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METHOD AND SYSTEM FOR TRANSMITTING INFORMATION IN A JET
DRILLING SYSTEM

5 The invention relates to an abrasive jet drilling system and to a method for transmitting information when using such system. The system and method can be used for drilling a borehole in a formation.

10 In abrasive jet drilling, abrasive particles are circulated through a drill string together with a drilling fluid. The downhole end of the drill string is provided with a jetting head and/or drill bit. During drilling, the mixture of drilling fluid and abrasive particles is expelled at high velocity from the jetting head onto the formation. By the combined action of the
15 abrasive particles and rotation of the drill string, the rock material of the formation is abraded, thus extending the borehole. By influencing the jet of abrasive particles, a specific direction can be selected for directional drilling of the borehole.

20 The jet drilling process may be monitored to control the trajectory of the borehole. Typically, the monitoring may use telemetry equipment for transmitting data from the downhole end of the borehole to surface. The telemetry equipment may comprise a mud pulse
25 generator. The mud pulse generator may be based on controlled movement flow restrictor components, for instance made of tungsten carbide. By means of these flow restrictors, the flow of the drilling fluid through the drill string may be restricted, thus creating a
30 pressure pulse in the drilling fluid. The pressure pulse propagates to surface via the drilling fluid, and can be measured by appropriate equipment at surface. By creating a set of these pressure pulses, information may be transmitted to surface in digital form.

When combined with abrasive jet drilling, the flow restrictor components are exposed to abrasive particles and increased fluid pressure relative to rotary drilling, resulting a increased wear and shorter lifetime.

Although the conventional data transmission technique performs satisfactorily, there is a need for an alternative way of transmitting in combination with abrasive jet drilling to overcome the above drawbacks.

The present invention provides a method for transmitting information from a downhole location to a surface location in an abrasive jet drilling system, comprising the steps of:

- providing a jet drilling system, comprising a drill string extending from surface to a downhole location in a borehole;
- generating a fluid flow in the drill string, the fluid flow comprising a mixture of drilling fluid and a quantity of abrasive particles;
- obtaining information regarding a downhole condition;
- modulating the quantity of abrasive particles in the mixture in dependence of said information, to generate data pulses downhole;
- detecting said data pulses at surface; and
- determining a transmitted downhole condition based on the detected data pulses.

The method according to the invention enables to communicate data to surface by using data pulses which are generated by modulating the abrasive particle concentration in the drilling fluid over time. The data pulses generated in the particle concentration are related to, for instance, the downhole condition information.

In an embodiment, a modulation frequency of the quantity of abrasive particles in the mixture is dependent on the rotational speed of the drill string. Modulating the frequency can be used both for telemetry and for directional drilling. For directional drilling, a specific part of the bore hole may be abraded more intensely than other parts. Herein, the bottom of the borehole will be eroded unevenly, providing a directional effect. However, in the method according to the invention, pulses which are generated by modulating the concentration of abrasive particles in the drilling fluid over time are used to transmit data to surface.

In an embodiment, the method comprises the step of modulating the amount of abrasive particles to influence the direction of the borehole. Directional drilling is thus possible, in addition to the modulating the particle concentration for data transmission.

In an embodiment, the particle concentration is modulated for data transmission while drilling a straight section of the borehole.

In a directional mode, data may be transmitted by eliminating a data pulse at specific intervals. Herein, the data pulses between two suppressed data pulses may represent the data to be transmitted.

According to yet another embodiment, a pulse shape of a data pulse may include information. The pulse shape herein may refer to a height or amplitude of the pulse, and a rise or fall characteristic of the pulse.

In an embodiment, the method according to the invention comprises the step of limiting correlation between the drill string rotation and a frequency of the modulation of the amount of abrasive particles. This embodiment is for instance suitable in combination with a drill bit having a single jet nozzle which points in a certain circumferential direction.

In an embodiment, the drill string is provided with a jetting head at a downhole end thereof, the jetting head comprising at least one jet nozzle; the method comprising the steps of:

- 5 - rotating the drill string at a selected rotational speed;
- expelling the fluid flow from said jet nozzle;
- controlling a frequency of the generated data pulses to prevent correlation between the selected
- 10 rotational speed and said frequency.

