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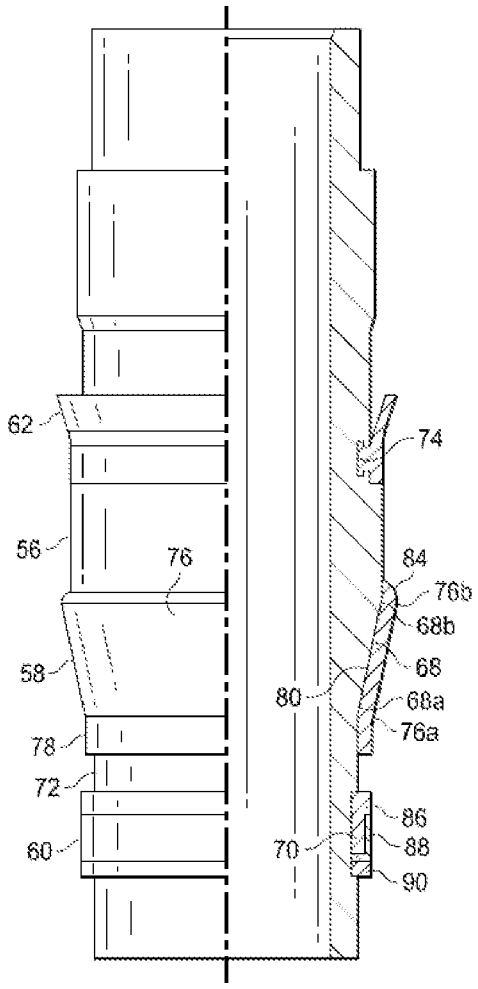
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(54) Title **Collapsible cone for an expandable liner hanger system**

(56) References Cited: US 2012/0222868 A1

(57) Abstract

An expandable liner hanger system and method of installing same. In an exemplary embodiment, the method includes positioning the expandable liner hanger system within a casing string, the expandable liner hanger system including a setting tool disposed within a hanger body, the setting tool including a cone mandrel defining a tapered external surface and an expansion cone defining a tapered internal surface; engaging the tapered external surface with the tapered internal surface; radially expanding the hanger body to engage the casing string by displacing the cone mandrel and the expansion cone in a first axial direction and relative to the hanger body; displacing the cone mandrel in a second axial direction and relative to the expansion cone to disengage the tapered internal surface from the tapered external surface, thus permitting the expansion cone to bell radially inward from the hanger body; and extricating the expansion cone from the hanger body.



Technical Field

The present disclosure relates generally to expandable liner hanger systems, and, more specifically, to a setting tool including a collapsible cone for an expandable liner hanger system.

Background

Expandable liner hanger systems operate, for example, by utilizing a setting tool to promote the expansion of a liner hanger, thus connecting the liner hanger to a casing string disposed within a wellbore. In order to effectuate the expansion of the liner hanger, an expansion cone is displaced axially through the liner hanger, thus engaging the interior of the liner hanger to radially expand the exterior thereof. The forces required to expand a liner hanger in this manner, which can be considerable, are a function of the geometry, material properties, and friction reducing coatings applied to the expansion cone and/or the liner hanger.

Certain differences in hardness and/or other basic metallurgical properties between the liner hanger and the expansion cone can help to mitigate galling between the respective contacting surfaces thereof, even if the friction reducing coating(s) becomes compromised. Accordingly, conventional liner hangers are manufactured with highly ductile low alloy steel, the expansion of which can be effectuated using an expansion cone manufactured with, for example, D2 tool steel. However, some liner hangers incorporate nickel and chromium-based alloys to provide corrosion resistance within the wellbore. Conventional expansion cones do not have the proper material properties to effectively expand such nickel and chromium-based liner hangers. Further, the use of more effective materials is often prohibitively expensive because of the geometry of conventional expansion cones.

Moreover, conventional expansion cones are often difficult or impossible to remove from the liner hanger once the liner hanger has been expanded. Although collapsible expansion cones exist to address this issue, such collapsible expansion cones often incorporate a collet feature that permits the expansion cone to bend radially inward

from the interior of the liner hanger. However, the machined slits of the collet feature create high contact stresses along the respective edges of the slits, which stresses can cause damage to, among other things, the friction reducing coating(s) applied to the liner hanger and/or the expansion cone.

Furthermore, some expansion cones require a sealing interface between the expansion cone and the interior of the liner hanger so that the expansion cone may be actuated by a fluid pressure. The machined slits associated with conventional collapsible expansion cones necessitate the use of a "lead cone" that has no slits, surface features, or other geometry that could create a leak path. Such a "lead cone" necessarily has a smaller diameter than the collapsible expansion cone, thereby reducing the effective axial force imparted to the setting tool by the fluid pressure.

Therefore, what is needed is an apparatus, method, or system that addresses one or more of the foregoing issues, among others.

Brief Description of the Drawings

Various embodiments of the present disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. In the drawings, like reference numerals may indicate identical or functionally similar elements.

Figure 1 is a schematic illustration of an offshore oil and gas platform operably coupled to an expandable liner hanger system, according to an exemplary embodiment.

Figure 2 is a partial-sectional view of the expandable liner hanger system of Figure 1, including a setting tool and a hanger body, according to an exemplary embodiment.

Figure 3 is a partial-sectional view of a cone mandrel, which is a component of the setting tool of Figure 2, according to an exemplary embodiment.

Figure 4 is a partial-sectional view of a collapsible expansion cone, which is another component of the setting tool of Figure 2, according to an exemplary embodiment.

Figure 5 depicts the cone mandrel of Figure 3 and the collapsible expansion cone of Figure 4, along with other components of the setting tool, in an assembled state,

according to an exemplary embodiment.

Figure 6A is a partial-sectional view of the expandable liner hanger system of Figures 1-5 disposed within a wellbore and proximate the lower end of a casing string, according to an exemplary embodiment.

Figure 6B is a partial-sectional view of the expandable liner hanger system of Figure 6A in a partially-expanded state, according to an exemplary embodiment.

Figure 6C is a partial-sectional view of the expandable liner hanger system of Figures 6A and 6B in a fully-expanded state, according to an exemplary embodiment.

Figure 6D(i) is an enlarged view of the expandable liner hanger system of Figure 6C, with the hanger body expanded and the setting tool in a first configuration, according to an exemplary embodiment.

Figure 6D(ii) depicts the expandable liner hanger system of Figure 6D(i), with the hanger body expanded and the setting tool in a second configuration, according to an exemplary embodiment.

Figure 6D(iii) depicts the expandable liner hanger system of Figures 6D(i) and (ii), with the hanger body expanded and the setting tool in a third configuration, according to an exemplary embodiment.

Detailed Description

This disclosure may repeat reference numerals and/or letters in the various examples or Figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the Figures. For example, if an apparatus in the

Figures is turned over, elements described as being “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Moreover, even though a Figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well suited for use in wellbores having other orientations including vertical wellbores, horizontal wellbores, slanted wellbores, multilateral wellbores or the like. Likewise, unless otherwise noted, even though a Figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well suited for use in onshore operations. Further, unless otherwise noted, even though a Figure may depict a cased-hole wellbore, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well suited for use in open-hole wellbore operations.

Referring to Figure 1, an offshore oil and gas platform is schematically illustrated and generally designated by the reference numeral 10. In an exemplary embodiment, the offshore oil and gas platform 10 includes a semi-submersible platform 12 that is positioned over a submerged oil and gas formation 14 located below a sea floor 16. A subsea conduit 18 extends from a deck 20 of the platform 12 to a subsea wellhead installation 22. One or more pressure control devices 24, such as, for example, blowout preventers (BOPs), and/or other equipment associated with drilling or producing a wellbore may be provided at the subsea wellhead installation 22 or elsewhere in the system. The platform 12 may include a hoisting apparatus 26, a derrick 28, a travel block 30, a hook 32, and a swivel 34, which components are together operable for raising and lowering a variety of conveyance vehicles 36, such as, for example, casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings, and/or other types of conveyance vehicles, such as wireline, slickline, and the like. In the embodiment of Figure 1, the conveyance vehicle 36 is a substantially tubular, axially extending drill string made up of a plurality of drill pipe joints coupled together end-to-end. The platform 12

may also include a kelly, a rotary table, a top drive unit, and/or other equipment associated with the rotation and/or translation of the conveyance vehicle 36. A wellbore 38 extends from the subsea wellhead installation 22 and through the various earth strata, including the formation 14. A portion of the wellbore 38 includes a casing string 40 cemented therein.

As shown in Figure 1, a section of the wellbore 38 has been formed below the casing string 40 through the use of, for example, a bottom-hole assembly (not shown). The bottom-hole assembly is adapted to be connected at the lower end portion of the conveyance vehicle 36 and to extend within the wellbore 38 during drilling operations. The bottom-hole assembly includes, for example, a rotary drill bit adapted to bore through the various earth strata, including the formation 14. The bottom-hole assembly may also include other components such as, for example, a directional drilling tool, a mud motor, a telemetry system, a power generation system, logging-while-drilling tools, measurement-while-drilling tools, drill collars, heavy-weight drill pipe, stabilizers, reamers, jarring devices, hole-openers, crossovers for various threadforms, other downhole components, or any combination thereof. Once the bottom-hole assembly has been utilized to form a section of the wellbore 38, the bottom-hole assembly is removed from the wellbore 38, via the conveyance vehicle 36. Accordingly, Figure 1 illustrates the wellbore 38 after the bottom-hole assembly has been removed.

Still referring to Figure 1, a running tool 42 is connected at the lower end portion of the conveyance vehicle 36. The running tool 42 and the conveyance vehicle 36 are utilized to lower an expandable liner hanger system 44, to which a liner string 46 is connected, into the wellbore 38. More particularly, once the expandable liner hanger system 44 is coupled to the running tool 42, the conveyance vehicle 36 is used to position the running tool 42 and, consequently, the expandable liner hanger system 44, at the lower end portion of the casing string 40, as shown in Figure 1. As a result, the liner string 46 extends downhole from the expandable liner hanger system 44 and into the "open-hole" section of the wellbore 38, below the casing string 40. When the liner string 46 and the expandable liner hanger system 44 are positioned as such, the expandable liner hanger system 44 is adapted to be expanded to engage the interior of the casing string 40, thus securing the expandable liner hanger system 44 and, consequently, the liner

string 46, to the casing string 40. In this manner, the expandable liner hanger system 44 is utilized to extend the "cased-hole" portion of the wellbore 38, as will be discussed in further detail below.

Referring to Figure 2, an exemplary embodiment of the expandable liner hanger system 44 is shown, which embodiment includes a hanger body 48 and a setting tool 50 that extends within the hanger body 48. The hanger body 48, in turn, is adapted to extend within the casing string 40 (as shown in Figure 1).

In an exemplary embodiment, as shown in Figure 2, the hanger body 48 includes a reduced diameter portion 52 having one or more contact elements 54 connected to the exterior thereof. When the hanger body 48 extends within the casing string 40, the reduced diameter portion 52 thereof is adapted to be expanded into engagement with the interior of the casing string 40. Moreover, the contact elements 54 are adapted to form a frictional interface with the interior of the casing string 40 when the reduced diameter portion 52 is expanded, thus connecting the hanger body 48 to the casing string 40. In several exemplary embodiments, the contact elements 54 are, include, or are part of a cylindrical seal made of a rubber material and adapted to form a frictional interface with the interior of the casing string 40 when the reduced diameter portion 52 is expanded. In several exemplary embodiments, the contact elements 54 are, include, or are part of a plurality of casing slips adapted to engage, or "bite" into, the interior of the casing string 40 when the reduced diameter portion 52 is expanded. In several exemplary embodiments, the contact elements 54 are integrally formed with the hanger body 48 and are designed to sealingly engage the interior of the casing string 40 when the hanger body 48 is expanded. In some embodiments, in order to provide corrosion resistance within the wellbore, the hanger body 48 is manufactured from a nickel-based alloy, such as, for example, Incoloy® Alloy 825 and/or Inconel® Alloy G3, among others. In some embodiments, in order to provide corrosion resistance within the wellbore, the hanger body 48 is manufactured from a chromium-based alloy, such as, for example, super 13 chromium alloy, among others.

