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(54) Title: BUOYANCY ASSIST TOOL WITH DEGRADABLE PLUG

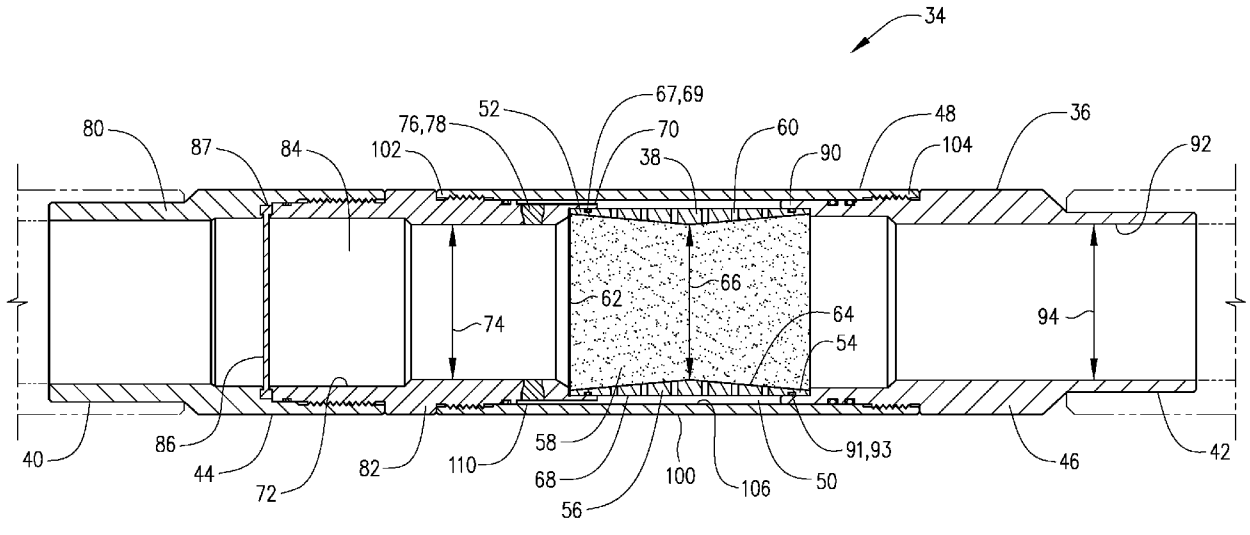

FIG. 2

(57) Abstract: A downhole apparatus comprises a casing string with a fluid barrier connected in the casing string. A degradable plug is positioned in the casing string above the fluid barrier. The degradable plug and fluid barrier define upper and lower ends of a buoyancy chamber in the casing string. The degradable plug may be degraded to leave an open bore through the casing string after the casing string is lowered into a wellbore.

[Continued on next page]

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

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BUOYANCY ASSIST TOOL WITH DEGRADABLE PLUG

BACKGROUND

[0001] The length of deviated or horizontal sections in well bores is such that it is sometimes difficult to run well casing to the desired depth due to high casing drag. Long lengths of casing create significant friction and thus problems in getting casing to the toe of the well bore. Creating a buoyant chamber in the casing utilizing air or a fluid lighter than the well bore fluid can reduce the drag making it easier to overcome the friction and run the casing to the desired final depth.

DESCRIPTION OF THE DRAWINGS

[0002] FIG. 1 is a schematic view of an exemplary well bore with a well casing including a buoyancy chamber therein.

[0003] FIG. 2 is a cross section of a buoyancy assist tool of the current disclosure.

[0004] FIG. 3 is a cross section of a buoyancy assist tool of FIG. 2 after the plug has degraded.

[0005] FIG. 4 is a cross section of an additional embodiment of a buoyancy assist tool.

DESCRIPTION

[0006] The following description and directional terms such as above, below, upper, lower, uphole, downhole, etc., are used for convenience in referring to the accompanying drawings. One who is skilled in the art will recognize that such directional language refers to locations in the well, either closer or farther from the wellhead and the various embodiments of the inventions described and disclosed here may be utilized in various orientations such as inclined, deviated, horizontal and vertical.

[0007] Referring to the drawings, a downhole apparatus 10 is positioned in a well bore 12. Well bore 12 includes a vertical portion 14 and a deviated or horizontal portion 16. Apparatus 10 comprises a casing string 18 which is made up of a plurality of casing joints 20. Casing joints 20 may have inner diameter or bore 22 which defines a central flow path 24 therethrough. Well casing 18 defines a buoyancy chamber 26 with upper end or boundary 28 and lower end or boundary 30. Buoyancy chamber 26 will be filled with a buoyant fluid which may be a gas such as nitrogen, carbon dioxide, or air but other gases may also be suitable. The buoyant fluid may

also be a liquid such as water or diesel fuel or other like liquid. The important aspect is that the buoyant fluid has a lower specific gravity than the well fluid in the well bore 12 in which casing 18 is run. The choice of gas or liquid, and which one of these are used is a factor of the well conditions and the amount of buoyancy desired.

