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(54) **CASING ANNULUS LEAKAGE REPAIR METHOD AND SYSTEM**

VERFAHREN UND SYSTEM ZUR REPARATUR EINES GEHÄUSERINGRAUMLECKS

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Description

TECHNICAL FIELD

[0001] The present disclosure is generally related to systems and processes for repairing a leak in a well and more particularly related to systems and processes for repairing a leak in a casing of a well.

BACKGROUND OF THE DISCLOSURE

[0002] Sufficient pressure isolation between casing strings has been an oil industry problem since its inception. Cement is used to seal the annulus between concentric casing strings, but cement fundamentally shrinks as it cures, resulting in micro channels and micro-annuli in the cement. The micro channels and micro-annuli can permit gas to flow between the casing strings. Sometimes the gas can flow for thousands of feet between the tubulars and can be measured at the surface wellhead. Further, downhole media can flow from one zone of the well to another via the micro channels (casing-to-casing leak path). Such problems occur more frequently in gas wells because of higher pressures and lower media viscosity. Moreover, casing-to-casing annular (CCA) pressure at the surface can be an indicator of much more serious conditions, such as a downhole circulation or a blowout in the most serious instances.

[0003] In recent years, new cements have been created with the aim of having less shrinkage during curing. These newer cement chemistries are generally composites with other materials such that the net behavior of the cement actually expands slightly during curing. These improvements in cement chemistries have resulted in better performance for sealing between casing strings (CCA sealing), but they have not solved the problem entirely. In particular, micro channels can still develop in the casing after the curing of the cement, which results in CCA leaks that are not detected until long after the casing is cemented. Currently, retrofit methods for repair of these CCA leaks in gas wells have been difficult to implement and are largely ineffective.

[0004] WO 2016/123166 A1 discloses a downhole tool for conveyance within a tubular secured in a wellbore extending into a subterranean formation. The downhole tool includes a sealing material and a laser apparatus operable to cut a slot in the tubular. The downhole tool is operable to provide melted sealing material within the slot.

[0005] US 2010/0155085 A1 discloses a method for forming a downhole plug within an abandoned well casing for preventing the flow of gas through the plug and reaching the surface, particularly for CO₂ sequestration projects. A milling tool mills out a longitudinal section of the perimeter of the well casing and surrounding cement and detritus to expose the well bore. A heater containing solid metallic alloy is lowered into the casing and the alloy is melted so that it fills the milled out area and flows into

the face of the well bore.

[0006] WO 2018/033760 A1 discloses a method of sealing a region of a sand screen of an Open Hole Gravel Pack without the need to perforate the sand screen and a tool for use in such. The tool being a eutectic/ bismuth based alloy well plugging/sealing tool having a tubular heater body with an internal cavity capable of receiving a chemical heat source.

[0007] WO 2016/049424 A1 discloses a sealing tool for conveyance within a tubular member within a wellbore extending into a subterranean formation. The sealing tool includes a mandrel and a eutectic sealing material disposed about the mandrel.

[0008] GB 2 568 519 A discloses an expandable downhole tool having a tubular body with eutectic alloy located on an outer surface thereof.

[0009] GB 2 561 255 A discloses a thermally deformable annular packer having a ring section set within the annulus between tubing and casing, wherein the ring section includes a chamber acting to release and relieve pressure which may increase as the thermal packer is set.

SUMMARY OF THE DISCLOSURE

[0010] Aspects of the invention are set out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0011]

Fig. 1 displays a cross-section of a portion of a well that has a leak in its casing in accordance with one or more embodiments; and

Fig. 2A displays a cross-section of a portion of a well during repair of the leak and a system for repairing the leak in accordance with one or more embodiments;

Fig. 2B displays a cross-section of a portion of the casing after repair of the leak in accordance with one or more embodiments; and

Fig. 3 displays a diagram of an exemplary annular packer tool of the system for repairing the leak in accordance with one or more embodiments.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS IN ACCORDANCE WITH THE DISCLOSURE

[0012] By way of overview and introduction, the present application discloses methods and systems for repairing a leak in a casing of a well. In one or more embodiments, the system can include an underreamer, a cleaning tool (e.g., hydrojet), a tubular (e.g., scab liner), an annular packer tool, and a heater. In accordance with one or more embodiments of the method, a leak such as a casing-to-casing annular (CCA) leak is located in a casing of the well. The casing can include an inner casing

string ("inner casing") and an outer casing string ("outer casing") with cement separating the inner and outer casings.

[0013] After the location of the leak is determined, an underreamer is used to remove a portion of the inner casing and sometimes the cement at the location of the leak, thereby creating an annular-shaped opening in the inner casing. This annular-shaped opening is then cleaned to remove any debris. It will be appreciated that the formed opening can be a concentric annular, partially eccentric annular, or fully eccentric annular in shape, for example.

[0014] A scab liner is inserted into the well and an annular packer tool is attached to the scab liner. The annular packer tool includes one or more segments of heat-deforming material (e.g., eutectic metal) on its outer surface. The scab liner and the annular packer tool are inserted into the well at a location adjacent to the created annular-shaped opening. A heater (e.g., thermite heater) is inserted into the well at a location adjacent to the annular packer tool, and then initiated. Initiation of the heater heats the location adjacent to the annular packer tool such that the segments of heat-deforming material of the annular packer tool melt. The melted heat-deforming material then flows into the annular-shaped opening and solidifies after cooling. Solidification of the heat-deforming material in the annular-shaped opening plugs the annular-shaped opening, thereby repairing (sealing) the previously identified leak in the casing.

[0015] These and other aspects of the present systems and methods are described in further detail below with reference to the accompanied drawing figures, in which one or more illustrated embodiments and/or arrangements of the systems and methods are shown. The systems and methods of the present application are not limited in any way to the illustrated embodiment and/or arrangement. It should be understood that the systems and methods as shown in the accompanying figures are merely exemplary of the systems and methods of the present application, which can be embodied in various forms as appreciated by one skilled in the art. Therefore, it is to be understood that any structural and functional details disclosed herein are not to be interpreted as limiting the present systems and methods, but rather are provided as a representative embodiment and/or arrangement for teaching one skilled in the art one or more ways to implement the present systems and methods.