In an exemplary embodiment, with continuing reference to Figure 2, the setting tool 50 is connected to the running tool 42 and extends within the hanger body 48. The setting tool 50 includes a cone mandrel 56, a collapsible expansion cone 58, and a cone

retainer 60. In several exemplary embodiments, the setting tool 50 also includes a wiper 62 adapted to prevent debris from settling on top of the collapsible expansion cone 58. The cone mandrel 56 has a generally annular shape and is connected to, and extends about, the running tool 42. Moreover, the cone mandrel 56 extends radially between the running tool 42 and the hanger body 48. In several exemplary embodiments, the interior of the cone mandrel 56 is adapted to be engaged by the running tool 42.

The collapsible expansion cone 58 extends circumferentially about the cone mandrel 56 and is adapted to be engaged by the cone mandrel 56 when the cone mandrel 56 is displaced in an axial direction 64. As a result, the cone mandrel 56 is adapted to urge the collapsible expansion cone 58 in the axial direction 64 so that the collapsible expansion cone 58 engages the reduced diameter portion 52 of the hanger body 48. The collapsible expansion cone 58 is thus adapted to be displaced relative to the hanger body 48 to engage, and radially expand, the reduced diameter portion 52 of the hanger body 48, as will be discussed in further detail below.

The cone retainer 60 extends circumferentially about, and is connected to, the cone mandrel 56. Once the reduced diameter portion 52 of the hanger body 48 has been radially expanded by the collapsible expansion cone 58, the cone mandrel 56 is adapted to be displaced in an axial direction 66, which is opposite the axial direction 64, and relative to the collapsible expansion cone 58. As a result, the cone mandrel 56 is adapted to slide axially in relation to the collapsible expansion cone 58. Moreover, the cone retainer 60 is adapted to engage the collapsible expansion cone 58, thereby urging the collapsible expansion cone 58 in the axial direction 66 and relative to the hanger body 48.

Referring now to Figure 3, an exemplary embodiment of the cone mandrel 56 is shown. The cone mandrel 56 defines opposing end portions 56a and 56b. A tapered annular surface 68 is formed in the exterior of the cone mandrel 56. The tapered annular surface 68 defines opposing end portions 68a and 68b, the end portion 68a having a relatively smaller diameter than the end portion 68b. As a result, the wall thickness of the cone mandrel 56 is relatively smaller at the end portion 68a of the tapered annular surface 68 and relatively larger at the end portion 68b thereof. In several exemplary embodiments, the maximum wall thickness of the cone mandrel 56 is located at the end

portion 68b of the tapered annular surface 68. Further, an external annular groove 70 is formed in the exterior of the cone mandrel 56, proximate the end portion 56a thereof. The external annular groove 70 is adapted to accommodate the cone retainer 60. Further still, a generally cylindrical annular contact surface 72 is formed in the exterior of the cone mandrel 56, and extends axially between the tapered annular surface 68 and the external annular groove 70. The annular contact surface 72 is adapted to be slidably engaged by the collapsible expansion cone 58 when the cone mandrel 56 is displaced in the axial direction 66 (as shown in Figure 2) and relative to the collapsible expansion cone 58. In several exemplary embodiments, the cone mandrel 56 also includes an external annular groove 74 adapted to accommodate and retain the wiper 62 to prevent debris from settling on top of the collapsible expansion cone 58.

Referring additionally to Figure 4, an exemplary embodiment of the collapsible expansion cone 58 is shown, which embodiment includes a frusto-conical member 76 and a contact ring 78 connected to one another. In some embodiments, the collapsible expansion cone 58 is manufactured from 8620 alloy steel. In several exemplary embodiments, at least a portion of the collapsible expansion cone 58 is case hardened. In several exemplary embodiments, at least a portion of the collapsible expansion cone 58 is heat treated. In several exemplary embodiments, the collapsible expansion cone 58 has a nominal wall thickness of .035", providing a ductile interior and core beneath the heat treated and/or case hardened exterior of the collapsible expansion cone 58.

In an exemplary embodiment, as shown in Figure 4, the frusto-conical member 76 has a generally annular shape and defines opposing end portions 76a and 76b. A tapered internal annular surface 80 is formed in the interior of the frusto-conical member 76 and extends between the respective end portions 76a and 76b thereof. The tapered internal annular surface 80 has a relatively smaller diameter at the end portion 76a of the frusto-conical member 76 as compared to the end portion 76b thereof. As a result, the tapered internal annular surface 80 is adapted to be complementarily engaged by the tapered annular surface 68 of the cone mandrel 56. A tapered external annular surface 82 is formed in the exterior of the frusto-conical member 76 and extends between the respective end portions 76a and 76b thereof. The tapered external annular surface 82 has a relatively smaller diameter at the end portion 76a of the frusto-conical member 76

as compared to the end portion 76b thereof. Further, the end portion 76a of the frusto-conical member 76 is connected to the contact ring 78. Thus, at the end portion 76a of the frusto-conical member 76, the tapered external annular surface 82 adjoins the exterior of the contact ring 78. A cone crest 84 is formed in the exterior of the frusto-conical member 76 at the end portion 76b thereof, adjacent the tapered external annular surface 82. The tapered external annular surface 82 and the cone crest 84 are each adapted to slidably engage the interior of the reduced diameter portion 52 of the hanger body 48. In several exemplary embodiments, the frusto-conical member 76 is, includes, or is part of the contact ring 78. In several exemplary embodiments, the frusto-conical member 76 is integrally formed with the contact ring 78.

In an exemplary embodiment, with continuing reference to Figure 4, the contact ring 78 has a generally annular shape and defines opposing end portions 78a and 78b. The interior of the contact ring 78 is adapted to slidably engage the annular contact surface 72 of the cone mandrel 56 when the cone mandrel is displaced relative to the collapsible expansion cone 58. The contact ring 78 includes an end face 85 at the end portion 78a thereof. The end face 85 is adapted to be engaged by the cone retainer 60 during operation of the setting tool 50. Further, the end portion 78b of the contact ring 78 is connected to the end portion 76a of the frusto-conical member 76. Thus, at the end portion 78b of the contact ring 78, the exterior of the contact ring 78 adjoins the tapered external annular surface 82 of the frusto-conical member 76. In several exemplary embodiments, the contact ring 78 is generally cylindrical in shape. In several exemplary embodiments, the contact ring 78 is, includes, or is part of the frusto-conical member 76. In several exemplary embodiments, the contact ring 78 is integrally formed with the frusto-conical member 76.

Referring now to Figure 5, the components of the setting tool 50, including the cone mandrel 56, the collapsible expansion cone 58, the cone retainer 60, and the wiper 62, are illustrated in an assembled state.

In an exemplary embodiment, as shown in Figure 5, the interior of the contact ring 78 of the collapsible expansion cone 58 engages, and extends circumferentially about, the annular contact surface 72 of the cone mandrel 56. Moreover, the tapered internal annular surface 80 of the frusto-conical member 76 extends circumferentially

about and engages, or nearly engages, the tapered annular surface 68 of the cone mandrel 56. As a result, the end portion 76a of the frusto-conical member 76 is located at, or near, the end portion 68a of the tapered annular surface 68. The relatively smaller wall thickness of the cone mandrel 56 at the end portion 68a of the tapered annular surface 68 is thus disposed proximate and interior to the end portion 76a of the frusto-conical member 76 and the end portion 78b of the contact ring 78. Moreover, the cone crest 84 and the end portion 76b of the frusto-conical member 76 are located at, or near, the end portion 68b of the tapered annular surface 68. The relatively larger wall thickness of the cone mandrel 56 at the end portion 68b of the tapered annular surface 68 is thus adapted to support the cone crest 84 and the end portion 76b of the frusto-conical member 76 when the collapsible expansion cone 58 engages the interior of the hanger body 48. Moreover, in several exemplary embodiments, the wall thickness of the cone mandrel 56 at the end portion 68b of the tapered annular surface 68 provides the geometry needed to maximize the strength of the cone mandrel 56 directly beneath the cone crest 84 of the collapsible expansion cone 58.

In an exemplary embodiment, with continuing reference to Figure 5, the cone retainer 60 is accommodated within, and extends circumferentially about, the external annular groove 70 of the cone mandrel 56. In several exemplary embodiments, the cone retainer 60 includes a pair of split-rings 86, a split-ring retainer 88, and a retaining ring 90. However, the cone retainer 60 may omit one or more of the split-rings 86, the split-ring retainer 88, and the retaining ring 90 in favor of one or more other components adapted to engage the collapsible expansion cone 58. Moreover, in addition to, or instead of, the cone retainer 60, another type of cone retainer may be utilized. In any event, the cone retainer 60 extends beyond the periphery of the external annular groove 70 and is adapted to engage the contact ring 78 of the collapsible expansion cone 58. The collapsible expansion cone 58 is thus trapped axially between the cone retainer 60 and the tapered annular surface 68 of the cone mandrel 56. In several exemplary embodiments, the wiper 62 is accommodated within, and retained by, the external annular groove 74 of the cone mandrel 56. In this position, the wiper is adapted to prevent debris from settling on top of the collapsible expansion cone 58.

In operation, according to an exemplary embodiment as illustrated in Figures 6A-

6D, the running tool 42 is connected at the lower end of the conveyance vehicle 36 (visible in Figure 1). Further, the expandable liner hanger system 44 and, consequently, the liner string 46, are coupled to the running tool 42 and the conveyance vehicle 36 is used to position the running tool 42 within the casing string 40.

Referring initially to Figure 6A, the expandable liner hanger system 44 is run into the casing string 40, via the running tool 42 and the conveyance vehicle 36, until the reduced diameter portion 52 of the hanger body 48 is located interior to the casing string 40 and at, or near, the lower end portion thereof. In this position, the liner string 46 extends from the hanger body 48 and into the "open-hole" portion of the wellbore 38 (shown in Figure 1). In several exemplary embodiments, once the liner string 46 has been positioned in the wellbore 38 as described, a cementing operation is commenced. For example, cement (not shown) is pumped into the annulus defined between the liner string 46 and the wellbore 38 in order to support the liner string 46 within the wellbore 38. In several exemplary embodiments, during the positioning of the liner string 46 and the subsequent cementing operation, the setting tool 50 is disposed within the hanger body 48, but is not yet engaged with the interior of the reduced diameter portion 52.

