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## (54) Casing hanger running and retrieval tools.

(57) A tool for setting or retrieving a packoff between the casing hanger and the wellhead utilizes differential area pistons. The tool has a mandrel (27) which connects to a string of drill pipe. The mandrel carries a body (55) and is axially movable relative to the body. A sleeve (75) is carried by the body for connection to the packoff (81). A sleeve piston (89) is carried by the body for relative movement relative to the body. A mandrel piston (97) is carried by the mandrel for movement with the mandrel. Passages (93) in the body communicate the mandrel piston (97) with the sleeve piston (89) and contain an incompressible fluid. Axial movement of the mandrel causes the pressure to increase to drive the sleeve piston downward to set the packoff, or in another embodiment, upward to retrieve the packoff.

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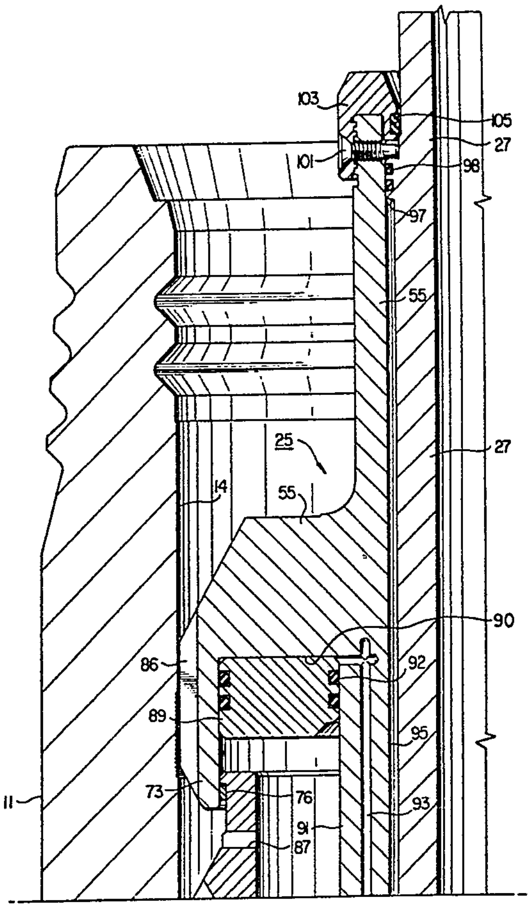

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FIG. 1a

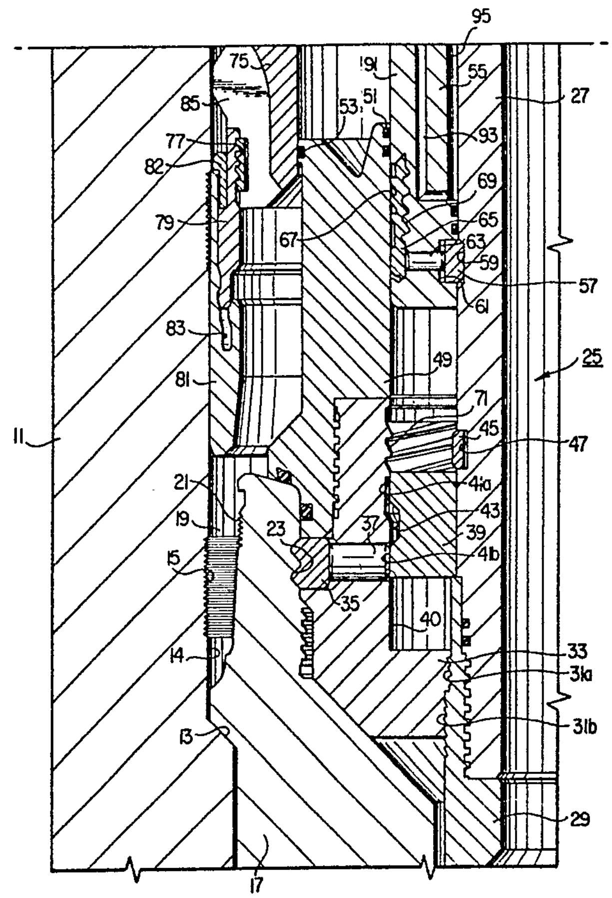

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FIG. 1b

This invention relates in general to tools for running and retrieving casing hangers in subsea wells, and in particular to a tool that utilizes pressure intensification through differential area pistons to set and retrieve the packoff for a casing hanger.

The subsea well of the type concerned herein will have a wellhead supported on the subsea floor. One or more strings of casing will be lowered into the wellhead from the surface, each supported on a casing hanger. The casing hanger is a tubular member that is secured to the threaded upper end of the string of casing. The casing hanger lands on a landing shoulder in the wellhead, or on a previously installed casing hanger having larger diameter casing. Cement is pumped down the string of casing to flow back up the annulus around the string of casing. After the cement hardens, a packoff is positioned between the wellhead bore and an upper portion of the casing hanger. This seals the casing hanger annulus.

One type of packoff proposed utilizes a metal seal so as to avoid deterioration with time that may occur with elastomeric seals. Metal seals require a much higher force to set than elastomeric seals. Prior art running tools have employed various means to apply the downward force needed to set the packoff. Some prior art tools use rotation of the drill string to apply setting torque. It is difficult to achieve sufficient torque to generate the necessary forces for a metal packoff, because the running tool may be located more than a thousand feet below the water surface in deep water.

Other running tools and techniques shown in the patented art apply pressure to the annulus surrounding the drill string on which the running tool is suspended. The amount of annulus pressure is limited, however, to the pressure rating of the riser through which the drill string extends, which is normally not enough to set a metal packoff.

Higher pressures can be achieved by pumping through the drill string. However, this requires a running tool with some type of ports that are opened and closed from the surface. This is necessary because cement must first be pumped down the drill string. The ports may be opened and closed by dropping a ball or dart. This requires a considerable amount of time, however, for the ball to reach the seat. Rig time is quite expensive. Another method employs raising and lowering the drill pipe and rotating in various manners to engage and disengage J-slots to open and close ports. This has a disadvantage of the pins for the J-slots wearing and not engaging properly.

Also, occasionally, a packoff may need to be retrieved to the surface. A floating vessel located at the surface will connect to the wellhead by means of a riser. A retrieving tool is lowered on a drill string.

The retrieving tool has a means for securing to the packoff. Then the drill string is pulled upward to release the packoff.

While this is satisfactory for elastomeric seal packoffs, it is more difficult to achieve with a metal packoff. Elastomeric packoffs are set at much lower forces than metal packoffs. It may be difficult to achieve sufficient pulling force with the drill string to pull a metal packoff loose.

In this invention, the drill string axial movement is used to set and retrieve the packoff. In one embodiment, the weight of the drill string is used. In another embodiment, the drill string is pulled upward. The drill string weight, itself, does not have sufficient force to set the packoff. The force due to the drill string weight is intensified by using differential pistons. The running tool has a mandrel that is connected to the drill string. The mandrel has a mandrel piston that moves with the mandrel. The mandrel carries a body that engages the casing hanger. The body has a setting sleeve piston that has a much larger pressure area than the mandrel piston. Sealed hydraulic passages connect the chamber of the mandrel piston with the chamber of the setting sleeve piston.

When setting the packoff, as the drill string is lowered relative to the body, the mandrel piston will apply hydraulic pressure to the liquid contained in the passages. This pressure acts on the setting sleeve piston, which in turn applies a downward force on the setting sleeve. The downward force of the setting sleeve will be much higher than the direct force from the weight of the drill string because of the intensification due to the differential area pistons.

Preferably the body has two parts, an upper body and a lower body. The upper body is carried in an upper position while running the casing hanger and while cementing. Then, the mandrel and the upper body are lowered relative to the lower body to position the packoff assembly in the annular space between the casing hanger and wellhead. Then, the mandrel is lowered relative to both the upper body and lower body to apply hydraulic pressure to the setting sleeve piston.

In another embodiment, the drill pipe and mandrel are pulled upward to move the sleeve downward to set the packoff. In still another embodiment, the tool is used to retrieve the packoff.

The invention will now be described by way of example with reference to the accompanying drawings, wherein:

Figures 1a and 1b are quarter sectional views of a running tool constructed in accordance with this invention, and shown in the running in and cementing position;

Figures 2a and 2b are quarter sectional views of the running tool of Figure 1, showing the packoff being moved into position for setting after the casing hanger has been cemented;

Figures 3a and 3b are quarter sectional views of the running tool of Figure 1, showing the packoff when fully set, with the mandrel in the lowermost position;

Figures 4a and 4b are quarter sectional views of the running tool of Figure 1, showing the mandrel moved back to an upper position relative to the upper body to release the running tool from the casing hanger ;

Figures 5a and 5b are quarter sectional views of the running tool of Figure 1, showing the running tool released from the casing hanger after the packoff has been set;

Figure 6 is a partial vertical sectional view of a first alternate embodiment of a running tool constructed in accordance with this invention and shown in the running in position ;

Figure 7 is a partial vertical sectional view of the running tool of Figure 6, and shown in a position of lowering the upper body relative to the lower body;

Figure 8 is a partial vertical sectional view of the running tool of Figure 6, and shown in a retrieving position;

Figure 9 is a partial vertical sectional view of a portion of the running tool of Figure 6, in the position shown in Figure 8;

Figures 10a and 10b are quarter sectional views of a second alternate embodiment of a running tool constructed in accordance with this invention, and shown in the running in and cementing position;

Figures 11a and 11b are quarter sectional views of the running tool of Figures 10a and 10b, showing the packoff being moved into position for setting after the casing hanger has been cemented;

Figures 12a and 12b are quarter sectional views of the running tool of Figures 10a and 10b, showing the packoff when fully set, with the mandrel moved back to an upper position ;

Figures 13a and 13b are quarter sectional views of the running tool of Figures 10a and 10b, showing the running tool released from the casing hanger;

Figure 14 is a quarter cross-sectional view of a fourth embodiment illustrating a tool constructed in accordance with this invention, used for retrieving a packoff and shown with the mandrel in a lower position; and

Figure 15 is a quarter cross-sectional view of the tool of Figure 14, and showing the mandrel lifted into an upper position for retrieving the packoff.

Referring to Figures 1a and 1b, and more particularly to Figure 1b, wellhead 11 is a tubular member extending upward from the subsea floor. An internal landing shoulder 13 is located in the bore 14 of the wellhead 11. Landing shoulder 13 is frustoconical. A set of wickers 15 is located a short distance above the landing shoulder 13. Wickers 15 are small, parallel, circumferential grooves.

A casing hanger 17 lands on the landing shoulder 13. Casing hanger 17 is a tubular member that is secured to the upper end of a string of casing (not shown). An annular clearance 19 exists between an upper portion of the casing hanger 17 and the bore 14 of the wellhead 11. A set of wickers 21 is formed on the casing hanger 17. Wickers 21 are of the same configuration, but extend upward farther and do not extend as far down as the wellhead wickers 15. Two large circumferential grooves 23 are located on the inner diameter of the upper portion of the casing hanger 17.

Casing hanger 17 is lowered into place and set by a running tool 25. Running tool 25 includes a mandrel 27 that has an upper end containing threads 26 (Fig. 3a) for connection to the lower end of the string of drill pipe (not shown). The drill pipe will be lowered through a riser (not shown) that extends from a floating vessel down to the wellhead 11. A collar 29 is secured to the lower end of the mandrel 27. Collar 29 has exterior threads 31a, 31b. The threads 31b are of larger diameter than the threads 31a. The threads 31a, 31b are adapted to screw into mating threads formed in a lower body 33.

An engaging element, preferably a split ring 35, is carried by the lower body 33. The ring 35 will extend from the exterior of the lower body 33. The ring 35 has a pair of annular bands separated by a groove on the outer side. The bands are adapted to mate with the grooves 23 in the casing hanger 17 to secure the lower body 33 to the casing hanger 17. Ring 35 will move between an extended position shown in Figure 1b to a retracted position shown in Figure 5b.

A plurality of linking pins 37 extend through the lower body 33 radially inward from the ring 35. The linking pins 37 are moved inward and outward by a cam 39, which is a solid ring. Cam 39 is carried inside a cavity 40 in the lower body 33. Cam 39 has a pair of lobes 41a, 41b, which are annular bands separated by a central recess 43. The cam 39 will move axially relative to the lower body 33.

Figure 1b shows the cam 39 in an upper position with the lower lobe 41b pressing the linking pins 37 and the ring 35 outward. Figure 2b shows the cam 39 in a lower position, with the upper lobe 41a pressing the linking pins 37 and the ring 35 outward. Figure 5b shows the cam 39 in an intermediate position, with the recess 43 engaging the linking pins 37, which allows the ring 35 to retract. The cam 39, linking pins 37 and ring 35 serve as connection means for releasably connecting the running tool 25 to the casing hanger 17.

The cam 39 is moved downward by retention means comprising a split ring 45 secured in a recess 47 in the mandrel 27. Split ring 45 bears against the upper end of the cam 39 to cause the cam 39 to move downward with the mandrel 27. The flexibility of the split ring 45 allows it to retract into the recess 47 and slide past the cam 39 when the cam is located in the lower position bearing against the bottom of the cavity 40. In Figure 2b, the split ring 45 is located a considerable distance below the cam 39.

The cam 39 moves back to the intermediate position by means of the collar 29, as shown in Figure 1b. The collar 29 has an upper edge that engages the lower end of the cam 39. When the collar 29 is fully screwed into the lower body 33, the upper end of the collar supports the cam 39 in the upper position. In the position of Figure 5b, the threads 31a and 31b have contacted the mating threads in the lower body 33, but have not yet been screwed into place. In this position, the upper end of the collar 29 supports the cam 39 in the intermediate position.

The lower body 33 is preferably constructed in two parts, the upper portion 49 being secured by threads to the lower portion. Ring 35 locates in an annular space between the lower body 33 and its upper portion 49. The upper portion 49 of the lower body 33 extends upward concentric with the mandrel 27. Inner and outer seals 51, 53 are located on the inner and outer diameters of this lower body upper portion 49.

Referring to Figure 1a, the running tool 25 has an upper body 55. Upper body 55 has an upper position relative to the lower body 33 that is shown in Figures 1a and 1b and also in Figures 5a and 5b. In the other figures, the upper body 55 is located in a lower position relative to a lower body 33. The upper body 55 is maintained in the upper position during running in and cementing by a locking element comprising a split ring 57 which is shown in Figure 1b.

When the upper body 55 is in the upper position, split ring 57 locates in a recess 59 formed on the outer diameter of the mandrel 27. In both the upper and lower positions of the upper body 55, split ring 57 remains located in a cavity 61 contained in the lower portion of the upper body 55. Cavity 61 has a radial width that is at least as wide as the radial thickness of the split ring 57 so as to allow the split ring 57 to expand outward into the cavity 61. This allows the split ring 57 to move out of the mandrel recess 59 as shown in Figure 2b, to enable the mandrel 27 to be lowered relative to the upper body 55.

A plurality of pins 63 extend radially outward from split ring 57. Pins 63 engage a latch ring 65 that is also split. Latch ring 65 has outer threads 67 and inner grooves 69. The inner grooves 69 engage mating grooves in the upper body 55 to retain the latch ring 65 with the upper body 55. The latch ring threads 67 are configured to ratchet past and engage mating threads 71 formed in the upper portion of the casing hanger cavity 40. The threads 67, 71, are of a saw-tooth configuration.

In Figure 1b, the latch ring 65 is positioned above the casing hanger threads 71. In Figures 2b and 3b, the latch ring 65 is engaging the threads 71. When engaging the threads 71, the latch ring 65 expands outward. The pins 63 move outward, allowing the split ring 57 to move outward. This withdraws the split ring 57 from the recess 59. While engaging the threads 71, the grooves 69 move outward to some extent from the mating grooves in the upper body 55, but still remain in engagement. The latch ring 65 and associated elements serve as means for latching the upper body 55 to the lower body 33 when the upper body 55 is in the lower position, to prevent any axial movement of the upper body 55 relative to the lower body 33.

Referring to Figure 1a, the upper body has an outer portion 73 that is substantially the diameter of the wellhead bore 14. The outer portion 73 depends from the upper body 55. A setting sleeve 75 is carried on the upper body outer portion 73. Setting sleeve 75 is secured by a ring 76 that is fixed to the outer portion 73 so that the sleeve 75 can move axially a limited extent relative to the upper body 55. A key (not shown) causes the setting sleeve 75 to rotate in unison with the upper body 55.

Referring to Figure 1b, the setting sleeve 75 is a tubular member that extends downward from the upper body 55. A threaded ring 77 is located on the lower end of the setting sleeve 75. Threaded ring 77 is a split, ratchet type ring that engages threads in a wedge ring 79. The wedge ring 79 is secured to a metal seal packoff 81 by means of a collar 82. The packoff 81 has a central annular cavity 83 that receives the wedge ring 79.

The setting sleeve 75 will move the packoff 81 from an upper position shown in Figure 1b to a lower position shown in the other figures. In the lower position, the packoff 81 is located in the annular clearance 19 between the casing hanger 17 and the wellhead 11. Furthermore, the setting sleeve 75 will move the wedge ring 79 downward from the upper position shown in Figure 1b to a setting position shown in Figure 3b. In that position, the wedge ring 79 expands portions of the packoff 81 on both sides of the cavity 83 to form a metal seal.

While running the casing hanger 17 in and while cementing, fluid in the riser and wellhead bore 14 is free to flow up through a return flow passage 85 in the setting sleeve 79 and a return flow passage 86 in the upper body 55 (Fig. 1a). There are also return flow passages through the casing hanger 17, but these are not shown in the drawings.

The lower body upper portion 49 sealingly locates between the upper body 55 and the setting sleeve 75. This is not a closed chamber, however, as fluid is free to flow out through the passage 87 shown in Figure 1a.

After the upper body 55 has been moved to its lower position shown in Figure 2b, the setting sleeve 75 is then moved downward relative to the upper body 55 to set the packoff 81. This is handled by a setting sleeve piston 89 shown in Figure 1a. The setting sleeve piston 89 is carried in a chamber 90 located between the upper body inner portion 91 and upper body outer portion 73. The setting sleeve piston 89 has seals 92 that will sealingly slide within chamber 90. The chamber 90 of the setting sleeve piston 89 is supplied with a substantially incompressible liquid, such as hydraulic fluid, through hydraulic passages 93. The hydraulic passages 93 communicate with a chamber 95 formed between the bore of the upper body 55 and the exterior of the mandrel 27, as shown in Figure 1b.