The present method of modulating the abrasive particle concentration can be combined with several possibilities for circulating the particles. In a first embodiment, the method according to the invention may

15 comprise the steps of:

- providing the drill string with a downhole recycling device for recycling of the abrasive particles; and
- recycling the abrasive particles by said downhole
- 20 recycling device.

Alternatively, the abrasive particles may be recycled using a particle recycling system at surface.

The step of modulating the abrasive particle concentration may include one or more of several

25 options.

According to a first option, modulation may be obtained by varying the duration between subsequent data pulses. Alternatively, modulation may include varying the amplitude of the data pulses. According to another

30 option, the frequency of the data pulses may be varied. Also, the particle release characteristic as a function of time may be varied. The data pulses may be provided in a regular pattern of pulses, wherein information may be included by omitting specific pulses according to a

35 specific coding.

In an embodiment, a start and end of the modulation step is triggered from surface. Several options are provided. According to a first embodiment, the modulation cycle can be activated by the following

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steps:

- defining an operating window of rotation, such as a specific range of rotations-per-minute (RPM) of the drill string, and/or a specific increase or decrease of RPM; and

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- upon detection of said operating window, starting the steps of modulating the amount of abrasive particles, detecting data pulses and establishing the downhole condition.

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The detection of a specific RPM value, or a derivative thereof, which is within said window, may trigger the drilling system to start or end data transmission. Upon detection of a value outside said window, said step of modulating the abrasive particle concentration can be ended.

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In an improved embodiment, a time delay may be included after detecting said window, before starting or ending data transmission. This embodiment prevents erroneous triggering of data transmission, for instance in case of stick-slip phenomena of the drill bit.

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Alternatively, the method may comprise the steps of:

- defining an operating window of fluid flow rate, such as a predetermined flow rate variation pattern;

- upon detection of said operating window, starting the steps of modulating the amount of abrasive

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particles, detecting data pulses and establishing the downhole condition.

When a predetermined flow rate variation pattern has been detected, the data transmission may be started or ended. For instance, restarting the flow rate after a break exceeding a threshold period, for instance in the

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range of two to four minutes, may trigger data transmission. A downhole sensor for pressure or flow rate measurement can be used to measure said variations. Alternatively, when a turbine generator is used for
5 downhole power generation, the voltage required by the generator or the rotations per minute (RPM) of a rotor of the generator can be used to detect the fluid flow rate through the drilling system.

According to yet another embodiment, the method may
10 comprise the steps of:

- defining a weight-on-bit operating window,
- upon detection of said operating window, starting the steps of modulating the amount of abrasive particles, detecting data pulses and establishing the
15 downhole condition.

Abrasive jet drilling may require only minimal or even no weight on bit. This means that typically the borehole may be drilled while the weight-on-bit is minimized. Thus, temporarily pushing down the drill
20 string and drill bit on the borehole bottom may be detectable by the bottom hole assembly. The bottom hole assembly may be provided, for instance, with at least one strain gauge for measuring changing stress or strain in the bottom hole assembly.

Defining the operating window and controlling the modulation cycle of the abrasive particle concentration as described above may limit or prevent reduction of rate-of-penetration and also limit or prevent unwanted deviations from a predetermined borehole trajectory.
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According to another aspect, the invention provides an abrasive jet drilling system for use in the method as described above.
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The invention provides an abrasive jet drilling system for drilling a borehole, comprising:

- a drill string comprising a drill bit at a downhole end thereof;
- a drive system for rotating the drill string;
- a pump for generating a fluid flow through the drill string, the fluid flow comprising a mixture of drilling fluid and an amount of abrasive particles;
- at least one sensor for sensing a downhole condition;
- a modulating device at or near the drill bit for modulating the amount of abrasive particles in the fluid flow in response to the downhole condition as provided by the at least one sensor to generate data pulses downhole;
- a detector at surface for detecting said data pulses; and
- a controller coupled to the detector for determining a transmitted downhole condition based on the detected data pulses.