[0016] Fig. 1 is a cross-section of a portion of a well 100 that has a leak in a casing 102 after the casing is cemented in accordance with one or more embodiments. The casing 102 comprises an inner casing 104 and an outer casing 106, which surrounds the inner casing 104. The inner casing 104 and outer casing 106 are separated by a cement sheath 108. In one or more embodiments, the outer casing 106 can be a 13 and 3/8ths inch (13-3/8") (33.97 cm) outer diameter (OD) casing and the inner casing can be a 9 and 5/8ths inch (9-5/8") (24.45 cm) OD casing. However, it should be understood that the sizes

of the inner casing 104 and the outer casing can vary, and thus are not limited to the above embodiment.

[0017] Leaks can develop between the inner casing 104 and the outer casing 106 over time. The root cause of these leaks is often a lack of sufficient sealing of the cement between the inner casing 104 and outer casing 106. This lack of sufficient sealing between the casing strings can occur for one or more of the following reasons: 1) cement shrinkage during curing; 2) poor casing centralization that yields non-uniform cement sealing stress; 3) cement leakage, particularly in horizontal wells as an annulus develops in the upper part of the casing seal; 4) development of micro-cracks due to excessive mechanical or thermal stresses that can cause the cement to fail (crack) and develop a leak; 5) mud channeling, particularly in deviated wells with poor centralization, which to leave a mud channel on a thin side of the casing which is not displaced with cement, resulting in future leakage; 6) gas channeling; and (7) micro-annuli. Gas channeling can occur as a result of cement slurry hardening as it goes through the gelation state, and the resulting shrinkage of the cement causes reduction in hydrostatic pressure. This shrinkage and reduction in hydrostatic pressure allows an influx of gas from permeable formations to form channels for gas to migrate between formation zones or between a zone and the surface of the well. Micro-annuli are concentric gaps created between tubular and cement due to high pressures such as fracturing causing the casing to elastically deform, excessive compression of the cement, then opening of an annulus as the pressure is reduced.

[0018] Gas wells are especially susceptible to leaks in the casing 102 (e.g., casing-to-casing annular [CCA] leaks) and are equally difficult to repair once they occur.

The present systems and methods allow for the effective repair of casing leaks, particularly in a well that has already been cemented using conventional techniques.

[0019] Figs. 2A-2B a cross-section of a portion of a well during and after repair of the leak via the systems and methods of the present application in accordance with one or more embodiments. As shown in Fig. 2A, a CCA leak 109 can develop in the cement sheath 108 of the casing 102. In other words, a CCA leak 109 develops in the cement sheath 108 because the cement is not sealing between the inner casing 104 and the outer casing 106. In one or more embodiments, the method for repairing the leak begins by determining the location of the leak. There are several ways to determine the location of the CCA leak 109 in the casing 102. For example, in one or more embodiments, the CCA leak 109 can be detected by identifying the inflow and outflow positions of the leak using one or more acoustic logging tools. The acoustic logging tools can be used in the well while the well is shut-in, for example. In one or more embodiments, the acoustic logging tools are used to listen for fluid and gas flows behind the casing. It will be appreciated that any number of suitable detection techniques can be used.

[0020] Once the location of the CCA leak 109 is determined, one or more portions of the inner casing 104 near the location of the leak 109 is removed so as to expose the leak. In one or more embodiments, at least one portion of the inner casing 104 that is removed is above the location of the leak 109 (i.e., above the inflow point).

[0021] In one or more embodiments, the one or more portions the inner casing 104 is removed using an underreamer to remove the selected portion of the inner casing 104. In one or more embodiments, in addition to removing the portion of the inner casing 104, an adjacent portion of the cement sheath 108 is also removed. For instance, the cement sheath 112 adjacent to the removed inner casing portion can also be removed, thereby revealing the outer casing 106 (see Fig. 2A). The removal of each portion of the inner casing 104 and, in some embodiments, an adjacent portion of the cement sheath 112, results in an annular-shaped opening 110 or "donut" being formed. In one or more embodiments of the present method, the step of removing the at least one portion of the inner casing 104 includes determining a length of the inner casing 104 to remove based on the locations of inflow and outflow positions of the leak in the casing. For example, in an embodiment in which there is a 13-3/8" (33.97 cm) outer casing and a 9-5/8" (24.45 cm) inner casing, the annular-shaped opening 110 can be approximately 3 feet (91.45 cm) in length. However, the size of the one or more formed annular-shaped openings 110 can vary depending on the distance between the inflow and outflow positions of the leak, as well as the size of inner and outer casings.

[0022] After the at least one annular-shaped opening 110 in the inner casing 104 is created (e.g., via underreaming), the at least one annular-shaped opening 110 is cleaned. In one or more embodiments, the annular-shaped opening 110 can be cleaned via a cleaning tool, such as a hydro-jetting tool ("hydrojet"). In one or more embodiments, the cleaning tool can be a laser tool, a sonic/acoustic tool, or a vibration tool, for example. Cleaning of the annular-shaped opening 110 cleans the debris and any remnants of the cement sheaths (excess cement) from the annular-shaped opening 110.

[0023] After the annular-shaped opening 110 is cleaned, a tubular 112 (e.g., scab liner) is inserted to a location adjacent to the annular-shaped opening 110. As shown and described in exemplary embodiments discussed below, the tubular 112 is a scab liner. In one or more embodiments, the scab liner is a 7" (17.78 cm) scab liner. However, in other embodiments, the diameter of the scab liner can vary depending on the size of the well and the size casing. The scab liner 112 is inserted along with an annular packer tool 114 that is attached to the scab liner along the outer surface of the scab liner 112. In other words, the annular packer tool 114 is disposed such that it surrounds the scab liner 112 and the annular packer tool 114 is disposed between the scab liner 112 and the inner casing 104. Since the scab liner 112 has a smaller inner diameter than the inner casing 104, the

location of the scab liner 112 represents a local constricted area.

[0024] In one or more embodiments, the annular packer tool 114 can be a modified version of the TDAP tool as produced by BiSN Tec Ltd, except that that the annular packer tool 114 of the present application does not include springs, annular seals, or axial hole for cementing as provided in TDAP tool of BiSN Tec Ltd. A diagram of an exemplary annular packer tool 114 attached to the scab liner 112 is shown at Fig. 3. The annular packer tool 114 is cylindrical in shape and is sized to run on the outside of the scab liner 112, which is also cylindrical. The annular packer tool 114 thus surrounds the scab liner 112 and can be positioned at the desired select position of the scab liner 112 for placement in the desired repair location relative to the leak which is located radially outward from the annular packer tool 114.

