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(54) Title: A METHOD OF PERFORATING A TUBULAR, A TUBULAR AND A TOOL THEREFOR

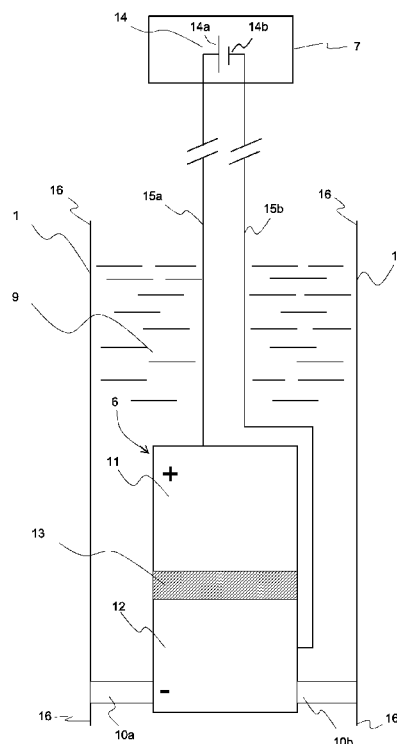


Figure 6

(57) Abstract: A method of perforating a tubular (1) located in production zone of a well (4), wherein the tubular (1) comprises a first material and a second material, wherein the first material is more resistant to corrosion than the second material, the method comprising applying an electric current to the tubular (1) in the presence of an electrolyte, whereby at least some of the second material is removed by a corrosion process to leave a structurally intact but perforated tubular. The tool (6) is configured to cause an electrical current to flow through the tubular (1) through an electrode (12) of the tool in contact with the tubular in the presence of an electrolyte (9).



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A METHOD OF PERFORATING A TUBULAR, A TUBULAR AND A TOOL THEREFOR

Technical Field

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The present invention relates to the field of hydrocarbon production, and specifically to the perforation of tubulars in wells for use, e.g. in hydrocarbon production or injection of gas/water. These tubulars may be, for example, liners or screens.

10 Background

When drilling a well in order to produce hydrocarbons, when the drilling has reached a predetermined depth, a tubular, typically made from steel, is lowered into the well. The term tubular is a generic term for a pipe used in the oil and gas industry. The tubular
15 may be a liner or a screen, for example. Cement is pumped down the tubular so that it flows back up and sets within an annulus between the tubular and the surrounding formation. The tubular is held in place at the top of the well and, together with the cement, provides structural support for the well. The drilling continues, and after a further depth has been reached, a further tubular is run down the well and the
20 cementing operation repeated. The top of the further tubular is anchored to the bottom of the first tubular. In this way, the tubulars are consecutively built up as the depth of the well increases.

Once the well has reached the desired depth, the completion stage can begin. During
25 this stage, a further tubular such as a liner, slotted liner or screen is run down hole and positioned over an interval of interest, i.e. a section of the formation containing hydrocarbons. Typically, in the case of a "solid" liner, the liner is run downhole and set over the interval of interest. The liner is then perforated while it is in the wellbore using, for example, a perforating gun. This is done while the well remains sealed at the
30 surface in order to prevent the escape of hydrocarbons.

Following perforation, the perforating tools, e.g. perforating gun, are removed from the well. Production tubing is then run from the top of the well to a location above the perforated liner. The production tubing is sealed against the surrounding tubular using
35 a packer. Valves at the surface can then be opened and production started.

The use of some explosive procedure, such as that involving a perforating gun, presents a health and safety risk that must be carefully managed. Handling explosives at the surface can be dangerous, and the technology can often fail at depth, either by not detonating at all or by accidentally going off in the wrong place. It can also be a challenge to achieve the correct placement of the explosive device downhole.

A perforated liner, such as a slotted liner for example, may be used instead of using a "solid" liner and associated perforation operation. A perforated liner has integral holes or slots pre-formed through the surface of the liner. This has the advantage that no perforation step using explosives needs to be carried out once the slotted liner is positioned downhole. It is often necessary to rotate the liner while running, for example, when running the liner while drilling, or where it is required to manipulate the liner to avoid obstructions and blockages. Since a perforated liner has less structural integrity than a "solid" liner, such rotation may be difficult in certain circumstances or under certain conditions.

Furthermore, in the case of a perforated or slotted liner, fluid circulation from the surface to the bottom of the well is not possible unless an additional inner string is run through the slotted liner, since the circulating fluid would permeate through the slots. Using an additional inner string increases the complexity and cost of the well completion process, and so can be undesirable. Circulation is desirable in order to move the slotted liner past obstructions in the well.

Liners comprising mesh screens may be used instead of *in situ* perforated liners and slotted liners, but have the same disadvantages as slotted liners. The screens act as a sieve, allowing hydrocarbons to flow into the liner while preventing sand from entering the liner. Due to their mesh like structure, screens have a low structural integrity and so cannot be rotated while running.

