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(54) **Methods and apparatus for wireline drilling on coiled tubing**

(57) Apparatus for drilling an underground borehole, comprising:

- a tubular conveyance system (18) including an electric cable and a supply of drilling fluid, the supply of drilling fluid being arranged in use to pump fluid from the surface down the inside of the tubular conveyance (18) so as to return to the surface via the annulus between the outside of the tubular conveyance (18) and the borehole;
- a drilling system (20) comprising an electrically powered pump (28) and a drilling motor (22), the pump (28) being arranged in use to pump fluid from the borehole outside the drilling system (20) up through the inside of the drilling system (20);
- a connector (30) connecting the drilling system (20) to the tubular conveyance system (18), through which the pump (28) and motor (22) are connected to the electric cable, and
- a flow diverter at which flow down the inside of the tubular conveyance system (18) is diverted into the annulus, and flow up the inside of the drilling system (20) is

diverted into the annulus.

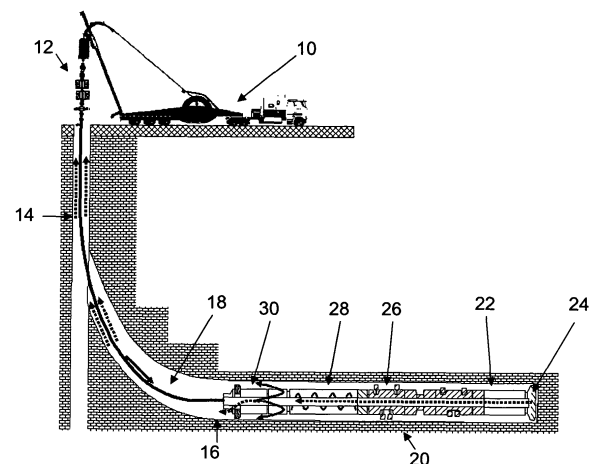


Figure 1

Description**Technical field**

[0001] This invention relates to methods and apparatus for drilling boreholes that is particularly applicable to drilling with wireline drilling apparatus carried on coiled tubing.

Background art

[0002] Current conventional coiled tubing drilling (CTD) employs high hydraulic power delivered from the surface through the coiled tubing (CT) to power a drilling positive displacement motor (PDM) that in turn powers the drill bit. This high drilling power requires a large-diameter CT that demands larger surface installations.

[0003] Current methods of changing the trajectory in CTD typically involve a fixed bend on the PDM, and a hydraulic or electric-over-hydraulic means of rotating the bend azimuth. Apart from the larger and heavier surface equipment, this way of drilling on CT is limited in reach by the buckling limit of the CT, and involves a low-efficiency conversion of hydraulic power to drilling footage.

[0004] US 2 548 616 describes a method of drilling a well with a conduit to surface through which a fluid is pumped (today's CTD). The option of a cable in the CT with an electric motor at the bottom-hole assembly driving the bit is also described but the conduit still provides the axial thrust for drilling.

[0005] EP 0 110 182 describes an apparatus with a hydraulic tractor/crawler (with anchors and a stroker), an umbilical from surface for communications and powering of an electric pump that powers the hydraulic tractor, and methods of steering. The means of rotating the bit are described as purely hydraulic (either from the hydraulic distribution system, or from a hydraulic line from the surface.) CT is also described.

[0006] US 6 629 570 describes a high-power electric motor capable of drilling on CT. In use drilling fluid flows through the motor to return to the surface through the bit and annulus (conventional circulation).

[0007] WO 2004 011766 describes a wireline powered drilling system in which produced fluid from the borehole is circulated as drilling fluid. A downhole pump is used to perform conventional or reverse circulation through the downhole drilling tool. Flow to the surface is through production tubing around the cable.

[0008] Other documents describing wireline drilling systems include WO 2004 072437 and WO 2005 071208.

[0009] The object of the invention is to provide a drilling apparatus that does not need large capacity CT due to reduced hydraulic power requirements yet which still provides effective hole cleaning in the drilling region to avoid sticking. The invention achieves this object by providing electric power to the drilling system via a cable and by providing a flow diverter to allow downward drilling fluid

flow around the outside of the drilling assembly while using normal annulus flow above the drilling system for good cuttings transport.