[0008] Lower boundary 30 may comprise a float device such as a float shoe or float collar. As is known, such float devices will generally allow fluid flow downwardly therethrough but will prevent flow upwardly into the casing. The float devices are generally a one-way check valve. The float device 30 is thus a fluid barrier that will be configured such that it will hold the buoyant fluid in the buoyancy chamber 26 until additional pressure is applied after the release of the buoyancy fluid from the buoyancy chamber. The upper boundary 28 is defined by a buoyancy assist tool as described herein.

[0009] Buoyancy assist tool 34 includes an outer case 36 that is connectable in casing string 18. Buoyancy assist tool 34 comprises a plug assembly 38 that is connected to and positioned in outer case 36. Buoyancy assist tool 34 has upper end 40 and lower end 42. Buoyancy assist tool 34 is connectable in the casing string at the upper and lower ends 40 and 42 thereof and forms a part of the casing string 18 lowered into well bore 12.

[00010] Outer case 36 comprises an upper outer case 44 and a lower outer case 46. A connecting shield 48 is connected to and extends between upper outer case 44 and lower outer case 46. Outer case 36 and plug assembly 38 define an annular space 50 therebetween. Annular space 50 in the embodiment shown is defined by and between connecting sleeve 48 and plug assembly 38.

[00011] Plug assembly 38 has upper end 52 and lower end 54. Plug assembly 38 is connected to upper outer case 44 at the upper end 52 thereof and to lower outer case 46 at the lower end 54 thereof. The plug assembly may be threadedly connected or connected by other means known in the art. Plug assembly 38 may comprise a plug housing 56 with upper and lower ends 52 and 54 which are the upper and lower ends of the plug assembly 38. A degradable plug or degradable core 58 is fixed in housing 56. The degradable core may be a matrix of sand and salt but can be other degradable substances that can be degraded with fluids or other means once the casing string 18 is lowered into the wellbore to a desired location in the well. Plug housing 56 has a plurality of housing ports 60 defined through the wall thereof. Housing ports 60 communicate the annular space 50 with the degradable plug or core 58 so that fluid passing therethrough can

contact degradable plug 58 and can degrade the plug to remove it from plug housing 56 to create a full bore flow path therethrough.

[00012] Buoyancy assist tool 34 may include a non-permeable cap 62 positioned across upper end 52 of plug assembly 38. Non-permeable cap 62 may be comprised of a resin or a rubber material or other non-permeable material that will prevent fluid thereabove from contacting the degradable plug at the upper end of the plug assembly 38 prior to the time casing string 18 is placed at the desired location in wellbore 12. The non-permeable cap 62 will be configured such that upon degradation of the plug 58 the cap will be easily ruptured by fluid flowing through the casing string 18, including outer case 36.

[00013] Plug housing 56 has an inner surface 64 defining a diameter 66 and has an outer surface 68. In the embodiment described diameter 66 is a diameter that is no smaller than an inner diameter of casing string 18 such that upon the degradation of plug 58 buoyancy assist tool 34 provides no greater restriction to the passage of well tools therethrough than that which already exists as a result of the inner diameter of the casing string 18.

[00014] Upper end 40 of buoyancy assist tool 34 is likewise the upper end of upper outer case 44. Upper outer case 44 has a lower end 70. Plug assembly 38 is connected at its upper end 52 to the lower end 70 of upper outer case 44. Outer surface 68 of plug housing 56 may have a groove 67 with an O-ring seal 69 therein to sealingly engage an inner surface of upper outer case 44. Upper outer case 44 has inner surface 72 which defines an inner diameter 74 that is a minimum inner diameter of upper outer case 44. In the embodiment shown upper outer case 44 has a port 76 therethrough. Inner diameter 74 is a diameter that is no smaller than an inner diameter of casing string 18 such that upon the degradation of plug 58 buoyancy assist tool 34 provides no greater restriction to the passage of well tools therethrough than that which already exists as a result of the inner diameter of the casing string 18.

[00015] A rupture disc or other rupturable membrane 78 is positioned in a port 76 in upper outer case 44. Rupture disc 78 will prevent flow through port 76 until a desired or pre-determined pressure is reached in casing string 18. Upon reaching the pre-determined pressure the rupture disc 78 will rupture and fluid will be communicated from casing string 18 through port 76 into annular space 50. Fluid will pass from annular space 50 through housing ports 60 and will contact the degradable plug 58. The fluid passing therethrough may be referred to as a degrading

fluid. The degrading fluid may be any fluid utilized to degrade the degradable plug and may be water or other degrading fluid.

