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(54) **DOWNHOLE COMPLETION SYSTEM**

(57) The present invention relates to a downhole completion system for providing plug and abandonment of a well having a top, comprising a first well tubular metal structure arranged in a borehole, a barrier arranged inside or around the first well tubular metal structure, isolating a first volume from a second volume, the barrier having a top face facing the first volume and a bottom face facing the second volume, wherein the barrier has a temperature-activated bypass assembly comprising a bypass channel and an obstruction part, the bypass channel extending from the top face to the bottom face for providing fluid communication between the first volume and the second volume when the obstruction part is removed by being heated. The invention also relates to a downhole completion method for providing plug and abandonment of a downhole completion system.

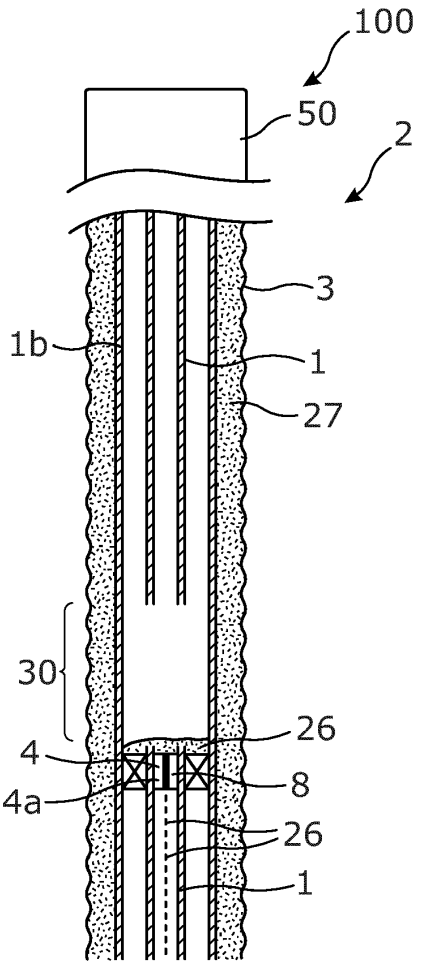

Fig. 1c

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Description

[0001] The present invention relates to a downhole completion system for providing plug and abandonment of a well having a top. The invention also relates to a downhole completion method for providing plug and abandonment of a downhole completion system.

[0002] When a well becomes less productive, and all attempts to improve the production of hydrocarbons from a reservoir have failed, the unproductive part of the well, if not the whole well, is plugged and abandoned. Plug and abandonment is an important part of the lifetime of a well. It is also a costly process since the authorities have high requirements for the plugging operations in order to ensure that the well does not pollute the environment.

[0003] When planning a well, costs for plug and abandonment have to be guaranteed so that the authorities are not left with a large bill to pay for the plug and abandonment of the well, and thus a well operator always seeks a less expensive solution for plug and abandonment so that less money is to be guaranteed.

[0004] In some cased wells, the well has parts where the casing or production tubing is surrounded by an annulus which has not been filled with cement during completion. Such cased wells may also have an annular space between the intermediate casing and the production casing in the upper part of the well. In such wells with an annulus or annular spaces, the plug and abandonment becomes complicated since when the casing is filled up with cement to plug the well, the cement cannot completely fill the annular space or the annulus, and there is a risk of a blowout through that annulus or annular space. In order to properly plug the well, a large rig is shipped to the well to pull the production casing out of the well. Such operation is thus, in the known solution, necessary and expensive.

[0005] In order to provide access to the annular space or annulus, the tubing can be removed by pyrotechnics or explosives, but this implies a risk to the remaining part of the completion that other barriers will be damaged and thus a too high risk that the plug and abandonment will leak.

[0006] 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 completion system capable of plugging also cased wells having an annulus between the casing/production tubing and the formation and/or having an annular space between the intermediate casing and the production casing without implying a risk to the remaining part of the completion.

[0007] 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 completion system for providing plug and abandonment of a well having a top , comprising:

- a first well tubular metal structure arranged in a borehole, and
- a barrier arranged inside or around the first well tubular metal structure, isolating a first volume from a second volume, the barrier having a top face facing the first volume and a bottom face facing the second volume,

wherein the barrier has a temperature-activated bypass assembly comprising a bypass channel and an obstruction part, the bypass channel extending from the top face to the bottom face for providing fluid communication between the first volume and the second volume when the obstruction part is removed by being heated.