[0025] The annular packer tool 114 has previously been utilized in methods as a proactive measure for preventing leaking during the construction phase of the well. For example, in previous methods, the annular packer tool is run with a casing string during the well construction phase. The annular packer tool 114 is used in a completely different manner and matter in the systems and methods of the present application as compared to its prior uses, and particularly for repairing existing leak in the casing of a well.

[0026] Specifically, in one of more embodiments of the present application as shown in Fig. 3, the annular packer tool 114 comprises one or more segments 116 (cylinders) of heat-deforming material on its outer surface. In one or more embodiments, the heat-deforming material 116 comprises a low-melting point metal, such as a eutectic metal. For example, the eutectic metal can comprise bismuth (Bi) and tin (Sn) (e.g., a bismuth-tin alloy). While the exemplary embodiments discussed herein often refer to the heat-deforming material 116 as eutectic metal segments, in other embodiments, the heat-deforming material 116 can comprise one or more other low-melting point materials or metals that are not considered eutectic metals.

[0027] In at least one embodiment, the annular packer tool 114 can also include other portions of one or more metals that have a higher melting point than the activation temperature of the heat-deforming material (e.g., eutectic metal) segments 116. For example, in one or more embodiments, the annular packer tool 114 can comprise centralizers 117 (e.g., carbon steel guides) that have the same or larger diameter as the eutectic metal segments 116 are configured to fix the ends of the annular packer tool 114 to the scab liner 112 such that the annular packer tool 114 remains on the scab liner 112. The annular packer tool 114 is inserted on the scab liner 112 to a location that is adjacent to the annular-shaped opening 110.

[0028] As the scab liner 112 and the annular packer tool 114 are inserted in the well at a location adjacent to the annular-shaped opening 110, the scab liner 112 is secured to a portion of the inner casing 104. In at least

one embodiment, the well can include a production liner 124 (e.g., 7" (17.78 cm) production liner) and the scab liner 112 can be tied back to the production liner 124 (e.g., via a tie or other fixture). In one or more embodiments, to attach the scab liner 112 and the production liner 124, an upper part of the production liner 124 can have a polished bore receptacle (PBR) and the bottom of the scab liner 112 can have a seal assembly. As the scab liner 112 is lowered, the seal assembly enters and seals in the PBR. In at least one embodiment, the scab liner can alternatively be tied back to a wellhead of the well. In one or more embodiments, the scab liner can be held at a location adjacent to the annular-shaped opening 110 with a running tool.

[0029] Once the scab liner 112 with the attached annular packer tool 114 is located adjacent to the annular-shaped opening 110, a heater 120 is inserted into the well 100 inside the scab liner 112 and thus can be positioned inside the annular packer tool 114. The heater 120 is lowered in the well 100 to a predetermined location adjacent to the annular packer tool 114. The heater 120 can be, for example, an electric heater, an inductive heater, or a chemical heater (e.g., thermite heater).

[0030] In one or more embodiments, the heater 120 is lowered into the well 100 via an electric line 121. In such an embodiment, the heater 120 is attached to the electric line 121 and both are then selectively lowered into the well to a predetermined location adjacent to the annular packer tool 114 with the scab liner 112 being between the heater 120 and the annular packer tool 114. Once the heater 120 has been lowered to the location adjacent to the annular packer tool 114, the heater 120 is initiated, thereby heating the location adjacent to the annular packer tool 114. The heat from the heater 120 thus passes through the scab liner 112 to the annular packer tool 114 that surrounds the scab liner 112.

[0031] The initiated heater 120 is configured to heat the location adjacent to the annular packer tool 114 to a temperature above an activation temperature of the one or more segments of heat-deforming material 116 (without adversely impacting the scab liner 112). As such, the increased temperature causes the heat-deforming material segments 116 to melt. In embodiments in which the annular packer tool 114 also includes portions of metal with a higher melting point than the activation temperature of the heat-deforming material (e.g., eutectic metal) segments 116, the heater 120 is configured to heat the location adjacent to the annular packer tool 114 to a temperature above the activation temperature of the heat-deforming material segments 116 but below the melting point of the other metal portions. As the heat-deforming material melts, the melted heat-deforming material flows into the at least one adjacent annular-shaped opening 110. In at least one embodiment, the preferred activation temperature of the heat-deforming material (e.g., eutectic metal) when the heat-deforming material is a Bi-Sn alloy is approximately 50°C greater than the highest expected temperature experienced during service in the

well. In one or more embodiments, the activation temperature can be in the range of 90°C to 500°C. However, it should be understood that higher or lower temperatures for the activation temperature of the heat-deforming material can be selected in other embodiments.

[0032] In one or more embodiments in which the scab liner is held in place by the running tool, the heater 120 can be run through the running tool and into the scab liner 112 adjacent to the heat-deforming material segments 116 (e.g., eutectic metal). In such an embodiment, the heater can then be initiated to melt the heat-deforming material.

[0033] As mentioned earlier, the annular packer tool 114 is constructed such that when the heat-deforming material segments 116 melt, the melted metal flows into the opening 110. The centralizers 117 that border the ends of the metal segments 116 limit where the melted heat-deforming material can flow until the melted heat-deforming material can solidify within the opening 110.

[0034] After the heat-deforming material segments 116 of the annular packer tool 114 has melted, the heater 120 is turned off or deactivated such that the reaction that causes the increase in temperature in the heater 120 is neutralized and the temperature around the heater 120 is lowered below the activation temperature of the heat-deforming material. As such, due to the decrease in temperature, the melted heat-deforming material solidifies within the at least one annular-shaped opening 110. Once the heater 120 has cooled, the heater 120 is removed from the location adjacent to the annular packer tool 114. In one or more embodiments, the heater 120 is removed from the location adjacent to the annular packer tool 114 via the electric line 121.

[0035] As shown in Fig. 2B, as the heat-deforming material (e.g., eutectic metal) solidifies in the annular-shaped opening 110, the heat-deforming material expands volumetrically in the annular-shaped opening 110. This volumetric expansion exerts radial stress on the portion of the inner casing 104 and outer casing 106 that surrounds the annular-shaped opening 110. Once the heat-deforming material solidifies in the annular-shaped opening 110, it forms a seal 126. This seal 126 forms a metal-to-metal seal with the metal of the inner casing 104 and the metal of the outer casing 106 that surrounds the annular-shaped opening 110, thereby providing a gas-tight seal at the location of the CCA leak.