[00016] Upper outer case 44 may be a two-piece outer case comprising an upper portion 80 that is threadedly and sealingly connected to lower portion 82. Lower portion 82 connects to plug assembly 38 as shown in the figures. Upper outer case 44 may define a fluid chamber 84 which is a closed fluid chamber 84. Fluid chamber 84 has an upper seal 86 that extends across an upper end 87 thereof. Fluid in fluid chamber 84 is thus trapped between seal 86 and the cap 62 of plug assembly 38. Fluid chamber 84 is an optional fluid chamber 84 and will not be used in every instance. Fluid chamber 84 will be utilized in those instances in which it is necessary to utilize a fluid to treat a formation, and the fluid may not be a degrading fluid for the degradable plug. For example, there are certain formations in which it is not desirable to pump water. In those instances oil or another fluid other than water may be utilized to fracture or otherwise treat the formation. Where, for example, water is the degrading fluid, but not the treatment fluid, water will be contained in the fluid chamber 84 such that upon reaching the appropriate position in the well oil or other fluid may be pumped through the casing which will cause seal 86 to burst and force the water in fluid chamber 84 through port 76 and into annular space 50. The fluid from fluid chamber 84 will then pass from annular space 50 through ports 60 in housing plug 56 and will contact the degradable plug 58 until it is degraded or dissolved.

[00017] Lower outer case 46 has upper end 90 and a lower end which is the lower end 42 of buoyancy assist tool 34. Upper end 90 of lower outer case 44 is connected to lower end 54 of plug assembly 38. Outer surface 68 of plug housing 56 may have a groove 91 with an O-ring seal 93 therein to sealingly engage lower outer case 44. Lower outer case 44 has inner surface 92 defining an inner diameter 94. Inner diameter 94 is a diameter that is no smaller than an inner diameter of casing string 18 such that upon the degradation of plug 58 buoyancy assist tool 34 provides no greater restriction to the passage of well tools therethrough than that which already exists as a result of the inner diameter of the casing string 18.

[00018] Connecting sleeve 100 has upper end 102 and lower end 104. Connecting sleeve 44 is connected at it upper end 102 to an outer surface of upper outer case 44 and is connected at its lower end 104 to an outer surface of lower outer case 46. O-ring seals 105 may be positioned in grooves in the outer surfaces of the upper and lower outer cases 44 and 46 respectively to sealingly engage an inner surface 106 of connecting shield 44. Inner surface 106 of connecting

shield 44 defines an inner diameter 108. An annular passageway 110 is defined by and between upper outer case 44 and connecting shield 48. Annular passageway 110 communicates fluid delivered through port 76 into annular space 50. Fluid is communicated through ports 60 so that it will contact degradable plug 58 to dissolve or degrade the plug.

[00019] The embodiment disclosed in FIG. 2 shows the fluid chamber 84 which is an optional fluid chamber. FIG. 4 shows the embodiment with no fluid chamber which is identical in all other respects. In the embodiment of FIG. 4 buoyancy assist tool 36 is shown prior to the time fluid has degraded plug 58 and without the seal 86 which forms the upper end of the fluid chamber 84 in the embodiment of FIG. 2. In an embodiment in which no fluid chamber is to be utilized upper outer case 44 can be one piece or can be a two-piece upper outer case as described herein.

[00020] In operation casing string 18 is lowered into wellbore 12 to a desired location. Running a casing such as casing 18 in deviated wells and long horizontal wells often results in significantly increased drag forces and may cause a casing string to become stuck before reaching the desired location in the wellbore. For example, when the casing produces more drag forces than the available weight to slide the casing down the well, the casing may become stuck. If too much force is applied to the casing string 18 damage may occur. The buoyancy assist tool 34 as described herein alleviates some of the issues and at the same time provides for a full bore passageway so that other tools or objects such as, for example production packers, perforating guns and service tools may pass therethrough without obstruction after well casing 18 has reached the desired depth. When well casing 18 is lowered into wellbore 12 buoyancy chamber 26 will aid in the proper placement since it will reduce friction as the casing 18 is lowered into horizontal portion 16 to the desired location.

[00021] Once the casing string 18 has reached the desired position in the wellbore, pressure is increased and fluid pumped through the casing string 18. In the case where fluid chamber 84 is utilized the pressure will burst the seal 86 and will push the degradable fluid contained in fluid chamber 84. Pressure will be increased until the rupture disc 78 bursts. Once that occurs degrading fluid from fluid chamber 84 will pass through port 76 into passageway 110 and into annular space 50. Fluid will pass from annular space 50 through ports 60 and will contact the degradable plug 58. A sufficient quantity of the degrading fluid will be utilized to degrade degradable plug 58 so that it will be completely removed from plug housing 56.

