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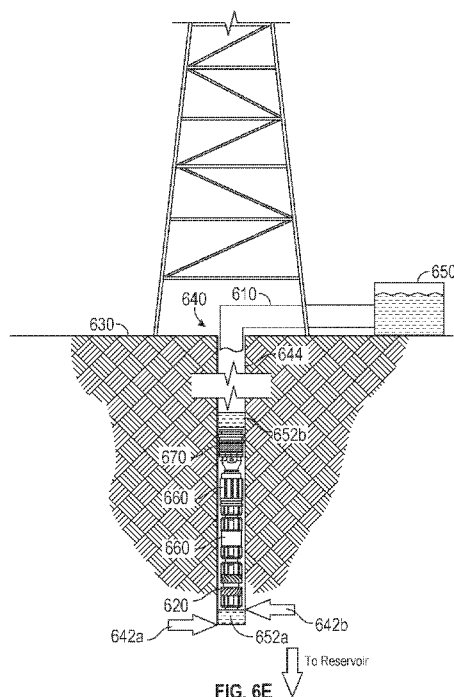
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(54) Title: BRUSH TOOL FOR WELL PLUG AND ABANDONMENT OPERATIONS AND INSTALLATION OF COMPLETION PRODUCTS



(57) Abstract: A brush tool for well plug and abandonment operations is provided by affixing a brush tool to an outer diameter of a work string; advancing the work string to a first predetermined depth in a wellbore of a well; retracting the brush tool to a second predetermined depth in the wellbore further uphole than the first predetermined depth; setting a cement retainer and injecting a sealing medium through the work string into the wellbore at the first predetermined depth to plug the well. In some cases, the brush tool is detached with a cement retainer from the work string, while down bore; and the work string (without the brush tool affixed thereto) is removed from the wellbore.



TITLE

BRUSH TOOL FOR WELL PLUG AND ABANDONMENT OPERATIONS AND INSTALLATION OF COMPLETION PRODUCTS

5

BACKGROUND

[0001] When permanently ceasing operations for a hydrocarbon well (referred to as well abandonment), the well should be plugged to seal off any zones that contain (or might later contain) hydrocarbons, thereby preventing the undesired release of hydrocarbons into other zones or into a bodies of water. When applying plugs in wells to be sealed, an operator may first retrieve any equipment present in the well that is to be reused or discarded (e.g., tubing and completion equipment), perform cleaning operations, and conduct various tests on the mechanical integrity of the well. A work string with a cement retainer is then inserted into the well to inject cement and other materials (e.g., abandonment mud, resins, gravel, and other sealants) to form one or more plugs in the well. Solids may be present in the wellbore fluids while running in hole with the cement retainer, potentially causing a tool failure. The operator may then, after ensuring that the plugs and casings are sound, remove any wellhead equipment and affix a metal cap to the borehole of the well after to complete the sealing process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Embodiments of the brush tool for well plug and abandonment operations and installation of completion products are described with reference to the following figures. The same or sequentially similar numbers are used throughout the figures to reference like features and components. The features depicted in the figures are not necessarily shown to scale. Certain features of the embodiments may be shown exaggerated in scale or in somewhat schematic form, and some details of elements may not be shown in the interest of clarity and conciseness.

[0003] FIGs. 1A-1C are diagrams showing a slotted brush design, according to embodiments of the present disclosure.

[0004] FIGs. 2A-2C are diagrams showing a bow spring brush design, according to embodiments of the present disclosure.

[0005] FIGs. 3A-3D are diagrams showing a pocketed brush design, according to embodiments of the present disclosure.

[0006] FIG. 4 is a diagram showing an end ring for use with a brush tool, according to embodiments of the present disclosure.

5 [0007] FIG. 5 is a diagram showing a connection face of a clamshell brush design, according to embodiments of the present disclosure.

[0008] FIGs. 6A-6E are diagrams showing plug and abandonment operations of a well using an integrated brush tool and work string, according to embodiments of the present disclosure.

10 [0009] FIG. 7 is a flowchart of an example method for using a brush tool for well plug and abandonment operations, according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0010] The present disclosure describes systems and methods of use of brush tools for well
15 plug and abandonment (P&A) operations or the installation of completions equipment during a workover of a well. P&A operations are often conducted at the end of the service life of a well, which can occur several years after initial extraction operations began. During this time, various scaling may build up and corrosion may occur on the inner diameter of the bore. Tools involved in the production of the hydrocarbons, such as packers and production tubing, may
20 also be located in the well. The cleaning operation includes removing any remaining tools. The cleaning operation also includes removing scaling and corrosion from the inner diameter of the bore; allowing for a stronger attachment of the sealing media (e.g., elastomers of a cement retainer or production packer, cement, resin, gravel, mud) within the bore. However, although operators are encouraged to perform a cleaning operation of the bore before inserting the work
25 string to deliver various sealing media, some operators may forego this step due to the time and costs associated with performing the cleaning operations relative to the success rate of performing sealing operations without the cleaning operations.

[0011] The present disclosure provides for brush tools that may be selectively integrated with a work string, thereby allowing operators to customize a work string to clean the inner

diameter of the bore while being inserted. By using a single integrated cleaning and insertion operation, operators may reduce the time and cost of P&A operations compared to operations that include a separate cleaning operation or improve the success rate of P&A operations compared to operations that omit a separate cleaning operation, among other benefits.

5 **[0012]** As used herein, the term “downhole”, and variations thereof, refers to a position that is further from the opening of the bore in which a work string is inserted along a selected path than a position referred to as “uphole”, regardless of the absolute depth within the substrate of an element so-described. For example, when describing a borehole that descends to a depth of X meters (m) and curves back upward to travel Y meters to end at a depth of X-Y m (e.g.,
10 in a “J” shape), a first element located at the end of the borehole is Y meters downhole from a second element located at the inflection point at X m of depth despite being located at a shallower absolute depth than the second element. Similarly, the second element may be referred to as “uphole” relative to the first element despite being located at a deeper absolute depth than the first element. Accordingly, elements attached to a work string for insertion into
15 a borehole may be identified relative to one another as being placed downhole or uphole along the length of the work string despite the relative depths of the objects changing as the work string advances downhole or retracts uphole in the borehole during operations.

[0013] Turning now to the figures, FIGs. 1A-1C are diagrams showing a slotted brush design, according to embodiments of the present disclosure. FIG. 1A shows a work string 110
20 that is used to deliver a sealing medium (e.g., cement, mud, etc.) to a wellbore that is being plugged and abandoned, with a first brush 120a (generally or collectively, brush 120) and a second brush 120b attached between a first coupling 112a (generally or collectively, coupling 112 or alternatively joint) and a second coupling 112b on the work string 110. The couplings 112 have a larger maximum outer diameter than the maximum diameter of other sections of
25 the work string 110, and therefore are able to secure the brushes 120 therebetween so the brushes 120 are prevented from moving axially past the respective couplings 112. In addition or alternatively to affixing bases 126 to the work string 110 via couplings 112 on the work string 110 (as in FIG. 1A), the bases 126 may be secured via end rings (as in FIG. 4) that are either incorporated into the bases 126 or placed downhole to and uphole to the bases 126, or
30 via a clamshell design (as in FIG. 5) for the bases 126.

[0014] Each of the brushes 120 includes a plurality of slots 124 (specifically or individually, slots 124a-h) defined in a base 126 (specifically or individually, bases 126a-b)

into which corresponding bristle cartridges 122 (specifically or individually, bristle cartridges 122a-h) are inserted, as is shown in the first brush 120a of FIG. 1A and the cross-sectional view of the brush 120 in FIG. 1B. Each bristle cartridge 122 may be individually inserted or removed by an operator; allowing the operator to change out bent or damaged bristle cartridges 122 for
5 fresh bristle cartridges 122 or trade out one set of bristle cartridges 122 for another with different characteristics. In one or more embodiments, the slots 124 may also engage with anti-rotation structures 114 included on the work string 110, the base 126 may include anti-rotation structures that engage with the work string 110, or the work string 110 and the base 126 may both include anti-rotation structures that engage with one another so as to reduce or prevent
10 rotation of the base 126 relative to the long axis of the work string 110. Although FIGs. 1A and 1B illustrate brushes 120 each with eight slots 124 for eight bristle cartridges 122, the present disclosure contemplates that designs that include more or fewer bristle cartridges 122 and that include more or fewer slots 124, with some of the slots 124 potentially being left unfilled by corresponding bristle cartridges 122.

15 **[0015]** FIG. 1C illustrates details of a bristle cartridge 122, as may be inserted into a slot 124 of a base 126 according to one or more embodiments of the present disclosure. The bristle cartridge 122 includes one or multiple springs 132 that, when the bristle cartridge 122 is installed in a slot 124, pushes the bristle cartridge 122 radially outward from the base 126. With the bristle cartridge 122 extended radially, one or more bristles 134 of the bristle cartridge 122
20 may contact the inner diameter of the wellbore to brush debris from the walls thereof. The bristle cartridge 122 is spring loaded to account for the presence of debris that may resist removal while ensuring contact with the inner diameter of the wellbore so as to remove other debris. An outer lip 136 and an inner lip 138 of the bristle cartridge 122 engage with the edges of the slot 124 to confine the radially inward or outward movement of the bristle cartridge 122
25 relative to the base 126 and to engage the bristle cartridge 122 to the slot 124. As the bristle cartridges 122 are intended to brush debris from the walls of a borehole, an operator may select bristle cartridges 122 of different dimensions (e.g., greater or lesser heights or thicknesses) or bristle characteristics (e.g., shape, hardness, location of brushing edge) based on the inner diameter of the borehole relative to the outer diameter of the work string 110.

30 **[0016]** FIGs. 2A-2C are diagrams showing a bow spring brush design, according to one or more embodiments of the present disclosure. FIG. 2A shows a work string 210, as may be used to deliver a sealing medium (e.g. cement retainer, cement, mud, etc.) to a wellbore that is being

plugged and abandoned, with a bow spring brush 220 attached to the work string 210 via a first base 226a (generally or collectively, base 226) on a first end of the bow spring brush 220 and a second base 226b on a second end of the bow spring brush 220, opposite to the first end. In various embodiments, the bases 226 may be secured to the work string 210 via couplings on the work string 210 (as in FIG. 1A), via end rings (as in FIG. 4) that are either incorporated into the bases 226 or placed downhole to and uphole to the bases 226, or via a clamshell design (as in FIG. 5) for the bases 226.

