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(54) A downhole fluid injection assembly and a downhole casing system

(57) A downhole fluid injection assembly (1) for injecting a treatment fluid (5) into an annulus (3) surrounding a well casing (2), the downhole fluid injection assembly having a longitudinal axis (6) and comprising: - a tubular part (7) for mounting as part of the well casing, - a sleeve (8) having a first end (9) and a second end (10), the sleeve surrounding the tubular part, and the first and second ends being connected with the tubular part and defining a space (11), - an aperture (12) arranged in the tubular part for bringing an inside (14) of the tubular part into fluid communication with the space, and - openings (15) arranged in the sleeve for bringing the space into fluid communication with the annulus, wherein the aperture is arranged opposite the sleeve.

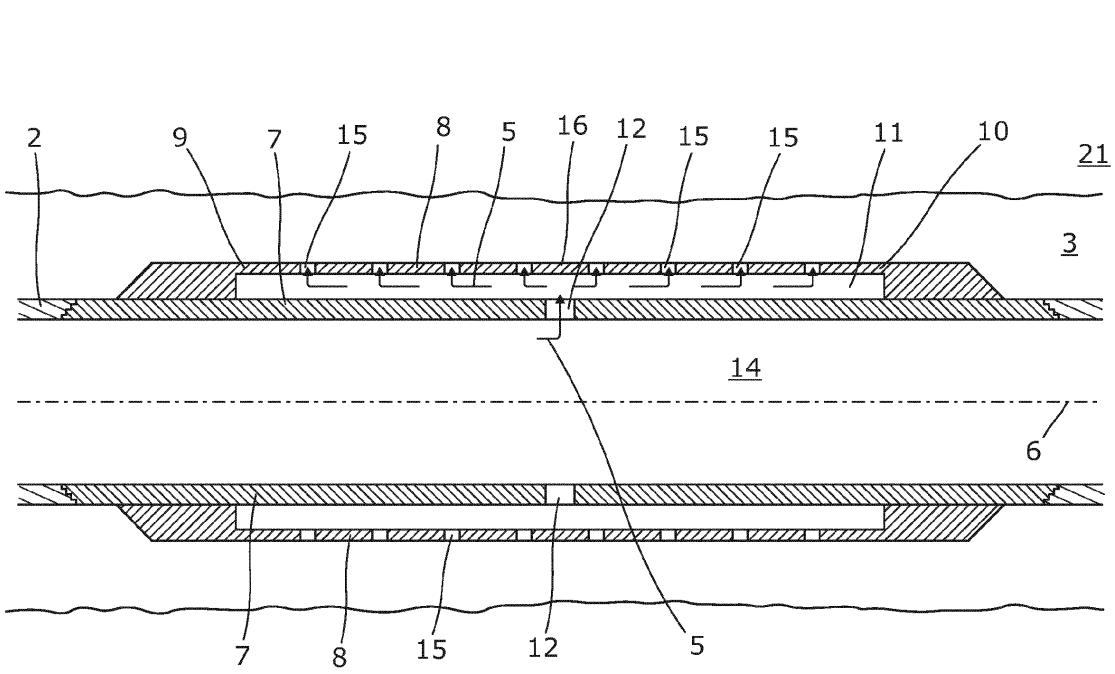

Fig. 1

EP 2 740 887 A1

Description

Field of the invention

[0001] The present invention relates to a downhole fluid injection assembly for injecting a treatment fluid into an annulus surrounding a well casing. The invention furthermore relates to a downhole casing system and a method for treating an annulus by means of the fluid injection assembly.

Background art

[0002] After completing a well, the hydrocarbon-containing fluid in the reservoir does not always flow out of the reservoir at a sufficiently high volume rate, and the formation is therefore treated to increase the volume rate of the fluid. One way of treating the formation is by injecting acid through the openings in the casing at a high velocity. However, this is not always sufficient to obtain the desired flow, and there is therefore a need for a more efficient way of treating the formation.

Summary of the invention

[0003] 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 fluid injection system which provides a more efficient way of treating a formation.

[0004] 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 fluid injection assembly for injecting a treatment fluid into an annulus surrounding a well casing, the downhole fluid injection assembly having a longitudinal axis and comprising:

- a tubular part for mounting as part of the well casing,
- a sleeve having a first end and a second end, the sleeve surrounding the tubular part, and the first and second ends being connected with the tubular part and defining a space,
- an aperture arranged in the tubular part for bringing an inside of the tubular part into fluid communication with the space, and
- openings arranged in the sleeve for bringing the space into fluid communication with the annulus,

wherein the aperture is arranged opposite the sleeve.

[0005] In an embodiment, the sleeve may comprise a first opening and a second opening, the first opening being arranged closest to one of the ends and being larger than the second opening.

[0006] Furthermore, the sleeve may comprise a sleeve section arranged between two adjacent openings, and the aperture may be arranged opposite the sleeve section.

[0007] Moreover, the sleeve section may taper radially towards the aperture.

[0008] Also, the sleeve section may have at least one flow channel.

[0009] The downhole fluid injection assembly may further comprise a spacing element arranged in the space.

[0010] The spacing element is arranged in the space to minimise the risk of the sleeve being pressed up against the tubular part so as to ensure that the space stays intact to enable the treatment fluid to flow in the space.

[0011] In one embodiment, the spacing element may taper towards at least one of the ends of the sleeve.

[0012] Further, a plurality of spacing elements may be arranged along the first axis.

[0013] Additionally, a plurality of spacing elements may be arranged in the space around a circumferential extension thereof.

[0014] Moreover, the spacing element may comprise a helical string or rod wound around the tubular part within the space.

[0015] Also, the spacing elements may be a plurality of balls arranged in the space.

[0016] In addition, the spacing elements and/or the balls may be made of a corrodible material.

[0017] Furthermore, the openings may be arranged in a predetermined pattern.

[0018] Moreover, the openings may be arranged with a mutual distance along the longitudinal axis.

[0019] Additionally, the mutual distance may decrease towards at least one of the ends of the sleeve.

[0020] In an embodiment, the distance between the openings may decrease towards at least one of the ends of the sleeve.

[0021] In another embodiment, each opening may have a size which increases towards at least one of the ends of the sleeve.

[0022] In yet another embodiment, the opening closest to one of the ends may be at least 20% larger than the opening closest to the aperture, preferably at least 30%, and more preferably at least 40%.

