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(54) **Downhole tool**

(57) The present invention relates to a downhole tool for performing an operation in an acid-containing well, comprising a tool housing of a first metal, a sacrificial anode made of a second metal and arranged in connection with the tool housing, the second metal having a more negative electrochemical potential than the first metal. Furthermore, the present invention relates to a downhole system comprising a downhole tool according to the invention and to a downhole operation method for operating the downhole tool according to the invention, comprising the steps of connecting an anode with the tool housing, submerging the tool into the well for performing an operation downhole, retracting the downhole tool from the well, replacing the sacrificial anode, and submerging the downhole tool for performing another operation in the same well or another well.

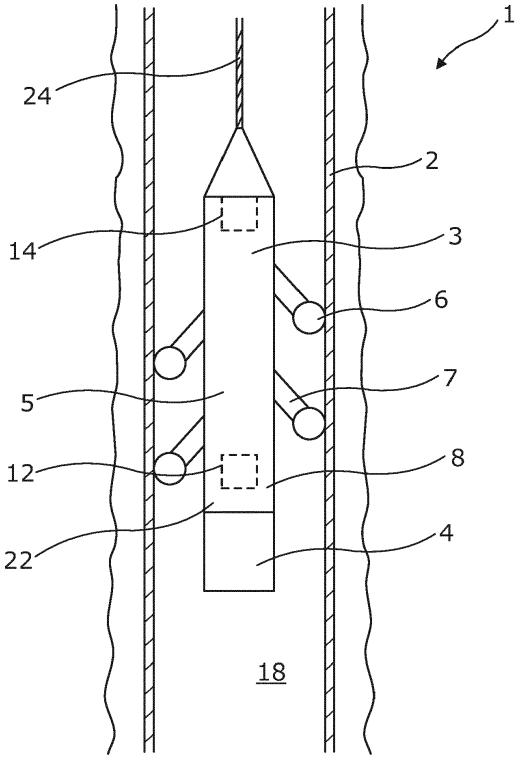

Fig. 1

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Description

Field of the invention

[0001] The present invention relates to a downhole tool for performing an operation in an acid-containing well. Furthermore, the present invention relates to a downhole system comprising a downhole tool according to the invention and to a downhole operation method for operating the downhole tool according to the invention.

Background art

[0002] Operations in a well are performed by means of different kinds of tools, and in some cases the well contains acid which complicates the operation since the acid environment is too harsh for the downhole tools used in performing the operations. Thus, operations in wells containing acid have to be performed after the well is flushed and the acid concentration has been brought down or tools have been entered for performing the operation. This flushing process is time-consuming and in some wells even impossible because circulation of fluid is not possible.

[0003] Another way is to use coiled tubing. However, transportation of coiled tubing equipment normally takes approximately 14 days which results in the well being prevented from producing in the meantime.

Summary of the invention

[0004] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved downhole system capable of performing the operation without using the coiled tubing equipment for performing operations in closed acid-containing wells.

[0005] The above objects, together with numerous other objects, advantages, and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a downhole tool for performing an operation in an acid-containing well, comprising:

- a tool housing of a first metal, and
- a sacrificial anode made of a second metal and arranged in connection with the tool housing, the second metal having a more negative electrochemical potential than the first metal.

[0006] When entering an acid-containing well with a downhole tool, the acid erodes the metal tool housing to such an extent that the downhole tool cannot be reused for another operation and is often simply discarded. Downhole tools are made as reusable tools since the operations often require a significant amount of force, and the downhole tools thus have a robust design and are made of robust materials, such as stainless steel, and they are therefore quite expensive to manufacture. However, operations requiring this kind of force and thus robust tools may still need to be performed in wells containing aggressive acids, and by arranging a sacrificial anode in connection with the tool housing, such operations in acid environment may be performed without having to compromise the tool itself.

[0007] In one embodiment, the tool may be a driving tool which is self-propelling.

[0008] In another embodiment, the tool may be a wireline tool.

[0009] Also, the well may be a cased well or an open-hole well.

[0010] Moreover, the tool may comprise a driving tool which is self-propelling.

[0011] Further, the driving tool may comprise wheels, each wheel being arranged on a wheel arm and being projectable from the tool housing.

[0012] In an embodiment, the sacrificial anode may be arranged in a first end or a second end of the tool housing.

[0013] Said anode may be threadingly connected with one of the ends of the housing.

[0014] The downhole tool may comprise several tool parts 1a, 1b and the anode may be arranged between two tool parts.

[0015] Furthermore, the sacrificial anode may be an elongated element and may be arranged on an outer face of the tool housing.

[0016] Also, the anode may be shaped as a rod.

[0017] In an embodiment, the sacrificial anode may be arranged in a groove in the tool housing.

[0018] Moreover, the anode may be shaped as a mesh surrounding at least part of the tool housing.

[0019] The first metal may be stainless steel.

[0020] The second metal may comprise chrome, magnesium, bismuth, zinc, aluminium, molybdenum, cobalt, copper, or a combination thereof.

[0021] Furthermore, the second metal may comprise additives or other constituents.