A mandrel piston 97 is sealingly carried in the chamber 95. The mandrel piston 97 is integrally formed on the mandrel 27 and protrudes outward. Chamber 95 is sealed by seals 98 on the mandrel piston 97. The hydraulic passage 93 communicates the chamber 95 of the mandrel piston 97 with the chamber 90 of the setting sleeve piston 89. The hydraulic fluid contained in the chambers 90, 95 and passage 93 is sealed from any exterior fluids in the riser (not shown), wellhead bore 14 or within the drill pipe (not shown). Downward movement of the mandrel piston 97 increases the pressure of the hydraulic fluid in the passage 93 to move the setting sleeve piston 89 downward.

The transverse cross-sectional area of the mandrel piston 97, or pressure area, is much less than the cross-sectional area or pressure area of the setting sleeve piston 89. Consequently, the downward force on the mandrel 27 due to the drill string weight is greatly intensified. That is, the downward force exerted by the piston 89 on the setting sleeve 75 will be much higher than the downward force on the mandrel 27, which is limited to the weight of the drill string.

Preferably, a sufficient difference exists between the pressure areas to increase a drill string weight on mandrel piston 97 of 20,000 pounds to provide a setting force on the setting sleeve piston 89 of about 500,000 pounds.

Referring to Figure 2a, a series of teeth or castellations 99 are formed on the upper side of the mandrel piston 97. The castellations 99 have slots (not shown) between them that are adapted to engage a pin 101. Pin 101 is located at the upper end of the upper body 55. Pin 101 is secured in threads in the upper body 55. A collar 103 is located on the upper end of the upper body 55. A wiper seal 105 is positioned between the collar 103 and the outer diameter of the mandrel 27.

In operation, the casing (not shown) will be lowered into the well. The upper end of the casing will be secured to the lower end of the casing hanger 17. A shown in Figure 1b, the running tool 25 will be connected to the casing hanger 17 through the ring 35. The upper end of the mandrel 27 of the running tool 25 is connected to the lower end of a string of drill pipe (not shown). The entire assembly is then lowered into the well until the casing hanger 17 lands on the landing shoulder 13 in the wellhead 11, as shown in Figure 1b.

Then, cement is pumped down the drill pipe. The cement will flow through the bore of the mandrel 27 to the bottom of the casing string, then back up the annulus surrounding the casing string. The returns from the cement will flow through the passages (not shown) in the casing hanger 17, and up through the passages 85 (Fig. lb) and passages 86 (Fig. 1a) to the surface through the riser (not shown).

After the cement has set sufficiently, the drill string is rotated to the right. This disengages the threads 31a, 31b from the lower body 33, as can be seen by comparing Figure 1b with Figure 2b. Once unscrewed, the drill string is lowered, allowing the mandrel 27 to move downward.

As mandrel 27 moves downward, the lower body 33 will remain stationary because it is seated in the casing hanger 17. The upper body 55 will move downward with the mandrel 27. This occurs because the split ring 57 (Fig. 1b) retains the upper body 55 with the mandrel 27 for a certain distance. The cam 39 will also move downward with the mandrel 27 for a short distance until it reaches the bottom of cavity 40. The split ring 45 will bear against the top of the cam 39, causing this downward movement. When the cam 39 is in the lower position shown in Figure 2b, the ring 35 will be maintained in the engaged position by means of the upper lobe 41a. Once the cam 39 reaches the lower position, the split ring 45 will contract into the recess 47 and slide on past the cam 39.

The downward movement of the mandrel 27 continues until the latch ring 65 (Fig. 1b) engages the threads 71 in the lower body 33. When this occurs, the latch ring 65 snaps outward. This allows the split ring 57 to expand outward from the recess 59 in the mandrel 27. The mandrel 27 is then free to move further downward relative to the upper body 55, as illustrated in Figure 2b.

When the upper body 55 is in the lower position, the packoff 81 will be properly positioned in the annular clearance 19 between the casing hanger 17 and the wellhead 11. The upper body 55 will be latched to the lower body 33 so that it can not move upward because of the latch ring 65. This is the position shown in Figure 2b.

Continued downward movement of the mandrel 27 relative to the upper body 55 and lower body 33 causes a pressure increase in the chambers 90, 95 and hydraulic passage 93. The pressure increase acts on the setting sleeve piston 89. The setting sleeve piston 89 acts on the setting sleeve 75. The setting sleeve 75 applies downward force to the wedge ring 79. The wedge ring 79 moves downward into the cavity 83, which sets the packoff 81. The inner portion of the packoff 81 embeds into the casing hanger wickers 21. The outer portion of the packoff 81 embeds into the wellhead bore wickers 15. The setting position is illustrated in Figure 3b. When fully set, the upper end of the setting sleeve 75 will be substantially flush with the upper end of the lower body upper portion 49.

After testing, the running tool 25 may be retrieved from the casing hanger 17. First, the drill string is picked up to pull the mandrel 27 upward. At a certain distance, the castellations 99 (Fig. 2a) will engage the pin 101 as shown in Figure 4a. Then, the drill string is rotated to the right again. The mandrel 27 will rotate. The castellations 99 and pin 101 will cause the upper body 55 to rotate with the mandrel 27. This will cause the threaded ring 77 to unscrew from the wedge ring 79. This rotation will also cause the latch ring 65 to unscrew from the threads 71. The mandrel 27 may then be picked up. This is the position shown in Figures 5a and 5b.

As the mandrel 27 is picked up, the recess 59 will move up and engage the split ring 57. This will cause the upper body 55 to begin moving upward with the mandrel 27. The collar 29 will contact the lower side of the cam 39 and move it up to intermediate position shown in Figure 5b. The threads 31a and 31b will contact the mating threads in the lower body 33 to limit the upward movement of the collar 29 to the position shown in Figure 5b. The intermediate position of the cam 39 allows the ring 35 to retract. The entire running tool 25 may then be pulled to the surface.

In the embodiments of Figures 6-9, the elements which are similar to the first embodiment are either not discussed, or when discussed, are indicated with a prime symbol. The principal difference is in the manner of releasing the lower body 33′ from the casing hanger 17′. The mandrel 27′ is secured by threads to an annular insert 107, which may be considered a part of the lower body 33′. The insert 107 has left-hand threads 108 which secure the insert 107 to the lower body 33′. While downhole, the insert 107 does not unscrew from the lower body 33′, rather it is removed and installed only during disassembly and assembly at the surface.

An annular stop 109 is formed on the upper end of the insert 107, extending into the cavity 40′ of the lower body 33′. The stop 109 serves as stop means for preventing a cam 111 from moving downward from its lower position shown in Figures 6, 7. Cam 111 is axially movable from the lower position shown in Figures 6, 7 to the upper position shown in Figure 8. Cam 111 has a central lobe 113 that pushes outward on link pins 37′ and split ring 35′ when cam 111 is in the lower position. The lobe 113 maintains the split ring 35′ in an engaged position with the casing hanger 17′. When in the upper position of Figure 8, the lobe 113 passes above the link pins 37′, allowing the split ring 35′ to retract.

Cam 111 has an inner diameter that slidingly receives the mandrel 27′. An annular slot 115, shown more clearly in Figure 9, is located in the inner diameter of cam 111. Slot 115 inclines downward and outward relative to the axis of mandrel 27′.

A spring element such as a split ring 117 locates in the slot 115. Split ring 117 has a circular transverse cross-section and is considerably smaller in cross-sectional diameter than the height of the slot 115. Split ring 117 is biased inward into engagement with the mandrel 27′.

A recess 119 is formed on the exterior of the mandrel 27′, at a point so that it is initially above the cam 111. As shown in Figure 9, the upper edge 119a and the lower edge 119b of the recess are bevelled. The upper edge 119a faces downward and outward, and the lower edge 119b faces downward and inward.

In operation of the second embodiment, after the cement has set, the drill string and mandrel 27′ are rotated to the right to unscrew the mandrel 27′ from the lower body 33′. The insert 107 will not unscrew because of the left-hand threads. As the mandrel moves downward, the cam 111 remains stationary. The recess 119 will slide past the split ring 117, as indicated in Figure 7. The upper edge 119a pushes the split ring 117 outward into the slot 115 as it moves past.

The packoff 81′ is set in the same manner as described in the first embodiment. To release the running tool 25′, the drill string and the mandrel 27′ are picked up. The recess 119 will move up and engage the ring 117. The lower edge 119b will push the ring 117 against the inclined upper edge of slot 115. The inclination of the lower edge 119b and the upper edge of slot 115 are substantially the same. This traps the ring 117 between the lower edge 119b and the upper edge of slot 115. This locks the cam 111 to the mandrel 27 for upward movement.

As the cam 111 moves upward, the lobe 113 passes above the link pin 37′. This allows the ring 35′ to retract, releasing the lower body 33′ from the casing hanger 17′. The setting sleeve 75′ releases from the packoff wedge ring 79′ by a straight upward pull. The grooves or threads on the ring 77′ are configured to allow releasing with a moderate upward pull. No rotation is necessary.

The upper body 55′ will remain in the lower position relative to lower body 33′ as the running tool 25′ is retrieved to the surface. The latch ring 65′ is not unscrewed from the threads 71′ until the running tool 25′ is at the surface. Consequently, there will be no structure such as the castellations 99 or pin 101 (Fig 2a) for locking the mandrel 27′ to the upper body 55′ for rotation.

A third embodiment is shown in Figures 10a through 13b. Referring to Figures 10a and 10b, and more particularly to Figure 10b, wellhead 2ll is a tubular member extending upward from the subsea floor. An internal landing shoulder 213 is located in the bore 214 of the wellhead 211. Landing shoulder 213 is frusto-conical. A set of wickers 215 is located a short distance above the landing shoulder 213. Wickers 215 are small, parallel, circumferential grooves.

A casing hanger 217 lands on the landing shoulder 213. Casing hanger 217 is a tubular member that is secured to the upper end of a string of casing (not shown). An annular clearance 219 exists between an upper portion of the casing hanger 217 and the bore 214 of the wellhead 211. Return flow passages 218 extend through the casing hanger 217 to return fluid from the annulus surrounding the casing with the annular clearance 219 during cementing before the casing hanger is fully set.

A set of wickers 221 is formed on the casing hanger 217. Wickers 221 are of the same configuration, but extend upward farther and do not extend as far down as the wellhead wickers 215. Two large circumferential grooves 223 are located on the inner diameter of the upper portion of the casing hanger 217.

Casing hanger 217 is lowered into place and set by a running tool 225. Running tool 225 includes a mandrel 227 that has an upper end containing threads 226 (Fig. 12a) for connection to the lower end of the string of drill pipe (not shown). The drill pipe will be lowered through a riser (not shown) that extends from a floating vessel down to the wellhead 211. A shoulder 229 is secured to the lower end of the mandrel 227. Mandrel 227 has exterior threads 231a, 231b. The threads 231b are of larger diameter than the threads 231a. The threads 231a, 231b are adapted to screw into mating threads formed in a lower body 233.

An engaging element, preferably a split ring 235, is carried by the lower body 233. The ring 235 will extend from the exterior of the lower body 233. The ring 235 has a pair of annular bands separated by a groove on the outer side. The bands are adapted to mate with the grooves 223 in the casing hanger 217 to secure the lower body 233 to the casing hanger 217. Ring 235 will move between an extended position shown in Figure 10b to a retracted position shown in Figure 14b.

A plurality of linking pins 237 extend through the lower body 233 radially inward from the ring 235. The linking pins 237 are moved inward and outward by a cam 239, which is a solid ring. Cam 239 is carried inside a cavity 240 in the lower body 233. Cam 239 has a pair of lobes 241a, 241b, which are annular bands separated by a central recess 243. The cam 239 will move axially relative to the lower body 233.

Figure 10b shows the cam 239 in an upper position with the lower lobe 241b pressing the linking pins 237 and the ring 235 outward. Figure 11b shows the cam 239 in a lower position, with the upper lobe 241a pressing the linking pins 237 and the ring 235 outward. Figure 13b shows the cam 239 in an intermediate position, with the recess 243 engaging the linking pins 237, which allows the ring 235 to retract. The cam 239, linking pins 237 and ring 235 serve as connection means for releasably connecting the running tool 225 to the casing hanger 217.

The cam 239 is held in the upper and the intermediate positions by means of a shoulder 229 which engages the lower end of the cam 239. When the mandrel 227 is fully screwed into the lower body 233, the upper end of the shoulder 229 supports the cam 239 in the upper position. Pins 245 are secured to the cam 239 and extend through holes in the bottom of cavity 240. The pins 245 provide an upper limit for the movement of the cam 239.

In the position of Figure 13b, the threads 231a and 231b have contacted the mating threads in the lower body 233, but have not yet been screwed into place. In this position, the shoulder 229 supports the cam 239 in the intermediate position.

The lower body 233 is preferably constructed in two parts, the upper portion 249 being secured by threads to the lower portion. Ring 235 locates in an annular space between the lower body 233 and its upper portion 249. The upper portion 249 of the lower body extends upward concentric with the mandrel 227. Inner and outer seals 251, 253 are located on the inner and outer diameters of this lower body upper portion 249.

Referring to Figure 10a, the running tool 225 has an upper body 255. Upper body 255 has an upper position relative to the lower body 233 that is shown in Figures 10a and 10b and also in Figures 13a and 13b. In the other figures, the upper body 255 is located in a lower position relative to a lower body 233. The upper body 255 moves to the lower position by its own weight and by the contact of a downward facing shoulder 257 on the exterior of mandrel 227, which is shown in Figure 11a.

A split latch ring 265 is carried on the exterior of the lower end of the upper body 255. Latch ring 265 has outer threads 267. The latch ring threads 267 are configured to ratchet past and engage mating threads 271 formed in the upper portion of the casing hanger cavity 240. The threads 267, 271 are of a saw-tooth configuration.

In Figures 10a and 10b, the latch ring 265 is positioned above the casing hanger threads 271. In Figures 11b and 12b, the latch ring 265 is engaging the threads 271. The latch ring 265 and threads 271 serve as means for latching the upper body 255 to the lower body 233 when the upper body 255 is in the lower position, to prevent any axial movement of the upper body 255 relative to the lower body 233.

Referring to Figure 10a, the upper body 255 has an outer portion 273 that is substantially the diameter of the wellhead bore 214. The outer portion 273 depends from the upper body 255. A setting sleeve 275 is carried on the upper body outer portion 273. Setting sleeve 275 is secured by a ring 276 that is fixed to the outer portion 273 so that the sleeve 275 can move axially a limited extent relative to the upper body 255. A key (not shown) causes the setting sleeve 275 to rotate in unison with the upper body 255.

Referring to Figure 10b, the setting sleeve 275 is a tubular member that extends downward from the upper body 255. A threaded ring 277 is located on the lower end of the setting sleeve 275. Threaded ring 277 is a split, ratchet type ring that engages threads in a wedge ring 279. The wedge ring 279 is secured to a metal seal packoff 281 by means of a collar 282. The packoff 281 has a central annular cavity 283 that receives the wedge ring 279.

The setting sleeve 275 will move the packoff 281 from an upper position shown in Figure 10b to a lower position shown in the other figures. In the lower position, the packoff 281 is located in the annular clearance 219 between the casing hanger 217 and the wellhead 211. Furthermore, the setting sleeve 275 will move the wedge ring 279 downward from the upper position shown in Figure 10b to a setting position shown in Figure 12b. In that position, the wedge ring 279 expands portions of the packoff 281 on both sides of the cavity 283 to form a metal seal.

While running the casing hanger 217 in and while cementing, fluid in the riser and wellhead bore 214 is free to flow up through a return flow passage 285 in the setting sleeve 279 and a return flow passage 286 in the upper body 255 (Fig. 10a).

The lower body upper portion 249 sealingly locates between the upper body 255 and the setting sleeve 275. This is not a closed chamber, however, as fluid is free to flow out through the passages (not shown) in the setting sleeve 275.

After the upper body 255 has been moved to its lower position shown in Figure 11b, the setting sleeve 275 is then moved downward relative to the upper body 255 to set the packoff 281. This is handled by a setting sleeve piston 289 shown in Figure 10a. The setting sleeve piston 289 is carried in a chamber 290 located between the upper body inner portion 291 and upper body outer portion 273. The setting sleeve piston 289 has seals 292 that will sealingly slide within chamber 290. During the setting process, the chamber 290 of the setting sleeve piston 289 will receive a substantially incompressible liquid, such as hydraulic fluid, through hydraulic passages 293. The hydraulic passages 293 communicate with a chamber 295 formed between the bore of the upper body 255 and the exterior of the mandrel 227, as shown in Figure 11a.

A mandrel piston 297 is sealingly carried in the chamber 295. The mandrel piston 297 is secured to the mandrel 227 for movement therewith and protrudes outward. The chamber 295 extends upward from the mandrel piston 297 when the mandrel piston 297 is in the lower position shown in Figure 11b. Chamber 295 is sealed by seals 298 on the mandrel piston 297. The hydraulic passage 293 communicates the chamber 295 of the mandrel piston 297 with the chamber 290 of the setting sleeve piston 289. The hydraulic fluid contained in the chambers 290, 295 and passage 293 is sealed from any exterior fluids in the riser (not shown), wellhead bore 214 or within the drill pipe (not shown). Upward movement of the mandrel piston 297 increases the pressure of the hydraulic fluid in the passage 293 to move the setting sleeve piston 289 downward.

The transverse cross-sectional area or pressure area of the mandrel piston 297 is much less than the cross-sectional area or pressure area of the setting sleeve piston 289. Consequently, the upward force on the mandrel 227 due to the drill string tension is greatly intensified. That is, the downward force exerted by the setting sleeve piston 289 on the setting sleeve 275 will be much higher than the upward force on the mandrel 227. Preferably, the pressure area of the mandrel piston 297 is about one-tenth that of the pressure area of the setting sleeve piston 289, so that 60,000 pounds pull on the drill string will provide a setting force of 600,000 pounds.

