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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **E21B 49/00**	**A1**	**(11) International Publication Number:** **WO 98/48146** **(43) International Publication Date:** 29 October 1998 (29.10.98)

(21) International Application Number: PCT/NO98/00114

(22) International Filing Date: 6 April 1998 (06.04.98)

(30) Priority Data:
971859 23 April 1997 (23.04.97) NO

(71) Applicant *(for all designated States except US)*: SHORE–TEC AS [NO/NO]; Donevikstraen 14, N–4048 Hafrsfjord (NO).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: WOIE, Rune [NO/NO]; Donevikstraen 14, N–4048 Hafrsfjord (NO).

(74) Agents: HÅMSØ, Borge et al.; Håmsø Patentbyrå Ans, P.O. Box 171, N–4301 Sandnes (NO).

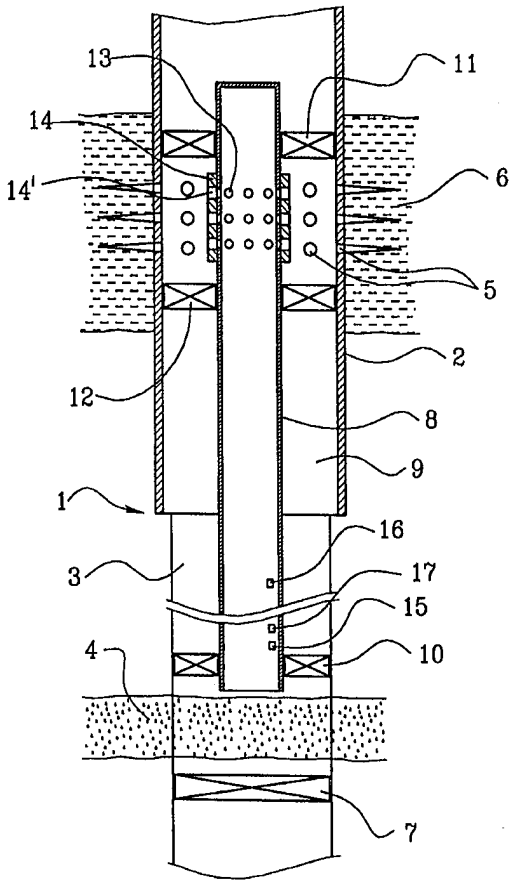
(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Norwegian).

(54) Title: A METHOD AND AN APPARATUS FOR USE IN PRODUCTION TESTS, TESTING AN EXPECTED PERMEABLE FORMATION

(57) Abstract

When production testing a permeable first formation (4), fluid flowing out therefrom is subjected to a pressure measurement and a flow rate control. In order to avoid bringing up the fluid flowing out during the production test to surface position where the fluid's inherent explosion and fire risk as well as poisonousness would cause substantial problems, a fluid flow path arranged for fluid transfer between the formations (4, 6) is established between said first formation (4) to be production tested and a second permeable formation (6), said fluid flow path which, in a suitable apparatus, is constituted by a channel–forming pipe (8). From this channel second permeable formation (6) receives said fluid and keeps it for some time. In the position of use, the apparatus is assigned sealing means, i.a. annulus packers (10, 11, 12) which are placed such that fluid flow between the formations (4, 6) is limited to only follow said fluid flow path.



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A METHOD AND AN APPARATUS FOR USE IN PRODUCTION TESTS, TESTING AN EXPECTED PERMEABLE FORMATION

This invention relates to a method and an apparatus for use in production test of a formation expected to be permeable. After having pointed out the existence of hydrocarbons upon drilling for oil and gas, a so-called production test is carried out, in order to provide information about permeable layers outside the bore hole or well itself.

Prior to a production test, when reservoir fluid is allowed to flow out of the formation, the well is provided with some equipment, including means to control the flow rate and measuring equipment to measure pressure and flow rate.

A production test has two phases, each with a duration of e.g. 24 hours. In both phases, a constant fluid flow is established from the formation.