5 Disclosure of the invention

[0010] One aspect of the invention comprises apparatus for drilling an underground borehole, comprising:

- 10 - a tubular conveyance system including an electric cable and a supply of drilling fluid, the supply of drilling fluid being arranged in use to pump fluid from the surface down the inside of the tubular conveyance so as to return to the surface via the annulus between the outside of the tubular conveyance and the borehole;
- 15 - a drilling system comprising an electrically powered drilling motor and a pump arranged in use to pump fluid from the borehole outside the drilling system up through the inside of the drilling system;
- 20 - a connector connecting the drilling system to the tubular conveyance system and to the electric cable, and
- 25 - a flow diverter at which flow down the inside of the tubular conveyance system is diverted into the annulus, and flow up the inside of the drilling system is diverted into the annulus.

[0011] The use of the flow diverter makes it possible to provide reverse circulation (circulation of fluid from the annulus into the BHA) where drilling is taking place, so improving hole cleaning in small diameter boreholes and reducing the risk of sticking.

[0012] Preferably, the drilling system has separate axial and rotary drive mechanisms. It is particularly preferred that the axial drive mechanism comprises a crawler system. The drilling motor can comprise an electric motor powered through the electric cable. The drilling system typically comprises an electric pump but can comprise a jet pump instead of the electrically powered pump.

[0013] Typically the tubular conveyance system comprises coiled tubing. This can be a single coiled tube or can comprise several sections joined end to end. Because the drilling action is handled by the drilling system, it is not necessary that the tubular conveyance system provide the torque for a rotary drilling action nor high axial stiffness to transfer the weight on the bit necessary for drilling.

[0014] In a particularly preferred configuration, the flow diverter forms part of the connector. Alternatively, the flow diverter is positioned in the tubular conveyance above the connector.

[0015] In use, the flow diverter can direct part of the drilling fluid down around the outside of the drilling system and the remainder of the fluid back to the surface around the outside of the tubular conveyance. Thus the reverse circulation around the drilling system changes to conventional circulation around the tubular conveyance which

allows improved cuttings transport in the main part of the borehole. The flow diverter can be arranged to divert flow from the inside of the drilling system to the annulus above the point at which it diverts flow from the tubular conveyance system into the annulus.

[0016] One embodiment of the apparatus further comprises a jetting system including one or more flow nozzles arranged to direct jets of fluid inside the borehole to remove accumulated deposits. Preferably, the flow nozzles are adjustable so as to change the direction of flow of fluid therefrom.

[0017] In this embodiment, the flow diverter can direct fluid into the flow nozzles for jetting and further comprises a valve adjustable to vary the amount of fluid directed through the flow nozzles and the amount of fluid directed into the annulus.

[0018] The apparatus can further comprise a rotatable crown driven by the motor for use in back reaming. A turbine driven by fluid flow from the tubular conveyance system can be connected to drive the crown via a gear train. An electric generator can be connected to the turbine and an electric motor connected to the crown via the gear train, the output of the generator being used to power the electric motor and drive the crown.

[0019] Another aspect of the invention comprises a method of drilling an underground borehole using an apparatus comprising a tubular conveyance system including an electric cable and a supply of drilling fluid; a drilling system comprising an electrically powered pump and a drilling motor; a connector connecting the drilling system to the tubular conveyance system, through which the pump and motor are connected to the electric cable; and a flow diverter; the method comprising:

- pumping fluid from the surface down the inside of the tubular conveyance so as to return to the surface via the annulus between the outside of the tubular conveyance and the borehole; and
- using the electrically powered pump of the drilling system to pump fluid from the borehole outside the drilling system up through the inside of the bit and drilling system;
- diverting fluid flow down the inside of the tubular conveyance system into the annulus, and diverting flow up the inside of the drilling system into the annulus using the flow diverter; and
- using the drilling motor to drill the borehole using the drilling system.

[0020] Preferably, the method comprises diverting part of the drilling fluid down around the outside of the drilling system and the remainder of the fluid back to the surface around the outside of the tubular conveyance.

[0021] It is also preferred that method further comprises directing jets of fluid from one or more nozzles of a jetting system inside the borehole to remove accumulated deposits. The flow nozzles can be adjusted so as to change the direction of flow of fluid therefrom.

