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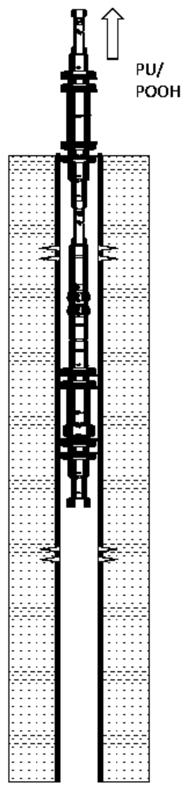
(54)	Title	**A drill pipe string borne well test tool**
(56)	References Cited:	US 2006/0266520 A1, WO 2015/115905 A1, US 8336620 B2
(57)	Abstract	

The invention is a drill pipe string borne well test tool comprising, as counted from bottom to top, - a set of lower and upper short perforation gun sections (34, 32) separated by a desired first length (L) of blank space-out gun sections (40); - a lower solid pressure seal (25); - a set of lower and upper casing perforation pressure isolation test tools (20, 10) arranged above separated by the same first length (L) by drill pipe space out sections (30) and a test isolation ball valve (15); - said lower pressure test tool (20) comprising a test pressure gauge carrier (26) comprising at least a pressure gauge (28) and a pressure recorder (29).



Field of the invention

[0001] The present invention relates to a one-trip tool for testing the sealing properties on the outside of a casing. The sealing properties may be due to naturally collapsed ductile geological formation about the casing, a cemented casing annulus, debris in the annulus, or a mixture of the three. More specifically the invention it is a combined dual perforation and pressure isolation tool with a memory, the tool for being run inside a casing in a well for perforating two axially separate locations along the well, pressure isolating both perforated locations, testing local pressure communication outside the casing by local measurements, storing the test data and retrieving the test data to analyze whether there is a qualified pressure barrier outside about the casing and between the two locations.

Background art

US-patent Statoil US8336620B1 defines a method of determining integrity of an annular seal in a wellbore, using a characteristic response associated with a formation providing an effective annular seal against a surface of a lining tubing section located in the wellbore, running a wellbore tool in a selected wellbore that extends through the geological formation to obtain selected wellbore response data associated with a property of the geological formation, and comparing the selected wellbore response data with the characteristic response to determine whether the geological formation forms an effective annular seal in the selected wellbore. Its description says that a first test well is used for the characteristic data acquisition and that "a selected wellbore" is another well.

US 2006/0266520A1 describes a method for the detection of a fluid leak from a plugged well extending from a surface of the earth to penetrate a subterranean formation which contains fluid by logging a collection chamber positioned in the plugged well.

WO2015/115905A1 discloses a bottom hole assembly (BHA) that enables a one trip procedure to set a bridge plug and release from that bridge plug with the BHA. A perforating gun is fired and a straddle tool above the gun is repositioned to wash the perforations as the opposed packer cups are moved along the perforations. At the end of the washing step a dropped ball closes the circulation port above the upper packer cups and the ball seat is blown out. A disconnect releases the lower part of the straddle tool with the lower packer cups that are uphole oriented. Cement can now be delivered past the upper packer cups and pressurized to squeeze the cement into the perforations using the upper cups to hold the pressure. Another ported sub above the upper cups has a port opened to prevent swabbing as the BHA is removed.

Short summary of the invention

[0002] A main object of the present invention is to disclose a tool and an annulus pressure integrity method to solve problems in the prior art.

The invention is a drill pipe string borne well test tool comprising, as counted from bottom to top,

- a set of lower and upper short perforation gun sections (34, 32) separated by a desired first length (L) of blank space-out gun sections (40),
- a lower solid pressure seal (25) arranged for being broken or sheared out at a predetermined high pressure through the drill pipe string,
- a set of lower and upper casing perforation pressure isolation test tools (20, 10) arranged above said perforation gun sections (34, 32) and separated by the same first length (L) by drill pipe space out sections (50),
- an isolation ball valve (15) for test purposes arranged above said lower casing perforation isolation test tool (20), and a test isolation ball valve (15);
- said lower casing perforation pressure isolation test tool (20) comprises a test pressure reception inlet (23),
- said lower pressure test tool (20) comprising a test pressure gauge carrier (26) comprising at least a pressure gauge (28) and a pressure recorder (29), and
- said upper casing perforation pressure isolation test tool (10) comprises a test pressure injection outlet (13).