[0008] By having a temperature-activated bypass assembly, the barrier functions as a conventional barrier during the production time of the well, and when needing to plug a part, if not all, of the well, the obstruction part is heated above a predetermined temperature so that the bypass channel is opened for fluid communication between the top face and the bottom face of the barrier, allowing the melted metal from the melted part of the first well tubular metal structure can flow down the well through the bypass channel. In that way, it is avoided that the heat is accumulated above the barrier, and the risk that such heat would damage other parts of the completion unintentionally is eliminated.

[0009] Thus, the barrier is pressure-tight during deployment and normal operations, but when heat is applied above the melting point of the obstruction part, the barrier melts, enabling a bypass between the top and the bottom part of the assembly.

[0010] The obstruction part is removable when heated above a predetermined temperature.

[0011] Further, the predetermined temperature may be above at least 600 °C, preferably above at least 1000 °C.

[0012] Moreover, the obstruction part may be meltable above at least 600 °C, preferably above at least 1000 °C.

[0013] Also, the temperature-activated bypass assembly may comprise a plurality of bypass channels.

[0014] In addition, each bypass channel may comprise an obstruction part.

[0015] Moreover, the obstruction part may be meltable above at least 600 °C, preferably above at least 1000 °C.

[0016] Also, the obstruction part may be arranged in the bypass channel or on top of the bypass channel.

[0017] Furthermore, the obstruction part may be a meltable, moldable or fusible obstruction part.

[0018] Moreover, the obstruction part may be an internal obstruction part or a part of the bypass channel.

[0019] In addition, the barrier may be a plug arranged inside the first well tubular metal structure so that the first and second volumes are arranged inside the first well tubular metal structure.

[0020] Further, the barrier may be an annular barrier arranged around the first well tubular metal structure between the first well tubular metal structure and a second well tubular metal structure or the borehole so that

the first and second volumes are annular volumes.

[0021] Also, the annular barrier may be a production packer.

[0022] Furthermore, the barrier may be a first barrier, and the downhole completion system may further comprise a second barrier, the first barrier being arranged to surround the first well tubular metal structure, and the second barrier being arranged inside the first well tubular metal structure.

[0023] Moreover, the second barrier may be a plug arranged inside the first well tubular metal structure, isolating a third volume above the plug from a fourth volume inside the first well tubular metal structure.

[0024] In addition, the second barrier may comprise a temperature-activated bypass assembly comprising a bypass channel and an obstruction part, the bypass channel extending from the top face to the bottom face for providing fluid communication in the bypass channel when the obstruction part is removed by being heated.

[0025] Further, the barrier may comprise bismuth material.

[0026] Also, the downhole completion system may further comprise a thermite composition arranged inside the first well tubular metal structure above the barrier.

[0027] Moreover, the downhole completion system may further comprise an ignitor for igniting the thermite composition.

[0028] In addition, the downhole completion system may further comprise cement arranged on top of the first barrier and/or the second barrier after igniting the thermite composition and melting part of the first well tubular metal structure.

[0029] Further, the annular barrier may comprise a tubular metal part for mounting as part of the first well tubular metal structure, the tubular metal part having an outer face, comprising:

- an expandable metal sleeve surrounding the tubular metal part and having an outer face facing towards the inner face of the borehole or the second well tubular metal structure and an inner face facing the outer face of the tubular metal part, and each end of the expandable metal sleeve being connected with the tubular metal part,
- an annular space between the expandable metal sleeve and the tubular metal part, and
- an expansion opening in the tubular metal part through which fluid may enter the annular space in order to expand the expandable metal sleeve.

[0030] Moreover, one of the ends of the expandable metal sleeve may be connected with the tubular metal part by means of a connection part, and the bypass channel may extend through the connection part, providing fluid communication across the annular barrier.

[0031] In addition, the tubular metal part may have an axial extension along the axial extension of the first well tubular metal structure.

[0032] Furthermore, the tubular metal part may have an inside being pressurised for expanding the expandable metal sleeve.

[0033] Moreover, the bypass channel may extend between the expandable metal sleeve and the tubular metal part for providing fluid communication past the annular barrier when the obstruction part is removed by being heated.

[0034] The invention also relates to a downhole completion method for providing plug and abandonment of a downhole completion system according to any of the proceeding claims, comprising:

- providing a barrier inside or around the first well tubular metal structure having a temperature-activated bypass assembly comprising a bypass channel and an obstruction part, the bypass channel extending from the top face to the bottom face for providing fluid communication between the first volume and the second volume when the obstruction part is removed by being heated,
- introducing thermite composition into the first well tubular metal structure,
- generating heat by igniting the thermite composition by means of an ignitor so that the thermite composition undergoes an exothermic reduction-oxidation (redox) reaction,
- removing the obstruction part by the heat,
- melting a part of the first well tubular metal structure,
- letting the melted metal from the first well tubular metal structure flow through the bypass channel and into the second volume, and
- introducing cement on top of the barrier.