[0022] Fluid can be diverted into the flow nozzles for jetting using the flow diverter and adjusting a valve to vary the amounts of fluid directed through the flow nozzles and the amount of fluid directed into the annulus.

[0023] The method can further comprise back reaming the borehole using the drilling system. The back reaming can be performed using a rotating crown driven by the drilling motor and/or a hydraulic system.

Brief description of the drawings

[0024]

Figure 1 shows a drilling operation using apparatus according to a first embodiment of the invention; Figure 2 shows details of the connection and flow diverter of Figure 1;

Figure 3 shows a drilling operation using apparatus according to a second embodiment of the invention; and

Figure 4 shows detail of jetting nozzles and the ensuing swirling flow pattern in a third embodiment of the invention.

Mode(s) for carrying out the invention

[0025] The drilling operation shown in Figure 1 is conducted using a conventional CT unit 10 and injector/pressure control setup 12 at the surface of the well 14 and is being used to drill a lateral well 16 extending away from the main well 14. The lateral well has been started in the usual manner by milling a window in the casing and drilling laterally using a whipstock to provide deviation in drilling direction. The drilling apparatus comprises a CT conveyance system 18 carrying a drilling assembly 20 at its lower end. The conveyance system 18 comprises a CT having an electric cable running inside from the surface. The weight of the tool is carried by the CT 18, so the electric cable only needs to be able to support its weight. A drilling fluid supply forms part of the CT unit 10 at the surface and pumps drilling fluid down the inside of the CT.

[0026] The drilling assembly comprises a motor section 22 including an electric motor providing rotary drive to a drill bit 24. Immediately behind the motor section is a crawler unit 26 comprising an open hole tractor for providing axial drive to the drill bit 24. Acting together, the electric motor and the crawler unit 26 provide the drive to the drill bit 24 to allow drilling to proceed. The crawler unit 26 can also be operated in reverse to pull the motor section and bit from the borehole. A pump section 28 is mounted above the crawler unit 26 and has an electric pump mounted therein. A channel extends from the drill bit up through the motor section 22 and crawler section 26 to the pump so that in normal use, the pump can draw fluid and drilled cuttings up through the drill bit 24 and inside the drilling assembly 20.

[0027] The drilling assembly 20 is connected to the end of the CT by means of a connection unit 30. The

connection unit 30 provides a mechanical connection between the CT and the drilling assembly 20 and an electrical connection between the electric cable and the electrical components of the drilling assembly 20.

[0028] In the embodiment of Figure 1, the connection unit 30 also comprises a flow diverter as is shown in more detail in Figure 2. The flow diverter is formed by flow channels 32, 34 in the connection unit 30. Flow channel 32 is connected to the interior of the CT so that fluid flowing down the CT is vented into the annulus surrounding the CT and drilling assembly via lower ports 36 in the lower part of the connector 30. Fluid exiting these lower ports 36 flows mainly back to the surface in the annulus but a portion of this fluid also flows down the annulus around the drilling assembly 20 to be drawn up through the bit 24 by the action of the pump. Flow channel 34 connects to the channel running through the inside of the drilling assembly 20 and is vented into the annulus via upper ports 38 in the upper part of the connector 30 above the lower ports 36. Thus any fluid and cuttings vented through the upper ports 38 are carried back to the surface in the annulus by the greater flow of fluids leaving the lower ports 36. In this way, cuttings are kept out of the region of the annulus around the drilling assembly 20, so reducing the likelihood of build-up and sticking in the smaller annular space. Venting to the annulus above the drilling assembly 20 allows normal well control to be exercised and avoids the possibility of hydrocarbons returning to the surface in the CT.

[0029] The connector shown in Figure 2 also has a back reaming device comprising a rotatable crown 40 mounted at the top of the connector 30. The crown 40 is driven by a turbine and gear train (not shown), the turbine being driven by the flow of fluid along the tool. In an alternative embodiment, the turbine can drive an electrical generator (alternator) for powering an electric motor for driving the crown 40. A still further version can take electric power from the cable. In use, the crown 40 can be operated when the drilling assembly 20 is pulled out of hole and allows any lips or ledges that have formed to be smoothed and allow easy passage of the drilling assembly 20 from the well with less likelihood of sticking.