The invention is also a casing annulus pressure integrity testing method
providing a test tool comprising, as counted from bottom to top,

- a set of lower and upper short perforation gun sections (34, 32) separated by a desired first length (L) of blank space-out gun sections (40),
- a lower solid pressure seal (25) arranged for being broken or sheared out at a predetermined high pressure through the drill pipe string,
- a set of lower and upper casing perforation pressure isolation test tools (20, 10) arranged above said perforation gun sections (34, 32) and separated by the same first length (L) by drill pipe space out sections (50),
- an isolation ball valve (15) for test purposes arranged above said lower casing perforation isolation test tool (20),
- said lower casing perforation pressure isolation test tool (20) comprises a test pressure reception inlet (23),
- said lower pressure test tool (20) comprising a test pressure gauge carrier (26) comprising at least a pressure gauge (28) and a pressure recorder (29), and

- said upper casing perforation pressure isolation test tool (10) comprises a test pressure injection outlet (13)

running said test tool to a desired depth in a casing in a well;

- making test perforations at two depths using the perforation gun sections (34, 32);
- running the lower and upper casing perforation pressure isolation test tools (20, 10) to straddle the lower and upper perforations, respectively;
- closing the test isolation ball valve (15);
- setting a test pressure via the drill pipe string into the upper perforations, and measuring and recording any pressure development at the lower perforations as registered using the pressure gauge (28);
- retrieving the pressure recorder (29) to the surface;
- retrieving and analyzing the recorded pressure data and determining whether the casing annulus has pressure integrity or not.

[0003] Further features of the invention is defined in the dependent claims attached.

[0004] One big advantage of the present invention is the very low volume of fluid involved in the pressure integrity test. Only the volume of free fluid in the annulus between the upper and lower pressure isolation tools (10, 20) is involved, and one may also conduct a pressure integrity test without annulus communication to the surface. Furthermore, much run-in and tripping-out time is saved. Another advantage is the precision at which the pressure isolation tools (10, 20) may be placed because one may have full control on the tool positioning and separation after the perforation has been conducted.

Figure captions

[0005] The attached figures illustrate some embodiments of the claimed invention.

[0006] Fig. 1 illustrates a test tool according to the invention.

[0007] Fig. 2 illustrates a first step of the method according to the invention comprising perforating the two locations in the well.

[0008] Fig. 3 illustrates a second step of the method according to the invention comprising running the two isolation toolsections to near above each two perforated locations, for testing the isolation tools' pressure integrity ahead of the perforation pressure test.

[0009] Fig. 4 shows the two isolation toolsections being located on the perforated locations and the pressure test is conducted.

[0010] Fig. 5 shows the isolation toolsections being pulled up after the test has been conducted.

Embodiments of the invention

[0011] The invention will in the following be described and embodiments of the invention will be explained with reference to the accompanying drawings.

[0012] **Fig. 1** illustrates a test tool according to the invention. I will begin its description from the lower end of the tool. A perforation gun tools section (30) has a trigger and release mechanism (31) at its upper end. It will drop the gun tools section (30) after firing. This is important for personnel and operations safety.

[0013] The lower gun (34) is short for making a test perforation inlet to be isolated by the swab cups (22, 24) of a lower pressure test tool section (20) to be described below. The lower gun (34) is separated by a predetermined desired length from a corresponding similar upper gun (32) above by so-called blank space-out gun sections. The upper perforations made by the upper gun (32) are made for being isolated by the swab cups (12, 14) of a corresponding upper pressure test tool section (10) also to be described below, the two pressure test tool sections having the same space-out distance between them as the guns. The significant advantage of this arrangement is that the perforation and pressure testing may be done in one run.

[0014] Above the perforation guns there is arranged the above initially described set of lower and upper pressure isolation tools (20, 10). At the bottom above the perforation gun release (31) is a lower so-called solid pressure seal (25) which is temporary, may be broken or sheared out at a predetermined high pressure through the drill pipe string, a pressure seal which shall withstand the communication test pressure between the upper and the lower isolation test tools (10, 20).

