

USING EXPANDABLE METAL AS AN ALTERNATE TO EXISTING METAL TO METAL SEALS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Application Serial No. 17/334,731, filed on May 29, 2021, entitled “USING EXPANDABLE METAL AS AN ALTERNATE TO EXISTING METAL TO METAL SEALS,” commonly assigned with this application and incorporated herein by reference in its entirety.

BACKGROUND

[0002] Metal seals are sometimes used to seal between structures in well tools, and in equipment used in other environments. However, several problems are frequently encountered when metal seals are used. For example, metal seals require very smooth and clean surfaces to seal against, and most metals can only be elastically deformed to a limited extent (which thereby limits the biasing force available from elastically deforming a metal seal), etc.

[0003] Elastomeric and other types of nonmetal seals may provide the ability to seal against irregular and unclean surfaces, and may provide sufficient resilient biasing force for urging the seals against the surfaces. However, nonmetal seals tend to degrade rapidly when used in dynamic configurations, i.e., where the seal must contact a moving surface while sealing against a pressure differential, or where the seal loses contact with the surface while the pressure differential still exists across the seal.

BRIEF DESCRIPTION

[0004] Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0005] FIG. 1 depicts a well system including a seal assembly designed, manufactured, and run according to the present disclosure;

[0006] FIGs. 2A and 2B depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to the disclosure;

[0007] FIGs. 3A and 3B depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to an alternative embodiment of the disclosure;

[0008] FIGs. 4A through 4D depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to an alternative embodiment of the disclosure;

[0009] FIGs. 5A through 5D depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to an alternative embodiment of the disclosure;

[0010] FIGs. 6A and 6B depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to an alternative embodiment of the disclosure; and

[0011] FIGs. 7A and 7B depict various different manufacturing states for a seal assembly designed, manufactured, and operated according to an alternative embodiment of the disclosure.

DETAILED DESCRIPTION

[0012] In the drawings and descriptions that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawn figures are not necessarily to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of certain elements may not be shown in the interest of clarity and conciseness. The present disclosure may be implemented in embodiments of different forms.

[0013] Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed herein may be employed separately or in any suitable combination to produce desired results.

[0014] Unless otherwise specified, use of the terms “connect,” “engage,” “couple,” “attach,” or any other like term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. Unless otherwise specified, use of the terms “up,” “upper,” “upward,” “uphole,” “upstream,” or other like terms shall be construed as generally away from the bottom, terminal end of a well, regardless of the wellbore orientation.; likewise, use of the terms “down,” “lower,” “downward,” “downhole,” or other like terms shall be construed as generally toward the bottom, terminal end of a well, regardless of the wellbore orientation. Use of any one or more of the foregoing terms shall not be construed as denoting positions along a perfectly vertical axis. In some instances, a part near the end of the well can be horizontal or

even slightly directed upwards. Unless otherwise specified, use of the term “subterranean formation” shall be construed as encompassing both areas below exposed earth and areas below earth covered by water such as ocean or fresh water.

[0015] Referring initially to FIG. 1, schematically illustrated is a well system 100, including a seal assembly designed, manufactured, and run according to the present disclosure. In the well system 100, a tubular 110 (such as a production tubing string) is positioned in a wellbore 120. In at least one embodiment, the wellbore 120 is lined with casing 130, for example using cement in one or more embodiments.

[0016] In the illustrated embodiment, downhole tools 140, 150 are coupled to the tubular 110. In at least one embodiment, the downhole tool 140 is a packer, and the downhole tool 150 is a flow control device (such as a valve or choke). In at least one embodiment, the packer provides an annular seal between the tubular 110 and the casing 130, and the flow control device regulates fluid communication between the interior of the tubular 110 and an annulus 160 formed between the tubular 110 and the casing 130. For example, the downhole tool 150 comprising the flow control device might include a closure mechanism 170, which is operated to regulate flow.

[0017] In accordance with the disclosure, one or more of the downhole tools 140, 150 include a seal assembly (not shown) designed, manufactured, and operated according to one aspect of the disclosure. The seal assembly, in accordance with one or more embodiments, includes a pipe (e.g., mandrel, base pipe, tubing, pup joint, or any other oilfield tube shaped structure, as well as an outer tubular (e.g., outer tubing, outer housing, etc.) positioned around the pipe. In at least one embodiment, the outer tubular of the seal assembly could coincide with the tubular 110. In yet another embodiment, the outer tubular of the seal assembly is a different tubular than the tubular 110.

