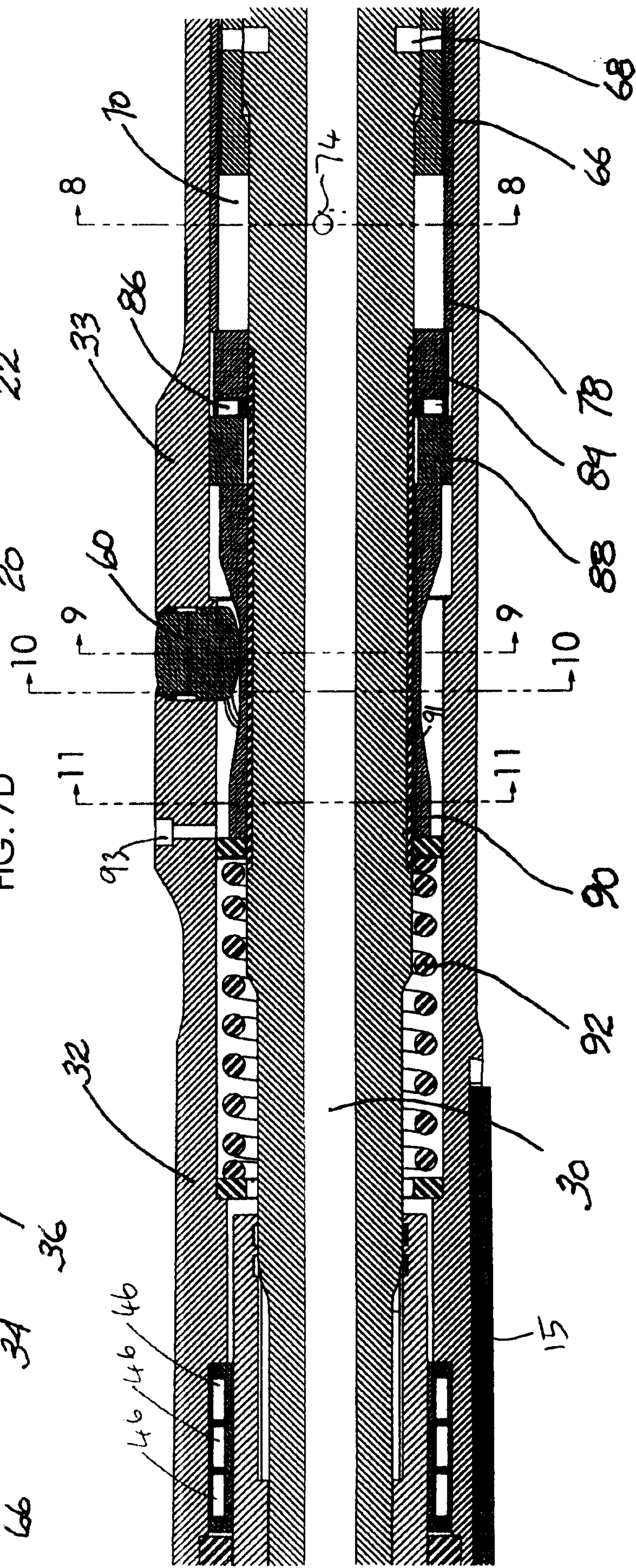


FIG. 7C

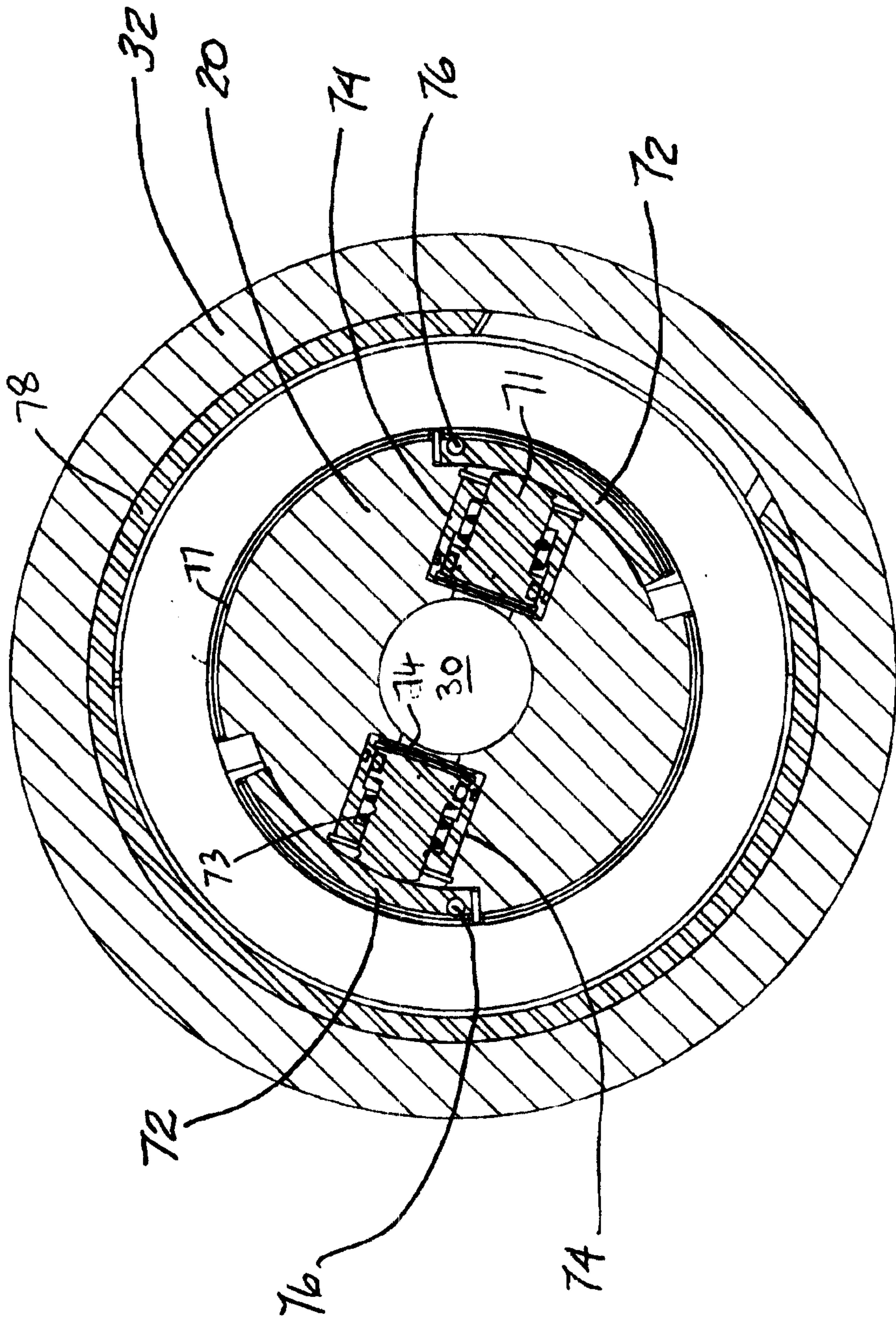


FIG. 8