The drilling system may comprise a flow sensor for sensing a flow condition of the drilling fluid, the control means being carried out for activating or de-activating the modulating device on the basis of the flow condition sensed. Alternatively, the drilling system may comprise a stress sensor or strain sensor for detecting a stress or strain of the drill string or the drill bit, the control means being adapted to activate or de-activate the modulating device based on the sensed stress or strain condition.

The invention will be described herein below with reference to the drawings, wherein:

Figure 1 shows a cross section of an embodiment of an abrasive jet drilling system; and

Figure 2 shows a cross section of an embodiment of a drill bit.

A jet drilling system 100 shown in figure 1 for drilling a borehole 9 in formation 10 comprises a drill string 1. The drill string extends in the borehole 9 from surface 20 to a downhole end 8 of the borehole. A downhole end 22 of the drill string 1 is provided with a drill bit 2. The upper end of the drill string is connected to a drive system 3 for rotating the drill string. A wellhead 24 typically encloses the upper end of the borehole 9. Pump 4, fluid supply line 5, and fluid discharge line 26 are provided for circulating fluid through the drill string 1 and the drill bit 2.

The drill bit 2 has at least one jet nozzle 6 for expelling the fluid onto the formation. The fluid may comprise a mixture of drilling fluid and abrasive particles. A jet of said mixture may be jetted at a predetermined pressure onto the bottom 8 of the borehole 9 to abrade the formation and extend the borehole.

The abrasive particles may either be circulated mixed in the drilling fluid through the pump 4, the fluid supply line 5 and the entire drill string 1. Alternatively, the abrasive particles may be recirculated downhole by a recirculating device which may be included in the drill string, preferably near the downhole end thereof. In the latter case, the abrasive particles are mixed in the drilling fluid by the recirculating device, the mixture continues towards the drill bit 2 and the at least one nozzle 6. The abrasive particles are subsequently at least partly extracted from a return fluid flow in the annulus 16 between the drill string and the borehole wall 19, to be subsequently mixed again with the drilling fluid within the drill string.

The abrasive jet drilling system 100 is able to corrode the rock material of the bottom 8 of the borehole. The corroding effect is at least partly due to

the abrasive impact of the mixture of drilling fluid and abrasive particles.

The amount of abrasive particles in the mixture may be modulated over time. This implies that the
5 concentration of the abrasive particles in the fluid varies over time. This variation may for instance be used in correspondence with the rotational speed of the drill string 1 to obtain a directional effect. See for instance US-7493966, US-7431104, US-7322433, WO-
10 2011/076845, WO-2011/076851, EP-2142747, GB-2444884, US-7017684. For details of modulation devices and systems, reference is made to these documents. Alternative modulation devices may be used as well.

According to the method of the invention, modulation
15 of the particle concentration is used to transmit data from the downhole end 22 of the drill string to surface.

The drilling system 100 may comprise a sensor 11 for detecting a certain downhole condition. The sensor may be provided on the drill bit 2 or on the drill string,
20 but typically near the drill bit. In addition, the drill bit 2 may be equipped with a modulation device 12 which is connected to the sensor 11. On the basis of data provided by the sensor 11, the modulation device 12 may apply a specific modulation pattern on the abrasive
25 particle concentration in the fluid mixture passing through the drill bit.

The modulation of the amount of abrasive particles in the mixture causes pressure pulses in the fluid flow. These pressure pulses are detectable at surface, for
30 instance by detection device 13. Thus, the pressure pulses can act as data pulses. Herein, the modulation device 12 creates pressure pulses according to a predetermined data transmission pattern. To transmit information, the data transmission pattern may comprise
35 one or more of: data pulse length, data pulse amplitude,

time between subsequent data pulses, rise time of a data pulse, decline time of a data pulse.

5 The detection device 13, for instance a pressure gauge, may be included in the fluid circulation circuit, for instance in the wellhead 24 or connected to the fluid discharge line 26. The pressure gauge is preferably positioned at surface. A data pulse evaluation device 14 is connected to the sensor 13, to evaluate the transmitted data pulses. The evaluation
10 device can translate the data pulses, to determine the downhole condition sensed by the downhole sensor 11. An operator or controller can subsequently evaluate the measured downhole condition and adjust the drilling process if deemed necessary.