Referring to Figure 6B, once the hanger body 48 is suitably positioned and the cementing operation is completed, the setting tool 50 is utilized to radially expand the hanger body 48. Specifically, when the hanger body 48 is positioned interior to the casing string 40 and proximate the lower end portion thereof, the cone mandrel 56 is displaced in an axial direction 92, thereby urging the collapsible expansion cone 58 to engage the interior of the reduced diameter portion 52 of the hanger body 48. In several exemplary embodiments, the cone mandrel 56 and the collapsible expansion cone 58 are displaced by increasing the hydraulic fluid pressure within an annular space 94 defined between the running tool 42 and the hanger body 48. The engagement of the collapsible expansion cone 58 with the interior of the reduced diameter portion 52 of the hanger body 48 forms a seal so that the setting tool 50 acts as a hydraulic piston within the hanger body 48. Additionally, a seal is incorporated on the interior of the cone mandrel 56 to seal against the running tool 42 so that the increased hydraulic fluid pressure within the annular space 94 acts upon the cone mandrel 56 and the collapsible expansion cone 58. As a result, the hydraulic fluid pressure within the annular space 94 urges the setting tool 50 in the

direction 92. Once a sufficient hydraulic fluid pressure has been reached, the cone mandrel 56 and the collapsible expansion cone 58 are displaced in the axial direction 92, and relative to the hanger body 48, so that the collapsible expansion cone 58 slidably engages, and radially expands, the interior of the reduced diameter portion 52 of the hanger body 48. In several exemplary embodiments, in addition to, or instead of, the collapsible expansion cone 58 being displaced by increasing the hydraulic fluid pressure within the annular space 94, the collapsible expansion cone 58 is displaced by imparting axial force to the cone mandrel 56 with the running tool 42.

As the collapsible expansion cone 58 slidably engages the hanger body 48, the tapered external annular surface 82 and the cone crest 84 impart radial force to the interior of the reduced diameter portion 52, causing the exterior of hanger body 48 to expand radially. In several exemplary embodiments, the uniform cross-section of the collapsible expansion cone 58 is fully supported radially by the cone mandrel 56 during the expansion of the hanger body 48. Moreover, the relatively larger wall thickness of the cone mandrel 56 at the end portion 68b of the tapered annular surface 68 supports the cone crest 84 during the radial expansion of the hanger body 48. The radial expansion of the hanger body 48 causes the exterior of the reduced diameter portion 52 to be urged into engagement with the interior of the casing string 40. Consequently, the contact elements 54 are expanded into engagement with the interior of the casing string 40. The contact elements 54 form a frictional interface with the interior of the casing string 40 when the reduced diameter portion 52 is expanded, thus connecting the hanger body 48 to the casing string 40. In several exemplary embodiments, the contact elements 54 are, include, or are part of a cylindrical seal made of a rubber material and adapted to form a frictional interface with the interior of the casing string 40 when the reduced diameter portion 52 is expanded. In several exemplary embodiments, the contact elements 54 are, include, or are part of a plurality of casing slips adapted to engage, or “bite” into, the interior of the casing string 40 when the reduced diameter portion 52 is expanded. In several exemplary embodiments, the contact elements 54 are integrally formed with the hanger body 48 and are designed to sealingly engage the interior of the casing string 40 when the hanger body 48 is expanded.

Referring additionally to Figure 6C, hydraulic pressure is continuously applied

within the annular space 94 until the entire length of the reduced diameter portion 52 is expanded to engage the casing string 40. At this point, expansion of the hanger body 48 is complete and the liner string 46 is set within the wellbore 38. Once the expansion of the hanger body 48 is complete, the cone mandrel 56 and the collapsible expansion cone 58 must be retrieved from the wellbore 38. However, due to the material properties of the hanger body 48 and the considerable force required to expand the hanger body 48, a small amount of strain is recovered by the interior of the reduced diameter portion 52 after it has been expanded by the collapsible expansion cone 58. The strain recovered by the interior of the reduced diameter portion 52 causes the expanded hanger body 48 to obstruct displacement of the collapsible expansion cone 58 in an axial direction 96, which is opposite the axial direction 92.

According to an exemplary embodiment, as illustrated in Figures 6D(i)-(iii), the interior of the expanded hanger body 48 acts as a restriction that prevents, or at least obstructs, respective portions of the collapsible expansion cone 58, including at least the cone crest 84, from being displaced in the axial direction 96 and relative to the hanger body 48.

As shown in Figure 6D(i), certain components of the setting tool 50, including at least the collapsible expansion cone 58 and the cone retainer 60, facilitate extrication of the setting tool 50 from the hanger body 48. Accordingly, the setting tool 50 is extricated from the hanger body 48 by first displacing the cone mandrel 56 in the axial direction 96 and relative to both of the collapsible expansion cone 58 and the hanger body 48. As the running tool 42 and the cone mandrel 56 are retracted from the expanded hanger body 48 in the axial direction 96, the tapered internal annular surface 80 of the collapsible expansion cone 58 and the tapered annular surface 68 of the cone mandrel 56 begin to disengage.

As shown in Figure 6D(ii), the cone mandrel 56 continues to be displaced relative to the collapsible expansion cone 58 until the cone retainer 60 engages the end face 85 of the contact ring 78. At the same time, the gap between the tapered internal annular surface 80 and the tapered annular surface 68 continues to grow until, eventually, the collapsible expansion cone 58 is un-propped from the cone mandrel 56. Moreover, during the displacement of the cone mandrel 56 in the axial direction 96 and relative to the

collapsible expansion cone 58, the annular contact surface 72 of the cone mandrel 56 slidably engages the interior of the contact ring 78.

As shown in Figure 6D(iii), subsequent displacement of the cone mandrel 56 in the axial direction 96 urges the collapsible expansion cone 58 to be displaced relative to the hanger body 48. The thickness and material properties of the collapsible expansion cone 58 permit the frusto-conical member 76 thereof to bell radially inward at the cone crest 84 when the collapsible expansion cone 58 is un-propped from the cone mandrel 56. Thus, as the collapsible expansion cone 58 is urged in the axial direction 96 and relative to the hanger body 48, the frusto-conical member 76 bells radially inward at the cone crest 84. In this manner, the inward belling of the frusto-conical member 76 permits the extrication of the setting tool 50 through the tight-fitting interior of the expanded hanger body 48.

In several exemplary embodiments, by eliminating the need for irregular surface features associated with expansion cones that incorporate, for example, collet features, the collapsible expansion cone 58 prevents, or at least reduces, damage to any friction reducing coatings applied to the hanger body 48 and/or the collapsible expansion cone 58. In several exemplary embodiments, the collapsible expansion cone 58 provides additional structural resistance to hoop or radial stress patterns imparted thereto during the expansion of the hanger body 48 as compared to conventional expansion cones incorporating, for example, a collet feature. In several exemplary embodiments, the collapsible expansion cone 58 provides a sealing interface with the interior of the hanger body 48 that is coincident with the cone crest 84, thus increasing the axial force imparted to the setting tool 50 by the hydraulic fluid pressure within the annular space 94 as compared to an expansion cone having, for example, a collet feature that requires a “lead cone” for effective expansion.

In several exemplary embodiments, the collapsible expansion cone 58 has an uninterrupted and/or uniform circumferential wall thickness that operates to reduce the stress transferred to the cone mandrel 56 during expansion of the hanger body 48. In several exemplary embodiments, the collapsible expansion cone 58 has a uniform cross-section that optimizes the material properties of the collapsible expansion cone 58 after the case hardening and/or the heat treatment thereof.

In several exemplary embodiments, the collapsible expansion cone 58 defines a continuous, slit-less, circumferentially-extending body. In several exemplary embodiments, every cross-section of the collapsible expansion cone 58 that is taken along a plane in which the longitudinal axis of the collapsible expansion cone 58 extends is substantially identical.

In several exemplary embodiments, the collapsible expansion cone 58 provides a simple, cost-effective, and easy-to-manufacture expansion cone that prevents, or at least reduces, damage to the expanded hanger body 48 during extrication of the setting tool 50. In several exemplary embodiments, the collapsible expansion cone 58 is a disposable, one-time use expansion cone that mitigates the risk associated with the expansion of nickel alloy and/or high-chromium alloy hanger bodies.

The present disclosure introduces an expandable liner hanger system, including a setting tool, including a cone mandrel defining a tapered external annular surface and adapted to be displaced in first and second axial directions; an expansion cone extending about the cone mandrel and defining a tapered internal annular surface adapted to be engaged by the tapered external annular surface when the cone mandrel is displaced in the first axial direction; and a cone retainer extending from the cone mandrel and adapted to engage the expansion cone when the cone mandrel is displaced in the second axial direction and relative to the expansion cone; and a hanger body adapted to be radially expanded by the expansion cone when the cone mandrel and the expansion cone are displaced in the first axial direction and relative to the hanger body; wherein, when the cone retainer engages the expansion cone, the tapered internal annular surface is disengaged from the tapered external annular surface, thus enabling the expansion cone to bell radially inward. In an exemplary embodiment, when the hanger body is radially expanded by the setting tool, the hanger body is adapted to fixedly engage a casing string disposed within a wellbore. In an exemplary embodiment, the expandable liner hanger further includes a liner string connected to the hanger body and adapted to extend into the wellbore beyond the casing string when the hanger body fixedly engages the casing string. In an exemplary embodiment, the expansion cone includes a contact ring adapted to be engaged by the cone retainer when the cone mandrel is displaced in the second axial direction and relative to the expansion cone; and a frusto-conical member connected

to the contact ring and defining a cone crest that is adapted to slidably engage, and radially expand, the hanger body when the expansion cone is displaced in the first axial direction and relative to the hanger body. In an exemplary embodiment, the tapered external annular surface of the cone mandrel defines first and second end portions; the cone mandrel defines a first wall thickness at the first end portion and a second wall thickness at the second end portion; and the first wall thickness of the cone mandrel is greater than the second wall thickness of the cone mandrel. In an exemplary embodiment, when the hanger body is radially expanded by the expansion cone, the first wall thickness of the cone mandrel is adapted to support a portion of the expansion cone, including at least the cone crest. In an exemplary embodiment, the cone mandrel further defines an external annular groove and an annular contact surface extending between the external annular groove and the tapered external annular surface; and the external annular groove accommodates the cone retainer, thus trapping the expansion cone axially between the cone retainer and the tapered external annular surface. In an exemplary embodiment, when the cone mandrel is displaced in the second axial direction and relative to the expansion cone, the annular contact surface slidably engages the contact ring and the tapered internal annular surface is disengaged from the tapered external annular surface. In an exemplary embodiment, the expansion cone is adapted to be displaced in the second axial direction and relative to the hanger body after the hanger body is radially expanded and the tapered internal annular surface is disengaged from the tapered external annular surface; and, when the expansion cone is displaced in the second axial direction and relative to the hanger body, the frusto-conical member is adapted to bell radially inward at the cone crest to permit extrication of the expansion cone from the hanger body. In an exemplary embodiment, when the hanger body is radially expanded by the expansion cone, the cone crest is adapted to be sealingly engaged with the hanger body; and the sealing engagement of the cone crest with the hanger body causes the displacement of the expansion cone in the first axial direction, and relative to the hanger body, to be effectuated by a fluid pressure within the hanger body.

