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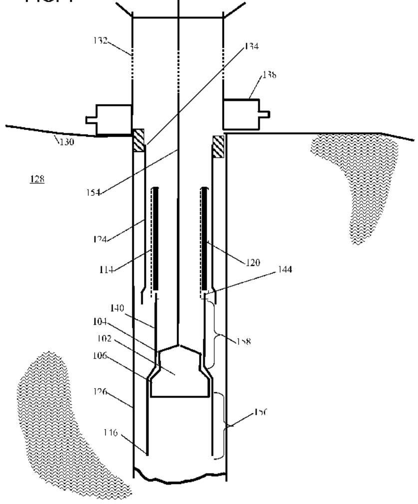
(54) Title: MODIFYING EXPANSION FORCES BY ADDING COMPRESSION

FIG. 1



(57) Abstract: A method for expanding a tubular in a borehole, the tubular having upper and lower ends, the system comprises a) applying a compressive load to the upper end of the tubular and b) expanding the tubular by moving an expansion device relative to the tubular while maintaining the compressive load. Step a) may include resting a weight on the upper end of the tubular or applying hydraulic pressure to the upper end of the tubular. The lower end of the tubular may engage the formation before step b) or as a result of step b).

WO 2010/059536 A2

MODIFYING EXPANSION FORCES BY ADDING COMPRESSION

RELATED APPLICATIONS

[0001] This application claims priority to application Serial No 61/115787 and is related to application Serial No 61/115779, filed concurrently herewith, entitled "Modifying Expansion Forces by Adding Compression."

STATEMENTREGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

TECHNICAL FIELD OF THE INVENTION

[0003] The present disclosure relates generally to a system and a method for expanding an expandable casing in a drilled hole. More particularly, the present invention relates to methods for reducing the amount of expansion force that is required to expand the casing.

BACKGROUND OF THE INVENTION

[0004] Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval typically has a smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cements is typically provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall.

[0005] As a consequence of this nested arrangement, a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. In addition, the small diameter casing that is required at the bottom of the hole may not allow desired flow rates of drilling fluid. For these reasons, it may be desirable to expand the diameter of one or more strings of casing so as to reduce the diameter reduction(s) that would otherwise be necessary. Expandable casings are known in the art.

[0006] Expanding the diameter of an upper casing interval allows lower casing intervals to have a greater diameter, since wider sections of pipe will fit through the expanded upper interval casing. Expansion of the casing may be accomplished by passing a mandrel through the casing, among other techniques. The mandrel is typically frustoconical in shape and has a diameter greater than the unexpanded diameter of the casing. In a bottom-up technique, the mandrel is typically placed at the bottom of the casing interval before the casing interval is inserted into the borehole. In some instances, the expandable casing may be lowered into the borehole on the mandrel. After the casing and the mandrel are placed into the borehole, the mandrel is drawn upward through the unexpanded casing, thereby expanding the casing.

[0007] If the expandable casing is resting on and supported by the mandrel, applying an upward force on the mandrel will cause the casing to move upward. In other instances, the casing may not be supported on the mandrel, but the available upward force on the mandrel is insufficient to overcome the expansion force required to begin radially expanding the casing. In either case, it is desired to reduce the expansion force that is required.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The following figures form part of the present specification and are included to further demonstrate certain aspects of the present claimed subject matter, and should not be used to limit or define the present claimed subject matter. Consequently, a more complete understanding of the present embodiments and further features and advantages thereof will be acquired by referring to the following description taken in conjunction with the accompanying drawings, wherein:

[0009] **FIG. 1** is a schematic diagram depicting a system for expanding a pipe, according to one embodiment of the present invention;

[0010] **FIG. 2** is a schematic diagram depicting another system for expanding a pipe, according to a second embodiment of the invention;

[0011] **FIG. 3** is a schematic diagram depicting yet another system for expanding a pipe, according to a third embodiment of the invention;

[0012] **FIG. 4** is a schematic diagram depicting yet another system for expanding a pipe, according to a fourth embodiment of the present invention; and

[0013] FIG. 5 is a schematic diagram depicting yet another system for expanding a pipe, according to a fifth embodiment of the invention.

[0014] It is to be noted, however, that the appended drawings illustrate only certain embodiments of the present claimed subject matter and are, therefore, not to be considered limiting of the scope of the present claimed subject matter, as the present claimed subject matter will admit to other equally effective embodiments.

[0015] It will be understood that the Figures are not to scale and are not intended to illustrate the size or relative sizes of the components. In addition, it will be understood that the concepts that are illustrated herein with respect to a vertical borehole are equally applicable to curved, deviated, and otherwise non-vertical boreholes.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Referring to FIG. 1, a first liner 124 is placed inside a borehole 126 within a formation 128. If the well is offshore, borehole 126 is drilled from a rig resting on the seafloor, a floating rig, or other vessel. In that case, a riser 132, comprising a long tube of steel from the sea floor to a surface vessel, allows drilling mud to be pumped into borehole 126 and returned to the surface.