[0018] The pipe and outer tubular of the seal assembly, in at least one embodiment, form an enclosed seal gland. The term enclosed seal gland, as used herein, is intended to exclude the annulus 160 between the wellbore casing 130 and the tubular 110. The term enclosed seal gland, as used herein, is intended to reference an easily recognizable and defined volume. In at least one embodiment, the defined volume for the seal gland is 230 cm³ or less. In at least one other embodiment, the defined volume for the seal gland is 100 cm³ or less, and in yet another embodiment 20 cm³ or less. While the enclosed seal gland may have leakage paths that enter and exit it, the enclosed seal gland is not a vast open space with limited boundaries.

[0019] In accordance with the disclosure, pre-expansion expandable metal is positioned within the enclosed seal gland, the pre-expansion expandable metal subjected to reactive fluid to form expanded metal within the enclosed seal gland. The expanded metal, in accordance with one or more aspects of the disclosure, comprises a metal that has expanded in response to hydrolysis to assist in sealing the enclosed seal gland. In certain embodiments, the expanded metal includes residual unreacted metal. For example, in certain embodiments the expanded metal is intentionally designed to include the residual unreacted metal. The residual unreacted metal has the benefit of allowing the expanded metal to self-heal if cracks or other anomalies subsequently arise, or for example to accommodate changes in the outer tubular or pipe diameter due to variations in temperature and/or pressure. Nevertheless, other embodiments may exist wherein no residual unreacted metal exists in the expanded metal.

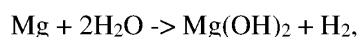
[0020] The pre-expansion expandable metal, in some embodiments, may be described as expanding to a cement like material. In other words, the pre-expansion expandable metal goes from metal to micron-scale particles and then these particles expand and lock together to, in essence, assist in sealing the enclosed seal gland. The reaction may, in certain embodiments, occur in less than 2 days in a reactive fluid and in downhole temperatures. Nevertheless, the time of reaction may vary depending on the reactive fluid, the expandable metal used, and the downhole temperature. In certain other embodiments, the reaction occurs uphole, for example by soaking the pre-expansion expandable metal located in the enclosed seal gland in the reactive fluid.

[0021] In some embodiments, the reactive fluid may be a brine solution such as may be produced during well completion activities, and in other embodiments, the reactive fluid may be one of the additional solutions discussed herein. The pre-expansion expandable metal is electrically conductive in certain embodiments. The pre-expansion expandable metal may be machined to any specific size/shape, extruded, formed, cast or other conventional ways to get the desired shape of a metal, as will be discussed in greater detail below. The pre-expansion expandable metal, in certain embodiments has a yield strength greater than about 8,000 psi, e.g., 8,000 psi +/- 50%.

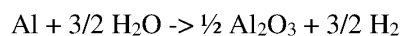
[0022] The hydrolysis of the metal can create a metal hydroxide. The formative properties of alkaline earth metals (Mg - Magnesium, Ca - Calcium, etc.) and transition metals (Zn - Zinc, Al - Aluminum, etc.) under hydrolysis reactions demonstrate structural characteristics that are

favorable for use with the present disclosure. Hydration results in an increase in size from the hydration reaction and results in a metal hydroxide that can precipitate from the fluid.

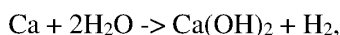
[0023] The hydration reactions for magnesium is:



where $\text{Mg}(\text{OH})_2$ is also known as brucite. Another hydration reaction uses aluminum hydrolysis. The reaction forms a material known as Gibbsite, bayerite, boehmite, aluminum oxide, and norstrandite, depending on form. The possible hydration reactions for aluminum are:



Another hydration reaction uses calcium hydrolysis. The hydration reaction for calcium is:



Where $\text{Ca}(\text{OH})_2$ is known as portlandite and is a common hydrolysis product of Portland cement. Magnesium hydroxide and calcium hydroxide are considered to be relatively insoluble in water. Aluminum hydroxide can be considered an amphoteric hydroxide, which has solubility in strong acids or in strong bases. Alkaline earth metals (e.g., Mg, Ca, etc.) work well for the expandable metal, but transition metals (Al, etc.) also work well for the expandable metal. In one embodiment, the metal hydroxide is dehydrated by the swell pressure to form a metal oxide.