15 The drill string 1 or the drill bit 2 may be provided with one or more additional sensors 15, such as a strain gauge. The sensor 15 provides measured data to the modulation device 12. The modulation device can subsequently transmit the measured data to surface as
20 described above.

The drill bit 2 may be an abrasive jetting head, which may operate substantially without weight-on-bit (WOB), or with relatively low WOB. It is possible to influence the stress sensor 15 by influencing
25 compressive forces in the drill string 1, i.e. by changing the WOB. Changes in WOB may thus be used to start or stop the data transmission operation of the modulation device 12. Thus, the data transmission process may be initiated or ended at any time.

30 The collector is a surface upon which or volume wherein particles can be collected, at least temporarily.

In an embodiment, the amount of particles in the drilling fluid may be modulated for the transfer of
35 information by deactivating one or more collectors.

Deactivating the collector(s) means that the particles are not hampered in their flow to the nozzle(s) and the bit pressure drop will be high. If in this phase the collector(s) are activated again for a relatively short duration the impact on the directional control will be relatively small whereas the (negative) pulses can still be detected and used for transmission of information. In other words, communication is restricted to the period of the directional control mode during which the collector(s) are not activated apart from short duration (negative) pressure pulses for communication. Similarly, the communication can also be restricted to the period of the directional control mode during which the collector(s) are activated apart from short duration (positive) pressure pulses for communication. Thus, transfer of data pulses may occur combined with directional drilling.

When having at least 2 collectors there is more freedom to manipulate the concentration. The collector closest to the bit is also manipulating the concentration pattern produced by the other collector. If the collector closest to the bit is not activated the concentration pattern from the other manipulator travels to the bit undisturbed, but if the collector closest to the bit is activated the amount collected per unit of time depends on the concentration pattern released by the other collector.

As an example, assume two collectors are designed and manipulated such that both collectors release their load during a short time and both produce a short concentration peak. If the peak of the collector closest to the bit is released exactly at the moment the peak of the other collector reaches the first collector both concentration peaks add up. If the collector closest to the bit is still activated, i.e. catches all particles

reaching the collector, this load is simply added to the mass already collected and will be released at the same time as the rest of particle mass on that collector:

this also produces a single sharp concentration peak. As
5 a third situation, the collector closest to the bit has produced a concentration peak after which it might still be deactivated. If during this deactivation period the concentration peak produced by the collector arrives at this collector it will pass undisturbed and will produce
10 a second concentration at the bit. The separation time between these two peaks will be shorter than the deactivation duration of the collector closest to the bit, but might be long enough to be detectable at surface.

15 During the period the pulses arrive at the bit the nozzle(s) should be dominantly aimed at the part of the borehole bottom of which the erosion is desired for the directional control. This way information can be transmitted by a predetermined code while still being in
20 directional control mode.

In a practical embodiment, the system may be operated in directional mode for a number of bit rotations and subsequently switch to communication mode for a number of rotations, then back to directional
25 mode.

In a practical embodiment, the sensors of the system can all be arranged in one module which is included in the drill string above the bit. It may be advantageous to keep all electronics relatively close together. The
30 system may include a downhole electronic control unit (not shown), for instance for downhole data storage, control of the modulation device 12, and/or interpretation of and response to any data signals. The control unit may be arranged between the modulation
35 device 12 and the sensor 15.

The system and method of the invention enable data transmission using equipment originally designed for directional drilling. The system and method obviate additional downhole equipment to create fluid pulses, 5 thereby obviating additional moving parts of said equipment, which are typically prone to wear and consume additional energy.

The present invention is not limited to the embodiments as described above, wherein various 10 modifications are conceivable within the scope of the appended claims. Features of respective embodiments may for instance be combined.