[0036] In one or more embodiments, the scab liner 112 remains in the well after the leak has been repaired/sealed, and thus permanently or semi-permanently constricts the area of the well in which the leak was repaired. For example, in one or more embodiments in which the scab liner 112 is held in place by the running tool, once the heater is deactivated and the heat-deforming material solidifies within the opening 110, the heater is removed, and the running tool is retrieved, but the scab liner can remain in the well.

[0037] Moreover, since the packer tool 114 is located between the scab liner 112 and the outer casing 106

within the opening 110, the heat-deforming material (e.g., eutectic metal) that flows and then cools and hardens is bonded to both the scab liner 112 and the outer casing 106. The cooled, hardened heat-deforming material that is formed thus in effect plugs the opening 110 and also causes the scab liner 112 to be bonded to the outer casing 106. The packer tool 114 is thus left in place and can be at least partially embedded within the hardened heat-deforming material. The annular packer tool 114 is thus sacrificed and left in place along with the scab liner 112.

[0038] As such, the present system and methods for repairing an existing leak in a casing effectively sections off one or more portions of the casing around the leak. This is accomplished by removing the inner casing 104 and cement sheath at these portions of the casing (e.g., via underreaming) and filling the created void in the casing (annular-shaped opening 110) with heat-deforming material from the annular packer tool 114 to form a gas-tight, metal-to-metal seal. Via the gas-tight, metal-to-metal seal, the present systems and methods provide an effective and durable repair of the casing compared to prior solutions.

[0039] As also mentioned, one or more production liners 125 can be provided and can be secured within the inner casing 104. The production liner 125 and the scab liner 112 preferably having the same inner diameter.

[0040] The present method and system thus provides a solution to remedying leaks that occur in the already formed cement sheath 108 of the well that is located between the two sheaths 104, 106. The tool (i.e., the packer tool 114) that repairs (e.g., plugs) the leak is delivered to a location radially inward of the inner casing 104 but is carried radially outward of the scab liner 112. After positioning the tool at the desired location that corresponds to an opening that is formed through the inner casing 104 and the cement sheath 108 so as to expose the inner surface of the outer casing 106. The melted heat-deforming material flows radially outward into such opening resulting in repair of the cement sheath, thereby forming a seal between the scab liner 112 and the outer casing 106.

[0041] Although much of the foregoing description has been directed to systems and methods for repairing a leak in a casing of a well, the system and methods disclosed herein can be similarly deployed and/or implemented in scenarios, situations, and settings far beyond the referenced scenarios. It should be further understood that any such implementation and/or deployment is within the scope of the system and methods described herein.

[0042] It is to be further understood that like numerals in the drawings represent like elements through the several figures, and that not all components and/or steps described and illustrated with reference to the figures are required for all embodiments or arrangements. Further, the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates other-

wise. It will be further understood that the terms "including," "comprising," or "having," "containing," "involving," and variations thereof herein, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0043] It should be noted that use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another or the temporal order in which acts of a method are performed, but are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements.

[0044] Notably, the figures and examples above are not meant to limit the scope of the present disclosure to a single implementation, as other implementations are possible by way of interchange of some or all of the described or illustrated elements. Moreover, where certain elements of the present disclosure can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present disclosure are described, and detailed descriptions of other portions of such known components are omitted so as not to obscure the disclosure. In the present specification, an implementation showing a singular component should not necessarily be limited to other implementations including a plurality of the same component, and vice-versa, unless explicitly stated otherwise herein. Moreover, applicants do not intend for any term in the specification or claims to be ascribed an uncommon or special meaning unless explicitly set forth as such. Further, the present disclosure encompasses present and future known equivalents to the known components referred to herein by way of illustration.

[0045] The foregoing description of the specific implementations will so fully reveal the general nature of the disclosure that others can, by applying knowledge within the skill of the relevant art(s) (including the contents of the documents cited and incorporated by reference herein), readily modify and/or adapt for various applications such specific implementations, without undue experimentation, without departing from the general concept of the present disclosure. Such adaptations and modifications are therefore intended to be within the meaning and range of equivalents of the disclosed implementations, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance presented herein, in combination with the knowledge of one skilled in the relevant art(s). It is to be understood that dimen-

sions discussed or shown are drawings are shown accordingly to one example and other dimensions can be used without departing from the disclosure.

[0046] The subject matter described above is provided by way of illustration only and should not be construed as limiting. Various modifications and changes can be made to the subject matter described herein without following the example embodiments and applications illustrated and described, and without departing from the scope of the invention encompassed by the present disclosure, which is defined by the set of recitations in the following claims and by structures and functions or steps which are equivalent to these recitations.

[0047] Aspects of the above disclosure are recited in the appended claims.

Claims

1. A method for repairing a leak in a casing (102) of a well (100), wherein the casing comprises an inner casing (104) and an outer casing (106) with a first space formed therebetween, the method comprising:
 - removing a portion of the inner casing to create an opening in the inner casing so that the first space is accessible;
 - inserting a scab liner (112) and an annular packer tool (114) attached to the scab liner to a location adjacent to the opening, wherein the annular packer tool surrounds the scab liner and comprises one or more segments (116) of heat-deforming material on an outer surface of the annular packer tool;
 - tying the scab liner to a production liner (124) or a wellhead of the well to secure the scab liner;
 - inserting a heater (120) into the well and positioning the heater at a location that is internally within the scab liner and is adjacent to the annular packer tool;
 - activating the heater to a temperature above an activation temperature of the one or more segments of heat-deforming material, thereby causing the heat-deforming material to melt, and wherein the melted heat-deforming material flows into the opening; and
 - reducing the temperature of the location adjacent to the annular packer tool to below the activation temperature of the heat-deforming material to cause the melted heat-deforming material to solidify within the opening and within the first space.
2. The method of claim 1, wherein the step of removing the portion of the inner casing comprises using an underreamer device to create the opening in the inner casing and to make the first space accessible.
3. The method of claim 1, wherein the opening comprises an annular-shaped opening (110) that is formed through the inner casing and through the first space so as to reveal an inner surface of the outer casing.
4. The method of claim 1, further comprising: locating the leak in the casing by identifying inflow and outflow positions of the leak in the casing.
5. The method of claim 4, wherein the step of identifying the inflow and outflow positions is performed by an acoustic logging tool.
6. The method of claim 1, further comprising: cleaning the opening to remove debris and excess cement that comes from a cement sheath (108) that is disposed within the first space.
7. The method of claim 1, wherein the inner casing and the outer casing are separated by a cement sheath (108), wherein the step removing a portion of the inner casing further comprises removing an adjacent portion of the cement sheath via underreaming such that the opening includes an area from which the portions of inner casing and cement sheath are removed.
8. The method of claim 1, wherein the heat-deforming material is a low melting point alloy.
9. The method of claim 8, wherein the low melting point alloy is an alloy that comprises bismuth (Bi) and tin (Sn).
10. The method of claim 1, wherein the step of inserting the heater into the well comprises:
 - lowering the heater into the well on an electric line (121), and
 - positioning the heater at a predetermined location that is adjacent to the annular packer tool; and
 - wherein the method further comprises: deactivating and subsequently removing the heater from the location adjacent to the annular packer tool.
11. The method of claim 1, wherein the annular packer tool further comprises metal portions having a higher melting point than the activation temperature of the heat-deforming material segments, and wherein the heater heats the location adjacent to the annular packer tool to a temperature above the activation temperature of the one or more segments of heat-deforming material but below a melting point of the metal portions.