The present disclosure also introduces a method of installing an expandable liner hanger system within a casing string, the method including positioning the expandable

liner hanger system within the casing string, the expandable liner hanger system including a hanger body and a setting tool disposed within the hanger body, the setting tool including a cone mandrel defining a tapered external annular surface and an expansion cone defining a tapered internal annular surface; engaging the tapered external annular surface of the cone mandrel with the tapered internal annular surface of the expansion cone; radially expanding the hanger body to engage the casing string by displacing the cone mandrel and the expansion cone in a first axial direction and relative to the hanger body; displacing the cone mandrel in a second axial direction and relative to the expansion cone to disengage the tapered internal annular surface from the tapered external annular surface, thus permitting the expansion cone to bell radially inward from the hanger body; and extricating the expansion cone from the expanded hanger body. In an exemplary embodiment, the expandable liner hanger system further includes a liner string connected to the hanger body; and, when the hanger body is expanded by the expansion cone to engage the casing string, the liner string extends into the wellbore beyond the casing string. In an exemplary embodiment, the setting tool further includes a cone retainer extending from the cone mandrel; and extricating the expansion cone from the expanded hanger body includes engaging the expansion cone with the cone retainer and displacing the expansion cone in the second axial direction and relative to the hanger body. In an exemplary embodiment, the cone mandrel further defines an external annular groove and an annular contact surface extending between the external annular groove and the tapered external annular surface; and the external annular groove accommodates the cone retainer, thus trapping the expansion cone axially between the cone retainer and the tapered external annular surface. In an exemplary embodiment, when the cone mandrel is displaced in the second axial direction and relative to the expansion cone to disengage the tapered internal annular surface from the tapered external annular surface, the annular contact surface of the cone mandrel slidably engages the contact ring. In an exemplary embodiment, the expansion cone includes a contact ring and a frusto-conical member connected to the contact ring, the frusto-conical member defining a cone crest; and radially expanding the hanger body to engage the casing string includes slidably engaging the frusto-conical member, including at least the cone crest, with a reduced diameter portion of the hanger body, thus imparting radially

outward force to the hanger body. In an exemplary embodiment, radially expanding the hanger body to engage the casing string further includes sealingly engaging the cone crest with the hanger body and effecting the displacement of the expansion cone in the first axial direction using a fluid pressure within the hanger body. In an exemplary embodiment, the tapered external annular surface of the cone mandrel defines first and second end portions; the cone mandrel defines a first wall thickness at the first end portion and a second wall thickness at the second end portion; and the first wall thickness of the cone mandrel is greater than the second wall thickness of the cone mandrel. In an exemplary embodiment, when the hanger body is radially expanded by the expansion cone, the first wall thickness of the cone mandrel is adapted to support a portion of the frusto-conical member, including at least the cone crest. In an exemplary embodiment, extricating the expansion cone includes displacing the expansion cone in the second axial direction and relative to the hanger body after the hanger body is radially expanded and the tapered internal annular surface is disengaged from the tapered external annular surface; and, when the expansion cone is displaced in the second axial direction and relative to the hanger body, the frusto-conical member is adapted to bell radially inward at the cone crest to permit extrication of the expansion cone from the hanger body.

In several exemplary embodiments, the elements and teachings of the various illustrative exemplary embodiments may be combined in whole or in part in some or all of the illustrative exemplary embodiments. In addition, one or more of the elements and teachings of the various illustrative exemplary embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various illustrative embodiments.

Any spatial references, such as, for example, “upper,” “lower,” “above,” “below,” “between,” “bottom,” “vertical,” “horizontal,” “angular,” “upwards,” “downwards,” “side-to-side,” “left-to-right,” “right-to-left,” “top-to-bottom,” “bottom-to-top,” “top,” “bottom,” “bottom-up,” “top-down,” etc., are for the purpose of illustration only and do not limit the specific orientation or location of the structure described above.

In several exemplary embodiments, while different steps, processes, and procedures are described as appearing as distinct acts, one or more of the steps, one or

more of the processes, and/or one or more of the procedures may also be performed in different orders, simultaneously and/or sequentially. In several exemplary embodiments, the steps, processes, and/or procedures may be merged into one or more steps, processes and/or procedures.

In several exemplary embodiments, one or more of the operational steps in each embodiment may be omitted. Moreover, in some instances, some features of the present disclosure may be employed without a corresponding use of the other features. Moreover, one or more of the above-described embodiments and/or variations may be combined in whole or in part with any one or more of the other above-described embodiments and/or variations.

Claims

What is claimed is:

1. An expandable liner hanger system (44), comprising:

a setting tool (50), comprising:

a cone mandrel (56) defining a tapered external annular surface (68) and adapted to be displaced in first and second axial directions;

an expansion cone (58) extending about the cone mandrel, the expansion cone defining a cone crest (84) and a tapered internal annular surface (82), which tapered internal annular surface is adapted to be engaged by the tapered external annular surface when the cone mandrel is displaced in the first axial direction; and

a cone retainer (60) connected to the cone mandrel and adapted to engage the expansion cone when the cone mandrel is displaced in the second axial direction and relative to the expansion cone;

and

a hanger body (48) adapted to be radially expanded by the expansion cone when the cone mandrel and the expansion cone are displaced in the first axial direction and relative to the hanger body;

wherein the expansion cone defines a sealing interface with the hanger body;

wherein, when the hanger body is radially expanded by the expansion cone, the cone crest is adapted to sealingly engage the hanger body to thereby define the sealing interface; and

wherein, when the cone retainer engages the expansion cone, the tapered internal annular surface is disengaged from the tapered external annular surface so that the expansion cone is permitted to bell radially inward.

2. The expandable liner hanger system (44) of claim 1, wherein, when the hanger body (48) is radially expanded by the setting tool (50), the hanger body is adapted to fixedly engage a casing string disposed within a wellbore; and

wherein the expandable liner hanger system further comprises a liner string connected to the hanger body and adapted to extend into the wellbore

beyond the casing string when the hanger body fixedly engages the casing string.

3. The expandable liner hanger system (44) of claim 1, wherein the expansion cone (58) comprises:

a contact ring (78) adapted to be engaged by the cone retainer (60) when the cone mandrel (56) is displaced in the second axial direction and relative to the expansion cone; and

a frusto-conical member (76) connected to the contact ring and defining the cone crest (84) that is adapted to slidably engage, and radially expand, the hanger body (48) when the expansion cone is displaced in the first axial direction and relative to the hanger body.

4. The expandable liner hanger system (44) of claim 3,

wherein:

the tapered external annular surface (68) of the cone mandrel (56) defines first and second end portions (68a, 68b);

the cone mandrel (56) defines a first wall thickness at the first end portion and a second wall thickness at the second end portion;

the first wall thickness of the cone mandrel is greater than the second wall thickness of the cone mandrel; and

when the hanger body (48) is radially expanded by the expansion cone, the first wall thickness of the cone mandrel is adapted to support a portion of the expansion cone (58), including at least the cone crest (84);

and/or

wherein:

the cone mandrel (56) further defines an external annular groove (70) and an annular contact surface (72) extending between the external annular groove and the tapered external annular surface (68);

the external annular groove accommodates the cone retainer (60), thus trapping the expansion cone (58) axially between the cone retainer and the tapered external annular surface; and

when the cone mandrel is displaced in the second axial direction and relative to the expansion cone, the annular contact surface slidably engages the contact ring (78) and the tapered internal annular surface (82) is disengaged from the tapered external annular surface.

5. The expandable liner hanger system (44) of claim 3,

wherein:

the expansion cone (58) is adapted to be displaced in the second axial direction and relative to the hanger body (48) after the hanger body is radially expanded and the tapered internal annular surface (82) is disengaged from the tapered external annular surface (68); and

when the expansion cone is displaced in the second axial direction and relative to the hanger body, the frusto-conical member (76) is adapted to bell radially inward at the cone crest (84) to permit extrication of the expansion cone from the hanger body;

and/or

wherein:

when the hanger body (48) is radially expanded by the expansion cone (58),

the sealing engagement of the cone crest (84) with the hanger body causes the displacement of the expansion cone (58) in the first axial direction, and relative to the hanger body, to be effectuated by a fluid pressure within the hanger body.

6. A method of installing an expandable liner hanger system (44) within a casing string (40), the method comprising:

positioning the expandable liner hanger system within the casing string, the expandable liner hanger system comprising a hanger body (48) and a

setting tool (50) disposed within the hanger body, the setting tool comprising: a cone mandrel (56) defining a tapered external annular surface (68); and an expansion cone (58) defining a tapered internal annular surface (82) and a cone crest (84);

engaging the tapered external annular surface of the cone mandrel with the tapered internal annular surface of the expansion cone;

radially expanding the hanger body to engage the casing string by displacing the cone mandrel and the expansion cone in a first axial direction and relative to the hanger body and creating a sealing interface between the expansion cone and the hanger body, wherein creating the sealing interface between the expansion cone and the hanger body comprises sealingly engaging the cone crest with the hanger body;

displacing the cone mandrel in a second axial direction and relative to the expansion cone to disengage the tapered internal annular surface from the tapered external annular surface, thus permitting the expansion cone to bell radially inward from the hanger body; and

extricating the expansion cone from the expanded hanger body.

7. The method of claim 6,

wherein:

the expandable liner hanger system (44) further comprises a liner string (46) connected to the hanger body (48); and

when the hanger body is expanded by the expansion cone (58) to engage the casing string (40), the liner string extends into the wellbore beyond the casing string;

and/or

wherein:

the setting tool (50) further comprises a cone retainer (60) extending from the cone mandrel (56);

extricating the expansion cone (58) from the expanded hanger body (48) comprises engaging the expansion cone with the cone retainer and

displacing the expansion cone in the second axial direction and relative to the hanger body;

wherein the cone mandrel further defines an external annular groove (70) and an annular contact surface (72) extending between the external annular groove and the tapered external annular surface;

the external annular groove accommodates the cone retainer (60), thus trapping the expansion cone axially between the cone retainer and the tapered external annular surface; and

when the cone mandrel is displaced in the second axial direction and relative to the expansion cone to disengage the tapered internal annular surface (68) from the tapered external annular surface (82), the annular contact surface of the cone mandrel slidably engages the contact ring (78).

8. The method of claim 6,

wherein the expansion cone (58) comprises a contact ring (78) and a frusto-conical member 76) connected to the contact ring, the frusto-conical member defining the cone crest (84); and

wherein radially expanding the hanger body (48) to engage the casing string (40) comprises slidably engaging the frusto-conical member, including at least the cone crest, with a reduced diameter portion (52) of the hanger body, thus imparting radially outward force to the hanger body.

9. The method of claim 8,

wherein radially expanding the hanger body (48) to engage the casing string (40) further comprises sealingly engaging the cone crest (84) with the hanger body and effecting the displacement of the expansion cone (58) in the first axial direction using a fluid pressure within the hanger body;

and/or

wherein:

extricating the expansion cone (58) comprises displacing the expansion cone in the second axial direction and relative to the hanger body (48) after the hanger body is radially expanded and the tapered internal annular surface (68) is disengaged from the tapered external annular surface (82); and

when the expansion cone is displaced in the second axial direction and relative to the hanger body, the frusto-conical member (76) is adapted to bell radially inward at the cone crest (84) to permit extrication of the expansion cone from the hanger body.

10. The method of claim 8,

wherein the tapered external annular surface (82) of the cone mandrel (56) defines first and second end portions (68a, 68b);

wherein the cone mandrel defines a first wall thickness at the first end portion and a second wall thickness at the second end portion;

wherein the first wall thickness of the cone mandrel is greater than the second wall thickness of the cone mandrel; and

wherein, when the hanger body (48) is radially expanded by the expansion cone (58), the first wall thickness of the cone mandrel is adapted to support a portion of the frusto-conical member (76), including at least the cone crest (84).