Referring to Figure 11b, a lug 299 is formed on the upper side of the mandrel piston 297. The lug 299 is adapted to engage a slot 301 (Fig. 10a). Slot 301 is located at the upper interior of the upper body 255. When engaged, as shown in Figures 10a and 13a, the upper body 255 will rotate with the mandrel 227.

In operation, the casing (not shown) will be lowered into the well. The upper end of the casing will be secured to the lower end of the casing hanger 217. As shown in Figure 10b, the running tool 225 will be connected to the casing hanger 217 through the ring 235. The upper end of the mandrel 227 of the running tool 225 is connected to the lower end of a string of drill pipe (not shown). Hydraulic fluid will be located in the passages 93. The entire assembly is then lowered into the well until the casing hanger 217 lands on the landing shoulder 213 in the wellhead 211, as shown in Figure 10b.

Then, cement is pumped down the drill pipe. The cement will flow through the bore of the mandrel 227 to the bottom of the casing string, then back up the annulus surrounding the casing string. The returns from the cement will flow through the passages 218 in the casing hanger 217, and up through the passages 285 (Fig. 10b) and passages 286 (Fig. 10a) to the surface through the riser (not shown).

Affer the cement has set sufficiently, the drill string is rotated to the right. This disengages the threads 231a, 231b from the lower body 233, as can be seen by comparing Figure 10b with Figure 11b. Once unscrewed, the drill string is lowered, allowing the mandrel 227 to move downward.

As mandrel 227 moves downward, the lower body 233 will remain stationary because it is seated in the casing hanger 217. The mandrel piston 297 moves downward in mandrel chamber 295, drawing hydraulic fluid from the setting sleeve chamber 290 and passages 293 into the mandrel chamber 295. The upper body 255 under its own weight is free to move downward with the mandrel 227. The cam 239 is also free to move downward under its own weight as shoulder 229 moves down. When cam 239 is at the bottom of cavity 240, mandrel piston 297 will bear against the top of cam 239, stopping further downward movement of mandrel 227. When the cam 239 is in the lower position shown in Figure 11b, the ring 235 will be maintained in the engaged position by means of the upper lobe 241a.

When mandrel 227 is in its lower position shown in Figures 11a, 11b, the latch ring 265 (Fig. lb) will be aligned with the threads 271 in the lower body 233. When this occurs, the latch ring 265 snaps outward into engagement with the threads 271. The mandrel shoulder 257 will assure that the upper body 255 reaches the lower position shown in Figures 11a, 11b.

When the upper body 255 is in the lower position, the packoff 281 will be properly positioned in the annular clearance 219 between the casing hanger 217 and the wellhead 211. The upper body 255 will be latched to the lower body 233 so that it can not move upward because of the latch ring 265. The mandrel piston 297 will be located in a lower position at the bottom of the chamber 295.

The drill string is then lifted upward. The upward movement of the mandrel 227 relative to the upper body 255 and lower body 233 causes the mandrel piston 297 to push hydraulic fluid through passage 293 into the setting sleeve chamber 290. Continued upward movement of the mandrel piston 297 causes a pressure increase in the chambers 290, 295 and hydraulic passage 293. The pressure increase acts on the setting sleeve piston 289.

The setting sleeve piston 289 acts on the setting sleeve 275. The setting sleeve 275 applies downward force to the wedge ring 279. The wedge ring 279 moves downward into the cavity 283, which sets the packoff 281. The inner portion of the packoff 281 embeds into the casing hanger wickers 221. The outer portion of the packoff 281 embeds into the wellhead bore wickers 215. The setting position is illustrated in Figures 12a, 12b. When fully set, the upper end of the setting sleeve 275 will be substantially flush with the upper end of the lower body upper portion 249.

After testing, the running tool 225 may be retrieved from the casing hanger 217. First, the drill string is picked up to pull the mandrel 227 upward. At a certain distance, the lug 299 (Fig. 11a) will engage the slot 301 as shown in Figure 13a. Then, the drill string is rotated to the right again. The mandrel 227 will rotate. The lug 299 and slot 301 will cause the upper body 255 to rotate with the mandrel 227. This will cause the threaded ring 277 to unscrew from the wedge ring 279. This rotation will also cause the latch ring 265 to unscrew from the threads 271. The mandrel 227 may then be picked up.

As the mandrel 227 is picked up, the shoulder 229 will contact the lower side of the cam 239 and move it up to the intermediate position shown in Figure 13b. The threads 231a and 231b will contact the mating threads in the lower body 233 to limit the upward movement of the shoulder 229 to the position shown in Figure 13b. The intermediate position of the cam 239 allows the ring 235 to retract. The entire running tool 225 may then be pulled to the surface as shown in Figures 13a, 13b.

Referring to Figure 14, wellhead 411 will be located on the subsea floor. A riser (not shown) will extend from a floating vessel down to the wellhead. A casing hanger 413 is landed in the wellhead 411. Casing hanger 413 will be connected to a string of casing (not shown) extending into the well. A packoff 415 locates in an annular space between the casing hanger 413 and the bore of the wellhead 411 to seal the annulus surrounding the casing.

In the embodiment shown, packoff 415 has a metal seal 417. A wedge ring 419 locates within an annular central cavity in the seal 417. A running tool (not shown) moves the wedge ring 419 downward to set the packoff 415, forcing the inner and outer walls of seal 417 farther apart to form a metal seal. The wedge ring 419 remains with the packoff 415 after the packoff 415 is set. It has threads or grooves 421 on its upper end on the inner wall to be used in retrieving the packoff 415 at a later date.

A retrieving tool 423 is used to retrieve the packoff 415 after it has been set. Retrieving tool 423 has a central, axial mandrel 425. Mandrel 425 has threads 427 on its upper end, which serve as connection means for connecting the mandrel 425 to the lower end of the string of conduit, such as a string of drill pipe (not shown).

A mandrel piston 429 is integrally formed on the mandrel 425. Mandrel piston 429 extends radially outward from the mandrel 425 and has seals 431 on its outer diameter. An exterior cylindrical wall 433 of smaller diameter than mandrel piston 429 is formed on the mandrel 425 above the mandrel piston 429.

The mandrel piston 429 slidingly and sealingly engages a bore 435 of a body 437. A pressure chamber 439 is defined by the space between the bore 435 of body 437 and the exterior wall 433 of mandrel 425. The pressure area of mandrel piston 429 is the transverse cross-sectional area of the mandrel piston 429. This pressure area corresponds to the difference between the diameter of the bore 435 and the outer diameter of the exterior wall 433.

Body 437 has a landing shoulder 441 on its lower end that serves as means for landing the retrieving tool 423 on the upper end of the casing hanger 413. Body 437 is tubular, having an exterior wall 443 that is cylindrical. Seals 445 are located on the exterior wall 443.

A retrieving sleeve piston 447 is carried by mandrel 425. The retrieving sleeve piston 447 is an annular member for carrying packoff 415. Retrieving sleeve piston 447 has an inner diameter containing seals 449 which sealingly engage the exterior wall 433 of mandrel 425. A retrieving sleeve 451 is integrally formed with and depends downward from the retrieving sleeve piston 447. The retrieving sleeve 451 has an inner cylindrical wall 453. The inner wall 453 sealingly and slidingly engages the exterior wall 443 of the body 437.

A latch means for latching into the packoff 415 is carried on the outer wall of the retrieving sleeve 451. This latch means comprises a split latch ring 455. The latch ring 455 is retained on its upper end by a collar 457 and is located in a recess 459 on the retrieving sleeve 451. The latch ring 455 has grooves on its exterior adapted to latch into and engage the grooves 421 on the packoff wedge ring 419. Once engaged, the retrieving sleeve 451 will be locked to the packoff wedge ring 419, so that upward movement of the retrieving sleeve 451 will cause upward movement of the wedge ring 419.

The retrieving sleeve piston 447 serves as reacting means in fluid communication with the pressure chamber 439 for upward movement relative to the body 437 in response to a pressure increase in the pressure chamber 439. The retrieving sleeve piston 447 has a pressure area that is greater than the pressure area of the mandrel piston 429. The pressure area of the retrieving sleeve piston 447 is the transverse cross-sectional area that is bounded on the inner side by the mandrel exterior wall 433 and on the outer side by the body exterior wall 443. The chamber 439 is filled with a substantially incompressible hydraulic fluid and is sealed from the exterior of the retrieving tool 423 by means of the seals 431, 445, and 449.

A pair of stop rings 461 located on the mandrel 425 serve as a stop to limit downward movement of the mandrel 425 relative to the retrieving sleeve piston 447 and body 437. The body 437 is retained with the retrieving tool 423 by means of a downward facing retention shoulder 463 formed on the exterior wall 443 of the body 437. The retention shoulder 463 is adapted to engage a plurality of pins 465 (only one shown) located on the lower end of the retrieving sleeve 451.

In operation, to retrieve packoff 415, the retrieving tool 423 is lowered on a string of conduit, such as drill pipe. Initially, the retrieving sleeve. piston 447 will be located in contact with the upper side of the mandrel piston 429. The body 437 will be located in a lower position (not shown) with the retention shoulder 463 in contact with the retention pins 465. The body 437 will first land on the upper end of the casing hanger 413. Continued downward movement of mandrel 425 results in the stop rings 461 contacting the upper end of retrieving sleeve piston 447. The weight of the drill string pushes down on the retrieving sleeve piston 447, causing the latch ring 455 to ratchet into engagement with the grooves 421 of the packoff 415.

Then, the drill string is pulled upward. The mandrel piston 429 will cause a pressure increase in the hydraulic fluid. The pressure of the hydraulic fluid in the chamber 439 acts against the retrieving sleeve piston 447. The piston 447 will start to move upward, pulling the wedge ring 419 upward from the seal 417.

The pressure in the pressure chamber 439 is equal to the upward force on the mandrel 425 divided by the pressure area of the mandrel piston 429. The force exerted on the packoff assembly 415 is equal to the pressure in the pressure chamber 439 times the pressure area of the retrieving sleeve piston 447. For example, if the pressure area of the retrieving sleeve 447 is ten times that of the pressure area of the mandrel piston 429, then the upward force exerted by the retrieving sleeve 451 will be ten times that of the upward force pulled on the drill string. The intensification of the force provides a sufficient force for retrieving a metal seal packoff 415.

When in the uppermost position, the retrieving tool 423 appears as shown in Figure 2. Continued upward pulling will retrieve the entire packoff assembly 415. A new packoff can then be lowered in place and set using a running tool (not shown).

The invention has significant advantages. A high force is achieved by using the differential pistons. This high force enables the setting of metal packoffs. Annulus fluid pressure is not needed. There is no need for dropping balls or darts, or to shift pins in J-slots in order to pump fluid down the drill pipe. The running tool can be released after setting by pulling upward and rotating in one embodiment, or by straight upward pull in the other embodiment. In another embodiment, the tool is able to retrieve a metal seal packoff by intensifying the actual force pulled on the drill string.

## Claims

1. A tool (25) (225) (423) for performing an operation on a packoff (81) (281) (415) located between a casing hanger (17) (217) (413) and a wellhead (11) (211) (411), comprising in combination:
a mandrel (27) (227) (425) having means (26) (226) (427) for connection to a string of drill pipe;
a body (55) (255) (437) carried by the mandrel (27) (227) (425), the mandrel (27) (227) (425) being axially movable relative to the body (55) (255) (425);
a sleeve (75) (275) (451) carried by the body (55) (255) (437) and having means (77) (277) (455) for connection to the packoff (81) (281) (415);
a sleeve piston (89) (289) (447) in engagement with the body (55) (255) (437) for movement relative to the body (55) (255) (437) and positioned to engage an upper end of the sleeve (75) (275) (451);
a mandrel piston (97) (297) (429) carried by the mandrel (27) (227) (425) for movement therewith; and
communication means (93) (293) (439) containing a fluid for communicating pressure created by axial movement of the mandrel piston (97) (297) (429) with the sleeve piston (89) (289) (447), whereby axial movement of the mandrel piston (97) (297) (429) and mandrel (27) (227) (425) relative to the body (55) (255) (437) due to axial movement of the drill string will increase the pressure of the fluid to exert an axial force on the sleeve piston (89) (289) (447) to move the sleeve (75) (275) (451) axially to perform the operation on the packoff (81) (281) (415).

2. The tool (25) (225) (423 according to claim 1 wherein the mandrel piston (97) (297) (429) has a smaller pressure area than the sleeve piston (89) (289) (447).

3. The tool (25) (225) (423) according to claim 2 wherein the communication means (93) (293) (439) is sealed from the exterior of the tool (25) (225) (423).

4. The tool (25) (225) according to claim 2 wherein the axial force exerted on the sleeve piston (89) (289) by the increase in pressure caused by the mandrel piston (97) (297) is downward in direction for moving the sleeve (75) (275) downward to set the packoff (81) (281).

5. The tool according to claim 4 wherein the communication means (93) (293) comprises:
a sleeve chamber (90) (290) within the body (55) (255), the sleeve piston (89) (289) being carried in the sleeve chamber (90) (290) for axial movement relative to the body (55) (255);
a mandrel chamber (95) (295) located between the body (55) (255) and the mandrel (27) (227), the mandrel piston (97) (297) being carried in the mandrel chamber (95) (295) for axial movement relative to the body (55) (255); and
passage means (93) (293) located in the body (55) (255) sealed from the exterior of the body (55) (255) for communicating the fluid from the mandrel chamber (95) (295) with the sleeve chamber (901 (290).

6. The tool (25) (225) according to claim 5 wherein the body (55) (255) has an upper portion (55) (255) and a lower portion (33) (233) which are axially movable relative to each other, the sleeve chamber (90) (290) being located in the upper portion (55) (255) of the body, and wherein the tool (25) (225) further comprises:
retaining means (31a,b) (231a,b) for retaining the upper portion (55) (255) of the body in an upper position relative to the lower portion (33) (233) of the body while cementing the casing hanger (17) (217) in place and for moving the upper portion (55) (255) of the body from the upper position to a lower position relative to the lower portion (33) (233) of the body, with the packoff (81) (281) lo-

cated between the casing hanger (17) (217) and the wellhead (11) (211), after the casing hanger (17) (217) has been cemented in place.

7. The tool (25) (225) according to claim 6 wherein the body (33,55) (233,255) has connection means (35) (235) for releasably connecting the lower portion of the body (33) (233) to the casing hanger (17) (217).

8. The tool (25) (225) according to claim 7 wherein the tool (25) (225) further comprises:
latch means (65) (265) for latching the upper portion (55) (255) of the body to the lower portion (33) (233) of the body when the upper portion (33) (233) of the body is in the lower position, to prevent upward movement of the upper portion (55) (255) of the body relative to the lower portion (33) (233) of the body.

9. The tool (25) (225) according to claim 8 further comprising release means (37, 43) (237, 243) for releasing the connection means (35) (235) from the casing hanger (17) (217) and the setting sleeve (75) (275) from the packoff (81) (281) to allow the tool (25) (225) to be retrieved after the packoff (81) (281) is set.

10. The tool (25) (225) according to claim 9 wherein the retaining means (31a,b) (231a,b) comprises:
mating threads (31a,b) (231a,b) in the mandrel (27) (227) and lower portion (33) (233) of the body for retaining the mandrel (27) (227) and the upper portion (55) (255) of the body in said upper position, and for allowing the mandrel (27) (227) and upper portion (55) (255) of the body to move downward by rotating the drill string and mandrel (27) (227) to unscrew the threads.

11. The tool (25) according to claim 9 further comprising:
a locking element (57) located in a recess (59) between the mandrel (27) and the upper portion (55) of the body, for moving the upper portion (55) of the body and sleeve (75) downward with the mandrel (27) from the upper position to the lower position; and
means (63) for releasing the locking element (57) when the upper portion (55) of the body is in the lower position, to allow downward movement of the mandrel (27) relative to the upper portion (55) of the body for moving the mandrel piston (97) in the mandrel chamber (95) downward to apply pressure to the sleeve chamber (90).

12. The tool (25) (225) according to claim 11 wherein the latch means (65) (265) comprises a split latch ring (65) (265) carried by the upper portion (55) (255) of the body, and a latch groove (71) (271) located in the lower portion (33) (233) of the body for receiving the latch ring (65) (265) when the upper portion (55) (255) of the body moves to the lower position.

13. The tool (25) according to claim 12 wherein the means (63) for releasing the locking element (57) comprises pin means (63) extending through the upper portion (55) of the body and connecting the latch ring (65) with the locking element (57), for causing the locking element (57) to move out of the recess (59) when the latch ring (65) engages the latch groove (69).

14. The tool (25) (225) according to claim 7 wherein the connection means (35) (235) comprises:
an engaging element (35) (235) carried by the lower portion (33) (233) of the body, and movable between an inner retracted position and an outer engaged position in engagement with a groove (23) (223) in the casing hanger (17) (217), for securing the lower portion (33) (233) of the body to the casing hanger (17) (217);
a cam (39) (239) carried by the mandrel (27) (227) in the lower portion (33) (233) of the body for axial movement relative to the lower portion (33) (233) of the body between an engaging position and a released position, the cam (39) (239) forcing the engaging element (35) (235) outward to the engaged position when the cam (39) (239) is moved to the engaging position.

15. The tool (25) according to claim 2 wherein the axial movement of the drill string to move the mandrel piston (97) to increase the pressure of the fluid is in a downward direction.

16. The tool (225) according to claim 2 wherein the axial movement of the drill string to move the mandrel piston (297) to increase the pressure of the fluid is in an upward direction.

17. The tool (423) according to claim 2 wherein the axial force exerted on the sleeve piston (447) by the increase in pressure caused by the mandrel piston (429) is upward in direction for moving the sleeve (451) upward to retrieve the packoff (415).

18. The tool (423) according to claim 17 wherein the means (455) for connection of the sleeve (451) to the packoff (415) comprises a latch (455) which latches to the packoff (415) when the sleeve (451) is lowered into contact with the packoff (415).

19. The tool (423) according to claim 17 wherein the sleeve (451) depends from the sleeve piston (447) and has an inner wall (453) that sealingly and slidingly engages an exterior wall (443) of the body (437).

20. The tool (423) according to claim 17 wherein the sleeve piston (447) has a lower portion that is in communication with the fluid in the communication means (439).