A non-ballistic tubular perforating system and method is disclosed in WO-A-2013109408, which comprises positioning a tubular having degradable plugs plugging perforations therein within a borehole; cementing an annular space between the tubular and the borehole with cement; exposing the degradable plugs to a first environment that dissolves the degradable plugs; dissolving the degradable plugs; exposing the

cement radially of the perforations to a second environment that dissolves or increases porosity of the cement; and opening an inside of the tubular to fluid communication with the borehole through the perforations and openings or porous channels dissolved in the cement. The dissolvable or degradable material is disclosed as one described in

5 US-A-2011135953, which discloses metallic powders comprising a plurality of metallic powder particles. Each powder particle includes a particle core. The particle core includes a core material comprising Mg, Al, Zn or Mn, or a combination thereof, having a melting temperature (T_p). Each powder particle also includes a metallic coating layer disposed on the particle core. The metallic coating layer includes a metallic coating

10 material having a melting temperature (T_C). The powder particles are configured for solid-state sintering to one another at a predetermined sintering temperature (T_S), and T_S is less than T_P and T_C . These powder compacts are made from coated metallic powders that include various electrochemically-active (e.g., having relatively higher standard oxidation potentials) lightweight, high-strength particle cores and core

15 materials, such as electrochemically active metals, that are dispersed within a cellular nanomatrix formed from the various nanoscale metallic coating layers of metallic coating materials, and are particularly useful in wellbore applications. These powder compacts provide a unique and advantageous combination of mechanical strength properties, such as compression and shear strength, low density and selectable and

20 controllable corrosion properties, particularly rapid and controlled dissolution in various wellbore fluids. These powders and powder compact materials may be configured to provide a selectable and controllable degradation or disposal in response to a change in an environmental condition, such as a transition from a very low dissolution rate to a very rapid dissolution rate in response to a change in a property or condition of a

25 wellbore proximate an article formed from the compact, including a property change in a wellbore fluid that is in contact with the powder compact. The selectable and controllable degradation or disposal characteristics described also allow the dimensional stability and strength of articles, such as wellbore tools or other components, made from these materials to be maintained until they are no longer

30 needed, at which time a predetermined environmental condition, such as a wellbore condition, including wellbore fluid temperature, pressure or pH value, may be changed to promote their removal by rapid dissolution. Alternatively, WO-A-2013109408, discloses the use of calcium carbonate, or a polymer as the dissolvable or degradable material.

The technique used in WO-A-2013109408 requires very specific plug materials that are sensitive to a particular condition, in particular, the disclosed conditions are temperature, pressure, pH value, flow rate and wellbore fluid composition. That is the plug material composition is specifically selected to react to a particular change in conditions.

SUMMARY

The invention provides in a first aspect a method of perforating a tubular located in production zone of a well, wherein the tubular comprises a first material and a second material, wherein the first material is more resistant to corrosion than the second material, the method comprising applying an electric current to the tubular in the presence of an electrolyte, whereby at least some of the second material is removed by a corrosion process to leave a structurally intact but perforated tubular.

The first material may comprise a first metal and the second material may comprise a second metal. The first metal may be in electrical contact with the second metal.

The step of applying an electric current may comprise placing a current supplying tool in physical contact with the tubular and causing a current to flow through the tubular. A negative electrode of the current supplying tool may be brought into physical contact with the tubular and wherein a positive electrode of the current supplying tool is exposed to an electrolyte, such that a current may flow between the electrodes through the tubular, the patches and electrolyte.

The method may further comprise the step of galvanically isolating sections of tubular from each other.

In a second aspect the invention provides a current supplying tool configured to be run downhole into a well, to a position adjacent a tubular fixed in the well, the tool being configured to cause an electrical current to flow through the tubular through an electrode of the tool in contact with the tubular in the presence of an electrolyte.

The current supplying tool may comprise a positive electrode and a negative electrode, wherein the negative electrode is arranged to make contact with said tubular. The positive electrode may be arranged to be exposed to well fluid, wherein the well fluid acts as an electrolyte.

The current supplying tool may further comprise one or more extendable arms which are arranged to connect with an inner surface of the tubular, clamping the

current supplying tool in place. One or more extendable arms may comprise the negative electrode of the tool.

The current supplying tool may be coupled to a power source which is configured to provide the electrical current.

5 The current supplying tool may comprise the power source.

10 In a third aspect the invention provides a tubular for use in a well, the tubular having a wall comprising a first material, the wall defining at least one opening patched by a second material, wherein the first and second materials are selected such that the first material is more resistant to corrosion than the second material, the materials being selected such that the second material can be at least partially removed by a corrosion inducing process including applying an electric current to the tubular in the presence of an electrolyte, to leave a structurally intact but perforated tubular.

15 The first material may comprise a first metal, and the second material may comprise a second metal. The first metal may be in electrical contact with the second metal.

The tubular may be any one of a liner or a screen.

The electric current may be provided to the tubular by a negative electrode and a positive electrode, the negative electrode being brought into contact with the tubular and the positive electrode being placed in the electrolyte.

20 In the absence of an electric current the rate of dissolution of the second material may be substantially unaffected by changes in any one or more of temperature, pressure, pH value, flow rate and wellbore fluid composition.

BRIEF DESCRIPTION OF DRAWINGS

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Figure 1 shows a perforated tubular in accordance with an embodiment

Figure 2 shows the tubular of figure 1 having patched openings

Figure 3 shows a tubular in accordance with a variation of the embodiment of Figure 1

Figure 4 shows the tubular of figure 3 having patched openings

30 Figure 5 shows an electrical tool and a tubular each in accordance with the invention in use in a well bore

Figure 6 shows a tool according to the invention in more detail

Figure 7 shows hydrocarbons flowing through a perforated tubular formed in accordance with the present invention.