[0015] Above the solid pressure seal (25) is the lower pressure isolation test tool section (20). It comprises a set of lower (24) and upper swab cups (22), and between them a test pressure reception inlet (23) and a gauge carrier (26) with a pressure P gauge (28). In a preferred embodiment of the invention the pressure gauge (28) is connected to a local pressure measurement time recording unit (29) arranged for registering and recording pressure vs. time during the pressure test. The recording unit (29) may be retrieved and upload its pressure vs. time data when the entire tool is retrieved to the surface. In an embodiment of the invention the recording unit may be retrieved on wire. In an embodiment the pressure gauge (28) is accompanied with a temperature gauge (28T) of which the temperature is recorded along with the pressure.

[0016] In an embodiment of the pressure test tool sections (10, 20) they are provided with local bypass lines across the swab cups (12, 14) and (22, 24) so as for facilitating their running through blank casing.

[0017] Above the lower pressure isolation test tool section (20) is a predetermined combined length of drill pipe string space out sections (50) and a test isolation ball valve (15). The distance between the reception/injection apertures (23, 13) of the test tool sections (20, 10) is the same as the distance between the centres of the short perforation gun sections (34, 32).

[0018] The test isolation ball valve (15) may be controlled to close and open from the surface via the drill pipe string (0). In a preferred embodiment it is closed by left hand rotation and opened by right hand rotation.

[0019] **Fig. 2** illustrates a first step of the method according to the invention comprising perforating the two locations in the well. The tool string is run into the casing to the desired depths for the test perforations to be made. In an embodiment of the invention the perforation gun trigger mechanism (31) is set off by increasing the pressure to 2500 psi (170 atm), and the two guns (32, 34) will set off simultaneously. In an embodiment of the invention the trigger (31) will have a 6 minutes delay before firing. In an embodiment of the invention both guns are made up with 12 perforating charges distributed over 1 foot.

[0020] **Fig. 3** illustrates a second step of the method according to the invention comprising running the two isolation toolsections (10, 20) to near above each two perforated locations, for testing the isolation tools' pressure integrity ahead of the perforation pressure test. The two pairs of swab cups (12, 14) and (22, 24) are located in blank casing above the relevant perforated locations, the pressure in the drill pipe string is increased to a swab cup test pressure while the lower solid pressure seal (25) is kept closed (without exceeding its shear out or break pressure). If there is not registered any significant pressure loss as observed at the surface for at least 1 minute during this test, the swab cups' pressure integrity is all right. After the blank casing pressure test, if swab cups are all right, the pressure is bled off before the tool is moved, please see next Figure.

[0021] **Fig. 4** shows the two isolation toolsections being located on the perforated locations and the pressure test is conducted. Here the two isolation toolsections (10, 20) have been placed straddling the perforations in the casing, the ball valve (15) has been closed, and pressure (P) is established in the drill pipe string. The pressure is monitored in the pressure gauge (28) and recorded. In an embodiment of the invention the pressure is recorded for 10 to 1000 minutes, in a more preferred embodiment it is recorded during 30 to 120 minutes; a most used recording duration is 60 minutes. The only allowable path for a pressure increase within the lower set of swab cups (22, 24) is via the casing annulus. The recorded pressure data are retrieved when the tool has been retrieved to the surface and the data are analyzed in order to determine whether there has been any leakage via the casing annulus, and if so, the casing annulus pressure integrity is not good.

[0022] **Fig. 5** shows the isolation toolsections being pulled up after the test has been conducted. Before pulling out of the well, the test pressure is bled off at the surface, the ball valve is opened by a right hand rotation of the drill pipe string, the tool is pulled up to above the perforations, the lower seal (25) is sheared out by increasing the drill pipe string pressure, and the tool is pulled out of hole (POOH). At surface the memory of the recording unit (29) is uploaded to a computer and the pressure integrity test data are analyzed.

[0023] If the pressure integrity test data are OK, the well may be safely plugged and abandoned or used for other purpose.

[0024] As an alternative to swab cups (12, 14, 22, 24), mechanically activated or inflatable packers may be used as will be known to the person skilled in the art. As an alternative to explosive perforation charges, a cutting or drilling perforation tool may be used. As an alternative to a retrievable recording unit (29) wired pipe or wireline sonde retrieved data may be used.