21. The tool (423) according to claim 17 wherein:
the mandrel (425) and the body (437) each has an exterior wall (433,443) and the body (437) has a

bore (435);
the mandrel piston (429) extends radially outward from the exterior wall (433) of the mandrel (425) and has an outer diameter sealingly engaging the bore (435) of the body (437), the mandrel piston (429) having a pressure area defined by the difference in diameter between the exterior wall (433) of the mandrel (425) and the bore (435) of the body (437);
the sleeve piston (447) has an inner diameter that sealingly and slidingly engages the exterior wall (433) of the mandrel (425) above the mandrel piston (429);
the sleeve (451) depends from the sleeve piston (447) and has an inner wall (453) that sealingly and slidingly engages the exterior wall (443) of the body (437), the sleeve piston (447) having a pressure area that is greater than the pressure area of the mandrel piston (429) and which is defined by the difference in diameter between the exterior wall (433) of the mandrel (425) and the exterior wall (443) of the body (437); and
the communication means comprises a chamber (39) between the mandrel piston (429) and the sleeve piston (447).

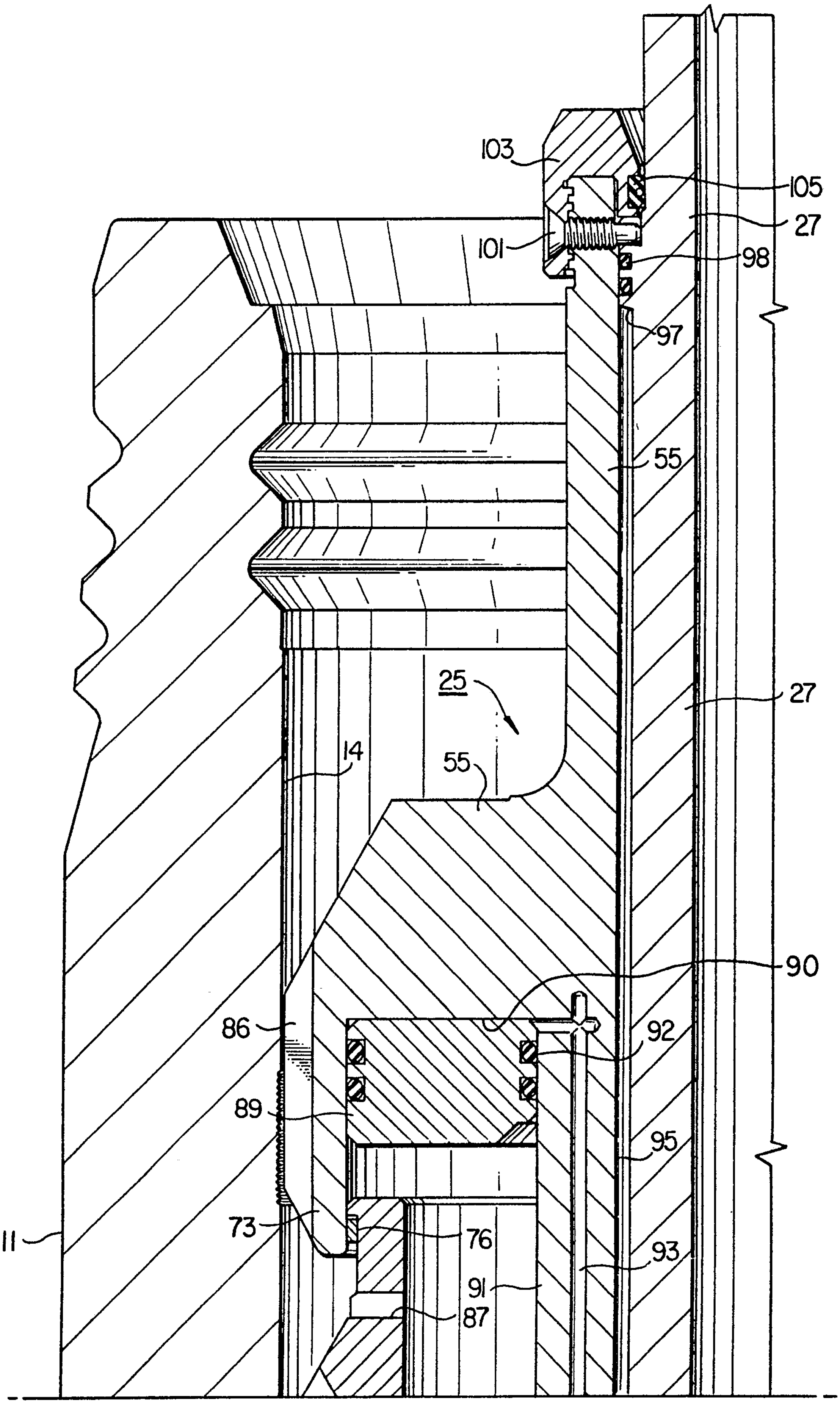


FIG. 1a

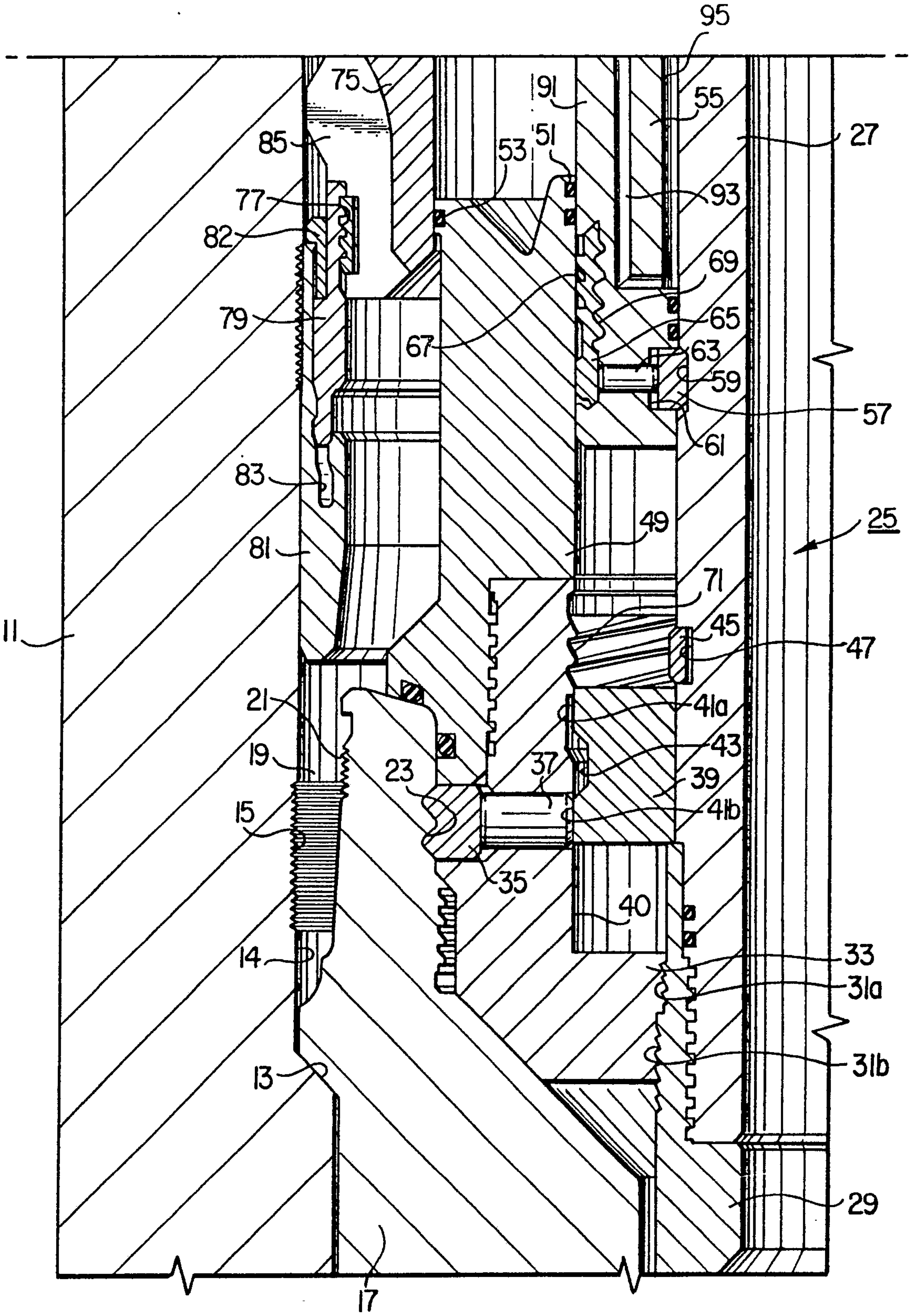
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FIG. 1b

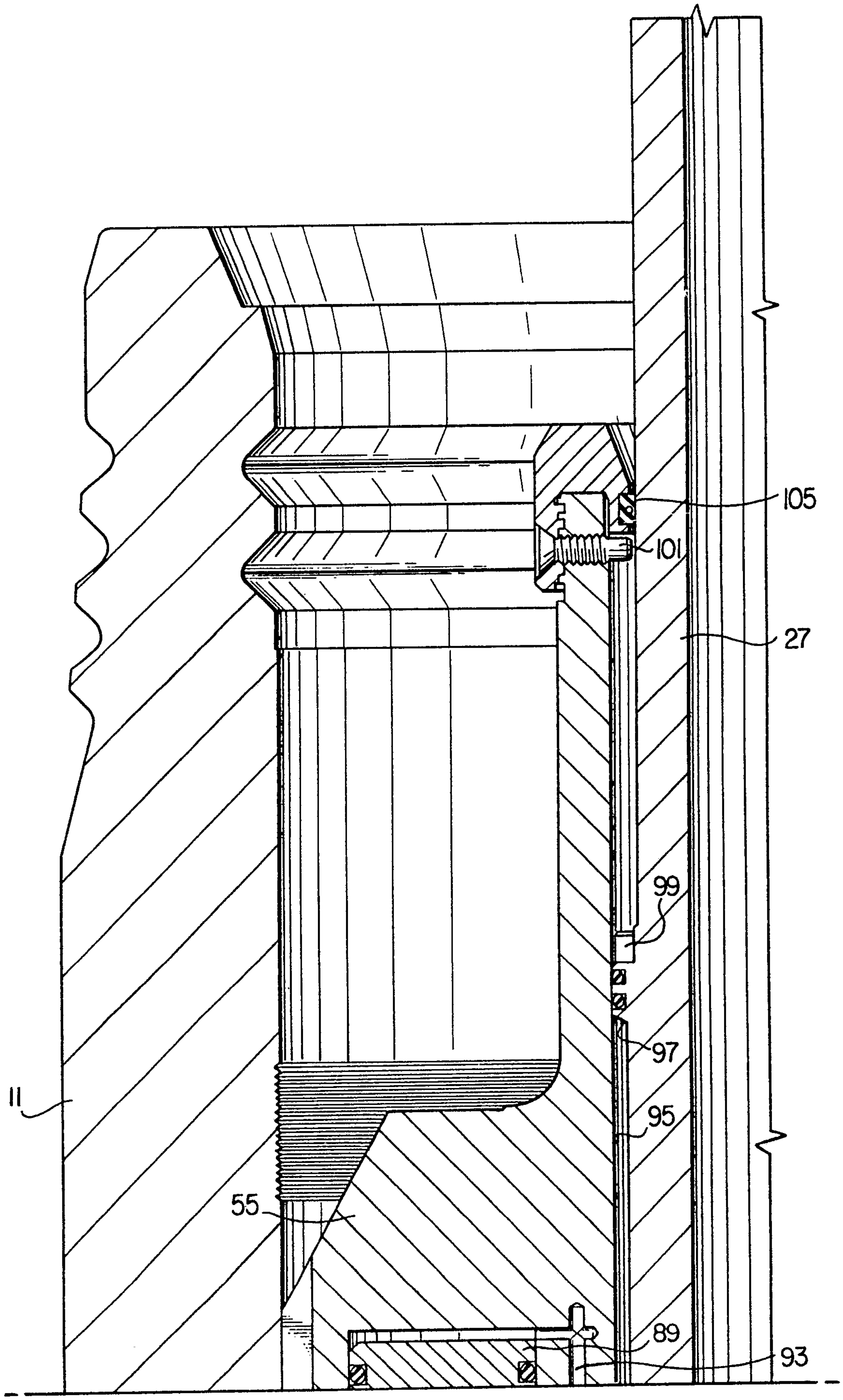


FIG. 2a

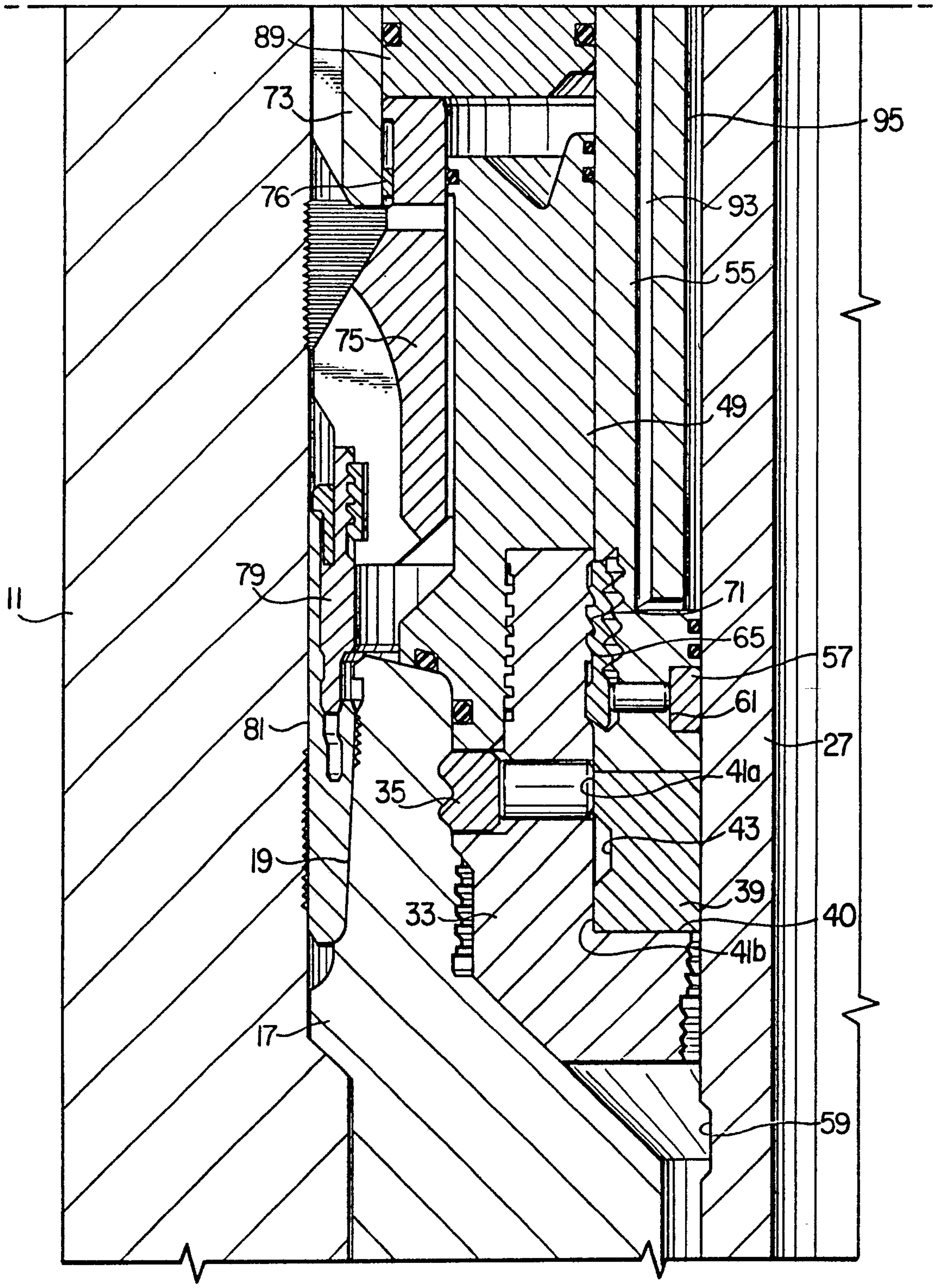
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FIG. 2b

