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Office de la Propriété Intellectuelle du Canada

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Canadian Intellectual Property Office

CA 2866367 C 2020/03/31

(11)(21) **2 866 367**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(86) **Date de dépôt PCT/PCT Filing Date:** 2013/03/06
(87) **Date publication PCT/PCT Publication Date:** 2013/09/12
(45) **Date de délivrance/Issue Date:** 2020/03/31
(85) **Entrée phase nationale/National Entry:** 2014/09/04
(86) **N° demande PCT/PCT Application No.:** NO 2013/050045
(87) **N° publication PCT/PCT Publication No.:** 2013/133719
(30) **Priorités/Priorities:** 2012/03/09 (US61/608,761); 2012/03/09 (NO20120277)

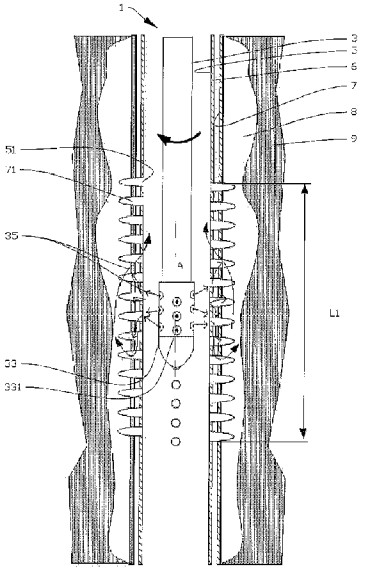
(51) **Cl.Int./Int.Cl.** ***E21B 37/00*** (2006.01), ***E21B 33/13*** (2006.01)

(72) **Inventeurs/Inventors:**
LARSEN, ARNE GUNNAR, NO;
ANDERSEN, PATRICK, NO;
JENSEN, ROY INGE, NO;
DAHL, ARNT OLAV, NO;
MYHRE, MORTEN, NO

(73) **Propriétaire/Owner:**
HYDRA SYSTEMS AS, NO

(74) **Agent:** RIDOUT & MAYBEE LLP

(54) **Titre : PROCEDE DE NETTOYAGE ET OBTURATION COMBINES DANS UN PUITS ET OUTIL DE RINCAGE POUR RINCAGE DANS UN PUITS**
(54) **Title: A METHOD FOR COMBINED CLEANING AND PLUGGING IN A WELL AND A FLUSHING TOOL FOR FLUSHING IN A WELL**



(57) **Abrégé/Abstract:**
A method for the combined perforation, cleaning, and the subsequent plugging of a longitudinal section (LI) of a well (1), the well (1) being provided with two pipe bodies (5, 7) placed substantially concentrically, and the method including the following steps: (A) lowering a perforation tool (31) into the innermost pipe body (5) to said longitudinal section (LI); (B) forming perforations (51, 71) in both pipe bodies (5, 7) along the longitudinal section (LI) by means of the perforation tool (31); (C) cleaning said longitudinal section (LI) by means of a flushing tool (33) which is attached to a lower portion of a string (3) allowing through-flow; (D) pumping a fluidized plugging material (37) down the string (3) and into the innermost pipe body (5) at the longitudinal section (LI); and (E) placing the fluidized plugging material (37) in the innermost pipe body (5), and thereby also into the entire cross section of the well (1) via the perforations (51, 71) within the longitudinal section (LI). A flushing tool (33) for cleaning said longitudinal section (LI) of the well (1) is described as well.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 September 2013 (12.09.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/133719 A1

(51) International Patent Classification:
E21B 37/00 (2006.01) *E21B 33/13* (2006.01)

(21) International Application Number:
PCT/NO2013/050045

(22) International Filing Date:
6 March 2013 (06.03.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

20120277	9 March 2012 (09.03.2012)	NO
61/608,761	9 March 2012 (09.03.2012)	US

(71) Applicant: **HYDRA SYSTEMS AS** [NO/NO]; Postboks 182, N-4098 Tananger (NO).

(72) Inventors: **LARSEN, Arne Gunnar**; Postveien 8, N-4319 Sandnes (NO). **ANDERSEN, Patrick**; Persokkrossen 22, N-4046 Hafrsfjord (NO). **JENSEN, Roy, Inge**; Rektor Oldens gate 60, N-4022 Stavanger (NO). **DAHL, Arnt, Olav**; Bergveien 15, N-4070 Randaberg (NO). **MYHRE, Morten**; Notveien 15, N-4056 Tananger (NO).

(74) Agent: **HÅMSØ PATENTBYRÅ ANS**; P.O. Box 171, N-4302 Sandnes (NO).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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(54) Title: A METHOD FOR COMBINED CLEANING AND PLUGGING IN A WELL AND A FLUSHING TOOL FOR FLUSHING IN A WELL

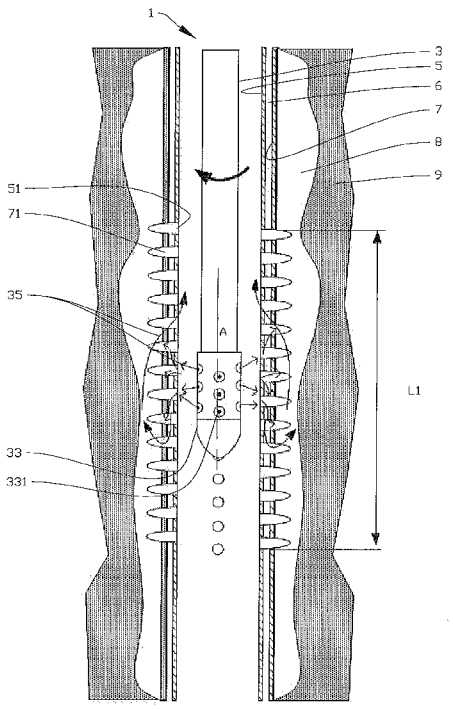


Fig. 6

(57) Abstract: A method for the combined perforation, cleaning, and the subsequent plugging of a longitudinal section (LI) of a well (1), the well (1) being provided with two pipe bodies (5, 7) placed substantially concentrically, and the method including the following steps: (A) lowering a perforation tool (31) into the innermost pipe body (5) to said longitudinal section (LI); (B) forming perforations (51, 71) in both pipe bodies (5, 7) along the longitudinal section (LI) by means of the perforation tool (31); (C) cleaning said longitudinal section (LI) by means of a flushing tool (33) which is attached to a lower portion of a string (3) allowing through-flow; (D) pumping a fluidized plugging material (37) down the string (3) and into the innermost pipe body (5) at the longitudinal section (LI); and (E) placing the fluidized plugging material (37) in the innermost pipe body (5), and thereby also into the entire cross section of the well (1) via the perforations (51, 71) within the longitudinal section (LI). A flushing tool (33) for cleaning said longitudinal section (LI) of the well (1) is described as well.

WO 2013/133719 A1

WO 2013/133719 A1

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

A METHOD FOR COMBINED CLEANING AND PLUGGING IN A WELL AND A FLUSHING TOOL FOR FLUSHING IN A WELL

The invention relates to a method for combined cleaning and plugging in a well. More specifically, the invention relates to a method which provides hydraulic isolation in the form of a well plug which is installed in the cross section of the well at a desired depth, wherein the well, at least in the portion where a well plug is to be positioned, is provided with at least two pipe bodies placed substantially concentrically. The invention also relates to a flushing apparatus for use in the method.

It is known to establish a barrier in a well by a section of casing being removed mechanically by section milling, after which the cross section of the well is filled with cement. Such an operation is very time-consuming and thus involves large costs for an operator. The operation generally requires surface installations for separating metal chips from the drilling mud and, often, several different types of cleaning fluids are required for metal chips to be transported up from the depth of the well.