[0017] As is known in the art, first liner 124 has an upper end 134, which may be fixed in the borehole by filling the annulus between first liner 124 and formation 128 with cement. Upper end 134 may be coupled to a blowout preventer (BOP) 138, which can be closed in the event that excess formation pressure threatens to blow out the well.

[0018] In a typical operation, a drilling cycle continues until the desired depth is reached, whereupon the drill bit is removed and first liner 124 is lowered into the borehole. First liner 124 is then expanded and/or cemented, if desired. The drill bit is then reinserted into borehole 126, though first liner 124, and a second drilling cycle begins and continues until the next desired depth is reached. The drill bit is again removed, and second liner 140 is inserted through first liner 124 and into borehole 126. The outer diameter of second liner 140 is smaller than the inner diameter of first liner 124, providing clearance as second liner 140 is passed through first liner 124. Liner 140 has an upper end 144 and a lower end 146.

[0019] If desired, second liner 140 may be expanded, and the drilling cycles can be continued through first liner 124 and second liner 140. Typically, one or more intervals of casing will already be positioned in borehole 126 before second liner 140 is placed in borehole 126.

[0020] Expansion of liner 140 may be carried out by pulling an expansion cone 102 upwardly through liner 140. Alternatively, expansion may be carried out by providing a hydraulic expansion device that provides a radial expansion force and is moved incrementally through liner 140. Regardless of how expansion is carried out, it is necessary to overcome the yield strength of the pipe in order to deform it to its expanded diameter.

[0021] Expansion cone or mandrel 102 preferably includes a narrow portion 104 that can fit within liner 140 and a wide portion 106 that has a larger diameter than liner 140. The wide portion 106 preferably has a diameter that is smaller than the inner diameter of first liner 124, so that that mandrel 102 can be removed from the casing and drawn up to the surface after expanding liner 140.

[0022] Mandrel 102 is preferably suspended from a drill string 154 or other guide string, such as are known in the art, that passes through liner 124 and liner 140. As it passes through liner 140, mandrel 102 will plastically deform liner 140 radially outward, thereby increasing the inner diameter (and, generally, the outer diameter) of liner 140.

[0023] In accordance with one embodiment of the present invention, a pressure mechanism 114 is applied to liner 140 in order to facilitate expansion of liner 140. For example, in the embodiment of FIG. 1, a ballast pipe 120 may be included at the upper end of second liner 140. Ballast pipe 120 preferably remains within first liner 124 when second liner 140 has been lowered to its desired depth. The weight of ballast pipe 120 applies downward compressive force on the upper end of liner 140. The weight of ballast pipe 120 and the weight of liner 140 itself result in a combined axial compressive load at the bottom of liner 140.

[0024] It has been found that applying an axial compressive load to an expandable pipe decreases the radial expansion force that is required to plastically deform the pipe. Thus, applying a ballast pipe 120 to the upper end of liner 140 results in a reduction of the required expansion force. When liner 140 is resting on mandrel 102, the added weight of ballast pipe 120 also results in an increased expansion force applied by the expansion cone to the liner 140. Thus, if the required expansion force is decreased and the applied expansion force is increased until the two become equal, the application of a ballast pipe or other weighting device to the upper end of liner 140 can be used to initiate radial expansion of liner 140. Even if liner 140 is not resting on mandrel 102, such as in cases where liner 140 is resting on the borehole bottom, the added weight of ballast pipe 120 still results in a reduction of the required expansion force. Thus, the use of a ballast pipe or other weighting device is advantageous regardless of whether liner 140 is supported on the expansion device and regardless of whether the expansion device is moving upwardly or downwardly through liner 140.

[0025] During expansion, liner 140 will have an expanded portion 156 and an unexpanded portion 158. As mandrel 102 continues to be drawn upward from lower end 146 toward upper end 144, expanded portion 156 will lengthen until there is nothing left of unexpanded portion 158. Mandrel 102 is preferably sufficiently narrow to fit through first liner 124 and be retrieved from the surface when drawn upward by a pipe string or other device 154.

[0026] It should be noted that mandrel 102 need not move upward relative to second liner 140; downward movement is also contemplated. Similarly, and as discussed below, liner 140 may be pushed downward over mandrel 102, or both items may move simultaneously relative to the borehole. Also, radial expansion force may be applied to liner 140 without use of a mandrel, such as through application of hydraulic pressure or mechanical force. If desired, explosives or high-pressure chemical reactions may also or alternatively be used to move mandrel 102 through the pipe.