[0035] 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. 1a shows a partly cross-sectional view of a downhole completion system having a temperature-activated bypass assembly,

Fig. 1b shows a partly cross-sectional view of the downhole completion system of Fig. 1a comprising a thermite composition,

Fig. 1c shows a partly cross-sectional view of the downhole completion system of Fig. 1b in which the thermite composition has melted part of the first well tubular metal structure,

Fig. 2a shows a partly cross-sectional view of another downhole completion system having a temperature-activated bypass assembly,

Fig. 2b shows a partly cross-sectional view of the

downhole completion system of Fig. 2a comprising a thermite composition,

Fig. 2c shows a partly cross-sectional view of the downhole completion system of Fig. 2b in which the thermite composition has melted part of the first well tubular metal structure,

Fig. 3 shows a partly cross-sectional view of yet another downhole completion system,

Fig. 4 shows a partly cross-sectional view of a barrier in the form of a plug having the temperature-activated bypass assembly, and

Fig. 5 shows a partly cross-sectional view of a barrier in the form of an annular barrier.

[0036] 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.

[0037] Fig. 1a shows a downhole completion system 100 for providing plug and abandonment of a well 2 having a top 50. The downhole completion system 100 comprises a first well tubular metal structure 1 arranged in a borehole 3, and a barrier 4 is arranged inside the first well tubular metal structure 1, isolating a first volume 101 from a second volume 102. The barrier 4 has a top face 5 facing the first volume 101 and a bottom face 6 facing the second volume 102. The barrier 4 has a temperature-activated bypass assembly 7 comprising a bypass channel 8 and an obstruction part 9. The bypass channel 8 is shown, even though it extends inside the barrier 4, for illustrative purpose only. The bypass channel 8 extends from the top face 5 to the bottom face 6 for providing fluid communication between the first volume 101 and the second volume 102 when the obstruction part 9 is removed by being heated. In Figs. 1a-1d, the barrier 4 is a plug 4a arranged inside the first well tubular metal structure 1 so that the first and second volumes 101, 102 are arranged inside the first well tubular metal structure 1. The first well tubular metal structure 1 is arranged at least partly inside a second well tubular metal structure 1b, and a conventional production packer is arranged between the first and second well tubular metal structures 1, 1b, creating an annular space therebetween. The second well tubular metal structure 1b is arranged in the borehole 3, and cement 27 is arranged therebetween.

[0038] Thus, when the temperature is increased by heating, the obstruction part 9 of the temperature-activated bypass assembly 7 is melted and flows down the bypass channel 8, creating fluid communication inside the bypass channel 8 from the top face 5 to the bottom face 6. The obstruction part 9 may also evaporate. The obstruction part 9 is meltable above at least 600 °C, preferably above at least 1000 °C.

[0039] When the well 2 needs to be plugged and abandoned, a thermite composition 11 is arranged inside the first well tubular metal structure 1 above the barrier 4 as shown in Fig. 1b, and an ignitor 12 for igniting the thermite composition 11 is activated. As the thermite composition 11 undergoes an exothermic reduction-oxidation (redox) reaction, heat is generated, melting a part 30 of the first well tubular metal structure 1 as shown in Fig. 1c and melting the obstruction part 9, providing fluid communication through the bypass channel 8. The melted metal 26 from the first well tubular metal structure 1 flows through the bypass channel 8 and into the second volume 102 instead of accumulating on top of the barrier 4. As the melted metal 26 flows through the bypass channel 8, heat is also removed from the area above the barrier 4, and the risk that the heat generated from the exothermic reaction will damage the second well tubular metal structure 1b and even the surrounding cement 27 is eliminated. After some time, the cement 27 can be introduced in the area above the barrier 4 where the part 30 has been removed, as shown in Fig. 1d, and the well 2 is sufficiently plugged. The removed part 30 of the first well tubular metal structure 1 may be more than 100 metres, preferably more than 200 metres, and the cement plug 27 provided on top of the barrier 4 as shown in Fig. 1d can be of equal length.

[0040] The obstruction part 9 is an internal obstruction part arranged in a top part of the bypass channel 8, but may also be arranged on top of the bypass channel 8. The obstruction part 9 is a meltable, moldable or fusible obstruction part. The obstruction part 9 may also be a part of the bypass channel 8 so that the bypass channel 8 and the obstruction part 9 are made as one monolithic whole.