It is also known that a well plug may be established by means of a method and devices as proposed in the Norwegian patent application 20111641 entitled "Method for combined cleaning and plugging in a well, washing tool for directional washing in a well, and use of the washing tool "and in the Norwegian patent application 20120099 entitled "Apparatus and method for positioning of a fluidized plugging material in an oil well or gas well", both filed by the present applicant.

In a well in which the portion to be plugged is provided with two or more pipe bodies placed substantially concentrically, it has turned out that the applicant's apparatus for cleaning before plugging, as described in the Norwegian patent document 20111641 mentioned, for a well provided with one pipe body, is not suitable for cleaning in a satisfactory manner. When two pipe bodies are cast together into the well, it has turned out to be difficult to remove residues of the casting material, which may be cement for example, in a satisfactory manner. This casting material may be superan-

nuated and in such condition that it no longer meets the requirements of a barrier element in the well. Further, it has proved difficult to clean in a satisfactory way even when there is no casting material between the pipe bodies, as, when washing as described in said patent application, there will be a pressure drop in the annuli between the pipe bodies.

The invention has for its object to remedy or reduce at least one of the drawbacks of the prior art or at least provide a useful alternative to the prior art.

The object is achieved through features which are specified in the description below and in the claims that follow.

In a first aspect, the invention relates to a method for the combined perforation, cleaning of annuli in a well over a longitudinal section of the well and subsequent plugging of the longitudinal section, the well being provided, at least over the longitudinal section to be plugged, with at least two pipe bodies placed substantially concentrically, and the method including the following steps:

(A) lowering a perforation tool into the innermost pipe body to said longitudinal section of the well;

(B) forming perforations in the pipe bodies along the longitudinal section by means of the perforation tool,

characterized by the method also including the steps of:

(C) by means of a flushing tool which is attached to a lower portion of a string allowing through-flow and which is lowered into the innermost pipe body to the longitudinal section, pumping a flushing fluid down the string, out through at least one outlet of the flushing tool, into the innermost pipe body and further out into the annulus/annuli between the pipe bodies and into the annulus outside the outermost pipe body via the perforations;

(D) pumping a fluidized plugging material down the string and into the innermost pipe body at the longitudinal section; and

(E) placing the fluidized plugging material in the innermost pipe body, and thereby also in the annuli via the perforations in the pipe bodies, along at least said longitudinal section of the well, whereby both the pipe bodies and the annuli are plugged along at least said longitudinal section of the well.

The string allowing through-flow may be, for example, a drill string or a coiled-tubing string of types known *per se*.

In one embodiment, the fluidized plugging material may include cement slurry for the

formation of a cement plug.

As an alternative, or in addition, the fluidized plugging material may include a fluidized unconsolidated mass for the formation of an unconsolidated-mass plug.

In a first embodiment, before step (C), the method may include
- lowering the perforation tool into the innermost pipe body and forming said perforations in the pipe bodies along said longitudinal section;
- pulling the perforation tool out of the well; and
- attaching the flushing tool to the lower portion of the string to subsequently perform steps (C)–(E). Perforation and flushing is thus carried out in separate trips down the well.

In a second embodiment, before step (A), the method may further include the following steps:
- connecting the perforation tool and the flushing tool into an assembly of the two;
- connecting the assembly to said lower portion of the string. Perforation and flushing are thus performed in one and the same trip down the well.

In a preferred embodiment, step (C) may include rotating the string while the flushing is going on. This will have the effect of enabling better cleaning of the pipe body and the annuli as, over time, the flushing tool may work a larger area.

In another preferred embodiment, the method may additionally or alternatively include moving the string in a reciprocating motion while flushing is going on. This will have the same effect as that mentioned above for a rotating motion, in addition to making it easier to get at the annuli that are to be cleaned.

In one embodiment, before step (C), the method may include adding an abrasive medium to the flushing fluid. This will be particularly appropriate if the annulus between the two pipe bodies is filled with cement or some other casting material, as this may be difficult to remove without any abrasive media in the flushing fluid.

The abrasive medium may be sand, for example. In a preferred embodiment, the amount of sand added to the flushing fluid may be between 0.05 per cent by weight and 1.00 per cent by weight. In a particularly preferred embodiment, approximately 0.1 per cent by weight of sand may be added to the flushing fluid.

The flushing fluid may be drilling mud of a kind known *per se*.

In a preferred embodiment, the flushing fluid may be carried out of the at least one

outlet of the flushing tool at a rate greater than 15 metres per second. The present applicant has done tests that have shown that 15 metres per second is a limit value above which the flushing tool is able to clean sufficiently.

In a further preferred embodiment, the flushing fluid may be carried out of the at least one outlet of the flushing tool at a rate which is greater than 50 metres per second. The above-mentioned tests have also shown that the flushing is particularly effective when the flushing fluid has an exit velocity greater than 50 metres per second.

Optimum flushing velocities and the amount of abrasive medium added depend on the type of flushing fluid and then primarily on the viscosity of the flushing fluid. High-viscosity flushing fluids will usually require greater exit velocities from the flushing tool as the velocity is retarded faster than that of low-viscosity liquids.

In another preferred embodiment, the flushing fluid may be carried out of the at least one outlet of the flushing tool in a spin-free output jet. The advantage of this is that there is no need for nozzles that are to provide a spinning effect on the output jet, as, these nozzles will usually require larger space for support.

In one embodiment, after step (C), the method may also include using a washing tool as disclosed in said Norwegian patent document 20111641. This may clean the longitudinal section further. Said washing tool could also be used as a base for subsequent plugging by means of a curable fluidized plugging material as described in said patent document.

In another embodiment, after step (C), the method may also include setting a packer element of a kind known *per se* in the well as a base for subsequent plugging with the fluidized plugging material.

In a second aspect, the invention relates to a flushing tool for flushing in a well, the flushing tool being arranged for connection to a lower portion of a string allowing through-flow, and the flushing tool being formed with at least one outlet allowing through-flow, characterized by at least one of said at least one outlet being angled in such a way that the output jet is non-normal to the longitudinal axis of the flushing tool.

In one embodiment, the output jet from the at least one outlet may be substantially spin-free.

In a first embodiment, a lower end portion of the flushing tool may be arranged to be

connected to a perforation tool for perforating surrounding pipe bodies. This may be an advantage as the operations of perforation and flushing may be carried out in one and the same trip down the well.

In a second embodiment, a lower end portion of the flushing tool may be arranged to be releasably connected to said perforation tool. This may be advantageous as the perforation tool may be dumped in the well.

In a preferred embodiment, at least one of said at least one outlet may be provided with a nozzle. This may be practical for the output jet to get the desired concentration and direction.

In a further preferred embodiment, the flushing tool may be formed with a plurality of outlets, the outlets being angled in such a way that the output jets are distributed within ± 80° from a plane which is normal to the longitudinal axis of the flushing tool. This will be particularly appropriate with a view to cleaning the annuli as it will be easier to achieve the desired effect with angled output jets. If, in addition, the flushing tool is rotated and/or moved up and down the well during flushing, this may give a very thorough cleaning of the inside and outside of both pipe bodies.

In what follows, an example of a preferred embodiment is described, which is visualized in the accompanying drawings, in which:

Figure 1 shows, in a side view, a well as used in the present invention;

Figure 2 shows, in a side view, the well after a longer portion of two pipe bodies has been removed, as used in plugging according to the prior art;

Figure 3 shows, in a side view, the well of figure 2 after a plug has been established in the well by means of the prior art;

Figure 4 shows, in a side view, the well after a perforation tool has been lowered into the well;

Figure 5 shows, in a side view, the well after two pipe bodies in the well have been perforated and the perforation tool has been pulled out of the well;

Figure 6 shows, in a side view, the well after a flushing tool has been lowered into the well and while the flushing tool is being used for cleaning in the well;

Figure 7 shows, in a side view, the well while, in a portion, a fluidized plugging material fills substantially the entire cross section of the well;

Figure 8 shows, in a side view, the well after it has been plugged by means of the method of the present invention; and

Figure 9 shows, in a side view, a combined perforating and flushing tool for use in one embodiment of the method of the present invention.

