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(54) **Downhole stimulation system**

(57) The present invention relates to a system for stimulating production. The system has first and second inflatable packers (6) for isolating a production zone (101), a sliding sleeve valve (17) arranged between the two packers, and a downhole tool (20) for moving the sleeve from the closed position to the open position, the tool comprising an inflatable device (22) and a key for engaging a profile in the sliding sleeve. In operation the inflatable device (22) is set downstream of the inflation orifice (15) of the lower packer, the well tubular (4) is pressurised, the tool (20) is moved downstream with keys

engaged in the profile forcing the sliding sleeve from the closed position to the open position. With the inflatable device set in that position the interior space of the lower packer is in fluid communication with the production zone (101). In this way, when treatment fluid is injected into the production zone through opening (19), the pressure between production zone and packer is equalised thereby preventing the packer from collapsing because of the pressure difference between production zone and packer becoming too large.

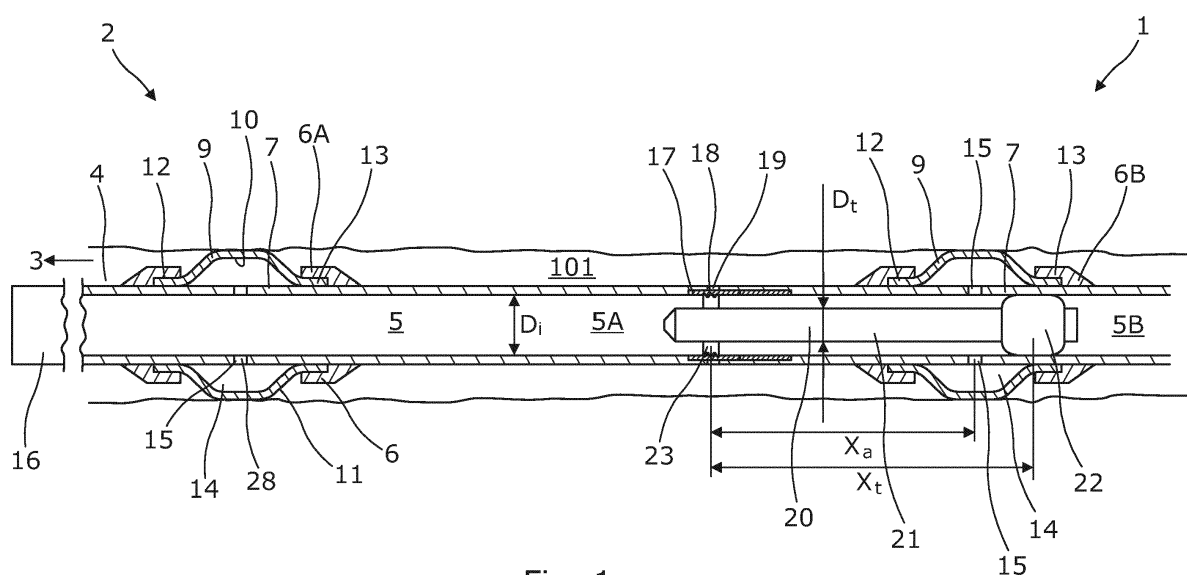


Fig. 1

Description

Field of the invention

[0001] The present invention relates to a downhole stimulation system for stimulating production of fluid from a well. The present invention further relates to a downhole stimulation method for stimulating production of fluid from a well by using the downhole stimulation system according to the present invention.

Background art

[0002] One of the last steps for completing a well and bringing in it into production is to expand expandable sleeves of annular barriers to isolate a production zone, and then the formation in the production zone is fractured in order to increase reservoir contact. The fracturing operation is performed by opening the frac ports and ejecting fluid out through the ports. However, when doing so there is a risk of the pressure in the production zone increasing more than the pressure within the annular barriers, and the annular barriers may therefore collapse if the pressure difference becomes too large.

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 downhole stimulation system decreasing the collapse risk of the annular barrier while stimulating the well.

[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 stimulation system for stimulating production of fluid from a well having a top, comprising:

- a well tubular structure having an inside and an inner diameter,
- a first annular barrier and a second annular barrier for isolating a production zone, the first annular barrier being arranged closest to the top of the well, each annular barrier comprising:
 - a tubular metal part for mounting as part of the well tubular structure, the tubular metal part having an outer face,
 - an expandable sleeve surrounding the tubular metal part and having an inner face facing the tubular metal part and an outer face facing the wall of the borehole, each end of the expandable sleeve being connected with the tubular metal part, and
 - an annular space between the inner face of the expandable sleeve and the tubular metal part,

and

- an aperture arranged in the tubular metal part for letting fluid into the space,

- 5 - a pump adapted to provide pressurised fluid down the well tubular structure in order to stimulate the well,
- a sliding sleeve having at least one profile and arranged between two annular barriers and having a closed position and an open position in which an opening in the well tubular structure provides fluid communication between the inside of the well tubular structure and the production zone, the profile of the sliding sleeve being positioned at a first distance from the aperture of the annular space, and
- 10 - a downhole tool for bringing the sliding sleeve from the closed position to the open position, comprising:
 - a tool body,
 - an inflatable device adapted to be inflated in the well tubular structure to divide the well tubular structure into a first part and a second part, and
 - at least one key engaging the profile so that when the inflatable device has been inflated and the first part of the well tubular structure is pressurised, the tool is moved downstream and the key drags in the profile, forcing the sliding sleeve from the closed position to the open position,

30 wherein the inflatable device is arranged downstream of the aperture of the second annular barrier so that the annular space of the second annular barrier is in fluid communication with the first part of the well tubular structure when the inflatable device is inflated.

35 **[0005]** Also, the expandable sleeve may be a metal sleeve.