In the beginning, it is fluid in the immediate neighbourhood of the well that flows into the well but, gradually, fluid from areas spaced at constantly larger distances from the well is drained off. The pressure within the well decreases due to the fact that the fluid must flow a constantly longer distance through the formation and, thus, is subjected to a

constantly increasing pressure loss. Upon the maintenance of a constant flow rate, it is achieved that the course of pressure within the well only depends on the character of the formation, which can be examined. Therefore, the course of pressure, i.e. interdependent values for pressure and time, is recorded during the production test. In the second phase of the production test, following immediately after the first phase, the fluid flow into the well is stopped.

Then, the pressure within the well will gradually increase to formation pressure as the formation around the well is refilled by means of the fluid flow into the well from remote areas. Also in this second phase, values for pressure and time are recorded.

Recorded pressure - time values in the two phases of the production test represent an important basis for subsequent analyses, appraisals and planning of further drilling activity and, possibly, development of an oil field. The question may well arise as to record other parameters, e.g. temperature, in addition to pressure and it is, of course, important to carry out chemical analyses of samples from the reservoir fluid.

Sealing means, e.g. in the form of annulus packers, are also adapted to take care of security requirements.

The present invention is directed to a method and an apparatus for maintaining a constant flow of reservoir fluid in the well while pressure and, possibly, other parameters are read off.

By a production test it is known to conduct fluid from the reservoir to the surface through a so-called tubing, which is installed in the well. Sealing means are disposed within the annulus between the production tubing and the well wall,

preferably on a place where a well casing has been installed, so that reservoir fluid is conducted to the surface through the tubing and not through the annulus. At the upper end thereof, the tubing is assigned a valve adapted to control the fluid flow, and sensors and measuring equipment are disposed, at least for allowing the reading off and recording time, flow rate in the tubing and pressure within the well.

It is known to install a downhole pump in order to achieve and maintain sufficient flow rate to carry out a production test if the pressure within the reservoir or the properties of the formation or reservoir fluid are such that this is required.

Even if the described technique is well developed and has been known for many years, it still suffers from a plurality of disadvantages and deficiencies.

Reservoir fluid constitutes, when it reaches the surface, a safety risk due to danger of explosion, fire hazard and toxicity. Therefore, substantial security measures must be made in connection with a production test. Additionally, reservoir fluid constitutes an environmental problem because production tests naturally are carried out before one takes the costs of installing process equipment. Therefore, it has been customary to conduct reservoir fluid to a burner. Due to the fact that combustion causes unwanted escapes of environmental gases and uncontrolled amounts of hydrocarbons into the sea, there exist some places, such as on the Norwegian continental shelf, where, owing to restrictions on burning and limitation in periods during a year for testing, it has become interesting to collect produced reservoir fluid and convey it to a suitable process plant. Even if this is an environmentally satisfactory solution, it is, nevertheless, awkward, price-raising as well as exhibitting many restrictions both in time and with respect to weather conditions.

The preparations taking place before production testing comprise typically setting and cementing of casings for insulating various permeable layers, and to take care of safety requirements. Additionally, special production tubing is used down to the layer/bed to be tested. These preparations are time-consuming and expensive. Safety considerations make it some times necessary to strengthen an already set well casing, perhaps over the entire or a substantial part of the length of the well; particularly in high pressure wells it might be required to install extra casings in the upper parts of the well.

It can be difficult to secure a good cementing, and it may arise channels, cracks or lack of cement. In many cases, it is difficult to define or measure the quality of the cement or the presence of cement. Unsatisfactory cementing causes great possibility for the occurrence of so-called cross flows to or from other permeable formations outside the casing. Cross flows may, to a high degree, influence the measurements carried out. Time-consuming and very expensive cementing repairs might be required in order to eliminate such sources of errors.

Today's system can take care of drilling of wells in deep waters, but does not provide a safe and secure production testing. In deep water, it is difficult to take care of security in case the drilling vessel drifts out of position, or whenever the riser is subjected to large, uncontrollable and not measurable vibrations or leeway. Such a situation requires a rapid disconnection of the riser or production tubing subsequently to the closing of the production valve at the seabed. To-day's system is defective in respect of reacting on and point out dangerous situations.