In what follows, the reference numeral 1 indicates a well as used in the present invention. The well 1 has been drawn in a schematic and very simplified manner, and elements that are not central to the invention may have been omitted from the figures.

Figure 1 shows the well to be plugged. The well 1 is provided with two pipe bodies 5, 7 placed substantially concentrically, here in the form of two casings. The casings 5, 7 separate a well path 2 from a surrounding formation 9. Well fluids which will be known to a person skilled in the art and which will typically be present in the well 1, *inter alia* in an annulus 6 between the two casings 5, 7 and in an annulus 8 between the outer casing 7 and the surrounding formation 9, are not shown in the figures for the sake of exposition.

Figure 2 shows how a portion of the casings 5, 7 has been removed for plugging of the well 1 in accordance with the prior art. A major length of the casings 5, 7 is milled away before the cross section of the well 1 is filled by a cement slurry or some other fluidized plugging material 37 for the formation of a plug as shown in figure 3. This method has several drawbacks which have been mentioned initially in the present application.

Figure 4 shows a first step in the method in accordance with the present invention. A string 3' has been lowered into the well 1 inside the innermost casing 5. To a lower portion of the string 3', a perforation tool 31 in the form of a perforation gun of a kind known *per se* has been connected. The perforation gun 31 is placed along a longitudinal section L1 of the well to be plugged. The perforation gun 31 forms perforations 51, 71 extending through both casings 5, 7 as shown in figure 5.

In figure 6, the well is shown after a flushing tool 33 has been lowered to the longitudinal section L1 on a string 3 allowing through-flow. The string 3 allowing through-flow may be the same as the string 3', on which the perforation tool 31 was lowered into the well 1, or it may be another string. A flushing fluid 35, indicated in the figure by its output jets in the form of straight arrows out of the flushing tool 33 and its direction of

flow in the form of curved arrows around the flushing tool 33, is flowing out of different outlets 331 in the flushing tool. The outlets 331 will typically be provided with nozzles for concentrating the output jets and achieving the desired concentration of the flushing fluid 35. The output jets from the outlets 331 are spin-free in a preferred embodiment. The different outlets 331 are angled in such a way that the output jets have different exit angles relative to a plane which is normal to a longitudinal axis A of the flushing tool. The angled output jets will make it possible to get sufficient cleaning of the annulus 6 between the casings 5, 7 and of the annulus 8 between the outermost casing 7 and the formation 9. The curved arrows at the flushing tool in the figures show possible flow paths of the flushing fluid 35; out towards the formation 9 via the perforations 51, 71 and back into the innermost casing 5 via other perforations 51, 71. A curved arrow at the upper portion of the string 3 indicates that the flushing tool 33 is rotating with the string 3 during flushing. In an alternative embodiment, the string 3 will, in addition or as an alternative, be moved in a reciprocating motion.

Figure 7 shows the well 1 as it is about to be filled over the longitudinal section L1 by a fluidized plugging material 37 flowing out of the lower end of the string 3 allowing through-flow. The fluidized plugging material 3 fills the inside of the inner casing 5 and flows on into the annulus 6 between the casings 5, 7 via the perforations 51 and further into the annulus 8 between the outermost casing 7 and the formation 9 via the perforations 71 so that substantially the entire cross section of the well 1 is filled within the longitudinal section L1. As a base for the fluidized plugging material 37 a packer element, not shown, of a type known *per se* may be used. Alternatively, a washing apparatus as described in the Norwegian patent document 20111641 mentioned earlier may be used after the flushing. As described in the patent document mentioned, the washing apparatus is arranged to be left in the well 1 and thus be used as a base for subsequent plugging.

Figure 8 shows the well 1 after the fluidized plugging material 37 has cured and a plug has been provided for temporarily or permanently closing the well 1 in accordance with the method of the present invention.

Figure 9 shows an assembly 34 of a perforation tool 31 and a flushing tool 33, in which the perforation tool 31 is connected to a lower end portion of the flushing tool 33 of the assembly 34. The perforation tool 31 is preferably releasable from the flushing tool 33 of the assembly 34 by means of a technique known *per se*. The assembly 34 will enable perforation and flushing in one and the same trip down the well 1.

W E C L A I M :

1. A method for the combined perforation and cleaning of annuli (6, 8) in a well (1) over a longitudinal section (L1) of the well (1) and subsequent plugging of the longitudinal section (L1), the well (1) being provided with, at least over the longitudinal section (L1) to be plugged, at least two pipe bodies (5, 7) placed substantially concentrically, including an innermost pipe body (5) and an outermost pipe body (7), the method including the following steps:

(A) lowering a perforation tool (31) into the innermost pipe body (5) to said longitudinal section (L1) of the well (1);

(B) forming perforations (51, 71) in the at least two pipe bodies (5, 7) along the longitudinal section (L1) by means of the perforation tool (31), wherein the method also includes the steps of:

(C) by means of a flushing tool (33), which is attached to a lower portion of a string (3) allowing through-flow, and which is lowered into the innermost pipe body (5) to the longitudinal section (L1), pumping a flushing fluid (35) down the string (3), out through at least one outlet (331) of the flushing tool (33), into the innermost pipe body (5) and further out via said perforations (51, 71) into said annuli (6, 8) comprising an annulus (6) located between the at least two pipe bodies (5, 7) and an annulus (8) located outside the outermost pipe body (7);

(D) pumping a fluidized plugging material (37) down the string (3) and into the innermost pipe body (5) at the longitudinal section (L1); and

(E) placing the fluidized plugging material (37) in the innermost pipe body (5), and thereby also in said annuli (6, 8) via the perforations (51, 71) in the at least two pipe bodies (5, 7), along at least said longitudinal section (L1) of the well (1), whereby the at least two pipe bodies (5, 7) and said annuli (6, 8) are plugged along at least said longitudinal section (L1) of the well (1); and

- wherein the flushing tool (33) used in step (C) is formed with a plurality of outlets (331) allowing through-flow;

- wherein at least one of said outlets (331) is angled in such a way that the output jet is non-normal to a longitudinal axis of the flushing tool (33); and

- wherein the outlets (331) are angled in such a way that the output jets are

distributed within ± 80° from a plane which is normal to the longitudinal axis of the flushing tool (33).

2. The method in accordance with claim 1, wherein the fluidized plugging material (37) includes cement slurry for the formation of a cement plug.

3. The method in accordance with claim 1 or 2, wherein the fluidized plugging material (37) includes a fluidized unconsolidated mass for the formation of an unconsolidated-mass plug.

4. The method in accordance with any one of claims 1 to 3, wherein the method, between steps (B) and (C), also includes the following steps:
- pulling the perforation tool (31) out of the well (1); and
- attaching the flushing tool (3) to the lower portion of the string (3) to subsequently perform steps (C)-(E);
whereby perforation and flushing are performed in separate trips down the well (1).

5. The method in accordance with any one of claims 1 to 3 wherein the method, before step (A), also includes the following steps:
- connecting the perforation tool (31) and the flushing tool (33) into an assembly (34) of the two; and
- connecting the assembly (34) to said lower portion of the string (3);
whereby perforation and flushing are performed in one and the same trip down the well (1).

6. The method in accordance with any one of claims 1 to 5, wherein step (C) includes rotating the string (3) while flushing is going on.