Patentkrav

Det søkes patent på:

1. Ekspanderbart røropphengssystem (44), omfattende:

et innstillingsverktøy (50), omfattende:

en kjeglerørstamme (56) som definerer en avsmalnende ytre ringformet overflate (68) og tilpasset til å forskyves i første og andre aksiale retninger;

en ekspansjonskjegle (58) som strekker seg rundt kjeglerørstammen, hvor ekspansjonskjeglen definerer en kjegletopp (84) og en avsmalnende indre ringformet overflate (82), den avsmalnende indre ringformede overflaten tilpasses til å bringes i inngrep med den avsmalnende ytre ringformede overflaten når kjeglerørstammen forskyves i den første aksiale retningen; og

en kjegleholder (60) koblet til kjeglerørstammen og tilpasset til å bringes i inngrep med ekspansjonskjeglen når kjeglerørstammen forskyves i den andre aksiale retningen og i forhold til ekspansjonskjeglen;

og

et opphengslegeme (48) tilpasset til å ekspanderes radielt av ekspansjonskjeglen når kjeglerørstammen og ekspansjonskjeglen forskyves i den første aksiale retningen og i forhold til opphengslegemet;

hvori ekspansjonskjeglen definerer et forseglende grensesnitt med opphengslegemet;

hvori, når opphengslegemet ekspanderes radielt av ekspansjonskjeglen, tilpasses kjegletoppen til forseglende å bringes i inngrep med opphengslegemet for derved å definere forseglingsgrensesnittet; og

hvori, når kjegleholderen bringes i inngrep med ekspansjonskjeglen, frigjøres den avsmalnende indre ringformede overflaten fra den avsmalnende ytre ringformede overflaten slik at ekspansjonskjeglen tillates å bues radielt innover.

2. Det ekspanderbare røropphengssystemet (44) ifølge krav 1, hvori, når opphengslegemet (48) ekspanderes radielt av innstillingsverktøyet (50), tilpasses opphengslegemet til festbart å bringes i inngrep med en fôringsrørstreng anordnet inne i et borehull; og

hvori det ekspanderbare røropphengssystemet videre omfatter en fôringsrørstreng koblet til opphengslegemet og tilpasset til å strekke seg inn i borehullet forbi fôringsrørstrengen når opphengslegemet festbart bringes i inngrep med fôringsrørstrengen.

3. Det ekspanderbare røropphengssystemet (44) ifølge krav 1, hvori ekspansjonskjeglen (58) omfatter:

en kontaktring (78) tilpasset til å bringes i inngrep med kjegleholderen (60) når kjeglerørstammen (56) forskyves i den andre aksiale retningen og i forhold til ekspansjonskjeglen; og

et kjeglestubformet element (76) koblet til kontaktringen og som definerer kjegletoppen (84) som tilpasses for glidbart å bringes i inngrep med og radielt ekspandere opphengslegemet (48) når ekspansjonskjeglen forskyves i den første aksiale retningen og i forhold til opphengslegemet.

4. Det ekspanderbare røropphengssystemet (44) ifølge krav 3, hvori:

den avsmalnende ytre ringformede overflaten (68) av kjeglerørstammen (56) definerer første og andre endedeler (68a, 68b);

kjeglerørstammen (56) definerer en første veggtykkelse ved den første endedelen og en andre veggtykkelse ved den andre endedelen;

den første veggtykkelsen til kjeglerørstammen er større enn den andre veggtykkelsen til kjeglerørstammen; og

når opphengslegemet (48) ekspanderes radielt av ekspansjonskjeglen, tilpasses den første veggtykkelsen til kjeglerørstammen for å støtte en del av ekspansjonskjeglen (58), som inkluderer minst kjegletoppen (84);

og/eller

hvori:

kjeglerørstammen (56) videre definerer et ytre ringformet spor (70) og en ringformet kontaktoverflate (72) som strekker seg mellom det ytre ringformede sporet og den avsmalnende ytre ringformede overflaten (68);

det ytre ringformede sporet rommer kjegleholderen (60), og fanger dermed ekspansjonskjeglen (58) aksialt mellom kjegleholderen og den avsmalnende ytre ringformede overflaten; og

når kjeglerørstammen forskyves i den andre aksiale retningen og i forhold til ekspansjonskjeglen, bringes den ringformede kontaktoverflaten i inngrep med kontaktringen (78) og den avsmalnende indre ringformede overflaten (82) frigjøres fra den avsmalnende ytre ringformede overflaten.

5. Det ekspanderbare røropphengssystemet (44) ifølge krav 3,

hvori:

ekspansjonskjeglen (58) tilpasses til å forskyves i den andre aksiale retningen og i forhold til opphengslegemet (48) etter at opphengslegemet er radielt ekspandert og den avsmalnende indre ringformede overflaten (82) er frigjort fra den avsmalnende ytre ringformede overflaten (68); og

når ekspansjonskjeglen forskyves i den andre aksiale retningen og i forhold til opphengslegemet, tilpasses det kjeglestubformede elementet (76) til å bue radielt innover ved kjegletoppen (84) for å tillate frigjøring av ekspansjonskjeglen fra opphengslegemet;

og/eller

hvori:

når opphengslegemet (48) ekspanderes radielt av ekspansjonskjeglen (58),

bevirker det forseglende inngrepet av kjegletoppen (84) med opphengslegemet at forskyvningen av ekspansjonskjeglen (58) i den første aksiale retningen, og i forhold til opphengslegemet, utføres av et fluidtrykk inne i opphengslegemet.

6. Fremgangsmåte for å installere et ekspanderbart fôringsrøropphengssystem (44) i en fôringsrørstreng (40), fremgangsmåten omfattende:

å posisjonere det ekspanderbare røropphengssystemet inne i fôringsrørstrengen, det ekspanderbare røropphengssystemet omfattende et opphengslegeme (48) og et innstillingsverktøy (50) anordnet inne i opphengslegemet, innstillingsverktøyet omfattende: en kjeglerørstamme (56) som definerer en avsmalnende ytre ringformet overflate (68); og en ekspansjonskjegle (58) som definerer en avsmalnende indre ringformet overflate (82) og en kjegletopp (84);

å bringe den avsmalnende ytre ringformede overflaten til kjeglerørstammen i inngrep med den avsmalnende indre ringformede overflaten til ekspansjonskjeglen;

å ekspandere opphengslegemet radielt for å bringes i inngrep med fôringsrørstrengen ved å forskyve kjeglerørstammen og ekspansjonskjeglen i en første aksial retning og i forhold til opphengslegemet og skape et forseglingsgrensesnitt mellom ekspansjonskjeglen og opphengslegemet, hvori å skape forseglingsgrensesnittet mellom ekspansjonskjeglen og opphengslegemet omfatter forseglende å bringe kjegletoppen i inngrep med opphengslegemet;

å forskyve kjeglerørstammen i en andre aksial retning og i forhold til ekspansjonskjeglen for å frigjøre den avsmalnende indre ringformede overflaten fra den avsmalnende ytre ringformede overflaten, og dermed tillate ekspansjonskjeglen å bues radielt innover fra opphengslegemet; og

å frigjøre ekspansjonskjeglen fra det ekspanderte opphengslegemet.

7. Fremgangsmåten ifølge krav 6,
hvori:
det ekspanderbare røropphengssystemet (44) videre omfatter en fôringsrørstreng (46) koblet til opphengslegemet (48); og
når opphengslegemet ekspanderes av ekspansjonskjeglen (58) for å bringes i inngrep med fôringsrørstrengen (40), strekker fôringsrørstrengen seg inn i borehullet forbi fôringsrørstrengen;
og/eller
hvori:
innstillingsverktøyet (50) videre omfatter en kjegleholder (60) som strekker seg fra kjeglerørstammen (56);
å frigjøre ekspansjonskjeglen (58) fra det ekspanderte opphengslegemet (48) omfatter å bringe ekspansjonskjeglen i inngrep med kjegleholderen og å forskyve ekspansjonskjeglen i den andre aksiale retningen og i forhold til opphengslegemet;
hvori kjeglerørstammen videre definerer et ytre ringformet spor (70) og en ringformet kontaktoverflate (72) som strekker seg mellom det ytre ringformede sporet og den avsmalnende ytre ringformede overflaten;
det ytre ringformede sporet rommer kjegleholderen (60), og fanger dermed ekspansjonskjeglen aksialt mellom kjegleholderen og den avsmalnende ytre ringformede overflaten; og
når kjeglerørstammen forskyves i den andre aksiale retningen og i forhold til ekspansjonskjeglen for å frigjøre den avsmalnende indre ringformede overflaten (68) fra den avsmalnende ytre ringformede overflaten (82), bringes den ringformede kontaktoverflaten til kjeglerørstammen glidbart i inngrep med kontaktringen (78).

8. Fremgangsmåten ifølge krav 6,

hvori ekspansjonskjeglen (58) omfatter en kontaktring (78) og et kjeglestubelement (76) koblet til kontaktringen, idet det kjeglestubformede elementet definerer kjegletoppen (84); og

hvori å ekspandere opphengslegemet (48) radielt for å bringes i inngrep med fôringsrørstrengen (40) omfatter glidbart å bringe det kjeglestubformede elementet, som inkluderer minst kjegletoppen, i inngrep med en del (52) med redusert diameter av opphengslegemet, og dermed gi kraft radielt utover til opphengslegemet.

9. Fremgangsmåten ifølge krav 8,

hvori å ekspandere opphengslegemet (48) radielt for å bringes i inngrep med fôringsrørstrengen (40) videre omfatter forseglende å bringe kjegletoppen (84) i inngrep med opphengslegemet og å bevirke forskyvningen av ekspansjonskjeglen (58) i den første aksiale retningen ved anvendelse av et fluidtrykk inne i opphengslegemet;

og/eller

hvori:

å frigjøre ekspansjonskjeglen (58) omfatter å forskyve ekspansjonskjeglen i den andre aksiale retningen og i forhold til opphengslegemet (48) etter at opphengslegemet er radialt ekspandert og den avsmalnende indre ringformede overflaten (68) er frigjort fra den avsmalnende ytre ringformede overflaten (82); og

når ekspansjonskjeglen forskyves i den andre aksiale retningen og i forhold til opphengslegemet, tilpasses det kjeglestubformede elementet (76) til å bues radielt innover ved kjegletoppen (84) for å tillate frigjøring av ekspansjonskjeglen fra opphengslegemet.

10. Fremgangsmåten ifølge krav 8,

hvori den avsmalnende ytre ringformede overflaten (82) av kjeglerørstammen (56) definerer første og andre endedeler (68a, 68b);

hvori kjeglerørstammen definerer en første veggtykkelse ved den første endedelen og en andre veggtykkelse ved den andre endedelen;

hvori den første veggtykkelsen til kjeglerørstammen er større enn den andre veggtykkelsen til kjeglerørstammen; og

hvori, når opphengslegemet (48) ekspanderes radielt av ekspansjonskjeglen (58), tilpasses den første veggtykkelsen til kjeglerørstammen til å støtte en del av det kjeglestubformede elementet (76), som inkluderer minst kjegletoppen (84).