[0027] FIG. 2 is a schematic diagram depicting another system for expanding a pipe, and includes at least one aspect of the present invention. The various elements shown in FIG. 2 are similar to like-numbered elements of FIG. 1. However, as shown in the system of FIG. 2, the ballast that is shown as a separate device 120 in FIG. 1 may instead comprise part of liner 140. For example, liner 140 will be slid entirely though first liner 124 until a desired portion 142 is below liner 124. The portion 143 of liner 140 that lies within liner 124 functions as a weight resting on the lower portion 142 of liner 140. As described above, the weight of upper portion 143 increases compressive force, reduces required expansion force, and may increase applied expansion force in lower portion 142. In this embodiment, it is preferred to provide means, such as are known in the art, for severing the portion of the pipe that serves as ballast from the rest of the pipe, so that the ballast can be removed from the borehole.

[0028] It will be understood that various other mechanisms for providing a weight or ballast pipe may be used. For instance, the ballast pipe may have a diameter that is unequal to the diameter of liner 140, with the result that ballast pipe cannot rest directly on liner 140. In these instances, the weight of the ballast pipe can be transferred to liner 140 by any suitable weight transfer mechanism at the interface between the ballast pipe and liner 140. Devices for coupling the ballast pipe or weight to liner 140 include but are not limited to hooks, pegs, teeth, braces, or the like, which may engage corresponding holes, slots, ridges or the like, or otherwise engage liner 140. The weight of ballast pipe 120 is thus preferably supported until mandrel 102 has passed fully through expandable portion 142, whereupon the weight of ballast pipe 120 is transferred to mandrel 102 for removal from the borehole.

[0029] Of course, if liner 140 is supported on the expansion device, it is preferred that the total downward force at bottom of second liner 140 not be so great that it overcomes the expansion force prematurely, or liner 140 would slide down over mandrel 102 before it was lowered to the desired position. Thus, either the ballast can be applied to the upper end of liner 140 after liner 140 has been positioned at the desired axial position in the borehole, or the ballast can be applied when liner 140 is not resting on the expansion device. In the former case, it will be preferred to provide some means for preventing the expanded liner 140 from falling downwardly into the borehole, such as by ensuring that the expanded liner 140 engages the borehole wall. Alternatively, the bottom of the expandable can be supported by something other than mandrel 102, e.g. either the expandable is resting on the borehole bottom or the bottom of the expandable has been expanded (using a jack) and is "set" against the borehole wall. In that case, the added compression merely makes it easier to expand the expandable.

[0030] Mandrel 102 may have a starting angle that provides a relatively large axial compression and a relatively small radial expansion to lower end 146 of liner 140 as mandrel 102 enters liner 140. Mandrel 102 may also have an expansion angle that is more tapered than the starting angle and that provides a relatively smaller axial compression and relatively greater radial expansion than the starting angle as mandrel 102 moves through second liner 140. A reverse situation is also possible: mandrel 102 may have a starting angle that is very tapered and that provides a relatively large radial expansion and only a relatively small axial compression to liner 140. Mandrel 102 may also have an expansion angle that is provides more axial compression and less radial expansion than the starting angle. Mandrels with more than two angles are also contemplated.

[0031] Ballast pipe 120 may comprise any suitable material and need not be expandable. Any weight or other means of providing an axial compression, force or pressure on second liner 140 may be used as ballast pipe 120. Liner 140 is preferably fabricated of an expandable material. Thus, mandrel 102 simply carries ballast pipe 120 out of the borehole when mandrel 102 is withdrawn from the well.

[0032] FIG. 3 is a schematic diagram depicting yet another system for expanding a pipe. The various elements shown in FIG. 3 are similar to like-numbered elements of FIG. 1 and FIG. 2. However, as shown in the system of FIG. 3, ballast pipe 12O.may be replaced by other means of providing axial compression on liner 140. If desired, for example, a pressure mechanism 114 may include a cup 122 (or a gripper, or a wedge) adjacent to upper end 144 of liner 140. The application of fluid pressure behind (above) cup 122 will cause cup 122 to deform against the inside of liner 124, forming a seal. Further pressure will cause cup 122 to bear on upper end 144 of liner 140. In this manner, cup 122 can apply a compressive force to upper lip 144 of liner 140, thereby resulting in the same benefits as ballast member 120. Stationary while an upward compressive force or pressure is applied to lower lip 146 of second liner 140. .

[0033] Referring now to FIG. 4 pressure mechanism 114 includes an alternative mechanism for providing axial compression to liner 140. In this embodiment, pressure mechanism 114 includes a first diaphragm 148, which may be coupled to first liner 124, and a second diaphragm 150, which may be coupled to upper lip 144 of second liner 140. First diaphragm 148 is preferably not coupled to string 154. A hydraulic line 152 provides fluid access to the space 159 between first and second diaphragms 148, 150. Pumping fluid through line 152 into space 159 results in the application of a compressive force to upper end 144 of liner 140. In contrast to the embodiment shown in FIG. 3, the embodiment shown in FIG. 4 does not require filling the entire volume of liner 124 with pressurized fluid. Hydraulic line 152 may comprise a hose or other suitable device, such as are known in the art.