12. The method of claim 11, wherein heat from the heater passes through the scab liner to heat the heat-deforming material segments that are located radially outward of both the heater and the scab liner.
13. The method of claim 11, wherein the heater heats the location adjacent to the annular packer tool to a temperature approximately 50°C above a highest expected service temperature of the well.
14. A system for repairing a leak in a casing (102) of a well (100), wherein the casing comprises an inner casing (104) and an outer casing (106), the system comprising:
- an underreamer configured to remove a portion of the inner casing at the location of the leak to create an annular-shaped opening (110) in the inner casing;
- a scab liner (112) and an annular packer tool (114) attached to the scab liner, wherein the scab liner is positioned a location adjacent to the annular-shaped opening, and wherein the annular packer tool comprises one or more segments (116) of heat-deforming material on its outer surface, and wherein the scab liner is tied to a production liner or a wellhead of the well to secure the scab liner; and
- a heater (120) configured to heat the well at the location adjacent to the annular packer tool, to a temperature above an activation temperature of the one or more segments of heat-deforming material.

Patentansprüche

1. Verfahren zum Reparieren eines Lecks in einer Verrohrung (102) eines Bohrlochs (100), wobei die Verrohrung eine innere Verrohrung (104) und eine äußere Verrohrung (106) mit einem ersten dazwischen gebildeten Raum umfasst, wobei das Verfahren Folgendes umfasst:

Entfernen eines Teils der inneren Verrohrung, um eine Öffnung in der inneren Verrohrung zu schaffen, sodass der erste Raum zugänglich ist; Einführen eines Schülpen-Liners (112) und eines ringförmigen Packerwerkzeugs (114), das an einer Position benachbart zu der Öffnung an dem Schülpen-Liner angebracht ist, wobei das ringförmige Packerwerkzeug den Schülpen-Liner umgibt und ein oder mehrere Segmente (116) aus wärmeverformendem Material auf einer Außenoberfläche des ringförmigen Packerwerkzeugs umfasst;

Anlegen des Schülpen-Liners an einen Produktionsliner (124) eines Bohrlochkopfs des Bohr-

lochs, um den Schülpen-Liner zu befestigen; Einführen eines Heizelements (120) in das Bohrloch und Positionieren des Heizelements an einer Position, die sich innerhalb des Schülpen-Liners und benachbart zu dem ringförmigen Packerwerkzeug befindet;

Aktivieren des Heizelements auf eine Temperatur über einer Aktivierungstemperatur des einen oder der mehreren Segmente von wärmeverformendem Material, wodurch bewirkt wird, dass das wärmeverformende Material schmilzt und wobei das geschmolzene wärmeverformende Material in die Öffnung fließt; und

Reduzieren der Temperatur der Position benachbart zu dem ringförmigen Packerwerkzeug auf unterhalb der Aktivierungstemperatur des wärmeverformenden Materials, um zu bewirken, dass sich das geschmolzene wärmeverformende Material innerhalb der Öffnung und innerhalb des ersten Raums verfestigt.

2. Verfahren nach Anspruch 1, wobei der Schritt des Entfernens des Teils der inneren Verrohrung die Verwendung eines Ausräumgeräts umfasst, um die Öffnung in der inneren Verrohrung zu erzeugen und um den ersten Raum zugänglich zu machen.
3. Verfahren nach Anspruch 1, wobei die Öffnung eine ringförmige Öffnung (110) umfasst, die durch die innere Verrohrung und durch den ersten Raum ausgebildet ist, um eine Innenfläche der äußeren Verrohrung freizulegen.
4. Verfahren nach Anspruch 1, das ferner Folgendes umfasst:
- Lokalisieren des Lecks in der Verrohrung durch Identifizieren von Zu- und Abflusspositionen des Lecks in der Verrohrung.
5. Verfahren nach Anspruch 4, wobei der Schritt des Identifizierens der Zu- und Abflusspositionen durch ein akustisches Bohrlochmesswerkzeug.
6. Verfahren nach Anspruch 1, das ferner Folgendes umfasst:
- Reinigen der Öffnung, um Rückstände und überschüssigen Zement zu entfernen, der aus einer Zementumhüllung (108) stammt, die innerhalb des ersten Raums angeordnet ist.
7. Verfahren nach Anspruch 1, wobei die innere Verrohrung und die äußere Verrohrung durch eine Zementumhüllung (108) getrennt sind, wobei der Schritt des Entfernens eines Teils der inneren Verrohrung ferner das Entfernen eines benachbarten Teils der Zementhülle durch Ausräumen umfasst, sodass die Öffnung einen Bereich umfasst, aus dem die Teile der inneren Verrohrung und der Zemen-

tumhüllung entfernt wurden.