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DETAILED DESCRIPTION

By providing a tubular having a wall defining at least one opening patched by a material such that the material of the tubular wall is more resistant to corrosion than the patching material, it is possible to remove patching material from the at least one openings by a corrosion inducing process including providing an electric current in the presence of an electrolyte to leave a structurally intact but perforated tubular. An electric current can be applied by current supplying tool configured to be run downhole into a well, to a position adjacent a tubular fixed in the well and being configured to cause an electrical current to flow through the tubular. By isolating sections of a tubular or isolating connected tubulars from each other, zonal control of the perforation process is possible.

The tubular of the invention includes a patch or patches that serve to plug perforations in the tubular wall and, in one embodiment, do not substantially corrode in the presence of, for example a well fluid, in the absence of an electric current, which may be supplied with the tool according to the invention.

With reference to the Figures, there will now be described an improved liner for use in a hydrocarbon producing well. The liner may also be used in so-called "injection" wells in which fluid is injected into, rather than extracted from, a formation. The liner may be used in both onshore and offshore wells. The liner utilises galvanic corrosion in order to create perforations in the liner and through which hydrocarbons or other fluids can flow. Galvanic corrosion occurs when two different metals are brought into electrical contact with each other in the presence of an electrolyte. The less corrosive resistant metal will act as an anode and corrode preferentially to the more corrosion resistant metal (sometimes known as a noble metal), which will act as a cathode. This process can be accelerated by use of an external electric current.

Figure 1 shows a metal liner as an example of a tubular 1 according to a first embodiment of the invention. Such liners are normally predominantly made of steel. The liner comprises a plurality of perforations or openings 2 (although these may take the form of slots or other suitable passages). The frequency, size and placement of the holes can vary depending on the application. Referring to Figure 2, the openings 2 are blocked with respective plugs or patches 3 comprising a metal that is less noble

than the metal of the liner, e.g. steel (i.e. less corrosion resistant than the metal of the liner), such as iron, nickel, copper or aluminium. The metal chosen for the patch 3 will be application dependent. In some applications you might want something that corrodes very slowly and need electrical current applied to corrode as this would
5 enable some of the patches to be left in place for later removal. Or when wanting to remove every patch shortly after having run to total depth (TD), a metal that corrodes quickly might be used.

Alternatively or additionally, the patch material may be welded onto the surface of the
10 liner 1, so as to cover one or more holes 2. For example, Figures 3 and 4 indicate a metal screen 1 having openings 2 in the form of slots. The slots can be patched by a single cladding layer 3 (Figure 4) that patches the slots to provide an apparently solid liner. Of individual patches could be applied, but it is efficient to clad the screen in a single step to patch all of the openings.

15 In use, the liner 1 of Figures 1 and 2 is run down a well 4 and placed in an area containing hydrocarbons 5 (i.e. a reservoir), as shown in Figure 5. The liner is sealed in place using, for example, one or more packers (not shown). The hydrocarbons in the reservoir 5 cannot permeate through the liner 1 as the patches 3 block the holes 2
20 in the liner 1. In order to unblock the liner 1, an electric current is provided which promotes or accelerates corrosion of the patches. This current may be provided by any possible means. In an embodiment, an electrical tool 6 and an electrolyte 9 (see figure 6) are used to cause corrosion of the patches 3 using galvanic corrosion. The liner 1 is filled with the electrolyte 9, which may be, for example, salt water, drilling fluid,
25 or completion fluid. The electrical tool 6 is run into the liner 1 from the surface 7 of the well 4 via a connecting cable 8, as shown in Figure 5. Once located within the liner 1, the electrical tool 6 clamps itself to the liner 1. In the embodiment shown in Figure 6, a pair extendable arms 10a, 10b extend from the electrical tool 6 and contact the inner surface of the liner 1. Any suitable number of extendable arms may be used.
30 Alternative methods for holding the electrical tool 6 in place relative to the liner 1 may be used, such as using spring loaded extensions.

The electrical tool 6 has a positive electrode 11 which is exposed to the electrolyte 9, and a negative electrode 12 which is arranged to make electrical contact with the liner
35 1. In the embodiment shown in Figure 6, the negative electrode 12 is brought into

contact with liner 1 via the anchors 10a, 10b, which effectively makes the liner 1 the negative electrode. The negative electrode 12 is connected to the electrolyte via the liner 1 and the patches 3 (shown in figures 4 and 5). The positive and negative electrodes of the electric tool are isolated from one another by an insulator 13

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Figure 6 shows a power source 14 located at the surface 7. Lines 15a and 15b schematically depict that a positive terminal 14a of the power source is in electrical contact with the positive electrode 11, and a negative terminal 14b of the power source 14 is in electrical contact with the negative electrode 12. In practice, cables for transporting current from the power source 14 to the tool 6 may be contained within the connecting cable 8 (which is not shown in Figure 6). In an alternative embodiment, the power source may be integrated within the electrical tool 6, where the power source may be a battery, for example.

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The liner 1 may be galvanically isolated from further apparatuses, such as the drill string or further tubulars. The liner may consist of several sections galvanically isolated from each other so that respective sections may have patches corroded away individually. Galvanic isolation may be provided by electrical insulators 16 located at threaded connections (not shown) of the liner 1. Insulators might also be placed at intervals inside the liner; this would enable patches to be corroded within specific intervals without corrosion occurring in the rest of the liner. This might be beneficial for zonal control of production, whereby sections of the tubular that are opened can be selected.