[0034] Referring now to FIG. 5, pressure mechanism 114 may alternatively include a upper diaphragm 148 that is coupled to mandrel 102, rather than to first liner 124. Hydraulic line 152 supplies fluid pressure to the space 159 between upper diaphragm 148 and lower diaphragm 150. In this embodiment, the fluid pressure will force lower diaphragm 150 downward from first diaphragm 148, while simultaneously forcing upper diaphragm 148 upward, thereby drawing mandrel 102 upward through liner 140. Upper diaphragm 148 and lower diaphragm 150 cooperate to apply an axial compressive force to second liner 140.

[0035] In the embodiments shown in to FIG. 4 and to FIG. 5, the application of hydraulic pressure will result in increased compressive force on liner 140.

[0036] In one implementation, the downward compressive force that is applied to liner 140 will approximately equal the upward axial force that is applied by the mandrel. Accordingly, the upward axial force applied by the mandrel and the compressive force in the second axial direction will provide a net zero axial force, such that the only net force on the pipe is radially outward. In another implementation, the compressive force that is applied in the second axial direction will be substantially greater than the upward axial force that is applied by the mandrel. In this case, if the liner is not resting on something (such as the borehole bottom), the downward force may be sufficient to move the pipe past the mandrel. In another implementation, the bottom of the pipe engages the borehole wall such that the wall applies a downward force in opposition to the upward force applied by the mandrel. In this case, the applied compressive facilitates expansion by reducing the required expansion force. In another, less desirable implementation, the upward axial force that is applied by the mandrel causes the mandrel to move upward through the pipe, while expanding the pipe.

[0037] In some embodiments, a jack may be used to initiate deformation (i.e. movement of the mandrel relative to the pipe). The pressure mechanism serves to increase compressive force on the pipe at the expansion point, thereby reducing the expansion (jacking) force.

[0038] Several implementations and embodiments have thus been described. It will be appreciated, however, that other implementations and embodiments will also be substituted within the scope of this disclosure. For example, the mandrel may be replaced with an electromechanical device (such as a motor) that can apply a radial force that is greater than the tension within the drill string, and that is also greater than the weight of the fluid in the well. The electromechanical device may also include a sensor that can detect cracks or other structural problems within the pipe, and may be able to adjust a magnitude of the radial force in accordance with an ability of the pipe to sustain the radial force without damage.

[0039] Thus, although the invention has been described with reference to several exemplary embodiments, it is understood that the words that have been used are words of description and illustration, rather than words of limitation. Although the invention has been described with reference to particular means, materials and embodiments, the invention is not intended to be limited to the particulars disclosed; rather, the invention extends to all functionally equivalent structures, methods, and uses such as are within the scope of the appended claims.

CLAIMS

1. A method for expanding a tubular in a borehole, the tubular having upper and lower ends and an expansion device positioned below the upper end, the method comprising:

   a) applying a compressive load to the upper end of the tubular; and

   b) expanding the tubular by moving the expansion device toward the upper end of the tubular while maintaining said compressive load.

2. The method of claim 1 wherein step a) includes resting a weight on the upper end of the tubular.

3. The method of claim 1 wherein step a) includes applying hydraulic pressure to the upper end of the tubular.

4. The method of claim 3 wherein step a) includes forming a moveable fluid seal above the upper end of the tubular and applying fluid pressure above the seal so as to cause the seal to bear on the upper end of the tubular.

5. The method of claim 3 wherein step a) includes forming a hydraulic chamber above the upper end of the tubular and applying fluid pressure within the chamber so as to cause the chamber to bear on the upper end of the tubular.

6. The method of claim 5 wherein the expansion device is a mandrel and applying fluid pressure to the chamber also causes the mandrel to move relative to the tubular.

7. The method of claim 1, further including the step of engaging the formation with the lower end of the tubular before step b).

8. The method of claim 7 wherein the lower end of the tubular does not engage the formation before step b).

9. The method of claim 8 wherein the lower end of the tubular engages the formation as result of step b).

10. The method of claim 7, further including the step of resting the tubular on the bottom of the borehole before step b).