[0017] A plurality of first bow spring arms 224a-d (generally or collectively, bow spring arm 224) are shown connected to the first base 226a and a second plurality of bow spring arms 224e-h are connected to the second base 226b (bow spring arms 224d, 224h obscured by the work string 210 in FIG. 2A). In some embodiments, a first end of each bow spring arm 224 is connected to a base 226, and a second end, opposite to the first end, is connected to a bristle support 222 that includes a plurality of bristles. In some embodiments, the outer edges of the bow spring arms are shaped as or include bristles in the middle to provide integrated bristles. In some embodiments, the bristles are separate elements that are attached to the bow springs at the bristle support 222. The bow spring arms 224 push the respective bristle support 222 radially outward from the work string 210 so as to maintain contact between the bristles and the inner diameter of a borehole that the bow spring brush 220 is inserted into. In one or more embodiments, the bristle support 222 may include various numbers of bristles, and may occupy different portions of the length of the brush 220 relative to the lengths occupied by the bow spring arms 224 than what is illustrated in FIGs. 2A-2C. Although illustrated with four bristle supports 222 (and associated pairs of bow spring arms 224), the present disclosure contemplates that more or fewer bristle supports 222 that occupy different ratios of the circumference of the work string 210 than what is illustrated.

[0018] FIGs. 3A-3D are diagrams showing a pocketed brush design, according to embodiments of the present disclosure. FIG. 3A shows a work string 310 used to deliver a sealing medium (e.g. cement retainer, cement, mud, etc.) to a wellbore that is being plugged and abandoned, with first through fourth brushes 320a-d (generally or collectively, brush 320) attached between a first coupling 312a (generally or collectively, coupling 312) and a second coupling 312b in the work string 310. The couplings 312 have a larger outer diameter than the other sections of the work string 310, and therefore are able to secure the brushes 320 therebetween so the brushes 320 are prevented from moving downhole or uphole past the

respective couplings 312. In addition or alternatively to affixing bases 326 to the work string 310 via couplings on the work string 310 (as in FIG. 3A), the bases 326 may be secured via end rings (as in FIG. 4) that are either incorporated into the bases 326 or placed downhole to and uphole to the bases 326, or via a clamshell design (as in FIG. 5) for the bases 326.

5 [0019] Each of the brushes 320 include a plurality of pockets 324 defined in a base 326 into which corresponding bristle cartridges 330 may be inserted. FIG. 3B illustrates a pocket 324 defined through the base 326, and FIG. 3C illustrates a bristle cartridge 330 inserted through the pocket 324. Each bristle cartridge 330 may be individually inserted or removed by an operator; allowing the operator to change out bent or damaged bristle cartridges 330 for
10 fresh bristle cartridges 330 or trade out one set of bristle cartridges 330 for another with different characteristics. In one or more embodiments, the bases 326 may include anti-rotation structures 322a-b (generally or collectively, anti-rotation structure 322) on one or both ends of the brush 320 to engage with corresponding anti-rotation structures 322 defined on other bases 326, end-rings, or other structures of the work string 310 to prevent or reduce rotation about a
15 long axis of the work string 310 relative to the other elements that the anti-rotation structures 322 are engaged with.

[0020] Although FIGs. 3A and 3B illustrate brushes 320 each with two pockets 324 for two bristle cartridges 330, the present disclosure contemplates that designs that include more or fewer bristle cartridges 330 and that include more or fewer pockets 324, with some of the
20 pockets 324 potentially being left unfilled by corresponding bristle cartridges 330.

[0021] FIG. 3D provides a detailed view of the bristle cartridge 330, as may be inserted into a pocket 324 of a base 326 according to embodiments of the present disclosure. The bristle cartridge 330 includes one or multiple springs 332 that, when the bristle cartridge 330 is installed in a pocket 324 of a base 326 secured to the work string 310, pushes the bristle
25 cartridge 330 upward and away from the outer circumference of the work string 310 to thereby engage the bristle 334 with the inner diameter of the wellbore to brush debris from the walls thereof. Flanges 336a-b project from two or more sides of the body of the bristle cartridge to engage with the edges of the pocket 324 to confine the inward or outward movement of the bristle cartridge 330 relative to the base 326 and to secure the bristle cartridge 330 to the work
30 string 310. As the bristle cartridges 330 are intended to brush debris from the walls of a borehole, an operator may select bristle cartridges 330 of different dimensions (e.g., greater or lesser heights or thicknesses) or bristle characteristics (e.g., shape, hardness, location of

brushing edge) based on the inner diameter of the borehole relative to the outer diameter of the work string 310.

[0022] FIG. 4 is a diagram showing an end ring 420 for use with a brush tool, according to embodiments of the present disclosure. In various embodiments, the end ring 420 may be part of a base of a brush tool or a separate device that secures one or more brush (or other slip-on type) tools along a length of the work string 410. The end ring 420 is shown with an outer diameter 422 along a substantially circular cross-section, but may have various structures extending outward or inward from the outer diameter 422 that provide different cross-sectional shapes for the end ring 420. The inner diameter 424 of the end ring 420 is sized to be (within machining tolerances) substantially similar to, but slightly larger than, the outer diameter 412 of the work string 410 to which the end ring 420 is to be attached, to ensure a tight fit between the end ring 420 and the work string 410.

[0023] In various embodiments, various set screws 430a-l (generally or collectively, set screws 430) are affixed through corresponding threaded holes defined in the end ring 420 to contact the outer diameter 412 of the work string 410 to account any gap between the inner diameter 424 of the end ring 420 and the outer diameter 412 of the work string 410. In various embodiments, more or fewer set screws 430 may be used than are illustrated in FIG. 4. Additionally, the set screws 430 may be secured to the work string 410 in various orders (e.g., a maximized rotational distance scheme; first set screw 430a, seventh set screw 430g, fourth set screw 430d, tenth set screw 430j, etc.) to ensure that the end ring 420 is substantially concentrically aligned with the work string 410 and that the pressure applied by the end ring 420 is evenly applied to the work string 410 (e.g., the inner diameter 414 of the work string 410 remains substantially constant and circular).

[0024] FIG. 5 is a diagram showing a connection face of a clamshell brush design, according to embodiments of the present disclosure. In some embodiments, the brush of the present disclosure may slide onto the respective work string 510, or be placed onto the work string via a base that is divided into two or more portions 520a-b (generally or collectively, portion 520) that are secured to one another around the work string 510 to form the base. The portions 520 are shown with a combined outer diameter 522 along a substantially circular cross-section, but may have various structures extending outward or inward from the outer diameter 522 that provide different cross-sectional shapes for the base. The combined inner diameter 524 of the joined portions 520 is sized to be (within machining tolerances)

substantially similar to, but slightly larger than, the outer diameter 512 of the work string 510 to which the base is to be attached to, to ensure a tight fit between the base and the work string 510, while ensuring that the pressure applied by the joined portions 520 is evenly applied to the work string 510 (e.g., the inner diameter 514 of the work string 510 remains substantially constant and circular).

[0025] Various set screws 530a-b (generally or collectively, set screws 530) secure the portions 520 to another and ensure a tight fit of the inner diameter 524 of the joined portions 520 to the outer diameter 512 of the work string 510. Although one cross-sectional view is shown in FIG. 5, in various other cross-sectional views, additional set screws 530 may be included to provide pressure at different portions of the base to the work string 510 along the lengths thereof. In various embodiments, these additional set screws 530 may be aligned to be parallel or non-parallel with the set screws 530 in other cross-sections of the portions 520.

[0026] FIGs. 6A-6E are diagrams showing plug and abandonment operations of a well using an integrated brush tool and work string, according to embodiments of the present disclosure. Each of FIGs. 6A-6E show a well that has a borehole 640 extending from the surface 630 to a depth in a subterranean formation. The borehole 640 extends at least to a first predetermined depth 642a. As discussed herein, a plug 652 is to be formed between at least the first predetermined depth 642a and a second predetermined depth 642b to block access between the well (reservoir or formation) and the surface, although the plug 652 may extend downhole or uphole from the second predetermined depth 642b or the first predetermined depth 642a, respectively, in various embodiments. The plug 652 contacts the walls 644 of the borehole 640 at the designated depths, and blocks access of various materials (e.g., hydrocarbons) passing through the space formerly occupied by the borehole 640.

[0027] FIG. 6A shows initial insertion of a brush 620 affixed to a work string 610 (also referred to as or alternatively referring to as tubing or a tailpipe) being inserted into a cased borehole 640 at the surface 630. The work string 610 is attached to a cement retainer 670 (also referred to as a packer) with a setting device to form an annular barrier in the well to allow for the delivery of a sealing medium into the wellbore (formation/reservoir) in order to form a plug in the well. The cement retainer with its tailpipe at the bottom of the work string 610 is positioned downhole with the affixed brush 620, and an opposing end of the work string 610 is connected to a supply 650 for a sealing medium located at the surface. In various embodiments, the supply 650 represents one or more of: a tank or other container to hold the

sealing medium; various pumps, worm screws, or other devices for delivery of the sealing medium to the work string 610; motors, agitators, paddles, and other devices for mixing or moving the sealing medium within the supply 650; various tubing or piping for the delivery of the sealing medium to the work string 610; and the like. In various embodiments, an operator
5 may delay connecting the supply 650 to the work string 610 until ready to form the plug 652 in the well, as is shown in FIG. 6C.

[0028] In some embodiments, an annular filter 660 is installed onto the work string 610 between the brush 620 and the cement retainer 670. The annular filter 660 has a diameter less than or equal to the diameter of the walls 644 of the borehole 640, and is provided to collect
10 debris removed from the walls 644 by the brush 620 in order to prevent the debris from causing a tool failure (e.g., of the cement retainer 670 or packer). In various embodiments, the annular filter 660 may include magnets, filter tools, or the like so that debris is caught and completion equipment uphole is protected from the debris.