[0041] The bypass channel 8 may be made as a tube of a temperature-resistant material such as ceramic or a similar material withstanding temperatures above 1300 °C.

[0042] The bypass channel 8 may be made as a tube of the same material as the obstruction part 9 and melting along with the obstruction part 9.

[0043] Fig. 2a shows another downhole completion system 100 where the barrier 4 is arranged around the first well tubular metal structure 1, isolating the first volume 101 from the second volume 102, and where the bypass channel 8 extends from the top face 5 to the bottom face 6 for providing fluid communication between the first volume 101 and the second volume 102 when the obstruction part 9 is removed by being heated.

[0044] The bypass channel 8 is shown, even though it extends inside the barrier 4, for illustrative purposes only. The barrier 4 is thus an annular barrier 4b arranged around the first well tubular metal structure 1 between the first well tubular metal structure 1 and the second well tubular metal structure 1b or the borehole 3 so that the first and second volumes 101, 102 are annular volumes. The annular barrier 4b may thus function as a production packer until the bypass channel 8 is used. The barrier 4 is a first barrier 4, and the downhole completion system 100

further comprises a second barrier 10, where the first barrier 4 is arranged to surround the first well tubular metal structure 1, and the second barrier 10 is arranged inside the first well tubular metal structure 1. The second barrier 10 is thus a plug 10a arranged inside the first well tubular metal structure 1, isolating a third volume 103 above the plug 10a from a fourth volume 104 below the plug inside the first well tubular metal structure 1. The second barrier 10 also comprises a temperature-activated bypass assembly 7b comprising a bypass channel 8b and the obstruction part 9b, where the bypass channel 8b extends from the top face 5 of the second barrier 10 to the bottom face 6 of the second barrier 10 for providing fluid communication in the bypass channel 8b of the second barrier 10 when the obstruction part 9b is removed by being heated, e.g. during the exothermic reaction or in a prior heating operation. The temperature-activated bypass assembly 7b of barriers comprises a plurality of bypass channels 8b, and each bypass channel 8b comprises an obstruction part.

[0045] In Fig. 2b, the thermite composition 11 is arranged inside the first well tubular metal structure 1 above the second barrier 10, and then the obstruction part 9b is removed by being heated, e.g. during the exothermic reaction or in a prior heating operation. In Fig. 2c, the part 30 of the first well tubular metal structure 1 is melted and flows through the bypass channels 8, 8b in both the first and second barriers 4, 10 as illustrated.

[0046] In Fig. 2d, the downhole completion system 100 further comprises the cement 27 arranged on top of the first and second barriers 4, 10 after igniting the thermite composition and melting part of the first well tubular metal structure 1.

[0047] The barrier 4, 10 may comprise bismuth material or alloy, so when heated the barrier 4, 10 decreases in volume for as long as the melted metal 26 passes the bypass channels 8, 8b, and after some time, the barrier 4, 10 is cooled down again, the bismuth material or alloy expands in volume, closing the bypass channel 8, 8b and increasing the barrier 4, 10 and the P&A (Plug and Abandonment) even further.

[0048] As shown in Fig. 3, the downhole completion system comprises a barrier 4 having the temperature-activated bypass assembly 7 comprising a bypass channel 8 and the obstruction part 9, where the bypass channel 8 extends from the top face 5 to the bottom face 6 for providing fluid communication between the first volume 101 and the second volume 102 when the obstruction part 9 is removed by being heated. The downhole completion system 100 further comprises a plug 10a, being a conventional plug, arranged inside the first well tubular metal structure 1, isolating a third volume 103 above the plug 10a from a fourth volume 104 below the plug 10a inside the first well tubular metal structure 1. Once the thermite composition 11 has been ignited, the part 30 of the first well tubular metal structure 1 melts, and the melted metal 26 flows radially outwards towards the barrier 4, 10, i.e. the annular barrier 4b, down the bypass channels 8 therein, and away from the first volume to the second volume 102.

[0049] The barrier in the form of a plug is illustrated in Fig. 4, where part of the plug is shown in a cross-sectional view in order to show the bypass channel 8 and the obstruction part 9 therein.