[0025] Among the advantages of the present invention is the one-trip perforation and testing made feasible. Another advantage is the low volume to be tested, less than 3 m3 of fluid is involved. Even a casing annulus a bad annulus log, which may be due to a mix of cement, old mud and formation material) may be tested.

[0026]

Claims

1. A drill pipe string borne well test tool comprising, as counted from bottom to top, characterized by
- a set of lower and upper short perforation gun sections (34, 32) separated by a desired first length (L) of blank space-out gun sections (40),
- a lower solid pressure seal (25) arranged for being broken or sheared out at a predetermined high pressure through the drill pipe string,
- a set of lower and upper casing perforation pressure isolation test tools (20, 10) arranged above said perforation gun sections (34, 32) and separated by the same first length (L) by drill pipe space out sections (50),
- an isolation ball valve (15) for test purposes arranged above said lower casing perforation isolation test tool (20),
- said lower casing perforation pressure isolation test tool (20) comprises a test pressure reception inlet (23),
- said lower pressure test tool (20) comprising a test pressure gauge carrier (26) comprising at least a pressure gauge (28) and a pressure recorder (29), and
- said upper casing perforation pressure isolation test tool (10) comprises a test pressure injection outlet (13).

2. The test tool according to claim 1,
- said lower and upper casing pressure isolation test tools (20, 10) comprising swab cups (22, 24) and (12, 14).

3. A casing annulus pressure integrity testing method
characterized by the following steps
- providing a test tool comprising, as counted from bottom to top,
- a set of lower and upper short perforation gun sections (34, 32) separated by a desired first length (L) of blank space-out gun sections (40),
- a lower solid pressure seal (25) arranged for being broken or sheared out at a predetermined high pressure through the drill pipe string,
- a set of lower and upper casing perforation pressure isolation test tools (20, 10) arranged above said perforation gun sections (34, 32) and separated by the same first length (L) by drill pipe space out sections (50),
- an isolation ball valve (15) for test purposes arranged above said lower casing perforation isolation test tool (20),

- said lower casing perforation pressure isolation test tool (20) comprises a test pressure reception inlet (23),
- said lower pressure test tool (20) comprising a test pressure gauge carrier (26) comprising at least a pressure gauge (28) and a pressure recorder (29), and
- said upper casing perforation pressure isolation test tool (10) comprises a test pressure injection outlet (13)

running said test tool to a desired depth in a casing in a well;
- making test perforations at two depths using the perforation gun sections (34, 32);
- running the lower and upper casing perforation pressure isolation test tools (20, 10) to straddle the lower and upper perforations, respectively;
- closing the test isolation ball valve (15);
- setting a test pressure via the drill pipe string into the upper perforations, and measuring and recording any pressure development at the lower perforations as registered using the pressure gauge (28);
- retrieving the pressure recorder (29) to the surface;
- retrieving and analyzing the recorded pressure data and determining whether the casing annulus has pressure integrity or not.

Krav

1. En borestrengsbåret brønntesteverktøy omfattende, regnet fra nedenfra og oppover,
k a r a k t e r i s e r t v e d
- et sett med nedre og øvre korte perforeringskanonseksjoner (34, 32) adskilt fra hverandre ved en ønsket første lengde (L) av en tom perforeringskanonseksjon (40),
- et nedre fast tetningsarrangement (25) anordnet for å brytes eller sprenges ved et forhåndsbestemt høyt trykk gjennom borestrengen,
- et sett med nedre og øvre forings-perforerings trykkisolerings-testeverktøy (20, 10) anordnet ovenfor perforeringskanonseksjonene (34, 32) og adskilt med den samme første lengde (L) av borestrengs-avstandsseksjoner (50),
- en isoleringskuleventil (15) for testformål anordnet ovenfor det nedre forings-perforerings trykkisolerings-testeverktøyet (20),
- hvor det nedre forings-perforerings trykkisolerings-testverktøyet (20) omfatter et trykktesteinnløp (23),
- hvor det nedre trykktesteverktøy (20) omfatter en testmanometer-medbringer (26) omfattende i det minste et manometer (28) og en trykkregistrator (29), og
- hvor det øvre forings-perforerings trykkisolerings-testverktøyet (10) omfatter et trykkinjiseringsutløp (13).