[0022] In an embodiment, the first metal may have an electrical potential between -0.32 and -0.40 V.

[0023] Also, the second metal may have an electrical potential between -0.82 and -0.60 V.

[0024] Further, the second metal may have an electrical potential which is at least -0.3 V lower than that of the first metal, preferably at least -0,40 V lower than that of the first metal, more preferably at least -0.5 V lower than that of the first metal.

[0025] Additionally, the anode may be replaceably arranged in connection with the tool housing.

[0026] Several anodes may be connected with each other.

[0027] The downhole tool as described above may further comprise a compartment, such as a magazine or cassette, of a plurality of anodes.

[0028] Said compartment may comprise anodes of various metals.

[0029] Additionally, the downhole tool as described above may further comprise an erosion detection sensor for detection of erosion of the first metal of the tool housing.

[0030] Moreover, the downhole tool as described above may comprise a communication unit for receiving information from the sensor for detection of erosion of the first metal and communicating the information to surface.

[0031] The sensor and the communication unit enable retraction of the downhole tool before the downhole tool is eroded to an extent that it cannot be reused. The sensor detects the thickness of the tool housing or another indication of the erosion of the tool housing, and the communication unit communicates the information to surface, e.g. only when the indicator is above a certain extent of erosion.

[0032] In an embodiment, the tool housing may be electrically connected with the sacrificial anode.

[0033] Also, the downhole tool as described above may further comprise a power supply for creating an electrical potential across the anode and the tool housing.

[0034] The power supply may have a negative pole connected with the tool housing and a positive pole connected with the anode.

[0035] Furthermore, the downhole tool may further comprise an acid detection sensor.

[0036] In an embodiment, the one or more anodes may cover at least 10% of a surface area of the tool housing.

[0037] Moreover, the downhole tool as described above may comprise several anodes arranged with at least one anode for each 10 metres of the downhole tool, preferably at least one anode for each 5 metres of the downhole tool, more preferably at least one anode for each 2 metres of the downhole tool, and even more preferably at least one anode for each 1 metre of the downhole tool.

[0038] In addition, the downhole tool as described above may further comprise an operational tool section, such as a drill bit, an anchor tool, a stroking tool, a key tool, a release tool or a milling tool.

[0039] The anodes may be arranged between the operation tool section and the tool housing.

[0040] Further, the driving tool may propel forward in the well at a velocity of at least 5 metres/hour.

[0041] The present invention furthermore related to a downhole system comprising a downhole tool as described above and the well containing acidic fluid.

[0042] The downhole system as described above may comprise several tools.

[0043] In an embodiment, anodes may be arranged between the tools.

[0044] The acid may be HCl, H_2S or H_2SO_4 or any combination thereof.

[0045] Also, the downhole system as described above may further comprise tubing string, such as coiled tubing, connected with the downhole tool for supplying acid.

[0046] The present invention also relates to a downhole operation method for operating the downhole tool as described above, comprising the steps of:

- connecting an anode with the tool housing,
- submerging the tool into the well for performing an operation downhole,
- retracting the downhole tool from the well,
- replacing the sacrificial anode, and
- submerging the downhole tool for performing another operation in the same well or another well.

[0047] Further, the downhole operation method as described above may further comprise the step of cleaning the downhole tool before submerging the tool again.

[0048] In the step of replacing the anode, the anode may be replaced for another anode of a material which is different from that of the anode which is replaced.

[0049] Moreover, the downhole operation method as described above may further comprise the step of detecting which acid is present in the well.

[0050] Finally, the downhole operation method may further comprise the step of measuring the erosion of the housing.

Brief description of the drawings

[0051] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which

Fig. 1 shows a cross-sectional view of a well in which a downhole tool according to the present invention is submerged,

Fig. 2 shows another embodiment of the downhole tool comprising anodes in both ends,

Fig. 3 shows yet another embodiment of the downhole tool comprising rod anodes arranged outside the tool housing,

Fig. 4 shows the downhole tool of Fig. 3 seen from one end,

Fig. 5 shows a downhole tool having mesh anode, and

Fig. 6 shows a downhole system according to the invention.

[0052] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

Detailed description of the invention

[0053] Fig. 1 shows a downhole tool 1 submerged into a well 2 containing an acid-containing fluid 18. The downhole tool comprises a tool housing 3 made of a first metal and a sacrificial anode 4 made of a second metal. The anode 4 is arranged in connection with one first end 22 of the tool housing being the end furthest away from the top of the well. In order to prevent erosion or etching of the tool housing when submerged in the acid-containing fluid 18, the second metal of the anode has a more negative electrochemical potential than the first metal of the tool housing.