[0006] The downhole stimulation system as described above may further comprise a third annular barrier arranged closer to the top than the first annular barrier and a fourth annular barrier arranged further away from the top than the second annular barrier, the inflatable device being inflated between the second and fourth annular barrier.

40 **[0007]** Moreover, the tool may comprise several keys which may be arranged at a distance from each other.

[0008] In addition, the profile may be a circumferential groove.

[0009] Further, the sliding sleeve may be a self-closing sleeve.

50 **[0010]** Additionally, the sliding sleeve may comprise a spring for closing the sleeve.

[0011] Also, a valve may be arranged in the aperture of at least one of the annular barriers.

[0012] Said valve may be a one-way valve.

55 **[0013]** A diameter of tool body may be smaller than an inner diameter of the well tubular structure defining a fluid passage between the tool and the well tubular structure.

[0014] Moreover, the tool may comprise an inflation

pump for inflating the inflatable device.

[0015] Furthermore, the tool may comprise a motor for driving the inflation pump.

[0016] In addition, the expandable sleeve may have a fracturing device arranged on the outer face of the expandable sleeve for fracturing the formation when the outer face is pressed against the wall of the borehole.

[0017] Also, the sliding sleeve and/or the aperture may comprise an identification tag.

[0018] Further, the tool may comprise a detection unit for detecting the sliding sleeve and/or the aperture.

[0019] Said detection unit may comprise a tag identification means for detecting the sliding sleeve and/or the aperture.

[0020] Moreover, the detection unit may be adapted to detect the profile of the sliding sleeve and the aperture of the annular barrier in order to detect the first distance between the profile and the aperture.

[0021] Furthermore, the tool may comprise an activation means for activating the inflation pump so that the inflatable device is inflated, and for stopping the inflation pump so that the inflatable device is deflated.

[0022] The key of the tool may be arranged at a second distance from the inflatable device of the tool, the second distance being equal to or larger than the first distance.

[0023] Also, said second distance may be adjustable.

[0024] Additionally, the tool body may comprise a telescopic body arranged between the key and the inflatable device, the telescopic body being adapted to adjust the second distance in relation to the detected first distance.

[0025] The downhole stimulation system as described above may further comprise an activation sensor adapted to cause the inflatable device to deflate when a condition in the well changes.

[0026] Moreover, the tool may further comprise a detection sensor for detecting a condition of the well and/or the sleeve.

[0027] Further, the tool may comprise a communication unit for loading information from a reservoir sensor.

[0028] Also, the tool may further comprise a self-propelling means, such as a turbine or a propeller.

[0029] The well tubular structure may comprise a plurality of sliding sleeves, each sliding sleeve having an identification tag.

[0030] Furthermore, at least one of the annular barriers may have at least one intermediate sleeve between the expandable sleeve and the tubular part.

[0031] In addition, the expandable sleeve may comprise an opening.

[0032] Moreover, the tool may be wireless and may comprise a power supply.

[0033] Additionally, the tool may be connected and powered through a wireline.

[0034] The present invention also relates to a downhole stimulation method for stimulating production of fluid from a well by using the downhole stimulation system according to any of the preceding claims, comprising the

steps of:

- detecting the sliding sleeve,
- projecting the keys of the tool,
- engaging the profile of the sliding sleeve,
- inflating the inflatable device,
- pressuring the inside of the well tubular structure,
- moving the tool away from the top of the well, sliding the sleeve from a closed position to an open position, and
- letting pressurised fluid from the inside of the well tubular structure in through the aperture of the second annular barrier to equalise the pressure between the production zone and the annular space of the second annular barrier.

[0035] The downhole stimulation method as described above may further comprise the step of deflating the inflatable device when a predetermined pressure or sequence of pressures is/are reached.

[0036] Moreover, downhole stimulation method as described above may comprise the following steps:

- disengaging the profile so that the sliding sleeve moves into the closed position,
- moving the tool further away from the top of the well,
- detecting a second sliding sleeve,
- projecting the keys of the tool,
- engaging the profile of the second sliding sleeve,
- inflating the inflatable device,
- pressuring the inside of the well tubular structure,
- moving the tool away from the top of the well, sliding the second sliding sleeve from a closed position to an open position, and
- letting pressurised fluid from the inside of the well tubular structure in through the aperture of the fourth annular barrier to equalise the pressure between the production zone and the annular space of the fourth annular barrier.

Brief description of the drawings

[0037] 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 partly cross-sectional view of a downhole stimulation system for stimulating production of hydrocarbon-containing fluid from a well,

Fig. 2 shows a partly cross-sectional view of another downhole stimulation system,

Fig. 3 shows a tool for operating a sliding sleeve,

Fig. 4 shows a cross-sectional view of another sliding

sleeve,

Fig. 5 shows a partly cross-sectional view of another downhole stimulation system,

and

Fig. 6 shows another tool for operating a sliding sleeve.

[0038] 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

[0039] Fig. 1 shows a downhole stimulation system 1 for stimulating production of hydrocarbon-containing fluid from a well 2. The downhole stimulation system 1 comprises a well tubular structure 4 and a first annular barrier 6, 6A and a second annular barrier 6, 6B for isolating a production zone 101, the first annular barrier being arranged closest to a top of the well. Each annular barrier comprises a tubular metal part 7 mounted as part of the well tubular structure and an expandable sleeve 9 surrounding the tubular metal part and having an inner face 10 facing the tubular metal part and an outer face 11 facing the wall of the borehole. Each end 12, 13 of the expandable sleeve is connected with the tubular metal part, defining an annular space 14 between the inner face of the expandable sleeve and the tubular metal part. The annular barrier further comprises an aperture 15 arranged in the tubular metal part for letting fluid into the space.