7. The method in accordance with any one of claims 1 to 6, wherein step (C) includes moving the string (3) in a reciprocating motion while flushing is going on.

8. The method in accordance with any one of claims 1 to 7, wherein the method, before step (C), includes adding an abrasive medium to the flushing fluid (35).

9. The method in accordance with claim 8, wherein sand is added to the flushing fluid (35) in an amount corresponding to between 0.05 per cent by weight and 1.00 per cent by weight.

10. The method in accordance with any one claims 1 to 9, wherein the flushing fluid (35) is drilling mud.

11. The method in accordance with any one of claims 1 to 10, wherein the flushing fluid (35) is carried out of the outlets (331) of the flushing tool (33) at a rate that is greater than 15 metres per second.

12. The method in accordance with claim 11, wherein the flushing fluid (35) is carried out of the outlets (331) of the flushing tool (33) at a rate that is greater than 50 metres per second.

13. The method in accordance with any one of claims 1 to 12, wherein the flushing fluid (35) is carried out of the outlets (331) of the flushing tool (33) in a spin-free output jet.

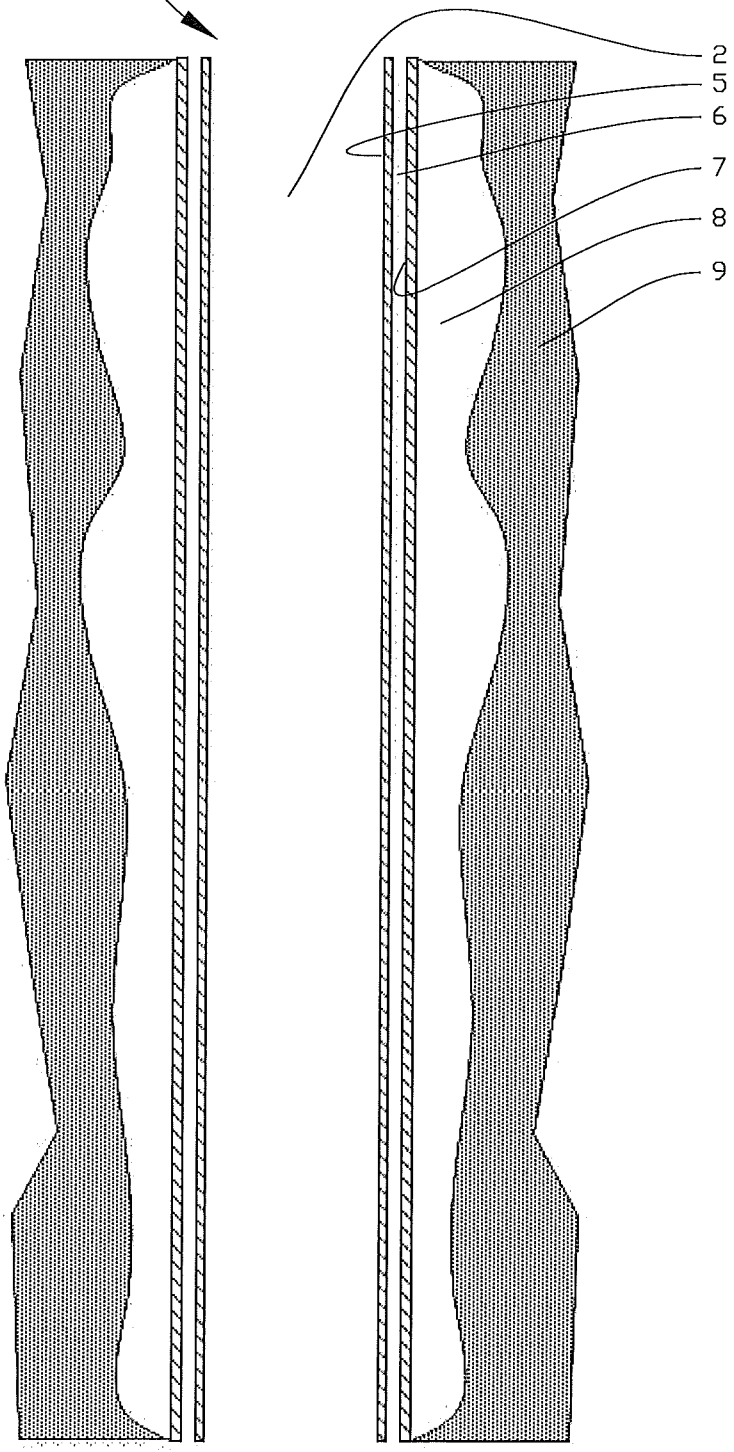


Fig. 1

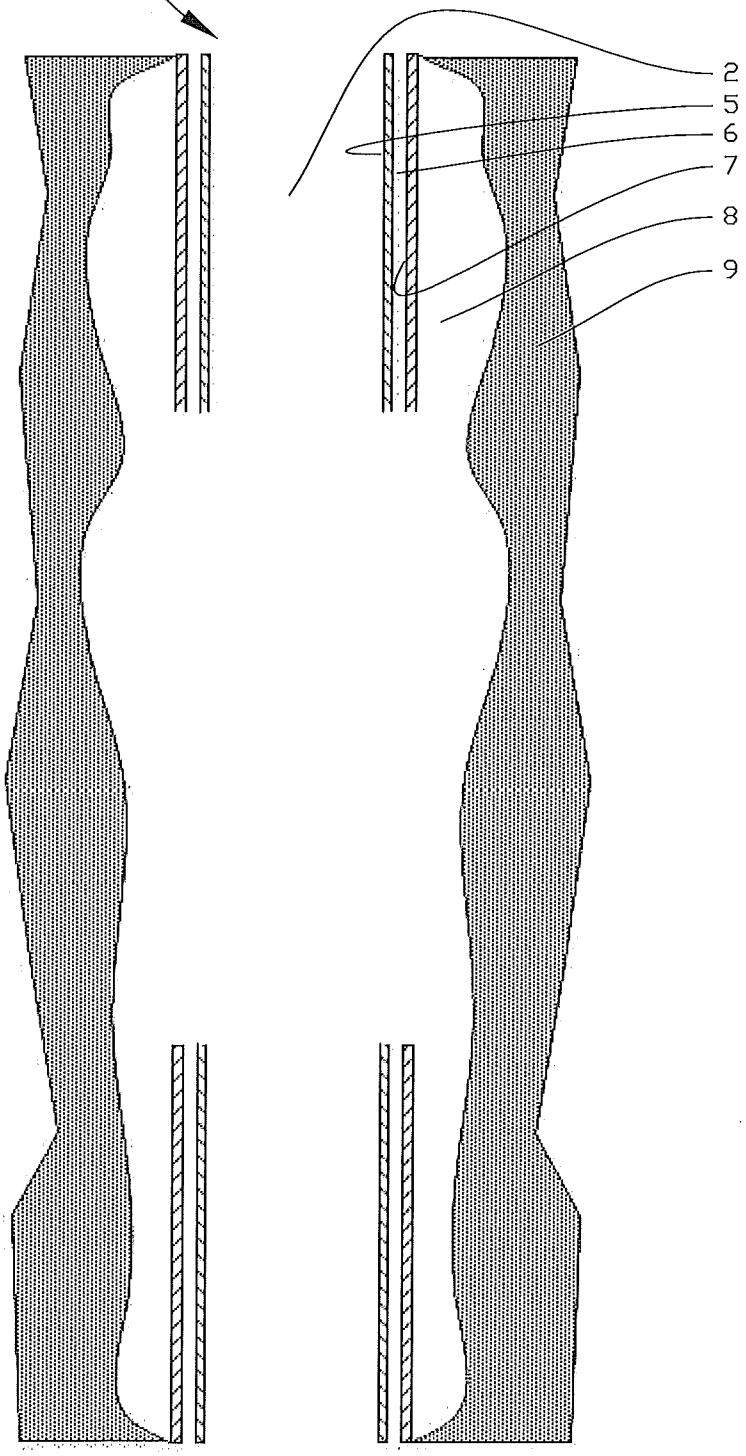


Fig. 2

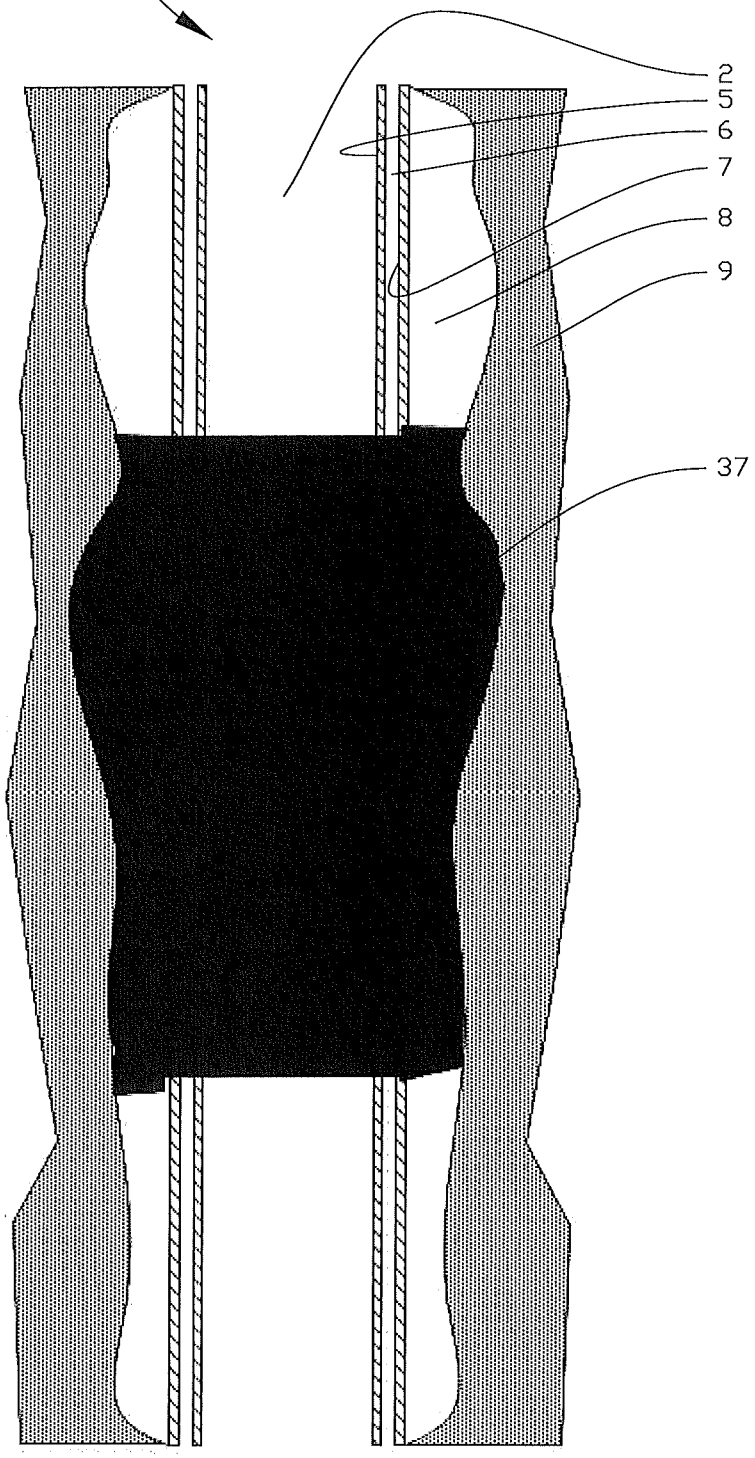


Fig. 3

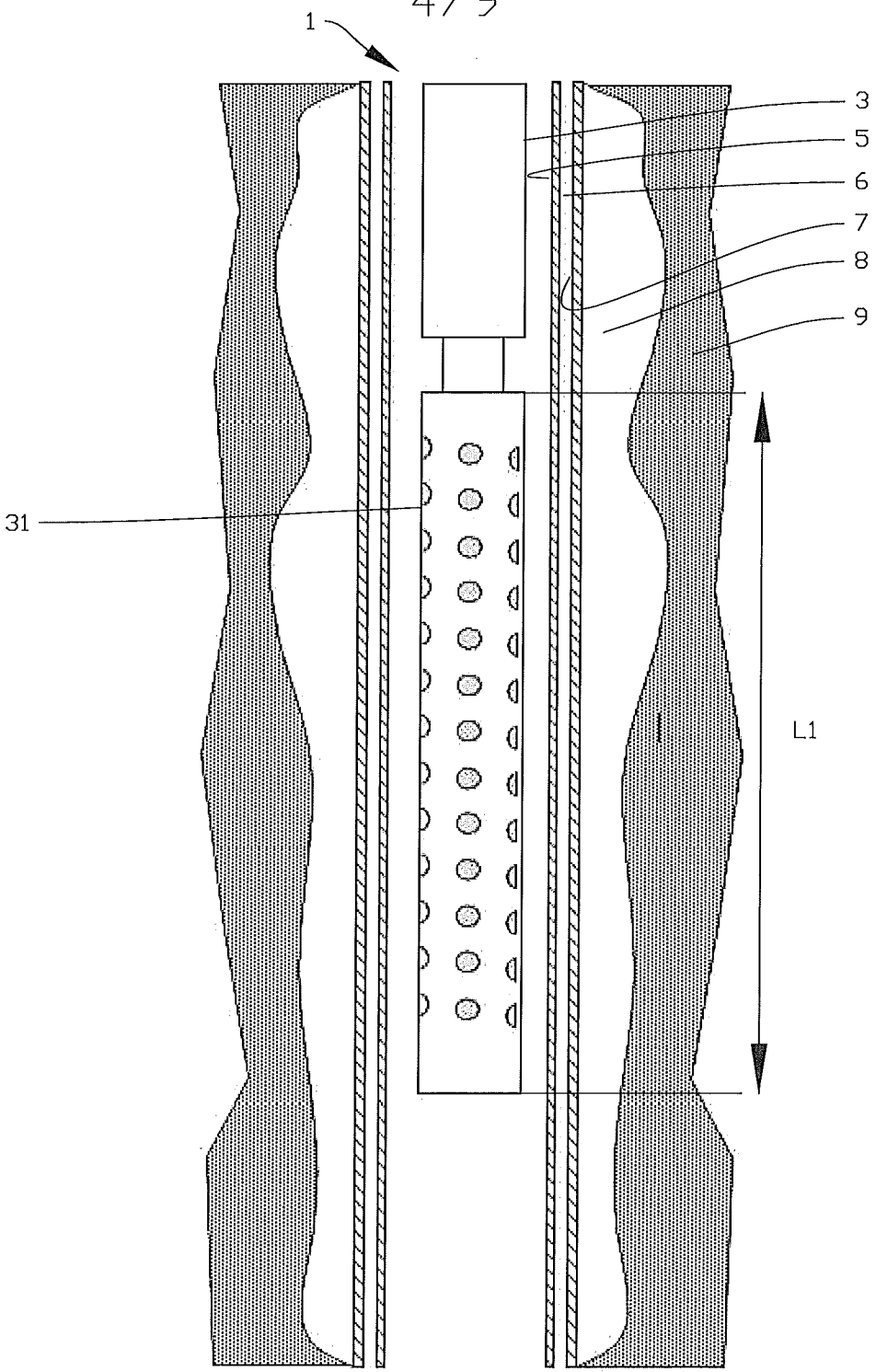


Fig. 4