FIG. 1

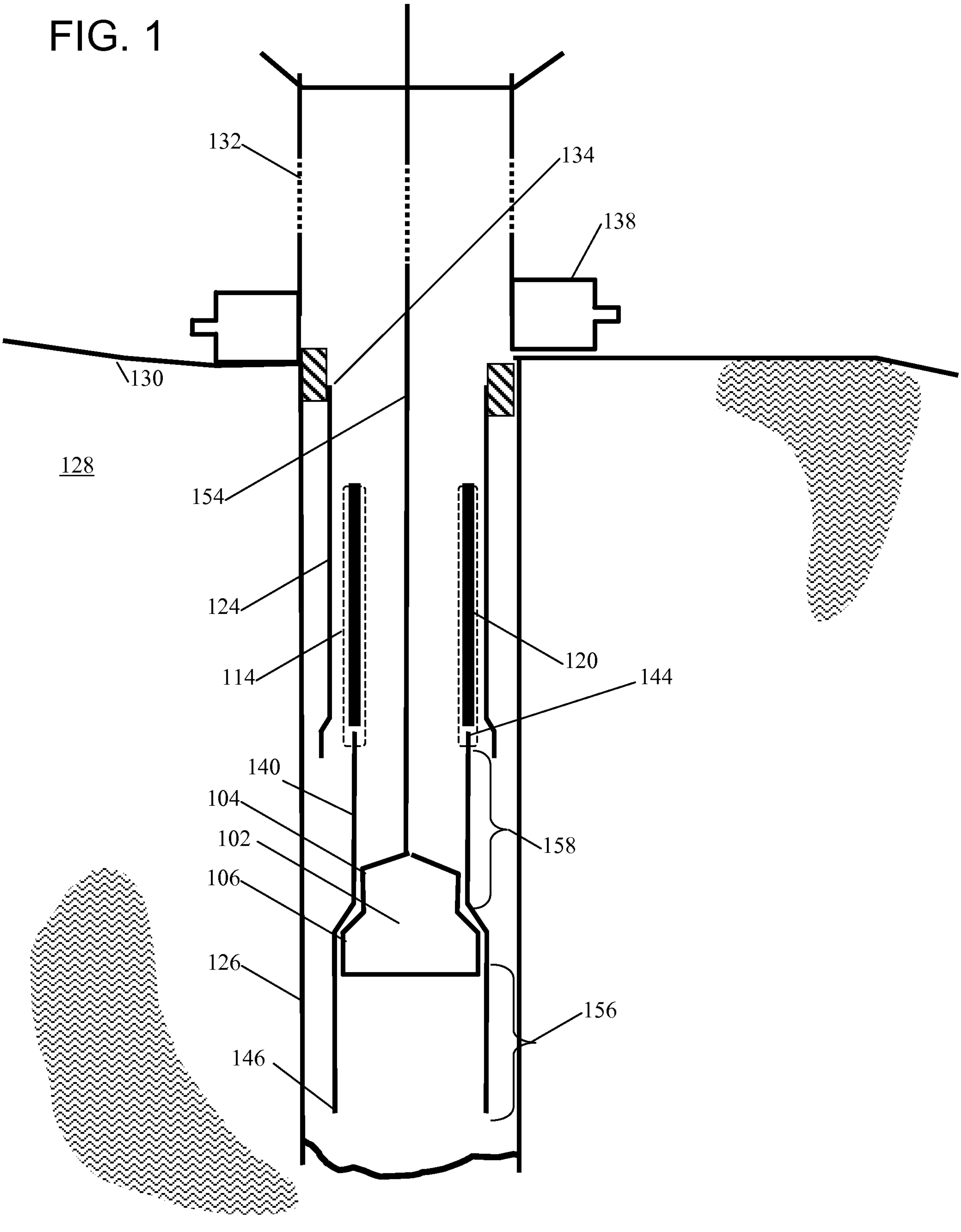

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FIG. 2