[0024] In an embodiment, the metal used can be a metal alloy. The metal alloy can be an alloy of the base metal with other elements in order to either adjust the strength of the metal alloy, to adjust the reaction time of the metal alloy, or to adjust the strength of the resulting metal hydroxide byproduct, among other adjustments. The metal alloy can be alloyed with elements that enhance the strength of the metal such as, but not limited to, Al - Aluminum, Zn - Zinc, Mn - Manganese, Zr - Zirconium, Y - Yttrium, Nd - Neodymium, Gd - Gadolinium, Ag - Silver, Ca - Calcium, Sn - Tin, and Re - Rhenium, Cu - Copper. In some embodiments, the alloy can be alloyed with a dopant that promotes corrosion, such as Ni - Nickel, Fe - Iron, Cu - Copper, Co - Cobalt, Ir - Iridium, Au - Gold, C - Carbon, Ga - Gallium, In - Indium, Mg - Mercury, Bi - Bismuth, Sn - Tin, and Pd - Palladium. The metal alloy can be constructed in a solid solution process where the elements are combined with molten metal or metal alloy. Alternatively, the

metal alloy could be constructed with a powder metallurgy process. The metal can be cast, forged, extruded, sintered, welded, mill machined, lathe machined, stamped, eroded or a combination thereof. The metal alloy can be a mixture of the metal and metal oxide. For example, a powder mixture of aluminum and aluminum oxide can be ball-milled together to increase the reaction rate.

[0025] Optionally, non-expanding components may be added to the starting metallic materials. For example, ceramic, elastomer, plastic, epoxy, glass, or non-reacting metal components can be embedded in the expanding metal or coated on the surface of the metal. Alternatively, the starting metal may be the metal oxide. For example, calcium oxide (CaO) with water will produce calcium hydroxide in an energetic reaction. Due to the higher density of calcium oxide, this can have a 260% volumetric expansion when converting 1 mole of CaO goes from 9.5cc to 34.4cc of volume. In one variation, the expanding metal is formed in a serpentine reaction, a hydration and metamorphic reaction. In one variation, the resultant material resembles a mafic material. Additional ions can be added to the reaction, including silicate, sulfate, aluminate, carbonate, and phosphate. The metal can be alloyed to increase the reactivity or to control the formation of oxides.

[0026] The pre-expansion expandable metal can be configured in many different fashions, as long as an adequate volume of material is available for fully expanding. For example, the pre-expansion expandable metal may be formed into a single long member, multiple short members, rings, among others. In certain other embodiments, the pre-expansion expandable metal is a collection of individual separate chunks of the metal held together with a binding agent proximate the enclosed seal gland. In yet other embodiments, the pre-expansion expandable metal is a collection of individual separate chunks of the metal that are not held together with a binding agent. Additionally, a coating may be applied to one or more portions of the pre-expansion expandable metal to delay the expanding reactions.

[0027] A seal assembly according to the present disclosure has many benefits over previous seal assemblies. In at least one embodiment, the seal assembly including the expanded metal provides for a design that is form-fitting with existing elastomeric seal cross-sections, and thus is not limited by certain seal surface tolerances and/or surface finishes. Accordingly, the cost of the seal pipe and/or outer tubular will be reduced, as the proposed expanded metal will form to the existing geometry and/or surface finish in the seal assembly. Additionally, the use of the pre-

expansion expandable metal allows for a reduction in installation force and/or reduction in the chance of galling the seal surfaces, as the pre-expansion expandable metal has greater clearances during the installation or assembly thereof. Furthermore, the use of the pre-expansion expandable metal allows for the compensation of any eccentricities or non-uniformness in either the pipe or the outer tubular. Moreover, the use of the pre-expansion expandable metal allows for the seal to be placed at or near a weld bead, small feature, or non-circular cross-section.

[0028] At this point, it should be reiterated that the principles of this disclosure are not limited to any of the details of the well system 100 described herein. For example, it is not necessary for the seal assembly of this disclosure to be used in a wellbore, in a downhole tool, in a cased wellbore, in a flow control device, in an outer tubular, etc. Thus, it should be clearly understood that the well system 100 is only a single example of a wide variety of uses for a seal assembly designed, manufactured, and operated according to one or more aspects of the disclosure.

