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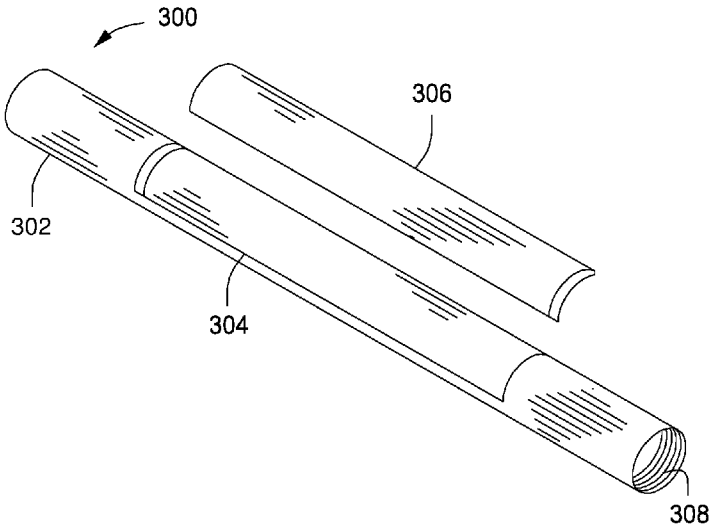


FIG. 3

(57) Abstract: A casing joint and systems and methods related thereto. The casing joint comprises a tubular body, a window formed through a sidewall of the tubular body, and a degradable material secured to the tubular body to occlude the window. The degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm2) at 93.3C when exposed to a 15% potassium chloride solution.

DEGRADABLE CASING JOINTS FOR USE IN SUBTERRANEAN FORMATION OPERATIONS

BACKGROUND

[0001] The present disclosure relates to subterranean formation operations and, more particularly, to degradable casing joints for completion of lateral wellbores.

[0002] Hydrocarbon producing wells (*e.g.*, oil producing wells, gas producing wells, and the like) are created and stimulated using treatment fluids introduced into the wells to perform a number of subterranean formation operations. A treatment fluid in this context refers generally to any fluid that may be used in a subterranean application in conjunction with a desired function and/or for a desired purpose, but unless otherwise indicated does not imply any particular action by the fluid or any component thereof.

[0003] Hydrocarbon producing wells are first formed by drilling a parent wellbore into a subterranean formation, involving circulating a drilling treatment fluid as the wellbore is bored out using a drill bit. The parent wellbore is then completed by positioning a casing string (which generally includes a plurality of interconnected casing joints) within the wellbore and cementing the casing string in position. A casing string is used to line a wellbore, which may be cemented in place, and which increases the integrity of the wellbore and provides a flow path between the casing surface and a selected subterranean formation. This flow path may be used to introduce treatment fluids into the surrounding formation to stimulate production, to receive the flow of hydrocarbons from the formation, and to permit the introduction of fluids for reservoir management or disposal purposes.

[0004] To make the production of hydrocarbons more economical, one or more lateral wellbores may be drilled from a wellbore and similarly completed. Typically, to form a lateral wellbore, a whipstock is positioned in the casing string in the parent wellbore at a desired intersection, and then a rotating mill is used to form an access window through the casing sidewall. Thereafter, a drill bit is used to bore the lateral wellbore through the window.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following figures are included to illustrate certain aspects of the present disclosure and should not be viewed as exclusive examples. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to one having ordinary skill in the art and the benefit of this disclosure.

[0006] FIG. 1 is a schematic cross-sectional view of an offshore oil and gas platform using an exemplary well system subassembly.

[0007] FIG. 2 is a schematic cross-sectional view of an enlarged view of a well system subassembly.

[0008] FIG. 3 is a schematic perspective view of a casing joint.

[0009] FIGS. 4A-4B are schematic cross-sectional views of a casing joint.

DETAILED DESCRIPTION

[0010] The present disclosure relates to subterranean formation operations and, more particularly, to the use of degradable materials to temporarily occlude a window (*i.e.*, aperture(s)) formed through a sidewall of a tubular body, (*e.g.*, a casing joint), so that the window can be selectively exposed (*i.e.*, unoccluded) for lateral entry or exit, such as in the completion of lateral wellbores.

[0011] A casing joint may have a tubular body, a window formed through a sidewall of the tubular body, and a degradable material substrate secured to the tubular body to initially occlude the window and form a fluidic seal therewith. The fluidic seal assures that no appreciable fluid will leak out from the occluded window while the degradable material substrate remains intact. A typical casing joint may include, for example, a length of casing (*e.g.*, steel pipe.). Multiple casing joints may be assembled to form a casing string of a desired length and specification for the wellbore in which it is installed. Each casing joint may be assembled, for example, by male to female threading either between the two joints or with a threaded casing coupling. The window may be a portion of the casing joint through which access to one or more specified zones of a subterranean formation to form a lateral wellbore is made. The window of the present disclosure is pre-milled such that an opening in the sidewall tubular body of the casing joint is made prior to its placement in a wellbore. The fluidic

seal (which may have grammatical variants below) refers to a seal that prevents fluid flow between opposite sides of the seal (*e.g.*, between an inside of the tubular body of the casing joint and through the occluded window to the outside of the tubular body of the casing joint). In the examples below, a sidewall may refer to a structural wall (including any surface thereof) of an apparatus (*e.g.*, the tubular wall of a casing joint), which may but does not necessarily extend between the apparatus' top surface and the apparatus' bottom surface.

[0012] The window of the casing joint described herein includes a degradable material secured to the tubular body to occlude the window and form a fluidic seal. The degradable materials may refer to materials that wholly or partially degrade in the presence of a reactant in a downhole environment. The degradable materials discussed in greater detail below, have a degradation rate of greater than about 0.1 (*e.g.*, as low as 0.0095) milligrams per square centimeters (mg/cm^2) at 93.3°C (200°F) when exposed to a 15% potassium chloride (KCl) solution. Accordingly, upon contact with an appropriate reactant in a wellbore, the degradable material degrades to expose the window for lateral exit or entry, such as for access to forming a lateral wellbore therethrough.

[0013] Thus, the casing joints of the present disclosure may avoid or reduce costs and equipment usage associated with milling a window in a casing string, avoid or reduce costs and equipment usage associated with actuating a pre-milled slidable sleeve window or use of a specialized milling tool to remove a smaller section of a pre-milled window, avoid or reduce operational costs associated with running tools into and out of a wellbore during the formation of a lateral wellbore, and the like. Instead, the casing joints described herein are able to be placed downhole using standard equipment and to endure typical downhole environments (*e.g.*, temperature, pressure, salinity, and the like), and thereafter upon contact with a reactant have a window exposed (*i.e.*, unoccluded) by degradation of the degradable material. Moreover, despite the presence of the degradable material, the casing joint of the present disclosure behaves as a standard section of casing string as it is placed downhole and until degradation is stimulated by contact with a reactant. Additionally, once degradation of the degradable material is stimulated, the structural integrity of the casing window assembly is not hindered, as only the degradable material itself is degraded, which may be designed to be merely large enough to

accommodate equipment for drilling and completing the lateral wellbore through the window (*e.g.*, a drilling assembly, a multilateral junction, and the like).