[0023] Furthermore, a plurality of apertures may be arranged opposite the sleeve.

[0024] Also, the apertures may have a mutual distance along the longitudinal axis.

[0025] In addition, the aperture may be closable.

[0026] Further, the treatment fluid may be an acid or a mixture of acids.

[0027] Additionally, the sleeve may be made of an acid-resistant metal.

[0028] The present relation further relates to a downhole casing system comprising:

- a casing string,
- a fluid injection assembly according to any of the preceding claims, the tubular part thereof being mounted as part of the casing string, and

- a first and a second annular barrier each mounted as part of the casing string on opposite sides of the fluid injection assembly.

[0029] The downhole casing system may further comprise an inflow section mounted as part of the casing string between the first and second annular barriers.

[0030] Finally, the present invention relates to a method for treating an annulus by means of the fluid injection assembly as described above, the method comprising the steps of:

- isolating the annulus surrounding the fluid injection assembly by means of the annular barriers,
- letting treatment fluid into the space via the aperture,
- distributing the treatment fluid along the longitudinal axis of the fluid injection assembly, and
- letting the treatment fluid out through the openings in order to treat the annulus.

[0031] The method may further comprise the step of corroding the corrodible spacing element or balls in the space.

Brief description of the drawings

[0032] 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 downhole fluid injection assembly according to the present invention,

Fig. 2 shows a cross-sectional view of part of another downhole fluid injection assembly,

Fig. 3 shows a cross-sectional view of part of yet another downhole fluid injection assembly,

Fig. 4 shows a cross-sectional view of part of a sleeve section of another downhole fluid injection assembly,

Fig. 5 shows a cross-sectional view of part of another embodiment of the sleeve section of another downhole fluid injection assembly,

Fig. 6 shows a perspective view of a downhole fluid injection assembly in which part of the sleeve has been removed for illustrative purposes,

Fig. 7 shows a cross-sectional view of part of yet another downhole fluid injection assembly, and

Fig. 8 shows a cross-sectional view of a downhole casing system according to the invention.

[0033] 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

[0034] Fig. 1 shows a downhole fluid injection assembly 1 for injecting a treatment fluid 5, illustrated by arrows, into an annulus 3 surrounding a well casing 2. When completing the well, the production zones are subsequently treated with acid injected from the casing through an aperture 12 arranged therein, through the downhole fluid injection assembly 1 and into the annulus. The downhole fluid injection assembly comprises a tubular part 7 for mounting as part of the well casing and a sleeve 8 surrounding the tubular part. The sleeve has a first end 9 and a second end 10 and is at its ends connected with the tubular part, thereby defining an annular space 11 between the sleeve and the tubular part. The annular space is brought into fluid communication with an inside 14 of the tubular part by means of the aperture 12 arranged in the tubular part. The sleeve has openings 15 arranged in the sleeve for bringing the annular space into fluid communication with the annulus. The aperture 12 is arranged opposite the sleeve 8, and the space 11 and the openings 15 in the sleeve distribute the treatment fluid 5 in such a way that only part of the treatment fluid is injected directly into the annulus 3 opposite the aperture, corroding merely one large hole in the formation 21. By the present invention, the treatment fluid 5 is distributed along a longitudinal axis of the assembly and along a circumference of the sleeve 8. Thus, the fluid 5 is distributed over a wider range than in prior art injection systems, thereby corroding a wider area of the formation 21.

[0035] The sleeve 8 has an increased thickness at its ends 9, 10 for fastening the sleeve to an outside the tubular part 7 while providing the annular space 11 opposite the thinner part of the sleeve. The ends 9, 10 of the sleeve 8 may be welded onto the tubular part 7 or tightly fitted around the tubular part. The annular space 11 functions as a distributing channel distributing the treatment fluid in such a way that it flows through all the openings 15 in the sleeve 8, as illustrated by arrows in Fig. 1. The treatment fluid 5 is thus distributed along the longitudinal axis and along the circumference of the sleeve 8. The sleeve 8 comprises a sleeve section 16 arranged between two adjacent openings 15, and the aperture 12 is arranged opposite the sleeve section so as to ensure that the treatment fluid 5 is not distributed directly into an opening but is forced towards both ends 9, 10 of the sleeve.

[0036] In Fig. 2, a first opening 15a of the sleeve 8 arranged closest to one of the ends is larger than a second opening 15b of the sleeve to be able to distribute the treatment fluid even better than the sleeve of Fig. 1. The pressure drops across the annular space, and by providing the sleeve 8 with larger openings near its ends, more treatment fluid is let out of the first opening. The pressure

of the treatment fluid near he ends of the sleeve 8 is lower than that of the fluid injected through the openings closer to the aperture 12. Thus, by varying the size of the openings, substantially the same volume flow of the treatment fluid entering through all openings in the sleeve is obtained. The diameter d_1 of the first opening 15a is larger than the diameter d_2 of the second opening 15b and so forth. Thus, each opening 15a, 15b has a size d which increases towards at least one of the ends of the sleeve 8. The opening 15 closest to one of the ends may be at least 20% larger than the opening closest to the aperture 12, preferably at least 30%, and more preferably at least 40%. The openings 15 arranged between the opening closest to the one end and the opening closest to the aperture vary in size between the size of the first opening 15a and the opening 15e closest to the aperture.

[0037] As shown in Fig. 3, the openings 15 are arranged with a mutual distance x along the longitudinal axis 6. The distance between the openings 15 decreases towards at least one of the ends of the sleeve 8 so that the openings are arranged more closely near the ends of the sleeve than near the aperture 12 of the tubular part 7. Even though not shown, the distance between a couple of adjacent openings may be the same, e.g. near the ends of the sleeve, while the distance between the next openings increases towards the aperture 12.

[0038] The sleeve section 16 of Fig. 4 tapers radially towards the aperture 12, and the sleeve 8 is thus thicker opposite the aperture. By having a tapering sleeve section, the treatment fluid is diverted from flowing radially to flowing axially towards the ends of the sleeve 8. Before initiating the injection process, the sleeve section 16 may be pushed radially inwards during installation of the downhole fluid injection assembly 1 so that the sleeve section 16 covers the aperture 12. The sleeve section 16 is therefore provided with flow channels 20 enabling the treatment fluid to push the sleeve section radially outwards and to initiate distribution of the treatment fluid along the annular space 11. In Fig. 4, the sleeve section 16 has a round shape when seen in cross-section, and in Fig. 5 showing another embodiment of the sleeve section, the sleeve section has a more triangular cross-sectional shape. The flow channel 20 in the embodiments of Figs. 4 and 5 has an inlet 22 arranged opposite the aperture 12 and outlets 23 facing the ends of the sleeve 8.