[0040] The downhole stimulation system 1 comprises a pump 16 adapted to provide pressurised fluid down the well tubular structure in order to stimulate the well and may also be used for expanding the expandable sleeves of the annular barriers. The downhole stimulation system 1 further comprises a sliding sleeve 17 having at least one profile 18, and the sliding sleeve is arranged between two annular barriers and has a closed position and an open position. In the open position, the sliding sleeve allows fluid communication between the inside of the well tubular structure and the production zone through an opening 19 in the well tubular structure. The profile of the sliding sleeve is positioned at a first distance X_a from the aperture of the annular space,

[0041] In addition, the downhole stimulation system 1 comprises a downhole tool 20 for bringing the sliding sleeve from the closed position to the open position. The downhole tool 20 comprises a tool body 21, an inflatable device 22 adapted to be inflated in the well tubular structure to divide an inside 5 of the well tubular structure 4 into a first part 5A and a second part 5B. The tool further comprises at least one key 23 engaging the profile in the sliding sleeve, so that when the inflatable device has

been inflated and the first part of the well tubular structure is pressurised, the tool is moved downstream and the keys of the tool drag in the profile, forcing the sliding sleeve from the closed position to the open position. The inflatable device is arranged downstream of the aperture of the second annular barrier, so that the annular space of the second annular barrier is in fluid communication with the first part of the well tubular structure when the inflatable device is inflated. In this way, the pressurised fluid jetted out through the opening in the tubular structure is also able to flow from the inside of the well tubular structure in through the aperture of the second annular barrier and into the annular space to equalise the pressure between the production zone and the annular space of the second annular barrier. When fracturing the formation in order to gain more reservoir contact, pressurised fluid is jetted out through such opening in the well tubular structure. However, such increase in pressure in the production zone may compromise the isolation properties of the second annular barrier if the inflatable device is not located downstream of the aperture and thus further away from the top of the well than the aperture.

[0042] In order to stimulate a well, the sliding sleeve, through which the fracturing is to occur, is detected, and then the keys of the tool are projected to engage the profile of the sliding sleeve. Shortly thereafter or simultaneously, the inflatable device is inflated, and then the inside of the well tubular structure is pressurised, whereby the pressurised fluid in the well tubular structure applies pressure onto the inflatable device, moving the tool away from the top of the well, sliding the sleeve from a closed position to an open position and letting pressurised fluid from the inside of the well tubular structure in through the aperture of the second annular barrier to equalise the pressure between the production zone and the annular space of the second annular barrier. Subsequently, the inflatable device is deflated when a predetermined pressure or sequence of pressures is/are reached.

[0043] The profile of the sliding sleeve has circumferential grooves matching the profile of the keys, so that the keys are able to get a firm grip of the sliding sleeve. As can be seen in Fig. 1, the tool has a diameter D_t of the tool body which is smaller than an inner diameter D_i of the well tubular structure, defining a fluid passage between the tool and the well tubular structure. The expandable sleeve is a metal sleeve and may be expanded by letting pressurised fluid in through the aperture of the annular barrier.

[0044] A valve 28 may be arranged in the aperture 15 of the annular barrier as shown in Fig. 1, and the valve may be a one-way valve so that fluid is allowed into the annular space but unable to flow out of the space. When having a valve in the aperture, the expandable sleeve may be expanded by means of a compound which is arranged in the annular space and is decomposable when subjected to heat generating gas, which expands the sleeve.

[0045] In Fig. 2, the downhole system further comprises a third annular barrier 6C arranged closer to the top than the first annular barrier and a fourth annular barrier 6D arranged further away from the top than the second annular barrier, the inflatable device being inflated between the second and fourth annular barrier. By having two annular barriers arranged on either side of the production zone, a double barrier is provided, so that if one barrier fails, the other will still provide the seal.

[0046] In Fig. 3, the tool comprises an inflation pump 29 for inflating the inflatable device 22. The tool further comprises a motor 31 for driving the inflation pump 29. The tool of Fig. 3 is wireless and is powered by a power supply 58, such as a rechargeable battery. The keys of the tool are arranged at a second distance X_t from the inflatable device of the tool and as shown in Fig. 3 the second distance X_t is greater than the first distance. The second distance may also be equal to the first distance in another embodiment. The keys are projectable keys 23 forming a piston part 32 which is slidable in a cavity 33 and projected by hydraulic fluid from the pump through channels 34, compressing a spring 43, which ensures that the keys return to their retracted position when no longer required, or if the power is cut off. The keys have a profile 42 matching the profile in the sliding sleeve. The pump further inflates the inflatable device 22 through channels 35. When deflated, the fluid leaves the inflatable device 22 through other channels 36. The tool further comprises a detection unit 37 for detecting the sliding sleeve. The detection unit 37 comprises a tag identification means 38 for detecting the sliding sleeve. The tool further comprises an activation means 39 for activating the inflatable device to both inflate and deflate when e.g. the fracturing operation has ended. The activation means 39 comprise an activation sensor 40 adapted to cause the inflatable device to deflate when a condition in the well changes, such as when a predetermined pressure is reached.

[0047] The tool further comprises a detection sensor 27 for detecting a condition of the well and/or the sliding sleeve, so that the operation is terminated if the conditions vary too much from the expected conditions. The tool also comprises a communication unit 47 for loading information from a reservoir sensor if requested.

[0048] In order to be able to propel itself up again, the tool comprises a self-propelling means 48, such as a turbine or a propeller. So when descending, a battery in the tool is charged in order to be ready to be used when emerging at the top of the well again. The tool further comprises a fishing neck 49 so that the tool is easily retrievable from the well.

[0049] In Fig. 4, the sliding sleeve is a self-closing sleeve comprising a spring 51 for closing the sleeve. When the tool moves the sliding sleeve from a closed position to an open position, the spring in a cylinder housing 52 is compressed through the piston 53. The sliding sleeve further comprises an identification tag 54 so that one sliding sleeve is recognisable from another. Thus,

the well tubular structure may comprise a plurality of sliding sleeves, each sliding sleeve having an identification tag 54.