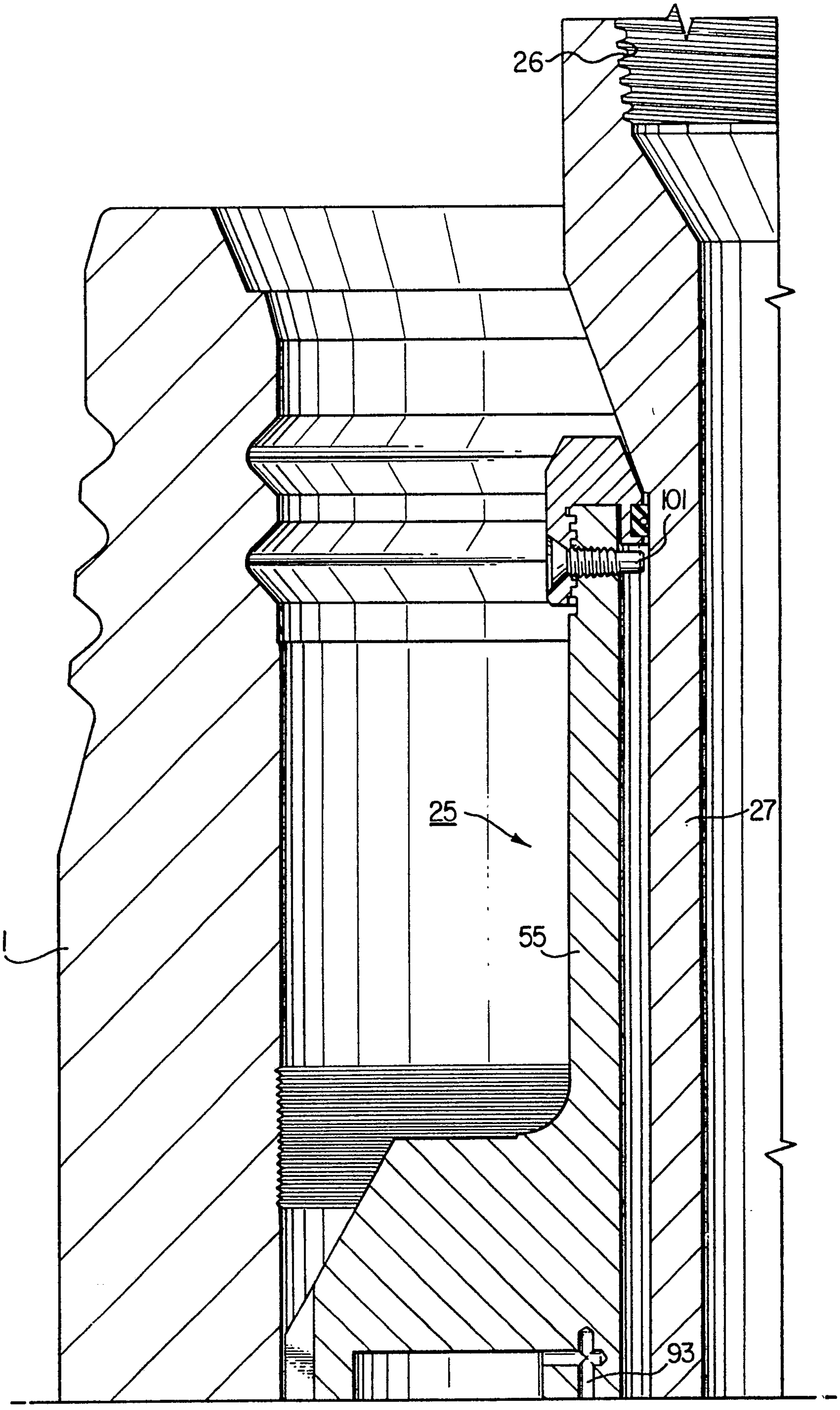



FIG. 3a

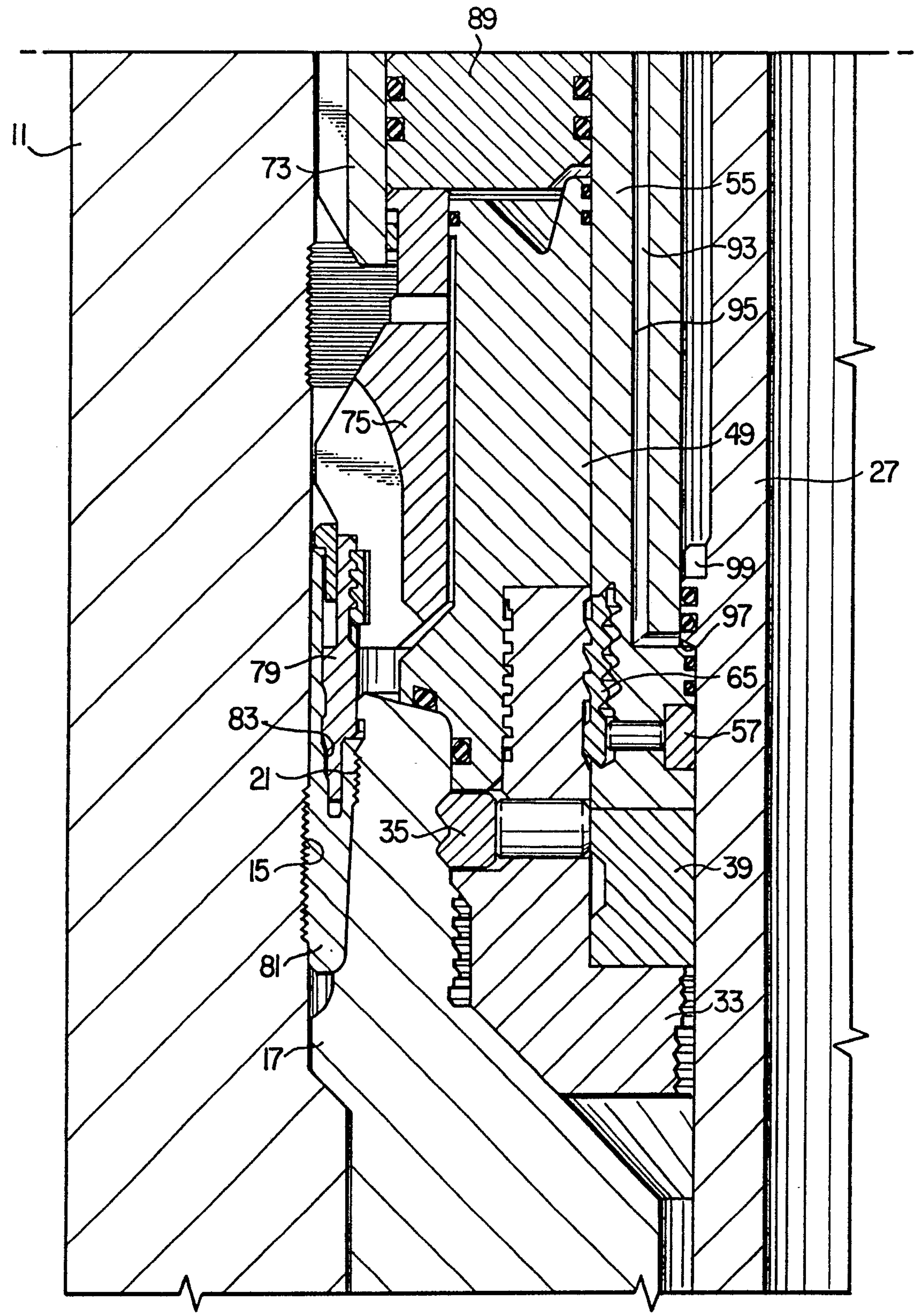



FIG. 3b

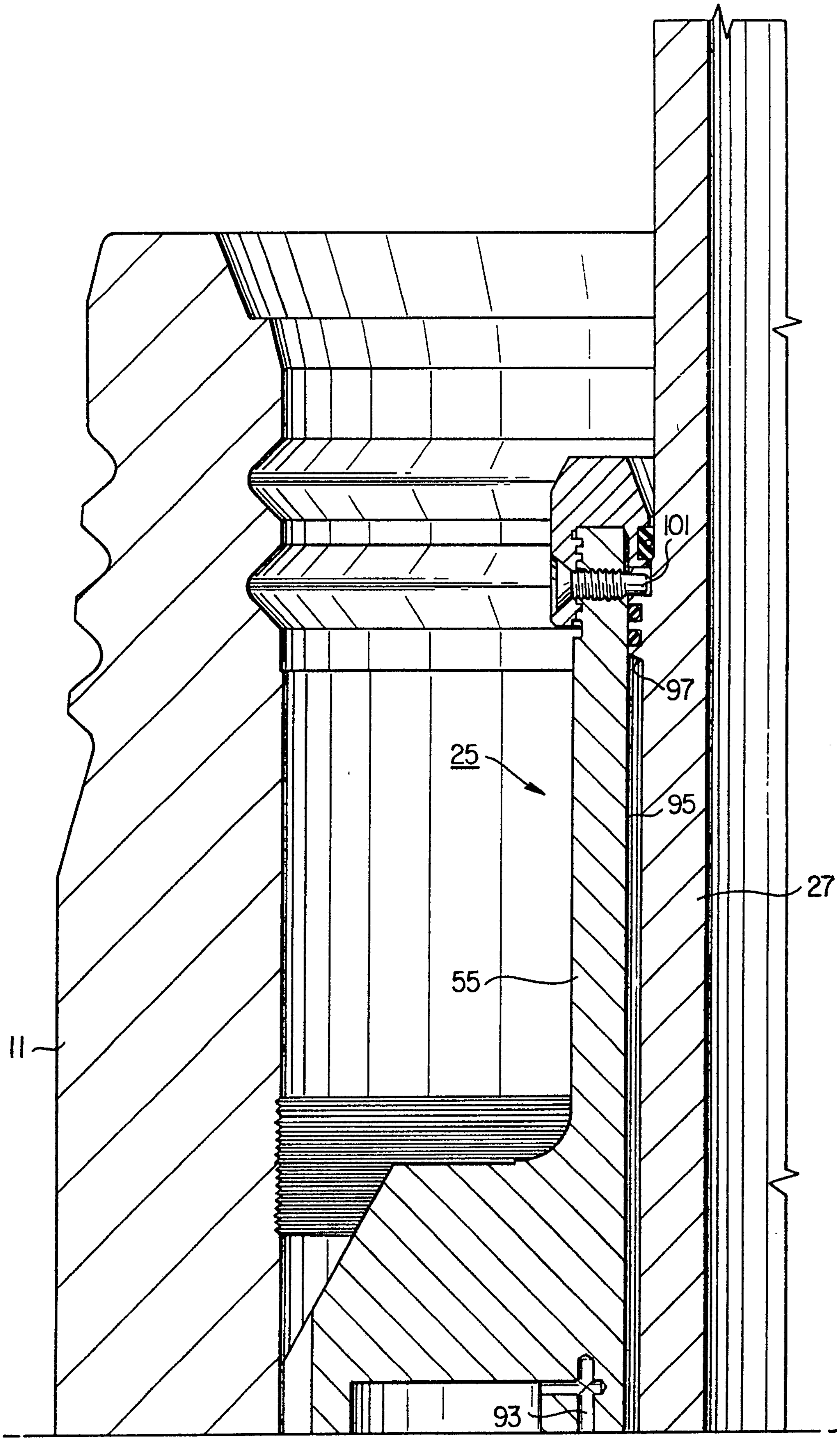



FIG. 4a

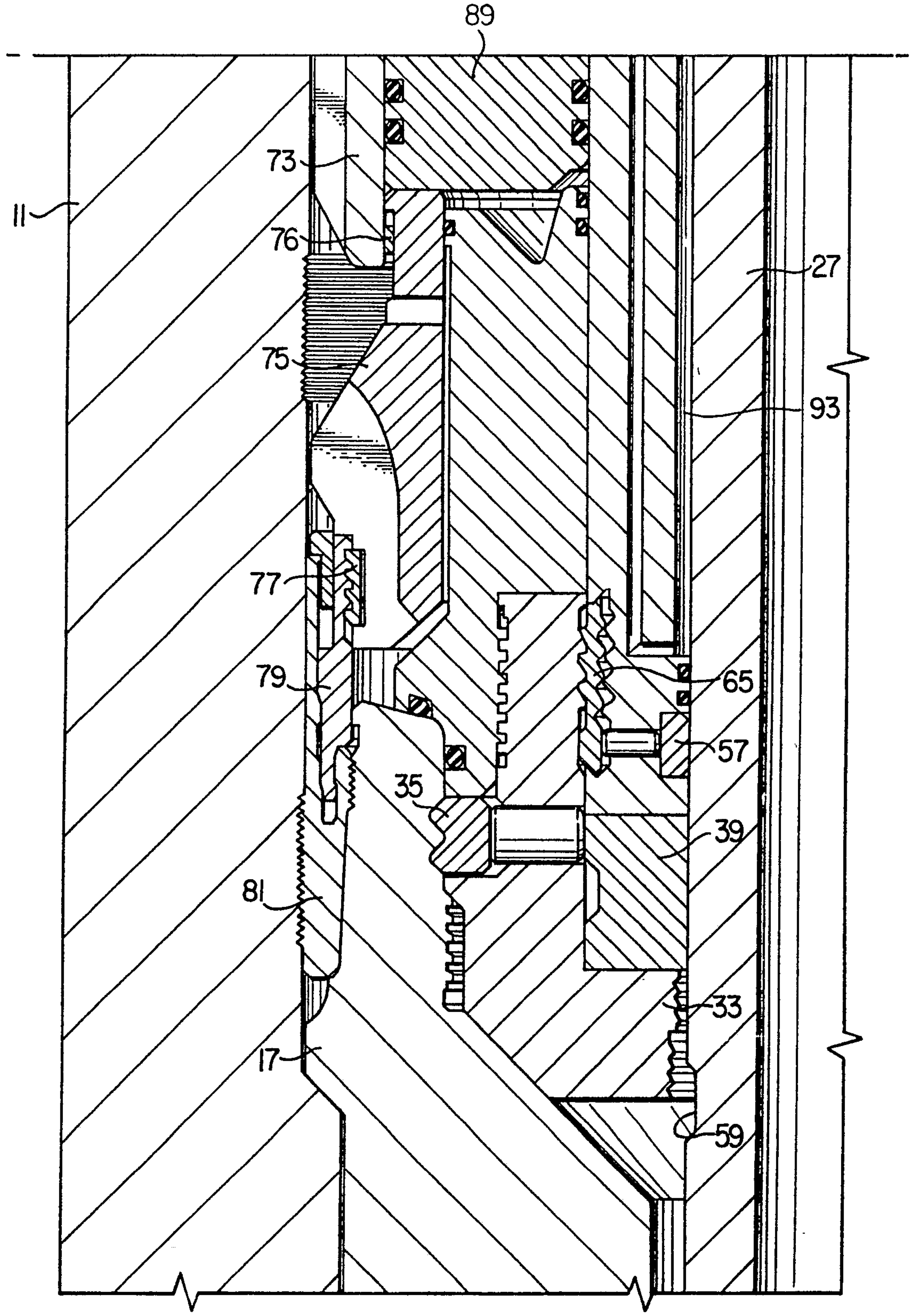



FIG. 4b

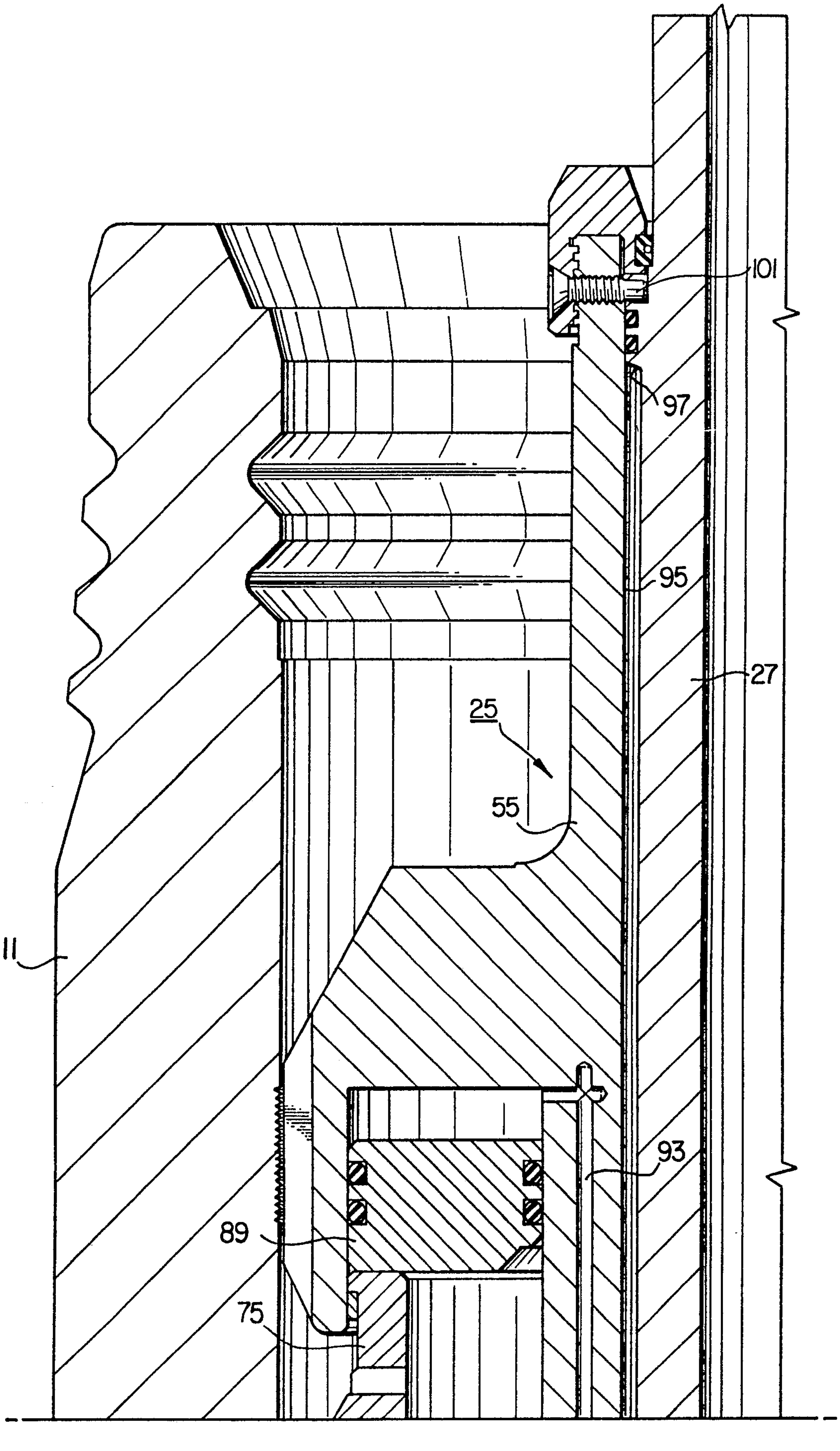
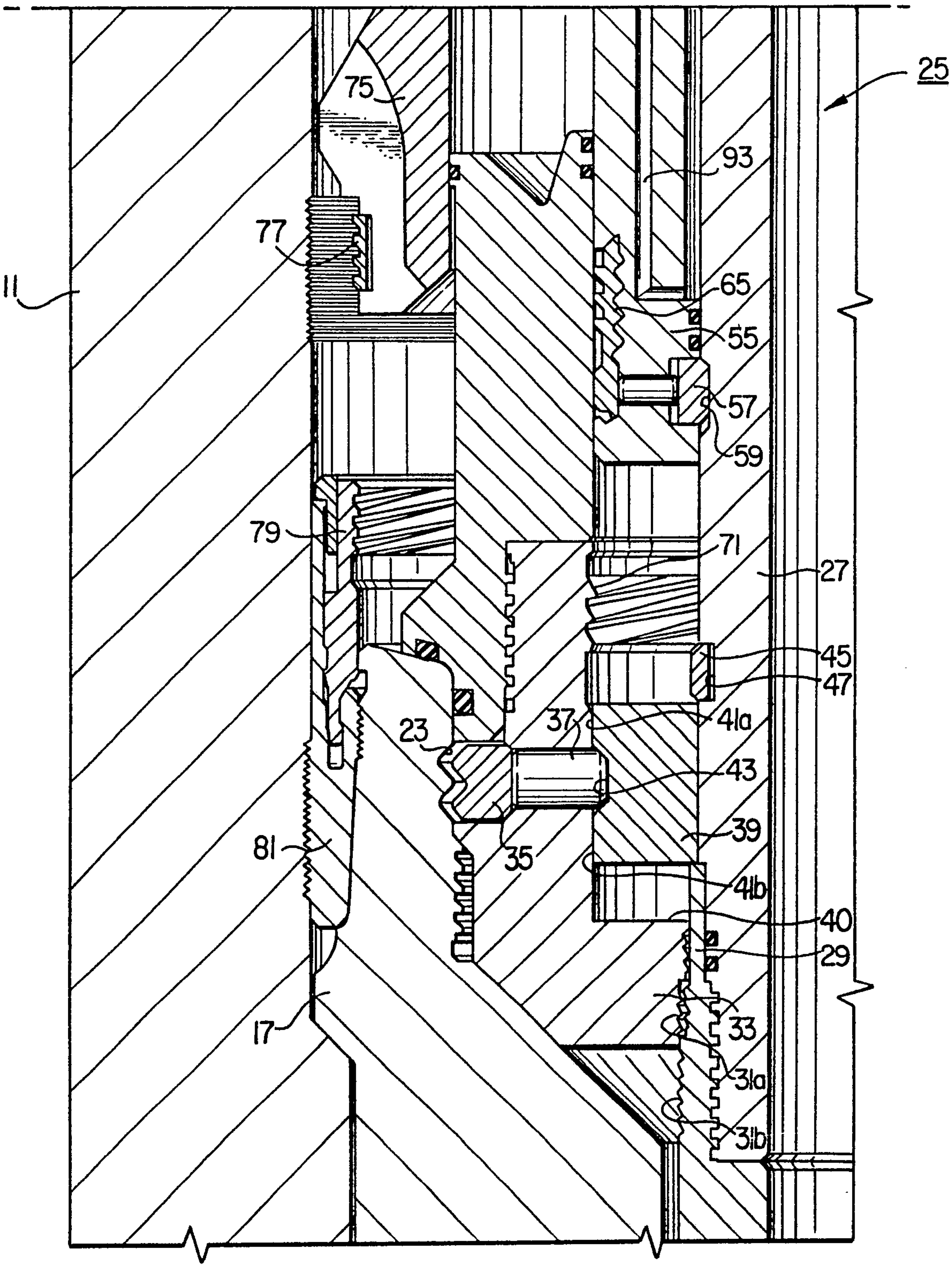