Further, in ordinary production it is usual to use various forms of well stimulation. Such stimulation may consist in the addition of chemicals into the formation in order to in-

crease the flow rate. A simple well stimulation consists in subjecting the formation to pressure pulses so that it cracks and, thus, becomes more permeable, so-called `'fracturing'' of the formation. A side-effect of fracturing can be a large increase in the amount of sand accompanying the reservoir fluid. In connection with production testing, it may in some relations be of interest to be able to effect a well stimulation in order to observe the effect thereof. Again, the case is such that an ordinary production equipment is adapted to avoid, withstand, resist and separate out sand, while corresponding measures are of less importance when carrying out a production test.

In some cases, it would be useful to be able to carry out a reversed production test, pumping produced fluid back into the formation again. However, this presupposes that produced fluid can be kept at approximate reservoir pressure and temperature. This will require extra equipment, and it will be necessary to use additional security measures. Further, it would require transfer of the production tubing. Probably, the production tubing would have to be pulled up and set once more, in order to give access to another formation. This is time-consuming as well as expensive. Therefore, it is not of actual interest to use such reversed production tests in connection with prior art technique. During a reversed production test, a pressure increase is observed in the well while a reversed constant fluid flow is maintained. When the reversed fluid flow is interrupted, a gradual pressure reduction will be observed in the well. Reversed production test may contribute to reveal a possible connection in the rock ground between formations connected by the channel, and may in some cases also contribute to define the distance from the well to such a possible connection between the formations.

The object of the invention is to provide a method and an apparatus for production testing a well where the described disadvantages of prior art technique have been avoided.

The object is achieved by means of features as defined in the following description and claims.

A main feature of the invention consists in that fluid is conducted from a first, expected permeable formation to a second permeable formation as opposed to prior art technique where fluid is conducted between a formation and the surface. According to the invention, prior to a production test, at least one channel connection is established between two formations, of which one (a first) formation is the one to be production tested. Further, sealing means are disposed to limit the fluid flow to take place only between the formations through the channel connection(s). When fluid flow takes place from first to second formation in an upward direction (the fluid flow may occur in the opposite direction, the formation being production tested then lying above said second, permeable formation accommodating the fluid flow), the sealing means, e.g. annulus packers, prevent fluid from flowing between the formations, outside the channel(s)

Within the channel, flow controlling means are disposed, inclusive a valve and, possibly, a pump, operable from the surface in order to control the fluid flow in the channel and, thus, between the formations. Further, within the channel, a sensor for flow rate in the channel is disposed. This sensor may, possibly, be readable from an surface position.

Additionally, sensors adapted to read pressure, temperature, detect sand, water and the like from the surface may be disposed. Of course, several sensors of each type may be disposed in order to monitor desired parameters at several places within the channel. As previously known, sensors for pressure and temperature are disposed within the well and, moreover, known equipment for timekeeping and recording of measuring values are used.

Upon a production test, by means of the flow rate sensor, the adjustable valve and, possibly, by means of said pump, a constant fluid flow is established and maintained in the channel, fluid flowing from one formation to the other formation. Pressure and, possibly, other well parameters are read and recorded as previously known. Thereafter, the fluid flow is closed, and a pressure built up within the well is monitored and recorded as known. By means of the invention, a production test might be extended to comprise a reversed flow through the utilisation of a reversible pump, so that fluid can be pumped in the opposite direction between the two formations.

Storing produced reservoir fluid in a formation results in the advantage that the fluid may have approximately reservoir conditions when it is conducted back into the reservoir. Further, according to the invention, well stimulating measures in the formation being production tested may be used. Fracturing may be achieved as known per se. To this end, the well is supplied with pressurised liquid, e.g. through a drill string coupled to the channel. Thereafter, a production test is carried out, such as explained. Additionally, a reversed production test may alternately give both injection and production date from two separated layers without having to pull the test string.