[0050] Some of the annular barriers may have at least one intermediate sleeve 55 between the expandable sleeve and the tubular part. When having the intermediate sleeve 55, the expandable sleeve comprises an opening for equalising the pressure between the reservoir and the inside of the annular barrier, in that the intermediate sleeve seals between the reservoir and the inside of the well tubular structure.

[0051] In Fig. 5, the pump pressurising the fluid for e.g. fracturing is submerged into the well tubular structure and powered through a wireline 56 so that only part of the well tubular structure is pressurised. The tool may be wireless as shown in Figs. 1-3 or be powered through a wireline 56 as shown in Fig. 5.

[0052] In Fig. 6, the tool comprises a detection unit 37 for detecting the sliding sleeve and the aperture in order to determine the first distance X_a . Thus, the detection unit comprises a tag identification means 38 for detecting the profile of the sliding sleeve and the aperture unit of the annular barrier and thus detecting the first distance between the profile and the aperture. The keys of the tool are arranged at a second distance from the inflatable device of the tool, and the second distance is adjustable due to the fact that the tool body comprises a length adjustable section 61 arranged between the key and the inflatable device. The adjustable section 61 is adapted to adjust the second distance in relation to the detected first distance and in Fig. 6, the length adjustable section is a telescopic section. If the first distance between the profile of the sliding sleeve and the aperture is known before entering the well, the length of the tool need not to be adjustable and the length adjustable section 61 can be dispensed with. However, if the first distance between the profile of the sliding sleeve and the aperture is not known before entering the well, or if the first distance seems to be different from what appears in the completion diagram, the tool length, and thus the second distance, is adjusted so as to fit the respective sliding sleeve. When the stimulation operation through one sliding sleeve has ended, the tool disengages the profile, so that the sliding sleeve moves into the closed position and the tool moves further away from the top of the well. Then a second sliding sleeve is detected, the keys of the tool are projected to engage the profile of the second sliding sleeve, and the inflatable device is inflated. Then the inside of the well tubular structure is pressurised, moving the tool away from the top of the well and sliding the second sliding sleeve from a closed position to an open position and letting pressurised fluid from the inside of the well tubular structure in through the aperture of the adjacent annular barrier, e.g. a fourth annular barrier, equalising the pressure between the production zone and the annular space of the fourth annular barrier.

[0053] 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.

[0054] By a casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0055] In the event that the tool is not submergible all the way into the casing, a downhole tractor can be used to push the tool all the way into position in the well. The downhole tractor may have projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0056] 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 stimulation system (1) for stimulating production of fluid from a well (2) having a top (3), comprising:

- a well tubular structure (4) having an inside (5) and an inner diameter (D_i),
- a first annular barrier (6, 6A) and a second annular barrier (6, 6B) for isolating a production zone (101), the first annular barrier being arranged closest to the top of the well, each annular barrier comprising:

- a tubular metal part (7) for mounting as part of the well tubular structure, the tubular metal part having an outer face (8),
- an expandable sleeve (9) surrounding the tubular metal part and having an inner face (10) facing the tubular metal part and an outer face (11) facing the wall of the borehole, each end (12, 13) of the expandable sleeve being connected with the tubular metal part, and
- an annular space (14) between the inner face of the expandable sleeve and the tubular metal part, and
- an aperture (15) arranged in the tubular metal part for letting fluid into the space,

- a pump (16) adapted to provide pressurised

fluid down the well tubular structure in order to stimulate the well,

- a sliding sleeve (17) having at least one profile (18) and arranged between two annular barriers and having a closed position and an open position in which an opening (19) in the well tubular structure provides fluid communication between the inside of the well tubular structure and the production zone, the profile of the sliding sleeve being positioned at a first distance (X_a) from the aperture of the annular space, and
- a downhole tool (20) for bringing the sliding sleeve from the closed position to the open position, comprising:

- a tool body (21),
- an inflatable device (22) adapted to be inflated in the well tubular structure to divide the well tubular structure into a first part (5A) and a second part (5B), and
- at least one key (23) engaging the profile so that when the inflatable device has been inflated and the first part of the well tubular structure is pressurised, the tool is moved downstream and the key drags in the profile, forcing the sliding sleeve from the closed position to the open position, wherein the inflatable device is arranged downstream of the aperture of the second annular barrier so that the annular space of the second annular barrier is in fluid communication with the first part of the well tubular structure when the inflatable device is inflated.

2. A downhole stimulation system according to claim 1, further comprising a third annular barrier (6C) arranged closer to the top than the first annular barrier and a fourth annular barrier (6D) arranged further away from the top than the second annular barrier, the inflatable device being inflated between the second and fourth annular barrier.

3. A downhole stimulation system according to claim 1 or 2, wherein the sliding sleeve is a self-closing sleeve.

4. A downhole stimulation system according to claim 3, wherein the sliding sleeve comprises a spring for closing the sleeve.