[0039] In order to prevent the sleeve from bulging radially inwards during insertion of the downhole fluid injection assembly 1, the downhole fluid injection assembly further comprises a spacing element 17 arranged in the annular space 11, as shown in Fig. 6. Thus, the spacing element 17 is arranged in the annular space 11 to minimise the risk of the sleeve being pressed up against the tubular part 7 and to ensure that the annular space stays intact to enable the treatment fluid to flow in the annular space. The downhole fluid injection assembly 1 is shown with the sleeve 8 partly removed to make the spacing elements 17 visible. Thus, the sleeve covers the spacing elements 17 and the apertures 12, and the spacing elements 17 is fastened to an outer face 24 of the tubular part 7 extending along the longitudinal axis of the downhole fluid injection assembly 1. As can be seen, the sleeve comprises a plurality of openings 15 arranged in a predetermined pattern.

[0040] In one embodiment, the spacing element 17 may taper towards at least one of the ends of the sleeve, and one spacing element extends from the sleeve section 16 towards the one end of the sleeve while another spacing element extends from the sleeve section 16 towards the other end of the sleeve. Thus, there is no spacing element 17 opposite the apertures, and the treatment fluid can therefore be distributed along the annular part of the space and flow in through all channels provided by the spacing elements.

[0041] The spacing element 17 may also be a helical string or rod wound around the tubular part 7 within the space 11.

[0042] In Fig. 7, the downhole fluid injection assembly 1 comprises a plurality of balls 18 arranged in the annular space 11. The balls 18 function as spacing elements in that they prevent the sleeve 8 from bulging radially inwards. The spacing elements 17 and/or the balls 18 are made of a corrodible material, such as aluminium, but may also be made of a ceramic material. By having the spacing elements 17 and/or the balls 18 made of a corrodible material, the acid corrodes the spacing elements 17 and/or the balls 18, allowing the fluid to flow freely in the space 11. Thus, the pressure is no longer decreased as much as when the spacing elements 17 and/or the balls 18 are still in the space 11.

[0043] In Fig. 7, the tubular part 7 comprises a plurality of apertures 12 arranged opposite the sleeve 8. The apertures 12 have a mutual distance along the longitudinal axis 6. The apertures are closable by means of a sliding sleeve 26 sliding in a groove 27 in the tubular part 7. Before or after the treatment process, i.e. the injection, the downhole fluid injection assembly 1 can be closed off, e.g. while pressurising the casing for inflating/expanding other components, such as a packer or an annular barrier. Furthermore, the sleeve 8 is fastened to the tubular part 7 by means of two connection parts 28. The sleeve 8 may be fastened in the connection parts 28 by means of a threaded or welded connection.

[0044] When the treatment fluid 5 is acid, the sleeve 8 and the tubular part 7 may be made of an acid-resistant metal.

[0045] Fig. 8 shows a downhole casing system 100 comprising a casing string 2, the downhole fluid injection assembly 1 described above and a first and a second annular barrier 50 each mounted as part of the casing string on opposite sides of the fluid injection assembly enclosing a production zone. The downhole casing system 100 further comprises an inflow section 60 mounted as part of the casing string between the first and second annular barriers for letting hydrocarbon-containing fluid into the casing after the treatment of the formation has ended. The inflow section 60 comprises a screen or a

filtering element ensuring that only oil and gas is let into the casing. After passing the screen or filter, the hydrocarbon-containing fluid is let into inflow channels, out through a valve 61 and into the casing. The annular barriers comprise en expandable sleeve which, prior to injection of treatment fluid, is expanded, thereby isolating the annulus surrounding the fluid injection assembly 1. Then, the treatment fluid is let into the annular space of the downhole fluid injection assembly 1 via the aperture 12 in the tubular part 7 and is distributed along the longitudinal axis of the fluid injection assembly and let out through the openings 15 to treat the annulus.

[0046] By 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.

[0047] By treatment fluid is meant any kind of fluid for treating the formation or reservoir to help the hydrocarbon-containing fluid, such as oil or gas, flow easier. The treament fluid may be any kind of acid, such as HCl, H_2S or H_2SO_4 or any combination thereof. The treatment fluid may also comprise proppants.

[0048] By a casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0049] 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 fluid injection assembly (1) for injecting a treatment fluid (5) into an annulus (3) surrounding a well casing (2), the downhole fluid injection assembly having a longitudinal axis (6) and comprising:

- a tubular part (7) for mounting as part of the well casing,
- a sleeve (8) having a first end (9) and a second end (10), the sleeve surrounding the tubular part, and the first and second ends being connected with the tubular part and defining a space (11),
- an aperture (12) arranged in the tubular part for bringing an inside (14) of the tubular part into fluid communication with the space, and
- openings (15) arranged in the sleeve for bringing the space into fluid communication with the annulus,

wherein the aperture is arranged opposite the sleeve.

2. A downhole fluid injection assembly according to claim 1, wherein the sleeve comprises a first opening (15a) and a second opening (15b), the first opening being arranged closest to one of the ends and being larger than the second opening.

3. A downhole fluid injection assembly according to claim(s) 1 and/or 2, wherein the sleeve comprises a sleeve section (16) arranged between two adjacent openings and the aperture is arranged opposite the sleeve section.

4. A downhole fluid injection assembly according to claim 3, wherein the sleeve section tapers radially towards the aperture.

5. A downhole fluid injection assembly according to any of the preceding claims, further comprising a spacing element (17) arranged in the space.

6. A downhole fluid injection assembly according to claim 5, wherein the spacing element tapers towards at least one of the ends of the sleeve.

7. A downhole fluid injection assembly according to claim 5, wherein the spacing elements are a plurality of balls (18) arranged in the space.

8. A downhole fluid injection assembly according any of the claims 5-7, wherein the spacing elements and/or the balls are made of a corrodible material.