[0050] In Fig. 5, the annular barrier 4b comprises the tubular metal part 16 for mounting as part of the first well tubular metal structure 1 having a longitudinal extension 24. The tubular metal part 16 has an outer face 17, and the annular barrier 4b further comprises the expandable metal sleeve 18 surrounding the tubular metal part 16 and having an outer face 19 facing towards the inner face of the borehole 3 or the second well tubular metal structure 1b and an inner face 20 facing the outer face of the tubular metal part 16. Each end 31, 32 of the expandable metal sleeve 18 is connected with the tubular metal part 16, and an annular space 21 is created between the expandable metal sleeve 18 and the tubular metal part 16. The tubular metal part 16 has an expansion opening 22 through which fluid may enter the annular space 21 in order to expand the expandable metal sleeve 18. At least one of the ends 31, 32 of the expandable metal sleeve 18 is connected with the tubular metal part 16 by means of a connection part 41, 42, and the bypass channel 8 extends through the connection part 41, 42 and through the annular space 21 between the expandable metal sleeve 18 and the tubular metal part 16, providing fluid communication across the annular barrier 4b when the obstruction part 9 is removed by being heated. The tubular metal part 16 has an axial extension 23 along the axial extension 24 of the first well tubular metal structure 1. The tubular metal part 16 has an inside 25 being pressurised for expanding the expandable metal sleeve 18.

[0051] 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.

[0052] By "casing" or "well tubular metal structure" is meant any kind of pipe, tubing, tubular, liner, string, etc., used downhole in relation to oil or natural gas production.

[0053] Although the invention has been described above in connection with preferred embodiments of the invention, it will be evident to 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 completion system (100) for providing plug and abandonment of a well (2) having a top (50),

comprising:

- a first well tubular metal structure (1) arranged in a borehole (3), and
- a barrier (4) arranged inside or around the first well tubular metal structure, isolating a first volume (101) from a second volume (102), the barrier having a top face (5) facing the first volume and a bottom face (6) facing the second volume, wherein the barrier has a temperature-activated bypass assembly (7) comprising a bypass channel (8) and an obstruction part (9), the bypass channel extending from the top face to the bottom face for providing fluid communication between the first volume and the second volume when the obstruction part is removed by being heated.

2. A downhole completion system according to claim 1, wherein the obstruction part is arranged in the bypass channel or on top of the bypass channel.

3. A downhole completion system according to claim 1 or 2, wherein the obstruction part is a meltable, moldable or fusible obstruction part.

4. A downhole completion system according to any of the preceding, wherein the obstruction part is an internal obstruction part or a part of the bypass channel.

5. A downhole completion system according to any of the preceding claims, wherein the barrier is a plug (4a) arranged inside the first well tubular metal structure so that the first and second volumes are arranged inside the first well tubular metal structure.

6. A downhole completion system according to any of claims 1-5, wherein the barrier is an annular barrier (4b) arranged around the first well tubular metal structure between the first well tubular metal structure and a second well tubular metal structure 1b or the borehole so that the first and second volumes are annular volumes.

7. A downhole completion system according to claim 6, wherein the annular barrier is a production packer.

8. A downhole completion system according to any of the preceding claims, wherein the barrier is a first barrier (4), and the downhole completion system further comprises a second barrier (10), the first barrier being arranged to surround the first well tubular metal structure, and the second barrier being arranged inside the first well tubular metal structure.

9. A downhole completion system according to claim 8, wherein the second barrier (10) is a plug (10a) arranged inside the first well tubular metal structure, isolating a third volume (103) above the plug from a fourth volume (104) below the plug inside the first well tubular metal structure.

10. A downhole completion system according to claim 8 or 9, wherein the second barrier comprises a temperature-activated bypass assembly (7b) comprising a bypass channel (8b) and an obstruction part (9b), the bypass channel extending from the top face to the bottom face for providing fluid communication in the bypass channel when the obstruction part is removed by being heated.

11. A downhole completion system according to any of the preceding claims, wherein the barrier comprises bismuth material.

12. A downhole completion system according to any of the preceding claims, further comprising a thermite composition (11) arranged inside the first well tubular metal structure above the barrier.

13. A downhole completion system according to claim 12, further comprising an ignitor (12) for igniting the thermite composition.

14. A downhole completion system according to claim 12 or 13, further comprising cement arranged on top of the first barrier and/or the second barrier after igniting the thermite composition and melting part of the first well tubular metal structure.

15. A downhole completion system according to claim 6 or 7, wherein the annular barrier comprises a tubular metal part (16) for mounting as part of the first well tubular metal structure, the tubular metal part having an outer face (17), comprising

- an expandable metal sleeve (18) surrounding the tubular metal part and having an outer face (19) facing towards the inner face of the borehole or the second well tubular metal structure and an inner face (20) facing the outer face of the tubular metal part, and each end (31, 32) of the expandable metal sleeve being connected with the tubular metal part,
- an annular space (21) between the expandable metal sleeve and the tubular metal part, and
- an expansion opening (22) in the tubular metal part through which fluid may enter the annular space in order to expand the expandable metal sleeve.