[0029] FIG. 6B shows the advancement of the integrated work string 610, cement retainer
15 670 with an associated setting device, and brush 620 to the first predetermined depth 642a in the borehole 640. The uphole end of the brush 620 is progressed through the borehole 640 to meet or pass the first predetermined depth 642a. Accordingly, because the brush 620 is held in contact with the wall 644 of the borehole 640 to the first predetermined depth 642a, the brush 620 is able to remove debris from the wall 644 down to the first predetermined depth 642a. In
20 various embodiments, an operator may move the work string 610 and integrated brush 620 downhole and uphole to brush the walls 644 of a designated section of the borehole 640 several times to improve the likelihood of the brush removing debris from the walls 644 in an area of interest.

[0030] In various embodiments, the operator may retract the integrated work string 610
25 with one plug 652 being formed in the well, and with various different sealing media being injected from different supplies 650 (e.g., cements, muds, gravels, sands, etc.). In some embodiments, the work string 610 is removed from the bore, while the brush 620 is left in the abandoned well; thereby reducing the time needed to abandon the well once sealed.

[0031] FIG. 6C shows the formation of a plug 652 in the borehole 640 that contacts the
30 walls of the borehole 640 (and is squeezed into the formation/annulus behind the casing) to thereby seal the well. As shown, the operator injects the sealing media via the work string 610

while the brush 620 is still attached to the work string 610 below the cement retainer 670 and is down bore. The work string 610 is then detached from the cement retainer 670 and brush 620 and removed from the bore with the cement retainer 670 and brush 620 remaining therein, uphole from the plug 652.

5 **[0032]** FIG. 6D shows the formation of a plug 652 in the borehole 640 that contacts the walls of the borehole 640 to thereby seal the well. As shown, the operator detaches the cement retainer 670 and brush 620 from the work string 610 before forming the plug 652 so that the cement retainer 670 and brush 620 remain in the well downhole from where the plug 652 is formed, while the work string 610 is removed from the well without the cement retainer 670
10 and brush 620 once the plug 652 is formed.

[0033] FIG. 6E shows the formation of a first plug 652a and a second plug 652b in the borehole 640 that contact the walls of the borehole 640 to thereby seal the well. As shown, the operator sets the cement retainer 670 with the setting device, injects the sealing media via the work string 610 and cement retainer 670 through the perforations into the
15 formation/reservoir/annulus while the brush 620 is still attached to the work string 610 and is downhole to form the first plug 652a. The work string 610 is then detached from the cement retainer 670 and the brush 620, which may rest on the first plug 652a or the walls uphole from the first plug 652a, and the work string 610 is moved uphole from the cement retainer 670 and brush 620 to then form the second plug 652b above the cement retainer 670.

20 **[0034]** FIG. 7 is a flowchart of an example method 700 for using a brush tool for well plug and abandonment operations, according to embodiments of the present disclosure. Method 700 begins at block 710, where an operator affixes a brush tool to an outer diameter of a work string. In various embodiments, the brush tool is affixed by sliding an inner diameter of the brush tool onto the outer diameter of the work string. In some embodiments, the brush tool is
25 affixed by connecting a first portion of the brush tool to a second portion of the brush tool around the outer diameter of the work string. The brush tool may be held in place along the length of the work string via one or more couplings between sections of the work string that have a greater diameter than the outer diameter of the work string and the inner diameter of the brush tool, or pressure and friction between the brush tool and the work string, which may be
30 applied via an end ring (either included in a base of the brush tool or separately secured to the work string).

[0035] In various embodiments, affixing the brush tool to the work string also includes engaging anti-rotation structures of the brush tool with the anti-rotation structures of one or more other brush tools (e.g., cleanout tools such as a slip-on magnets and/or annular filters) or of the work string to thereby reduce a freedom of rotation of the brush tool relative to the work string. For example, an operator may engage a first anti-rotation structures of a first brush tool with a second anti-rotation structure of the work string to thereby reduce rotation of the first brush tool relative to the work string along a long axis of the work string. In another example, an operator may engage a third anti-rotation structure of the first brush tool with a fourth anti-rotation structure of a second brush tool to thereby reduce rotation of the first brush tool relative to the second brush tool along the axis of the work string. When the first brush tool of the above examples engages both the anti-rotation structures of the second brush tool and the work string, the combined set of first brush tool, second brush tool, and work string may thereby reduce rotation of the two brush tools relative to the work string (or other tools) along the axis of the work string.

[0036] In various embodiments, the one or more brush tools affixed to the work string may include repeated instances of a single design or instances of different designs for the brush tools. In some embodiments, a brush tool affixed to the work string includes a plurality of slots defined circumferentially about an outer diameter of a base of the brush tool and a plurality of bristle cartridges each disposed in a corresponding slot of the plurality of slots and including one or more springs that push the bristle cartridge outward from the base and into contact with the inner diameter of the bore while the work string is inserted into the bore. In some embodiments, a brush tool affixed to the work string includes a first base, a second base, and a plurality of bow springs defined between and circumferentially about outer diameters of the first base and the second base, each including at least one bristle defined on a central portion of a corresponding bow spring, wherein the central portion projects outward from the work string to place at least one bristle in contact with the inner diameter of the bore while the work string is inserted into the bore. In some embodiments, a brush tool affixed to the work string includes a plurality of pockets defined circumferentially through an outer diameter of a base of the brush tool and a plurality of bristle cartridges each disposed in a corresponding pocket of the plurality of pockets and including one or more springs that push the bristle cartridge outward from the work string and into contact with the inner diameter of the bore while the work string is inserted into the bore.

[0037] At block 720, once the brush tool (or brush tools, annular filter, and other attached devices) is affixed to the outer diameter of the work string (per block 710), the operator advances the work string to a first predetermined depth in a wellbore of a well. While traveling from the opening of the bore to the first predetermined depth, the bristles of the brush tool
5 contact an inner diameter of the bore to brush off or otherwise remove debris from the inner diameter of the bore. The first predetermined depth corresponds to a start position to form a plug in the wellbore, and the removal of debris to this depth allows for improved contact between the sealing media (e.g., cement retainer elements) and the walls of the wellbore; thereby improving the seal once the plug is formed.

10 [0038] As the brush tool is located uphole relative to an open end of the work string (through which the sealing media are delivered), the open end of the work string is inserted into the wellbore to a depth greater than the brush tool. In one or more embodiments, an annular filter is installed on the work string between the cement retainer and the brush tool, which captures some or all of the debris removed from the walls of the wellbore by the brush tool, to
15 further protect the cement retainer from debris.

[0039] At block 730, the operator retracts the brush tool to a second predetermined depth in the wellbore, uphole from the first predetermined depth to place the open end of the work string at or uphole to the first predetermined depth. In various embodiments, the operator may move the work string downhole and uphole between the first and second predetermined depths
20 to move the brush tool against the walls of the bore between these depths several time to loosen and remove debris from the walls before setting the cement retainer and depositing the sealing media to form a plug in the well. Accordingly, method 700 may return to block 720 from block 730 or proceed to block 740 according to operator preference.

[0040] At block 740, the operator sets the cement retainer into the wellbore to provide a
25 platform on which to deposit the sealing medium. In various embodiments, the operator expands the cement retainer from a first diameter that allows for insertion through the wellbore without contacting the inner walls to a second diameter that contacts the inner walls.

[0041] At block 750, the operator injects a sealing medium into the bore at the first
30 predetermined depth from a source located at the surface to the designated depth in the borehole via the work string. In various embodiments, the operator may inject the sealing media to a thickness that fills from the first predetermined depth to the second predetermined depth (and

through perforations into the formation/reservoir and the annulus behind the casing), but may apply more or less of the sealing medium according to the intended design of the plug used to seal a well to be abandoned. In various embodiments, the operator may use various different sealing media at different depths in the wellbore, which include various cements, epoxies, mud,
5 gravel, sand, and the like.

[0042] At block 760, the operator removes the work string from the bore. In some embodiments, the operator detaches the work string with the setting device from the cement retainer (with the brush tool below) before removing the work string from the bore; leaving the cement retainer and brush tool downhole as part of the well plug and abandonment operations.
10 Although not required, in some embodiments, the operator may also remove cement retainer (after unsetting from the wellbore) and brush tool when removing the work string from the wellbore. Method 700 may then conclude with the operator having performed a single insertion operation for both the placement of sealing media and the cleaning of the walls of the wellbore to be sealed and a single removal operation.

15 [0043] Certain terms are used throughout the description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function.

[0044] While descriptions herein may relate to “comprising” various components or steps,
20 the descriptions can also “consist essentially of” or “consist of” the various components and steps.

[0045] As used herein, any element referred to using the articles “a” and “an” refer to one or to more than one (e.g., to at least one) of the grammatical object of the article. Similarly, when any element is referred to using a given number (whether or ordinal or cardinal), that
25 number inherently refers to any number of that element equal to or greater than the referred number. For example, when discussing two widgets or a first widget and a second widget, the present disclosure contemplates that an unstated third, fourth, fifth, ... n th widget may be included unless identified using a bounding phrase such as “only n ”, “exactly n ”, “up to n ”, or the like.

30 [0046] Unless otherwise indicated, all numbers expressing quantities are to be understood as being modified in all instances by the term “about” or “approximately”. Accordingly, unless

indicated to the contrary, the numerical parameters are approximations that may vary depending upon the desired properties of the present disclosure. As used herein, “about”, “approximately”, “substantially”, and “significantly” will be understood by persons of ordinary skill in the art and will vary to some extent on the context in which they are used. If there are
5 uses of the term which are not clear to persons of ordinary skill in the art given the context in which it is used, “about” and “approximately” will mean plus or minus 10% of the particular term and “substantially” and “significantly” will mean plus or minus 5% of the particular term.