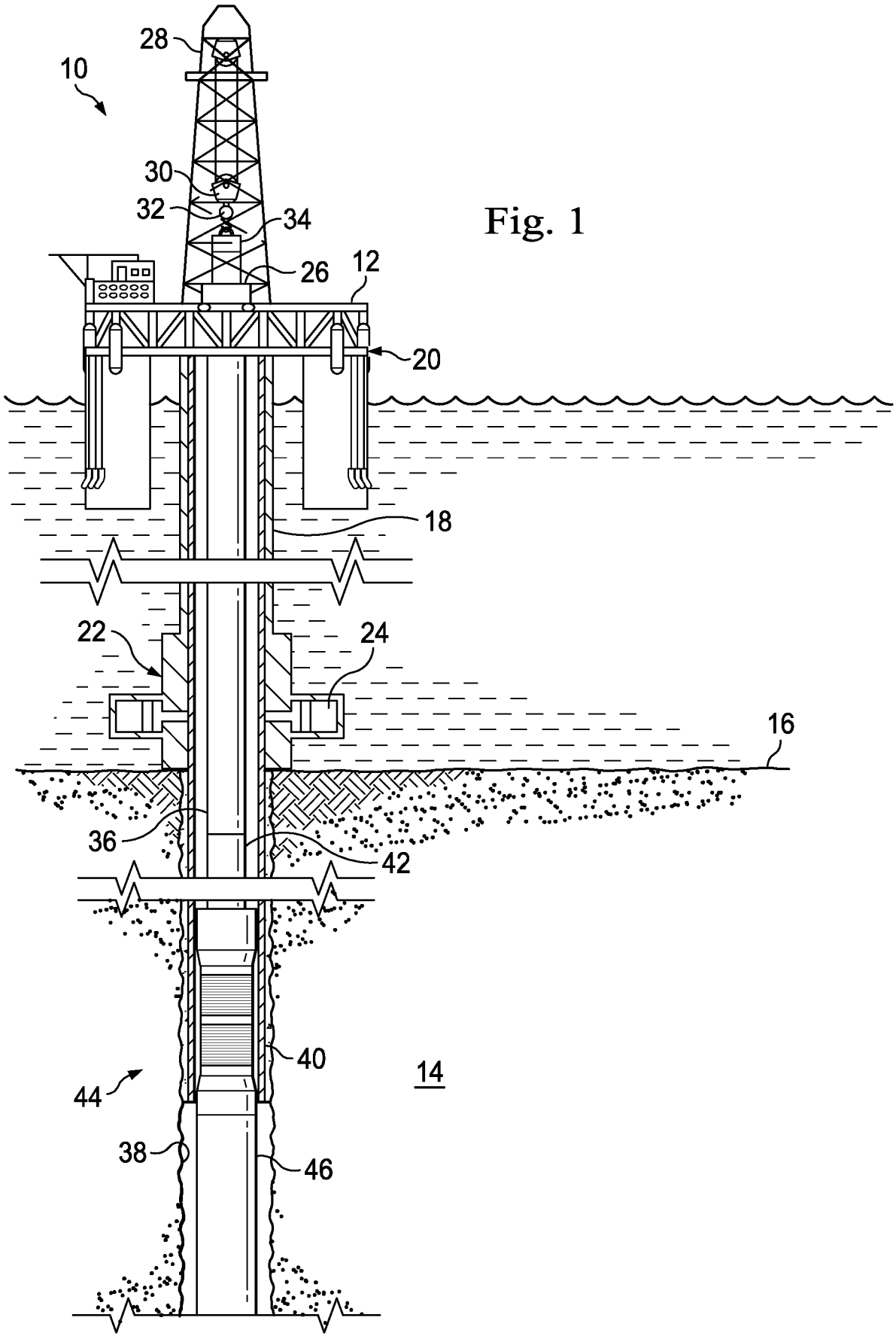


Fig. 1

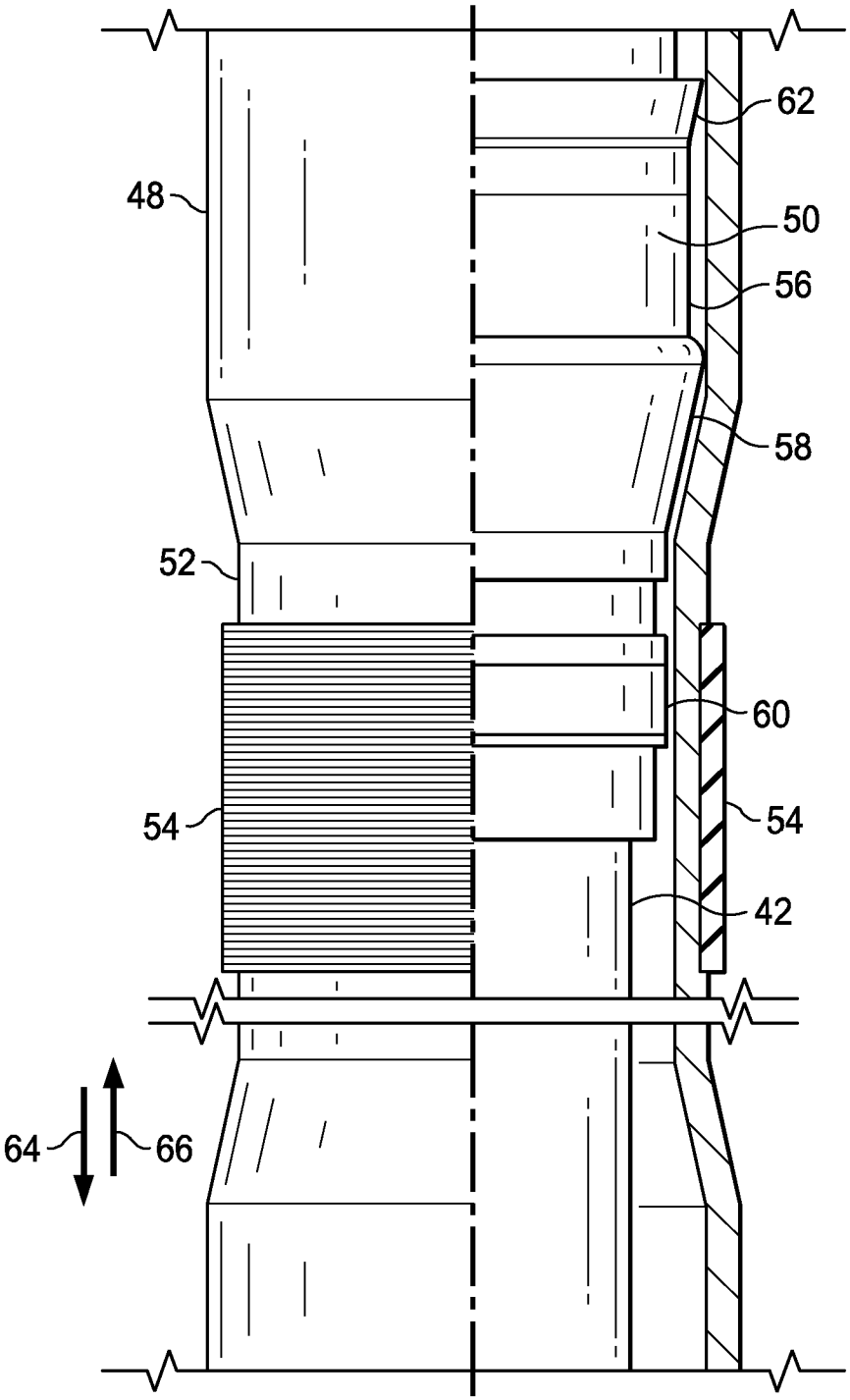


Fig. 2

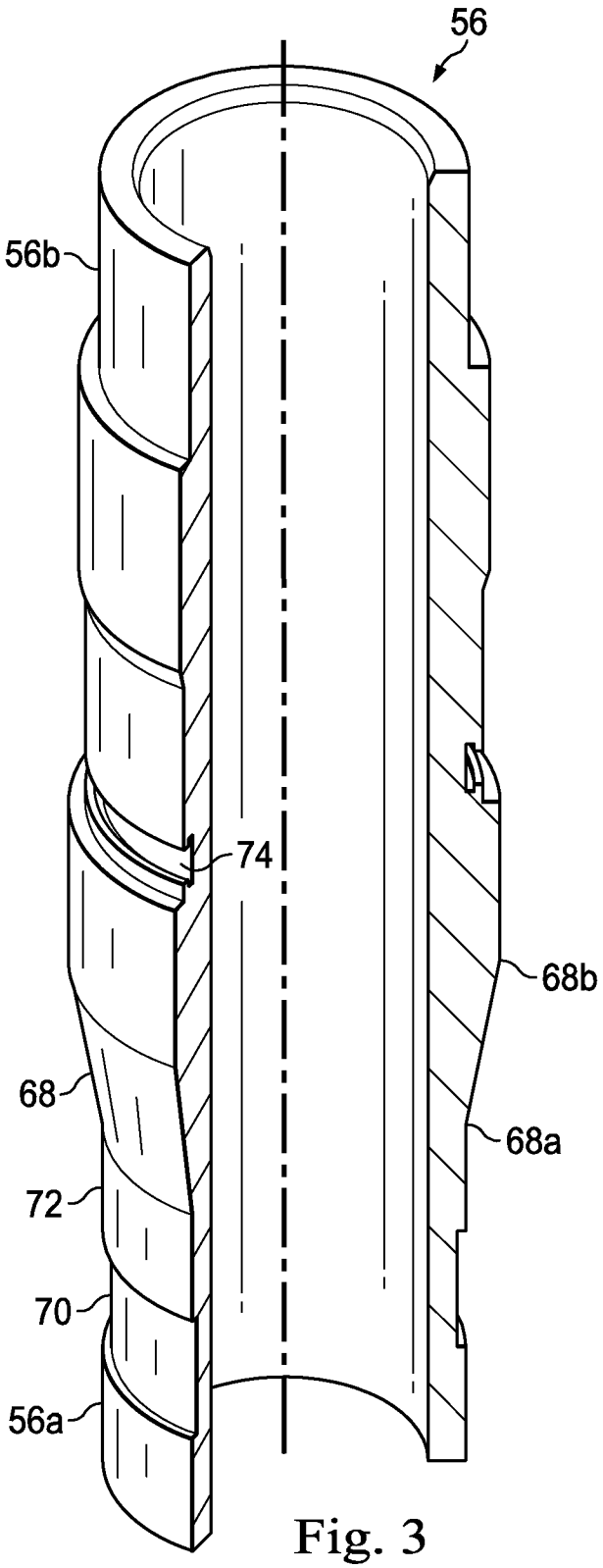


Fig. 3

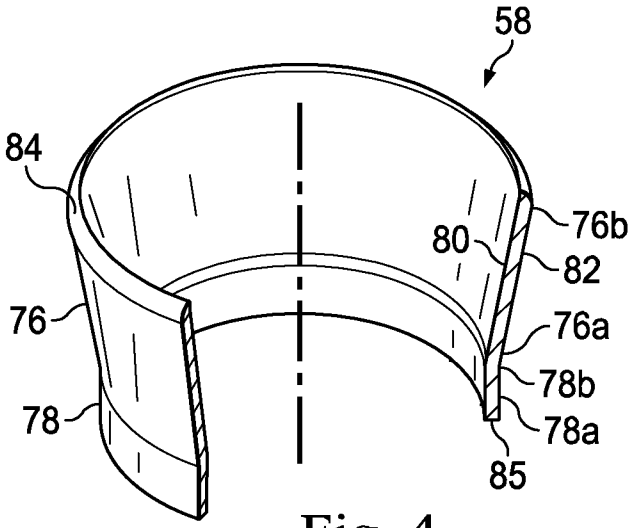