[0054] When performing an operation in an acid-containing well, the acid erodes the metal tool housing to such an extent that the downhole tool cannot be reused for another operation. Downhole tools cannot be made in disposable materials, such as plastic, since the operations often require a significant amount of force. Thus the tools have a robust design and are made of robust materials, such as stainless steel. The tools are therefore quite expensive to manufacture and hence being able to avoid discarding a tool after having performed one operation in an acid-containing well is very beneficial. The well may contain acid before the tool enters the well, or the tool may be used to perform the acid stimulation. By arranging a sacrificial anode in connection with the tool housing, the anode material is eroded or sacrificed in favour of the metal of the tool itself, and thus operations in the acid environment may be performed without having to compromise the tool itself. Typical acids in an acid-containing well may be HCl (hydrogen chloride) which is typically injected into the well for performing a stimulation operation, or H_2S (hydrogen sulphide) and H_2SO_4 (hydrogen sulphate) which develop in the well. Furthermore, inhibitors are added to the fluid in the well for protecting for example the metal casing, and the sacrificial anode therefore has to be designed to match the specific well in which the tool is to operate.

[0055] In Fig. 1, the tool is a driving tool 5 which is self-propelling, meaning that the tool is able to propel itself forward in the well. The tool is connected with the top of the well via a wireline 24 and is thus a so-called wireline tool. The well is a cased well but may also be an openhole well. The driving tool comprises four wheels 6 and each wheel is arranged on a wheel arm 7 which is radially projectable from the tool housing 3, as shown also shown in Fig. 4.

[0056] In Fig. 2, a sacrificial anode is arranged in both the first end 22 and a second end 25 of the tool housing 3. The downhole tool comprises two tool parts 1a, 1b constituted by two operational tool sections being an anchor tool 20 and a key tool 21. The anchor tool has four radially projectable anchors 27 anchoring the tool in the longitudinal direction of the well so that the key tool can project its keys 28 and engage a sliding sleeve 29 for opening or closing the sleeve. A third anode is arranged between the anchor tool and the key tool, and the anodes are thus able to cover the entire tool surface so that the downhole tool is not eroded or etched and thus damaged. In another embodiment, the downhole tool comprises another operational tool section, such as a drill bit, a stroking tool, a release tool or a milling tool.

[0057] The anodes are detachable and are threadingly connected with the ends of the housing of the anchor tool and the ends of the housing of the key tool as shown in Fig. 2. The anodes are designed as cylindrical modules also referred to as "subs" which can easily be connected to any tool by normal detachable connection means.

[0058] In Fig. 3, the downhole tool comprises several sacrificial anodes 4. The anodes are shaped as elongated elements and are arranged on an outer face 8 of the tool housing of the driving tool 5. The anodes are shaped as solid rods, and the sacrificial anodes are arranged in a groove 9 in the tool housing as shown in Fig. 4.

[0059] As shown in Fig. 5, the anode may also be shaped as a mesh 30 surrounding at least part of the outer surface 8 of the tool housing 3. In Fig. 5, the downhole tool 1 comprises a sensor unit 26 which e.g. comprises an acid detecting sensor 16, which is submerged into an openhole well 2 containing acid 18. The sensor unit 26 may also be another kind of sensor, such as a casing collar locator, a temperature measuring unit, a pressure measuring unit, a diagnostics related sensor or similar sensor unit. In the event that the tool is not submergible all the way into the casing, a driving unit such as a downhole tractor can be used to push the tool all the way into position in the well.

[0060] The outer face of the tool is mostly made of the first metal which is a suitable stainless steel type. The anode is made of the second metal which may be chrome, magnesium, bismuth, zinc, aluminium, molybdenum, cobalt, copper, or a combination thereof. The sacrificial anode is designed to match a specific well, the condition of which depends on the acid and inhibitor content of the well in which the tool is to operate, and may therefore comprise any combination of suitable anode metals or metal alloys and even additives or other constituents for providing the most efficient sacrificial anode for the tool in that particular environment of the well. The second material may - apart from the suitable anode material - comprise additives or other kinds of metal. Even though the anode is very efficient, the tool may still be attacked by the acid, but the tool will be less damaged than if no sacrificial anode is used and not to such an extent that the tool cannot be reused for another operation.

[0061] The first metal is substantially stainless steel or similar material and has an electrical potential between -0.32 and -0.40 V. The second metal has an electrical potential between -0.82 and -0.60 V. Thus, the second metal has an electrical potential which is at least -0.3 V lower than that of the first metal, preferably at least -0,40 V lower than that of the first metal, more preferably at least -0.5 V lower than that of the first metal.

[0062] The tool of Fig. 1 comprises an erosion detec-

tion sensor 12 for continuously detecting if the first metal of the tool housing has been attacked by acid and thus has eroded. The erosion detection sensor 12 communicates with a communication unit 14 which communicates information from the erosion detection sensor 12 to the top of the well. By communicating erosion information to an operator at the top of the well, the operator is able to retract the downhole tool before the tool is eroded to an extent that the tool cannot be reused. The erosion detection sensor 12 detects the thickness of the tool housing, e.g. by means of magnetic sensor or an ultrasonic sensor, or by another indication of the erosion of the tool housing. The communication unit 14 communicates the information to surface, e.g. when the indicator is above a certain amount of erosion so that the downhole tool may be retracted from the well before the tool is damaged too much. After retracting the tool from the well, the used anodes may be replaced by new anodes of the same material or anodes of another anode material.