[0029] Turning to FIGs. 2A and 2B, depicted are various different manufacturing states for a seal assembly 200 designed, manufactured, and operated according to the disclosure. FIG. 2A illustrates the seal assembly 200 pre-expansion, whereas FIG. 2B illustrates the seal assembly 200 post-expansion. As disclosed above, the pre-expansion expandable metal may be subjected to the reactive fluid within the wellbore, for example relying on the Bernoulli Effect, or may be subjected to the reactive fluid outside of the wellbore.

[0030] The seal assembly 200, in the illustrated embodiment of FIGs. 2A and 2B, includes a pipe 210. The pipe 210, in the illustrated embodiment, is centered about a centerline (C_L). The seal assembly 200, in at least the embodiment of FIGs. 2A and 2B, additionally includes an outer tubular 220 positioned around the pipe 210. In accordance with the disclosure, the pipe 210 and the outer tubular 220 form an enclosed seal gland 230. The enclosed seal gland 230, in one or more embodiments, includes a width (w) and a height (h), and furthermore may circle the centerline (C_L). In at least one embodiment, the width (w) is less than 5 cm, and the height is less than about 1 cm. In accordance with this embodiment, the enclosed seal gland 230 might have a seal gland volume of no more than 100 cm³.

[0031] With reference to FIG. 2A, pre-expansion expandable metal 240 is located at least partially within the enclosed seal gland 230. The pre-expansion expandable metal 240, in accordance with one or more embodiments of the disclosure, comprises a metal configured to expand in response to hydrolysis. The pre-expansion expandable metal 240, in the illustrated

embodiment, may comprise any of the expandable metals discussed above. The pre-expansion expandable metal 240 may have a variety of different lengths and thicknesses, for example depending on the size of the enclosed seal gland 230, and remain within the scope of the disclosure.

[0032] With reference to FIG. 2B, illustrated is the pre-expansion expandable metal 240 illustrated in FIG. 2A after subjecting it to a reactive fluid to expand the metal in the enclosed seal gland 230, and thereby form the expanded metal 250. In the illustrated embodiment, the expanded metal 250 fills the enclosed seal gland 230. The expanded metal 250 may have a variety of different volumes and remain within the scope of the disclosure. Such volumes, as expected, are a function of the size of the enclosed seal gland 230, among other factors.

[0033] In the illustrated embodiment of FIG.s 2A and 2B, the expanded metal 250 forms an expanded metal seal within the enclosed seal gland 230. For example, in at least one or more embodiments, the expanded metal seal is operable to seal the enclosed seal gland 230. In at least one embodiment, such as is shown, the expanded metal seal is the only seal located within the enclosed seal gland 230. Other embodiments may exist, however, wherein more than one seal resides within the enclosed seal gland 230.

[0034] In at least one embodiment, the enclosed seal gland 230 includes unwanted particulate matter, such as sand, proppant, etc. Unique to the present disclosure, the expanded metal 250 conforms to, and is not substantially affected by, the unwanted particulate matter. Accordingly, the expanded metal is particulate tolerant.

[0035] Turning to FIGs. 3A and 3B, depicted are various different manufacturing states for a seal assembly 300 designed, manufactured, and operated according to an alternative embodiment of the disclosure. FIG. 3A illustrates the seal assembly 300 pre-expansion, whereas FIG. 3B illustrates the seal assembly 300 post-expansion. The seal assembly 300 of FIGs. 3A and 3B is similar in many respects to the seal assembly 200 of FIGs. 2A and 2B. Accordingly, like reference numbers have been used to illustrate similar, if not identical, features. The seal assembly 300 differs, for the most part, from the seal assembly 200, in that the seal assembly 300 additionally includes a reactive fluid enclosure 310 located proximate and/or within the enclosed seal gland 230. The reactive fluid enclosure 310, in on or more embodiments, is a reactive fluid sac that is configured to melt, degrade, leak, rupture, or pierce at a desired time. For example, the reactive fluid sac could be configured to rupture when the pipe 210 and the outer tubular 220

are brought into contact with one another, and thus start the process of subjecting the pre-expansion expandable metal 240 to the reactive fluid from the reactive fluid sac to form the expanded metal 250.