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When electrical power is supplied to the electrodes 11, 12, the patches 3 undergo accelerated corrosion. The half reaction at the patches 3 may be described by the chemical reaction $\text{Me} \rightarrow \text{Me}^+ + \text{e}^-$, where Me is the reduced species of the patch 3 and Me^+ is an oxidized species. The half reaction at the positive electrode 11 may be described by $\text{H}^+ + \text{e}^- \rightarrow \frac{1}{2} \text{H}_2$.

25

Having used the electrical current to dissolve the patches, the electrical tool 6 is pulled out of the well 4. Corrosion of the patches results in a perforated liner 1 which allows hydrocarbons to flow (arrow 17 in figure 7) from the reservoir 5 into the liner 1, as seen in Figure 5. For simplicity, only one arrow 17 shows hydrocarbons flowing into the liner via a hole 3.

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While discussed in terms of a liner, the above can also apply to a screen, for example as shown in Figures 3 and 4. Screens are used to help prevent sand or dirt flowing into the liner and can be arranged around the outer surface of a liner. In such an embodiment, a mesh of the screen would comprise the more noble metal (i.e. more corrosive resistant metal), and a less noble metal (i.e. less corrosive resistant metal) would be arranged so as to "plug" the mesh, preventing hydrocarbons from flowing through the mesh until the less noble metal has been removed.

10 In a further embodiment, a patch for use in the liner 1 may comprise a mesh structure so as to act as a screen. The mesh structure would comprise a more noble metal (i.e. more corrosive resistant metal), and a less noble metal (i.e. less corrosive resistant metal) would be arranged so as to "plug" the mesh of the patch. The less corrosive resistant metal covering the mesh provides a greater structural integrity to the liner 1, allowing rotation of the liner while running. Furthermore, it is also possible to circulate fluid through the liner.

Advantageously, the tubular of the invention acts as a "solid" tubular when being run downhole. For example, when the liner 1 of figures 1 and 2 is being run into the well, it is possible to carry out fluid circulation without the need for an inner string. By being able to circulate through the liner while running, it is possible to wash through any restriction that are encountered downhole and thereby better ensure that the liner is able to be run to total depth and can be placed at a planned interval. Furthermore, the patches 3 provide additional structural support to the liner 1, meaning that the liner 1 has a greater structural integrity than a traditional slotted liner or screen. This makes it possible to rotate the liner 1 while running into the well, or drilling, meaning that the liner 1 can be used in combination with existing liner drilling technology.

A further advantage of the tubular of the invention is that it provides the ability to selectively decide which intervals to erode after the liner 1 is put in place, in a more controlled way than is possible using explosives. As the corrosion is controlled through use of the electrical tool, selected intervals can be perforated while some patches can be left intact, depending on the conditions downhole. Furthermore, there is a reduced health and safety risk as no explosive devices are required in order to perforate a "solid" liner. This zonal control of the perforation process can be achieved by

electrically isolating the connections between tubulars or otherwise isolating sections of a single tubular. For example, a non-conductive material can be added to the treads between tubulars, or two conductive tubulars can be separated by a non-conductive tubular or short connecting piece. The reservoir sections may be isolated from each other by use of swelling packers as is known.

Embodiments provide a robust solution for enabling differential pressure integrity over the liner when drilling or working the liner to total depth. A further advantage of the embodiments described is that it is possible to use the tubular for drilling in combination with the steerable drilling liner technology. Perforations can be created in the tubular at selected intervals after the liner has been placed at the selected depth.

It will be appreciated by the person of skill in the art that various modifications may be made to the above described embodiments without departing from the scope of the present invention. For example, the electrical tool may be incorporated into a part of the drill sting. Furthermore, while the tubular is described as being made of steel, it will be appreciated that the liner can comprise any suitable metal having a higher resistance to corrosion than the metal used for patching the openings or perforations. Furthermore, while several separate embodiments have been described, the skilled person will recognise that features of these embodiments may be combined.

CLAIMS:

1. A method of perforating a tubular located in production zone of a well, wherein the tubular comprises a first material and a second material, wherein the first material is more resistant to corrosion than the second material, the method comprising applying an electric current to the tubular in the presence of an electrolyte, whereby at least some of the second material is removed by a corrosion process to leave a structurally intact but perforated tubular.
2. A method according to claim 1, wherein the first material comprises a first metal and the second material comprises a second metal.
3. A method according to claim 2, wherein the first metal is in electrical contact with the second metal.
4. A method according to any one preceding claim, wherein the step of applying an electric current comprises placing a current supplying tool in physical contact with the tubular and causing a current to flow through the tubular.
5. A method according to claim 4, wherein a negative electrode of the current supplying tool is brought into physical contact with the tubular and wherein a positive electrode of the current supplying tool is exposed to an electrolyte, such that a current may flow between the electrodes through the tubular, the patches and electrolyte.
6. A method according to any one preceding claim, further comprising the step of galvanically isolating sections of tubular from each other.
7. A current supplying tool configured to be run downhole into a well, to a position adjacent a tubular fixed in the well, the tool being configured to cause an electrical current to flow through the tubular through an electrode of the tool in contact with the tubular in the presence of an electrolyte.
8. A current supplying tool according to claim 7, comprising a positive electrode and a negative electrode, wherein the negative electrode is arranged to make contact with said tubular.