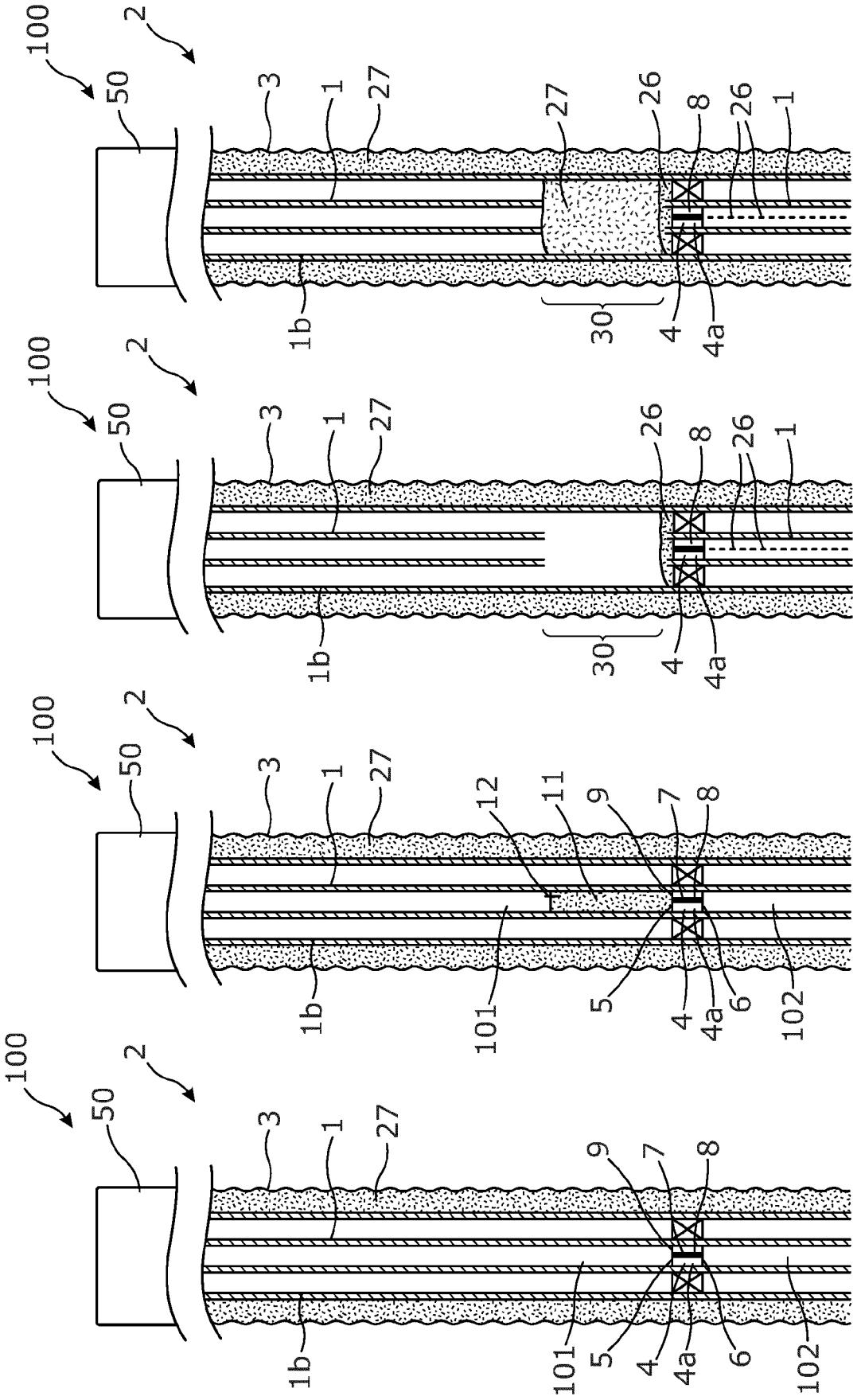

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

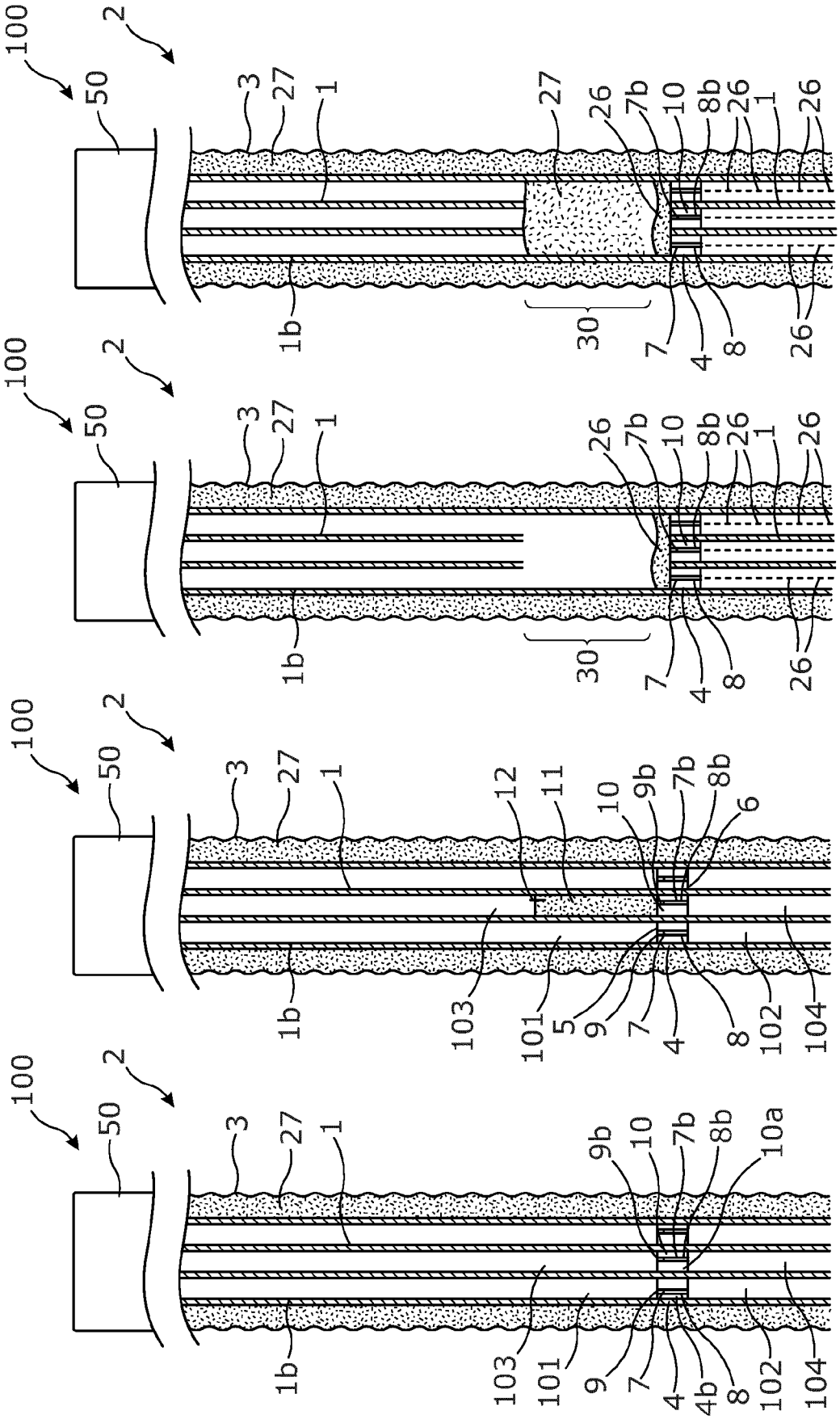

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

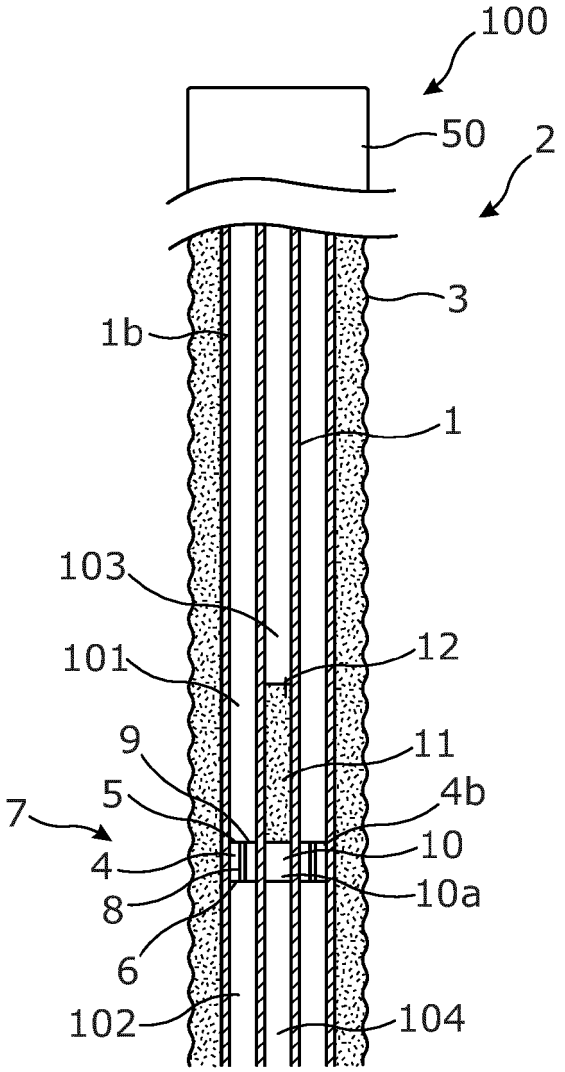

Fig. 3

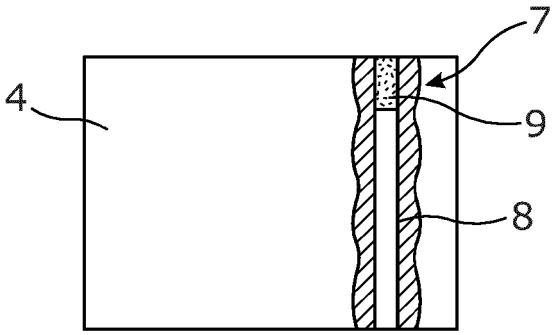

Fig. 4

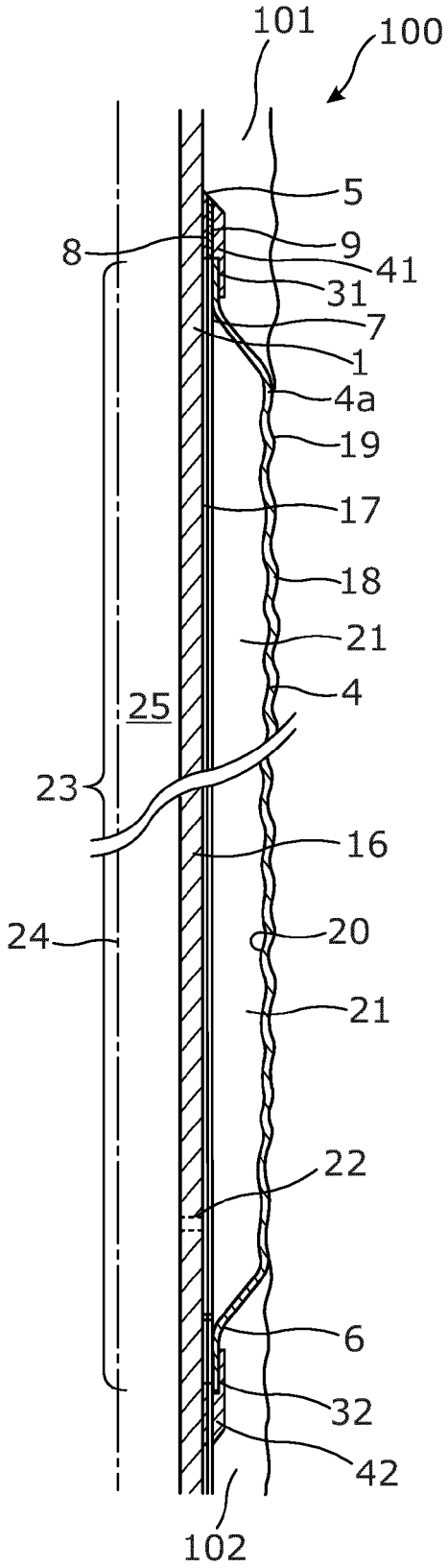

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 19 0430

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	US 11 536 111 B2 (BISN TEC LTD [GB]) 27 December 2022 (2022-12-27) * figures 1-2 *	1-3,5, 11-13	INV. E21B33/12 E21B33/134
X	WO 2018/215786 A1 (BISN TEC LTD [GB]) 29 November 2018 (2018-11-29) * figures 1-2 *	1-3,5, 11-13	
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TECHNICAL FIELDS SEARCHED (IPC)

E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 January 2024	Beran, Jiri

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 19 0430

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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