9. A downhole fluid injection assembly according to any of the preceding claims, wherein the openings are arranged with a mutual distance (x) along the longitudinal axis, which distance decreases towards at least one of the ends of the sleeve.

10. A downhole fluid injection assembly according to any of the claims 1-8, wherein the distance between the openings decreases towards at least one of the ends of the sleeve.

11. A downhole fluid injection assembly according to any of the preceding claims, wherein each opening has a size (d) which increases towards at least one of the ends of the sleeve.

12. A downhole casing system (100) comprising:

- a casing string (2),
- a fluid injection assembly (1) according to any of the preceding claims, the tubular part thereof being mounted as part of the casing string, and
- a first and a second annular barrier (50) each mounted as part of the casing string on opposite

sides of the fluid injection assembly.

13. A downhole casing system according to claim 12, further comprising an inflow section (60) mounted as part of the casing string between the first and second annular barriers.

14. A method for treating an annulus by means of the fluid injection assembly according to any of the claims 1 to 11, the method comprising the steps of:

- isolating the annulus surrounding the fluid injection assembly by means of the annular barriers,
- letting treatment fluid into the space via the aperture,
- distributing the treatment fluid along the longitudinal axis of the fluid injection assembly, and
- letting the treatment fluid out through the openings in order to treat the annulus.

15. A method according to claim 14, further comprising the step of corroding the corrodible spacing element or balls in the space.