9. A current supplying tool according to claim 8, wherein the positive electrode is arranged to be exposed to well fluid, wherein the well fluid acts as an electrolyte.
- 5 10. A current supplying tool according to claim 7, 8, or 9, further comprising one or more extendable arms which are arranged to connect with an inner surface of the tubular, clamping the current supplying tool in place.
- 10 11. A current supplying tool according to claim 10, wherein the one or more extendable arms comprise the negative electrode of the tool.
12. A current supplying tool according to any one of claims 7 to 11, wherein the current supplying tool is coupled to a power source which is configured to provide the electrical current.
- 15 13. A current supplying tool according to any one of claims 7 to 11, wherein the current supplying tool comprises the power source.
- 20 14. A tubular for use in a well, the tubular having a wall comprising a first material, the wall defining at least one opening patched by a second material, wherein the first and second materials are selected such that the first material is more resistant to corrosion than the second material, the materials being selected such that the second material can be at least partially removed by a corrosion inducing process including applying an electric current to the tubular in the presence of an electrolyte, to leave a
- 25 structurally intact but perforated tubular.
15. A tubular according to claim 14, wherein the first material comprises a first metal, and the second material comprises a second metal.
- 30 16. A tubular according to claim 15, wherein the first metal is in electrical contact with the second metal.
17. A tubular according to any one of claims 14 to 16, wherein the tubular is any one of a liner or a screen.

18. A tubular according to any one of claims 14 to 17, wherein the electric current is provided to the tubular by a negative electrode and a positive electrode, the negative electrode being brought into contact with the tubular and the positive electrode being placed in the electrolyte.

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19. A tubular as claimed in any one of claim 14 to 18, wherein in the absence of an electric current the rate of dissolution of the second material is substantially unaffected by changes in any one or more of temperature, pressure, pH value, flow rate and wellbore fluid composition.

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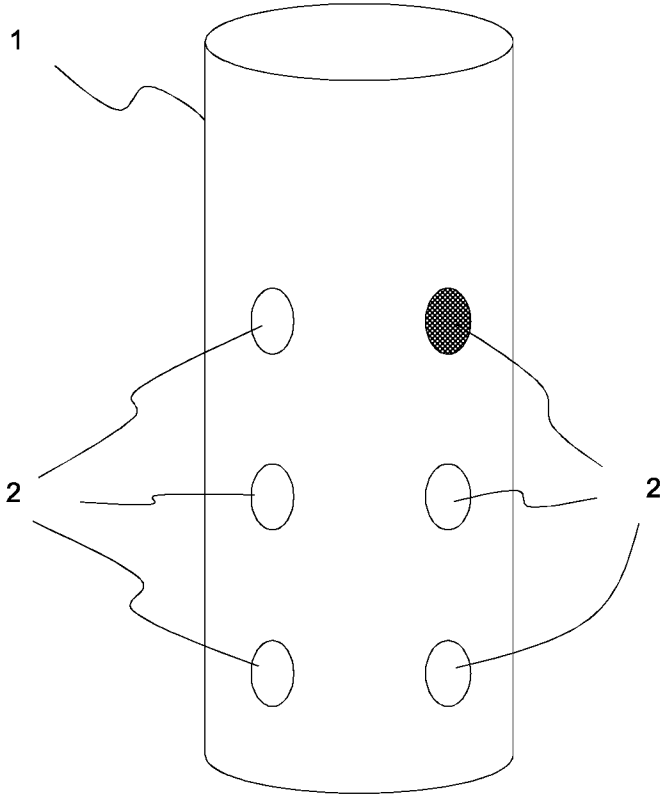