C L A I M S

1. Method for transmitting information from a downhole location to a surface location in an abrasive jet
5 drilling system, comprising the steps of:

- providing a jet drilling system, comprising a drill string (1) extending from surface to a downhole location in a borehole (9);
- generating a fluid flow in the drill string, the
10 fluid flow comprising a mixture of drilling fluid and a quantity of abrasive particles;
- obtaining information regarding a downhole condition;
- modulating the quantity of abrasive particles in
15 the mixture in dependence of said information, to generate data pulses downhole;
- detecting said data pulses at surface;
- determining a transmitted downhole condition based on the detected data pulses.

20 2. Method of claim 1, the drill string being provided with a jetting head (2) at a downhole end thereof, the jetting head comprising at least one jet nozzle (7);

- the method comprising the steps of:
- rotating the drill string (1) at a selected
25 rotational speed;
 - expelling the fluid flow from said jet nozzle;
 - controlling a frequency of the generated data pulses to prevent correlation between the selected rotational speed and said frequency.

30 3. Method of claim 1, comprising the steps of:

- providing the drill string with a downhole recycling device for recycling of the abrasive particles; and

5 - recycling the abrasive particles by said downhole recycling device.

4. Method of one of the preceding claims, wherein the step of modulating the amount of abrasive particles includes varying the time duration of the data pulses.

10 5. Method of one of the preceding claims, wherein the step of modulating the amount of abrasive particles includes varying the amplitude of the data pulses.

6. Method according to any of the preceding claims, wherein the step of modulating the amount of abrasive particles includes varying the frequency of the data pulses.

15 7. Method according to any of the preceding claims, wherein the step of modulating the amount of abrasive particles includes varying a particle release characteristic as a function of time.

20 8. Method according to any of the preceding claims, wherein the step of modulating the amount of abrasive particles includes providing a regular rhythm of data pulses.

25 9. Method of one of the preceding claims, wherein the step of modulating the amount of abrasive particles includes omitting data pulses according to a predetermined coding.

10. Method according to one of the preceding claims, comprising the steps of:

30 - defining an operating window for rotation of the drill string, selected from a specific range of rotations per minute (RPM), a preselected increase of RPM, or a preselected decrease of RPM;

- detecting the operating window;

- upon detection of said operating window, starting the steps of modulating the amount of abrasive particles, detecting data pulses, and determining the downhole condition.

5 11. Method according to any of the preceding claims, comprising the steps of:

- defining an operating window of flow rate;
- detecting said operating window of flow rate;
- upon detection of said operating window of flow

10 rate, starting the steps of modulating the amount of abrasive particles, detecting data pulses, and determining the downhole condition.

12. The method of claim 11, wherein the operating window of flow rate includes a predetermined flow rate variation pattern.

15 13. Method of any of the preceding claims, comprising the steps of:

- defining a weight-on-bit operating window;
- detecting said weight-on-bit operating window;

20 - upon detection of said weight-on-bit operating window, starting the steps of modulating the amount of abrasive particles, detecting data pulses, and determining the downhole condition.

25 14. Abrasive jet drilling system for drilling a borehole, comprising:

- a drill string (1) comprising a drill bit (2) at a downhole end thereof;

- a drive system (3) for rotating the drill string;

30 - a pump for generating a fluid flow through the drill string, the fluid flow comprising a mixture of drilling fluid and an amount of abrasive particles;

- at least one sensor (11) for sensing a downhole condition;