[0063] As mentioned, the anode is replaceably arranged in connection with the tool housing, e.g. as rods in grooves or as detachable components or subs. The downhole tool may further comprise a compartment 11, such as a magazine or cassette, of a plurality of anodes, said compartment 11 being illustrated by dotted lines in Fig. 3. The compartment may comprise anodes of various metals, so that instead of having to retract the tool from the well in order to replace the anodes, the replacement may occur downhole just by releasing the used anodes and collecting new anodes from the compartment. The anodes in the compartment may be used to push the used anodes radially outwards, and the used anodes just drop to the bottom of the well.

[0064] The tool housing is electrically connected with the sacrificial anode, and the downhole tool may further comprise a power supply 15 for creating an electrical potential across the anode and the tool housing as shown in Fig. 2. Thus, the power supply 15 has a negative pole connected with the tool housing and a positive pole connected with the anode.

[0065] In order to protect the downhole tool, the one or more anodes cover(s), in some embodiments, at least 10% of a surface area of the tool housing. The amount of anode material depends on a variety of factors, such as acid type, acid concentration, period of time the tool is submerged, temperature and pressure, anode material, surface area of the anode and surface area of the tool. The optimal design of the anode, choice of anode material and arrangement of the anodes must be determined from operation to operation, but if the acid turns out to be more aggressive than expected, more anodes can easily be connected with the ends of the tool housing in the required number.

[0066] The anodes are arranged so that they are able to cover the entire tool housing which is at least one anode for each 10 metres of the downhole tool, preferably at least one anode for each 5 metres of the downhole tool, more preferably at least one anode for each 2 metres of the downhole tool, and even more preferably at least one anode for each 1 meter of the downhole tool.

[0067] The invention further relates to a downhole system 100 comprising the downhole tool and the well containing acidic fluid 18, where the system may comprise several tools or operational tools. The acid is typically HCl or H_2SO4, where HCl is particularly aggressive. The acid is typically used for stimulating the well by injecting acid under high pressure into the well opposite the production zones. The injection of acid may be performed by inserting a tubing string 19, such as coiled tubing or similar pipe or tubing, at the top 23 of the well. The tubing string 19 may be connected with the downhole tool, such as a driving tool arranged in front of the tubing for dragging the tubing even further down the well as shown in Fig. 6. When the tubing is positioned in the well, acid 18 is supplied down the tubing 19 and injected through openings in the end of the tubing close to the driving tool. The acid is supplied while the tubing and thus the driving tool is retracted slowly from the well. During the acid treatment, the housing 8 of the driving tool is subjected to the acid, since the tool is retracted through the well which was just treated with acid. The anode 4 may thus be advantageously arranged in the end facing the tubing string 19. To further protect the tool, the propelling means, which in this embodiment are the wheels on the projectable wheel arms, may be retracted into the body of the tool while performing the acid treatment.

[0068] The downhole operation is initiated by connecting an anode with the tool housing before submerging the tool into the well for performing an operation downhole. Then the downhole tool is retracted from the well and the sacrificial anode is replaced, and then the downhole tool may be submerged again and is ready to perform another operation in the same well or another well. Before submerging the tool again, the downhole tool may also be cleaned, e.g. flushed. The tool may detect what kind of acid is present in the well in order to insert the most suitable anode for protecting the tool.

[0069] A stroking tool is a tool providing an axial force. The stroking tool comprises an electrical motor for driving a pump. The pump pumps fluid into a piston housing to move a piston acting therein. The piston is arranged on the stroker shaft. The pump may pump fluid into the piston housing on one side and simultaneously suck fluid out on the other side of the piston.

[0070] By fluid or well fluid is meant any kind of fluid that may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By gas is meant any kind of gas composition present in a well, completion, or open hole, and by oil is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil, and water fluids may thus all comprise other elements or substances than gas, oil, and/or water, respectively.

[0071] By a casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0072] The driving unit may be a downhole tractor with projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0073] Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

1. A downhole tool (1) for performing an operation in an acid-containing well (2), comprising:

   - a tool housing (3) of a first metal, and
   - a sacrificial anode (4) made of a second metal and arranged in connection with the tool housing, the second metal having a more negative electrochemical potential than the first metal.

2. A downhole tool according to claim 1, wherein the tool is a driving tool (5) which is self-propelling.

3. A downhole tool according to claim 2, wherein the driving tool comprises wheels (6), each wheel being arranged on a wheel arm (7) and being projectable from the tool housing.

4. A downhole tool according to any of the preceding claims, wherein the sacrificial anode is arranged in a first end (22) or a second end (25) of the tool housing.

5. A downhole tool according to any of the preceding claims, wherein the sacrificial anode is an elongated element and is arranged on an outer face (8) of the tool housing.

6. A downhole tool according to any of the preceding claims, wherein the sacrificial anode is arranged in a groove (9) in the tool housing.

7. A downhole tool according to any of the preceding claims, wherein the anode is shaped as a mesh surrounding at least part of the tool housing.

8. A downhole tool according to any of the preceding claims, wherein the second metal comprises chrome, magnesium, bismuth, zinc, aluminium, molybdenum, cobalt copper, or a combination thereof.

9. A downhole tool according to any of the preceding claims, wherein the anode is replaceably arranged in connection with the tool housing.