8. Verfahren nach Anspruch 1, wobei das wärmeverformende Material eine Legierung mit niedrigem Schmelzpunkt ist. 5
9. Verfahren nach Anspruch 8, wobei die Legierung mit niedrigem Schmelzpunkt eine Legierung ist, die Bismut (Bi) und Zinn (Sn) umfasst. 10
10. Verfahren nach Anspruch 1, wobei der Schritt des Einführens des Heizelements in das Bohrloch Folgendes umfasst:
 - Absenken des Heizelements in das Bohrloch an einer elektrischen Leitung (121) und 15
 - Positionieren des Heizelements an einer vorbestimmten Position, die benachbart zu dem ringförmigen Packerwerkzeug ist; und
 - wobei das Verfahren ferner Folgendes umfasst: 20
 - Deaktivieren und anschließendes Entfernen des Heizelements von der Position benachbart zu dem ringförmigen Packerwerkzeug.
11. Verfahren nach Anspruch 1, wobei das ringförmige Packerwerkzeug ferner Metallteile mit einem höheren Schmelzpunkt als die Aktivierungstemperatur der Segmente aus wärmeverformbarem Material umfasst, und wobei das Heizelement die Position benachbart zu dem ringförmigen Packerwerkzeug auf eine Temperatur über der Aktivierungstemperatur des einen oder der mehreren Segmente aus wärmeverformbarem Material, aber auf unterhalb eines Schmelzpunkts der Metallteile erhitzt. 30
12. Verfahren nach Anspruch 11, wobei die Wärme aus dem Heizelement durch den Schülpen-Liner hindurchdringt, um die Segmente aus wärmeverformbarem Material, die sowohl von dem Heizelement als auch dem Schülpen-Liner radial nach außen angeordnet sind, zu erhitzen. 35
13. Verfahren nach Anspruch 11, wobei das Heizelement die Position benachbart zu dem ringförmigen Packerwerkzeug auf eine Temperatur von etwa 50 °C über einer höchsten erwarteten Betriebstemperatur des Bohrlochs erhitzt. 40
14. System zum Reparieren eines Lecks in einer Verrohrung (102) eines Bohrlochs (100), wobei die Verrohrung eine innere Verrohrung (104) und eine äußere Verrohrung (106) umfasst, wobei das System Folgendes umfasst:
 - einen Ausräumer, der ausgelegt ist, um einen 55
 - Teil der inneren Verrohrung an der Position des Lecks zu entfernen, um eine ringförmige Öffnung (110) in der inneren Verrohrung zu erzeugen;

gen;

einen Schülpen-Liner (112) und ein ringförmiges Packerwerkzeug (114), das an dem Schülpen-Liner angebracht ist, wobei der Schülpen-Liner an einer Position benachbart zu der ringförmigen Öffnung angeordnet ist, und wobei das ringförmige Packerwerkzeug ein oder mehrere Segmente (116) aus einem wärmeverformenden Material auf dessen Außenfläche umfasst, und wobei der Schülpen-Liner an einen Produktionsliner oder einen Bohrlochkopf des Bohrlochs angebunden ist, um den Schülpen-Liner zu befestigen; und
ein Heizelement (120), das ausgelegt ist, um das Bohrloch an der Position benachbart zu dem ringförmigen Packerwerkzeug auf eine Temperatur über einer Aktivierungstemperatur des einen oder der mehreren Segmente aus wärmeverformendem Material zu erhitzen.

Revendications

1. Procédé pour réparer une fuite dans un tubage (102) d'un puits (100), dans lequel le tubage comprend un tubage intérieur (104) et un tubage extérieur (106) avec un premier espace formé entre ceux-ci, le procédé comprenant les étapes consistant à :

retirer une partie du tubage intérieur pour créer une ouverture dans le tubage intérieur afin que le premier espace soit accessible ;
insérer une doublure d'obturation(112) et un outil de garniture d'étanchéité annulaire (114) fixé à la doublure d'obturation à un emplacement adjacent à l'ouverture, dans lequel l'outil de garniture d'étanchéité annulaire entoure la doublure d'obturation et comprend un ou plusieurs segments (116) de matériau thermo-déformable sur une surface extérieure de l'outil de garniture d'étanchéité annulaire ;
attacher la doublure d'obturation à une doublure de production (124) ou à une tête de puits du puits pour fixer la doublure d'obturation ;
insérer un dispositif de chauffage (120) dans le puits et positionner le dispositif de chauffage à un emplacement qui est à l'intérieur de la doublure d'obturation et est adjacent à l'outil de garniture d'étanchéité annulaire ;
activer le dispositif de chauffage à une température supérieure à une température d'activation des un ou plusieurs segments de matériau thermo-déformable, en provoquant ainsi la fusion du matériau thermo-déformable, et dans lequel le matériau thermo-déformable fondu s'écoule dans l'ouverture ; et
réduire la température de l'emplacement adjacent à l'outil de garniture d'étanchéité annulaire