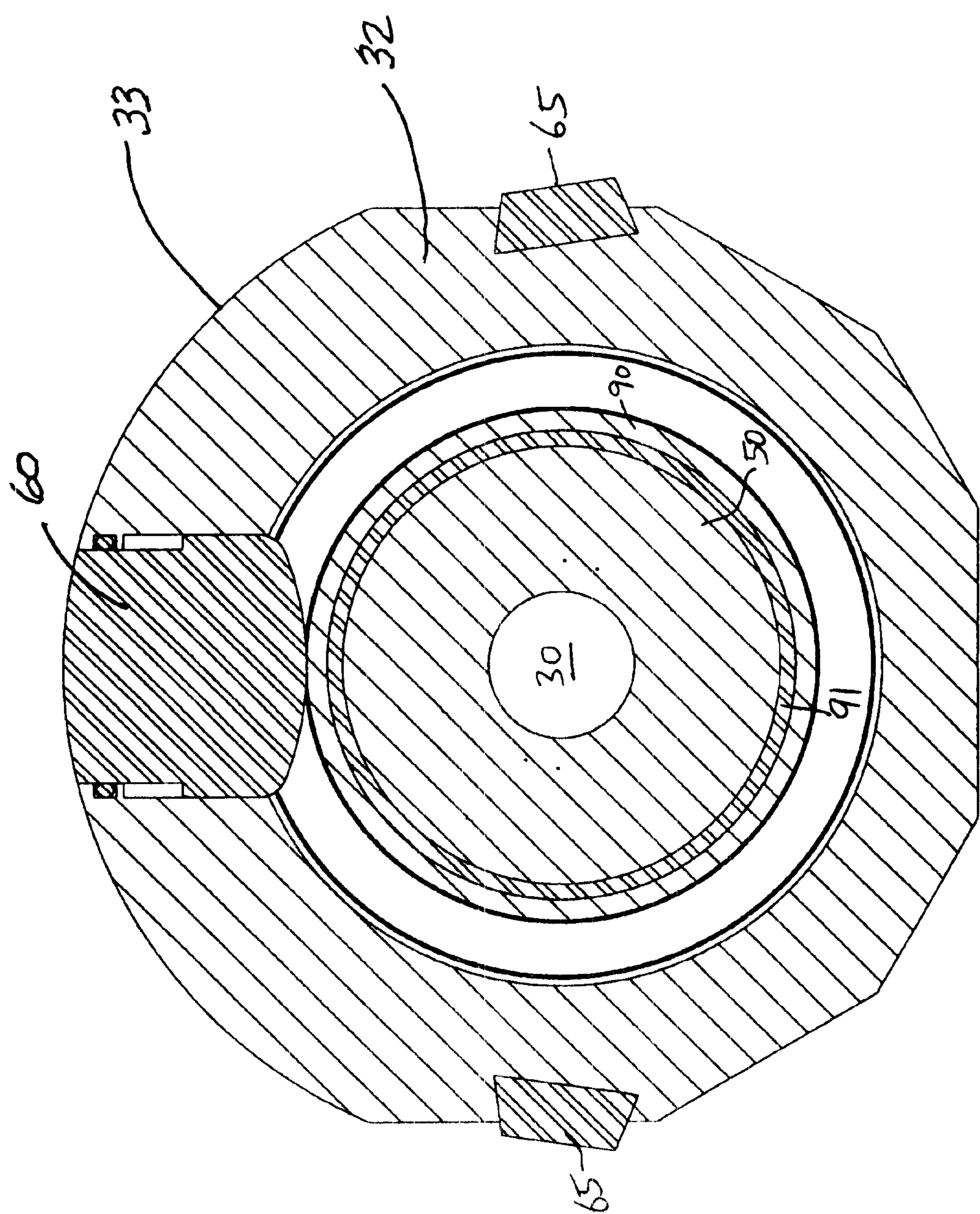


FIG. 9

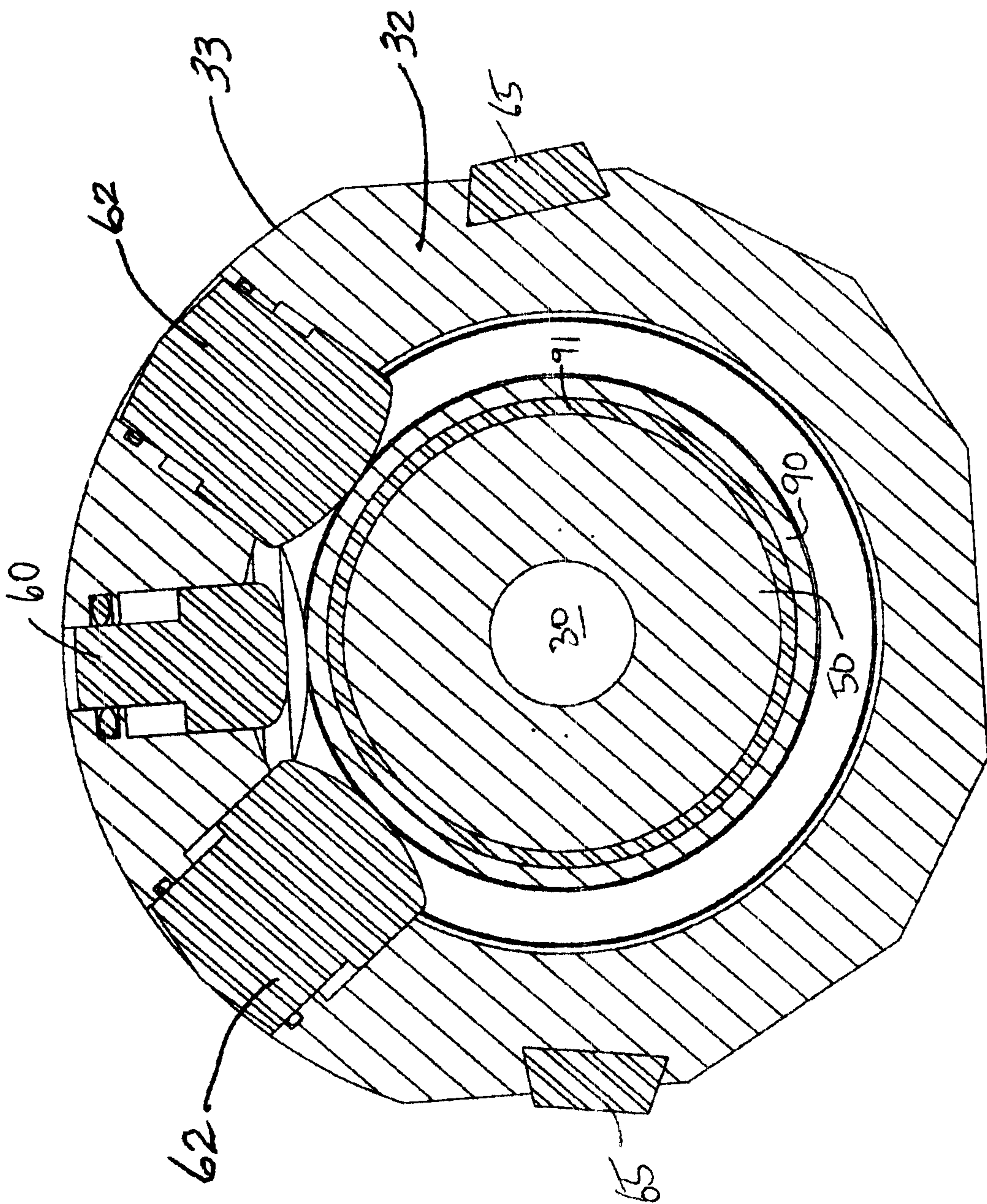


FIG. 10