[0036] The seal assembly 300 of FIGs. 3A and 3B additionally includes a coating or barrier 320 substantially enclosing, if not entirely enclosing, the pre-expansion expandable metal 240. As discussed above, the coating or barrier 320 may be a delay coating or barrier configured to delay the activation of the pre-expansion expandable metal 240 when it is contacted by the reactive fluid (e.g., the reactive fluid from the reactive fluid enclosure 310). Those skilled in the art understand the materials that the coating or barrier could comprise while staying within the scope of the disclosure.

[0037] Turning to FIGs. 4A and 4B, depicted are various different manufacturing states for a seal assembly 400 designed, manufactured and operated according to an alternative embodiment of the disclosure. FIG. 4A illustrates the seal assembly 400 pre-expansion, whereas FIG. 4B illustrates the seal assembly 400 post-expansion. The seal assembly 400 of FIGs. 4A and 4B is similar in many respects to the seal assembly 200 of FIGs. 2A and 2B. Accordingly, like reference numbers have been used to illustrate similar, if not identical, features. The seal assembly 400 differs, for the most part, from the seal assembly 200, in that the seal assembly 400 includes a metal seal 410 located within the enclosed seal gland 230. For example, in this embodiment, the pre-expansion expandable metal 240 is positioned in the enclosed seal gland 230 and proximate the metal seal 410, such that when the pre-expansion expandable metal 240 is subjected to the reactive fluid, it expands into the expanded metal, and thus activates the metal seal 410 against the outer tubular 220 or the pipe 210 to seal the enclosed seal gland 230. Thus, in the embodiment of FIGs. 4A and 4B, a metal-to-metal seal is formed with at least one, if not both, of the outer tubular 220 or the pipe 210.

[0038] Referring now to FIGs. 4C and 4D, illustrated are enlarged scale cross-sectional views of the metal seal 410, and pre-expansion metal 240 and expanded metal 250 illustrated in FIGs. 4A and 4B, respectively. The metal seal 410 illustrated in FIGs. 4C and 4D is an I-shaped metal seal. For example, in at least one embodiment, the metal seal 410 includes radially outwardly projecting metal sealing surfaces 420a, 420b on each of two arms 430a, 430b extending in opposite directions from a central feature 440. Similarly, the metal seal 410 includes radially inwardly projecting metal sealing surfaces 420c, 420d on each of two arms 430c, 430d extending

in opposite directions from the central feature 440. The metal sealing surfaces 420a, 420b, 420c, 420d are preferably made of strong, durable, and resilient metals, such as Inconel 718, 13-chrome steel, etc. It should be clearly understood that any metal materials may be used for the metal sealing surfaces 420a, 420b, 420c, 420d in keeping with the principles of this disclosure.

[0039] Between the pairs of arms 430a, 430b, and 430c, 430d, and separated by the central feature 440, are recesses 450, 455. In the embodiment of FIGs. 4C and 4D, the recesses 450, 455 are axially displaced about the central feature 440. As is illustrated in FIG. 4C, the pre-expansion metal 240 is positioned within the recesses 450, 455, as described below. As is further illustrate in FIG. 4D, expanded metal 250 is positioned within the recesses 450, 455, as described below. The metal sealing surfaces 420a, 420b, 420c, 420d are used to seal against one or both of the pipe or outer tubular (FIGs. 4A and 4B), as described below. If one or both of the pipe or outer tubular (FIGs. 4A and 4B) are made of a metal, then a metal-to-metal seal will be formed between the metal sealing surfaces 420a, 420b, 420c, 420d. The arms 430a, 430b are sufficiently resilient to bias the metal sealing surfaces 420a, 420b into sealing contact with the outer tubular. Similarly, the arms 430c, 430c are sufficiently resilient to bias the metal sealing surfaces 420c, 420d into sealing contact with the pipe.

[0040] Differential pressure from the pre-expansion metal 240 expanding in response to hydrolysis (e.g., thus becoming the expanded metal 250) applied to either of the recesses 450, 455 will also cause the pairs of arms 430a, 430b, and 430c, 430d to be biased radially outward and inward (as shown by the arrows), respectively, thereby increasing contact pressure between the metal sealing surfaces 420a, 420b, 420c, 420d and the radially exterior outer tubular and radially interior pipe. As is illustrated, each of the pairs of arms 430a, 430b, and 430c, 430d may include multiple metal sealing surfaces.