Fig. 4

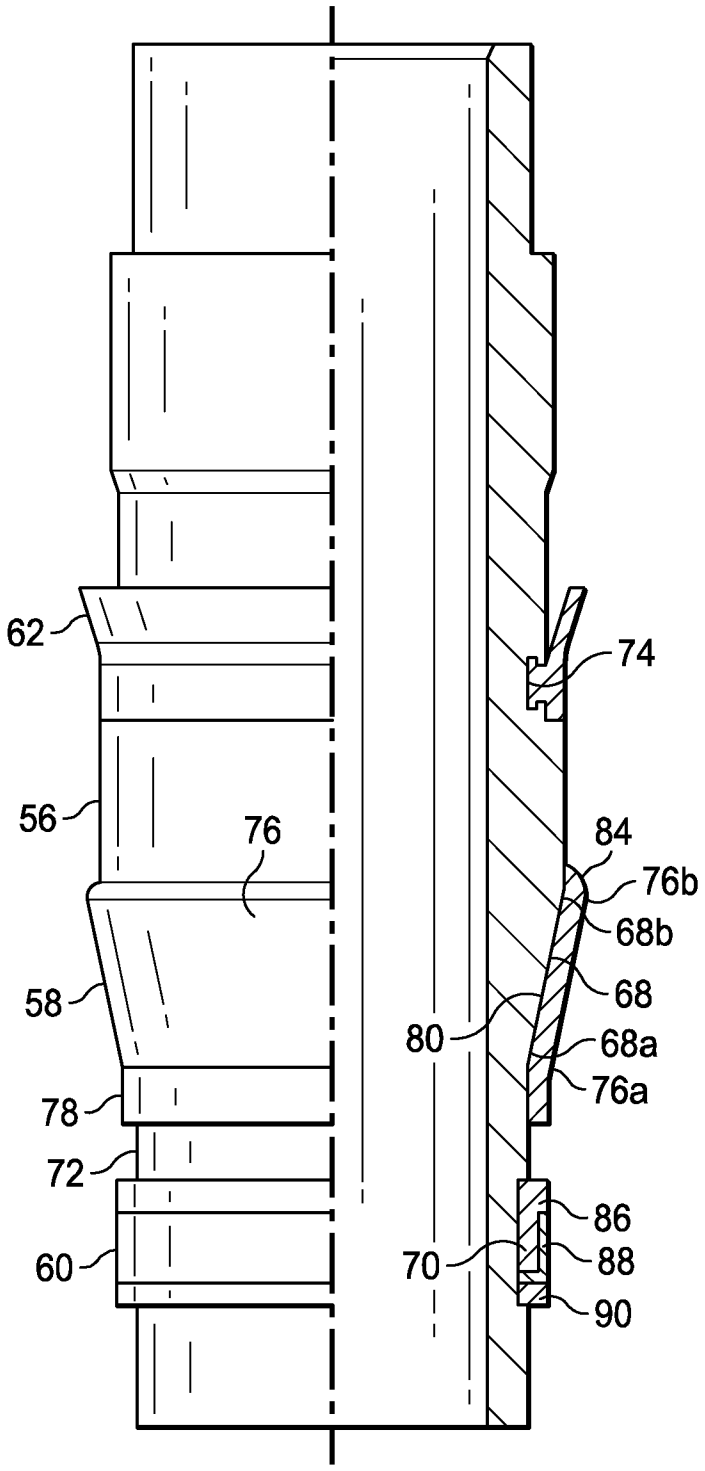


Fig. 5

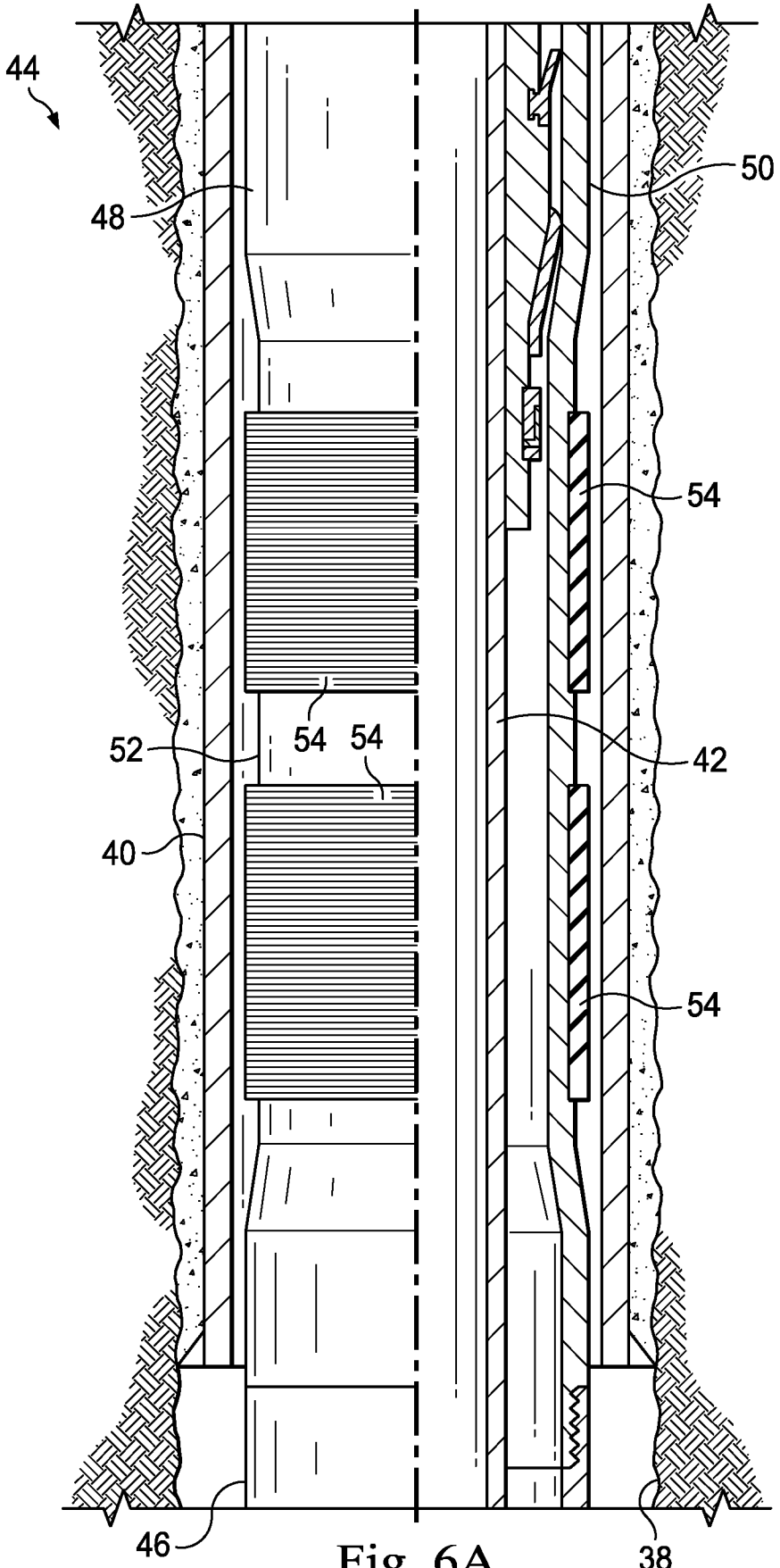


Fig. 6A

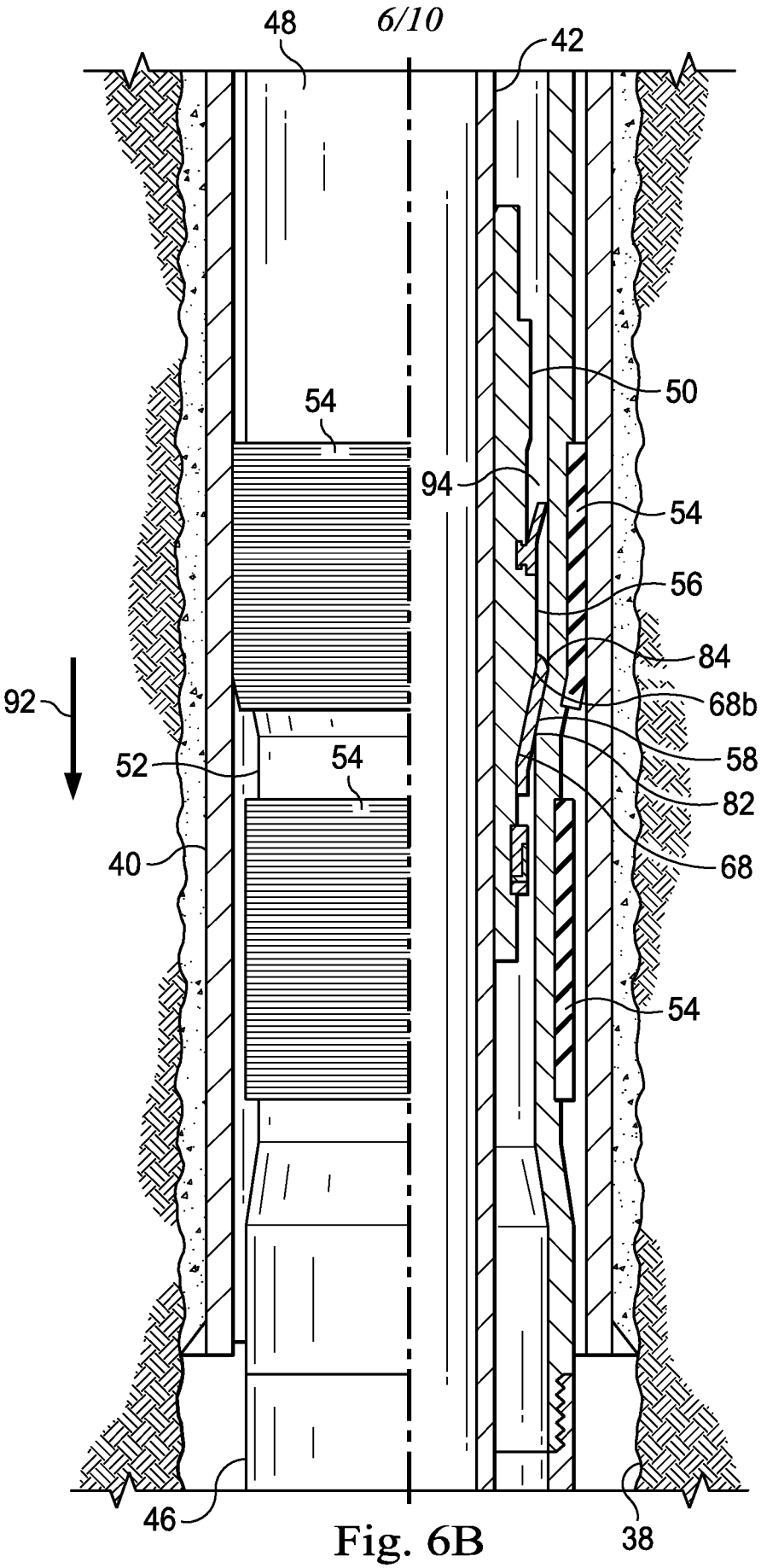


Fig. 6B

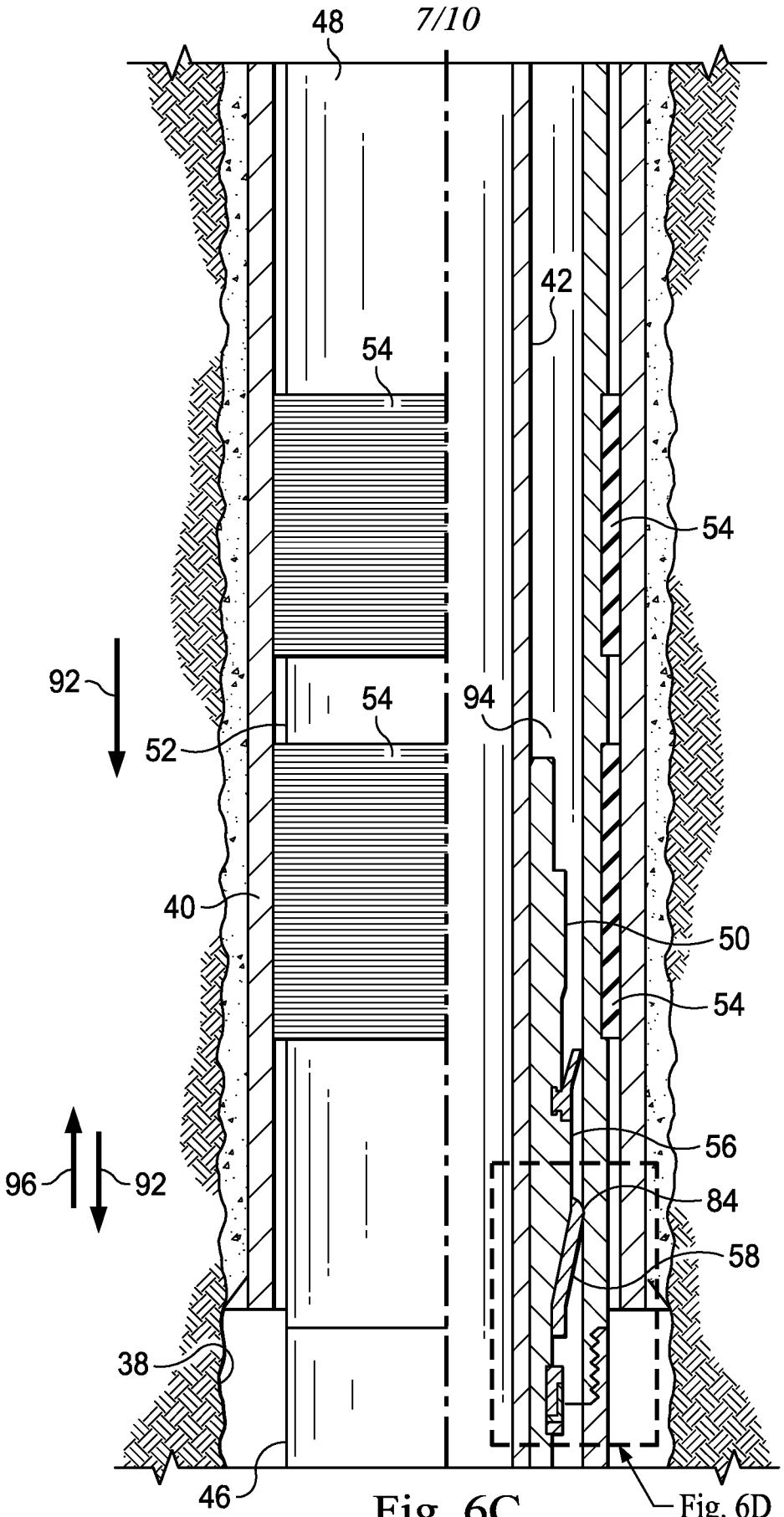