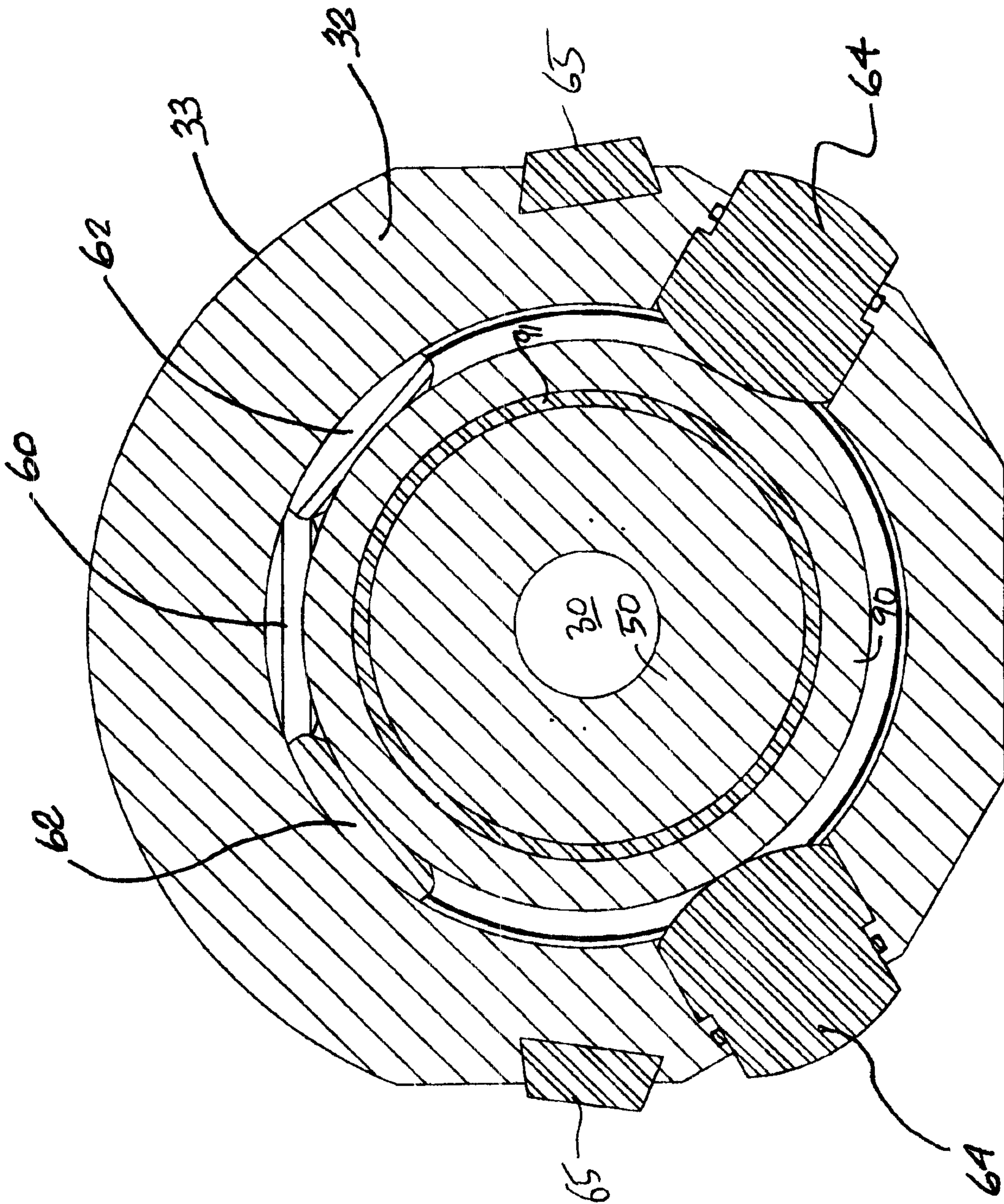


FIG. 11

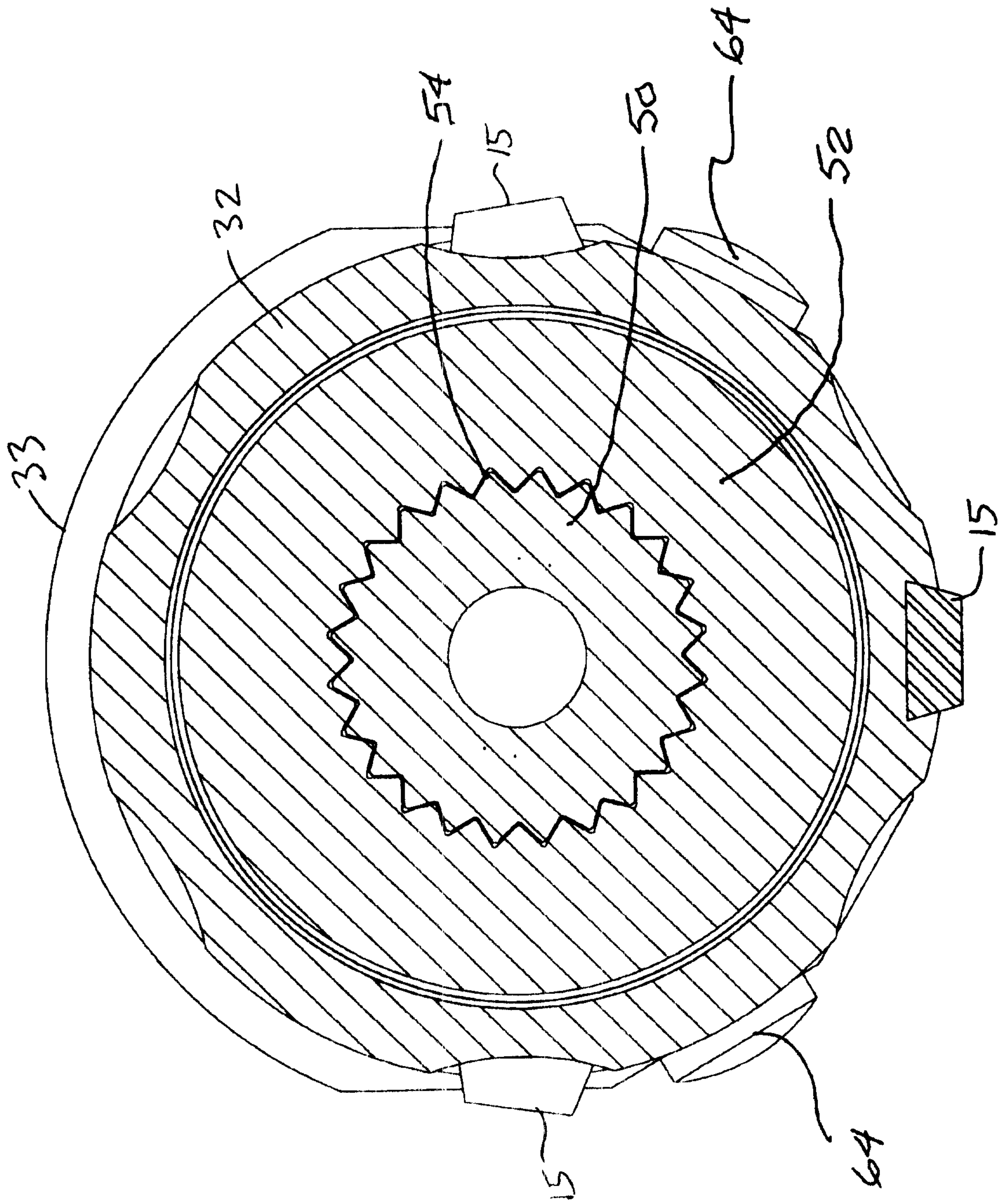


FIG. 12