[0030] Figure 3 shows a further embodiment of the invention in which the flow diverter is positioned in the main well 14 in order to reduce the issues relating to transport of cuttings in the lateral borehole 16 and possible contamination of the reservoir with cuttings infiltration through the borehole wall. The CT is split during deployment, as described in European patent application no. 05291698.8 and the flow diverter 42 is inserted at this point. The combination with a CT connector 44 between the CT and the drilling assembly 20 allows the drilled cuttings to be returned to the main well 14 (preferably a cased section) by ejecting the cuttings from the flow diverter 42 into the annulus. The conventional drilling fluid circulation at this point is used to transport the cuttings to the surface. This approach eliminates cuttings transport in the open-hole annulus section of the lateral well

16, and therefore decreases the possibility of accumulation of cuttings beds. This in turn reduces the sticking risks when pulling the drilling assembly 20 out of hole.

[0031] Once the drilling operation has been performed, the task of pulling the drilling assembly 20 out of hole (POOH) can potentially encounter problems depending on the condition of the drilled hole. Solutions depend on the POOH condition. The drilling assembly 20 can include sensors to assess the condition of the borehole for the risk of solids build-up that can potentially impede the movement of the BHA and/or CT in the well. The sensors included in the tool to detect such conditions include caliper, azimuthal density neutron, and internal and annular pressure sensors.

[0032] As the drilling assembly 20 is pulled back, it can drag with it cuttings left in the borehole and these can eventually accumulate sufficiently to create a barrier through which it cannot be pulled by use of the CT alone. One solution for such a case is to jet fluid backwards in the annulus while POOH to mobilize cuttings and transport them in the annulus, so that they do not accumulate to cause a potential sticking problem. The fluid jetting can be provided by nozzles, preferably in or near the connector 30 but potentially in other parts of the drilling assembly 20 or elsewhere in the CT. One preferred form of jetting arrangement is shown in Figure 4. The nozzles 46 are configured to provide a jetting flow with a helical swirl as it exits a nozzle. Such nozzles are known in other well cleaning applications and can be applied mutatis mutandis to this application.

[0033] The jetting arrangement can include a mechanism using hydraulic or electric signals such that allows the direction of the flow from the nozzle to be adjusted in the vicinity of the cuttings, to further mobilize the cuttings, or to give some directional jetting focus as necessary. Dictation of the outward and rear jetting flow ratio will give further control on the cleaning efficiency for the specific conditions. As previously mentioned, measurements incorporated in the tool (e.g. internal and annular pressures) can be used to determine the condition, optimum jetting configuration, and to confirm the effectiveness of the cleaning operation (e.g. by a decreased equivalent circulating density ECD).

[0034] Hydraulic signalling can include methods such as flow rate changes and modulation from the surface unit pump, and ball drops. Electric signals can include solenoid activation, or use of bi-stable valves (to decrease the need for high power consumption during extended periods of time as is the case with traditional solenoids). Such bi-stable valves are described by EP113578.

[0035] A pure jetting of a ledge as the tool is being pulled (or is tractor) back out, might not be enough to overcome the 'step' it encounters. Swelling formations such as shales, coal sloughing, or other such formations can cause large steps to form. In such a case, mechanical means of smoothing out the ledge or drilling some of the swelled formation (to a dimension larger than the diam-

eter of the tool) might be required. Various solutions are described above in relation to Figure 2.

[0036] One solution to this problem is to use an electric motor driving a rotating crown. However, since the hydraulic power of the CT flow is available, other methods are possible for creating the reaming action without consuming power from the wireline cable.

[0037] One such approach involves using the CT flow to power a turbine whose axis turns the reamer crown via a gear train. Another involves using the CT flow to power a turbine connected to an alternator to create electrical power that can then run an electric motor that turns the reamer crown through a gear train.

[0038] It can be particularly advantageous to use both techniques, back reaming with a rotating crown and jetting, for difficult conditions where one method alone might prove slow or less effective.