[0014] Not all features of an actual implementation are described or shown in this application for the sake of clarity. It is understood that numerous implementation-specific decisions may need to be made to achieve the developer's goals, such as compliance with system-related, lithology-related, business-related, government-related, and other constraints, which vary by implementation and from time to time. While a developer's efforts might be complex and time-consuming, such efforts would be, nevertheless, a routine undertaking for those of ordinary skill in the art having benefit of this disclosure.

[0015] At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claim, each numerical parameter herein should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0016] While compositions and methods are described herein in terms of "comprising" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. When "comprising" is used in a claim, it is open-ended.

[0017] As used herein, the term "substantially" means largely, but not necessarily wholly.

[0018] The use of directional terms such as above, below, upper, lower, upward, downward, left, right, uphole, downhole and the like are used as they are depicted in the figures, and unless otherwise indicated, 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 well and the downhole direction being toward the toe of the well.

[0019] As used herein, the term "degradable," and grammatical variants thereof (*e.g.*, "degrade," "degradation," "degrading," "dissolve," dissolving," and the like), refers to the dissolution or chemical conversion of solid materials such that reduced-mass solid end products result by at least one of solubilization, hydrolytic degradation, biologically formed entities (*e.g.*, bacteria or enzymes), chemical reactions (including electrochemical and galvanic reactions), thermal reactions, reactions induced by radiation, or combinations thereof. The term "degradable," and its grammatical variants, does not imply

complete degradation, although complete degradation may take place without departing from the scope of the present disclosure. The degradable materials of the present disclosure are at least partially degraded or wholly degraded, where at least partial degradation refers to a degradation of at least about 80% (*e.g.*, as low as 76%) of the volume of the degradable material.

[0020] The conditions for degradation are generally downhole conditions in a wellbore environment where an external reactant may be used to initiate or affect the rate of degradation. The external reactant (or simply "reactant) is introduced into the wellbore (*e.g.*, fluids, chemicals). However, naturally occurring wellbore environment conditions may additionally influence either initiation or the rate of degradation of the degradable material (*e.g.*, pressure, pH, temperature, and the like), without departing from the scope of the present disclosure. Accordingly, the term "wellbore environment" includes both naturally occurring wellbore environments and materials or fluids introduced into the wellbore.

[0021] Referring to FIG. 1, illustrated is an offshore oil and gas platform 100 that is able to use one or more of the exemplary casing joint assemblies described herein. Even though FIG. 1 depicts an offshore oil and gas platform 100, the casing joints disclosed herein may be equally well suited for use in or on other types of oil and gas rigs, such as land-based oil and gas rigs or rigs located at any other geographical site. The platform 100 may be a semi-submersible platform 102 centered over a submerged oil and gas formation 104 located below the sea floor 106. A subsea conduit 108 extends from the deck 110 of the platform 102 to a wellhead installation 112 that includes one or more blowout preventers 114. The platform 102 has a hoisting apparatus 116 and a derrick 118 for raising and lowering pipe strings, such as a drill string 120, within the subsea conduit 108.

[0022] As depicted, a parent wellbore 122 has been drilled through the various earth strata, including the formation 104. The term "parent" wellbore is used herein to designate a wellbore from which another wellbore is drilled. It is to be noted, however, that a parent or parent wellbore does not necessarily extend directly to the earth's surface, but could instead be a branch of another wellbore. A casing string 124 is at least partially cemented within the parent wellbore 122.

[0023] A casing joint 126 may be interconnected between elongate portions or lengths of the casing string 124 and positioned at a desired location within the wellbore 122 where a lateral wellbore 128 is to be drilled (already drilled as shown). The term "lateral" wellbore is used herein to designate a wellbore that is drilled outwardly from its intersection with another wellbore, such as a parent wellbore. Moreover, a lateral wellbore may have another lateral wellbore drilled outwardly therefrom. A multilateral assembly 130 may be positioned within the casing string 124 and/or the casing joint 126. The multilateral assembly 130 may deflect one or more cutting tools (*i.e.*, drill bit(s)) through an open window 132 formed in a sidewall of the casing joint 126. The window 132, as described herein, is occluded by a degradable material that degrades in a wellbore environment (*e.g.*, upon contact of a reactant) to cause the window 132 to become exposed (*i.e.*, unoccluded), such that the one or more cutting tools of the multilateral assembly 130 can drill the lateral wellbore 128.

[0024] The multilateral assembly 130 may include a variety of additional components in addition to the drill bit(s) including, but not limited to, a whipstock, a motor, a multilateral junction, one or more screens, a motor, a deflector, one or more latching mechanisms for anchoring the multilateral assembly 130 or components thereof in the parent wellbore 122 and/or the lateral wellbore 128, and the like, without departing from the scope of the present disclosure.

[0025] While FIG. 1 depicts a vertical section of the parent wellbore 122, the casing joints described may be equally applicable for use in wellbores having other directional configurations including horizontal wellbores, deviated wellbores, combinations thereof, and the like. Moreover, while FIG. 1 depicts a deviated and horizontal section of the lateral wellbore 128, the lateral wellbore 128 may extend from the parent wellbore 122 in other directional configurations including vertical wellbores depending on the directional configuration of the parent wellbore 122 and the location of desired reservoirs in the formation 104.

[0026] Referring now to FIG. 2, with continued reference to FIG. 1, illustrated is an enlarged view of the junction or intersection between the main wellbore 122 and the lateral wellbore 128, as shown in FIG. 1. As illustrated, the multilateral assembly 130 may be coupled to or otherwise arranged adjacent to various tools (*e.g.*, a measurement while drilling tool) and/or tubular lengths

202, and either arranged within or interconnected with a portion of the casing string 124. Such tools and/or tubular lengths 202 may be used to determine the appropriate circumferential angle and orientation for the formation of the lateral wellbore 128 through the window 132 of the casing joint 126. As illustrated, the multilateral assembly 130 may include a deflector surface 204 operable to direct a cutting tool through the window 132 of the casing joint 126 to create the lateral wellbore 128.

[0027] The casing joint 126 may be coupled to and otherwise interpose separate elongate segments of the casing string 124. Each end of the casing joint 126 may be threaded to the corresponding elongate lengths of the casing string 124. Alternatively, the casing joint 126 may be coupled to the casing string 124 via couplings 206 made of, for example, steel or a steel alloy (*e.g.*, low alloy steel). One or more ends of the casing joint 126 may alternatively be tapered to wedge within corresponding elongate lengths of the casing string 124, or the corresponding elongate lengths of the casing string 124 may be tapered to wedge into the ends of the casing joint 126.