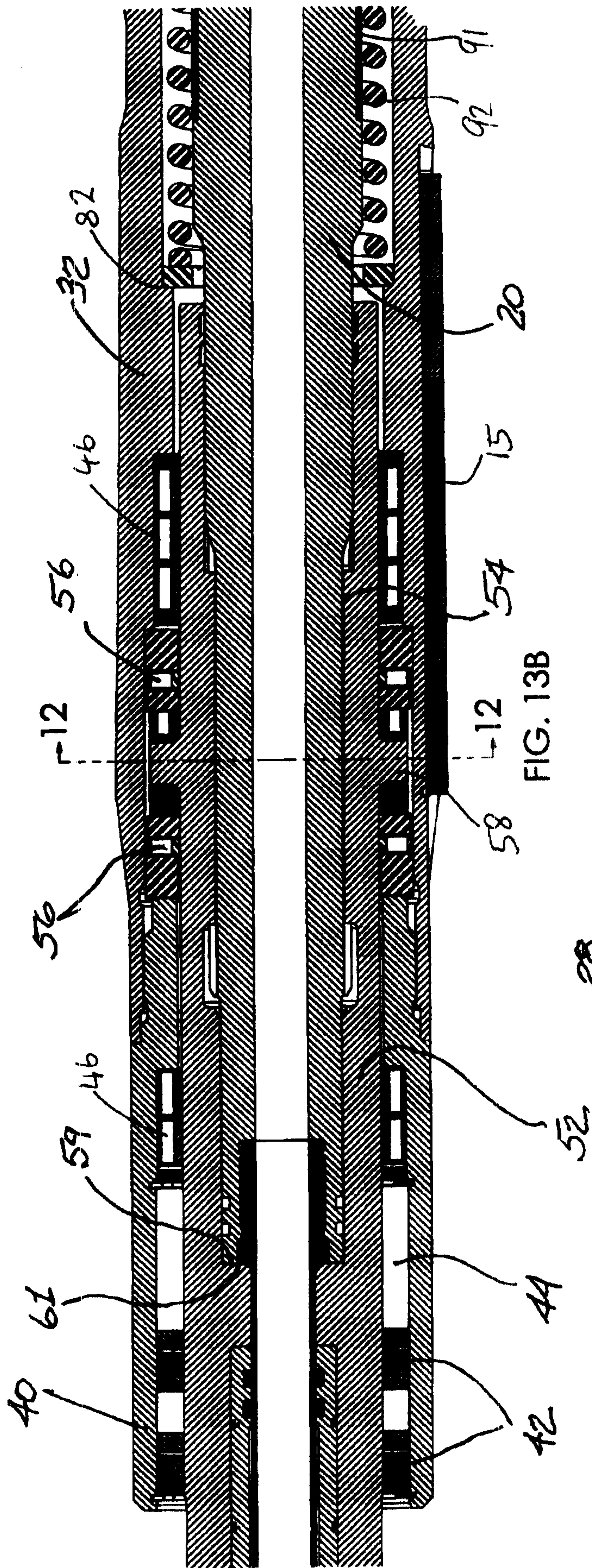


FIG. 13B

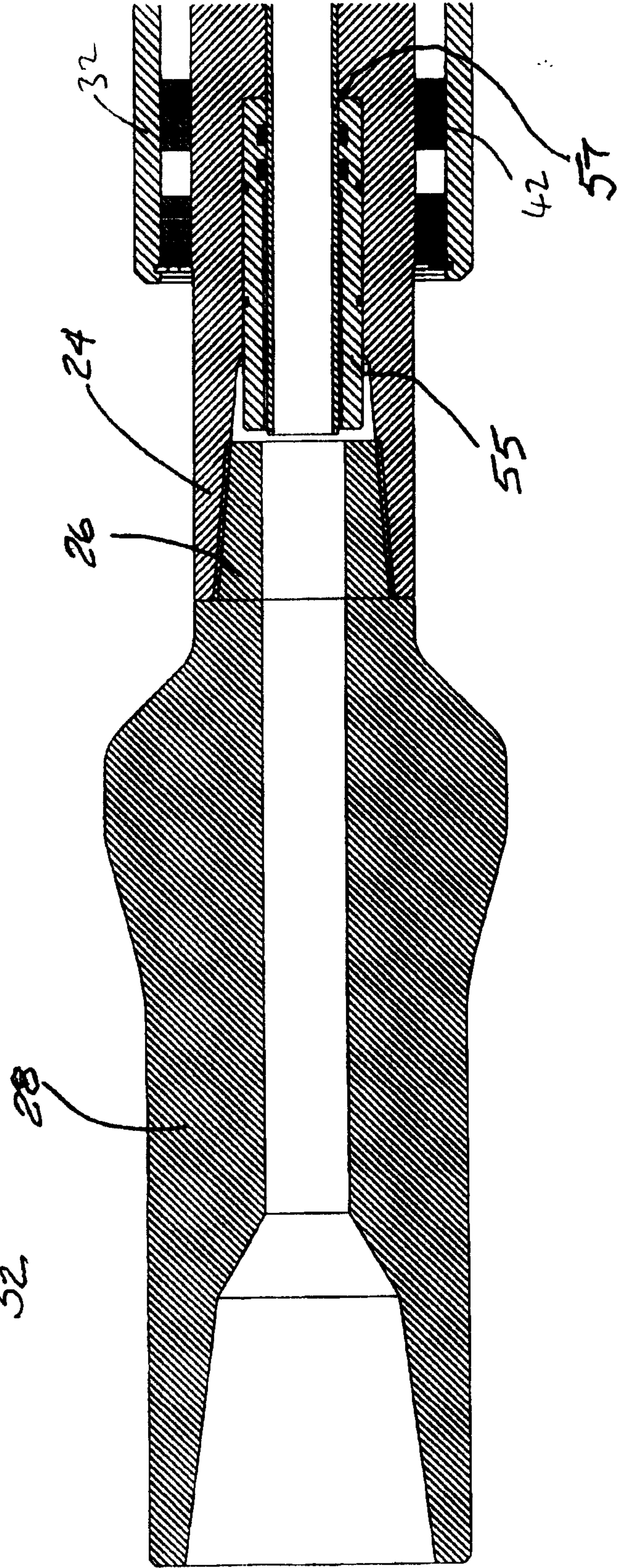


FIG. 13A