[0047] The embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. It is to be fully recognized that the different
10 teachings of the embodiments discussed may be employed separately or in any suitable combination to produce desired results. In addition, one skilled in the art will understand that the description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

CLAIMS

What is claimed is:

1. A method, comprising:
5 affixing a brush tool to an outer diameter of a work string;
 advancing the work string to a first predetermined depth in a wellbore of a well;
 retracting the brush tool to a second predetermined depth in the wellbore further uphole
 than the first predetermined depth; and
 injecting a sealing medium through the work string into the wellbore at the first
10 predetermined depth to plug the well.
2. The method of claim 1, wherein the brush tool is affixed by sliding the brush tool onto
the outer diameter of the work string.
- 15 3. The method of claim 1, wherein the brush tool is affixed by connecting a first portion
of the brush tool to a second portion of the brush tool around the outer diameter of the work
string.
4. The method of claim 1, further comprising securing the brush tool in place along a
20 length of the work string via an end ring.
5. The method of claim 1, further comprising securing the brush tool in place along a
length of the work string via a coupling between a first section of the work string and a second
section of the work string having a greater diameter than the outer diameter of the work string.
25
6. The method of claim 1, further comprising reducing a freedom of rotation of the brush
tool relative to the work string by engaging a first anti-rotation structure of the brush tool with
a second anti-rotation structure of the work string.

7. The method of claim 1, further comprising:
securing at least one bristle cartridge into at least one slot defined circumferentially
about an outer diameter of a base of the brush tool;
pushing the at least one bristle cartridge radially outward from the base via a spring in
5 the bristle cartridge that pushes against the at least one slot; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
removing debris from the inner diameter of the wellbore via brushing the debris from
the inner diameter with the bristle while advancing to the first predetermined
depth.
- 10
8. The method of claim 1, wherein affixing the brush tool further comprises:
affixing a first base of the brush tool to first portion of the work string;
affixing a second base of the brush tool to second portion, downhole to the first portion,
of the work string;
15 pushing a central portion of a bow spring radially outward from the first base and the
second base that the bow spring is connected to;
contacting an inner diameter of the wellbore via a bristle of the brush tool defined on
the central portion; and
removing debris from the inner diameter of the wellbore via brushing the debris from
20 the inner diameter with the bristle while advancing to the first predetermined
depth.
9. The method of claim 1, further comprising:
securing at least one bristle cartridge into at least one pocket defined circumferentially
25 about an outer diameter of a base of the brush tool;
pushing the at least one bristle cartridge radially outward from the work string via a
spring in the bristle cartridge that pushes against the work string; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
removing debris from the inner diameter of the wellbore via brushing the debris from
30 the inner diameter with the bristle while advancing to the first predetermined
depth.

10. The method of claim 1, further comprising:
catching debris in the wellbore using an annular filter installed on the outer diameter of
the work string between the brush tool and a cement retainer when advancing
the work string in the wellbore;
- 5 detaching, down bore, the cement retainer with the brush tool from the work string; and
removing the work string without the cement retainer and the brush tool from the
wellbore.
11. A method, comprising:
10 sliding a brush tool onto an outer diameter of a work string;
advancing the work string into a wellbore to a first predetermined depth in the wellbore,
wherein the brush tool contacts an inner diameter of the wellbore;
retracting the work string to a second predetermined depth in the wellbore, uphole from
the first predetermined depth; and
- 15 after retracting the work string to the second predetermined depth in the wellbore,
injecting a sealing medium into the wellbore at the first predetermined depth to
the second predetermined depth.
12. The method of claim 11, further comprising:
20 securing at least one bristle cartridge into at least one slot defined circumferentially
about an outer diameter of a base of the brush tool;
pushing the at least one bristle cartridge radially outward from the base via a spring in
the bristle cartridge that pushes against the at least one slot; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
- 25 removing debris from the inner diameter of the wellbore via brushing the debris from
the inner diameter with the bristle while advancing to the first predetermined
depth.

13. The method of claim 11, wherein affixing the brush tool further comprises:
affixing a first base of the brush tool to a first portion of the work string;
affixing a second base of the brush tool to a second portion of the work string, downhole
to the first portion;
5 pushing a central portion of a bow spring radially outward from the first base and the
second base that the bow spring is connected to;
contacting an inner diameter of the wellbore via a bristle of the brush tool defined on
the central portion; and
removing debris from the inner diameter of the wellbore via brushing the debris from
10 the inner diameter with the bristle while advancing to the first predetermined
depth.
14. The method of claim 11, further comprising:
securing at least one bristle cartridge into at least one pocket defined circumferentially
15 about an outer diameter of a base of the brush tool;
pushing the at least one bristle cartridge radially outward from the work string via a
spring in the bristle cartridge that pushes against the work string; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
removing debris from the inner diameter of the wellbore via brushing the debris from
20 the inner diameter with the bristle while advancing to the first predetermined
depth.
15. The method of claim 11, further comprising:
catching debris in the wellbore using an annular filter installed on the outer diameter of
25 the work string between the brush tool and a cement retainer when advancing
the work string in the wellbore;
detaching, down bore, the cement retainer with the brush tool from the work string; and
removing the work string without the cement retainer and brush tool from the wellbore.

16. A method, comprising:
securing a brush tool around an outer diameter of a work string by securing a first
portion of the brush tool to a second portion of the brush tool;
advancing the work string to a first predetermined depth in a wellbore of a well, wherein
5 the brush tool contacts an inner diameter of the wellbore;
retracting the work string to a second predetermined depth in the wellbore, less than the
first predetermined depth; and
injecting, after retracting the work string to the second predetermined depth in the
wellbore and setting a cement retainer, a sealing medium into the wellbore at
10 the first predetermined depth to the second predetermined depth.
17. The method of claim 16, further comprising:
securing at least one bristle cartridge into at least one slot defined circumferentially
about an outer diameter of a base of the brush tool;
15 pushing the at least one bristle cartridge radially outward from the base via a spring in
the bristle cartridge that pushes against the at least one slot; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
removing debris from the inner diameter of the wellbore via brushing the debris from
the inner diameter with the bristle while advancing to the first predetermined
20 depth.
18. The method of claim 16, wherein affixing the brush tool further comprises:
affixing a first base of the brush tool to a first portion of the work string;
affixing a second base of the brush tool to a second portion of the work string, downhole
25 to the first portion;
pushing a central portion of a bow spring radially outward from the first base and the
second base that the bow spring is connected to;
contacting an inner diameter of the wellbore via a bristle of the brush tool defined on
the central portion; and
30 removing debris from the inner diameter of the wellbore via brushing the debris from
the inner diameter with the bristle while advancing to the first predetermined
depth.

19. The method of claim 16, further comprising:
securing at least one bristle cartridge into at least one pocket defined circumferentially
about an outer diameter of a base of the brush tool;
pushing the at least one bristle cartridge radially outward from the work string via a
5 spring in the bristle cartridge that pushes against the work string; and
contacting an inner diameter of the wellbore via a bristle of the bristle cartridge; and
removing debris from the inner diameter of the wellbore via brushing the debris from
the inner diameter with the bristle while advancing to the first predetermined
depth.
10
20. The method of claim 16, further comprising:
catching debris in the wellbore using an annular filter installed on the outer diameter of
the work string between the brush tool and a cement retainer when advancing
the work string in the wellbore;
15 detaching, down bore, the cement retainer with the brush tool from the work string; and
removing the work string without the cement retainer and brush tool from the wellbore.