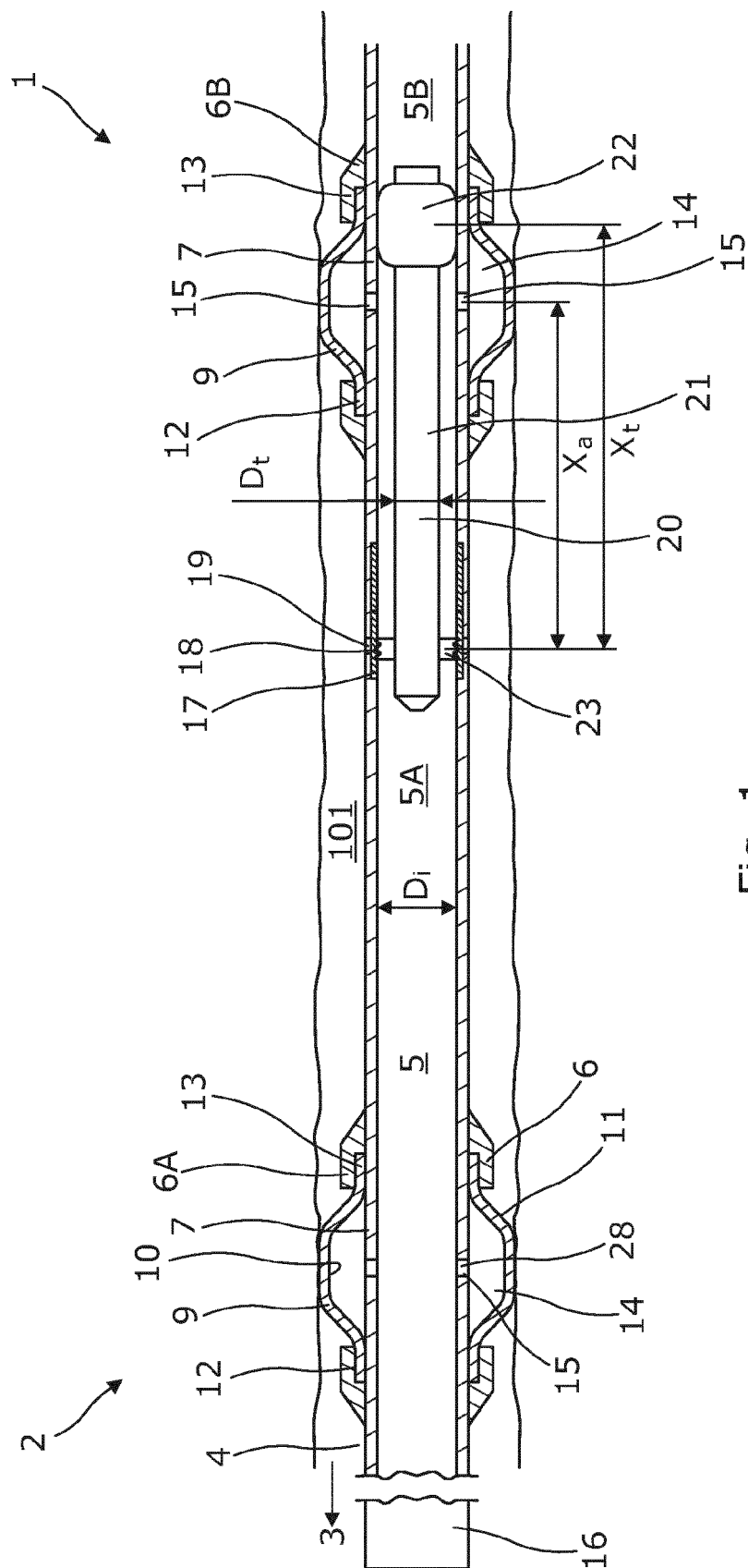
5. A downhole stimulation system according to any of the preceding claims, wherein a valve is arranged in the aperture of at least one of the annular barriers.

6. A downhole stimulation system according to any of the preceding claims, wherein a diameter of tool body is smaller than an inner diameter of the well tubular structure defining a fluid passage between

the tool and the well tubular structure.

7. A downhole stimulation system according to any of the preceding claims, wherein the tool comprises an inflation pump for inflating the inflatable device 5
8. A downhole stimulation system according to claim 7, wherein the tool comprises a motor for driving the inflation pump. 10
9. A downhole stimulation system according to any of the preceding claims, wherein the sliding sleeve and/or the aperture comprises an identification tag (54). 15
10. A downhole stimulation system according to any of the preceding claims, wherein the tool comprises a detection unit (37) for detecting the sliding sleeve and/or the aperture. 20
11. A downhole stimulation system according to claim 10, wherein the detection unit comprises a tag identification means (38) for detecting the sliding sleeve and/or the aperture. 25
12. A downhole stimulation system according to any of the preceding claims, wherein the tool comprises an activation means for activating the inflation pump so that the inflatable device is inflated, and for stopping the inflation pump so that the inflatable device is deflated. 30
13. A downhole stimulation system according to any of the preceding claims, wherein at least one of the annular barriers has at least one intermediate sleeve (55) between the expandable sleeve and the tubular part. 35
14. A downhole stimulation system according to any of the preceding claims, wherein the tool is wireless and comprises a power supply. 40
15. A downhole stimulation method for stimulating production of fluid from a well by using the downhole stimulation system according to any of the preceding claims, comprising the steps of: 45
 - detecting the sliding sleeve,
 - projecting the keys of the tool,
 - engaging the profile of the sliding sleeve, 50
 - inflating the inflatable device,
 - pressuring the inside of the well tubular structure,
 - moving the tool away from the top of the well, sliding the sleeve from a closed position to an open position, and 55
 - letting pressurised fluid from the inside of the well tubular structure in through the aperture of

the second annular barrier to equalise the pressure between the production zone and the annular space of the second annular barrier.