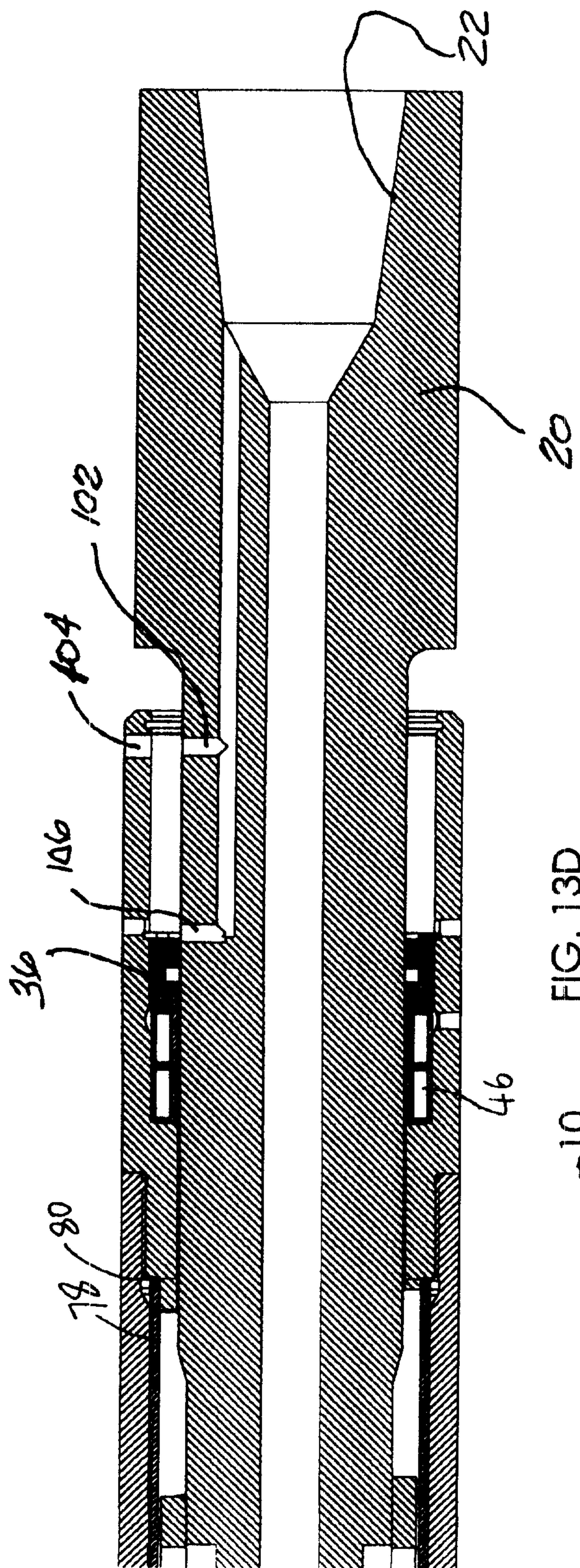


FIG. 13D

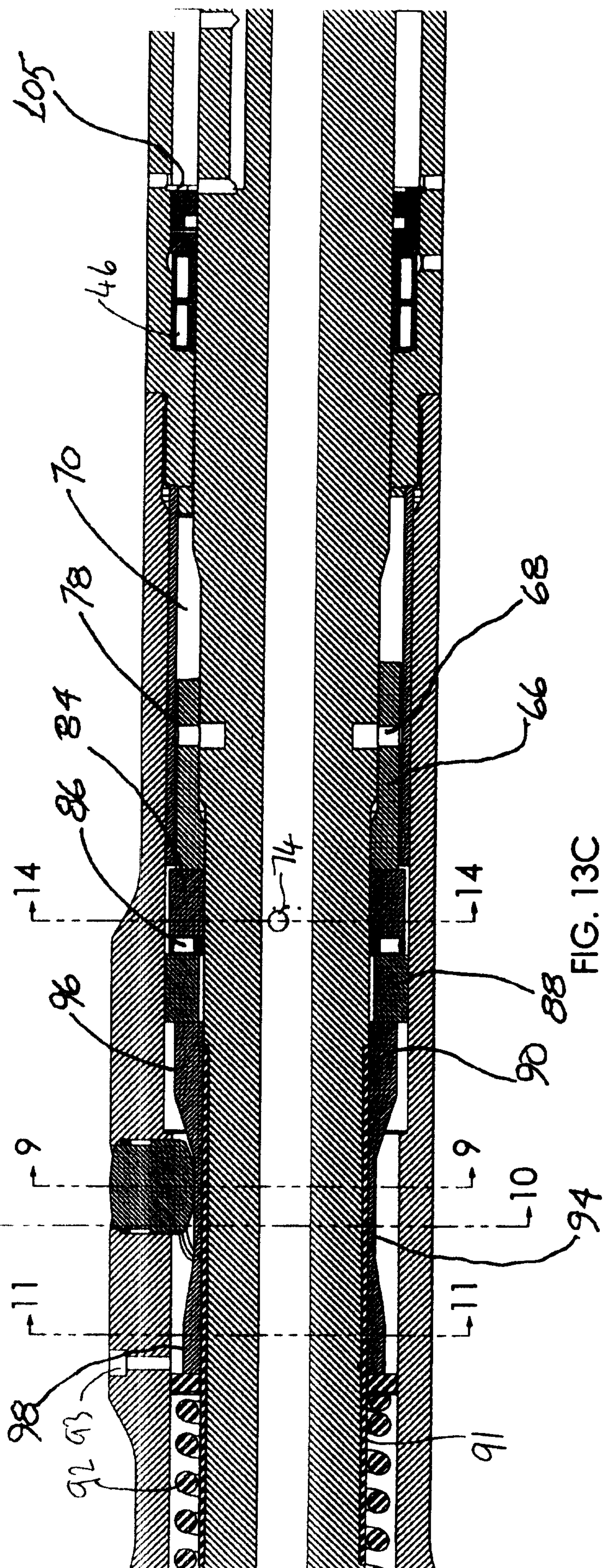


FIG. 13C