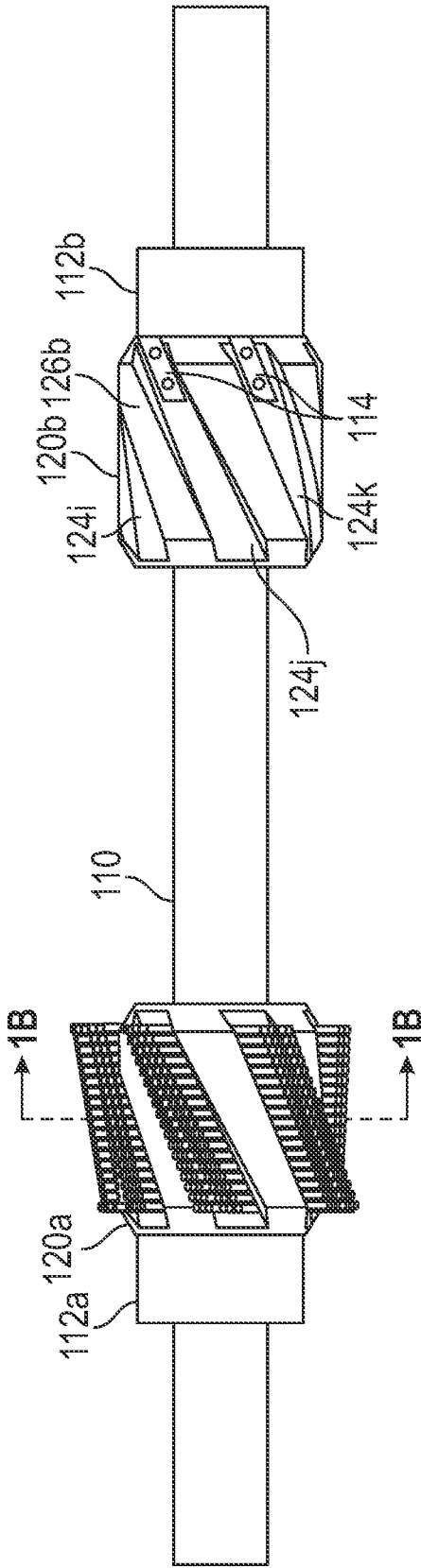


FIG. 1A

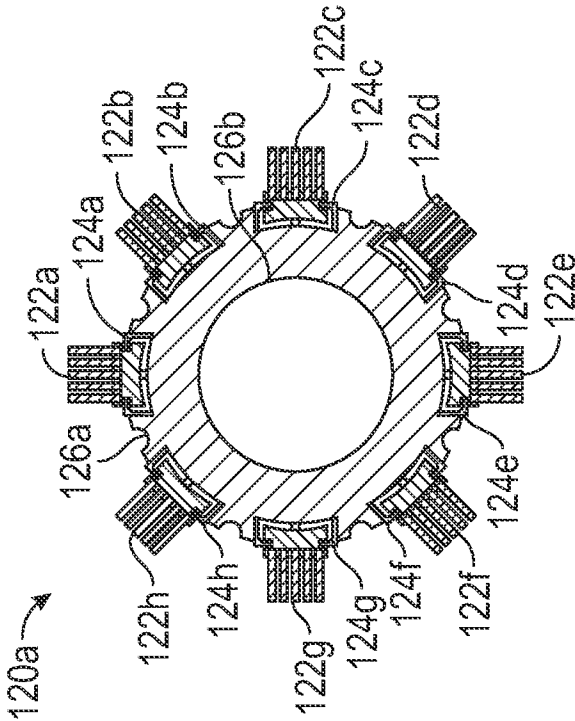


FIG. 1B

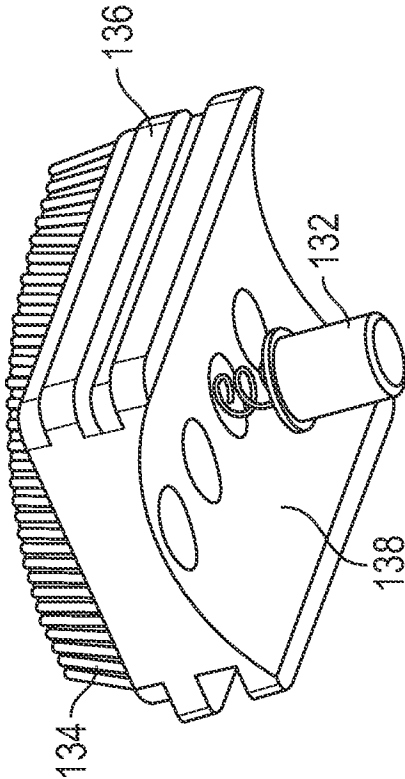
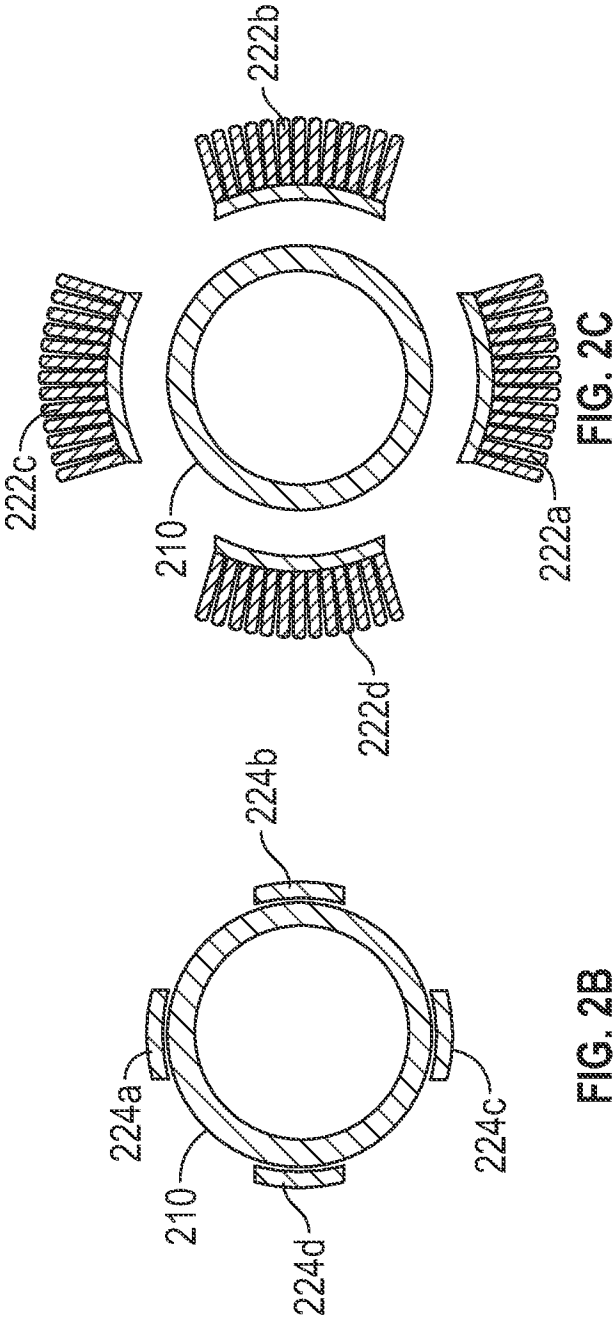
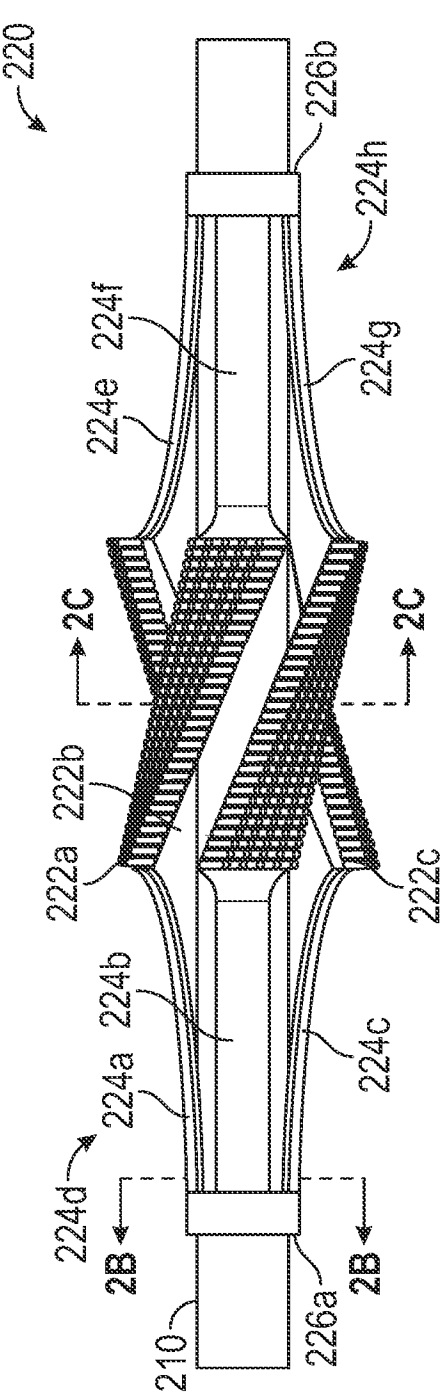