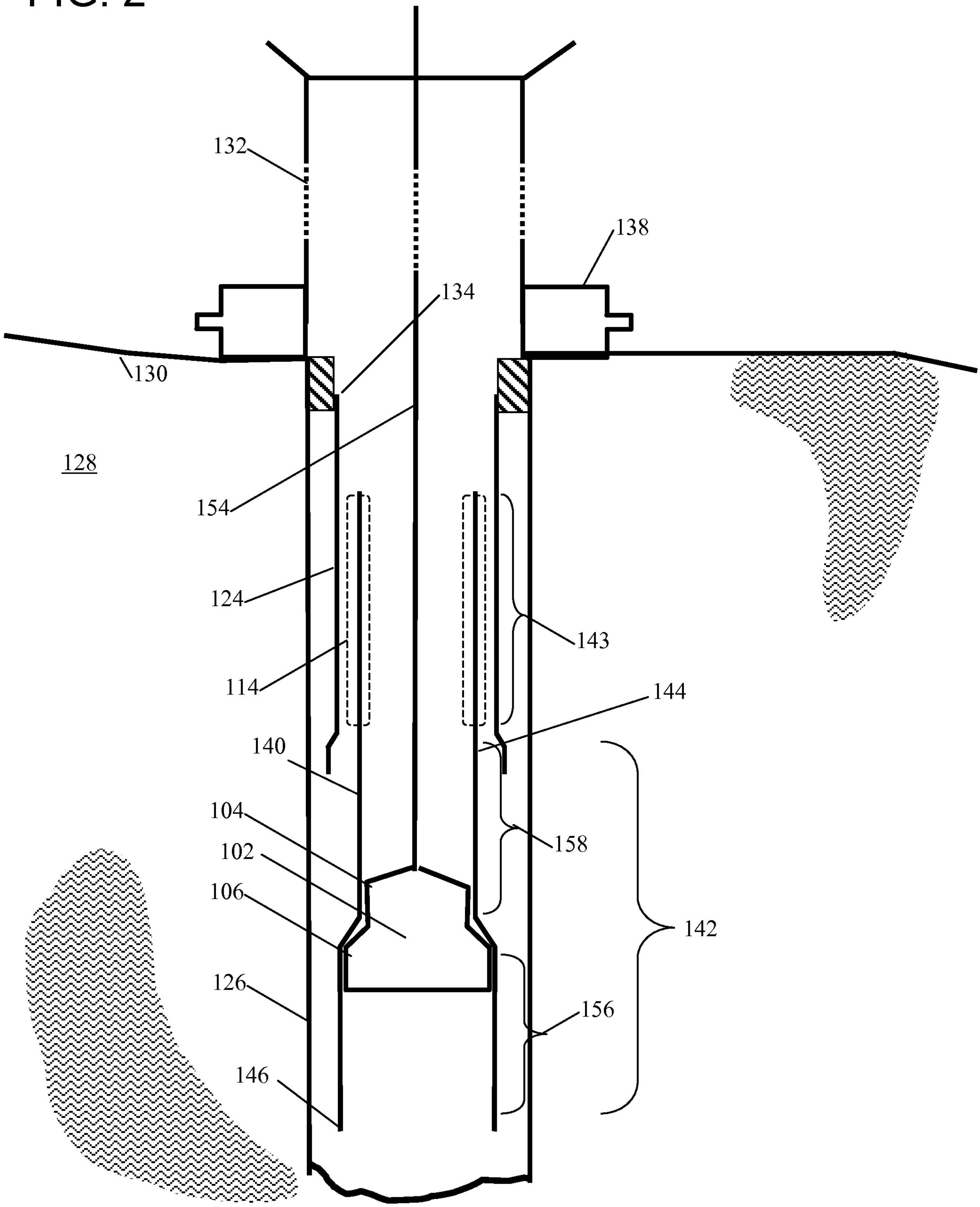
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FIG. 3