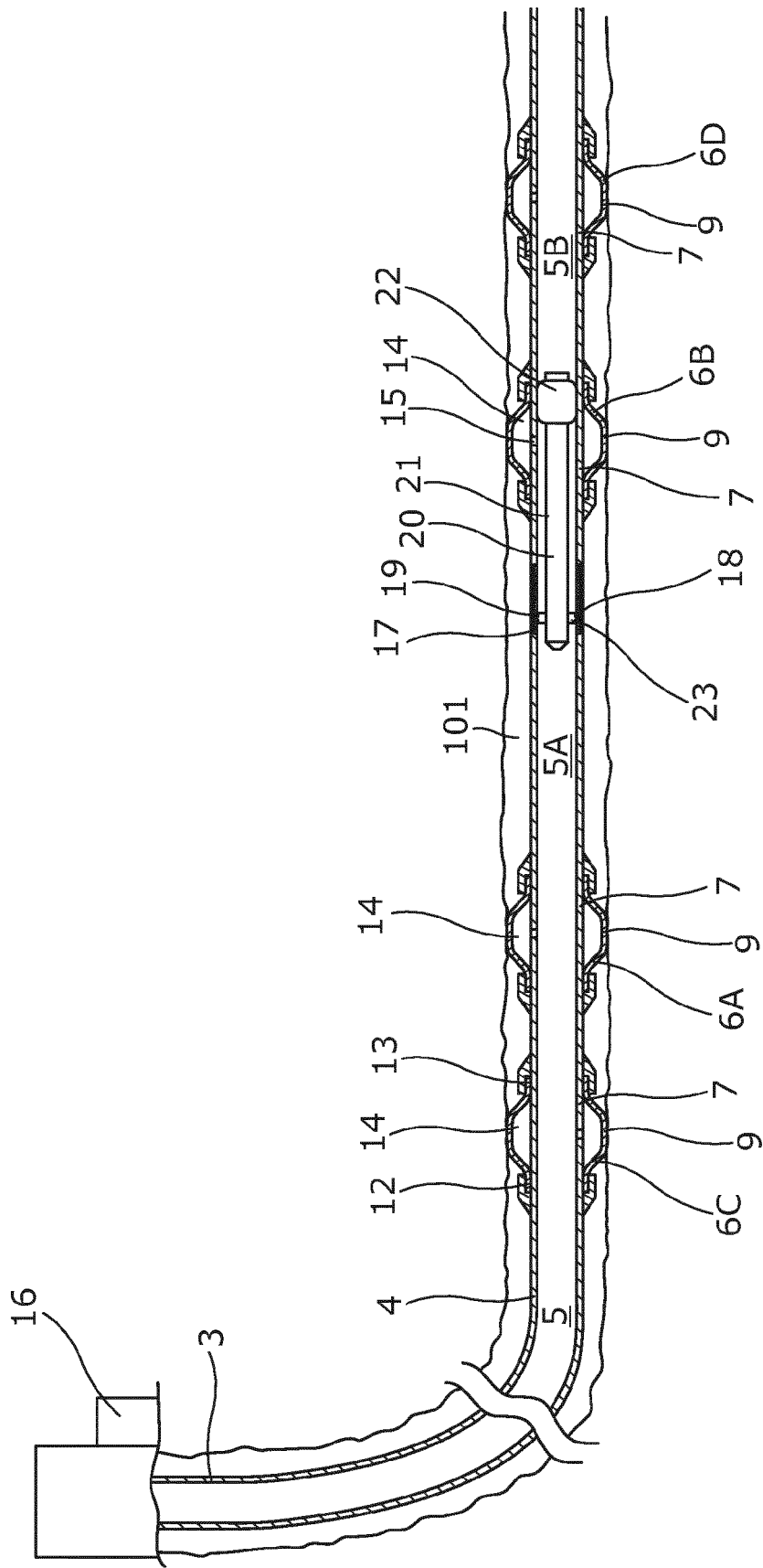


Fig. 2

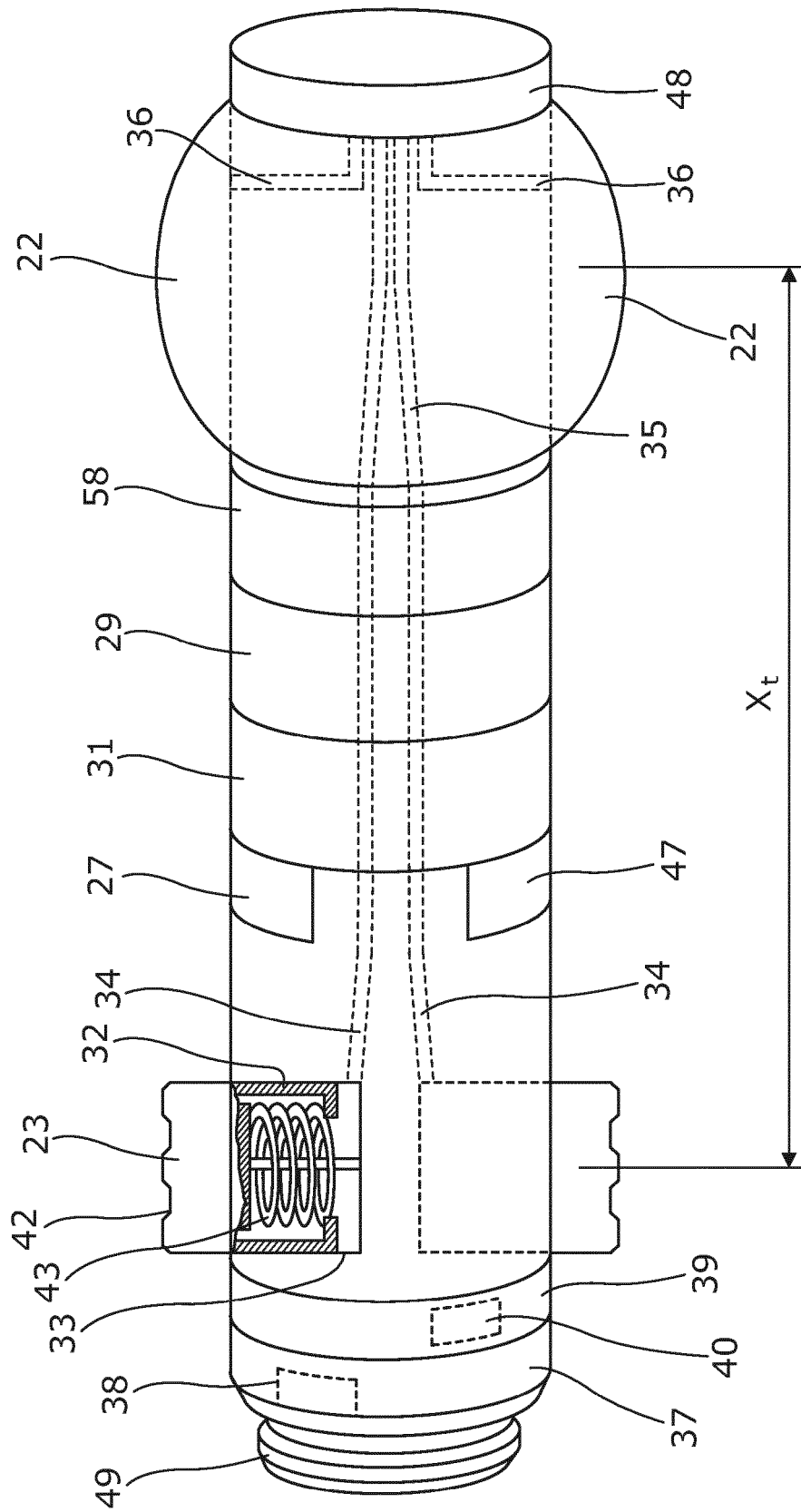


Fig. 3

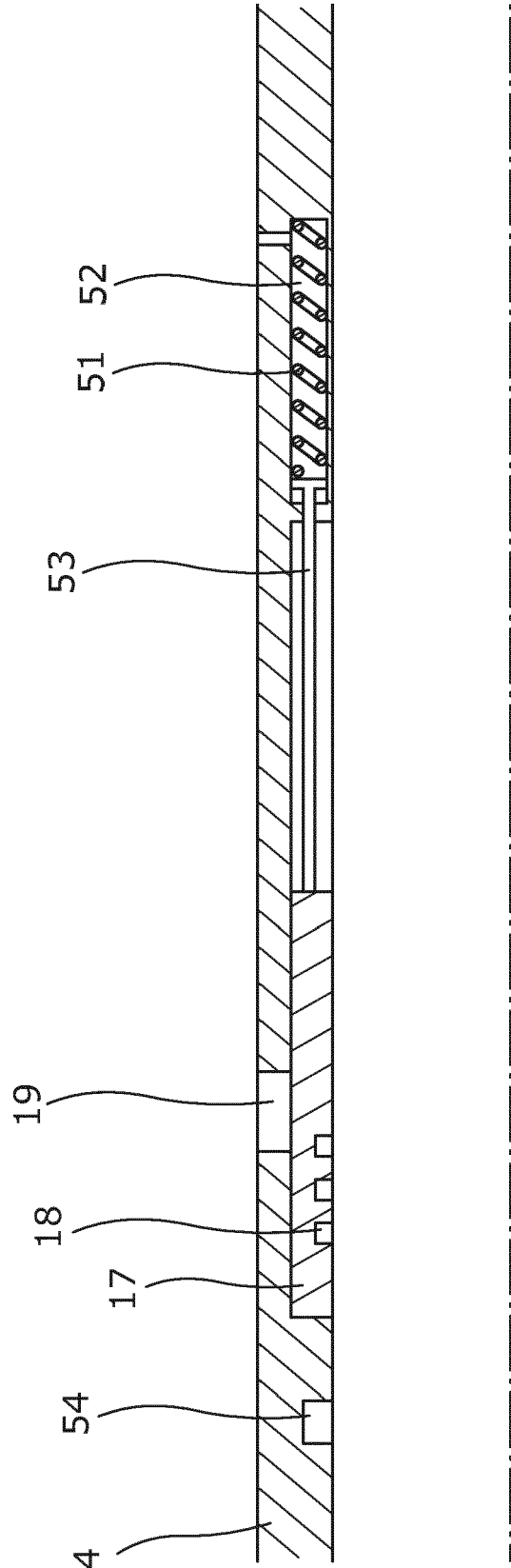


Fig. 4

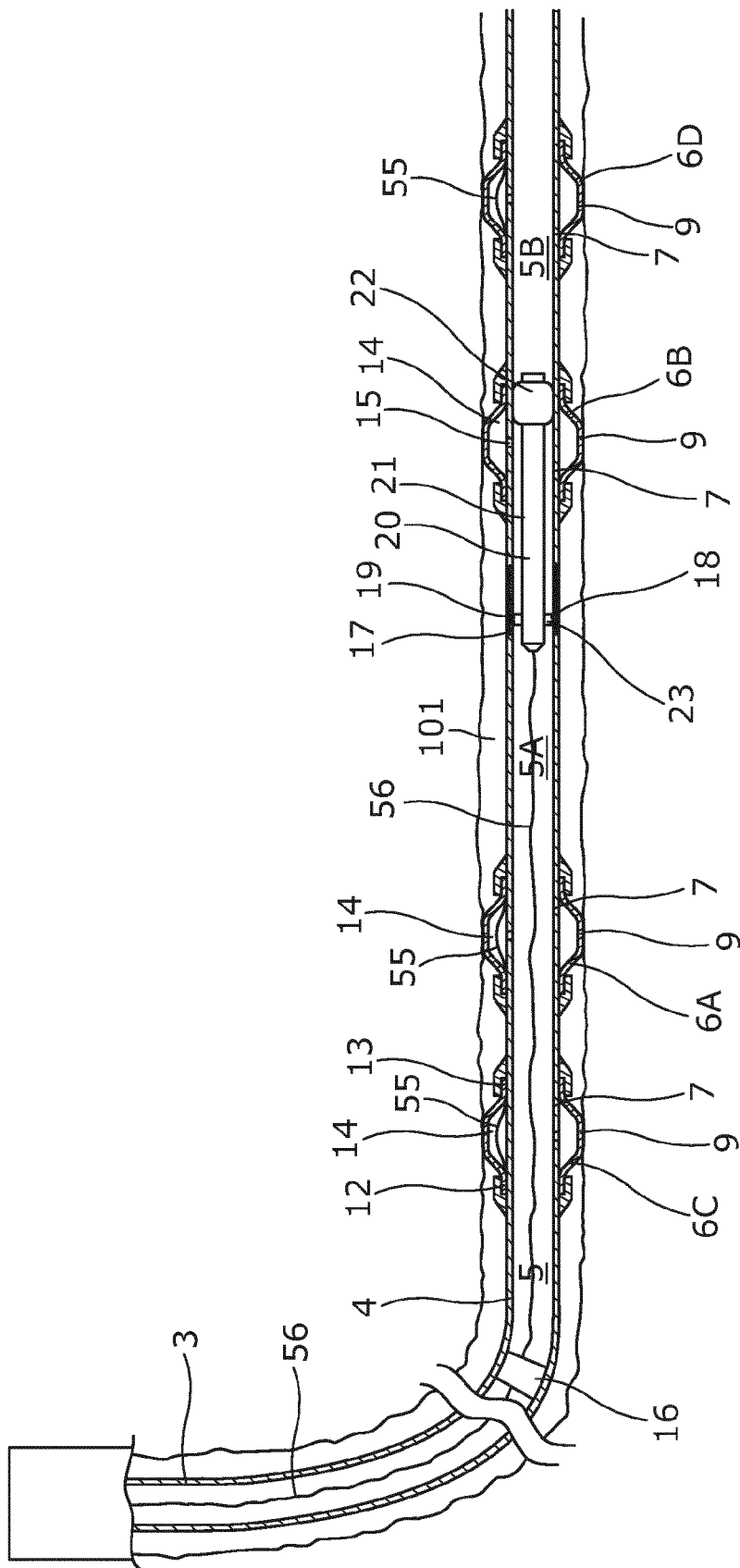


Fig. 5

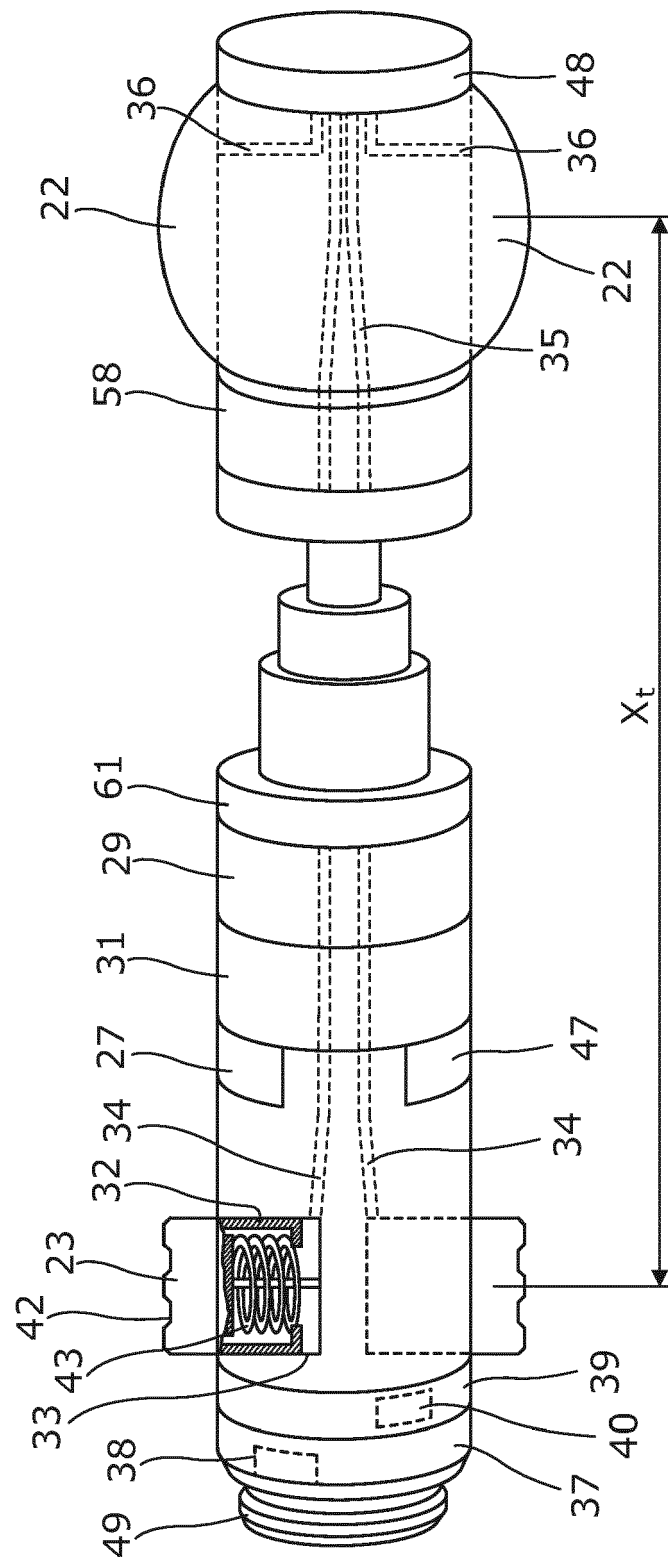


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 14 17 3461

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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	EP 2 728 108 A1 (WELLTEC A/S) 7 May 2014 (2014-05-07)	1-12, 14, 15	INV. E21B23/00
Y	* the whole document *	13	E21B33/124 E21B33/127
Y	US 6 998 557 B2 (WHANGER ET AL) 14 February 2006 (2006-02-14) * column 5, line 29 - line 57 *	13	E21B34/14
			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 January 2015	Examiner Rampelmann, Klaus
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 14 17 3461

5

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US 6998557	B2	14-02-2006	NONE

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