A non-restricting exemplary embodiment of an apparatus for carrying out the invention, is further described in the following, reference being made to the attached drawings, in which:

Figure 1 shows, diagrammatically and in a side elevational view, a part of a principle sketch of a well where a channel has been disposed which connects two permeable formations;

Figure 1a corresponds to figure 1, but here is shown a minor modification of the channel-forming pipe establishing the

fluid flow path between the two formations, the bore hole through said second formation not being lined;

Figure 2 shows a part of a well having a channel, corresponding to figure 1, and where a pump has been disposed.

In figure 1, reference numeral 1 denotes a part of a vertical well lined with a casing 2. The well 1 is extended with an open (not lined) hole 3 drilled through a first, expected permeable formation 4 to be production tested. The casing 2 is provided with a perforation 5 in an area where the well 1 passes through a second, permeable formation 6.

According to figure 1a, second permeable formation 6 is not insulated by means of casings (2 in figure 1).

First formation 4 is insulated from possible permeable formations adjacent the bottom of the well by means of a bottom packer 7. A tubular channel 8 extends concentrically with the well 1 from the area at first formation 4 to a place above the perforations 5. Thus, an annulus 9 is formed between the channel 8 and the wall defining the open hole 3 and between the channel 8 and the casing 2.

A lower annular packer 10 placed further from the bottom of the well 1 than first permeable formation 4, defines the lower end of the annulus 9.

An upper annular packer 11 placed further from the bottom of the well 1 than the perforations 5, defines the upper end of the annulus 9.

An intermediate annular packer 12 placed closer to the bottom of the well 1 than the perforations 5, prevents communication between the perforations 5 and possible other permeable formations above the lower packer 10.

The channel 8 is closed at the upper end and, according to figures 1 and 2, open at the lower end. In an area distanced from the upper end of the channel 8, below the place where the upper packer 11 is mounted, the channel 8 is provided with gates 13 establishing a fluid communication between the channel 8 and the annulus 9 outside the channel. Thus, fluid may flow from the first formation 4 to the well 1 and into the channel 8 at the lower end thereof, through the channel 8 and out through the gates 13 and further, through the perforations 5, to second formation 6.

In accordance with figure 1a, there is no need here for the perforations 5 in figures 1 and 2. The annulus packers 11 and 12 will then act against the wall defining the bore hole. The packer 7 can also be a part of the channel-forming pipe 8 when the pipe wall is perforated (21) between the packer 7 and the packer 10.

When the annulus packer 7 is mounted to the channel-forming pipe 8, the latter may be closed at the lower end thereof which, according to figure 1a, is positioned below the first, expected permeable formation layer 4. In an area above the annulus packer 7, the channel-forming pipe 8 is, thus, provided with through-going lateral gates 21 which, together with the through-going lateral gates 13, establish fluid communication between the formations 4, 6.

In the channel 8, a remotely operable valve (not shown) is disposed, said valve being adapted to control a fluid flow through the channel 8. The valve may, as known per se, comprise a remotely operated displaceable, perforated sleeve 14 adapted to cover the gates 13, wholly or in part, the radially directed holes 14' of the sleeve 14 being brought to register more or less with the gates 13 or not to register therewith.

Further, in the channel 8, remotely readable sensors are disposed, inclusive a pressure sensor 15 and a flow sensor 16 and a temperature sensor 17. The channel 8 may be assigned a pump 18 adapted to drive a flow of fluid through the channel 8.

The pump can be driven by a motor 19 placed in the extension of the channel 8. As known, a drive shaft 20 between motor 19 and pump 18 is passed pressure-tight through the upper closed end of the channel 8.

Advantageously, the motor 19 may be of a hydraulic type, adapted to be driven by a liquid, e.g. a drilling fluid which, as known, is supplied through a drill string or a coilable tubing, not shown. Also, an electrical motor can be used which can be cooled through the circulation of drilling liquid or through conducting fluid flowing in the channel 8, through a cooling jacket of the motor 19.

In the annulus 9, sensors may be disposed, in order to sense and point out communication or cross flowing to or from the permeable layers, above or below the annulus.