[0028] Referring now to FIG. 3, illustrated is a casing joint 300, which may be substantially similar or the same as casing joint 126 in FIGS. 1 and 2. As shown, the casing joint 300 has a tubular body 302 and a window 304 formed in the sidewall of the tubular body 302. The tubular body 302 may be made from a corrosive-resistant material such as steel (*e.g.*, 13-chromium steel, 28-chromium steel), or other stainless steel or nickel alloys that are corrosive-resistant. One or both ends of the tubular body 302 of the casing joint 300 may comprise threading 308 (one shown), as previously described, to accept an adjacent casing string or joint. The threading 308 may be male or female depending on the configuration of the adjacent casing string or casing joint the casing joint 300 is intended to be coupled or connected.

[0029] As shown, the window 304 is a pre-milled window in the sidewall of the tubular body 302, such that a fluidic opening is formed through the window 304. The window 304 can be formed by any mechanism, including, but not limited to, casting (*i.e.*, the mold is formed with the window 304 opening), etching (which may require several etch passes until the window 304 is formed), cutting, chiseling, and the like, and any combination thereof. The shape of the window 304 is determined based on the drill bit size and shape that is to be used to form the lateral wellbore 128 (FIGS. 1 & 2). As shown, the

window 304 is rectangle-shaped; however, the window 304 may have a different shape, such as a teardrop-shape, a circle-shape, an oval-shape, or a square-shaped, without departing from the scope of the present disclosure. For example, the window 304 may be tear-drop shaped to accommodate the angle at which a drill bit is defected to drill the lateral wellbore 128 (FIGS. 1 & 2) through the window 304.

[0030] The casing joint 300 includes a degradable material 306 secured to the tubular body 302 to occlude the window 304; the degradable material 306 is shown detached from the tubular body 302 merely for illustrative purposes. The degradable material is secured to the tubular body 302 to occlude the window 304 and form a fluidic seal between the interior of the casing joint 300 and the exterior of the casing joint 300. This fluidic seal allows operations, such as primary cementing operations, to be performed as normal despite the presence of the degradable material 306. After such operations are completed, the degradable material 306 is degraded (*e.g.*, by contact with a reactant) to remove the degradable material 306 and expose the opened window 304. That is, the casing joint 300 may be cemented within a wellbore (*e.g.*, parent wellbore 124 of FIGS. 1 & 2) prior to degrading the degradable material 306. The degradable material 306 occludes and forms the fluidic seal by any means that is compatible with the material of the tubular body 302, the material of the degradable material 306, and the wellbore environment. For example, the degradable material 306 is secured to the tubular body by one or more of an adhesive, an epoxy, an elastomer, a weld, brazing, a mechanical seal (*e.g.*, a shrink fit, a metal-to-metal seal, a threaded engagement, and the like), and the like, and any combination thereof.

[0031] As previously discussed, the degradable material of the present disclosure has a degradation rate of greater than 0.0095 mg/cm^2 at 93.3°C when exposed to a 15% KCl solution (a "reactant"). The degradable material loses typically greater than 0.095% of its total mass per day at 93.3°C in a 15% KCl solution. Typically, the degradation of the degradable material for use in forming the casing joint of the present disclosure degrades in the range of 2 hours to 120 days, encompassing any value and subset therebetween. Each of these values depend on a number of factors including, but not limited to, the type of degradable material, the type of reactant contacting the degradable material, the wellbore environment, and the like, and any combination thereof.

The degradation rate of the degradable material 306 described herein allows performance of various wellbore operations while the casing joint 300 is in a downhole environment prior to degradation, such as where a fluidic seal is required (*e.g.*, primary cementing operations). The degradation rate thus permits the casing joint to 300 function as a typical casing joint (*i.e.*, one lacking a degradable window) during the normal course of operations, followed by subsequent degradation of the degradable material 306 after those operations are complete, as described herein.

[0032] The degradable material described herein may degrade by a number of mechanisms. For example, the degradable material may degrade by swelling, dissolving, undergoing a chemical change, undergoing an electrochemical change, undergoing thermal degradation in combination with any of the foregoing, and any combination thereof. Degradation by swelling involves the absorption by the degradable material of a fluid in the wellbore environment such that the mechanical properties of the degradable material degrade. That is, the degradable material continues to absorb the fluid until its mechanical properties are no longer capable of maintaining the integrity of the degradable material and it at least partially falls apart. Degradation by dissolving involves use of a degradable material that is soluble or otherwise susceptible to a fluid in the wellbore environment (*e.g.*, an aqueous fluid or a hydrocarbon fluid), such that the fluid is not necessarily incorporated into the degradable material (as is the case with degradation by swelling), but becomes soluble upon contact with the fluid. Degradation by undergoing a chemical change may involve breaking the bonds of the backbone of the degradable material (*e.g.*, polymer backbone) or causing the bonds of the degradable substance to crosslink, such that the degradable substance becomes brittle and breaks into small pieces upon contact with even small forces expected in the wellbore environment. Degradation by undergoing an electrochemical change involves corrosion (*e.g.*, galvanic corrosion) by an electrolytic process (*e.g.*, oxidation of the degradable material). Thermal degradation involves a chemical decomposition due to heat, such as the heat present in a wellbore environment. Thermal degradation of some degradable substances described herein may occur at wellbore environment temperatures of greater than 93.3°C (200°F), or greater than 50°C (122°F). Each degradation method may work in concert with

one or more of the other degradation methods, without departing from the scope of the present disclosure.

[0033] Although the degradation rate of the degradable material is defined in terms of exposure to a 15% KCl solution at 93.3°C, other reactant types can be used to initiate or accelerate the degradation of the degradable material. Reactants can be introduced into a formation (*e.g.*, pumped) to contact the degradable material and initiate or accelerate degradation thereof. As discussed previously, the reactants may be selected to work in concert with the surrounding wellbore environment to enhance or delay degradation compared to the combination of the reactant(s) and the degradable material in the absence of the wellbore environment, without departing from the scope of the present disclosure. Examples of suitable reactants include, but are not limited to, an acid, a base, an electrolyte (*e.g.*, a brine), and any combination thereof.