2. Testverktøyet ifølge krav 2,
- hvor det nedre og øvre forings-isolasjons-trykktesteverktøyet (20, 10) omfatter swab cups (22, 24) og (12, 14).

3. En fremgangsmåte for å utføre en trykkintegritetstest i ringrommet til et foringsrør
k a r a k t e r i s e r t v e d
følgende trinn
- å anbringe et borestrengsbåret brønntesteverktøy omfattende, regnet fra nedenfra og oppover,
- et nedre og øvre sett med korte perforeringskanonseksjoner (34, 32) adskilt fra hverandre ved en ønsket første lengde (L) av tomme perforeringskanonseksjoner (40),
- et nedre fast tetningsarrangement (25) anordnet for å brytes eller sprenges ved et forhåndsbestemt høyt trykk gjennom borestrengen,
- et sett med nedre og øvre forings-perforerings trykkisolerings-testverktøy (20, 10) anordnet ovenfor perforeringskanonseksjonene (34, 32) og adskilt med den samme første lengde (L) av borestrengs-avstandsseksjoner (50),
- en isoleringskuleventil (15) for testformål anordnet ovenfor det nedre forings-

perforerings trykkisolerings-testverktøyet (20),
- hvor det nedre forings-perforerings trykkisolerings-testverktøyet (20) omfatter et trykktesteinnløp (23),
- hvor det nedre trykktesteverktøy (20) omfatter en testmanometer-medbringer (26) omfattende i det minste et manometer (28) og en trykkregistrator (29), og
- hvor det øvre forings-perforerings trykkisolerings-testverktøyet (10) omfatter et trykkinjiseringsutløp (13),
- å kjøre brønntesteverktøyet til ønsket dybde i en foring i en brønn;
- å utføre testperforering i to dybder ved anvendelse av perforeringskanonseksjonene (34, 32),
- å kjøre de nedre og øvre forings-perforerings trykkisolerings-testverktøyene (20, 10) slik at de respektivt spenner over de nedre og øvre perforeringene,
- å stenge isoleringskuleventilen (15),
- å sette et testtrykk via borerørsstrengen inni de øvre perforeringene, og måle og registrere enhver trykkutvikling i de nedre perforeringene som registrert ved anvendelse av manometeret (28),
- å hente trykkregistratoren (29) opp til overflaten,
- å hente ut og analysere de registrerte trykkdataene og avgjøre om ringrommet til foringsrøret har trykkintegritet eller ikke.

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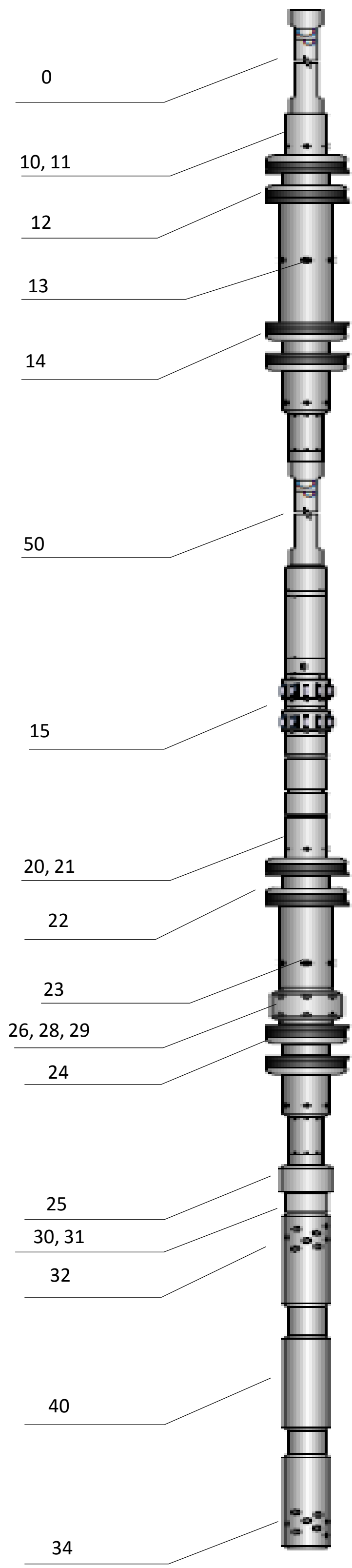