[00022] It will be understood that in the case where no fluid chamber 84 is utilized, the degrading fluid will be pumped through casing 18 and through port 76. In other words, the degrading fluid will be that which is pumped through the casing string 18 as opposed to that contained in a fluid chamber. The choice of degrading fluid will be dependent on the plug material, but in many cases water will be used to degrade a plug formed of a sand and salt matrix. Once the degradable plug 58 is dissolved or degraded service tools may be passed through plug assembly 38, and more particularly through plug housing 56. As described herein, buoyancy assist tool 34 provides no size restriction on the tools that can be passed therethrough that does not already exist due to the size of the inner diameter of casing 18. Thus, in the embodiments described inner diameters 66, 74 and 94 may be generally the same as or larger than the minimum outer diameter of casing.

[00023] The current disclosure is directed to a downhole apparatus comprising a casing string and a fluid barrier connected in the casing string. A degradable plug is positioned in the casing string above the fluid barrier and the degradable plug and fluid barrier comprise upper and lower ends of a buoyancy chamber in the casing string. In one embodiment the downhole apparatus has a non-permeable cap covering an upper end of the degradable plug.

[00024] The downhole apparatus may further comprise an outer case connected in the casing string with the degradable plug positioned in the outer case. The outer case and the degradable plug define an annular space configured to receive a degrading fluid. In one embodiment, the downhole apparatus comprises a plug housing with the degradable plug fixed in the plug housing. The plug housing defines ports through a wall thereof configured to communicate fluid from the annular space to the degradable plug. In one embodiment the outer case comprises an upper outer case configured to connect in the casing string and a lower outer case configured to connect in the casing string. A connecting sleeve is connected at one end to the upper outer case and at a second end to the lower outer case. The annular space may be defined between the connecting sleeve and the degradable plug. The outer case of the downhole apparatus has a port defined therein configured to communicate the degrading fluid to the annular space. In one embodiment the outer case defines a fluid chamber containing the degrading fluid.

[00025] A buoyancy assist tool comprises a plug assembly. The plug assembly comprises a plug housing with a degradable plug fixed therein. The buoyancy assist tool in one embodiment has an upper outer case connected at a lower end to the plug assembly and is configured to connect

in a casing string at an upper end thereof. A lower outer case is connected at an upper end to the plug assembly and a connecting sleeve connecting the upper and lower outer cases. The connecting sleeve and plug assembly define an annular space therebetween configured to receive a plug degrading fluid.

[00026] The plug housing of the buoyancy assist tool defines a plurality of ports therein configured to communicate a degrading fluid from the annular space with the degradable plug. The upper outer case defines a port in a wall thereof, the port having a rupturable plug therein. The port is configured to communicate degrading fluid into the annular space when the plug ruptures.

[00027] In one embodiment of the buoyancy assist tool a non-permeable cap covers an upper end of the degradable plug. The non-permeable plug will prevent premature degrading of the plug, by preventing a degrading fluid from contacting the degradable plug until the desired time. That time will generally be when a casing string with the buoyancy assist tool has been lowered to a desired location in a wellbore. In an embodiment the non-permeable cap comprises a rubber coating. The buoyancy assist tool may comprise the upper end of a buoyancy chamber in a casing string. The upper outer case of the buoyancy assist tool may define a fluid chamber containing the degrading fluid.

[00028] An embodiment of the downhole apparatus is casing string comprised of a plurality of casing joints. A degradable plug is configured to block flow through the casing string until the casing string reaches a desired depth in a well bore. A flow barrier is positioned in the casing string below the degradable plug, and the degradable plug and the flow barrier define upper and lower ends of a buoyancy chamber in the casing.

[00029] The casing string in one embodiment has a plug assembly connected therein. The plug assembly comprises a plug housing with the degradable plug fixed therein. The plug housing defines a plurality of ports configured to communicate a degrading fluid therethrough to contact the degradable plug. An outer case connected in the casing string and the plug assembly define an annular space configured to receive a degrading fluid. In one embodiment a closed fluid chamber positioned above the plug assembly chamber contains the degrading fluid. In another embodiment no fluid chamber is included and the degrading fluid is delivered through the casing string.

[00030] Thus, it is seen that the apparatus and methods of the present invention readily achieve the ends and advantages mentioned as well as those inherent therein. While certain preferred embodiments of the invention have been illustrated and described for purposes of the present disclosure, numerous changes in the arrangement and construction of parts and steps may be made by those skilled in the art, which changes are encompassed within the scope and spirit of the present invention.

What is claimed is:

1. A downhole apparatus comprising:

a casing string;

a fluid barrier connected in the casing string; and

a degradable plug positioned in the casing string above the fluid barrier, the degradable plug and fluid barrier comprising upper and lower ends of a buoyancy chamber in the casing string.