[0039] In the simplest configuration, as shown in Figure 2, all the flow through the CT exits at the flow diverter in the connector 30 above the drilling assembly 20 and below the CT connection. If large enough exit ports 36 are provided and the flow rate is sufficient, cuttings are transported in the annulus, but no jetting is performed and no extra mobilization of the cuttings is achieved. Of the flow exiting the CT, a small percentage flows downwards around the drilling assembly 20 as the pump forces the fluid through the bit 24 and up through the drilling assembly 20 in 'reverse' circulation, and then ejects it above the exit ports 36 so that the low flow and cuttings are commingled with the CT flow coming out of the flow diverter.

[0040] In another embodiment, a downhole valve can also be included to dictate the proportion of flow split between exit ports 36 and jetting nozzles 46. Apart from being able to change between jetting and simply circulating, this valve can also produce pressure pulses to remove harder ledges in a similar manner to that described in US5944123 and US6062311. The valve can either be electrically activated using surface commands, or hydraulically commanded using flow variation schemes (e.g. switches to jetting above a specific flow rate and pressure drop.)

[0041] An additional advantage of power available in the fluid in the CT is the ability to power a jet pump in the pump section 28. This jet pump can replace the electric motor driving the pump. The use of a jet pump will create a small increase in surface power needs but has the advantage that the tool length can be substantially reduced (pump, transmission, gear box, motor, oil compensation, motor control and drive electronics), while increasing the reliability.

[0042] Furthermore, a dual pump system can be employed to circulate around the drilling assembly and in the lateral borehole 16, and to act as a booster in the well 14 to circulate cuttings to the surface.

[0043] Other changes can be made while staying within the scope of the invention.

Claims

1. Apparatus for drilling an underground borehole, comprising:

- a tubular conveyance system including an electric cable and a supply of drilling fluid, the supply of drilling fluid being arranged in use to pump fluid from the surface down the inside of the tubular conveyance so as to return to the surface via the annulus between the outside of the tubular conveyance and the borehole;
- a drilling system comprising an electrically powered drilling motor and a pump arranged in use to pump fluid from the borehole outside the drilling system up through the inside of the drilling system;
- a connector connecting the drilling system to the tubular conveyance system and to the electric cable, and
- a flow diverter at which flow down the inside of the tubular conveyance system is diverted into the annulus, and flow up the inside of the drilling system is diverted into the annulus.

2. Apparatus as claimed in claim 1, wherein the drilling system has separate axial and rotary drive mechanisms.

3. Apparatus as claimed in claim 2, wherein the axial drive mechanism comprises a crawler system.

4. Apparatus as claimed in claim 1, 2 or 3, wherein the drilling motor comprises an electric motor powered through the electric cable.

5. Apparatus as claimed in claim 1, 2 or 3, wherein the drilling system comprises a jet pump for pumping fluid through the drilling system.

6. Apparatus as claimed in any preceding claim, wherein the tubular conveyance system comprises coiled tubing.

7. Apparatus as claimed in any preceding claim, wherein the flow diverter forms part of the connector.

8. Apparatus as claimed in any of claims 1-6, wherein the flow diverter is positioned in the tubular conveyance above the connector.

9. Apparatus as claimed in any preceding claim, wherein in use, the flow diverter directs part of the drilling fluid down around the outside of the drilling system and the remainder of the fluid back to the surface around the outside of the tubular conveyance.

10. Apparatus as claimed in any preceding claim, where-

in the flow diverter is arranged to divert flow from the inside of the drilling system to the annulus above the point at which it diverts flow from the tubular conveyance system into the annulus.

11. Apparatus as claimed in any preceding claim, further comprising a jetting system including one or more flow nozzles arranged to direct jets of fluid inside the borehole to remove accumulated deposits.

12. Apparatus as claimed in claim 11, wherein the flow nozzles are adjustable so as to change the direction of flow of fluid therefrom.

13. Apparatus as claimed in claim 11 or 12, wherein the flow diverter directs fluid into the flow nozzles for jetting and further comprises a valve adjustable to vary the amount of fluid directed through the flow nozzles and the amount of fluid directed into the annulus.

14. Apparatus as claimed in any preceding claim, further comprising a rotatable crown driven by a motor powered for use in back reaming.