Fig. 1

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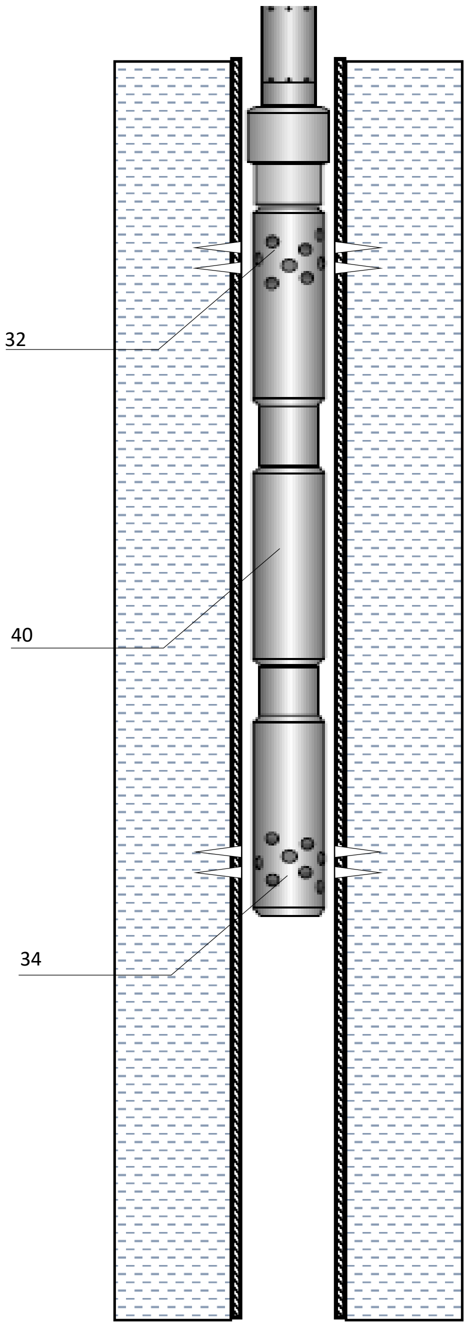