2. The downhole apparatus of claim 1 further comprising a non-permeable cap covering an upper end of the degradable plug.

3. The downhole apparatus of claim 1 further comprising an outer case connected in the casing string, the degradable plug positioned in the outer case, the outer case and the degradable plug defining an annular space configured to receive a degrading fluid.

4. The downhole apparatus of claim 3, further comprising a plug housing, the degradable plug being fixed in the plug housing, the plug housing defining ports through a wall thereof configured to communicate fluid from the annular space to the degradable plug.

5. The downhole apparatus of claim 3, the outer case comprising:

an upper outer case configured to connect in the casing string;

a lower outer case configured to connect in the casing string; and

a connecting sleeve connected at one end to the upper outer case and at a second end to the lower outer case, the annular space being defined between the connecting sleeve and the degradable plug.

6. The downhole apparatus of claim 3, the outer case having a port defined therein configured to communicate the degrading fluid to the annular space.

7. The downhole apparatus of claim 3, the outer case defining a fluid chamber containing, the degrading fluid.

8. A downhole apparatus comprising:

a plug assembly, the plug assembly comprising a plug housing with a degradable plug fixed therein;

an upper outer case connected at a lower end to the plug assembly and configured to connect in a casing string at an upper end thereof;

a lower outer case connected at an upper end to the plug assembly; and

a connecting sleeve connecting the upper and lower outer cases, the connecting sleeve and plug assembly defining an annular space therebetween configured to receive a plug degrading fluid.

9. The downhole apparatus of claim 8, the plug housing defining a plurality of ports therein configured to communicate a degrading fluid from the annular space with the degradable plug.

10. The downhole apparatus of claim 8, the upper outer case defining a port in a wall thereof, the port having a rupturable plug therein, the port configured to communicate degrading fluid into the annular space when the plug ruptures.

11. The downhole apparatus of claim 8, further comprising a non-permeable cap covering an upper end of the degradable plug.

12. The downhole apparatus of claim 11, wherein the non-permeable cap comprises a rubber coating.

13. The downhole apparatus of claim 8 connected in a casing string and defining an upper end of a buoyancy chamber in the casing string.

14. The downhole apparatus of claim 8, the upper outer case defining a fluid chamber containing the degrading fluid.

15. A downhole apparatus comprising:

a plurality of casing joints defining a casing string;

a degradable plug configured to block flow through the casing string until the casing string reaches a desired depth in a wellbore, and

a flow barrier positioned in the casing string below the degradable plug, the degradable plug and the flow barrier defining upper and lower ends of a buoyancy chamber in the casing.

16. The downhole apparatus of claim 15 comprising:

a plug assembly connected in the casing string, the plug assembly comprising

a plug housing case with the degradable plug fixed therein.

17. The downhole apparatus of claim 16, the plug housing defining a plurality of ports configured to communicate a degrading fluid therethrough to contact the degradable plug.

18. The downhole apparatus of claim 16 further comprising an outer case connected in the casing string, the outer case and the plug assembly defining an annular space configured to receive a degrading fluid.

19. The downhole apparatus of claim 18 further comprising a closed fluid chamber positioned above the plug assembly, the closed fluid chamber containing the degrading fluid.