FIG. 1C



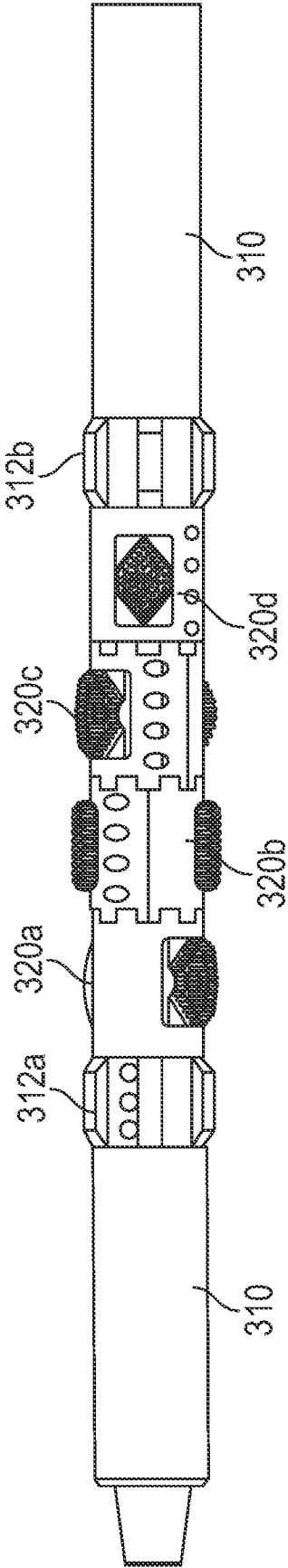


FIG. 3A

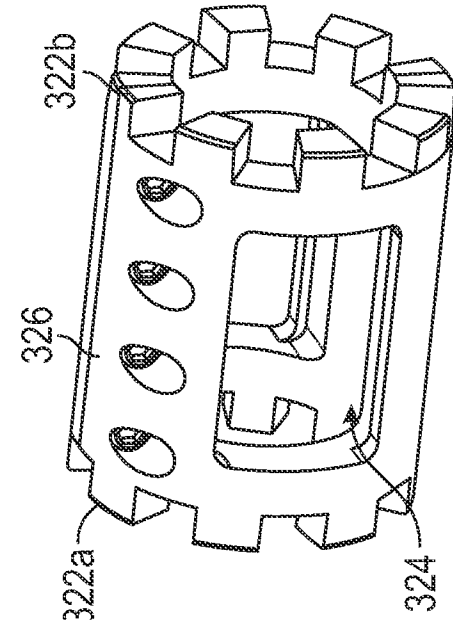


FIG. 3B

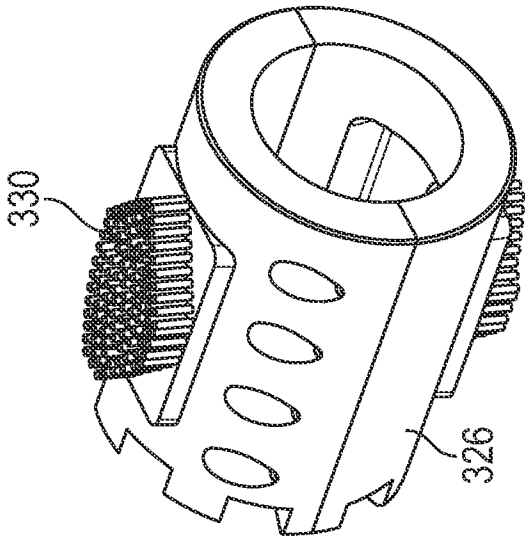


FIG. 3C

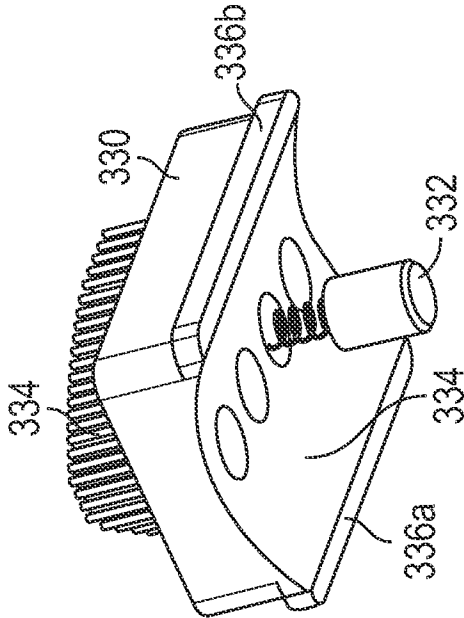


FIG. 3D

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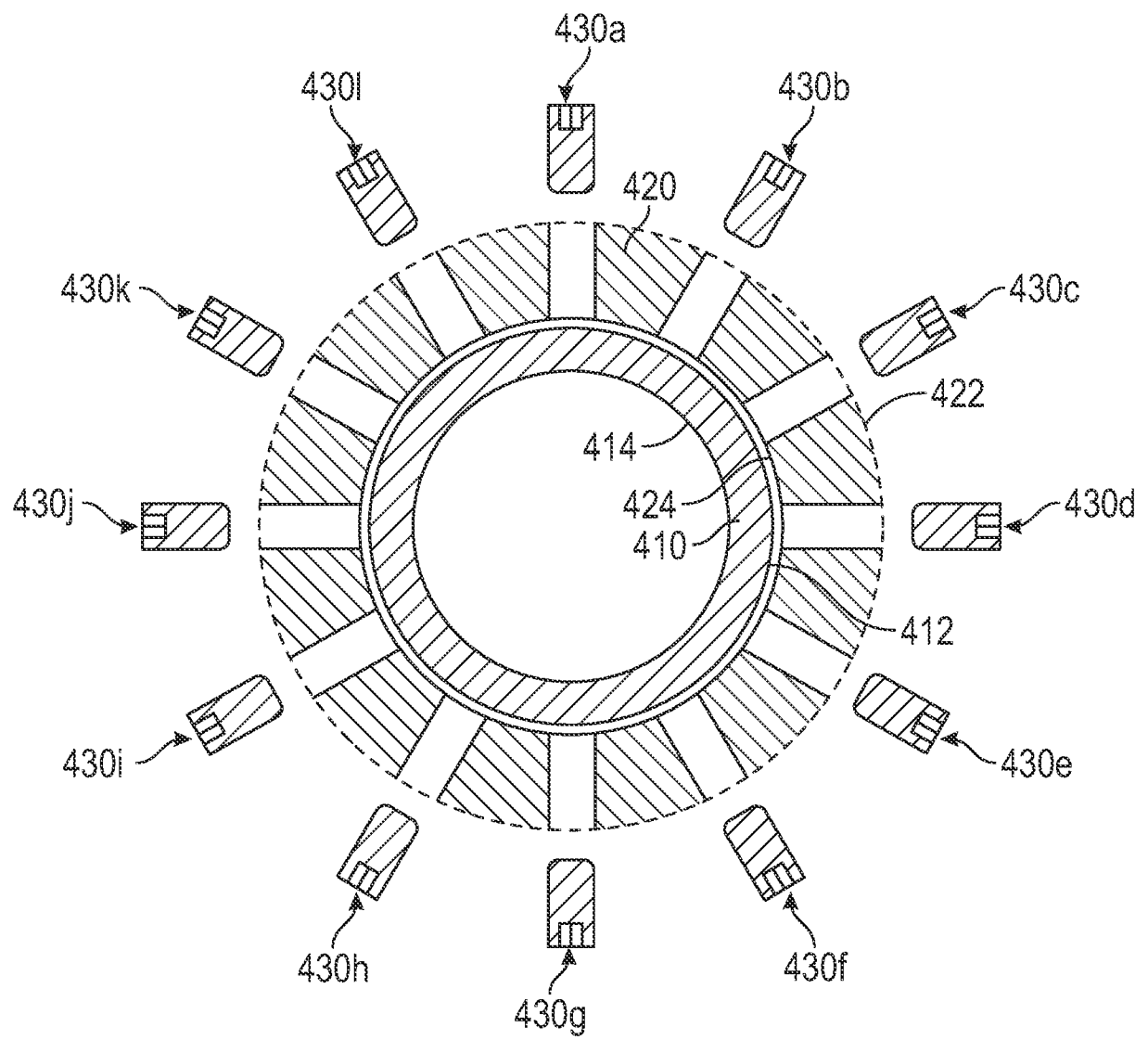


FIG. 4

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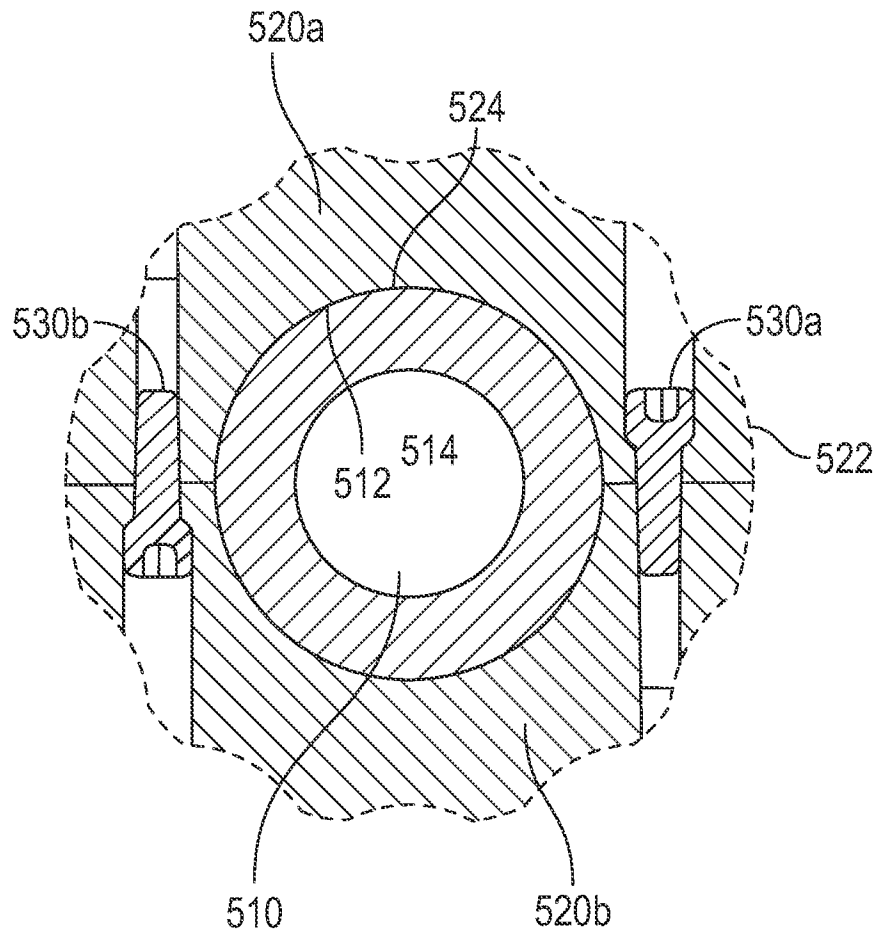


FIG. 5

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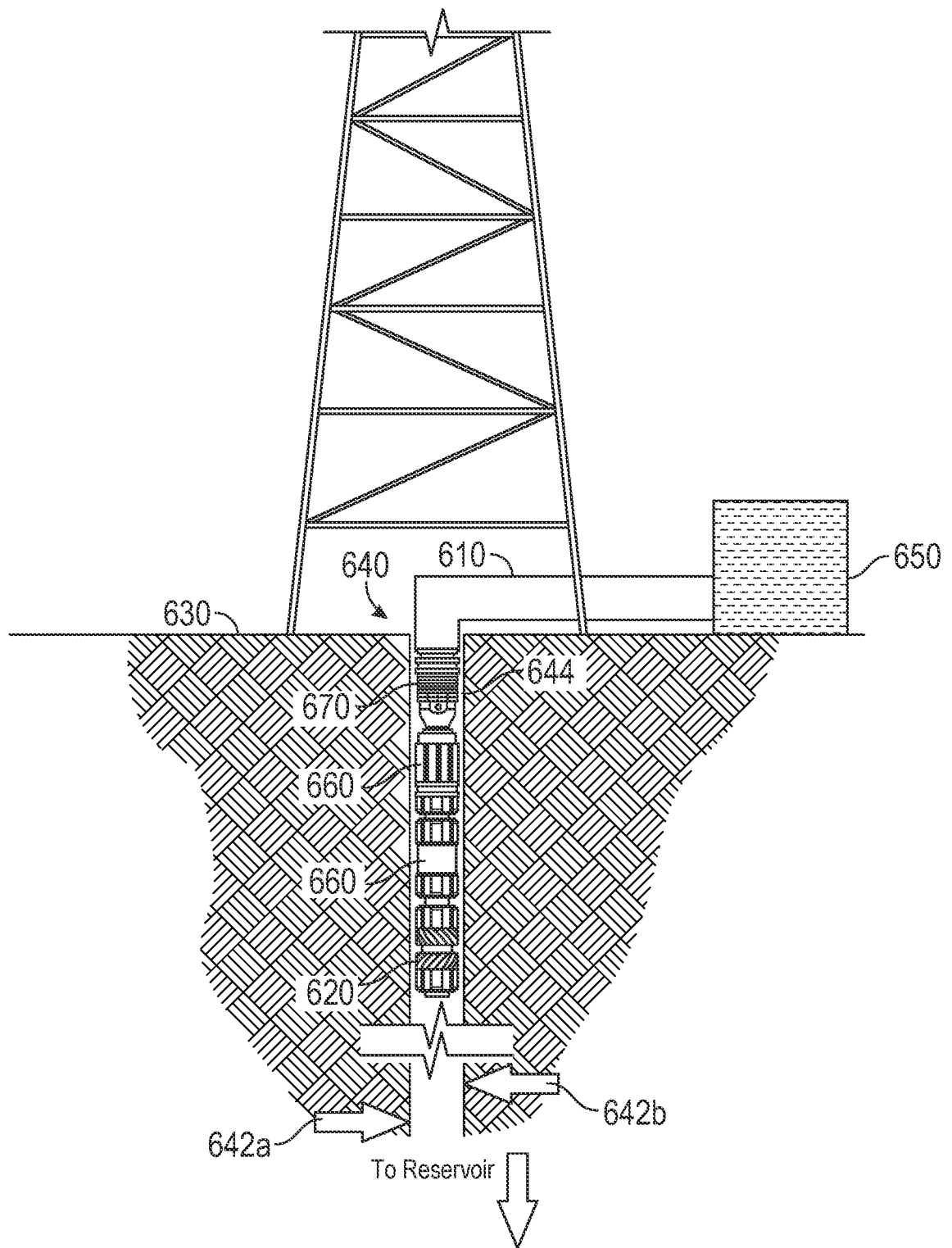