FIG. 5a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43
81
39
35
41b
40
29
17
33
31a
31b

FIG. 5b

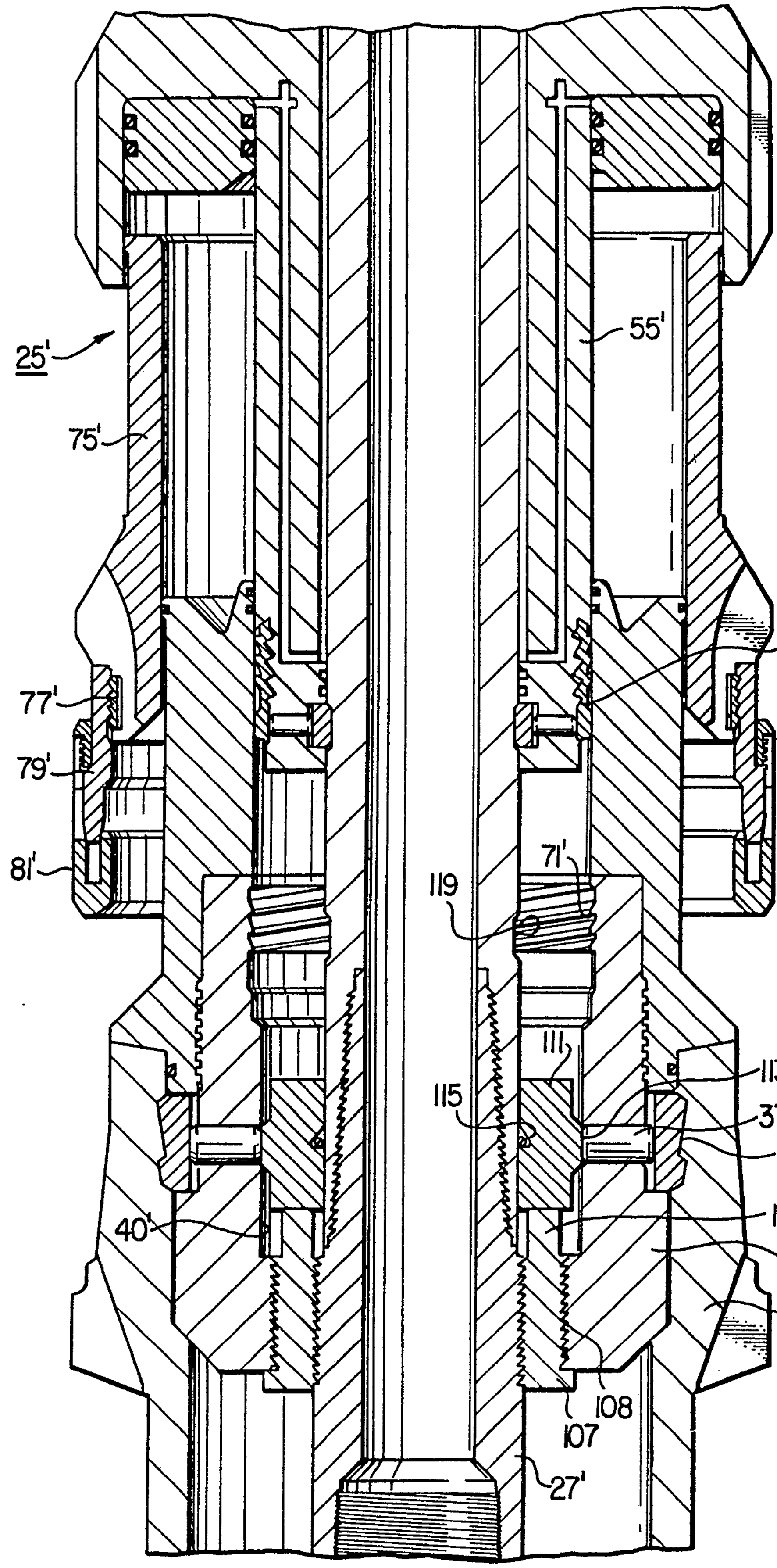



FIG. 6

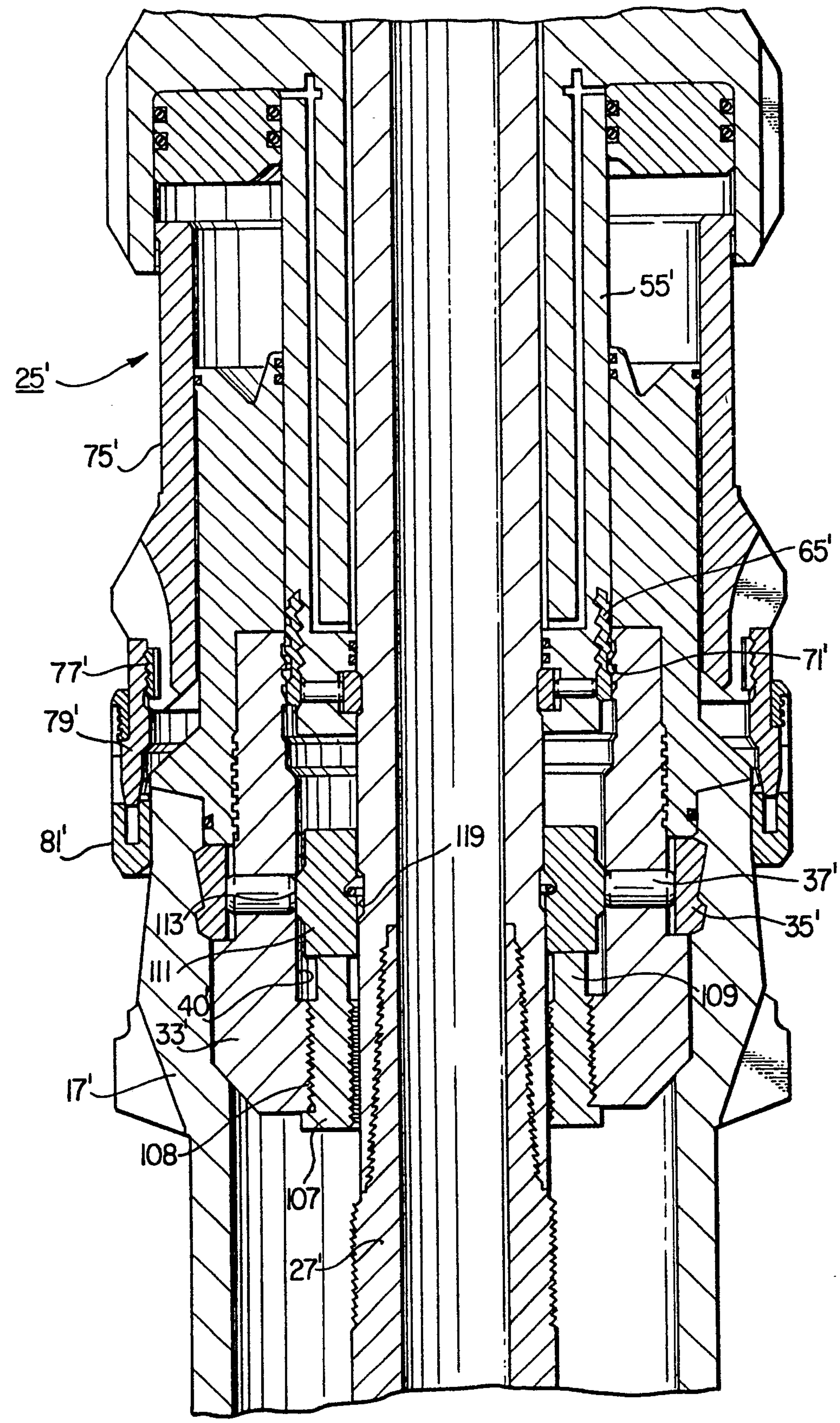



*FIG. 7*

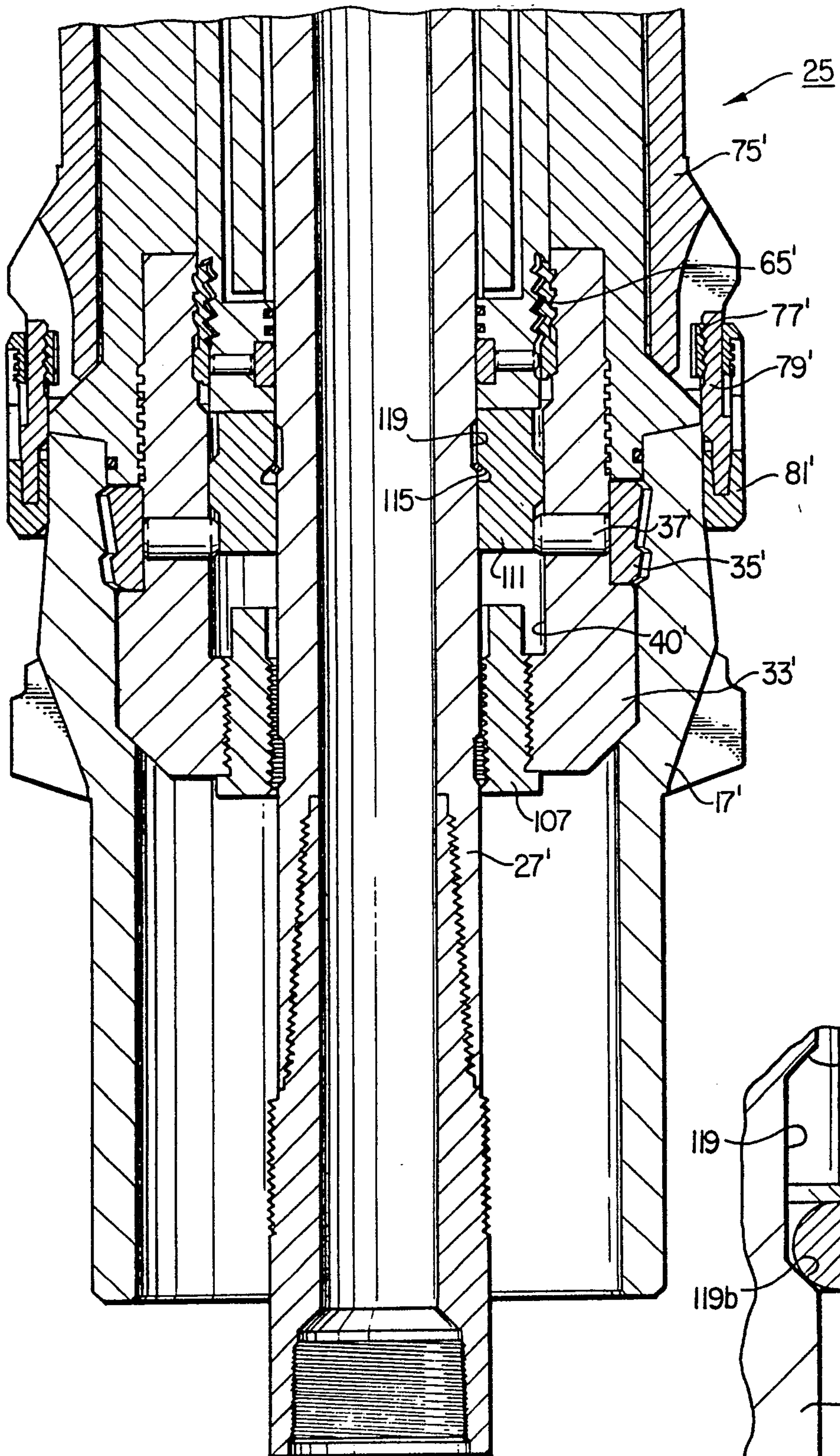

25
75'
65'
77'
79'
119
81'
115
37'
35'
111
40'
33'
17'
107
27'

FIG. 8

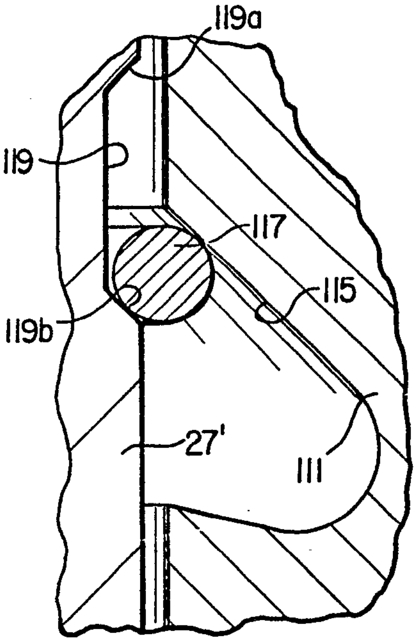

119a
119
117
115
119b
27'
111

FIG. 9

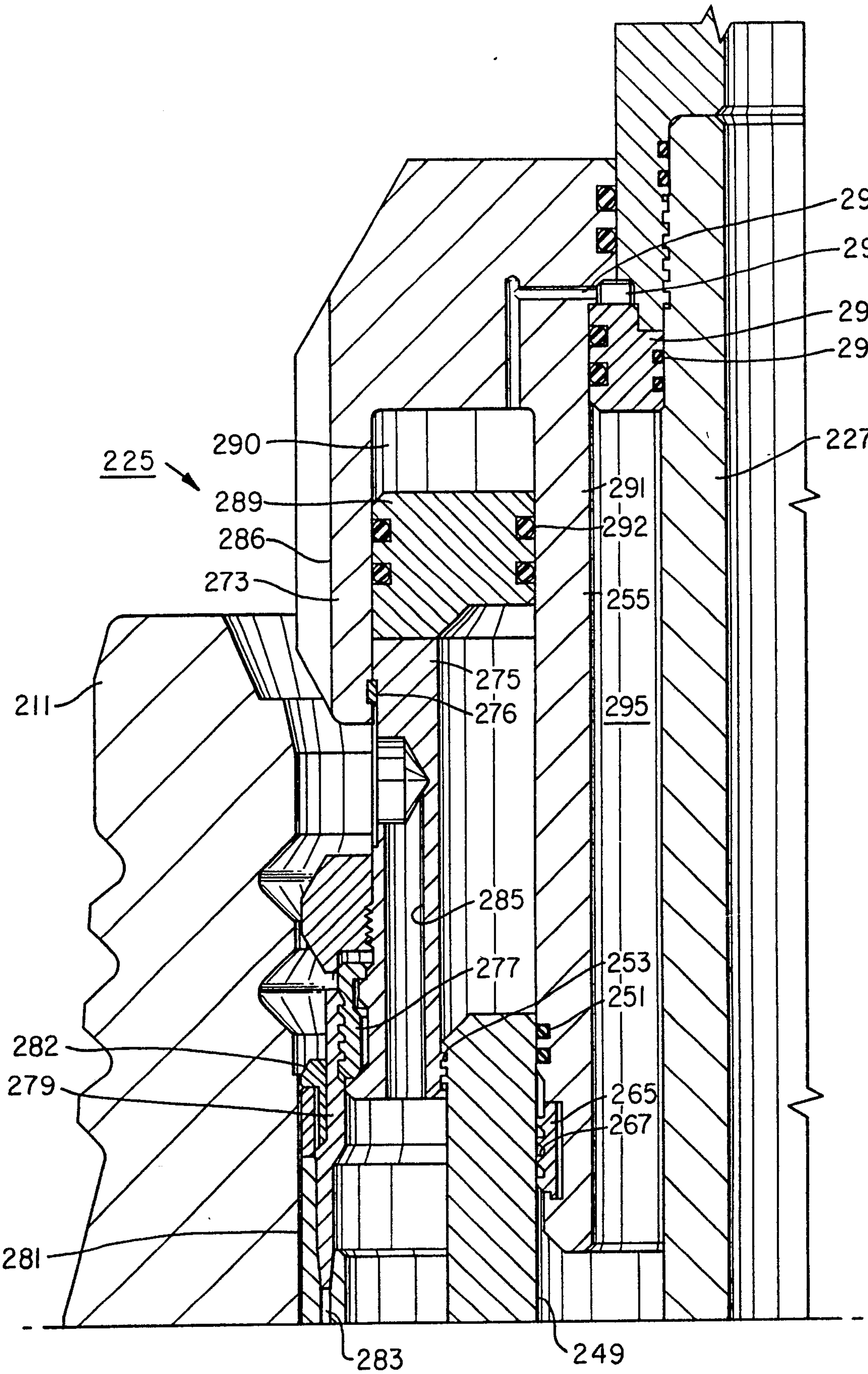

293
299
297
298
290
225
227
289
291
292
286
273
255
275
211
276
295
285
253
277
251
282
279
265
267
281
283
249