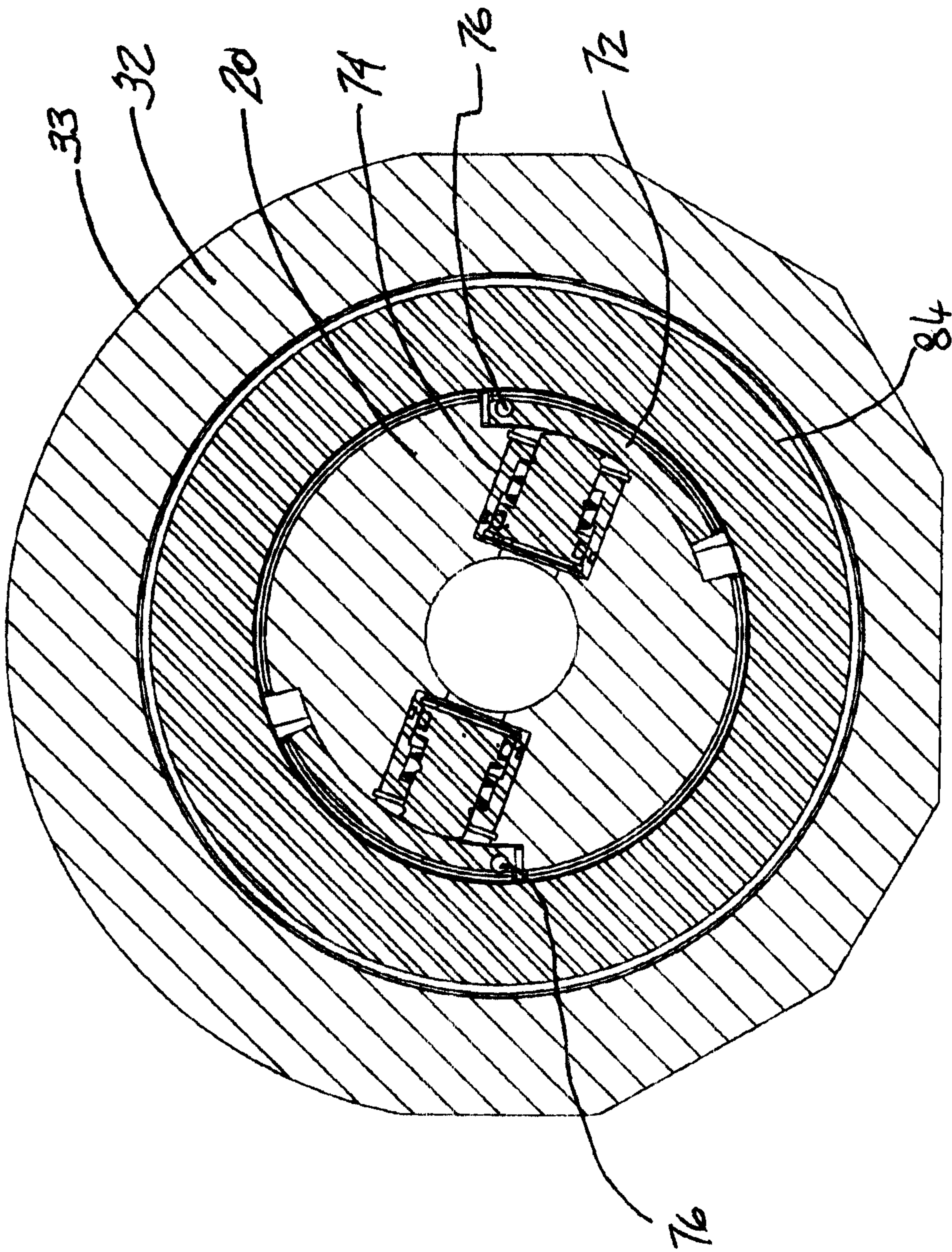


FIG. 14

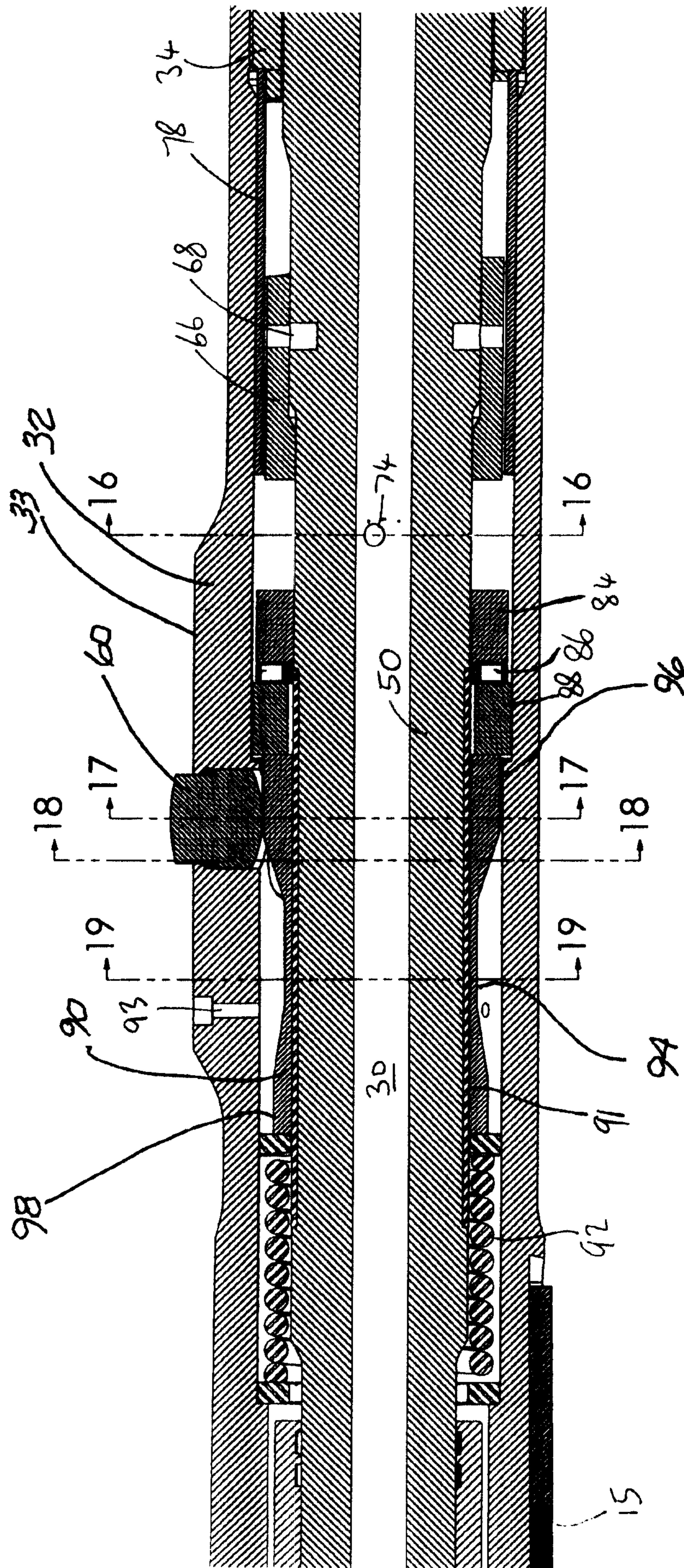


FIG. 15