Figure 1

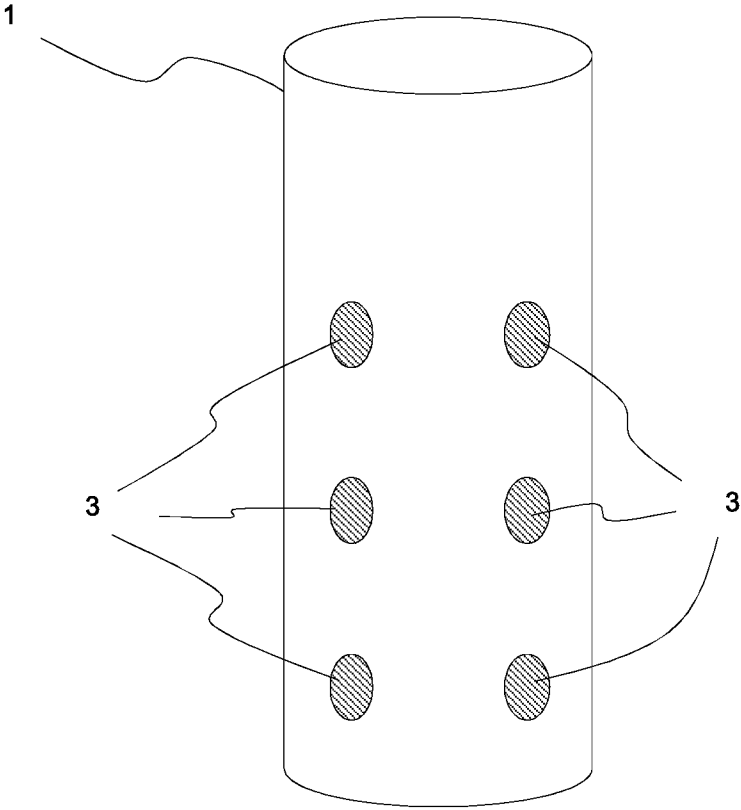


Figure 2

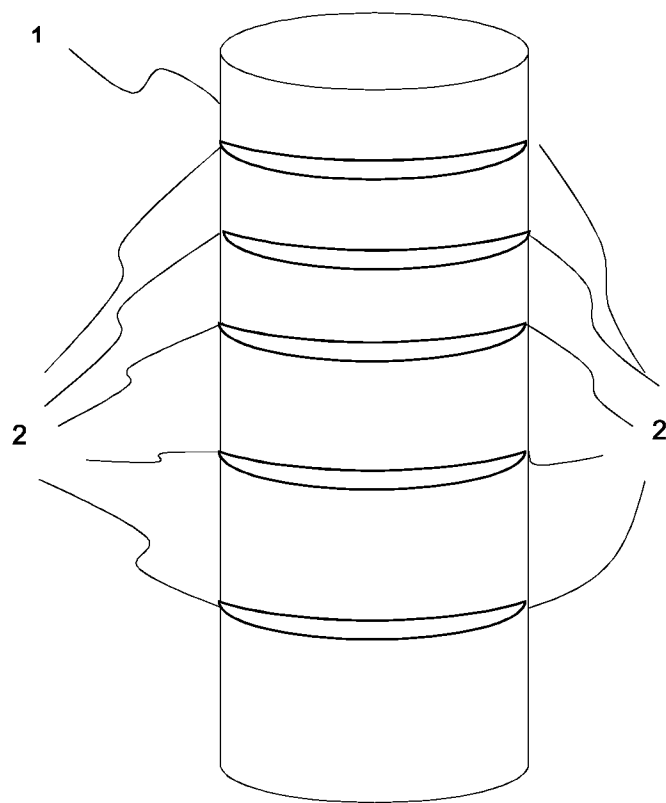


Figure 3

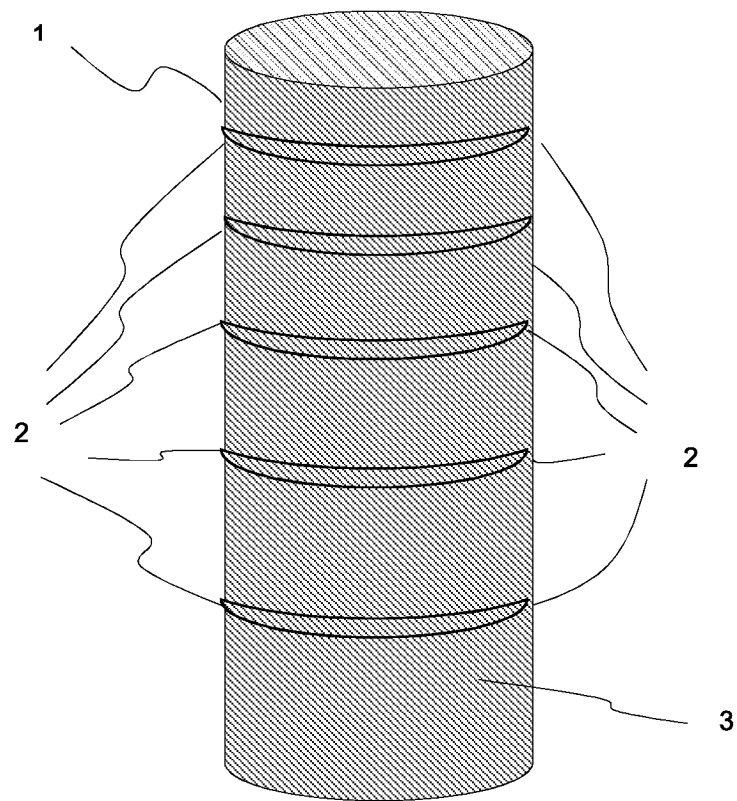