[0041] Turning to FIGs. 5A and 5B, depicted are various different manufacturing states for a seal assembly 500 designed, manufactured and operated according to an alternative embodiment of the disclosure. FIG. 5A illustrates the seal assembly 500 pre-expansion, whereas FIG. 5B illustrates the seal assembly 500 post-expansion. The seal assembly 500 of FIGs. 5A and 5B is similar in many respects to the seal assembly 400 of FIGs. 4A and 4B. Accordingly, like reference numbers have been used to illustrate similar, if not identical, features. The seal assembly 500 differs, for the most part, from the seal assembly 400, in that the metal seal 510

illustrated in FIGs. 5C and 5D is an I-shaped metal seal that has been rotated by 90 degrees relative to the metal seal 410.

[0042] Referring now to FIGs. 5C and 5D, illustrated are enlarged scale cross-sectional views of the metal seal 510 and pre-expansion metal 240 and expanded metal 250 illustrated in FIGs. 5A and 5B, respectively. The metal seal 510 illustrated in FIGs. 5C and 5D is an I-shaped metal seal, but the I-shaped metal seal of FIGs. 5C and 5D is rotated by about 90 degrees relative to the I-shaped metal seal of FIGs. 4C and 4D. For example, in at least one embodiment, the metal seal 510 includes axially projecting metal sealing surfaces 520a, 520b on each of two arms 530a, 530b extending in opposite directions from a central feature 540. Similarly, the metal seal 510 includes axially projecting metal sealing surfaces 520c, 520d on each of two arms 530c, 530d extending in opposite directions from the central feature 540. The metal sealing surfaces 520a, 520b, 520c, 520d are preferably made of strong, durable, and resilient metals, such as Inconel 718, 13-chrome steel, etc. It should be clearly understood that any metal materials may be used for the metal sealing surfaces 520a, 520b, 520c, 520d in keeping with the principles of this disclosure.

[0043] Between the pairs of arms 530a, 530b, and 530c, 530d, and separated by the central feature 540, are recesses 550, 555. In the embodiment of FIGs. 5C and 5D, the recesses 550, 555 are radially displaced about the central feature 540. As is illustrated in FIG. 5C, the pre-expansion metal 240 is positioned within the recesses 550, 555. As is further illustrate in FIG. 5D, expanded metal 250 is positioned within the recesses 550, 555. The metal sealing surfaces 520a, 520b, 520c, 520d are used to seal against one or both of the pipe or outer tubular (FIGs. 5A and 5B).

[0044] Differential pressure from the pre-expansion metal 240 expanding in response to hydrolysis (e.g., thus becoming the expanded metal 250) applied to either of the recesses 550, 555 will also cause the pairs of arms 530a, 530b, and 530c, 530d to be biased axially uphole and downhole, respectively. As is illustrated, each of the pairs of arms 530a, 530b, and 530c, 530d may include multiple metal sealing surfaces.

[0045] Turning to FIGs. 6A and 6B, depicted are various different manufacturing states for a seal assembly 600 designed, manufactured and operated according to an alternative embodiment of the disclosure. FIG. 6A illustrates the seal assembly 600 pre-expansion, whereas FIG. 6B illustrates the seal assembly 600 post-expansion. The seal assembly 600 of FIGs. 6A and 6B is

similar in many respects to the seal assembly 200 of FIGs. 2A and 2B. Accordingly, like reference numbers have been used to illustrate similar, if not identical, features. The seal assembly 600 differs, for the most part, from the seal assembly 200, in that the seal assembly 600 includes a second elastomeric seal 610 positioned within the enclosed seal gland 230. Thus, in accordance with this embodiment, when the expanded metal is in an expanded state it axially activates the second elastomeric seal 610 to further seal the enclosed seal gland 230. While a specific chevron type elastomeric seal has been illustrated in FIG. 6, any type of elastomeric seal could be used and remain within the scope of the present disclosure.