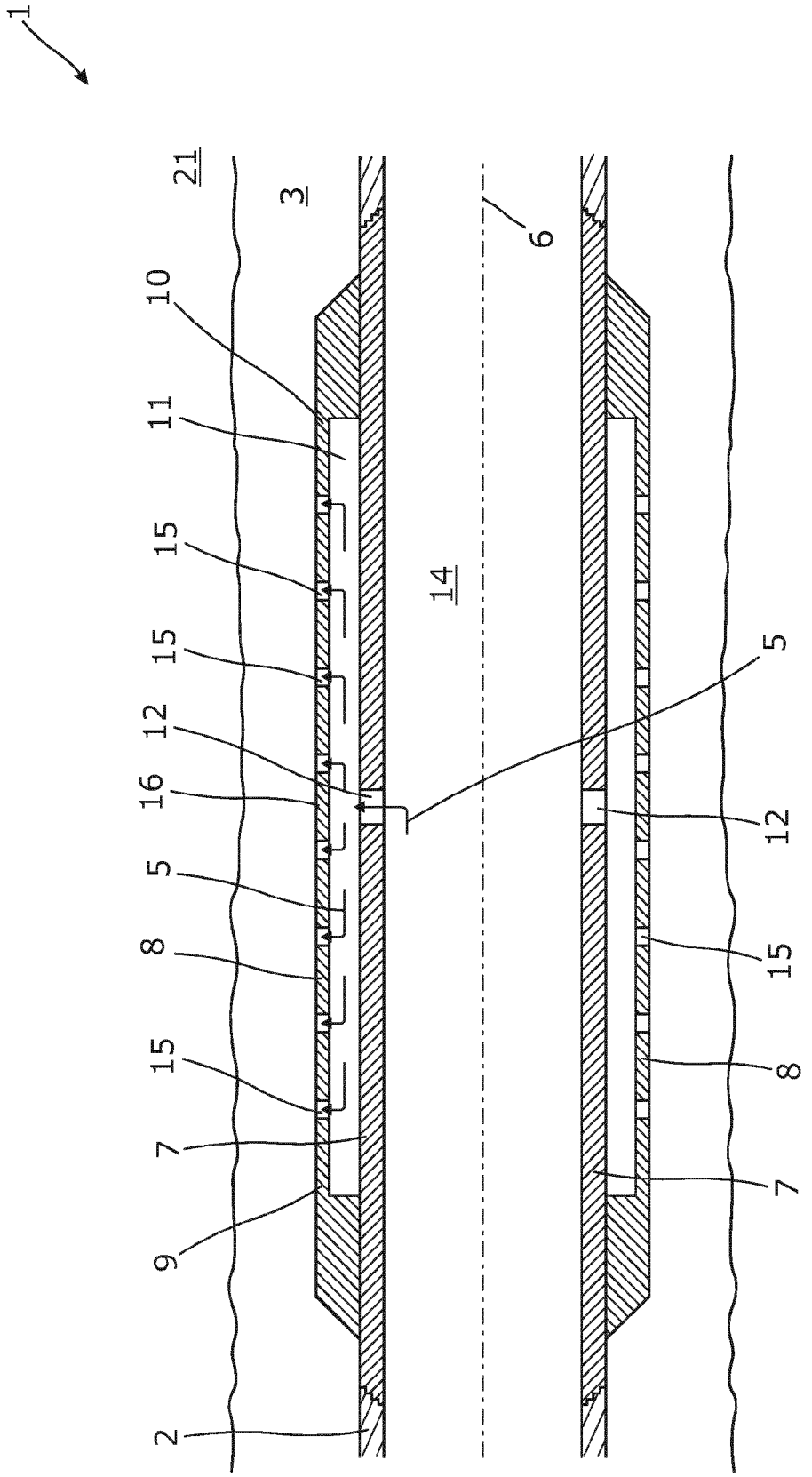

Fig. 1

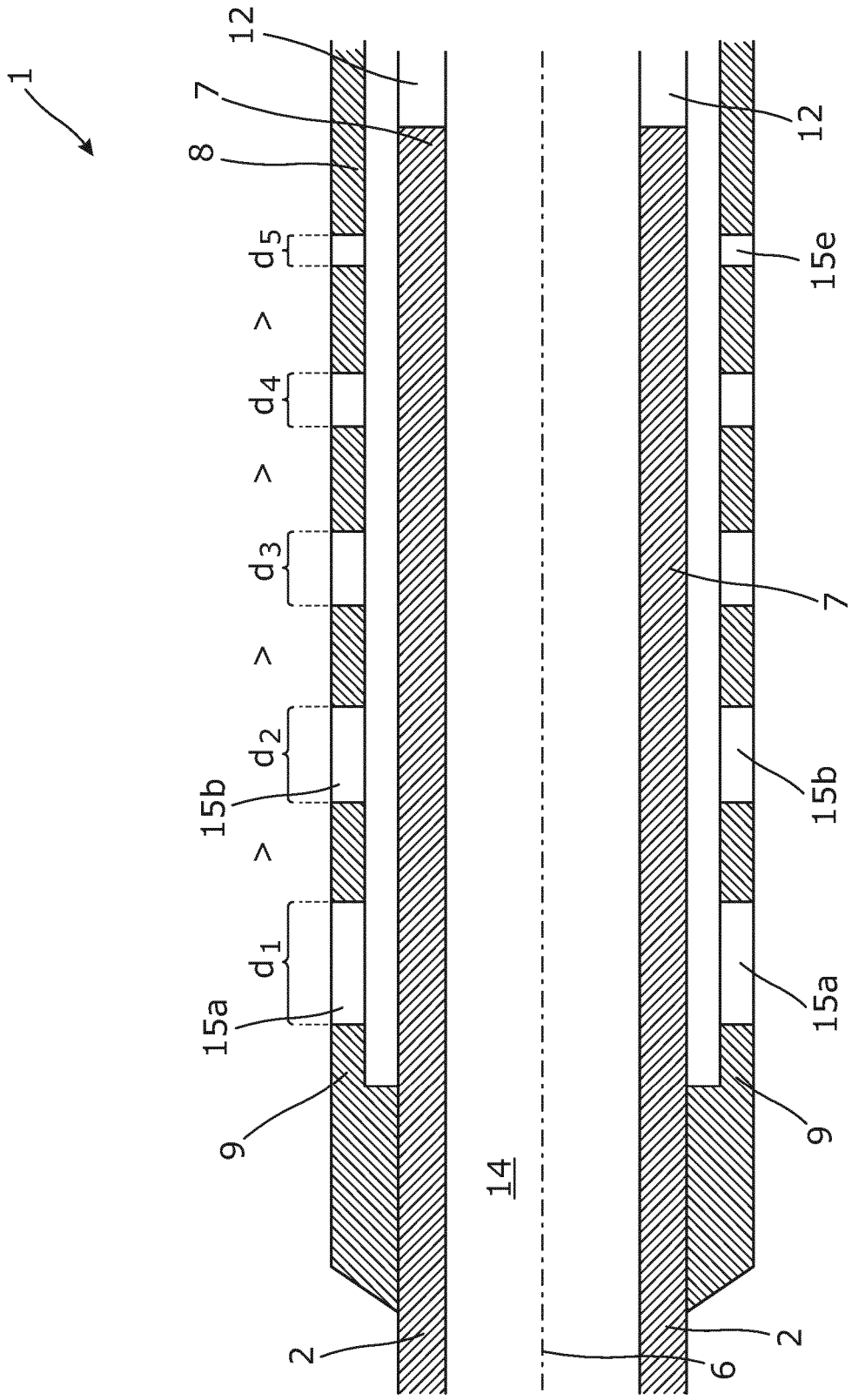

Fig. 2

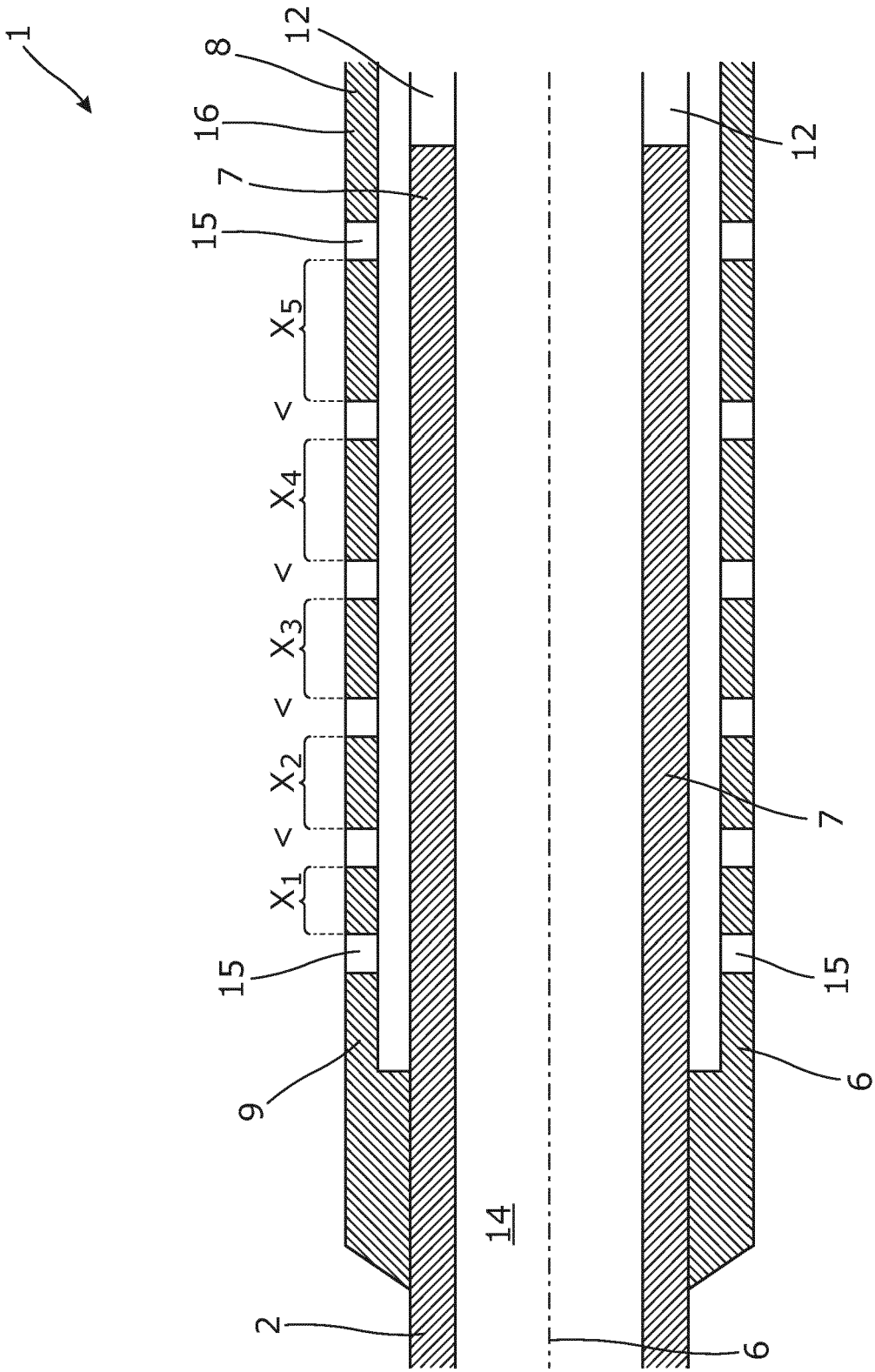

Fig. 3

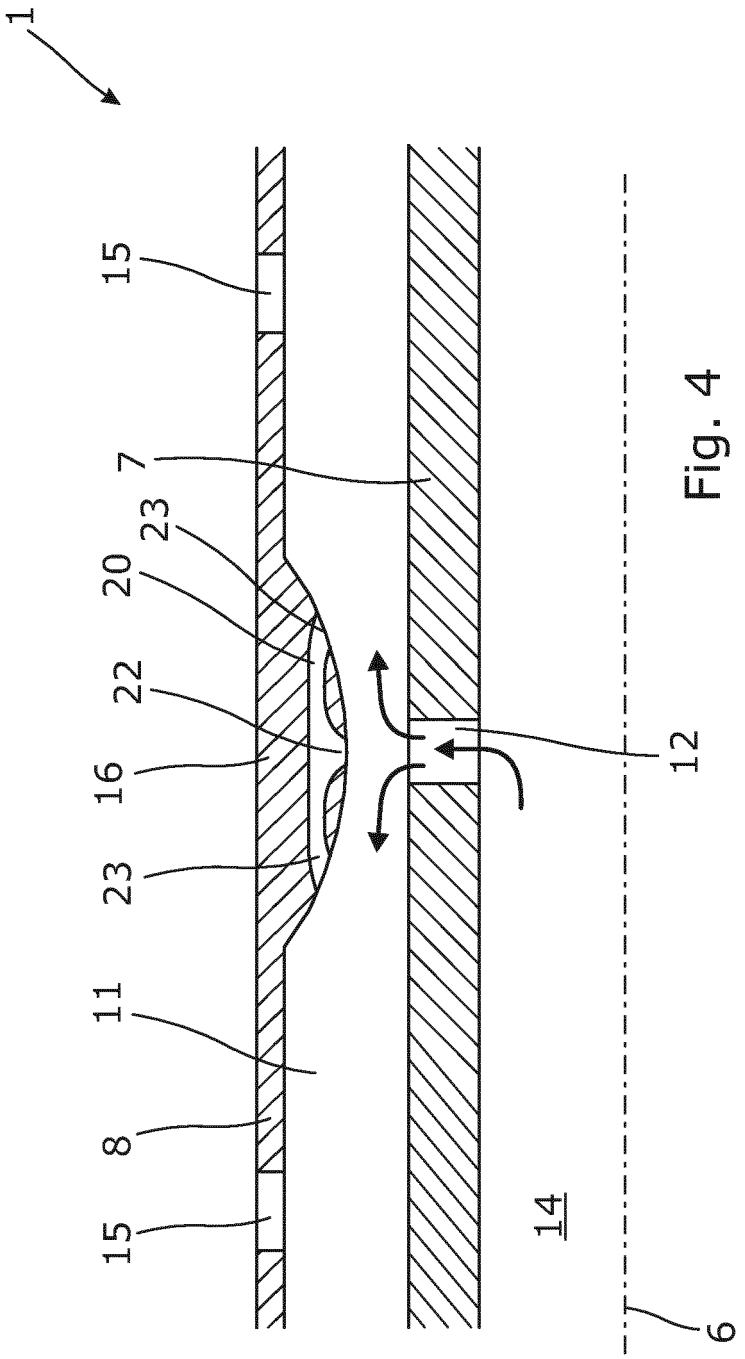

Fig. 4

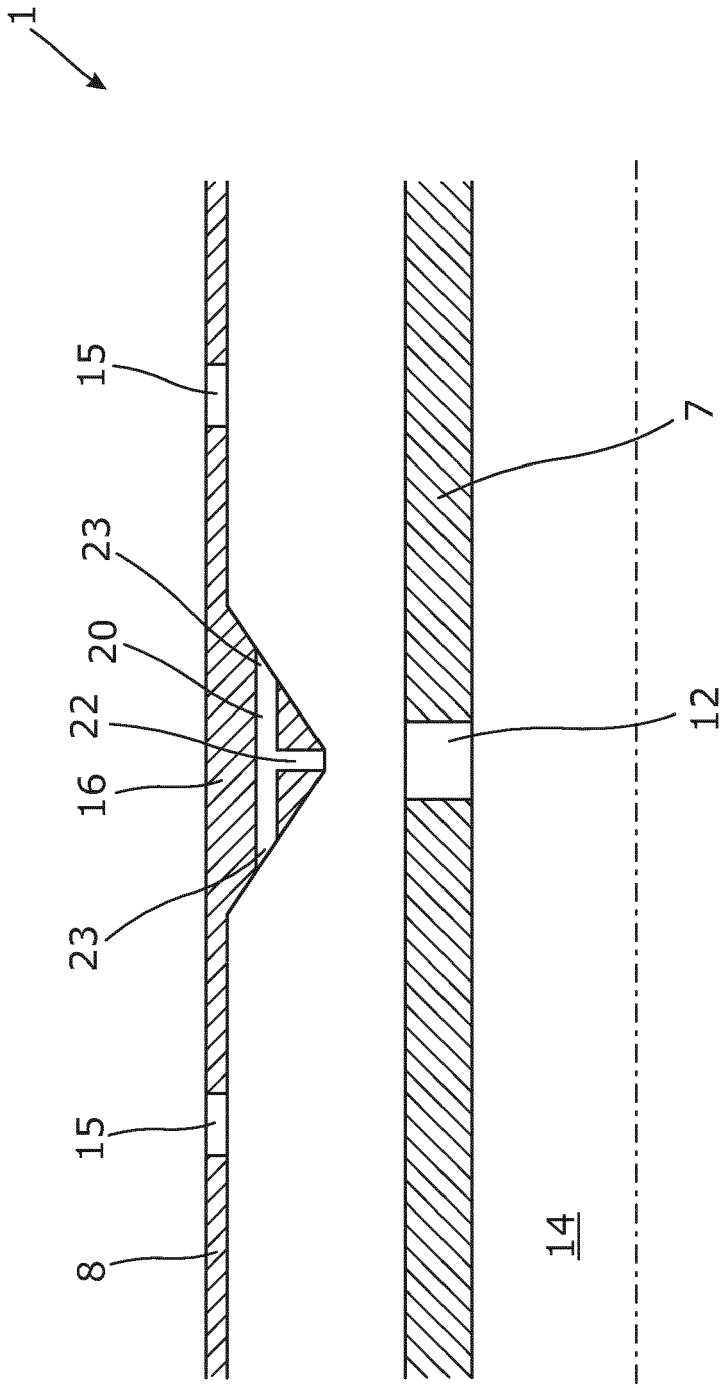

Fig. 5

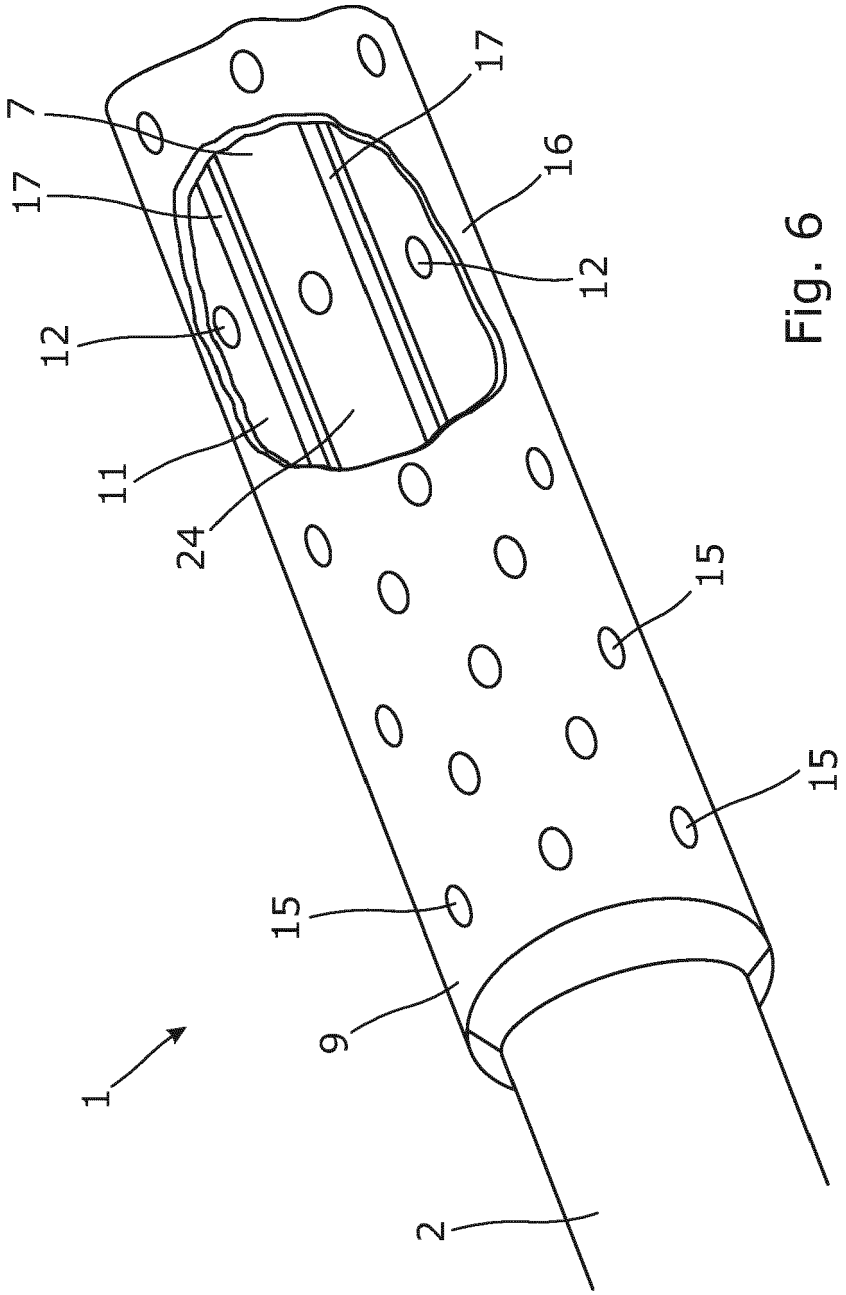

Fig. 6

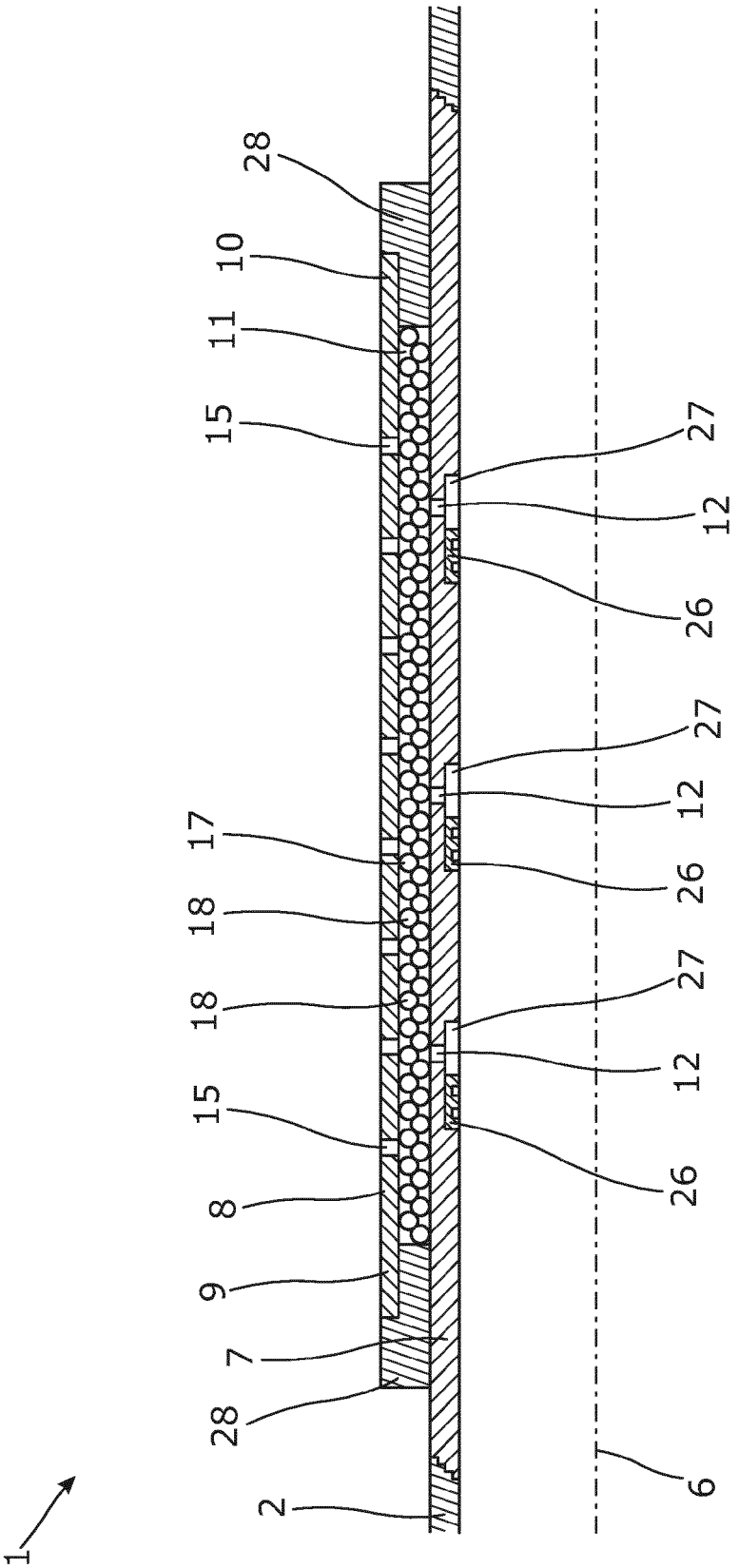

Fig. 7

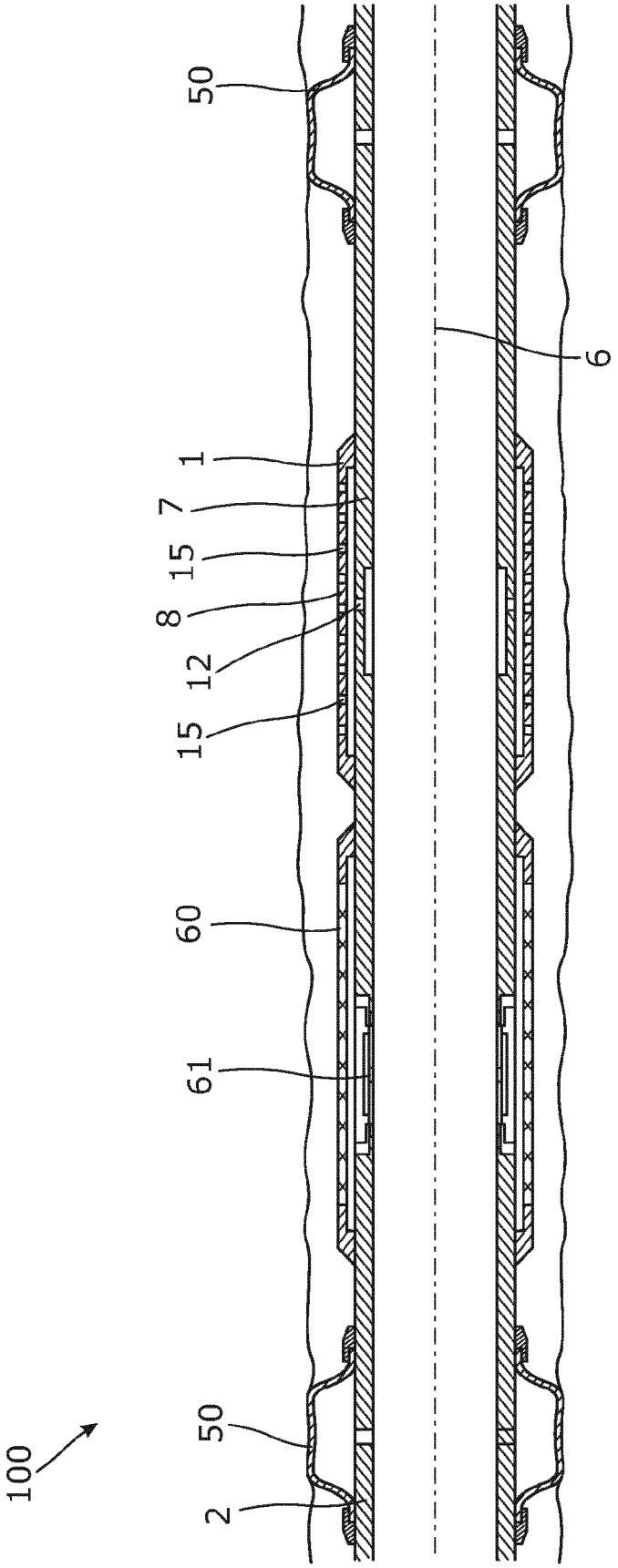

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 6093

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 2002/189809 A1 (NGUYEN PHILIP D [US] ET AL) 19 December 2002 (2002-12-19) * the whole document * * paragraph [0071]; figures 2,1,3 * -----	1,3,5,6, 12-14 2,9-11	INV. E21B43/04 E21B43/08 E21B43/26
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X	US 2003/221828 A1 (MCGREGOR RONALD W [US] ET AL) 4 December 2003 (2003-12-04) * paragraph [0039]; figure 2 * -----	1,2	
A	US 5 165 476 A (JONES LLOYD G [US]) 24 November 1992 (1992-11-24) * the whole document * * figure 2 * -----	1	
A	US 2003/066651 A1 (JOHNSON CRAIG DAVID [US]) 10 April 2003 (2003-04-10) * paragraph [0039]; figure 11 * -----	2	

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
The Hague	2 May 2013	van Berlo, André

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 12 19 6093

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-3, 5, 6, 9-14

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 12 19 6093

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-3, 5, 6, 9-14

   Downhole fluid injection assembly

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2. claim: 4

   Tapering sleeve section

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3. claim: 7

   Plurality of balls as spacing elements

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4. claim: 8

   Corrodible spacing element

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 19 6093

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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02-05-2013

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82