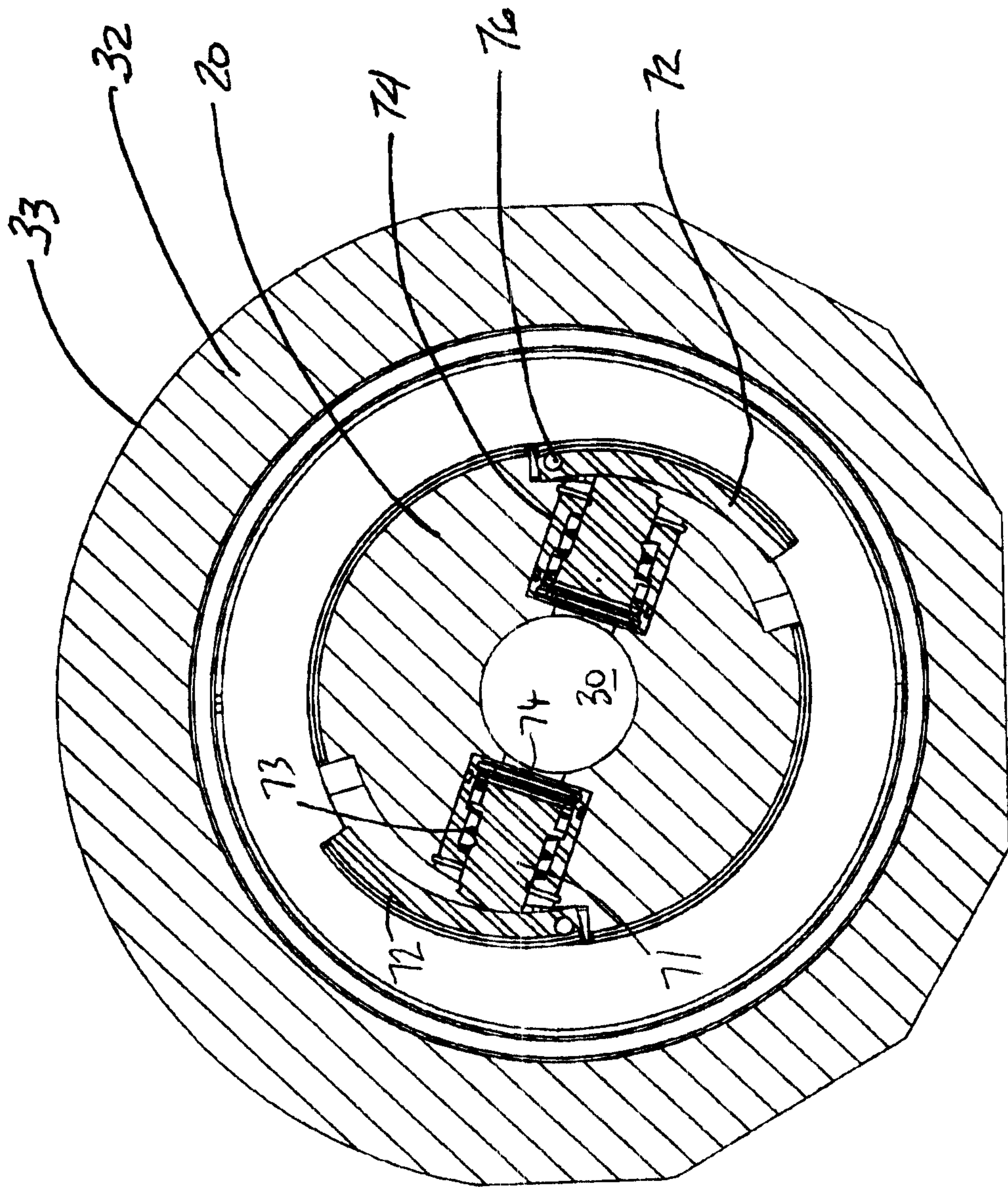


FIG. 16

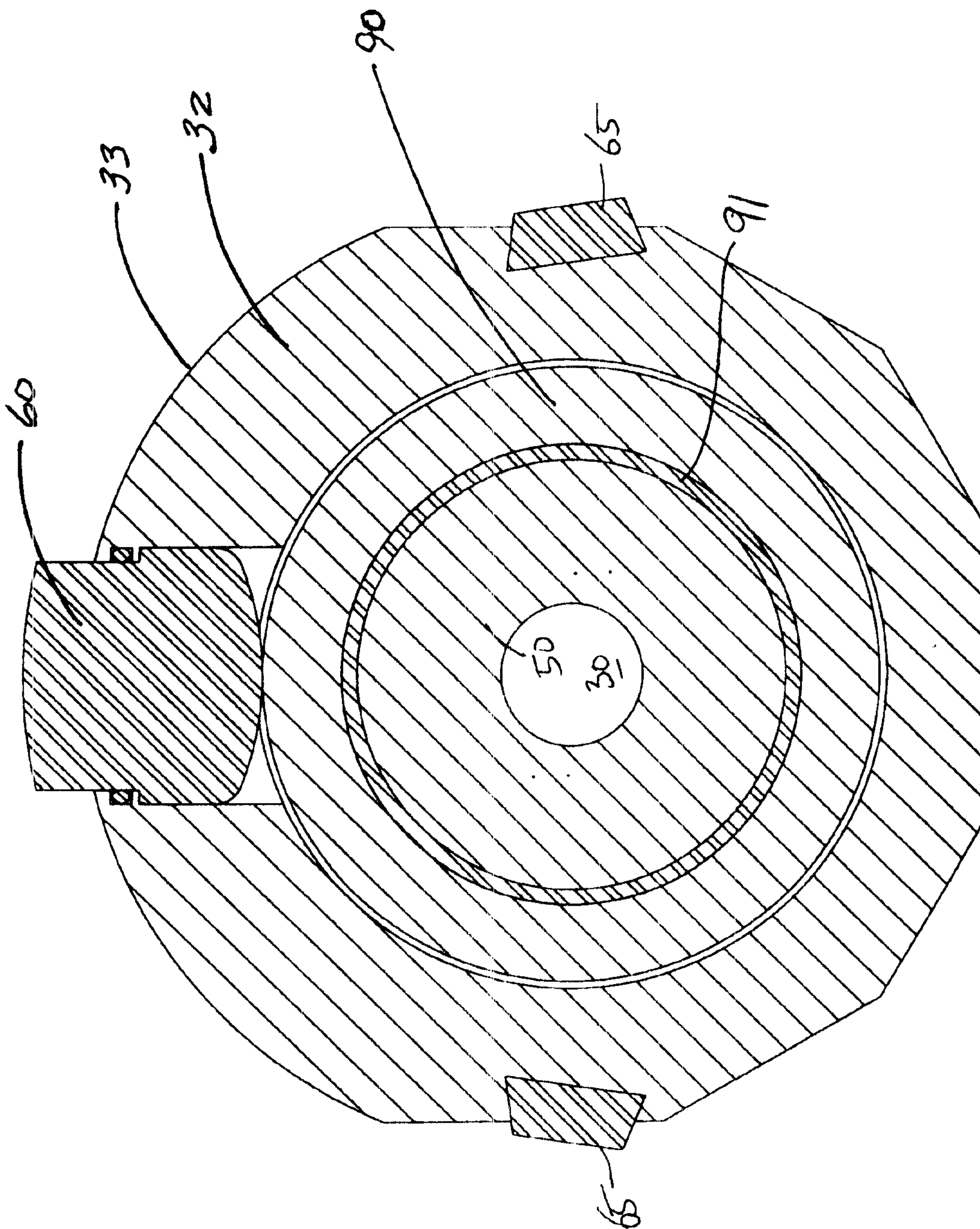


FIG. 17