- 5 - a modulating device (12) at or near the drill bit (2) for modulating the amount of abrasive particles in the fluid flow in response to the downhole condition as provided by the at least one sensor to generate data pulses downhole;
- a detector at surface for detecting said data pulses; and
- a controller coupled to the detector for determining a transmitted downhole condition based on the detected data pulses.
- 10 15. Abrasive jet drilling system of claim 14,
- the at least one sensor being selected from the group of: a flow sensor for sensing a flow condition of the drilling fluid, and a stress sensor (15) for detecting a stress condition of the drill string (1) or the drill bit (2);
- 15 - the modulating device being coupled to said sensor and being adapted to be activated or deactivated based on the flow condition or the stress condition.
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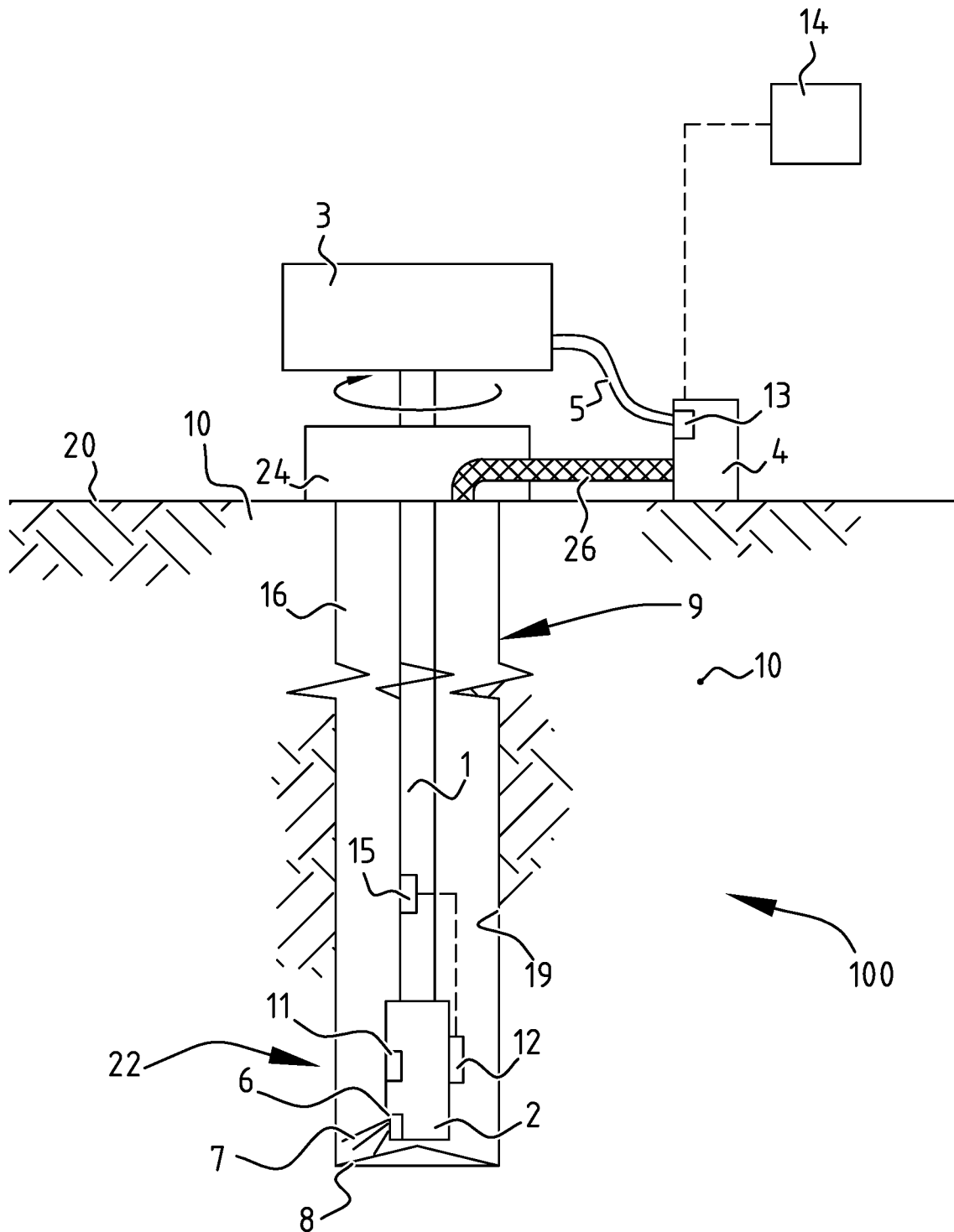