15. Apparatus as claimed in claim 14, wherein the motor is an electric motor powered by the electric cable.

16. Apparatus as claimed in claim 14, further comprising a turbine driven by fluid flow from the tubular conveyance system and connected to drive the crown via a gear train.

17. Apparatus as claimed in claim 16, further comprising an electric generator connected to the turbine and an electric motor connected to the crown via the gear train, the output of the generator being used to power the electric motor and drive the crown.

18. A method of drilling an underground borehole using an apparatus comprising a tubular conveyance system including an electric cable and a supply of drilling fluid; a drilling system comprising an electrically powered pump and a drilling motor; a connector connecting the drilling system to the tubular conveyance system, through which the pump and motor are connected to the electric cable; and a flow diverter; the method comprising:

- pumping fluid from the surface down the inside of the tubular conveyance so as to return to the surface via the annulus between the outside of the tubular conveyance and the borehole; and
- using the electrically powered pump of the drilling system to pump fluid from the borehole outside the drilling system up through the inside of the drilling system;
- diverting fluid flow down the inside of the tubular

conveyance system into the annulus, and diverting flow up the inside of the drilling system into the annulus using the flow diverter; and
- using the drilling motor to drill the borehole using the drilling system.

19. A method as claimed in claim 18, comprising diverting part of the drilling fluid down around the outside of the drilling system and the remainder of the fluid back to the surface around the outside of the tubular conveyance.

20. A method as claimed in claim 18 or 19, further comprising a directing jets of fluid from one or more nozzles of a jetting system inside the borehole to remove accumulated deposits.

21. A method as claimed in claim 20, further comprising adjusting the flow nozzles so as to change the direction of flow of fluid therefrom.

22. A method as claimed in claim 18, 19 or 20, comprising directing fluid into the flow nozzles for jetting using the flow diverter and adjusting a valve to vary the amount of fluid directed through the flow nozzles and the amount of fluid directed into the annulus.

23. A method as claimed in any of claims 18-22, further comprising back reaming the borehole using an additional electric motor in the drilling system.