FIG. 6A

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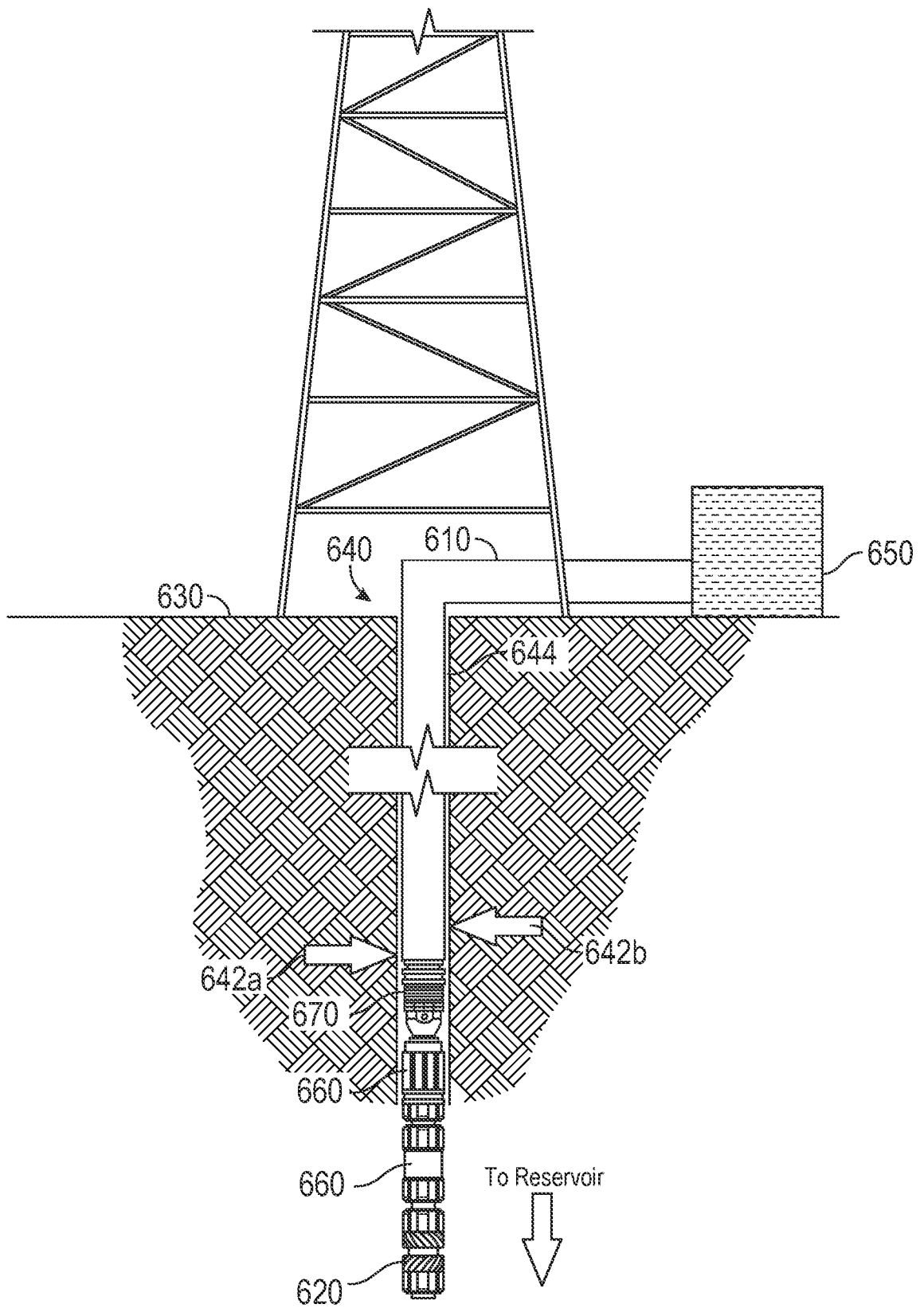
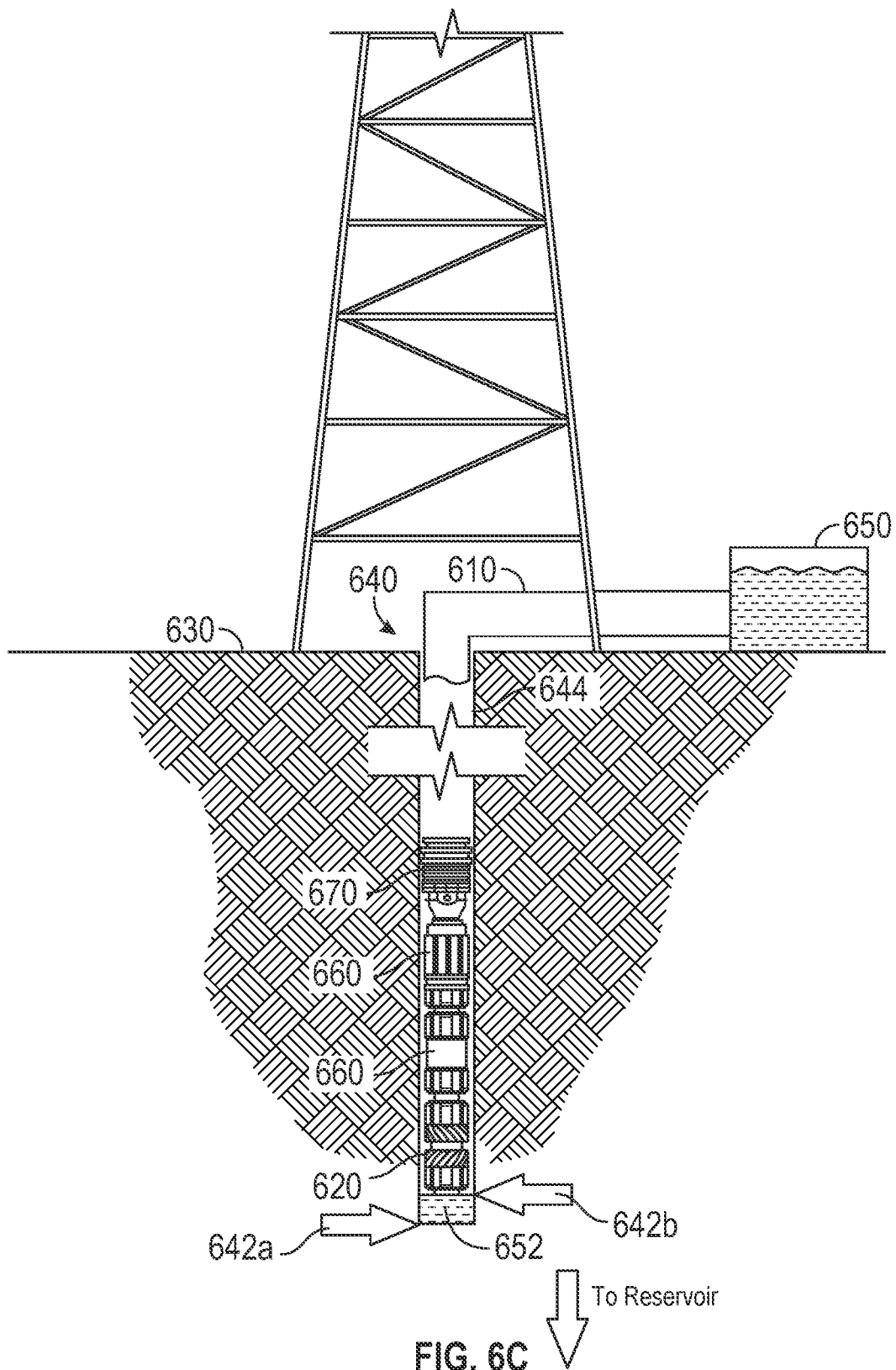