[0034] Suitable acid reactants may also include chemical etchants that are capable of etching completely through the degradable material to expose the window (unocclude) of the casing joint described herein. The acid reactants are selected to have a pKa of less than 1.84. Examples of suitable acid reactants include, but are not limited to, ferric chloride, hydrochloric acid, hydroiodic acid, perchloric acid, nitric acid, sulfuric acid, hydrobromic acid, chloric acid, acetic acid, boric acid, carbonic acid, citric acid, hydrofluoric acid, oxalic acid, phosphoric acid, picric acid, acetic-picral, p-toluenesulfonic acid, methanesulfonic acid, hydronium ion, bromic acid, perbromic acid, iodic acid, periodic acid, fluoroantimonic acid, triflic acid, fluorosulfuric acid, and any combination thereof.

[0035] Suitable base reactants may include any base suitable for use in a subterranean formation and capable of degrading the degradable materials as described herein. Examples of suitable base reactants include, but are not limited to a hydroxide (*e.g.*, sodium hydroxide, magnesium hydroxide, barium hydroxide, lithium hydroxide, potassium hydroxide, strontium hydroxide, cesium hydroxide, rubidium hydroxide, and the like), an oxide (*e.g.*, magnesium oxide, calcium oxide, barium oxide, silicon dioxide, aluminum oxide, beryllium oxide, and the like), butyl lithium, lithium diisopropylamide, lithium diethylamide, sodium hydride, sodium amide, lithium bis(trimethylsilyl)amide, and any combination thereof.

[0036] The electrolyte reactants described herein may be solutions of salt (*e.g.*, a salt dissolved in water), which provides free ions for reacting with the degradable material to initiate or accelerate degradation of the degradable material. Common free ions in an electrolyte reactant include, but are not limited to, sodium (Na^+) ions, potassium (K^+) ions, calcium (Ca^{2+}) ions, magnesium (Mg^{2+}) ions, chloride (Cl^-) ions, bromide (B^-) ions, hydrogen phosphate (HPO_4^{2-}) ions, hydrogen carbonate (HCO_3^-) ions, and any combination thereof. The electrolyte reactant can be a fluid that is introduced into a wellbore to contact the degradable material or a fluid emanating from the wellbore itself, such as from a surrounding subterranean formation, without departing from the scope of the present disclosure.

[0037] The degradable material may be a degradable metal material and the reactant causes degradation thereof by corrosion. Examples of suitable degradable metal materials include, but are not limited to, gold, a gold-platinum alloy, silver, nickel, a nickel-copper alloy, a nickel-chromium alloy, copper, a copper alloy (*e.g.*, brass, bronze, and the like), chromium, tin, aluminum, an aluminum alloy, iron, an iron alloy, magnesium, a magnesium alloy, beryllium, tungsten, zinc, a zinc alloy, and any combination thereof.

[0038] Suitable magnesium alloys include alloys having magnesium at a concentration in the range of from 38% to 99% by weight of the magnesium alloy, encompassing any value and subset therebetween. Each of these values may depend on a number of factors including, but not limited to, the type of magnesium alloy, the desired degradability of the magnesium alloy, and the like. Magnesium alloys comprise at least one other ingredient besides the magnesium. The other ingredients can be selected from one or more metals, one or more non-metals, or a combination thereof.

[0039] Suitable metals that may be alloyed with magnesium include, but are not limited to, lithium, sodium, potassium, rubidium, cesium, beryllium, calcium, strontium, barium, aluminum, gallium, indium, tin, thallium, lead, bismuth, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, niobium, molybdenum, ruthenium, rhodium, palladium, praseodymium, silver, lanthanum, hafnium, tantalum, tungsten, terbium, rhenium, osmium, iridium, platinum, gold, neodymium, gadolinium, erbium, oxides of any of the foregoing, and any combinations thereof.

[0040] Suitable non-metals that may be alloyed with magnesium include, but are not limited to, graphite, carbon, silicon, boron nitride, and combinations thereof. The carbon can be in the form of carbon particles, fibers, nanotubes, fullerenes, and any combination thereof. The graphite can be in the form of particles, fibers, graphene, and any combination thereof. The magnesium and its alloyed ingredient(s) may be in a solid solution and not in a partial solution or a compound where inter-granular inclusions may be present. The magnesium and its alloyed ingredient(s) may be uniformly distributed throughout the magnesium alloy; however, some variations in the distribution of particles of the magnesium and its alloyed ingredient(s) can occur. The magnesium alloy may also or instead be a sintered construction.

[0041] Suitable aluminum alloys include alloys having aluminum at a concentration in the range of from 38% to 99% by weight of the aluminum alloy, encompassing any value and subset therebetween. Each of these values may depend on a number of factors including, but not limited to, the type of aluminum alloy, the desired degradability of the aluminum alloy, and the like. The aluminum alloys may be wrought or cast aluminum alloys and comprise at least one other ingredient besides the aluminum. The other ingredients can be selected from one or more any of the metals, non-metals, and combinations thereof described above with reference to magnesium alloys, with the addition of the aluminum alloys additionally being able to comprise magnesium.

[0042] Suitable zinc alloys include alloys having zinc at a concentration in the range of from 38% to 99% by weight of the zinc alloy, encompassing any value and subset therebetween. Each of these values may depend on a number of factors including, but not limited to, the type of zinc alloy, the desired degradability of the zinc alloy, and the like. The zinc alloys may be wrought or cast zinc alloys and comprise at least one other ingredient besides the zinc. The other ingredients can be selected from one or more of any of the metals, non-metals, and combinations thereof described above with reference to magnesium alloys, with the addition of the zinc alloys additionally being able to comprise magnesium and/or aluminum.

[0043] Alternatively or in combination with the degradable metal materials (*i.e.*, a combination of both degradable metal and degradable non-metal materials), the degradable material may be a non-metal degradable material that at least partially degrades in a wellbore environment upon contact

with one or more reactants. Suitable non-metal degradable materials include, but are not limited to, a polyurethane rubber (*e.g.*, cast polyurethanes, thermoplastic polyurethanes, polyethane polyurethanes); a polyester-based polyurethane rubber (*e.g.*, lactone polyester-based thermoplastic polyurethanes); a polyether-based polyurethane rubber; a thiol-based polymer (*e.g.*, 1,3,5,-triacryloylhexahydro-1,3,5-triazine); a thiol-epoxy polymer (*e.g.*, having an epoxide functional group, such as bisphenol-A diglycidyl ether, triglycidylisocyanurate, and/or trimethylolpropane triglycidyl ether); a hyaluronic acid rubber; a polyhydroxobutyrate rubber; a polyester elastomer; a polyester amide elastomer; a starch-based resin (*e.g.*, starch-poly(ethylene-co-vinyl alcohol), a starch-polyvinyl alcohol, a starch-polylactic acid, starch-polycaprolactone, starch-poly(butylene succinate), and the like); a polyethylene terephthalate polymer; a polyester thermoplastic (*e.g.*, polyether/ester copolymers, polyester/ester copolymers); a polylactic acid polymer; a polybutylene succinate polymer; a polyhydroxy alkanoic acid polymer; a polybutylene terephthalate polymer; a polysaccharide; chitin; chitosan; a protein; an aliphatic polyester; poly(ε-caprolactone); a poly(hydroxybutyrate); poly(ethyleneoxide); poly(phenyllactide); a poly(amino acid); a poly(orthoester); polyphosphazene; a polylactide; a polyglycolide; a poly(anhydride) (*e.g.*, poly(adipic anhydride), poly(suberic anhydride), poly(sebacic anhydride), poly(dodecanedioic anhydride), poly(maleic anhydride), and poly(benzoic anhydride), and the like); a polyepichlorohydrin; a copolymer of ethylene oxide/polyepichlorohydrin; a terpolymer of epichlorohydrin/ethylene oxide/allyl glycidyl ether; copolymers thereof; terpolymers thereof; and any combination thereof.