[0046] Turning to FIGs. 7A and 7B, depicted are various different manufacturing states for a seal assembly 700 designed, manufactured and operated according to an alternative embodiment of the disclosure. FIG. 7A illustrates the seal assembly 700 pre-expansion, whereas FIG. 7B illustrates the seal assembly 700 post-expansion. The seal assembly 700 of FIGs. 7A and 7B is similar in many respects to the seal assembly 400 of FIGs. 4A and 4B. Accordingly, like reference numbers have been used to illustrate similar, if not identical, features. The seal assembly 700 differs, for the most part, from the seal assembly 400, in that the seal assembly 700 includes a second elastomeric seal 710 positioned within the enclosed seal gland 230. Thus, in accordance with this embodiment, when the expanded metal is in an expanded state it also axially activates the second elastomeric seal 710 to further seal the enclosed seal gland 230.

[0047] Aspects disclosed herein include:

A. A seal assembly, the seal assembly including: 1) a pipe; 2) an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and 3) expanded metal positioned within the enclosed seal gland, the expanded metal comprising a metal that has expanded in response to hydrolysis to assist in sealing the enclosed seal gland.

B. A method for sealing, the method including: 1) providing a downhole tool, the downhole tool having a sealing assembly, including: a) a pipe; b) an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and c) pre-expansion expandable metal positioned within the enclosed seal gland, the pre-expansion expandable metal comprising a metal configured to expand in response to hydrolysis; and 2) subjecting the pre-expansion expandable metal to reactive fluid to form an expanded metal in the enclosed seal gland and thereby assist in sealing the enclosed seal gland.

C. A well system, the well system including: 1) a wellbore extending through one or more subterranean formations; and 2) a downhole tool located within the wellbore, the downhole tool having a seal assembly, the seal assembly including: a) a pipe; b) an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and c) expanded metal positioned within the enclosed seal gland, the expanded metal comprising a metal that has expanded in response to hydrolysis to assist in sealing the enclosed seal gland.

[0048] Aspects A, B, and C may have one or more of the following additional elements in combination: Element 1: wherein the expanded metal is an expanded metal seal operable to seal the enclosed seal gland. Element 2: wherein the expanded metal seal is a first seal, and further including a second elastomeric seal positioned within the enclosed seal gland. Element 3: wherein the expanded metal seal is in an expanded state axially activating the second elastomeric seal to further seal the enclosed seal gland. Element 4: further including a metal seal located within the enclosed seal gland, wherein the expanded metal is in an expanded state activating the metal seal against the outer tubular or the pipe to seal the enclosed seal gland. Element 5: wherein the metal seal is an I-shaped metal seal having pairs of arms separated by a central feature, the pairs of arms and central feature forming first and second recesses, and further wherein the expanded metal is in an expanded state within the first and second recesses thereby activating the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland. Element 6: wherein the expanded metal is in an expanded state within the first and second recesses thereby radially activating the pairs of arms against ones of the outer tubular and the pipe to seal the enclosed seal gland. Element 7: wherein the expanded metal is in an expanded state within the first and second recesses thereby axially activating the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland. Element 8: wherein the metal seal is a first seal, and further including a second elastomeric seal positioned within the enclosed seal gland. Element 9: wherein the expanded metal is in an expanded state axially activating the second elastomeric seal to further seal the enclosed seal gland. Element 10: wherein the expanded metal includes residual unreacted metal. Element 11: wherein subjecting the pre-expansion expandable metal to reactive fluid occurs outside of a wellbore, and further including positioned the downhole tool having the expanded metal within the wellbore. Element 12: wherein providing the downhole tool includes providing the downhole tool within a wellbore, and subjecting the pre-expansion expandable metal to the reactive fluid occurs inside the

wellbore. Element 13: wherein the expanded metal is a first expanded metal seal, and further including a second elastomeric seal positioned within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the second elastomeric seal to further seal the enclosed seal gland. Element 14: further including a metal seal located within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal activates the metal seal against the outer tubular or the pipe to seal the enclosed seal gland. Element 15: wherein the metal seal is an I-shaped metal seal having pairs of arms separated by a central feature, the pairs of arms and central feature forming first and second recesses, the pre-expansion expandable metal located within the first and second recesses, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland. Element 16: wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal radially activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland. Element 17: wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland. Element 18: wherein the I-shaped metal seal is a first metal seal, and further including a second elastomeric seal positioned within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the second elastomeric seal to further seal the enclosed seal gland.

[0049] Those skilled in the art to which this application relates will appreciate that other and further additions, deletions, substitutions, and modifications may be made to the described embodiments.