Figure 4

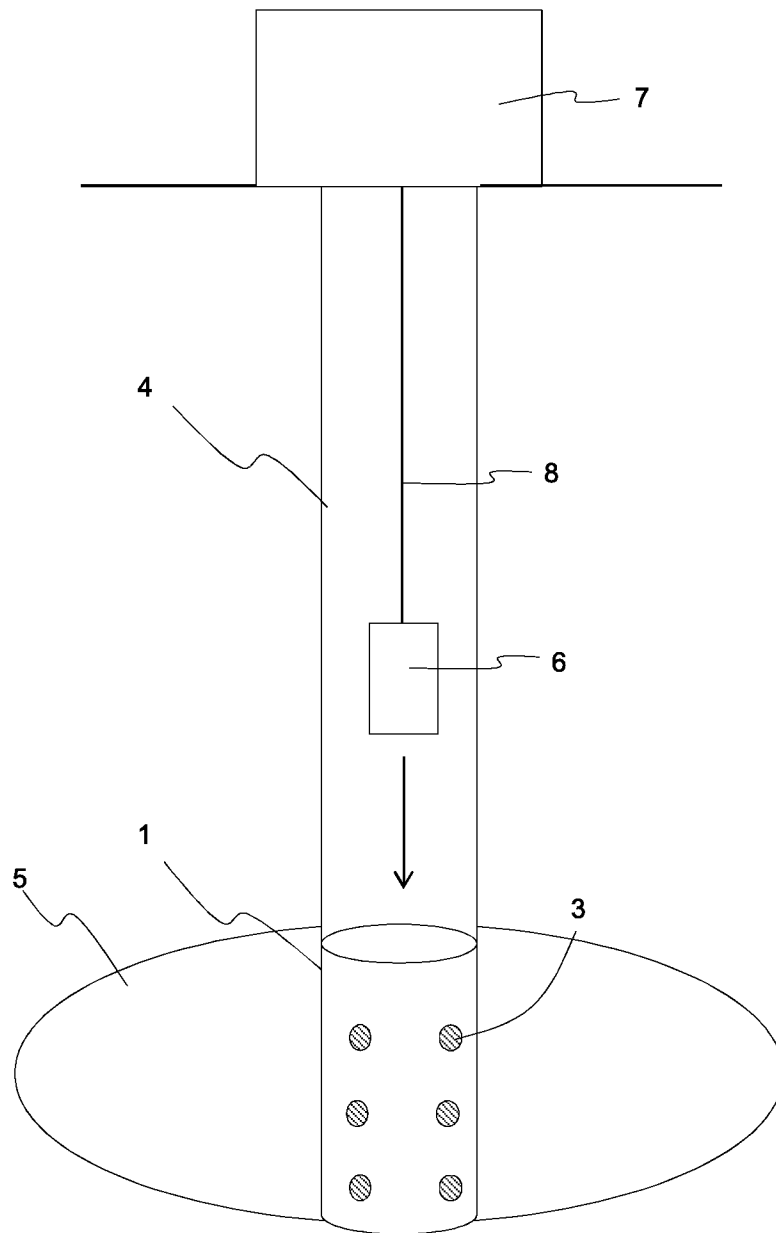


Figure 5

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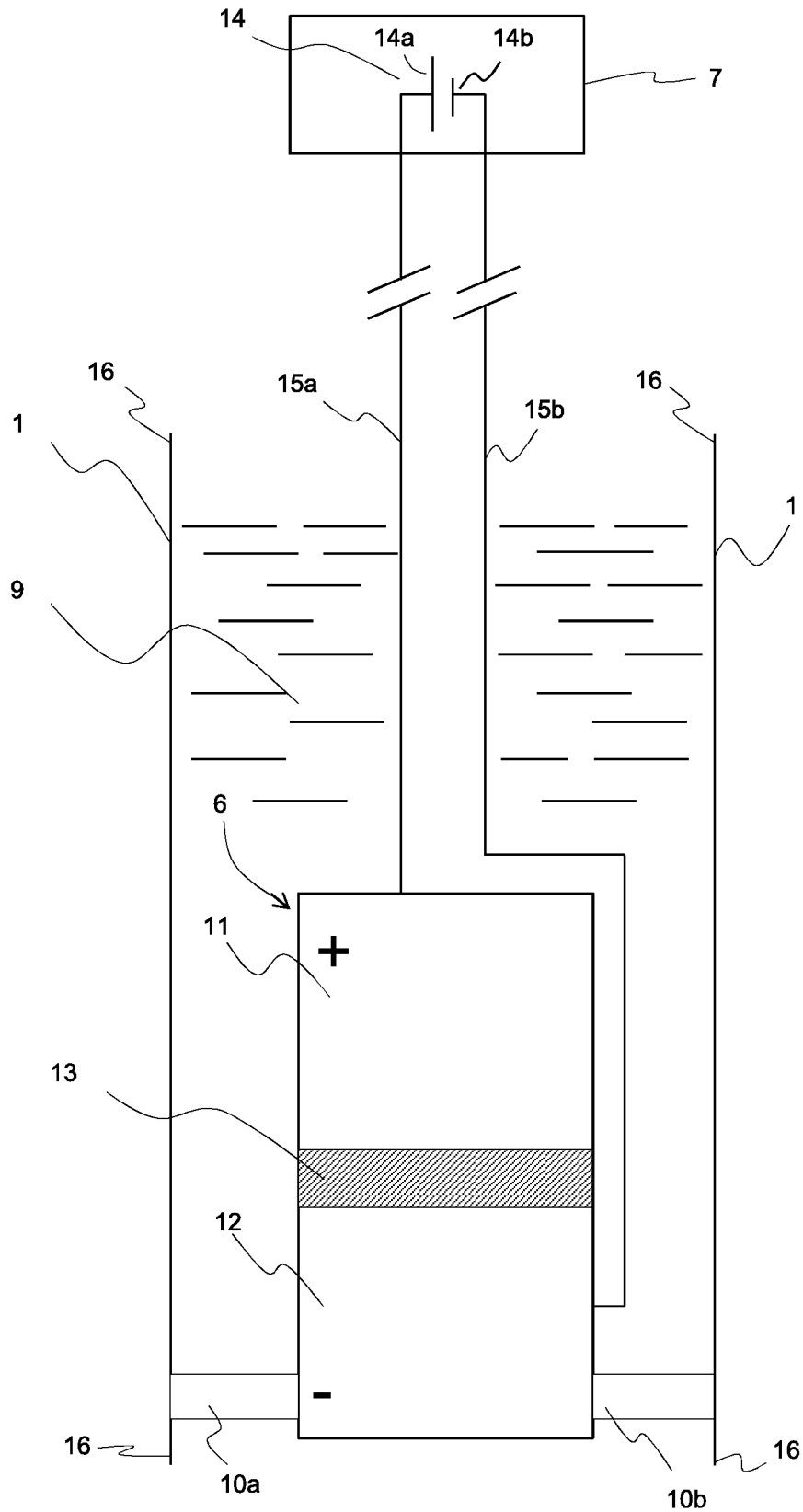