- à une température inférieure à la température d'activation du matériau thermo-déformable pour amener le matériau thermo-déformable fondu à se solidifier dans l'ouverture et dans le premier espace. 5
2. Procédé selon la revendication 1, dans lequel l'étape consistant à retirer la partie de tubage intérieur comprend l'utilisation d'un dispositif d'alésage pour créer l'ouverture dans le tubage intérieur et pour rendre le premier espace accessible. 10
 3. Procédé selon la revendication 1, dans lequel l'ouverture comprend une ouverture de forme annulaire (110) qui est formée à travers le tubage intérieur et à travers le premier espace de manière à révéler une surface intérieure du tubage extérieur. 15
 4. Procédé selon la revendication 1, comprenant en outre l'étape consistant à : 20
localiser la fuite dans le tubage en identifiant les positions d'entrée et de sortie de la fuite dans le tubage.
 5. Procédé selon la revendication 4, dans lequel l'étape d'identification des positions d'entrée et de sortie est effectuée par un outil de diagraphie acoustique. 25
 6. Procédé selon la revendication 1, comprenant en outre l'étape consistant à : 30
nettoyer l'ouverture pour éliminer les débris et l'excès de ciment qui provient d'une gaine de ciment (108) qui est disposée à l'intérieur du premier espace.
 7. Procédé selon la revendication 1, dans lequel le tubage intérieur et le tubage extérieur sont séparés par une gaine de ciment (108), dans lequel l'étape consistant à retirer une partie du tubage intérieur comprend en outre un retrait d'une partie adjacente de la gaine de ciment via un sous-élargissement de telle sorte que l'ouverture comprenne une zone à partir de laquelle les parties du tubage intérieur et de la gaine de ciment sont retirées. 35
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 8. Procédé selon la revendication 1, dans lequel le matériau thermo-déformable est un alliage à bas point de fusion. 45
 9. Procédé selon la revendication 8, dans lequel l'alliage à bas point de fusion est un alliage qui comprend du bismuth (Bi) et de l'étain (Sn). 50
 10. Procédé selon la revendication 1, dans lequel l'étape d'insertion du dispositif de chauffage dans le puits comprend les étapes consistant à : 55
abaissier le dispositif de chauffage dans le puits sur une ligne électrique (121), et
- positionner le dispositif de chauffage à un emplacement prédéterminé qui est adjacent à l'outil de garniture d'étanchéité annulaire ; et dans lequel le procédé comprend en outre les étapes consistant à :
désactiver et retirer ensuite le dispositif de chauffage à partir de l'emplacement adjacent à l'outil de garniture d'étanchéité annulaire.
11. Procédé selon la revendication 1, dans lequel l'outil de garniture d'étanchéité annulaire comprend en outre des parties métalliques présentant un point de fusion plus élevé que la température d'activation des segments de matériau thermo-déformable, et dans lequel le dispositif de chauffage chauffe l'emplacement adjacent à l'outil de garniture d'étanchéité annulaire à une température supérieure à la température d'activation des un ou plusieurs segments de matériau thermo-déformable mais inférieure à un point de fusion des parties métalliques.
 12. Procédé selon la revendication 11, dans lequel la chaleur provenant du dispositif de chauffage passe à travers la doublure d'obturation pour chauffer les segments de matériau thermo-déformable qui sont situés radialement à l'extérieur à la fois du dispositif de chauffage et de la doublure d'obturation.
 13. Procédé selon la revendication 11, dans lequel le dispositif de chauffage chauffe l'emplacement adjacent à l'outil de garniture d'étanchéité annulaire à une température d'environ 50°C au-dessus d'une température de service attendue la plus élevée du puits.
 14. Système pour réparer une fuite dans un tubage (102) d'un puits (100), dans lequel le tubage comprend un tubage intérieur (104) et un tubage extérieur (106), le système comprenant :
un élargisseur configuré pour retirer une partie du tubage intérieur au niveau de l'emplacement de la fuite afin de créer une ouverture de forme annulaire (110) dans le tubage intérieur ;
une doublure d'obturation (112) et un outil de garniture d'étanchéité annulaire (114) fixé à la doublure d'obturation, dans lequel la doublure d'obturation est positionnée en un emplacement adjacent à l'ouverture de forme annulaire, et dans lequel l'outil de garniture d'étanchéité annulaire comprend un ou plusieurs segments (116) de matériau thermo-déformable sur sa surface extérieure, et dans lequel la doublure d'obturation est attachée à une garniture de production ou à une tête de puits du puits pour fixer la doublure d'obturation ; et
un dispositif de chauffage (120) configuré pour chauffer le puits au niveau de l'emplacement ad-

jacent à l'outil de garniture d'étanchéité annulaire, à une température supérieure à une température d'activation des un ou plusieurs segments de matériau thermo-déformable.