[0044] Referring now to FIGS. 4A-4B, illustrated are two cross-sectional views of a casing joint 400. FIGS. 4A and 4B show two configurations in which the degradable material 406 can be secured to the tubular body 402 to occlude the window 404. Referring first to FIG. 4A, shoulders 408 are defined in the sidewall of the tubular body 402 at the window 404. As shown, the shoulders 408 are defined at each end of the tubular body 402 at the window 404 along the inner diameter of the tubular body 402, such that the window 404 occupies a greater circumference of the inner radial surface of the tubular body 402 than the outer radial surface of the tubular body 402. Although the shoulders 408 are defined along the inner radial surface of the tubular body 402,

such shoulders 408 may alternatively be defined along the outer radial surface of the tubular body 402, without departing from the scope of the present disclosure. Moreover, a single shoulder 408 at only one end of the window 404 may additionally be defined rather than two shoulders 408 at each end, without departing from the scope of the present disclosure. The degradable material 406 is received by the shoulders 408 and otherwise flush with the radial surface(s) that does not have a shoulder 408 (*e.g.*, the outer radial surface, as shown in FIG. 4A). Referring now to FIG. 4B, the degradable material 406 is flush with both the outer radial surface and the inner radial surface of the tubular body 402, such that no shoulders, protrusion, or depression forming the ends of the window 404.

[0045] Additionally or alternatively, a shoulder, protrusion, and/or depression (*e.g.*, divot) can be located at any position along one or both edges of the window 404 and extending from or into one or both edges of the tubular body 402. Such shoulders, protrusions, and/or depressions, for example, may be along the inner radial surface of the tubular body 402 (as shown in FIG. 4A), along the outer radial surface of the tubular body 402, and/or any surface therebetween. The shoulders, protrusions, and/or depressions can receive the degradable material 406 and aid in securing the degradable material 406 to the tubular body 402 to occlude the window 404, and work synergistically with the one or more mechanisms for forming a fluidic seal with the degradable material 406, as described above.

[0046] While various examples have been shown and described herein, modifications may be made by one skilled in the art without departing from the scope of the present disclosure. The examples described here are exemplary only, and are not intended to be limiting. Many variations, combinations, and modifications of the examples disclosed herein are possible and are within the scope of the disclosure. Accordingly, the scope of protection is not limited by the description set out above, but is defined by the claims which follow, that scope including all equivalents of the subject matter of the claims.

[0047] Examples disclosed herein include:

[0048] **Example A**: A casing joint comprising: a tubular body; a window formed through a sidewall of the tubular body; and a degradable material secured to the tubular body to occlude the window, wherein the degradable material has a degradation rate of greater than 0.0095 milligrams

per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution.

[0049] **Example B:** A method comprising: lining a wellbore with casing that includes a casing joint interconnected in the casing, wherein the casing joint includes a tubular body, a window formed through a sidewall of the tubular body, and a degradable material secured to the tubular body to occlude the window, wherein the degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution; and degrading the degradable material to expose the window.

[0050] **Example C:** A system comprising: a wellbore lined with casing that includes a casing joint interconnected in the casing, wherein the casing joint includes a tubular body, a window formed through a sidewall of the tubular body, and a degradable material secured to the tubular body to occlude the window, wherein the degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution.

[0051] Examples A, B, and C may have one or more of the following additional elements in any combination:

[0052] Element 1: Wherein the degradable material is a degradable metal.

[0053] Element 2: Wherein the degradable material is a degradable metal selected from the group consisting of gold, a gold-platinum alloy, silver, nickel, a nickel-copper alloy, a nickel-chromium alloy, copper, a copper alloy, chromium, tin, aluminum, an aluminum alloy, iron, an iron alloy, magnesium, a magnesium alloy, beryllium, tungsten, zinc, a zinc alloy, and any combination thereof.

[0054] Element 3: Wherein the window exhibits a shape selected from the group consisting of teardrop-shaped, circle-shaped, oval-shaped, square-shaped, rectangle-shaped, and any combination thereof.

[0055] Element 4: Wherein the tubular body has a first end and a second end, and wherein at least one of the first and second ends is threaded for coupling to a wellbore casing.

[0056] Element 5: Wherein the degradable material fluidically seals the window using at least one of an adhesive, an epoxy, an elastomer, a weld, brazing, a mechanical seal, and any combination thereof.

[0057] Element 6: Wherein the tubular body comprises an inner radial surface and an outer radial surface, and wherein the degradable material is flush with the inner and outer radial surfaces.

[0058] Element 7: Wherein a shoulder is defined in the sidewall of the tubular body at the window, and wherein the degradable material is received by the shoulder.

[0059] Element 8: Wherein when the casing joint is interconnected in casing lined in a wellbore, and further comprising introducing a reactant into the wellbore to degrade the degradable material, wherein the reactant is selected from the group consisting of an acid, a base, an electrolyte, and any combination thereof; or wherein the wellbore further comprises the one or more of the reactants contacting the degradable material.

[0060] Element 9: Wherein when the casing joint is interconnected in casing lined in a wellbore, and further comprising introducing a reactant into the wellbore to degrade the degradable material, wherein reactant is selected from the group consisting of sodium ions, potassium ions, calcium ions, magnesium ions, chloride ions, bromide ions, hydrogen phosphate ions, hydrogen carbonate ions, ferric chloride, hydrochloric acid, hydroiodic acid, perchloric acid, nitric acid, sulfuric acid, hydrobromic acid, chloric acid, acetic acid, boric acid, carbonic acid, citric acid, hydrofluoric acid, oxalic acid, phosphoric acid, picric acid, acetic-picral, p-toluenesulfonic acid, methanesulfonic acid, hydronium ion, bromic acid, perbromic acid, iodic acid, periodic acid, fluoroantimonic acid, triflic acid, fluorosulfuric acid, a hydroxide, an oxide, butyl lithium, lithium diisopropylamide, lithium diethylamide, sodium hydride, sodium amide, lithium bis(trimethylsilyl)amide, and any combination thereof, or wherein the wellbore further comprises the one or more of the reactants contacting the degradable material.