20. The downhole apparatus of claim 18 wherein the degrading fluid is delivered through the casing string.

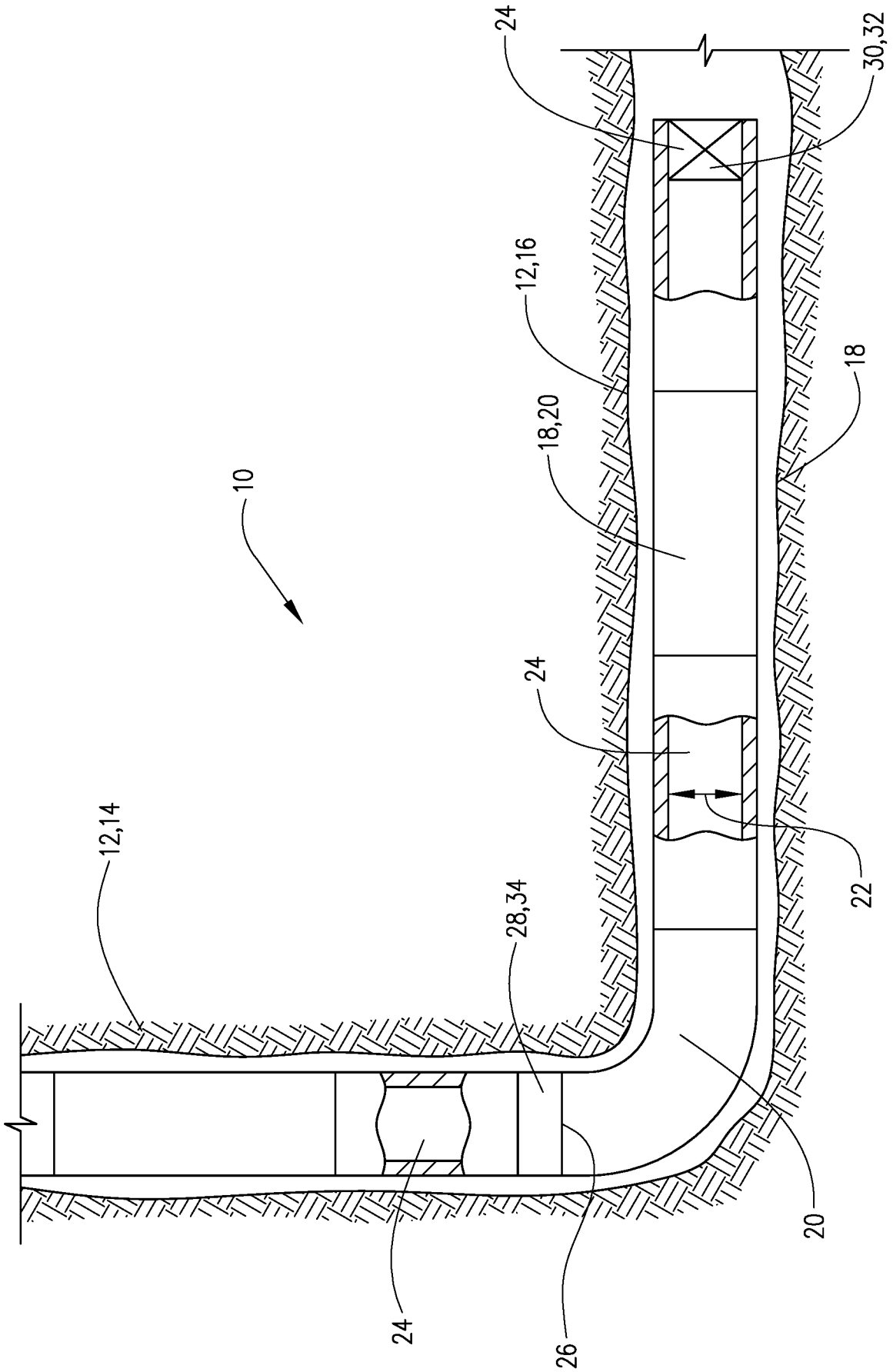

FIG. 1

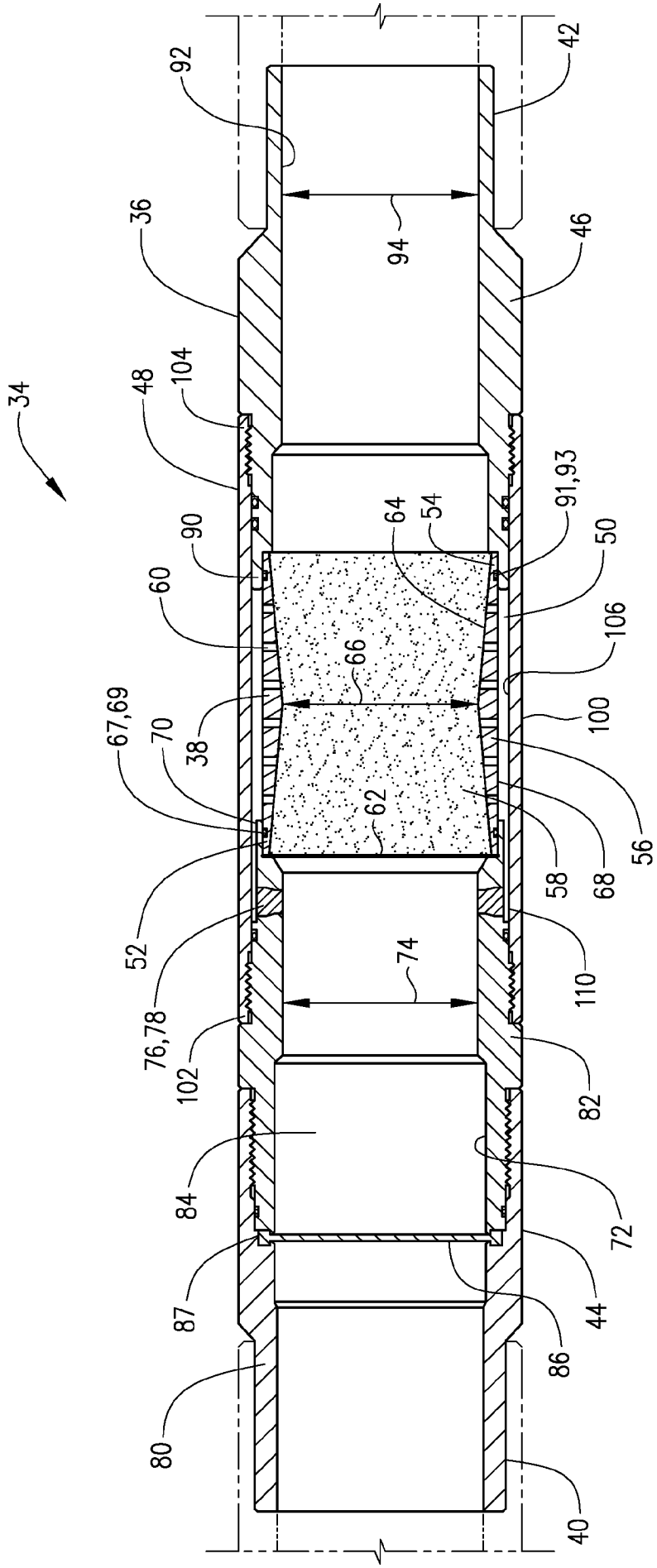
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FIG. 2