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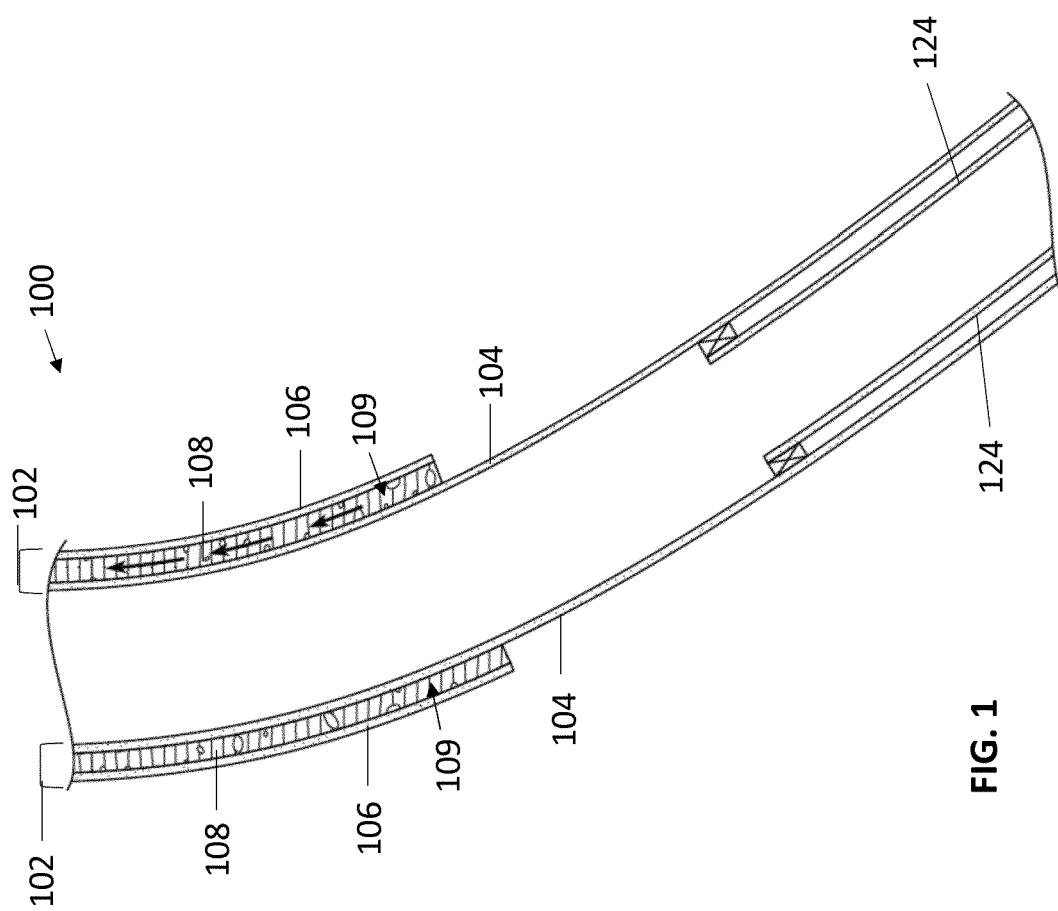
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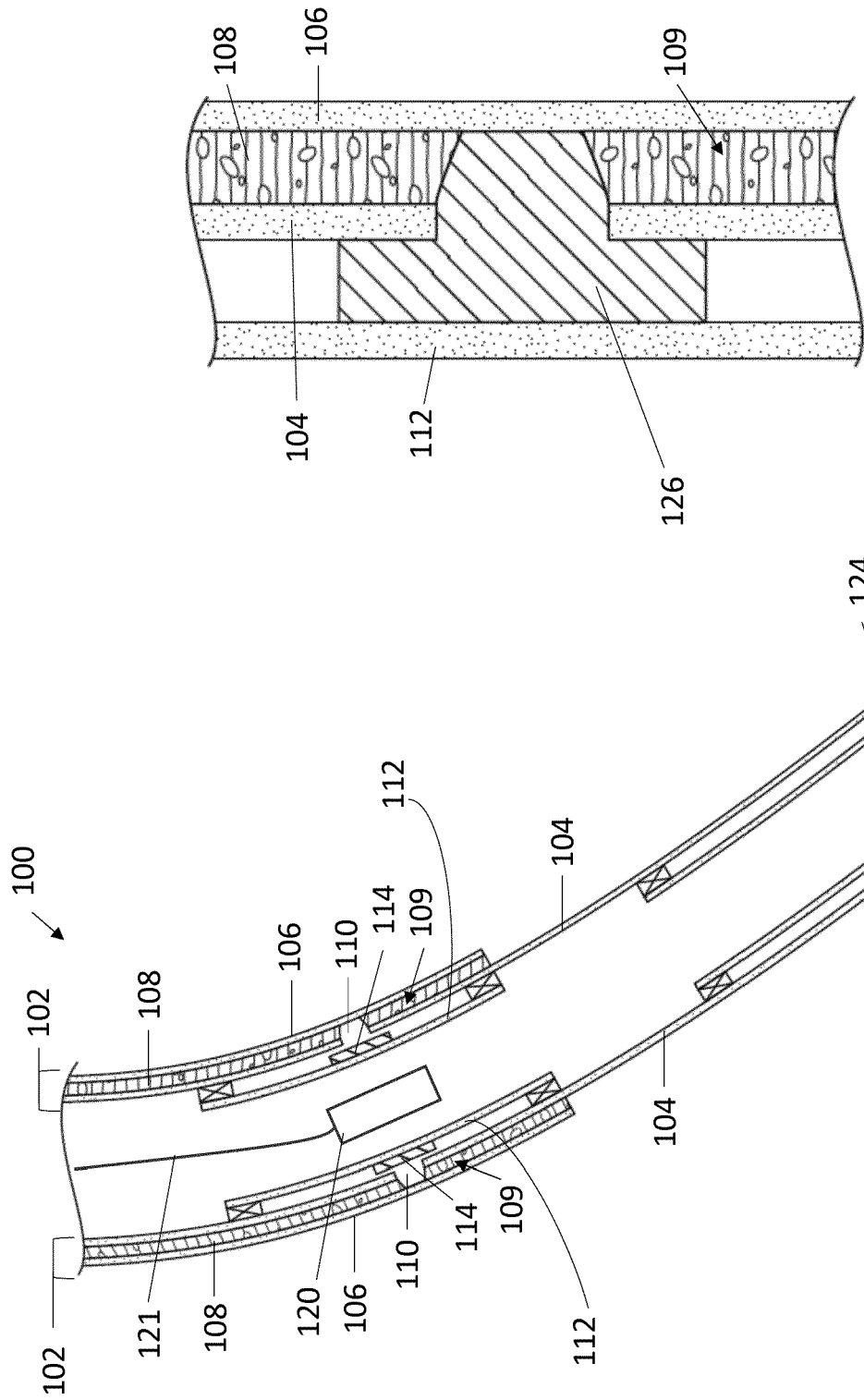


FIG. 2B

FIG. 2A

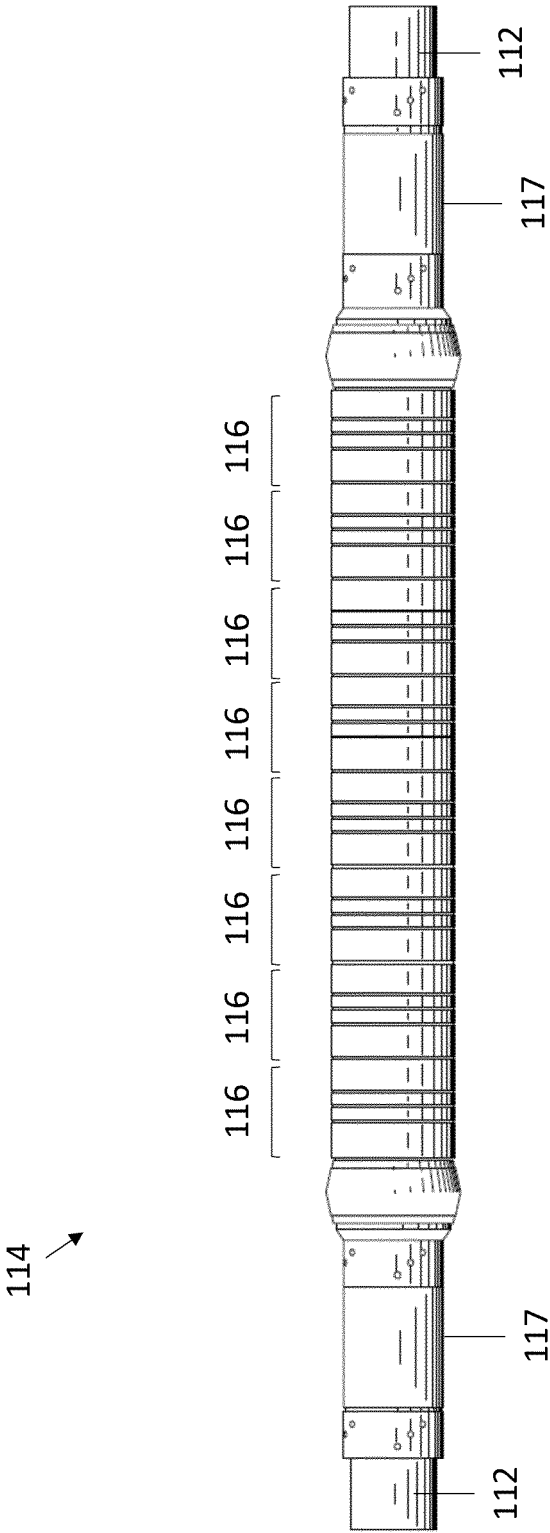


FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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