[0061] Element 10: Wherein when the casing joint is interconnected in casing lined in a wellbore, and further comprising cementing the casing joint in the wellbore prior to degrading the degradable material, or wherein the casing joint is cemented in the wellbore.

[0062] Element 11: Wherein when the casing joint is interconnected in casing lined in a wellbore, and further comprising drilling a lateral wellbore through the window after degrading the degradable material, or wherein the degradable material is degraded and further comprising a lateral wellbore extending through the window.

[0063] By way of non-limiting example, exemplary combinations applicable to A, B, and C include: 1-11; 1, 2, and 10; 3, 4, and 11; 5 and 6; 3, 7, and 9; 8 and 10; 2 and 4; 5, 7, and 8; 10 and 11; and the like.

[0064] Therefore, the present disclosure is able to attain the ends and advantages mentioned as well as those that are inherent therein. The particular Examples disclosed above are illustrative only, as the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative Examples disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present disclosure. The disclosure illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range are specifically disclosed. In particular, every range of values (of the form, "from a to b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces.

CLAIMS

What is claimed is:

1. A casing joint comprising:
a tubular body;
a window formed through a sidewall of the tubular body; and
a degradable material secured to the tubular body to occlude the window,
wherein the degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution.

2. The casing joint of claim 1, wherein the degradable material is a degradable metal.

3. The casing joint of claim 1, wherein the degradable material is a degradable metal selected from the group consisting of gold, a gold-platinum alloy, silver, nickel, a nickel-copper alloy, a nickel-chromium alloy, copper, a copper alloy, chromium, tin, aluminum, an aluminum alloy, iron, an iron alloy, magnesium, a magnesium alloy, beryllium, tungsten, zinc, a zinc alloy, and any combination thereof.

4. The casing joint of claim 1, wherein the window exhibits a shape selected from the group consisting of teardrop-shaped, circle-shaped, oval-shaped, square-shaped, rectangle-shaped, and any combination thereof.

5. The casing joint of claim 1, wherein the tubular body has a first end and a second end, and wherein at least one of the first and second ends is threaded for coupling to a wellbore casing.

6. The casing joint of claim 1, wherein the degradable material fluidically seals the window using at least one of an adhesive, an epoxy, an elastomer, a weld, brazing, a mechanical seal, and any combination thereof.

7. The casing joint of claim 1, wherein the tubular body comprises an inner radial surface and an outer radial surface, and wherein the degradable material is flush with the inner and outer radial surfaces.

8. The casing joint of claim 1, wherein a shoulder is defined in the sidewall of the tubular body at the window, and wherein the degradable material is received by the shoulder.

9. A method comprising:

lining a wellbore with casing that includes a casing joint interconnected in the casing, wherein the casing joint includes a tubular body, a window formed through a sidewall of the tubular body, and a degradable material secured to the tubular body to occlude the window,

wherein the degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution; and

degrading the degradable material to expose the window.

10. The method of claim 9, further comprising introducing a reactant into the wellbore to degrade the degradable material, wherein the reactant is selected from the group consisting of an acid, a base, an electrolyte, and any combination thereof.

11. The method of claim 9, further comprising introducing a reactant into the wellbore to degrade the degradable material, wherein reactant is selected from the group consisting of sodium ions, potassium ions, calcium ions, magnesium ions, chloride ions, bromide ions, hydrogen phosphate ions, hydrogen carbonate ions, ferric chloride, hydrochloric acid, hydroiodic acid, perchloric acid, nitric acid, sulfuric acid, hydrobromic acid, chloric acid, acetic acid, boric acid, carbonic acid, citric acid, hydrofluoric acid, oxalic acid, phosphoric acid, picric acid, acetic-picral, p-toluenesulfonic acid, methanesulfonic acid, hydronium ion, bromic acid, perbromic acid, iodic acid, periodic acid, fluoroantimonic acid, triflic acid, fluorosulfuric acid, a hydroxide, an oxide, butyl lithium, lithium diisopropylamide, lithium diethylamide, sodium hydride, sodium amide, lithium bis(trimethylsilyl)amide, and any combination thereof.

12. The method of claim 9, further comprising cementing the casing joint in the wellbore prior to degrading the degradable material.

13. The method of claim 9, further comprising drilling a lateral wellbore through the window after degrading the degradable material.

14. The method of claim 9, wherein the degradable material is a degradable metal selected from the group consisting of gold, a gold-platinum alloy, silver, nickel, a nickel-copper alloy, a nickel-chromium alloy, copper, a copper alloy, chromium, tin, aluminum, an aluminum alloy, iron, an iron alloy, magnesium, a magnesium alloy, beryllium, tungsten, zinc, a zinc alloy, and any combination thereof.

15. A system comprising:

a wellbore lined with casing that includes a casing joint interconnected in the casing,

wherein the casing joint includes a tubular body, a window formed through a sidewall of the tubular body, and a degradable material secured to the tubular body to occlude the window,

wherein the degradable material has a degradation rate of greater than 0.0095 milligrams per square centimeters (mg/cm^2) at 93.3°C when exposed to a 15% potassium chloride solution.

16. The system of claim 15, wherein the degradable material is degraded and further comprising a lateral wellbore extending through the window.

17. The system of claim 15, wherein the casing joint is cemented in the wellbore.

18. The system of claim 15, wherein the wellbore further comprises a reactant contacting the degradable material, wherein the reactant is selected from the group consisting of an acid, a base, an electrolyte, and any combination thereof.

19. The system of claim 15, wherein the wellbore further comprises a reactant contacting the degradable material, wherein reactant is selected from the group consisting of sodium ions, potassium ions, calcium ions, magnesium ions, chloride ions, bromide ions, hydrogen phosphate ions, hydrogen carbonate ions, ferric chloride, hydrochloric acid, hydroiodic acid, perchloric acid, nitric acid, sulfuric acid, hydrobromic acid, chloric acid, acetic acid, boric acid, carbonic acid, citric acid, hydrofluoric acid, oxalic acid, phosphoric acid, picric acid, acetic-picral, p-toluenesulfonic acid, methanesulfonic acid, hydronium ion, bromic acid, perbromic acid, iodic acid, periodic acid, fluoroantimonic acid, triflic acid, fluorosulfuric acid, a hydroxide, an oxide, butyl lithium, lithium diisopropylamide, lithium diethylamide, sodium hydride, sodium amide, lithium bis(trimethylsilyl)amide, and any combination thereof.