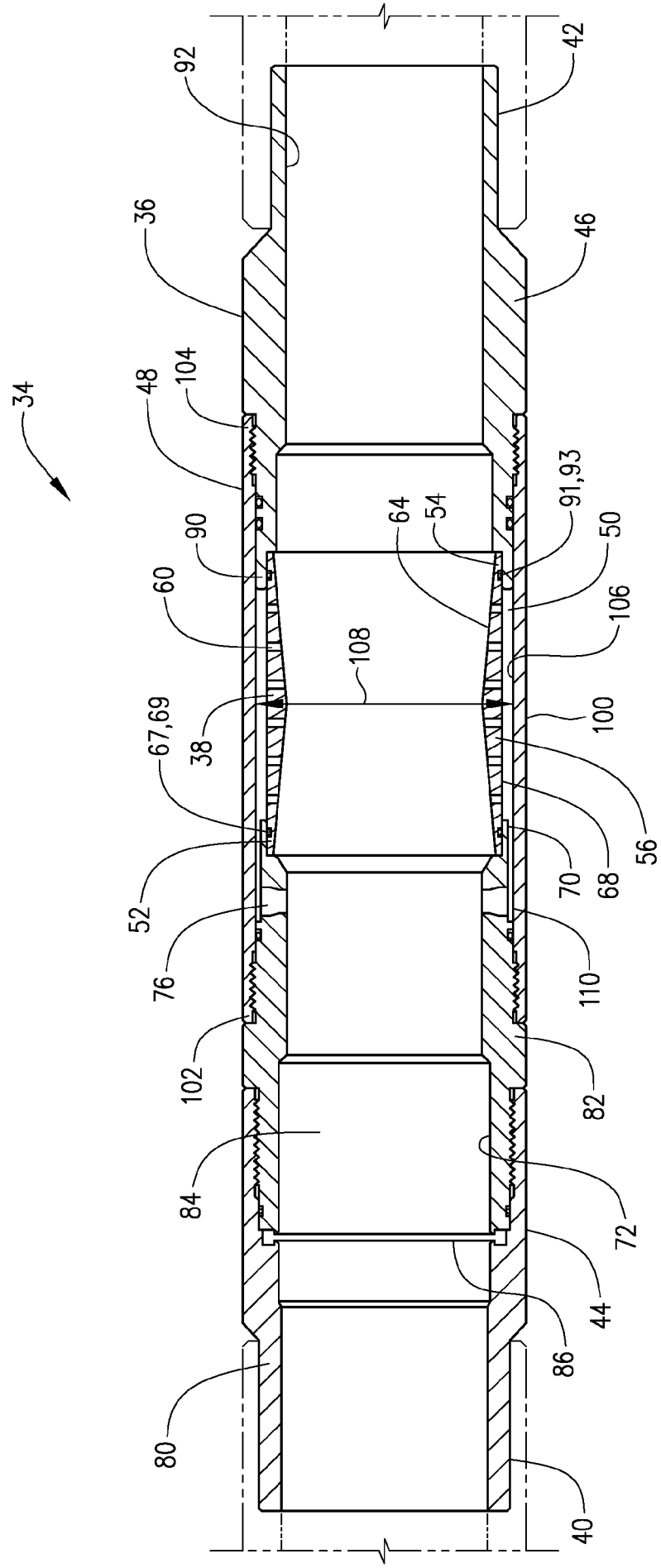
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FIG-3