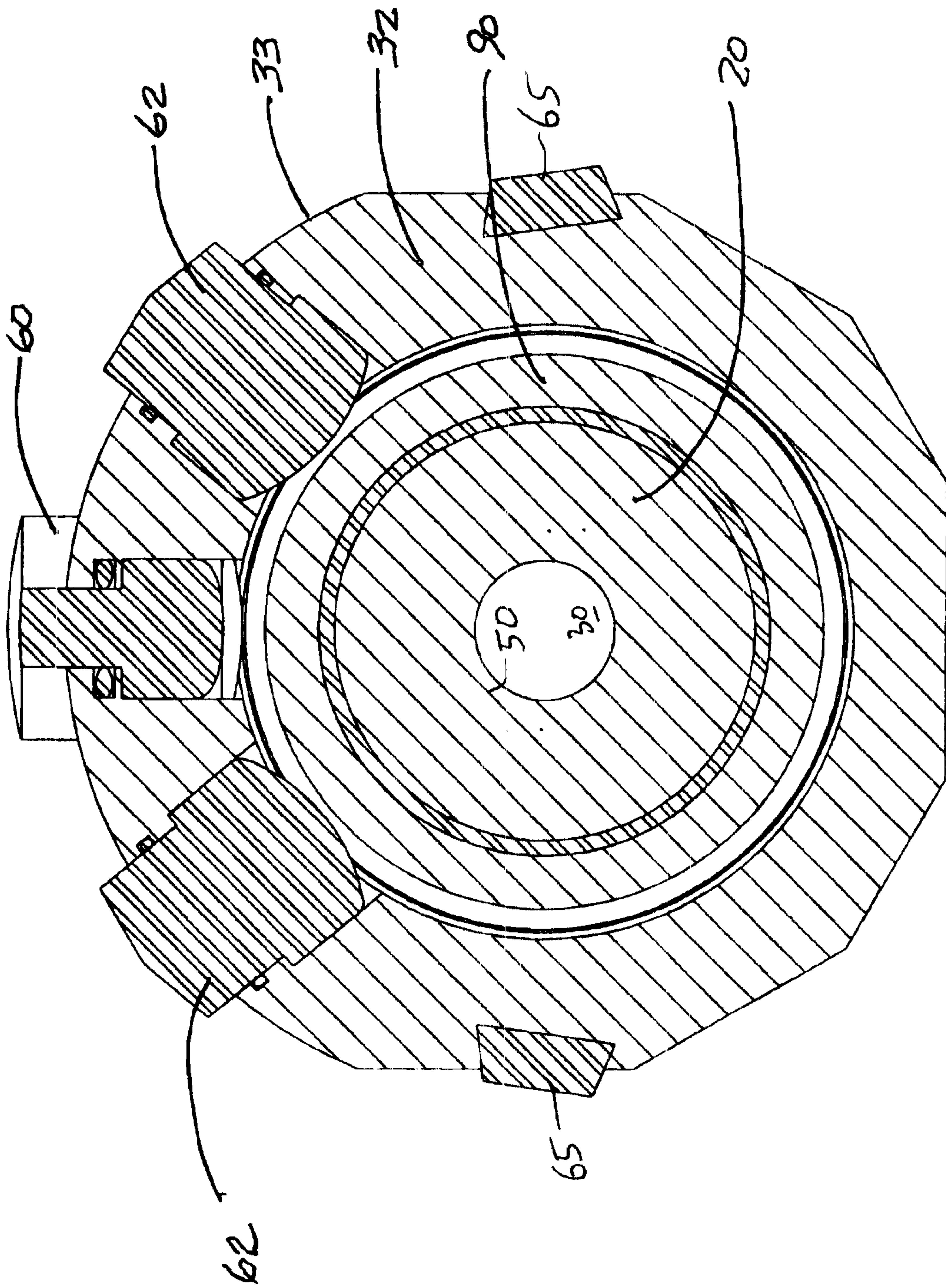


FIG. 18

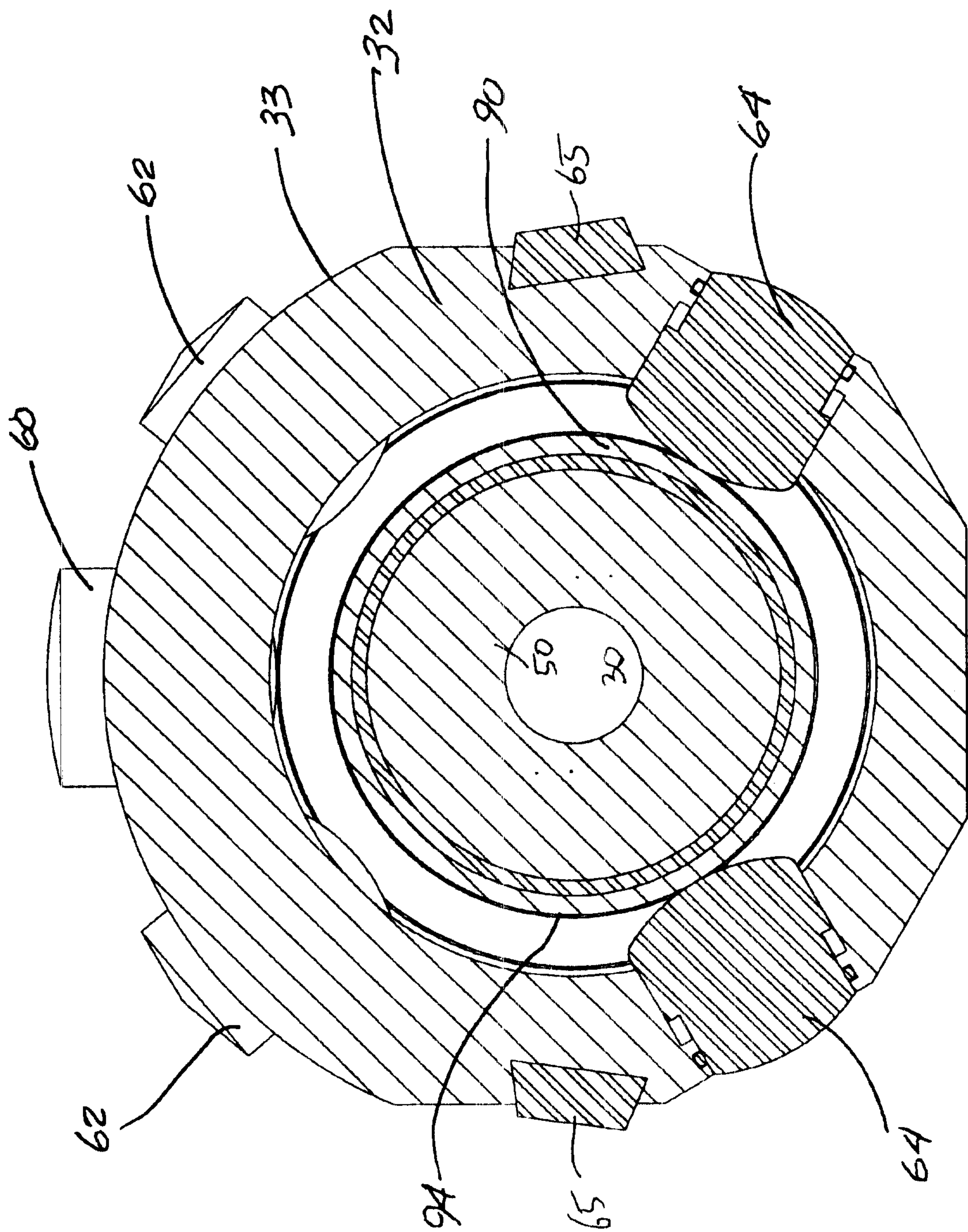


FIG. 19