10. A downhole tool according to any of the preceding claims, further comprising a compartment (11), such as a magazine or cassette, of a plurality of anodes.

11. A downhole tool according to any of the preceding claims, further comprising an erosion detection sensor (12) for detection of erosion of the first metal of the tool housing.

12. A downhole system comprising a downhole tool according to any of the preceding claims, and the well containing acidic fluid (18).

13. A downhole system according to claim 12, wherein the system comprises several tools.

14. A downhole system according to claim 12 or 13, further comprising tubing string (19), such as coiled tubing, connected with the downhole tool for supplying acid.

15. A downhole operation method for operating the downhole tool according to any of claims 1-11, comprising the steps of:

   - connecting an anode with the tool housing,
   - submerging the tool into the well for performing an operation downhole,
   - retracting the downhole tool from the well,
   - replacing the sacrificial anode, and
   - submerging the downhole tool for performing another operation in the same well or another well.

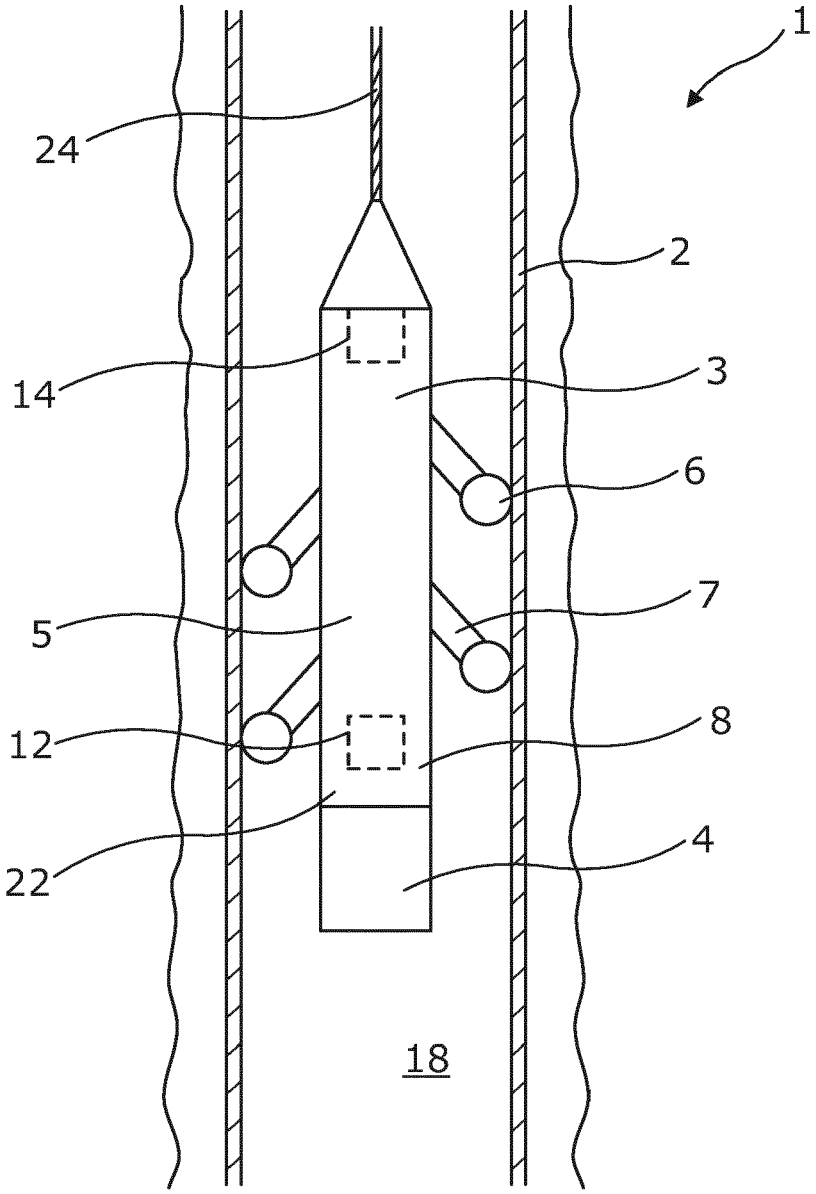

Fig. 1

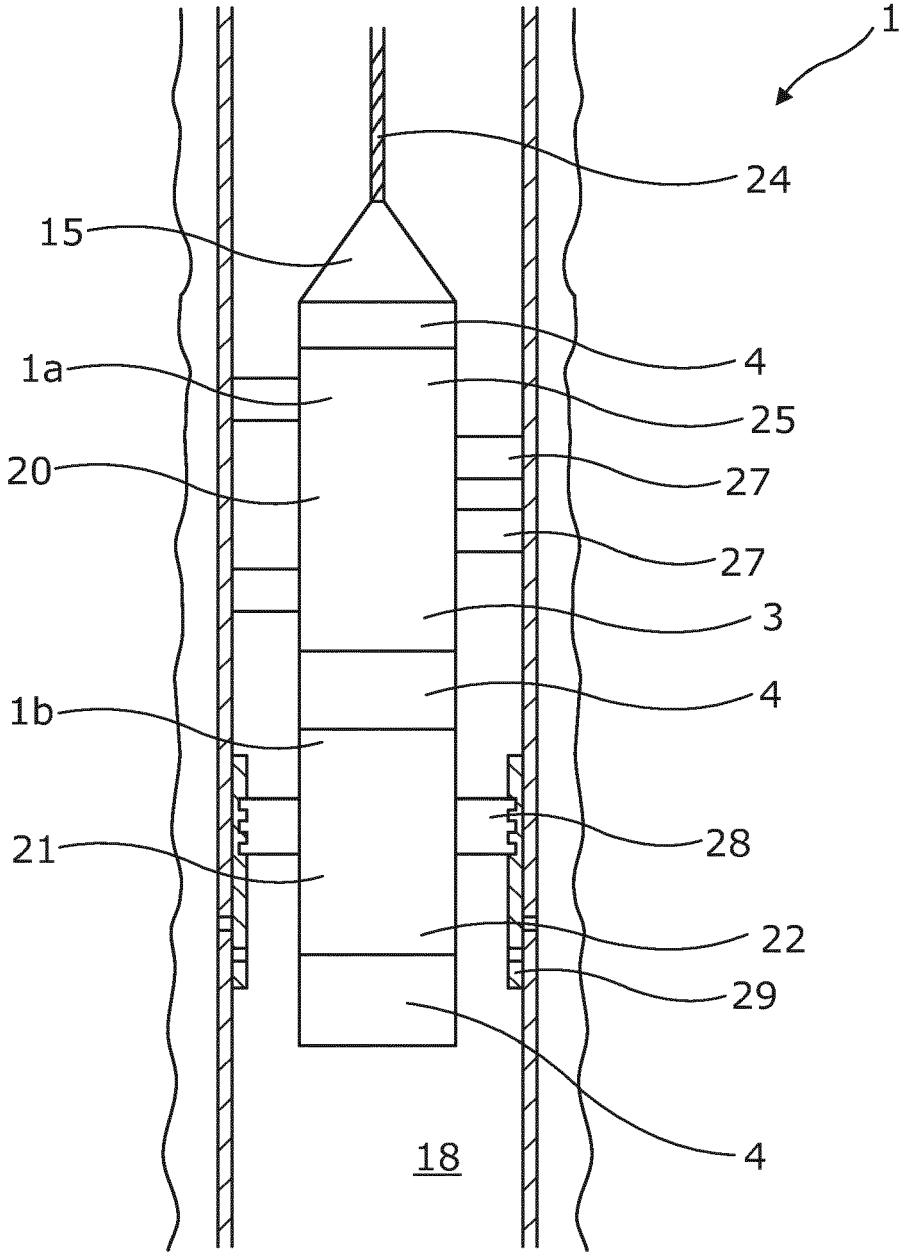

Fig. 2

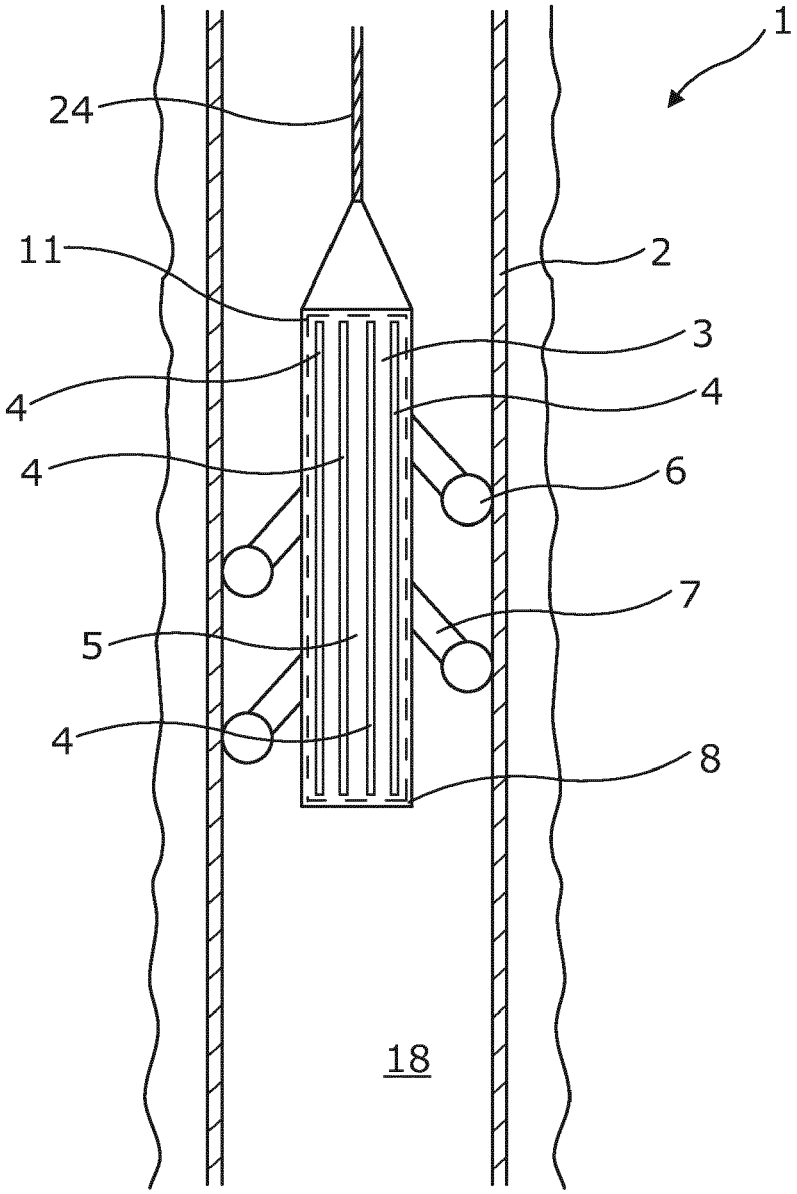

Fig. 3

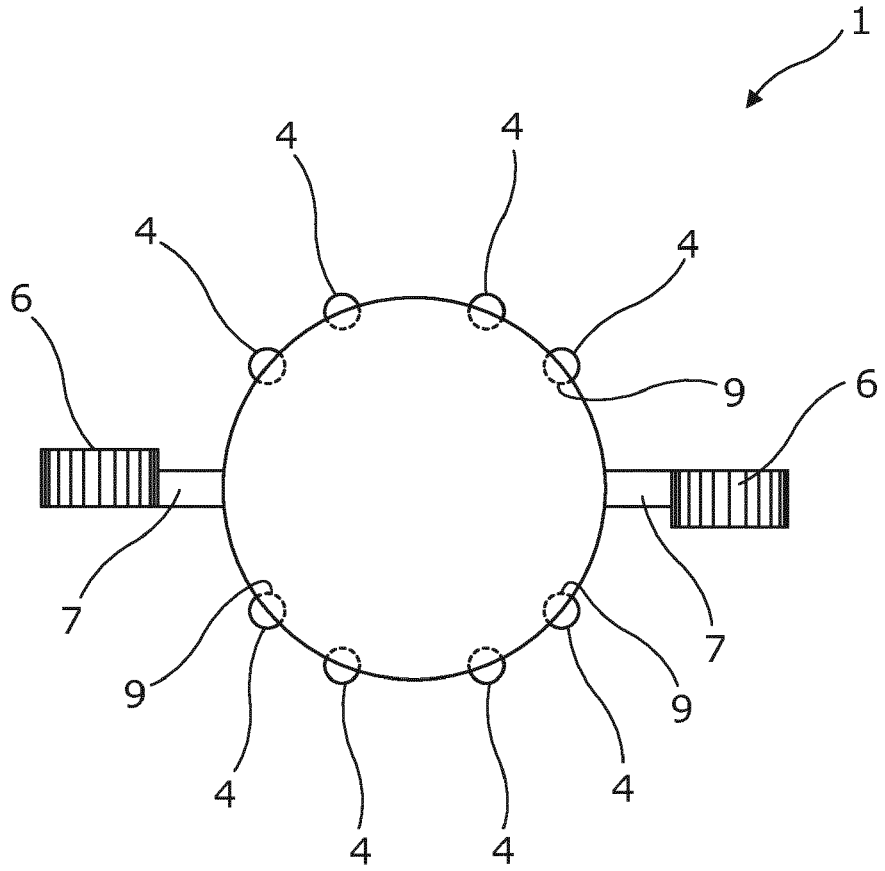

Fig. 4

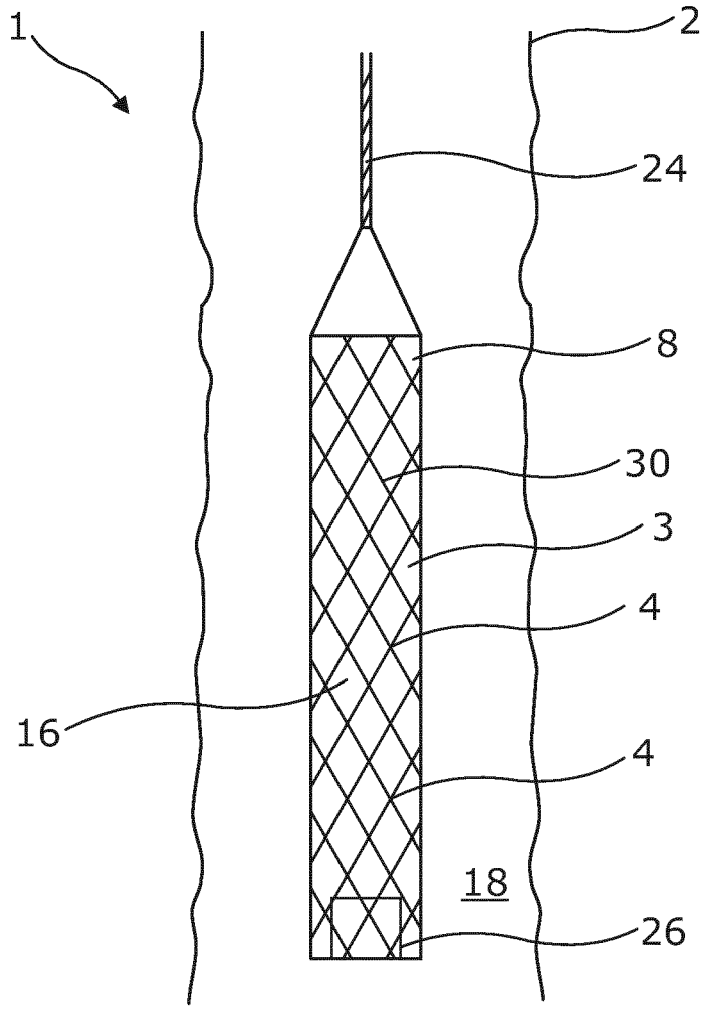

Fig. 5