Fig. 6C

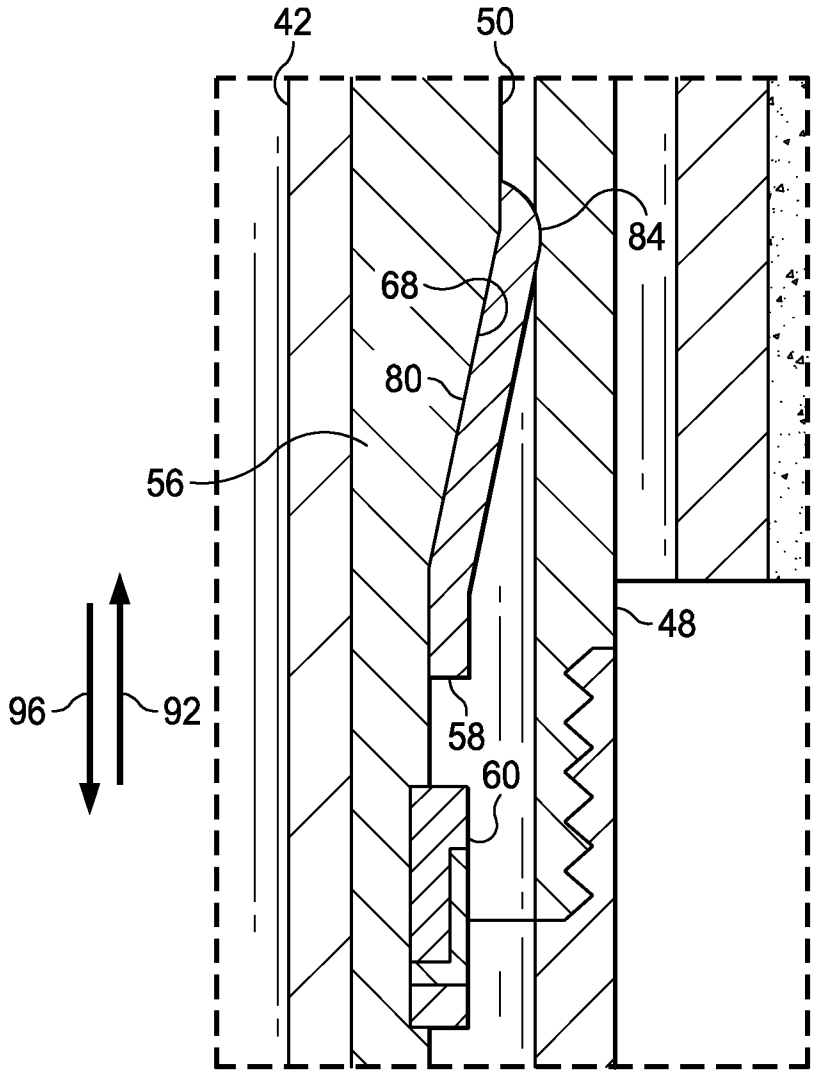


Fig. 6D(i)

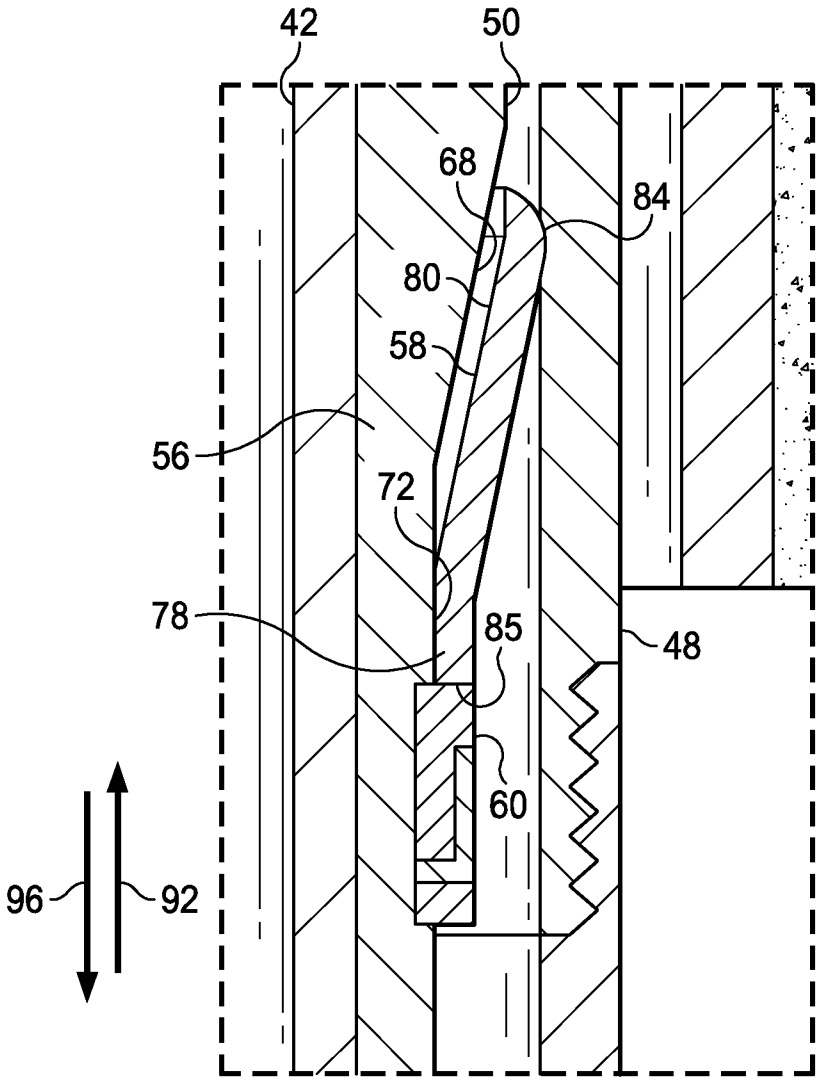


Fig. 6D(ii)

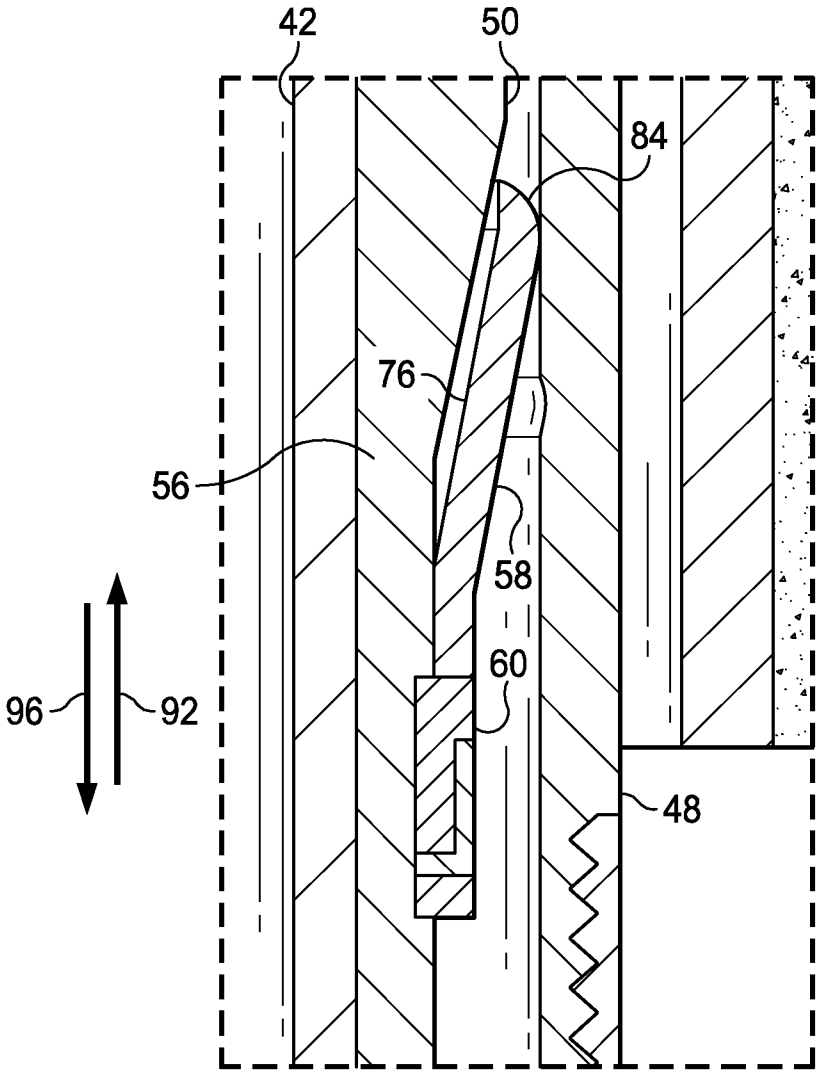


Fig. 6D(iii)