FIG. 10a

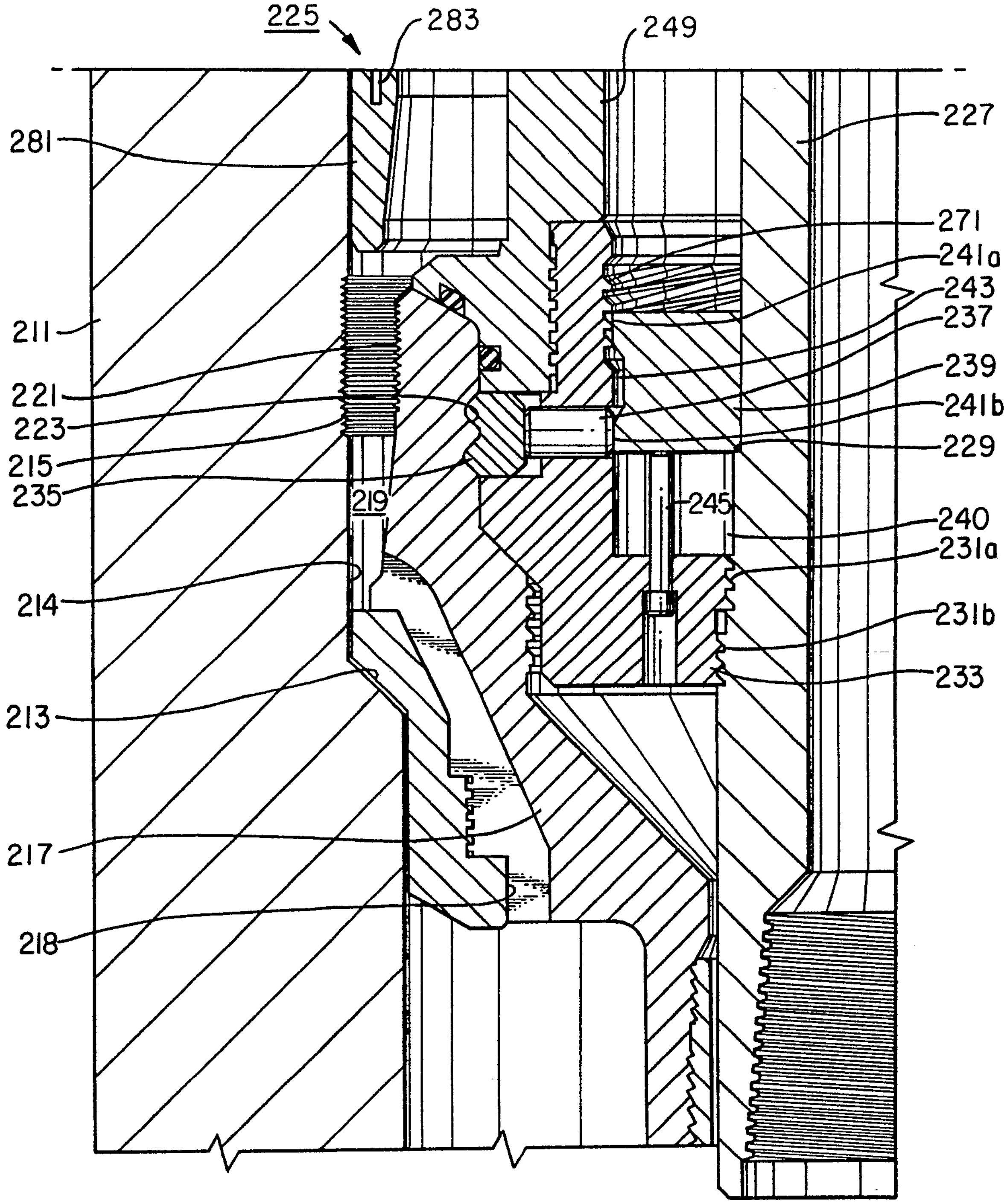

225
283
249
227
281
271
241a
243
211
237
239
221
241b
223
229
215
235
219
245
240
231a
214
231b
233
213
217
218