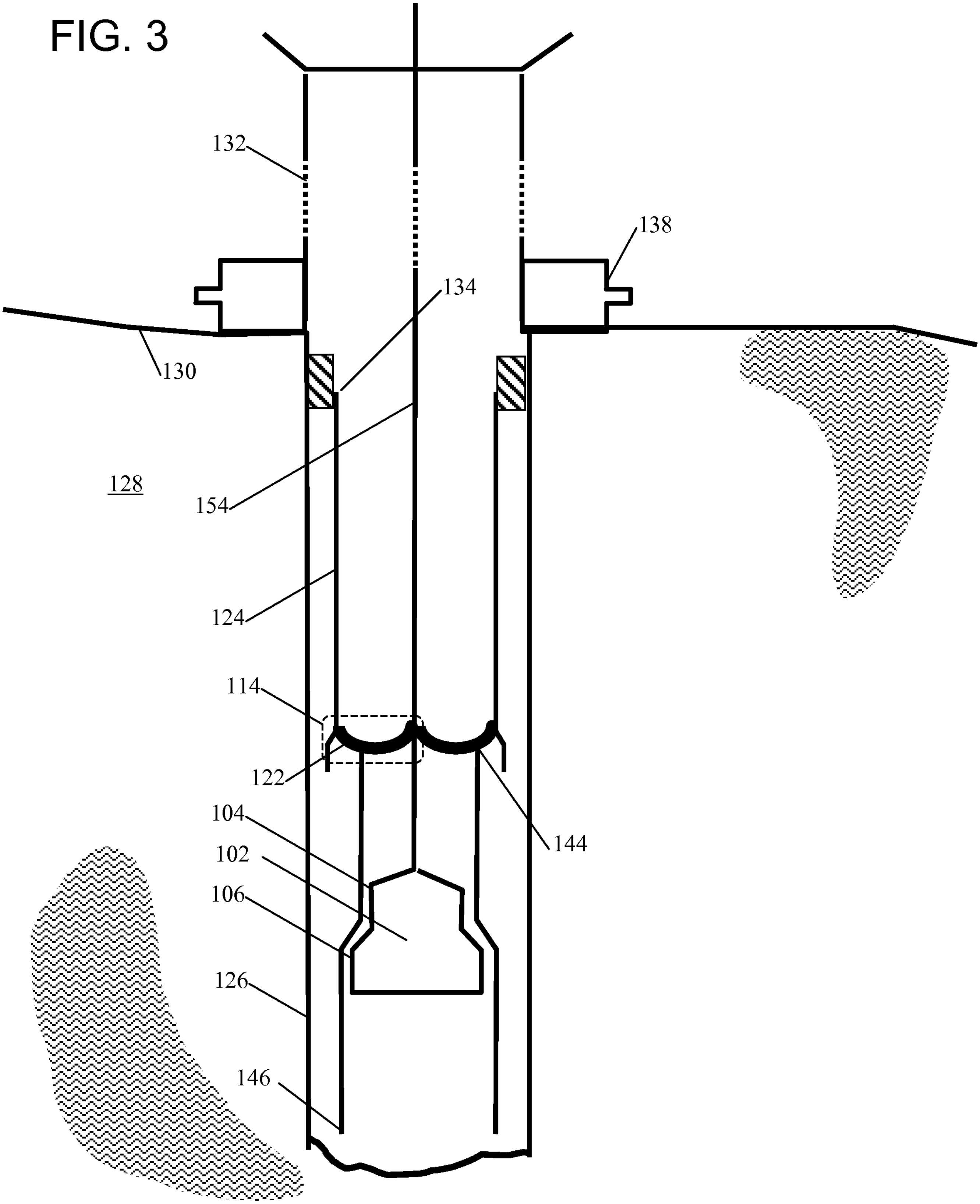

FIG. 4

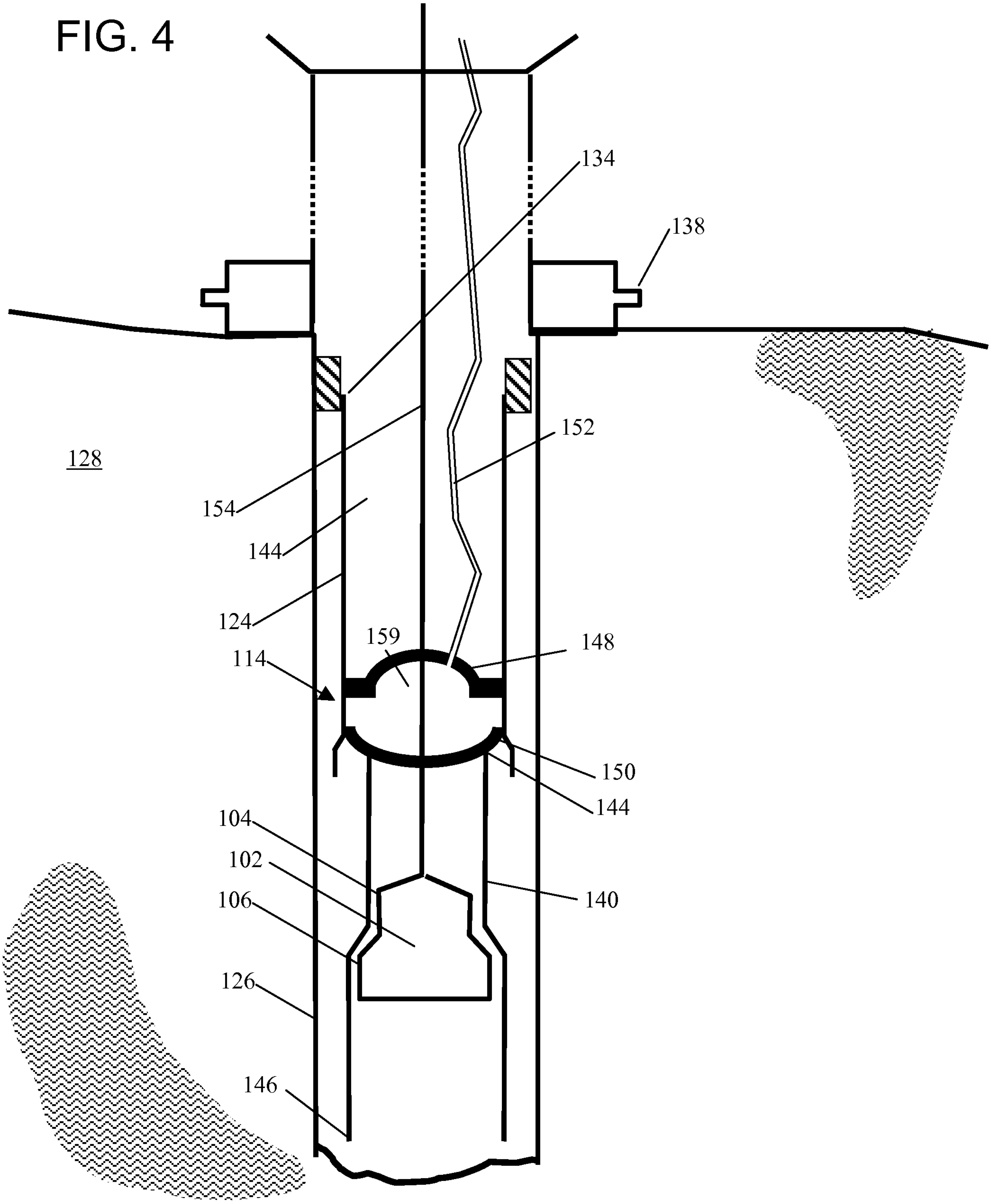
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