C l a i m s

1. A method for use in connection with an expected permeable, first formation (4), where fluid flowing out therefrom, during the production test is subjected to i.a. pressure measurement and flow rate control, c h a r a c t e r i z e d i n that at least one defined fluid flowing path (8) is established between said expected permeable, first formation (4) and a permeable, second formation (6), and that fluid flowing out from said first formation (4) is conducted through said fluid flowing path (8) to said second formation (6) which receives this fluid and keeps it at least temporarily.

2. A method according to claim 1, c h a r a c t e r i z e d i n that the fluid flowing path(s) is(are) established by means of channel-forming pipe(s) (8) which is positioned preferably concentrically with the surrounding bore hole wall/casing face between first and second formations (4, 6) situated at different levels, and that sealing means (7, 10, 12, 11) are placed in order to prevent fluid from flowing from first formation (4) to second formation (6) outside the fluid flowing path(s) (8).

3. A method according to claim 1 or 2, c h a r a c t e r i z e d i n that, after fluid has been transferred from first formation (4) to second formation (6), a reversed production test is carried out in that (transferred) fluid is returned forcedly from second formation (6) to first formation (4).

4. A method according to any one of the preceding claims, c h a r a c t e r i z e d i n that a fracturing of said first formation (4) is carried out, the well in the area of first formation (4) being supplied with pressurised

liquid, e.g. through a drill string which is connected to said fluid flowing path(8).

5. An apparatus for carrying out the method as defined in claim 1, and intended to be mounted into a well (1) between two formations, an expected permeable first formation (4) to be production tested, and a second permeable formation (6) comprising for the production test one or more sensors/meters/ regulators/controllers (15, 17) for i.a. sensing/ measuring, recording pressure conditions and flowing rate as well as adjusting the latter, c h a r a c t e r i z e d i n that the apparatus comprises at least one channel-forming pipe (8) which, within the well (1), establishes a fluid flow path between a first formation (4) to be production tested and a second permeable formation (6), sealing means (7, 10, 11, 12) assigned the apparatus being placed in order to restrict the fluid flow between the formations (4, 6) to take place only in the channel or channels (8) formed to establish at least one restricted fluid flow path, so that this/these channel(s) (8) constitutes the only fluid communication between the two permeable formations (4, 6).

6. An apparatus according to claim 5, c h a r a c t e r i z e d i n that said channel-forming pipe (8), respectively each channel-forming pipe (8), is open at the end situated closest to the formation (4) to be production tested, but closed at the opposite end, where an adjacent pipe portion situated within said second formation (6) has one or more lateral, through-going gates (13).

7. An apparatus according to claim 5, c h a r a c t e r i z e d i n that the channel-forming pipe (8), respectively each pipe (8), has closed axial ends, and that it/they, adjacent each end portion, within an area surrounded by the respective formation (4, 6), has one or more lateral, through-going gates (21).

8. An apparatus according to claim 6 or 7, c h a r a c - t e r i z e d i n that each through-going lateral gate (21 respectively 13) in each portion of the channel-forming pipe (8), respectively each pipe (8), surrounded by one of the formations (4 respectively 6), is assigned a movable, perforated sleeve (14) which, upon displacement in relation to lateral gate (21 respectively 13) in the channel-forming pipe, respectively each such pipe (8), can provide unthrottled or throttled ingoing/outgoing flow of fluid, respectively closure of the fluid flow.

9. An apparatus according to any one of the claims 5-8, c h a r a c t e r i z e d i n that the channel- forming pipe (8), respectively each channel-forming pipe (8), is assigned a motor-driven pump means (18), preferably a reversible pump means, for forced displacement of the fluid between the formations (4, 6).

10. An apparatus according to any one of the claims 5-9, c h a r a c t e r i z e d i n that the channel-forming, fluid flow path establishing pipe (8) is assigned a remotely operable valve adapted to control and adjust a fluid flow through the channel (8).