FIG. 10b

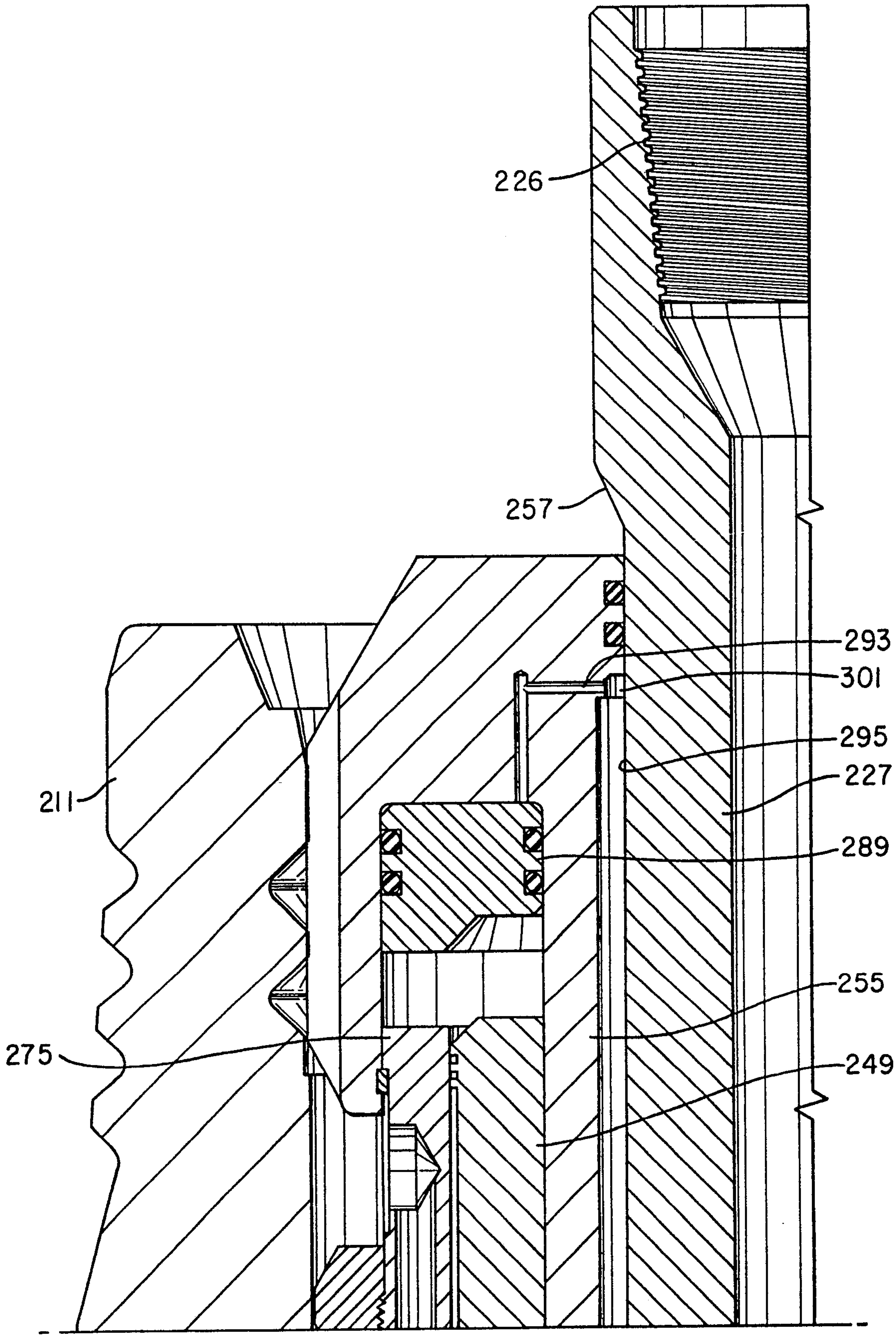



FIG. 11a

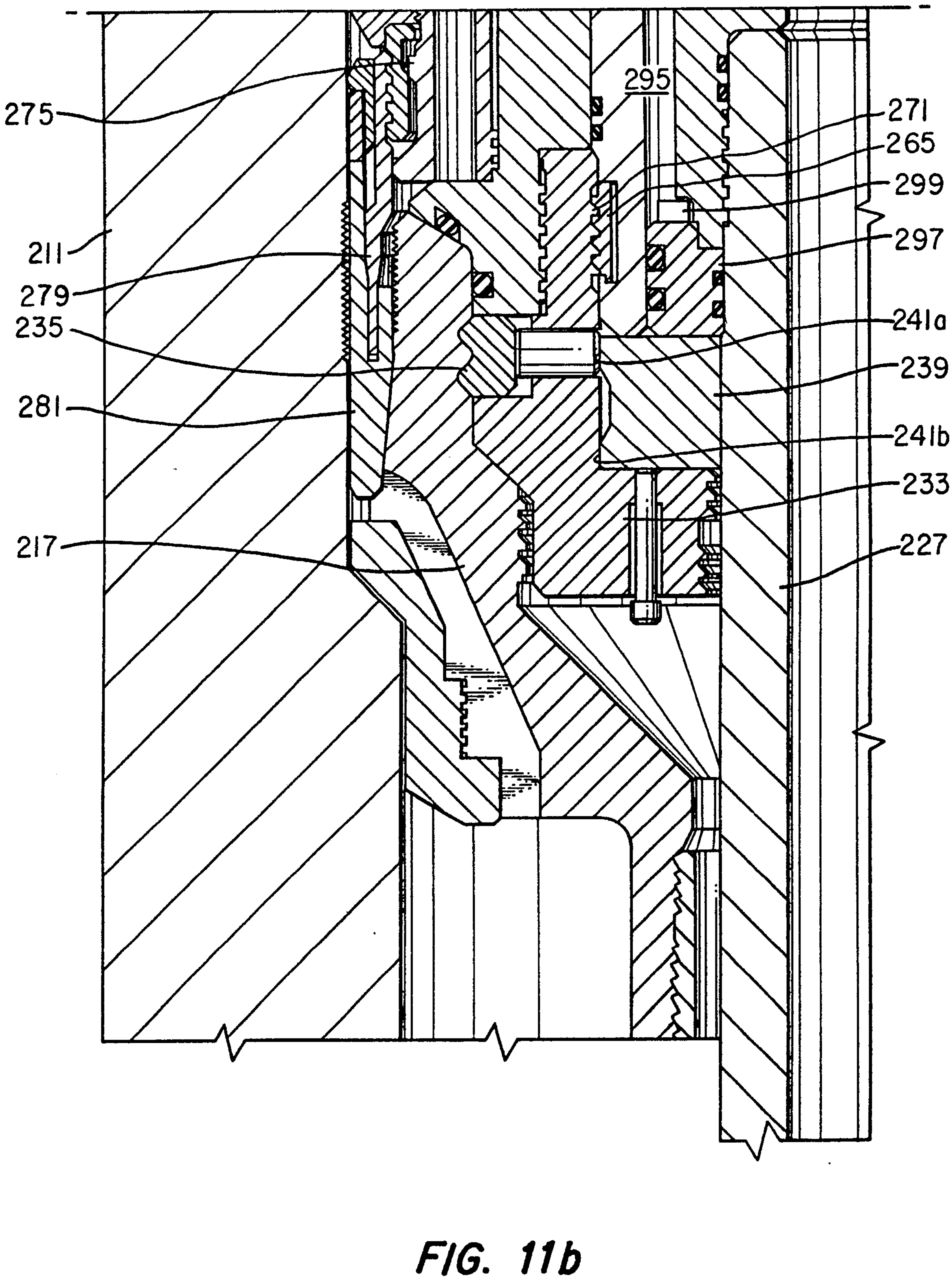

275
211
279
235
281
217
295
271
265
299
297
241a
239
241b
233
227

FIG. 11b

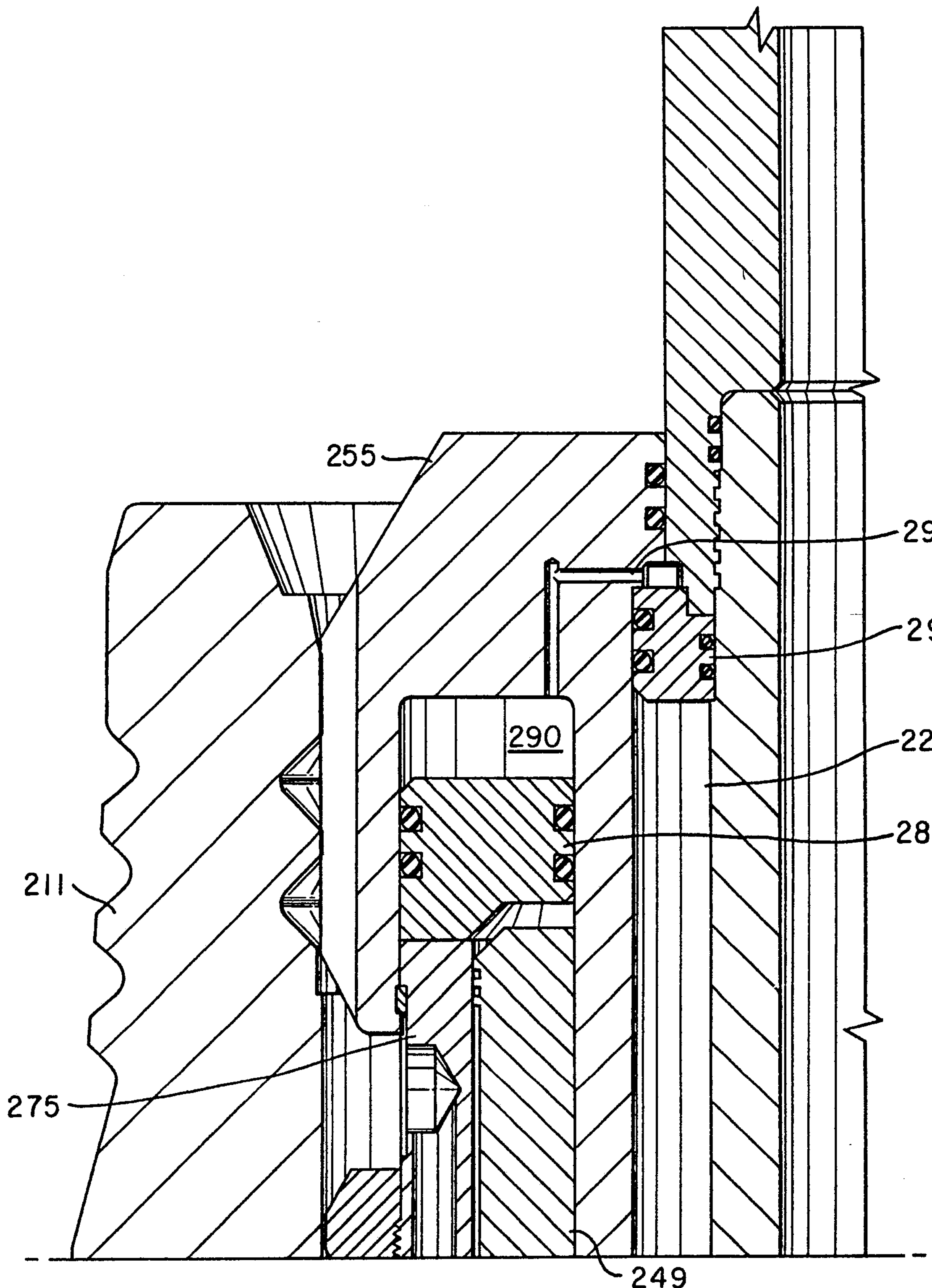



FIG. 12a

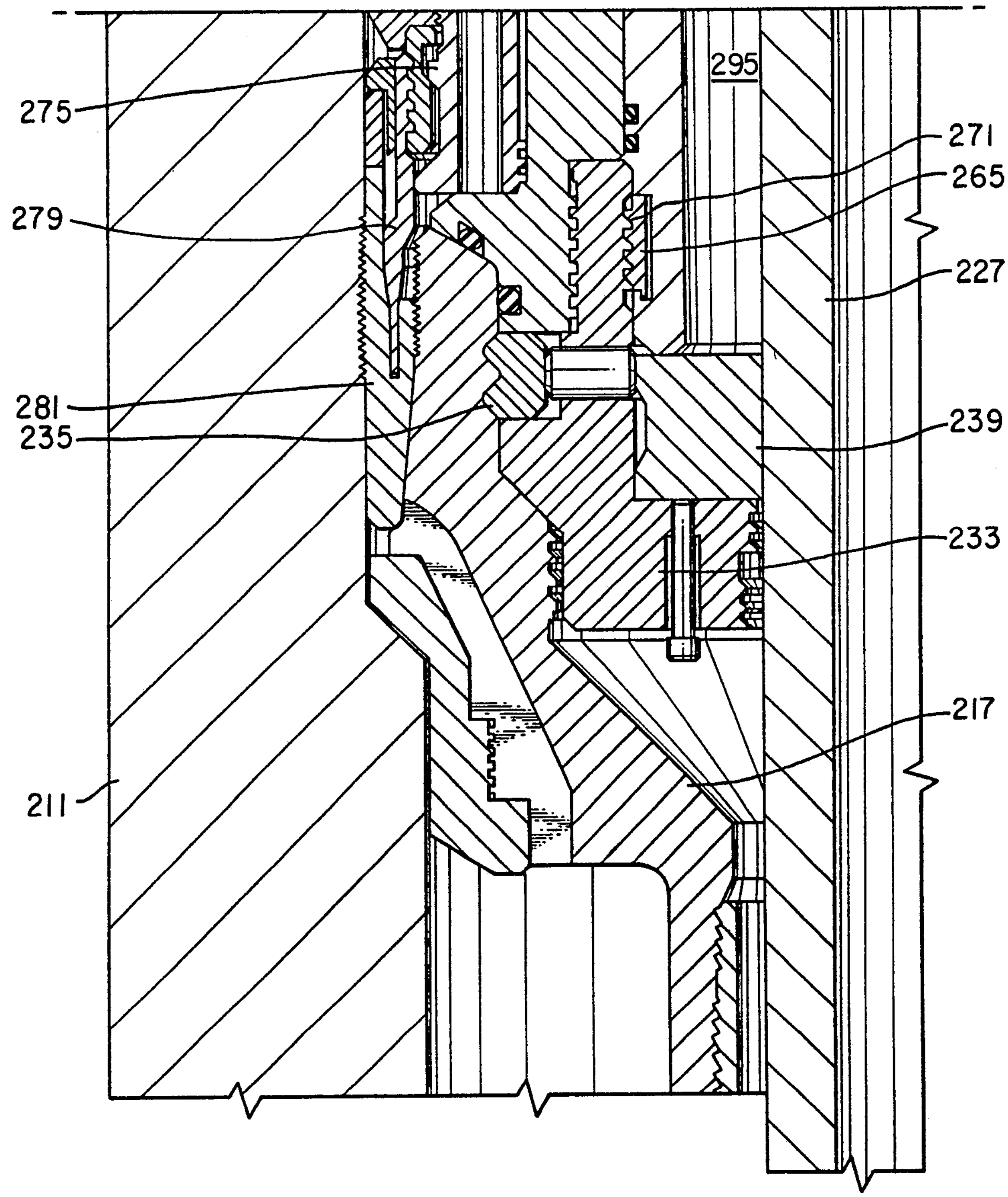



FIG. 12b

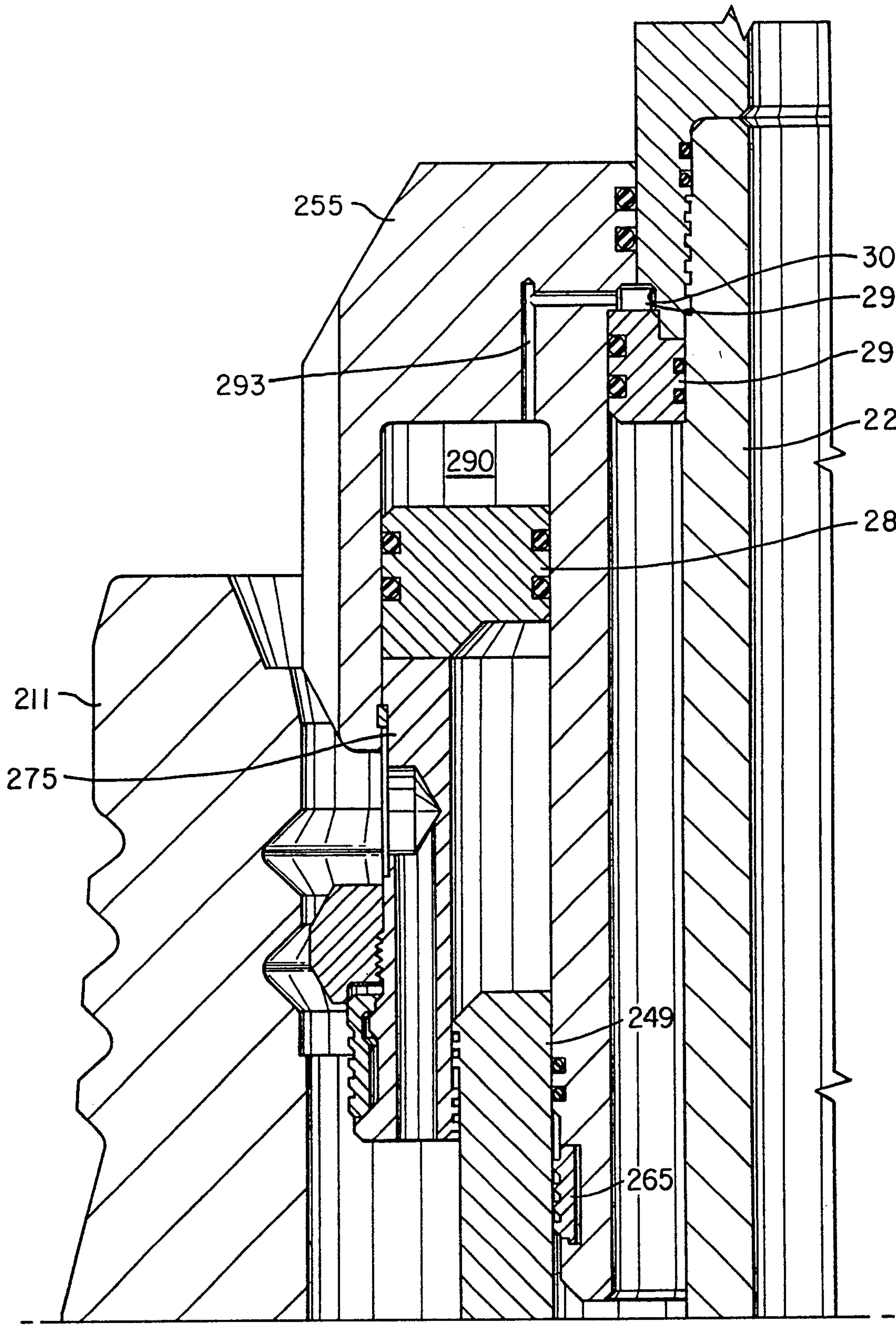



FIG. 13a

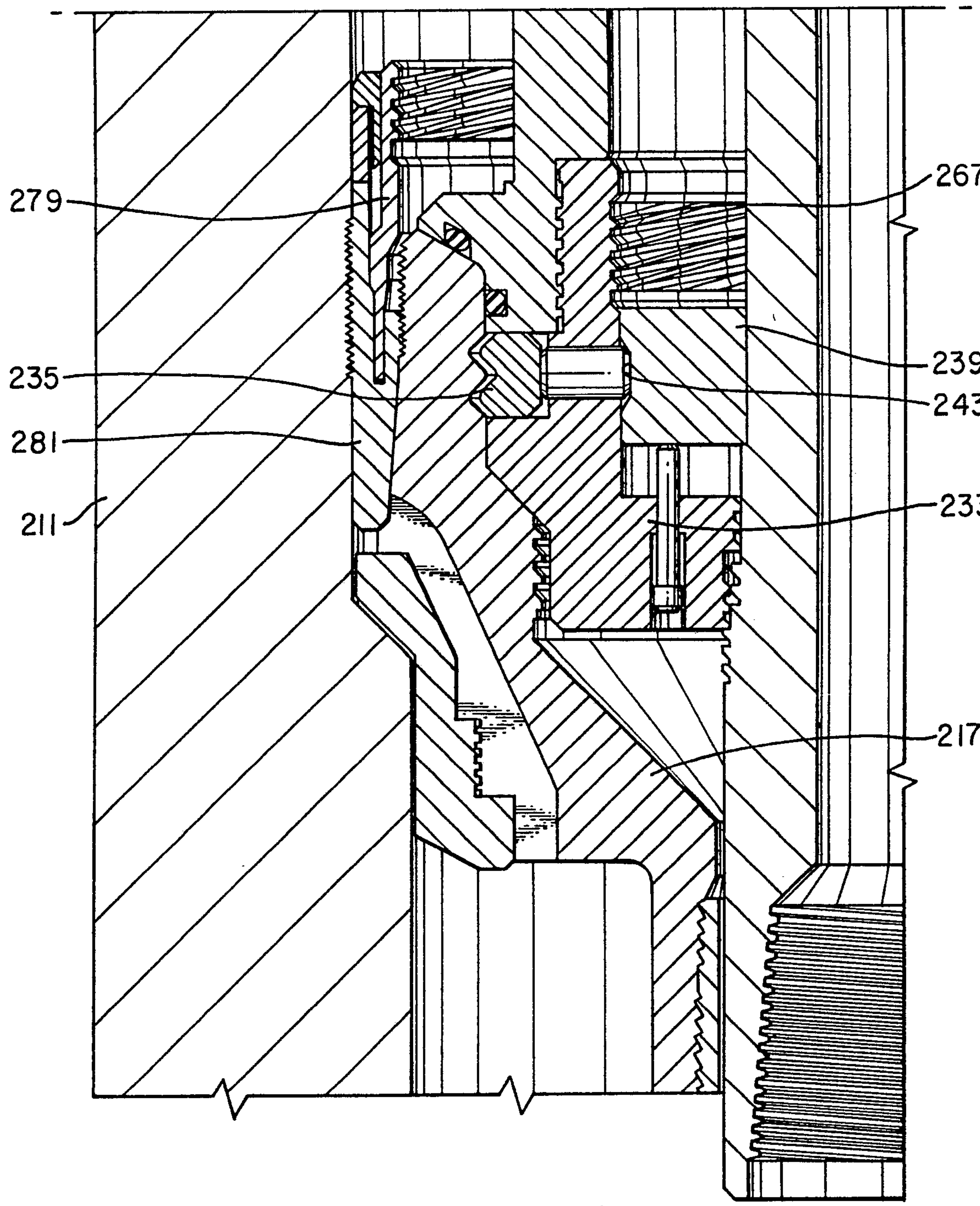
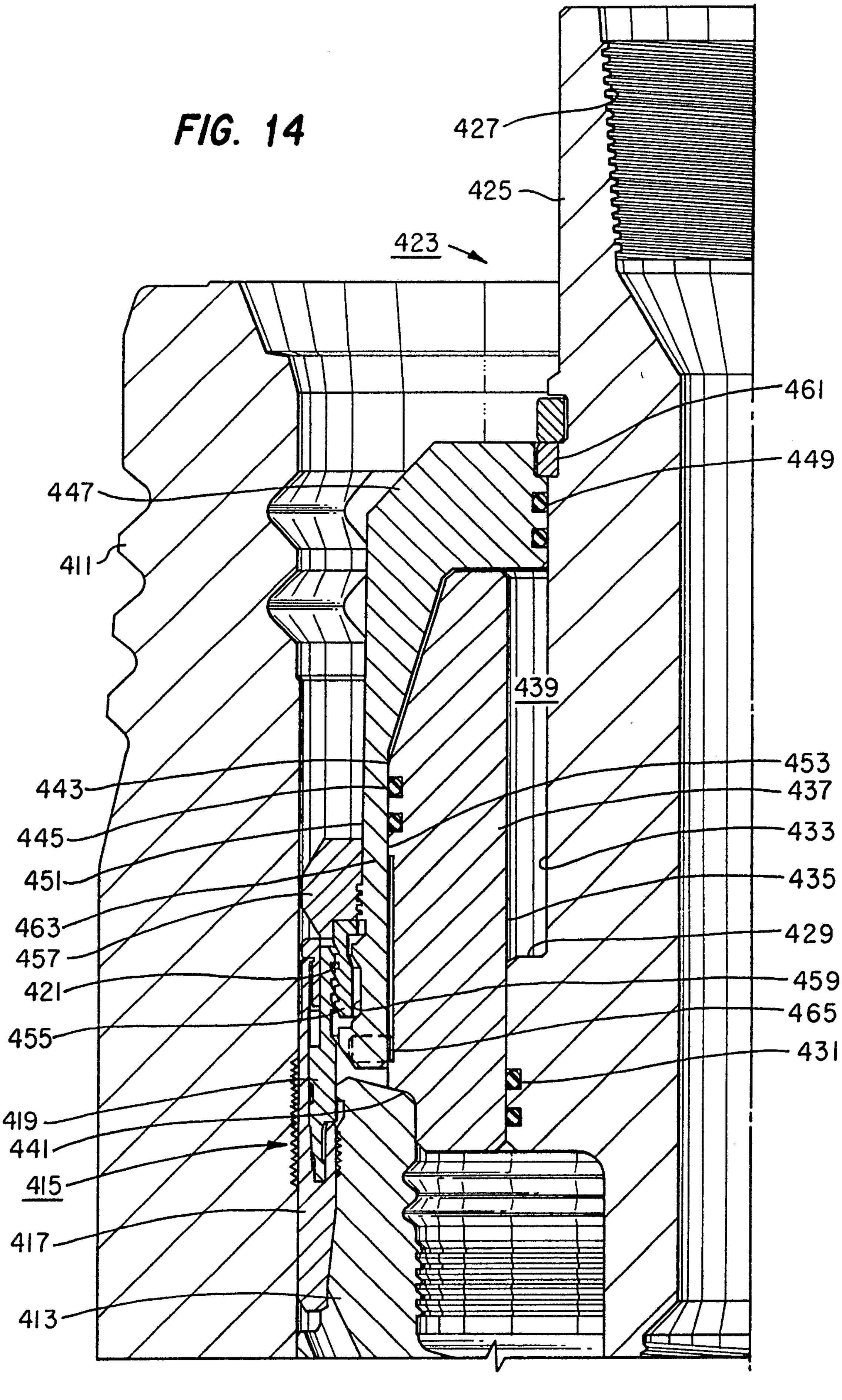



FIG. 13b

*FIG. 14*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421
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465
455
431
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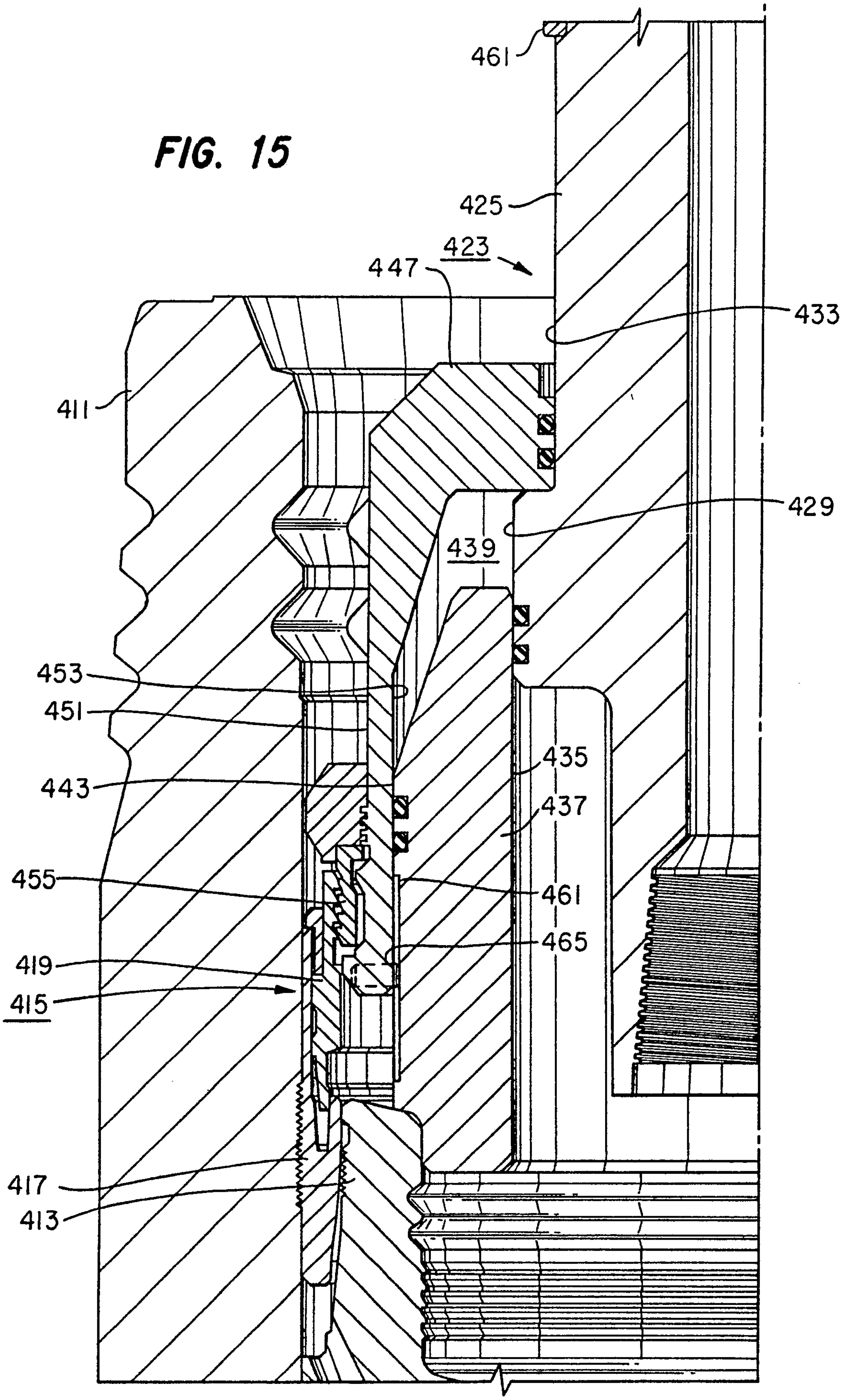
441
415
417
413

FIG. 15


461
425
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435
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461
465
419
415
417
413

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 89 63 0226

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
|---|---|---|---|
| A | EP-A-0 289 108 (CAMERON)<br>* Column 4, lines 10-20; figure 4 *<br>--- | 1 | E 21 B 33/043 |
| A | US-A-3 693 714 (B. BAUGH)<br>* Column 9, lines 43-67; figure 3 *<br>--- | 1 | |
| A | US-A-3 520 360 (J. KISLING)<br>* Column 4, line 62 - column 5, line 1; figures 2a,b *<br>--- | 1 | |
| A | US-A-3 360 049 (J. KISLING)<br>* Column 4, line 68 - column 5, line 16; figure 5 *<br>--- | 1 | |
| A | GB-A-2 160 241 (J. GRASER)<br>* Page 2, lines 42-51; figure 1 *<br>----- | 1 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

E 21 B

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 30-03-1990 | RAMPELMANN K. |

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