Figure 6

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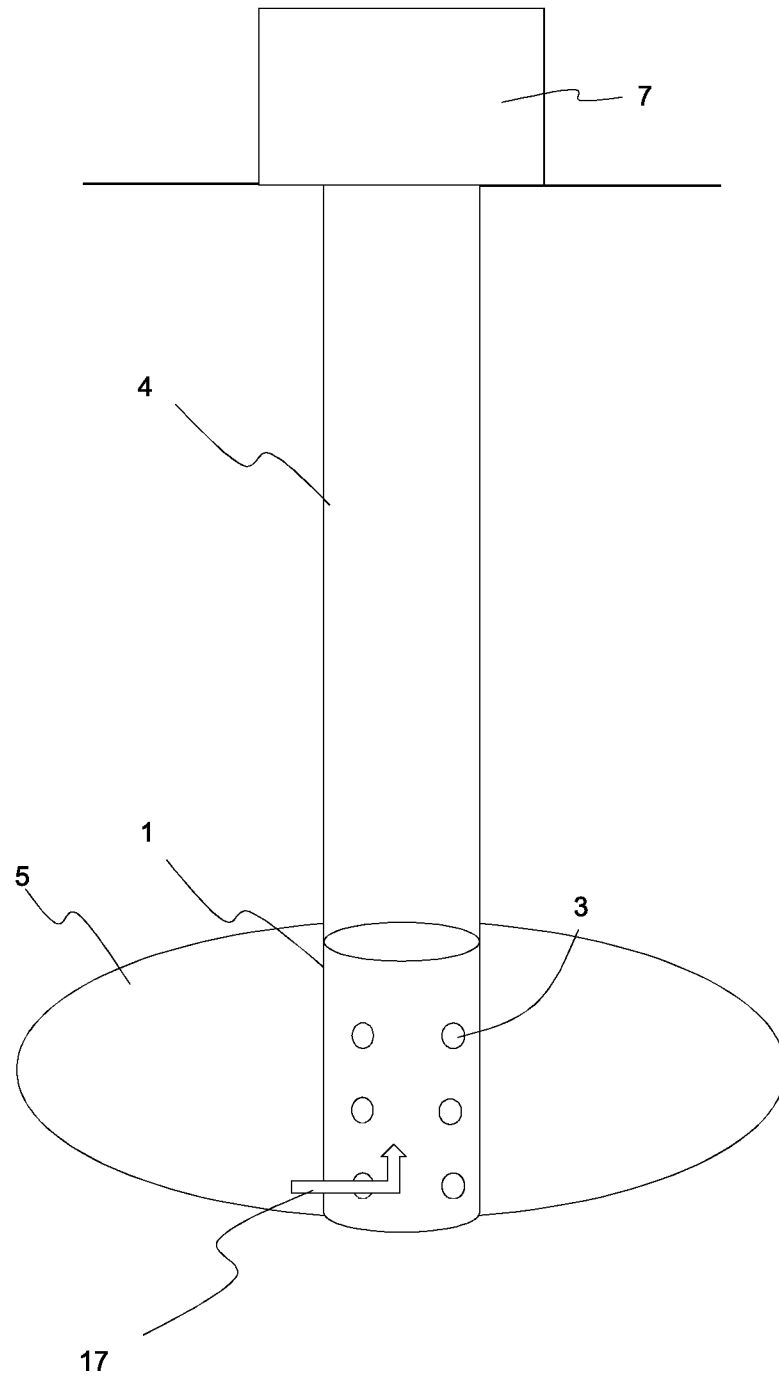


Figure 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2016/050061

A. CLASSIFICATION OF SUBJECT MATTER E21B 43/11 (2006.01), E21B 43/08 (2006.01) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: E21B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched DK, NO, SE, FI: Classes as above. Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC, WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0135249 A1 (FRIPP, M. L. et al.), 2008.06.12, paragraphs [0024] to [0031] and [0071] to [0075].	1-19
A	US 2013/0081814 A1 (GAUDETTE, S. L. et al.), 2013.04.04, paragraph [0014].	1-19
A	US 4157732 A (FONNER, F. A. et al.), 1979.06.12, column 5 lines 47 to 66.	1-19
A	US 5355956 A (RESTARICK, H. L.), 1994.10.18, column 5 line 49 to column 6 line 2.	1-19
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 26/07/2016		Date of mailing of the international search report 29/07/2016
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. + 45 43 50 80 08		Authorized officer Løvås, Bjørn Telephone No. +47 22 38 75 30

INTERNATIONAL SEARCH REPORT

Information on patent family members

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