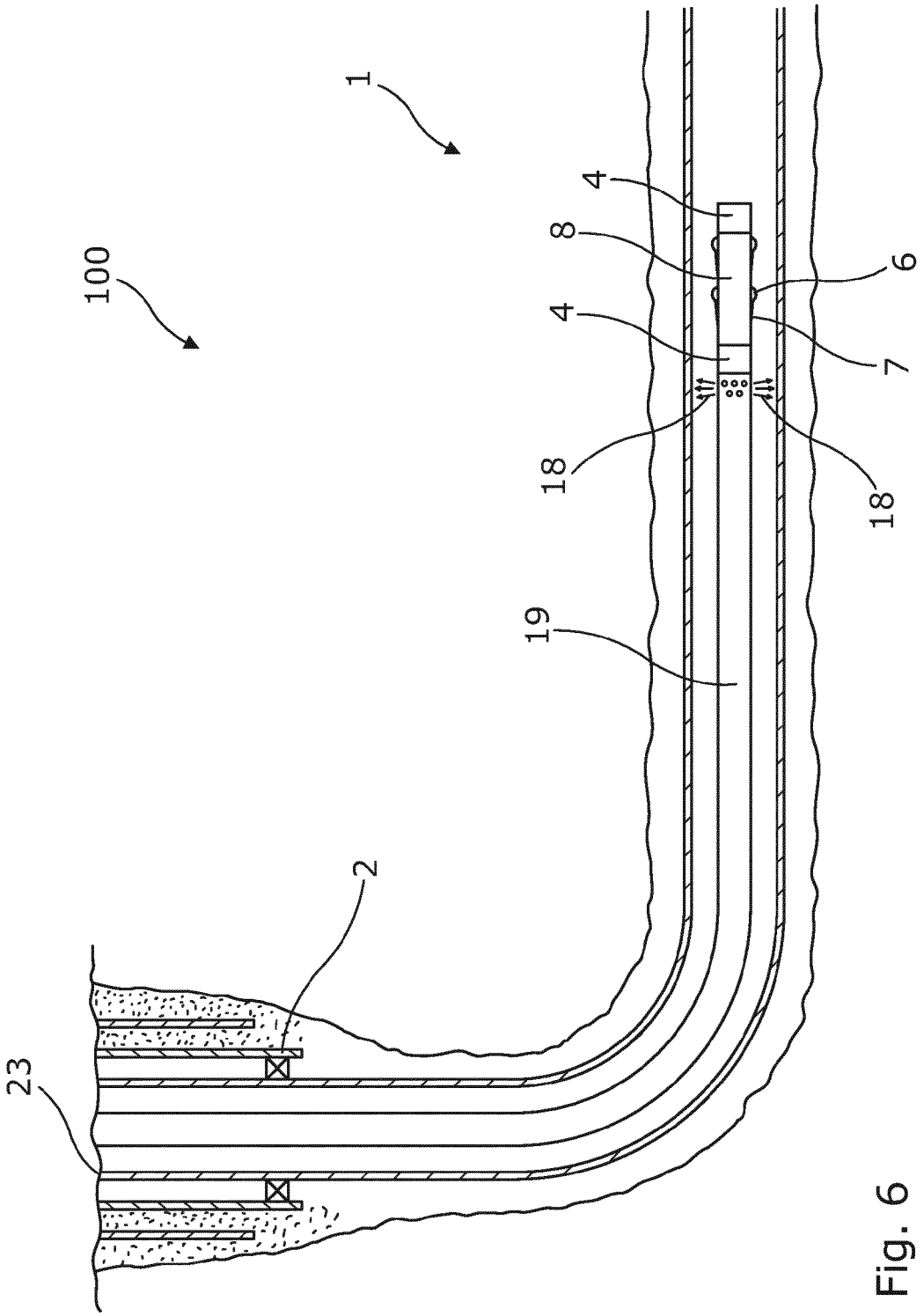

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 3847

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2011/315444 A1 (TRINH TU TIEN [US] ET AL) 29 December 2011 (2011-12-29) * paragraphs [0021], [0024], [0025], [0030] * * figure 2 * -----	1-4,8,9, 11-15 7	INV. E21B41/02 E21B47/01
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 April 2013	Schouten, Adri

CATEGORY OF CITED DOCUMENTS

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