FIG. 6B

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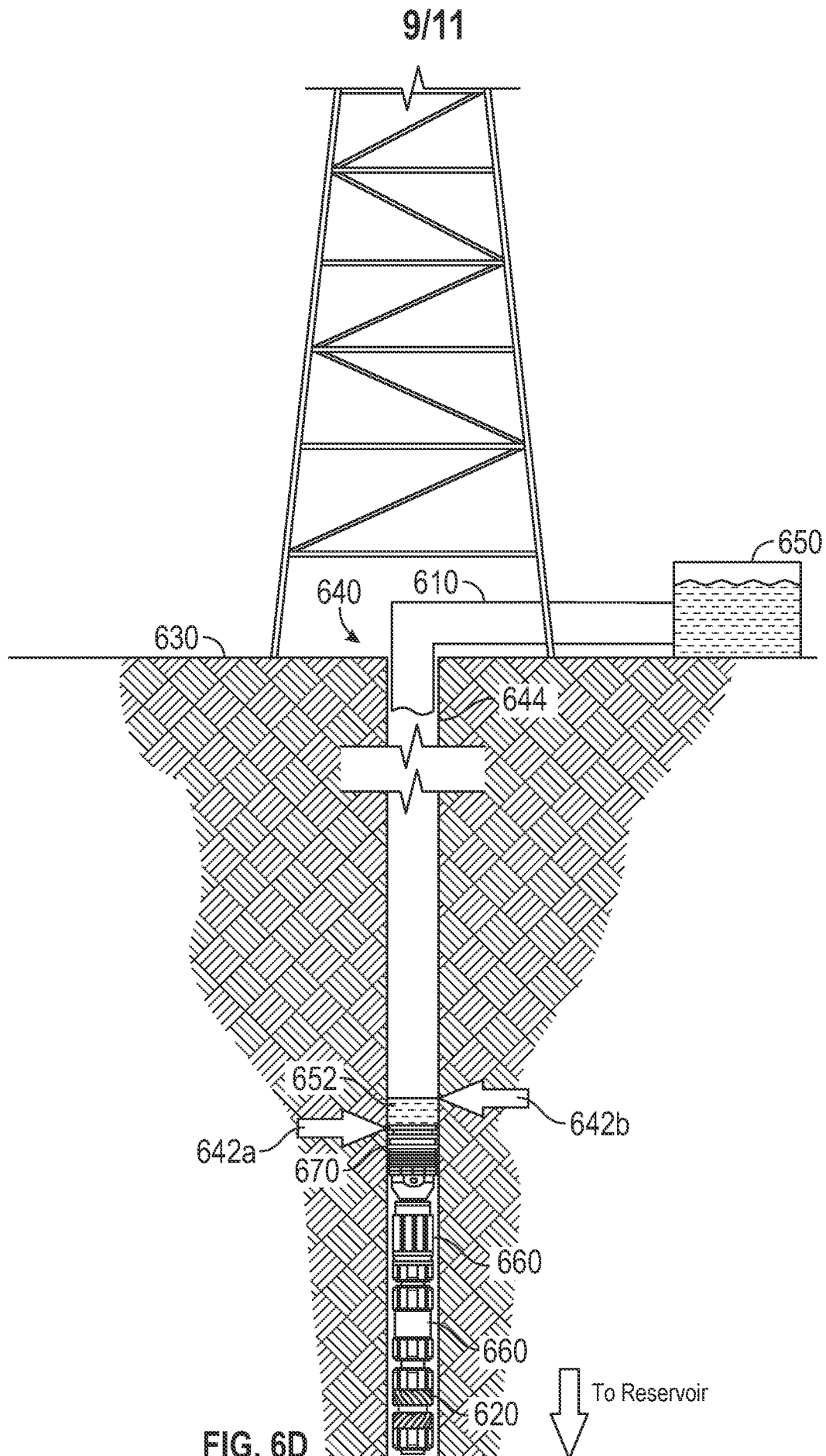
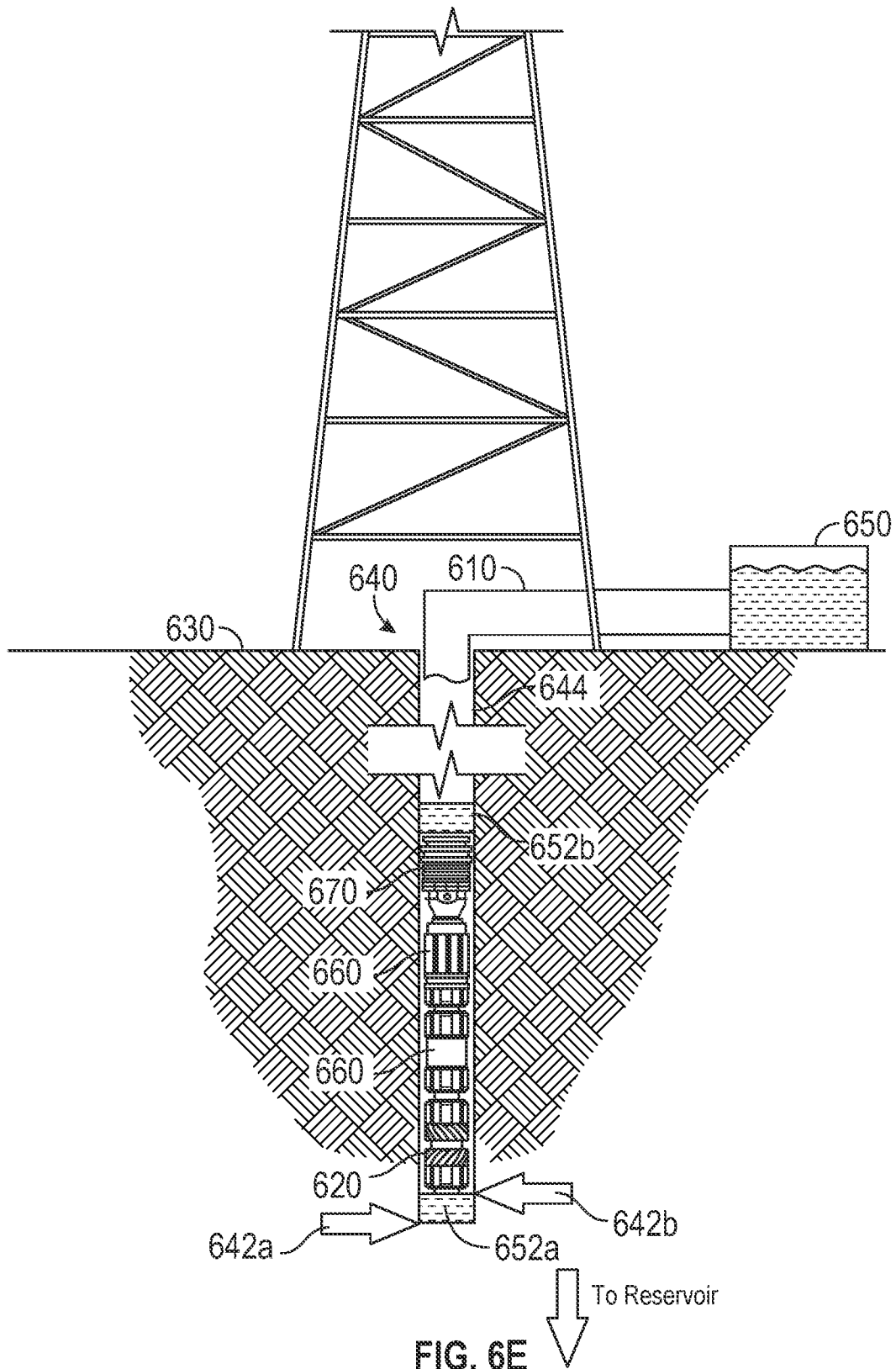


FIG. 6D

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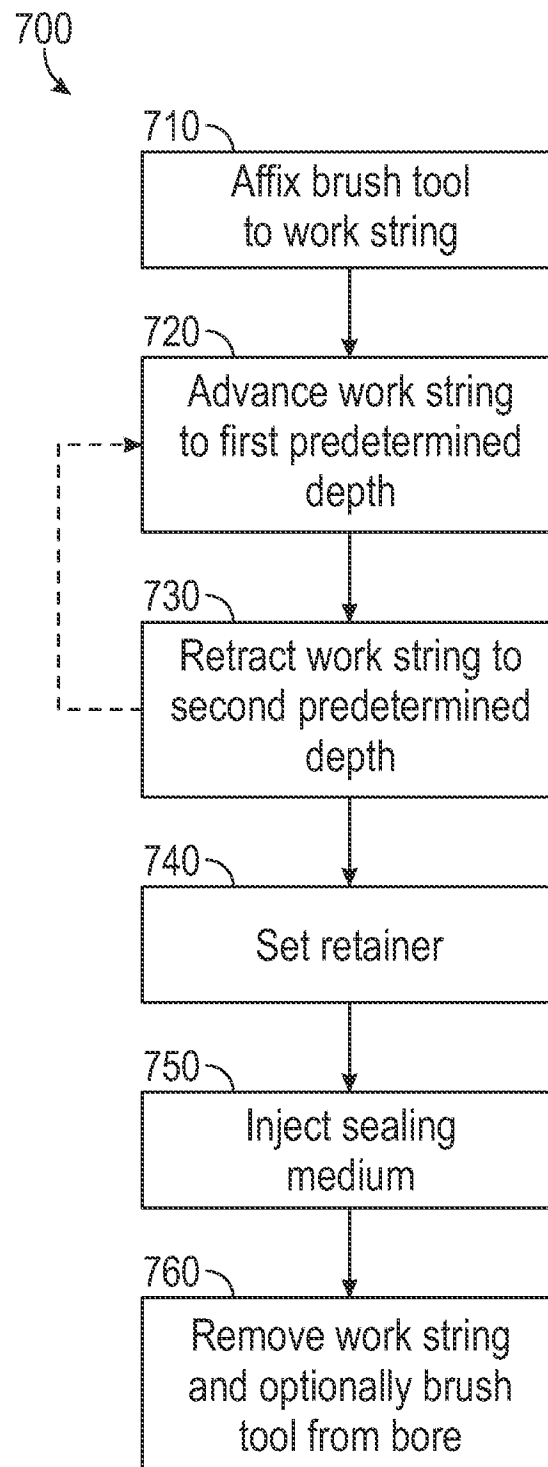


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/069617

A. CLASSIFICATION OF SUBJECT MATTER**E21B 33/14(2006.01)i; E21B 37/02(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 33/14(2006.01); E21B 12/06(2006.01); E21B 37/02(2006.01); E21B 47/12(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: borehole, brush, sealing, spring, slot, clean

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2020-0332625 A1 (HALLIBURTON ENERGY SERVICES, INC.) 22 October 2020 (2020-10-22) paragraphs [0018]-[0035] and figures 1-6C	1-20
Y	US 2021-0079735 A1 (HALLIBURTON ENERGY SERVICES, INC.) 18 March 2021 (2021-03-18) paragraph [0031] and figures 1-7	1-20
Y	US 2015-0027713 A1 (PENISSON, DENNIS JOEL) 29 January 2015 (2015-01-29) paragraph [0030] and figures 1-8	9,14,19
Y	US 2013-0192818 A1 (WELL GROUNDED ENERGY, LLC.) 01 August 2013 (2013-08-01) paragraph [0080] and figure 13	10,15,20
A	US 2006-0124359 A1 (BUNNEY, LARRY R.) 15 June 2006 (2006-06-15) paragraph [0018] and figures 1-4	1-20

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

26 March 2024

Date of mailing of the international search report

26 March 2024

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/069617

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				GB	2590259	B	28 September 2022
				NO	20210263	A1	26 February 2021
				US	11319778	B2	03 May 2022
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				GB	2591644	B	31 August 2022
				NO	20210345	A1	18 March 2021
				US	11066876	B2	20 July 2021
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				CA	2487380	C	19 February 2013
				US	7520340	B2	21 April 2009