WHAT IS CLAIMED IS:

1. A seal assembly, comprising:
a pipe;
an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and
expanded metal positioned within the enclosed seal gland, the expanded metal comprising a metal that has expanded in response to hydrolysis to assist in sealing the enclosed seal gland.
2. The seal assembly as recited in Claim 1, wherein the expanded metal is an expanded metal seal operable to seal the enclosed seal gland.
3. The seal assembly as recited in Claim 2, wherein the expanded metal seal is a first seal, and further including a second elastomeric seal positioned within the enclosed seal gland.
4. The seal assembly as recited in Claim 3, wherein the expanded metal seal is in an expanded state axially activating the second elastomeric seal to further seal the enclosed seal gland.
5. The seal assembly as recited in Claim 1, further including a metal seal located within the enclosed seal gland, wherein the expanded metal is in an expanded state activating the metal seal against the outer tubular or the pipe to seal the enclosed seal gland.
6. The seal assembly as recited in Claim 5, wherein the metal seal is an I-shaped metal seal having pairs of arms separated by a central feature, the pairs of arms and central feature forming first and second recesses, and further wherein the expanded metal is in an expanded state within the first and second recesses thereby activating the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland.

7. The seal assembly as recited in Claim 6, wherein the expanded metal is in an expanded state within the first and second recesses thereby radially activating the pairs of arms against ones of the outer tubular and the pipe to seal the enclosed seal gland.

8. The seal assembly as recited in Claim 6, wherein the expanded metal is in an expanded state within the first and second recesses thereby axially activating the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland.

9. The seal assembly as recited in Claim 5, wherein the metal seal is a first seal, and further including a second elastomeric seal positioned within the enclosed seal gland.

10. The seal assembly as recited in Claim 9, wherein the expanded metal is in an expanded state axially activating the second elastomeric seal to further seal the enclosed seal gland.

11. The seal assembly as recited in Claim 1, wherein the expanded metal includes residual unreacted metal.

12. A method for sealing, comprising:
providing a downhole tool, the downhole tool having a sealing assembly, including:
a pipe;
an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and
pre-expansion expandable metal positioned within the enclosed seal gland, the pre-expansion expandable metal comprising a metal configured to expand in response to hydrolysis; and
subjecting the pre-expansion expandable metal to reactive fluid to form an expanded metal in the enclosed seal gland and thereby assist in sealing the enclosed seal gland.

13. The method as recited in Claim 12, wherein subjecting the pre-expansion expandable metal to reactive fluid occurs outside of a wellbore, and further including positioned the downhole tool having the expanded metal within the wellbore.

14. The method as recited in Claim 12, wherein providing the downhole tool includes providing the downhole tool within a wellbore, and subjecting the pre-expansion expandable metal to the reactive fluid occurs inside the wellbore.

15. The method as recited in Claim 12, wherein the expanded metal is a first expanded metal seal, and further including a second elastomeric seal positioned within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the second elastomeric seal to further seal the enclosed seal gland.

16. The method as recited in Claim 12, further including a metal seal located within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal activates the metal seal against the outer tubular or the pipe to seal the enclosed seal gland.

17. The method as recited in Claim 16, wherein the metal seal is an I-shaped metal seal having pairs of arms separated by a central feature, the pairs of arms and central feature forming first and second recesses, the pre-expansion expandable metal located within the first and second recesses, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland.

18. The method as recited in Claim 17, wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal radially activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland.

19. The method as recited in Claim 17, wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the pairs of arms against ones of the outer tubular or the pipe to seal the enclosed seal gland.

20. The method as recited in Claim 17, wherein the I-shaped metal seal is a first metal seal, and further including a second elastomeric seal positioned within the enclosed seal gland, and further wherein the subjecting the pre-expansion expandable metal to the reactive fluid to form the expanded metal axially activates the second elastomeric seal to further seal the enclosed seal gland.

21. A well system, comprising:
a wellbore extending through one or more subterranean formations; and
a downhole tool located within the wellbore, the downhole tool having a seal assembly, the seal assembly including:
a pipe;
an outer tubular positioned around the pipe, the outer tubular and pipe forming an enclosed seal gland; and
expanded metal positioned within the enclosed seal gland, the expanded metal comprising a metal that has expanded in response to hydrolysis to assist in sealing the enclosed seal gland.