FIG. 1

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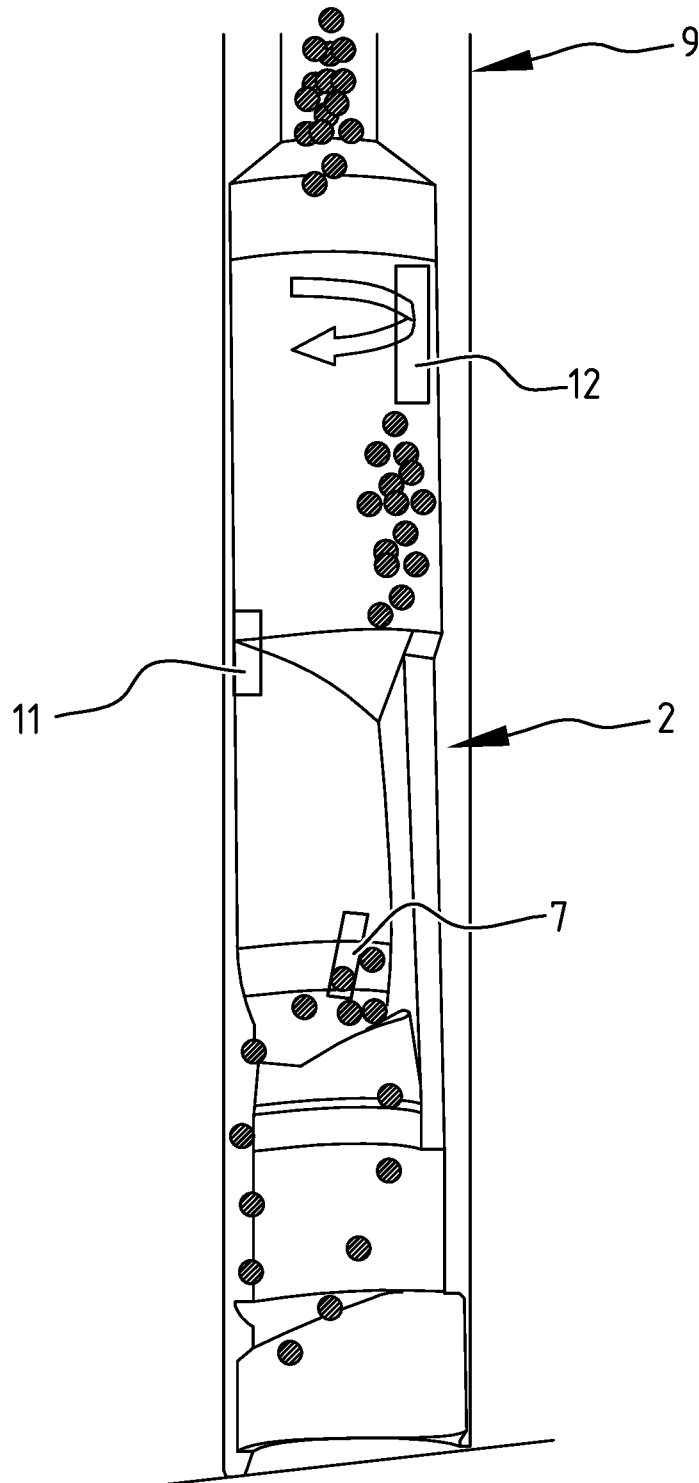


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/066857

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B47/12 E21B7/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 263 984 B1 (BUCKMAN SR WILLIAM G [US]) 24 July 2001 (2001-07-24) column 3, lines 21-23; 56-62; figure 1 -----	1-14
A	WO 2011/076851 A1 (SHELL INT RESEARCH [NL]; BLANGE JAN-JETTE [NL]; VAN NIEUWKOOP PIETER []) 30 June 2011 (2011-06-30) cited in the application page 12, line 32 - page 13, line 10 page 29, lines 23-30 page 30, lines 4-8 -----	1,14
A	US 2014/118157 A1 (JAMISON DALE E [US]) 1 May 2014 (2014-05-01) abstract -----	1,14
A	US 2012/273277 A1 (BLANGE JAN-JETTE [NL] ET AL) 1 November 2012 (2012-11-01) paragraph [0069] -----	1,14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bellingacci, F

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/066857

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