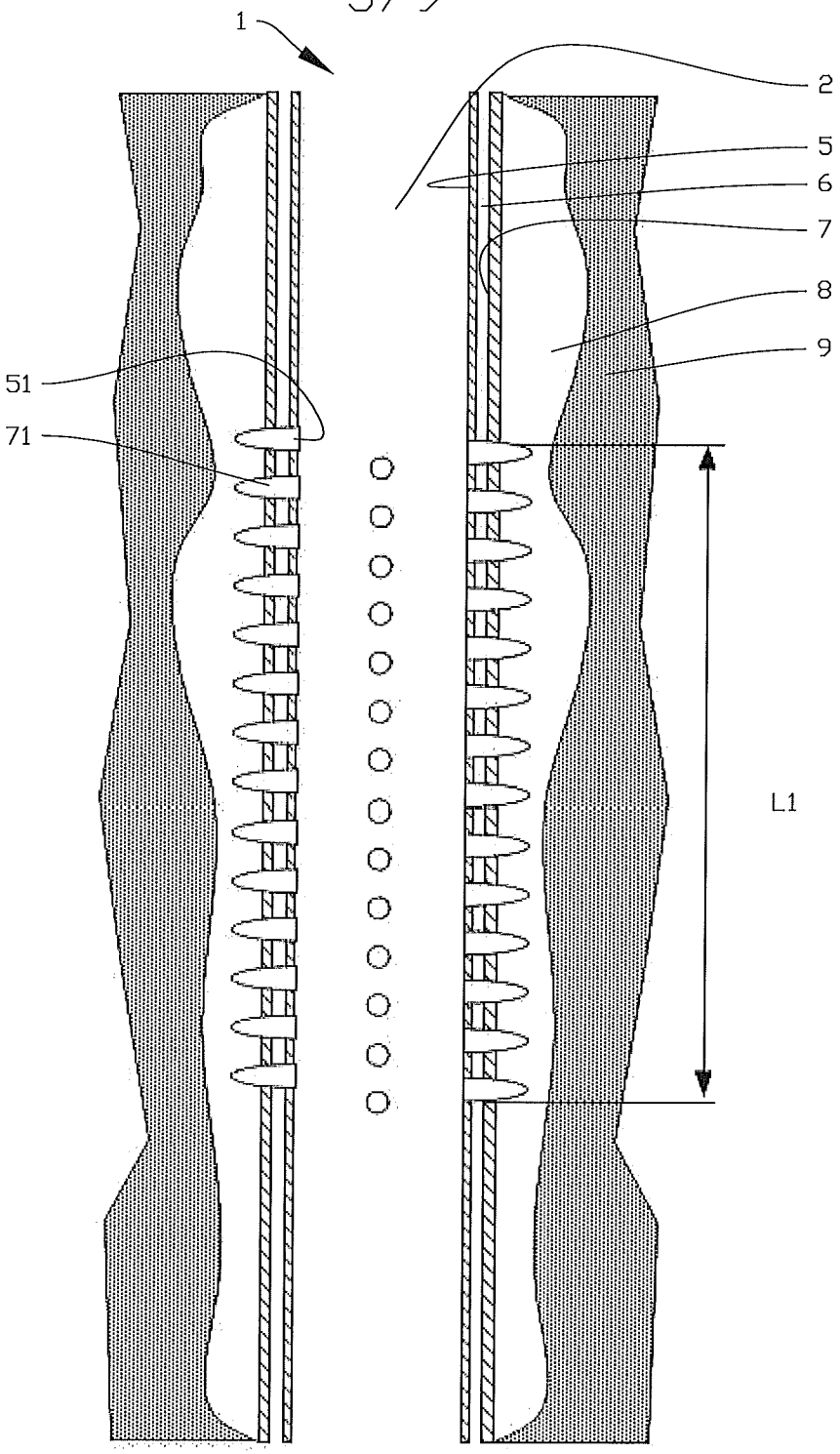


Fig. 5

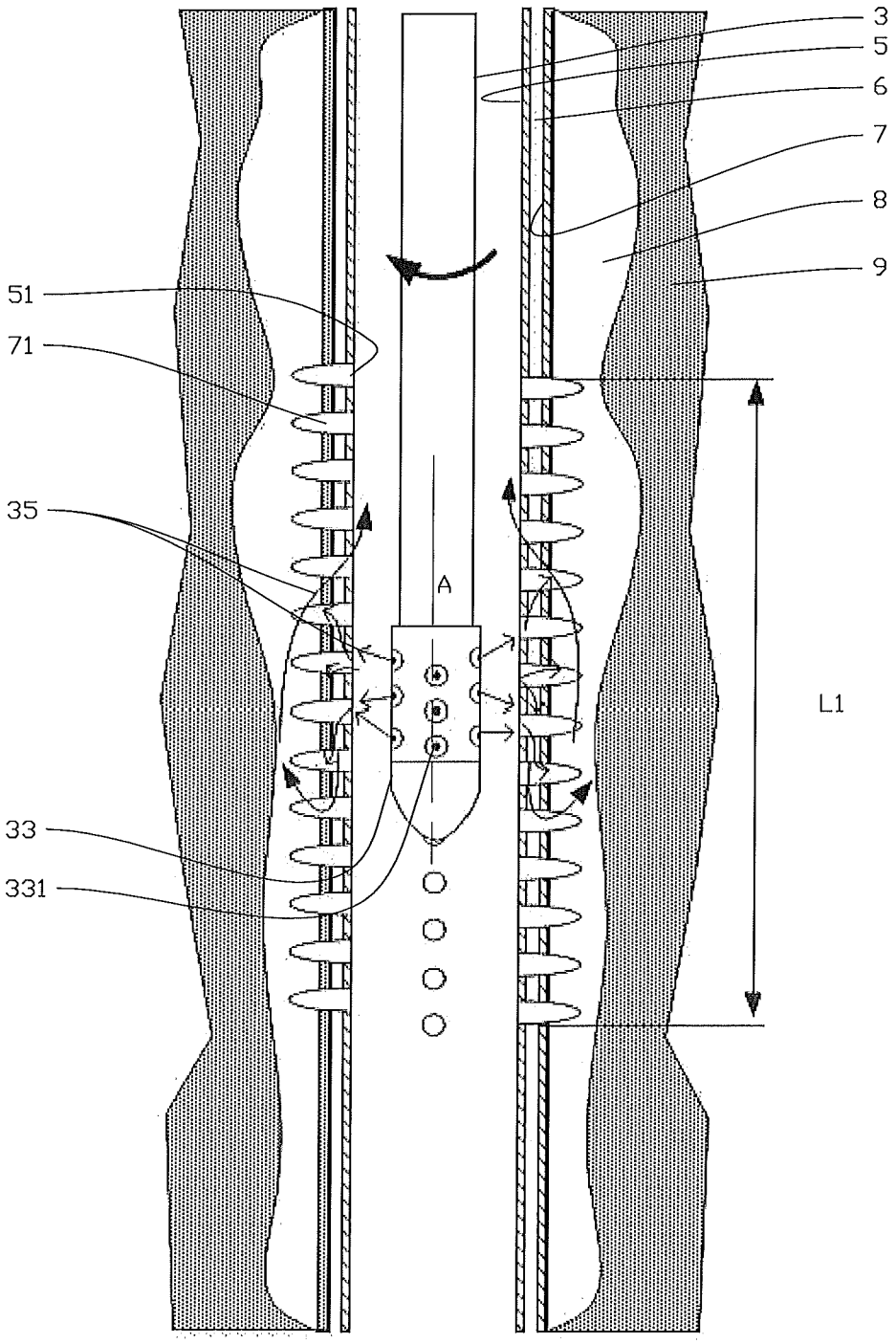


Fig. 6

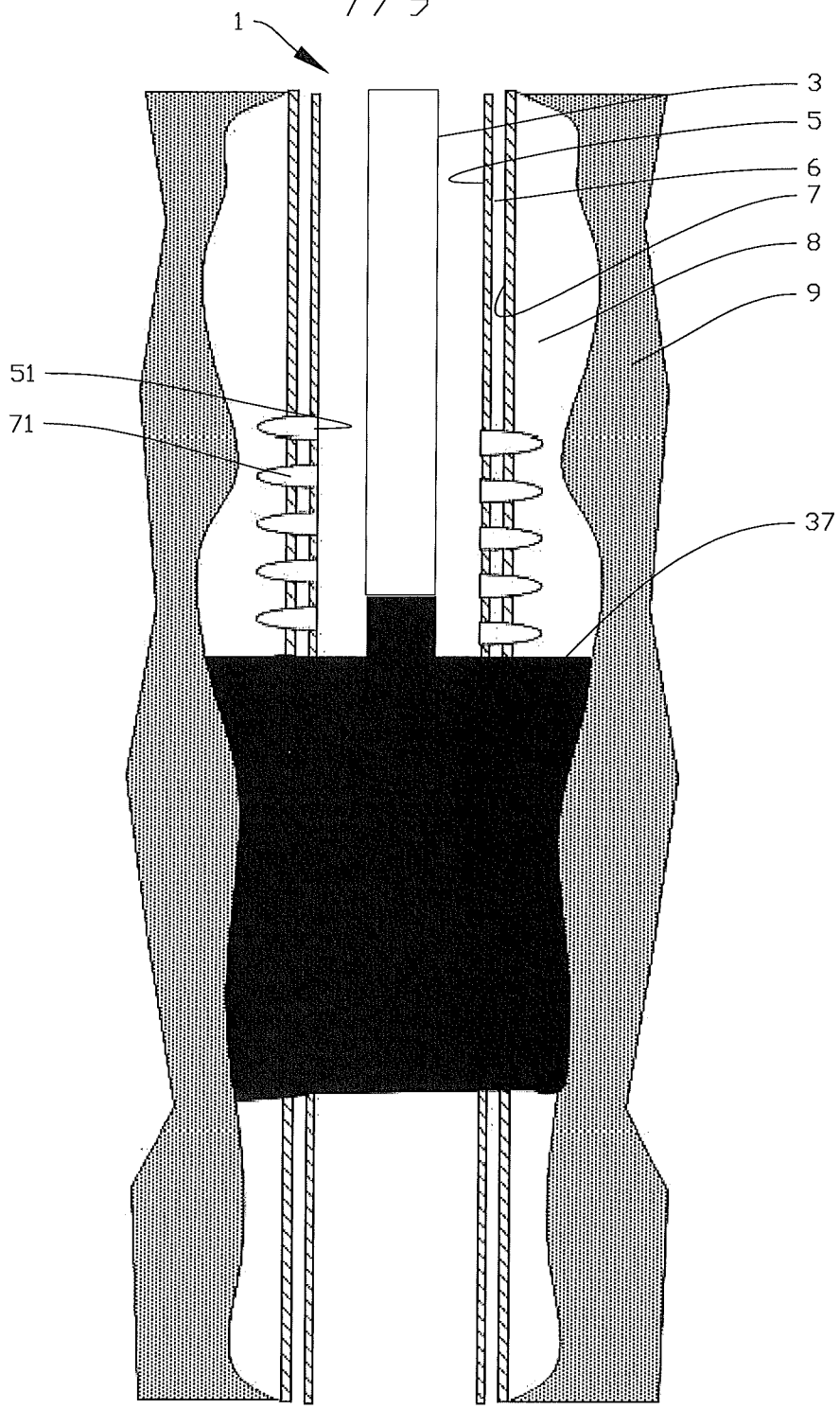


Fig. 7

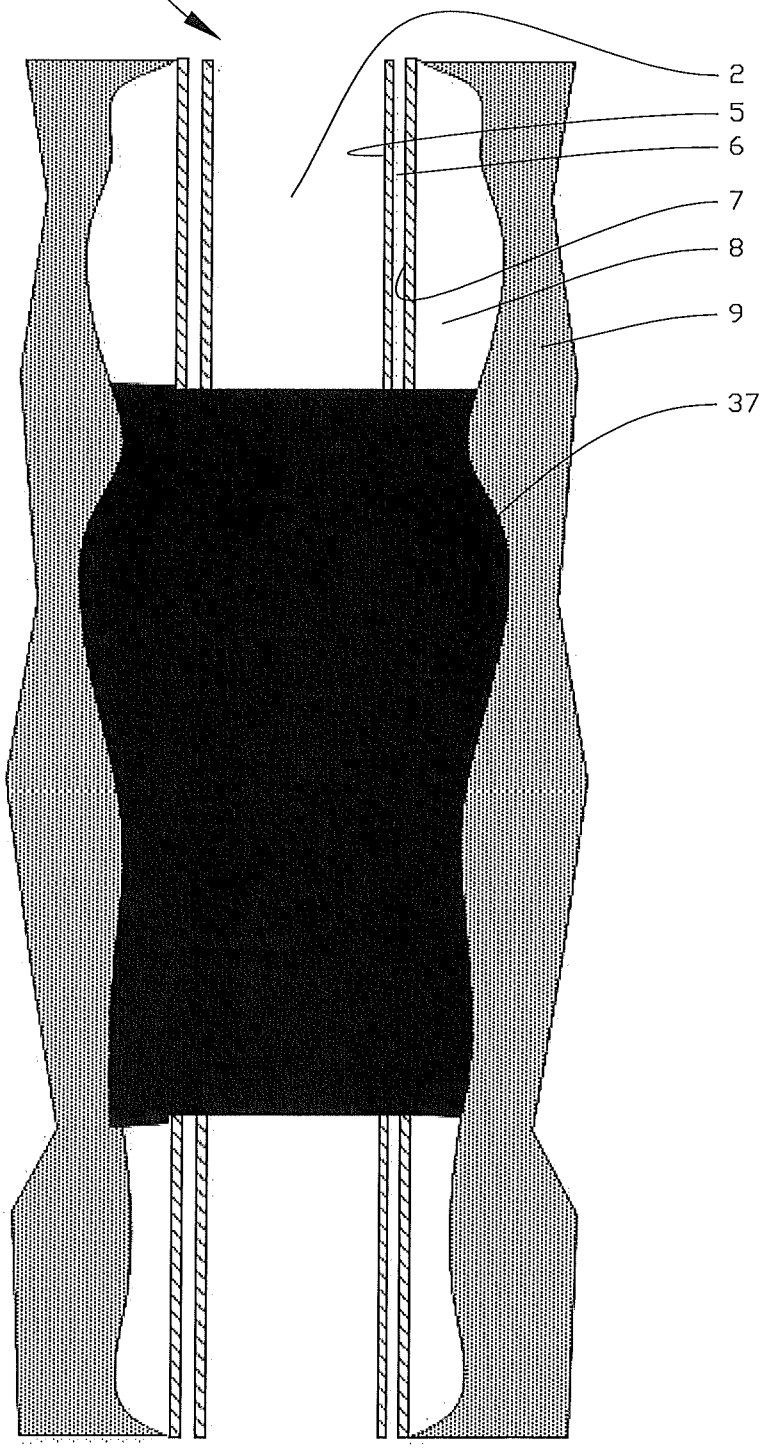


Fig. 8

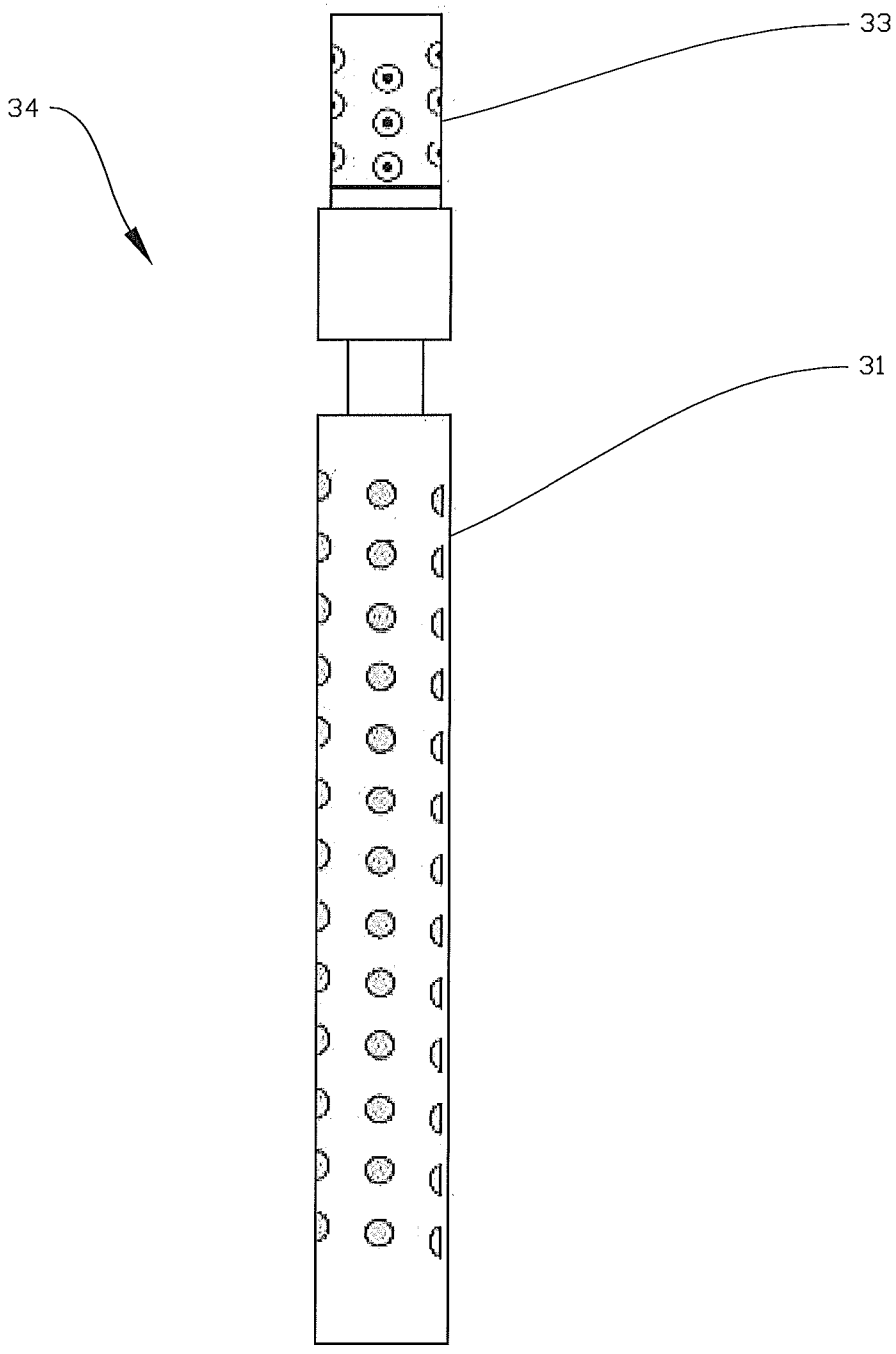
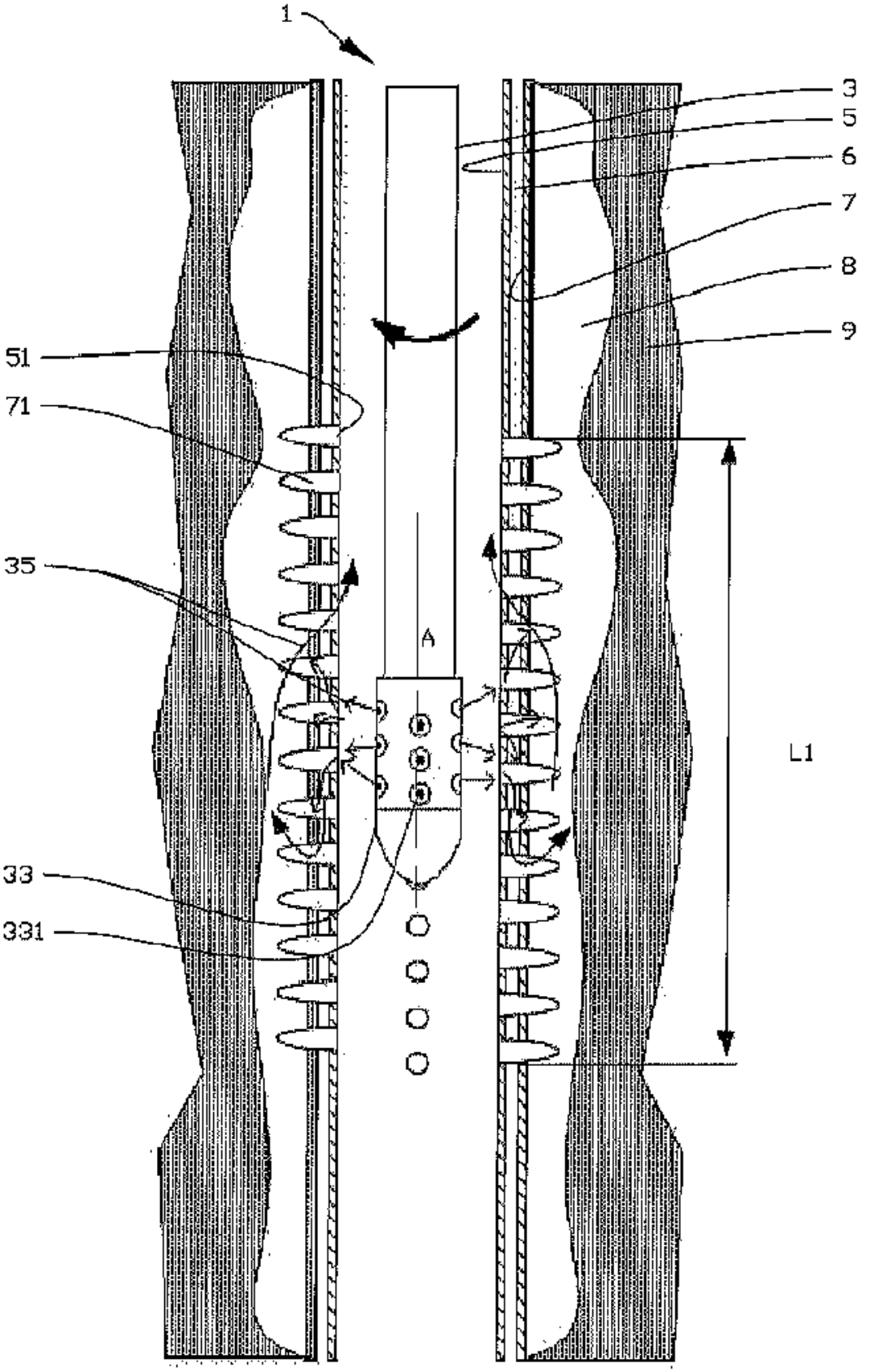


Fig. 9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