24. A method as claimed in claim 18-22, comprising back reaming using a rotating crown driven by the drilling motor.

25. A method as claimed in claim 23 or 24, comprising back reaming using a jetting system.

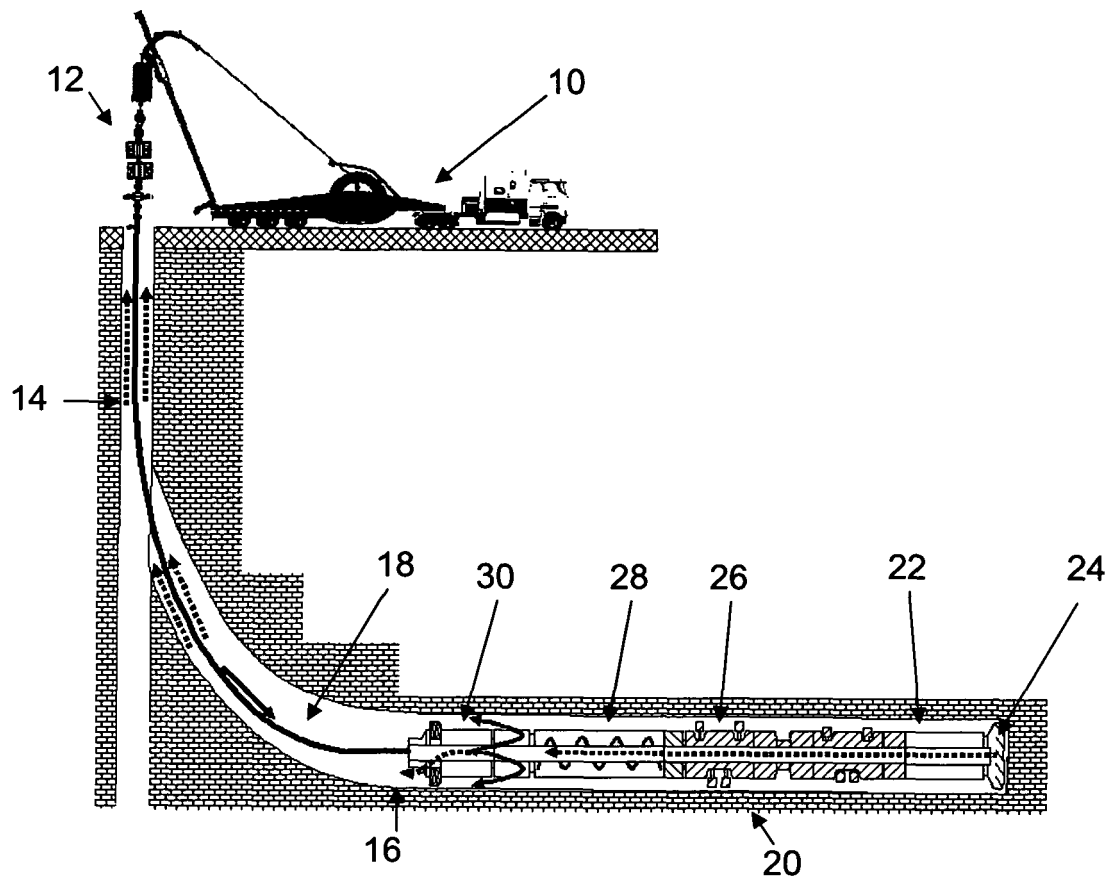


Figure 1

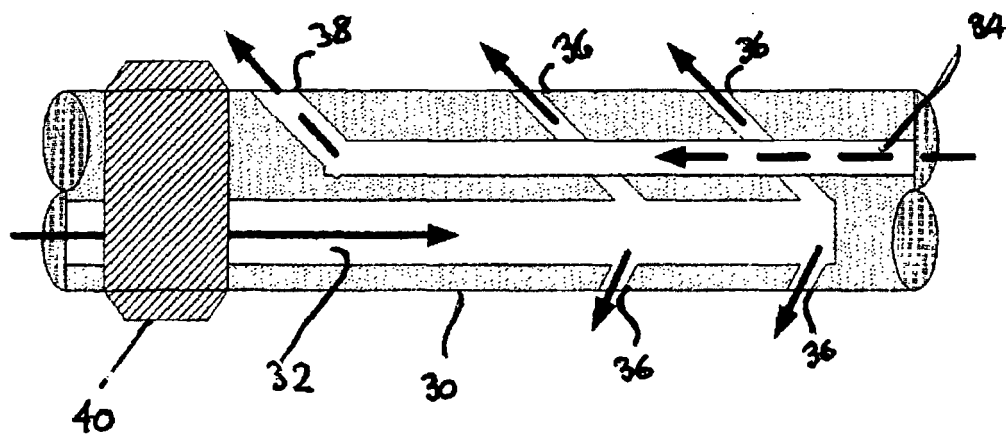


Figure 2

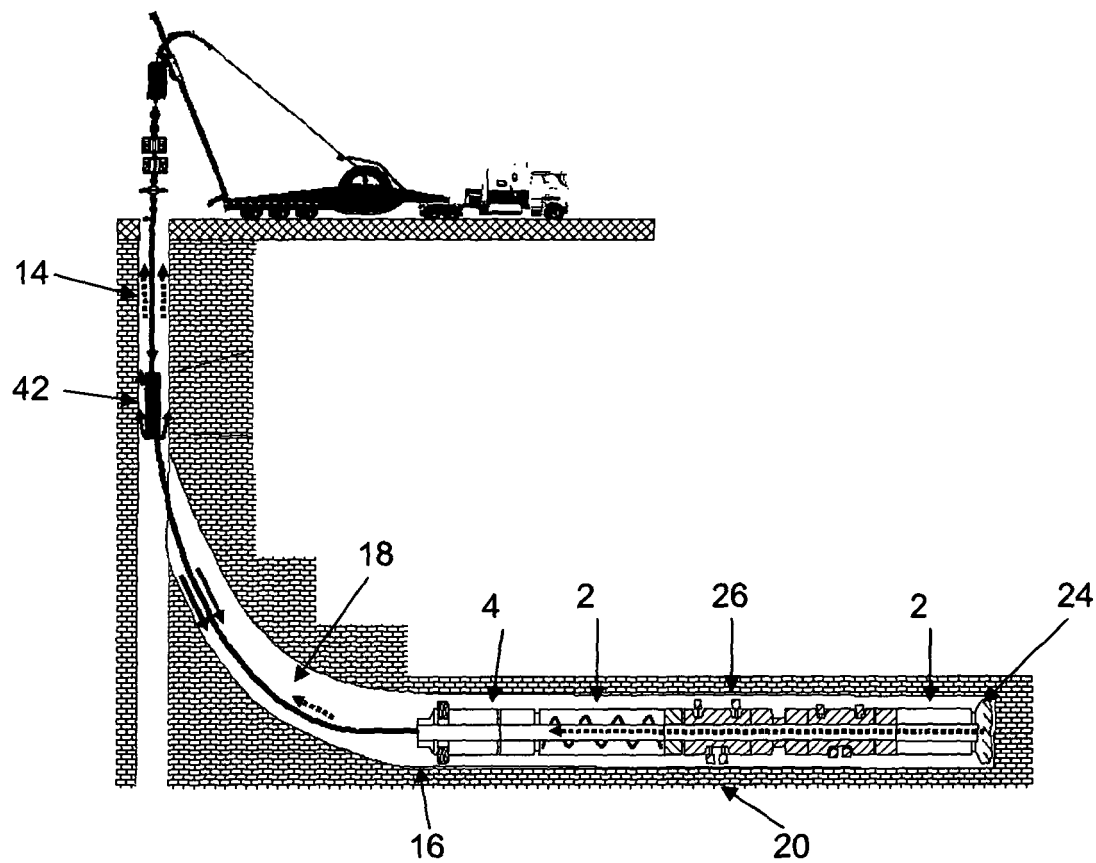


Figure 3

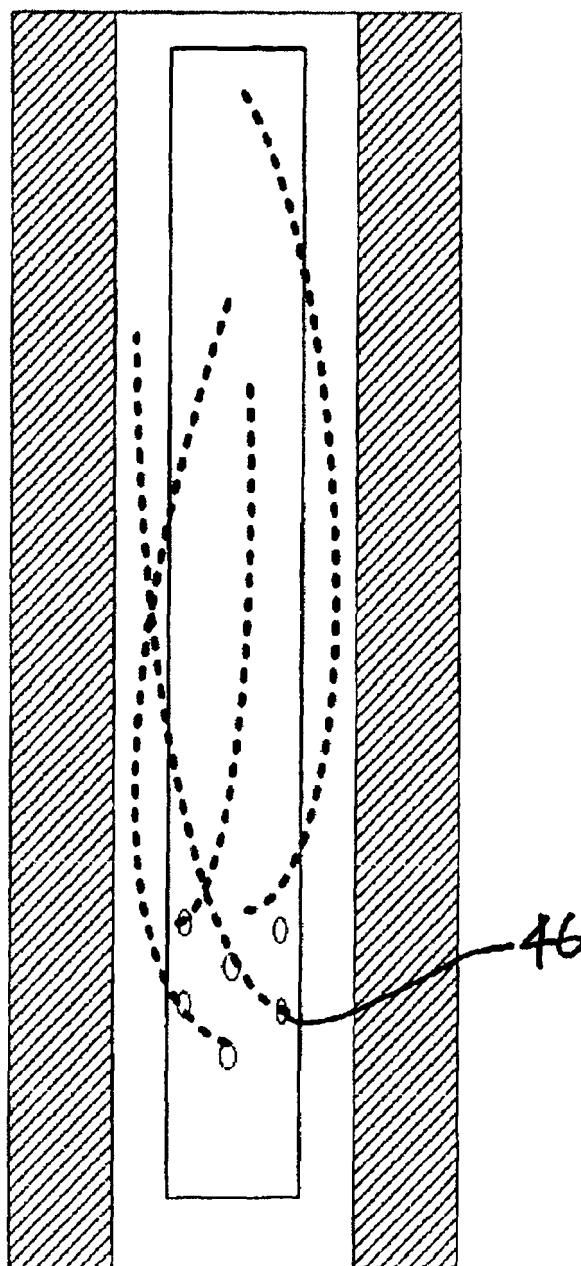


Figure 4



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 29 1008

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		20 November 2006	GARRIDO GARCIA, M
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 06 29 1008

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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20-11-2006

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