20. The system of claim 15, wherein the degradable material is a degradable metal selected from the group consisting of gold, a gold-platinum alloy, silver, nickel, a nickel-copper alloy, a nickel-chromium alloy, copper, a copper alloy, chromium, tin, aluminum, an aluminum alloy, iron, an iron alloy, magnesium, a magnesium alloy, beryllium, tungsten, zinc, a zinc alloy, and any combination thereof.

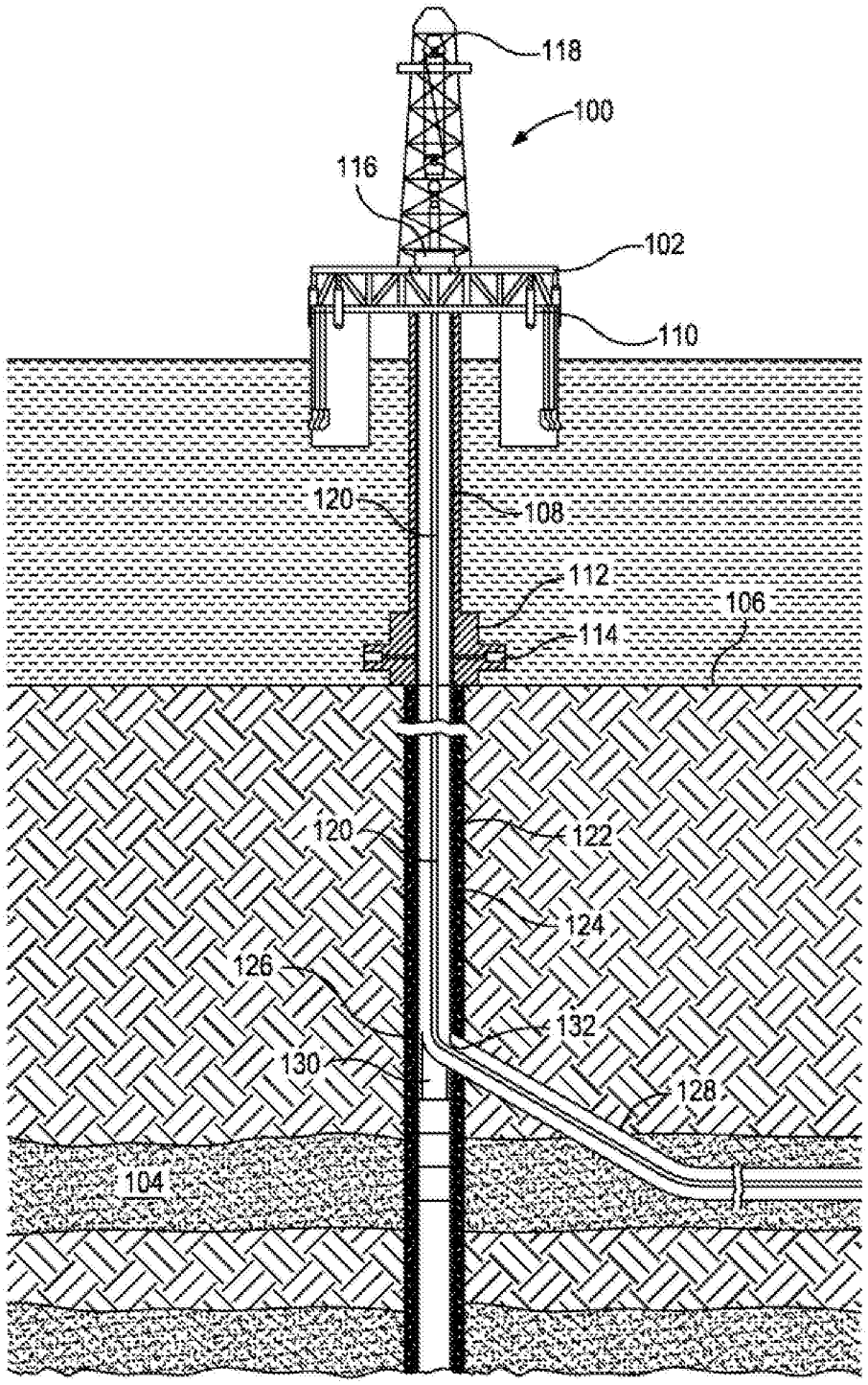

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FIG. 1

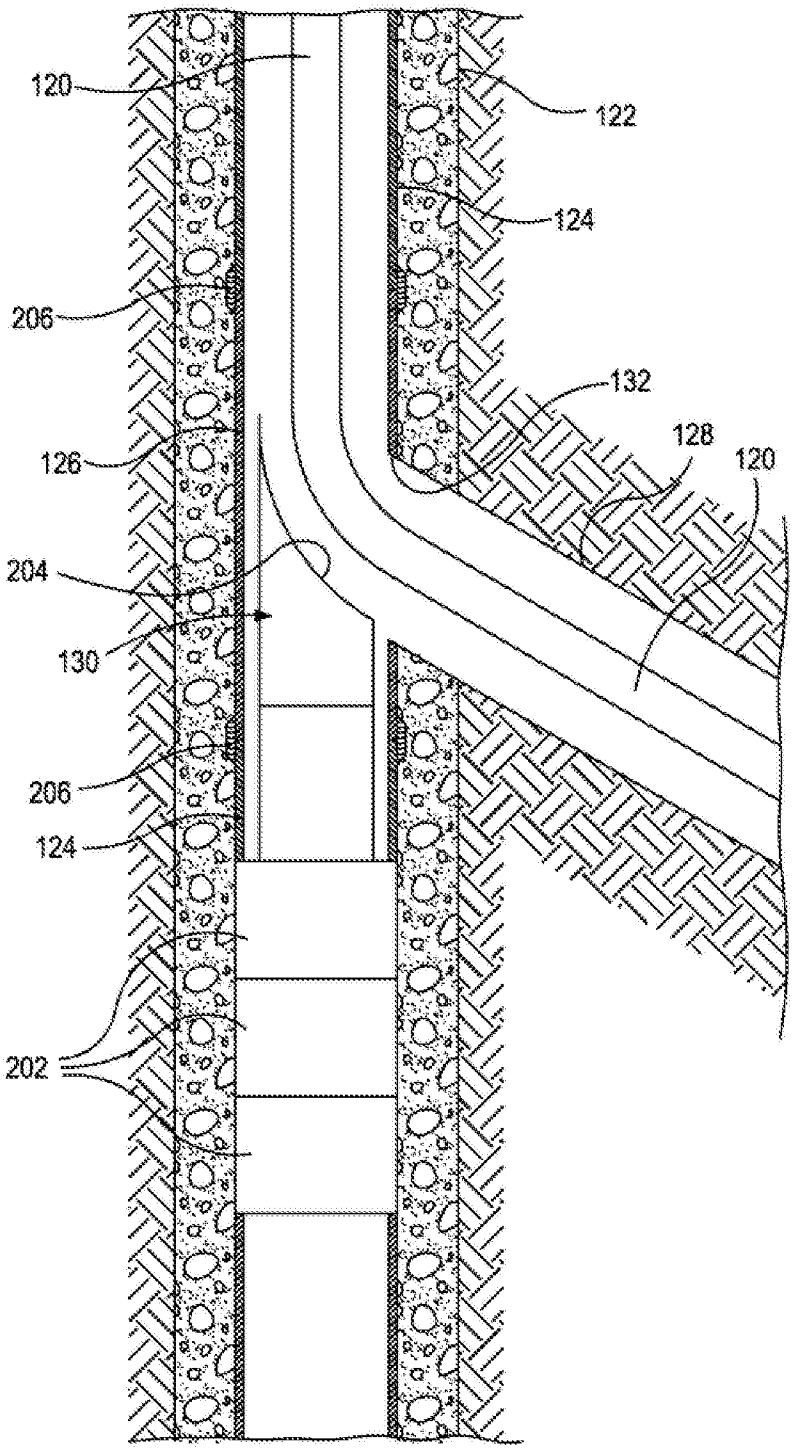


FIG. 2

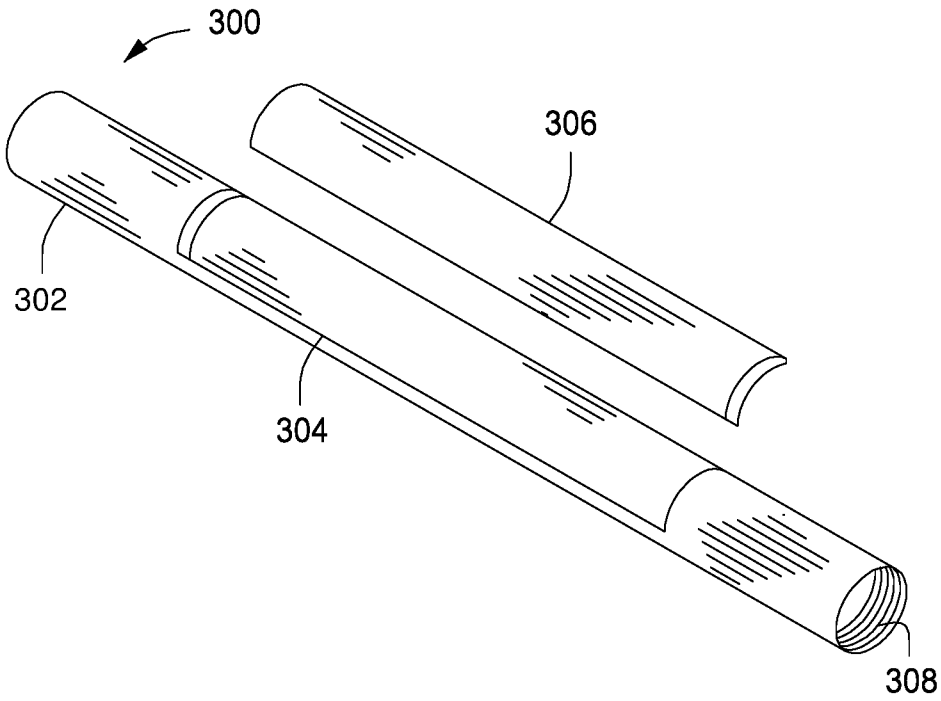


FIG. 3

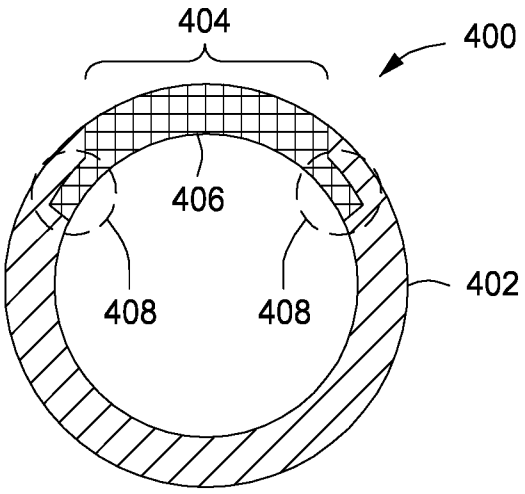


FIG. 4A

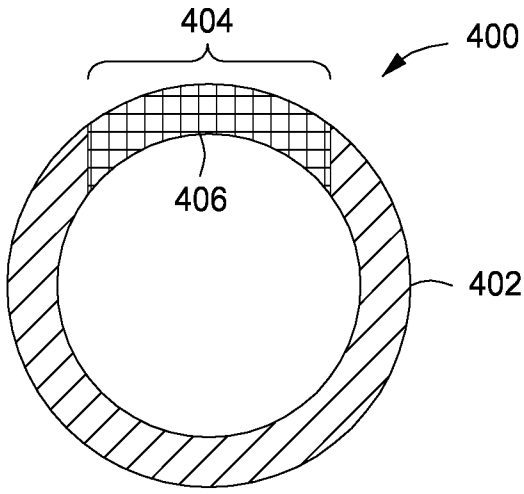


FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/017135

A. CLASSIFICATION OF SUBJECT MATTER

E21B 17/00(2006.01)i, E21B 17/02(2006.01)i, E21B 7/08(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 17/00; E21B 17/10; E21B 17/18; B05D 1/36; E21B 21/10; E21B 33/14; E21B 43/08; E21B 43/11; B23K 31/02; E21B 17/02; E21B 7/08

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: casing joint, tubular body, window, degradable, potassium chloride solution, wellbore, borehole, shoulder, radial surface, polymer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0005754 A1 (DANIELS et al.) 13 January 2011 See abstract, paragraphs [0036]-[0048], and figures 1-2, 5A.	1-20
A	EP 2256287 B1 (HALLIBURTON ENERGY SERVICES, INC.) 24 July 2013 See paragraphs [0038], [0086], claim 1, and figures 1, 24-25.	1-20
A	US 2014-0060846 A1 (HALLUNDBAEK et al.) 06 March 2014 See abstract, paragraphs [0051]-[0053], and figures 4a-4c.	1-20
A	US 2012-0292043 A1 (THORNTON, THOMAS JOHN OLIVER) 22 November 2012 See abstract, paragraphs [0051]-[0053], [0061], and figures 5A-5B.	1-20
A	US 2014-0360718 A1 (ANTON ENERGY SERVICES CORPORATION) 11 December 2014 See abstract, claim 1, and figure 1.	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
"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	Date of mailing of the international search report
07 November 2016 (07.11.2016)	**07 November 2016 (07.11.2016)**

Name and mailing address of the ISA/KR
International Application Division
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/017135

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