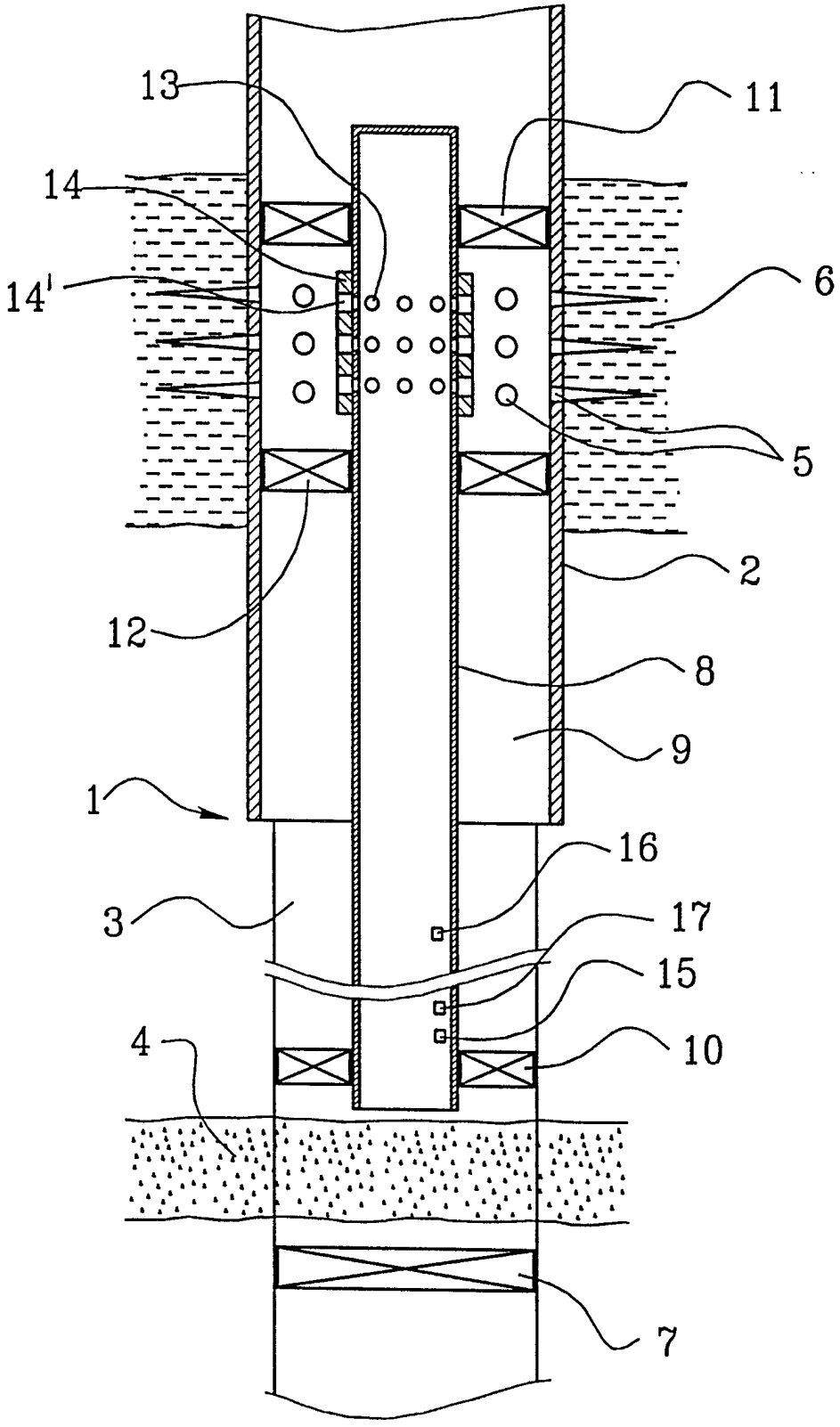


Fig. 1

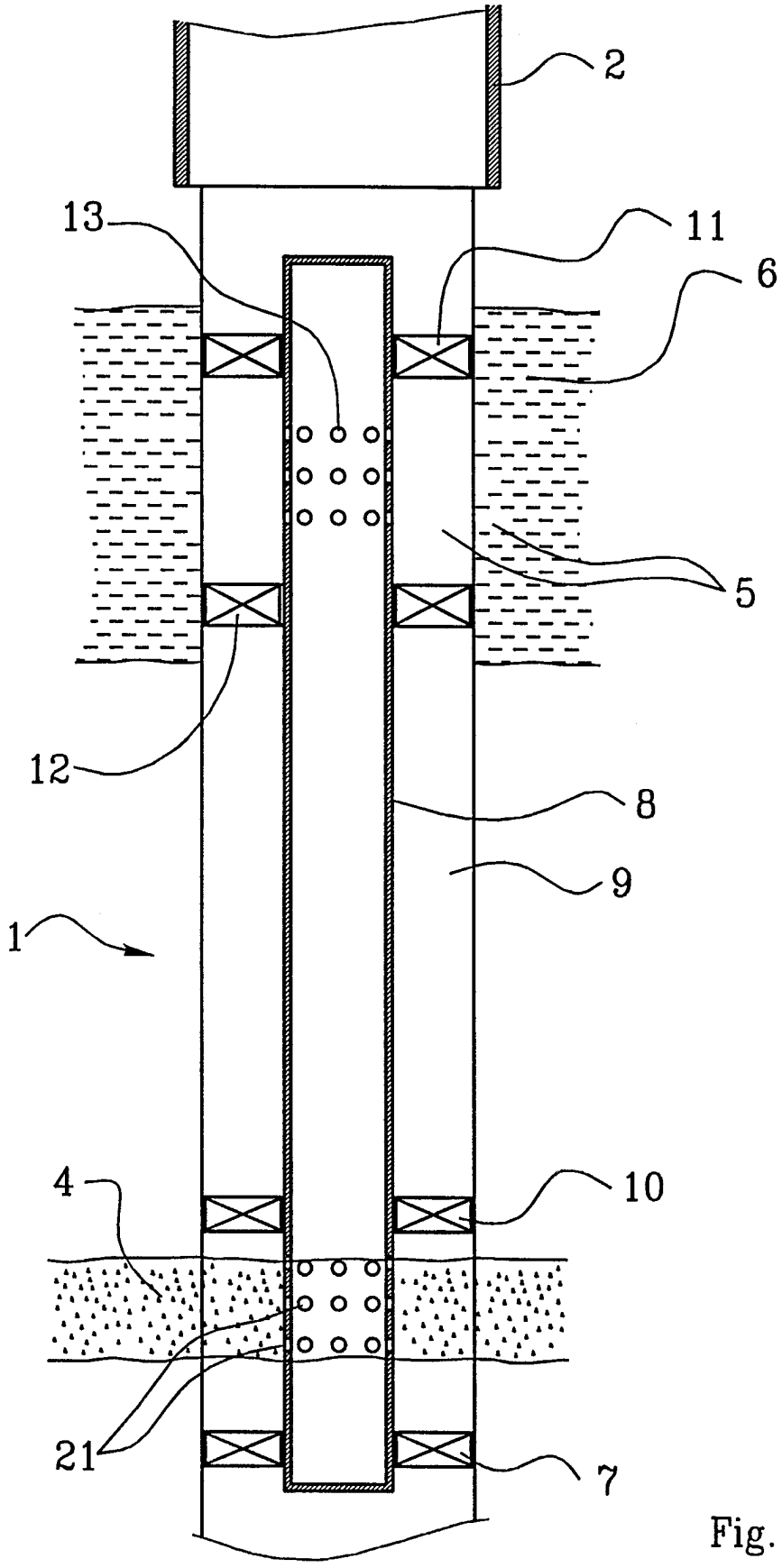


Fig. 1a

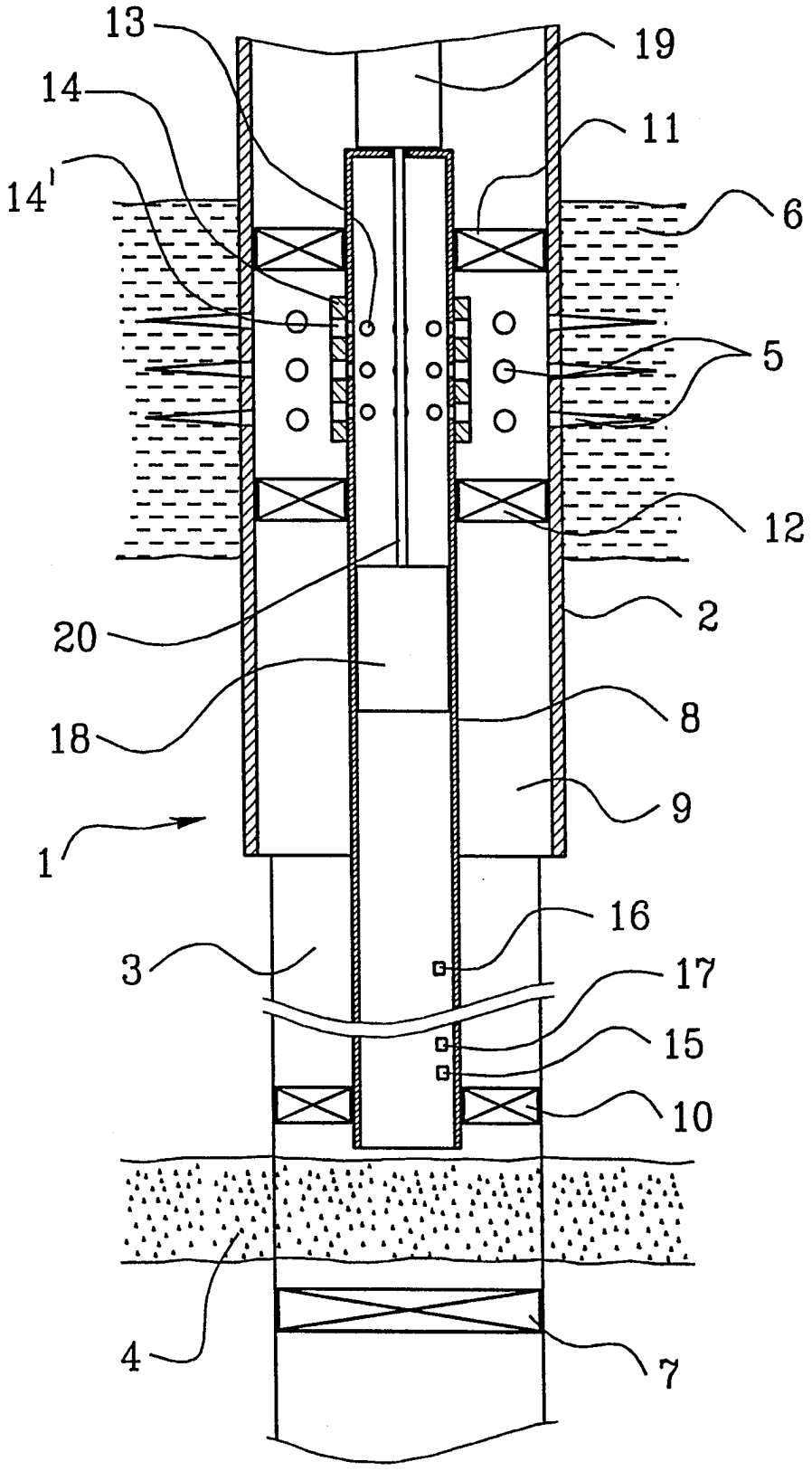


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 98/00114

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E21B 49/00
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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0176410 A1 (SCHLUMBERGER LIMITED), 2 April 1986 (02.04.86) --	1-10
A	EP 0481866 A2 (SCHLUMBERGER LIMITED), 22 April 1992 (22.04.92) --	1-10
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A	US 5337821 A (PETERSON), 16 August 1994 (16.08.94) -- --------	1-10

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Date of the actual completion of the international search	Date of mailing of the international search report
15 July 1998	23 -07- 1998
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INTERNATIONAL SEARCH REPORT

Information on patent family members

30/06/98

International application No.
PCT/NO 98/00114

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