Fig. 2

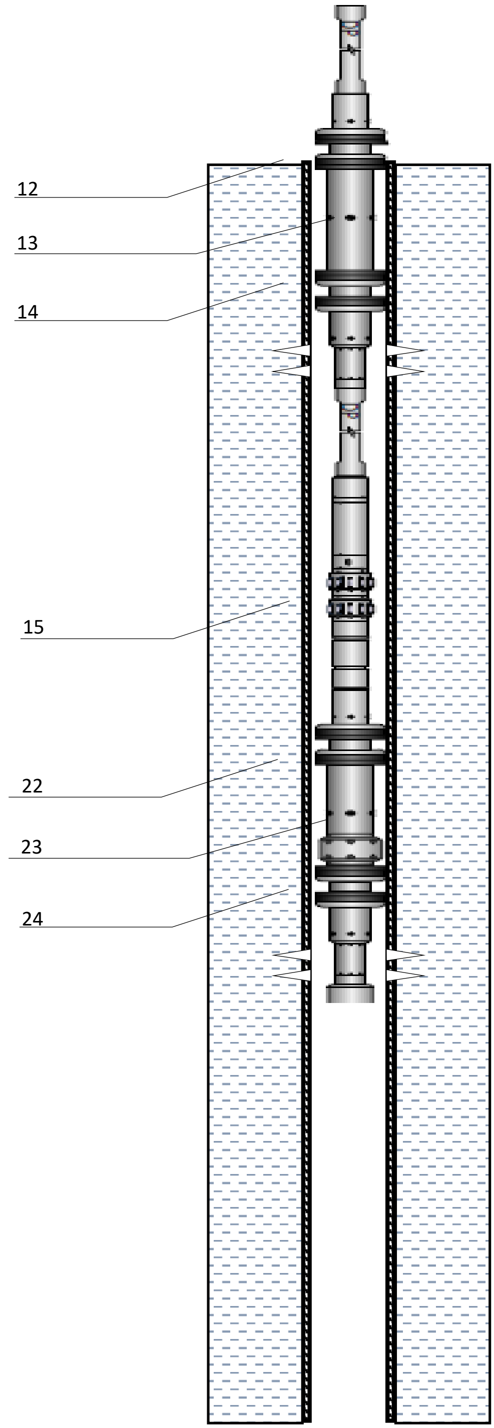

Fig. 3

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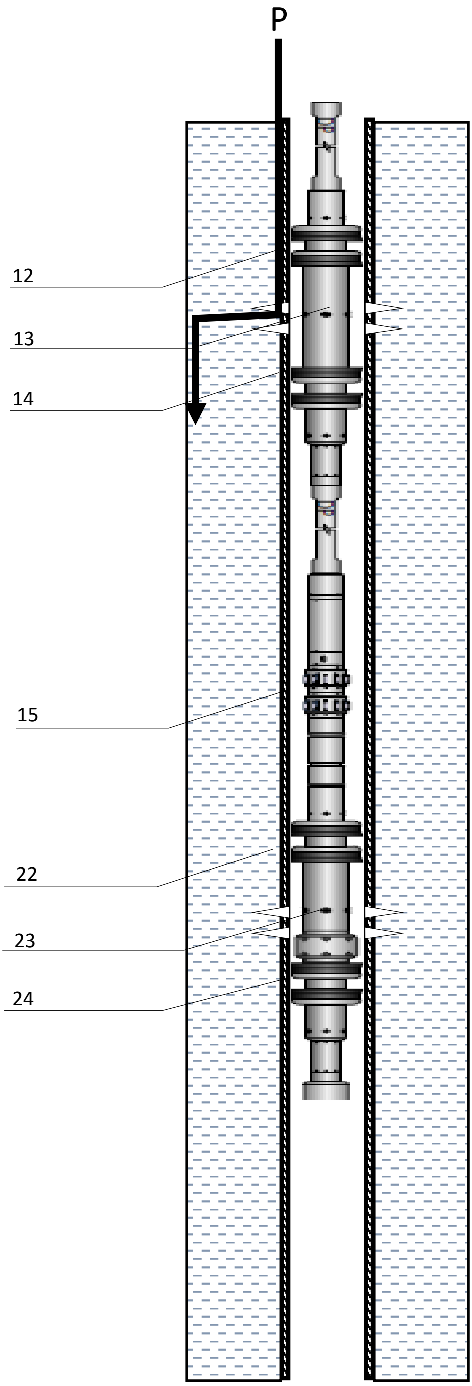

Fig. 4

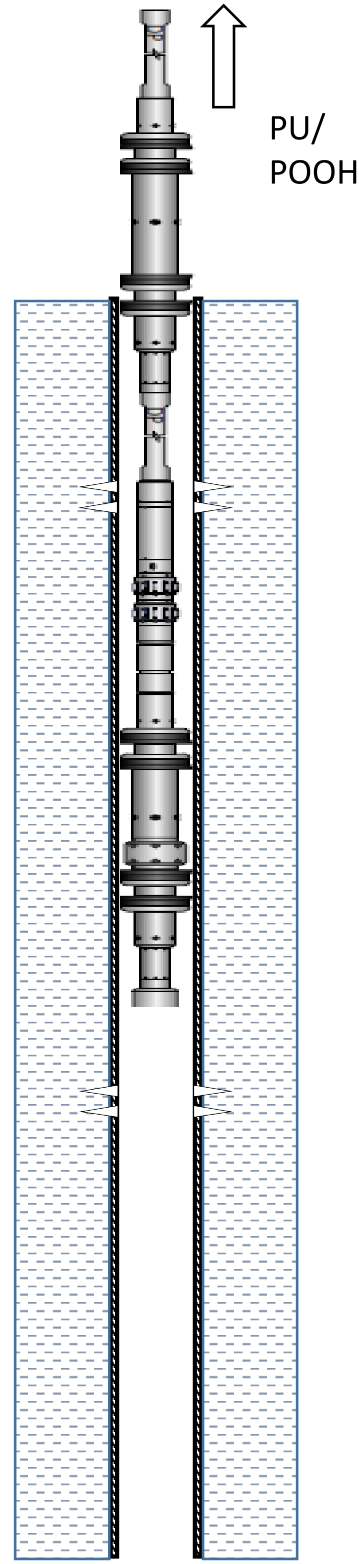

Fig. 5