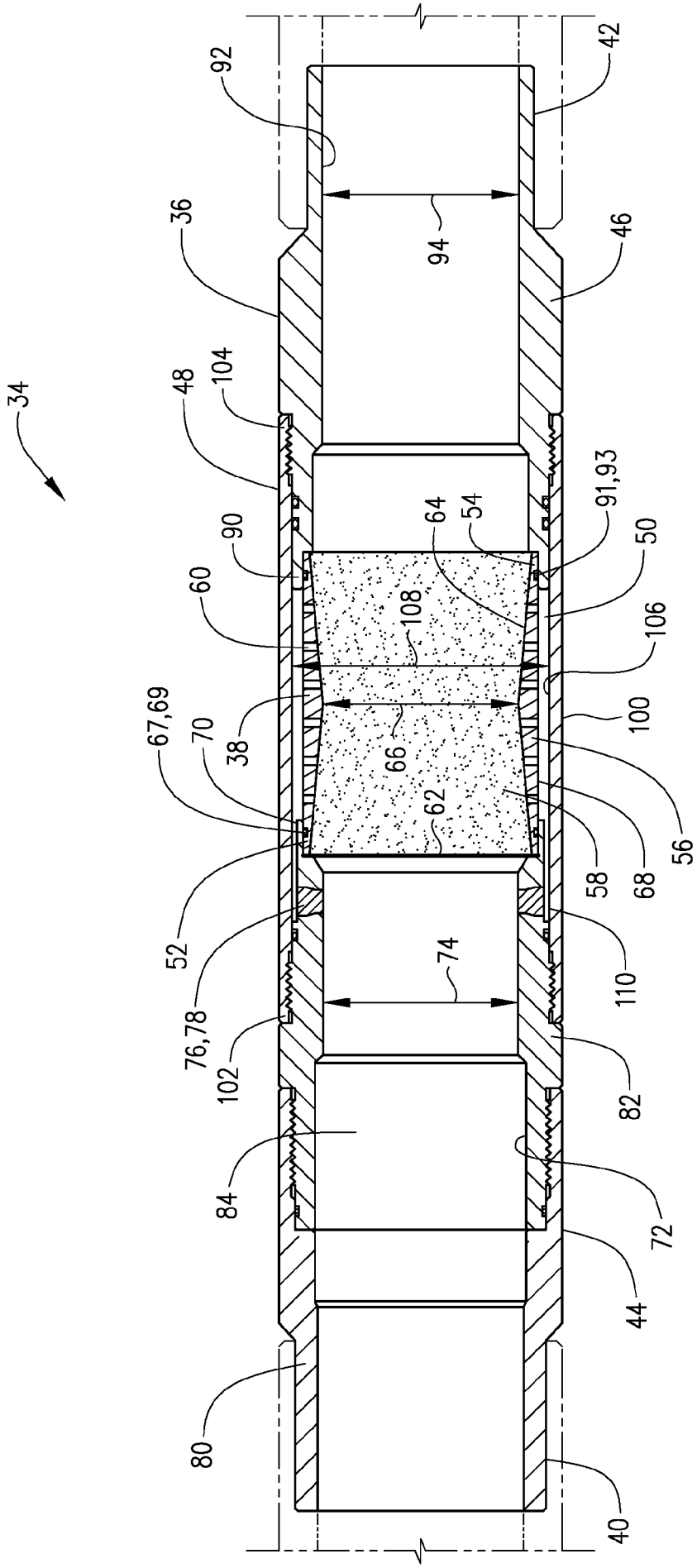
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FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/028508

A. CLASSIFICATION OF SUBJECT MATTER

E21B 7/20(2006.01)i, E21B 23/08(2006.01)i, E21B 17/01(2006.01)i, E21B 33/12(2006.01)i

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)
E21B 7/20; E21B 033/10; E21B 33/12; E21B 33/14; E21B 34/06; E21B 43/10; E21B 43/26; E21B 23/08; E21B 17/01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: buoyancy chamber, degradable plug, deviated, horizontal, drag, friction

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2018-0080308 A1 (KLX INC.) 22 March 2018 paragraphs [0022]-[0027] and figures 1-3	1-7,13,15-20
X	US 2014-0174757 A1 (FRIPP et al.) 26 June 2014 paragraphs [0013]-[0022] and figures 1, 2	8-12,14
Y		1-7,13,15-20
A	US 2016-0333658 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 17 November 2016 paragraphs [0017]-[0024] and figures 1, 2	1-20
A	US 2015-0107843 A1 (TALLEY et al.) 23 April 2015 paragraphs [0011], [0012], [0023], [0024] and figure 1	1-20
A	US 2003-0116324 A1 (DAWSON et al.) 26 June 2003 paragraphs [0018], [0019] and figure 1	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2020 (21.01.2020)	**21 January 2020 (21.01.2020)**

Name and mailing address of the ISA/KR
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/028508

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