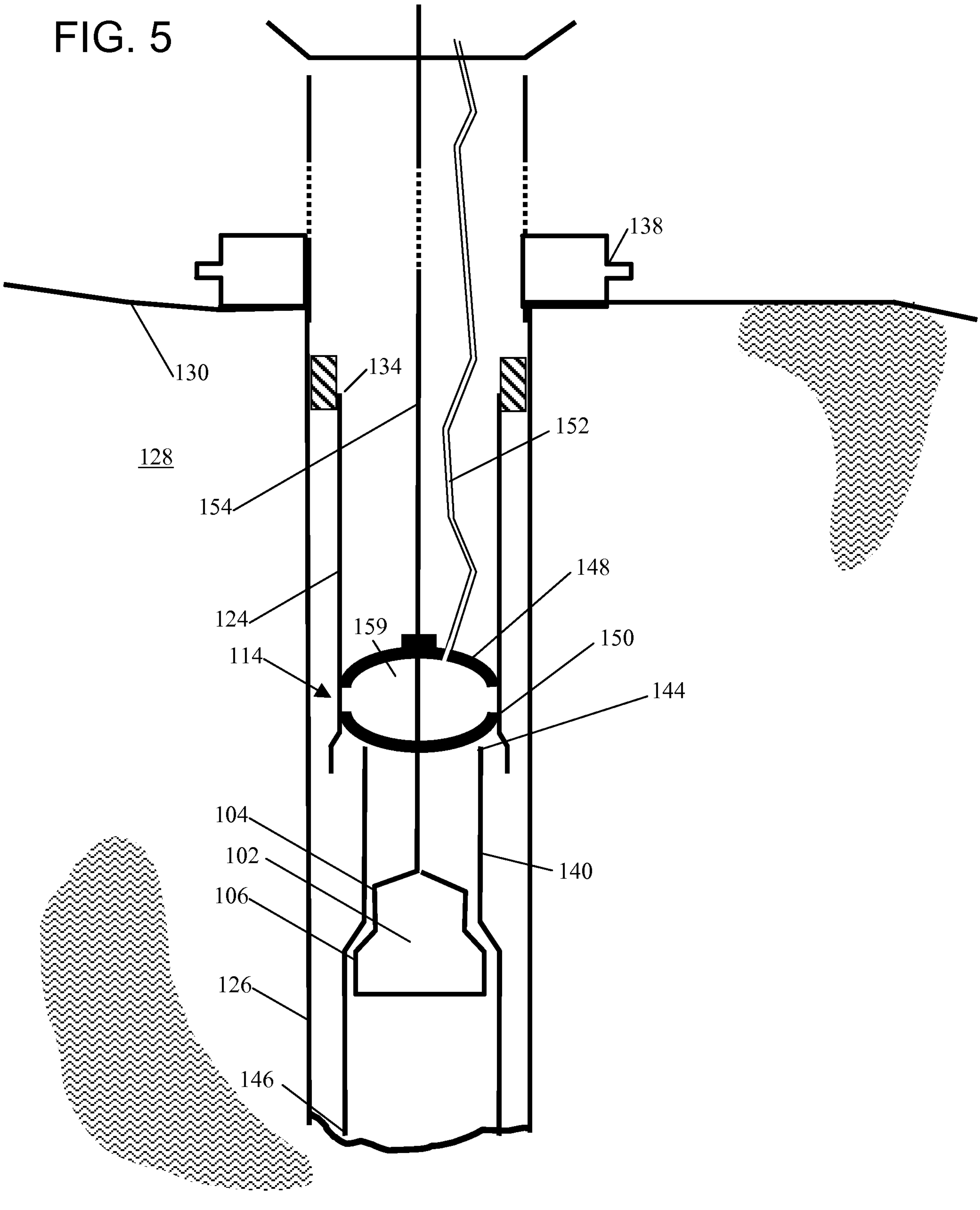
FIG. 5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