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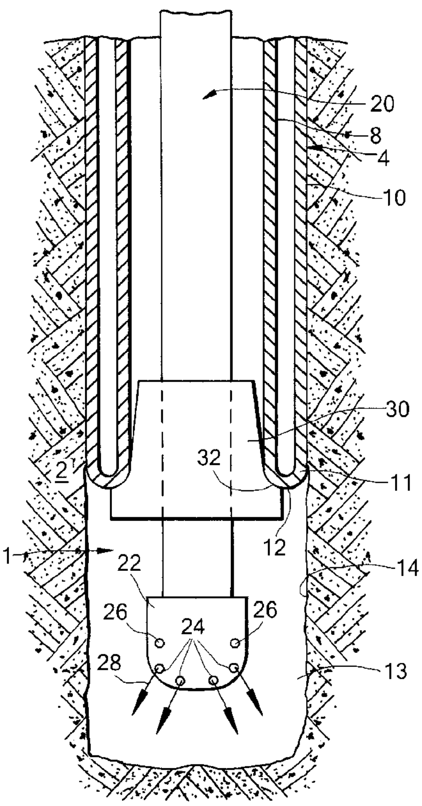
(54) Title: SYSTEM FOR DRILLING A WELLBORE

Fig.1



(57) Abstract: A system is disclosed for drilling a wellbore (1) into an earth formation. The system comprises an expandable tubular element (4) extending into the wellbore, whereby a lower end portion (11) of the wall of the tubular element (8) extends radially outward and in axially reverse direction so as to define an expanded tubular section (10) extending around a remaining tubular section (4) of the tubular element. The expanded tubular section is extendable by downward movement of the remaining tubular section relative to the expanded tubular section whereby said lower end portion (14) of the wall bends radially outward and in axially reverse direction.

WO 2009/074526 A1

NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report*

SYSTEM FOR DRILLING A WELLBORE

The present invention relates to a system for drilling a wellbore into an earth formation whereby an expandable tubular element extends into the wellbore.

The technology of radially expanding tubular elements in wellbores finds increasing application in the industry of oil and gas production from subterranean formations. Wellbores are generally provided with one or more casings or liners to provide stability to the wellbore wall, and/or to provide zonal isolation between different earth formation layers. The terms "casing" and "liner" refer to tubular elements for supporting and stabilising the wellbore wall, whereby it is generally understood that a casing extends from surface into the wellbore and that a liner extends from a certain depth further into the wellbore. However, in the present context, the terms "casing" and "liner" are used interchangeably and without such intended distinction.

In conventional wellbore construction, several casings are set at different depth intervals, and in a nested arrangement, whereby each subsequent casing is lowered through the previous casing and therefore has a smaller diameter than the previous casing. As a result, the cross-sectional wellbore size that is available for oil and gas production, decreases with depth. To alleviate this drawback, it has become general practice to radially expand one or more tubular elements at the desired depth in the wellbore, for example to form an expanded casing, expanded liner, or a clad against an existing casing or liner. Also, it has been proposed to radially expand each subsequent casing to substantially the same diameter as the previous casing to form a monobore wellbore. It is thus achieved that the available diameter of the wellbore remains substantially constant along (a portion of) its depth as opposed to the conventional nested arrangement.

EP 1438483 B1 discloses a system for expanding a tubular element in a wellbore whereby the tubular element, in unexpanded state, is initially attached to a drill string during drilling of a new wellbore section.

To expand such wellbore tubular element, generally a conical expander is used with a largest outer diameter substantially equal to the required tubular diameter after expansion. The expander is pumped, pushed or pulled through the tubular element. Such method can lead to high friction forces between the expander and the tubular element. Also, there is a risk that the expander becomes stuck in the tubular element.

EP 0044706 A2 discloses a flexible tube of woven material or cloth that is expanded in a wellbore by eversion to separate drilling fluid pumped into the wellbore from slurry cuttings flowing towards the surface.

However there is a need for an improved system for drilling a wellbore whereby an expandable tubular element extends into the wellbore.

In accordance with the invention there is provided a system for drilling a wellbore into an earth formation, comprising

- an expandable tubular element extending into the wellbore, whereby a lower end portion of the wall of the tubular element extends radially outward and in axially reverse direction so as to define an expanded tubular section extending around a remaining tubular section of the tubular element, the expanded tubular section being extendable by downward movement of the remaining tubular section relative to the expanded tubular section whereby said lower end portion of the wall bends radially outward and in axially reverse direction; and

- a drill string extending through the remaining tubular section, wherein the tubular element and the drill string are arranged for transferring a thrust force from the remaining tubular section to the drill string, and wherein the drill string includes a jetting head for deepening the wellbore by jetting a stream of fluid against the bottom of the wellbore.

By moving the remaining tubular section downward relative to the expanded tubular section during drilling, the tubular element is effectively turned inside out whereby the lower end portion of the wall of the tubular element is continuously bent radially outward and in axially reverse direction so that the tubular element is progressively expanded without the need for an expander that is pushed, pulled or pumped through the tubular element. In this manner the expanded tubular section forms a casing or liner that is installed in the wellbore during the drilling process, so that a relatively short open-hole section can be maintained during drilling.

Furthermore, the thrust force transmitted from the remaining tubular section to the drill string can be kept small since the jetting head requires only a small thrust force when compared to the large thrust force required for drilling with a conventional drill bit. In view thereof, the downward force that must be exerted to the remaining tubular section to move it downward includes only a small component for thrusting the drill string during drilling. It is thereby achieved that the risk of exceeding the yield strength of the remaining tubular section is significantly reduced, when compared to drilling with a conventional drill bit.

Suitably the system of the invention comprises means for centralising the jetting head in the remaining tubular section.

In a preferred embodiment, the drill string is provided with a reamer for reaming the wellbore to at least an outer diameter of the expanded tubular section.

To maintain a short open-hole section while drilling, it is preferred that the remaining tubular section and the drill string are arranged for simultaneous lowering in the wellbore whereby, for example, said lower end portion of the wall is arranged for lowering into the wellbore at substantially the same speed as the speed of lowering of the drill string during drilling of the wellbore.

It is preferred that the wall of the tubular element includes a material that is plastically deformed during the bending process, so that the expanded tubular section retains an expanded shape as a result of said plastic deformation. Thus, there is no need for an external force or pressure to be applied to the expanded tubular section to maintain its expanded form. If, for example, the expanded tubular section is expanded against the wellbore wall as a result of said bending of the wall, no external radial force or pressure needs to be exerted to the expanded tubular section to keep it against the wellbore wall. Suitably the wall of the tubular element is made of a metal such as steel or any other ductile metal capable of being plastically deformed by eversion of the tubular element. The expanded tubular section then has adequate collapse resistance, for example in the order of 100-150 bars.

Suitably the remaining tubular section is induced to move downward while the expanded tubular section is kept stationary in the wellbore.

In order to induce said downward movement it is preferred that the remaining tubular section is subjected to an axially compressive force, which at least partly can result from the weight of the remaining tubular section. If necessary the weight can be supplemented by an external, downward, force applied to the remaining tubular section to induce said movement. As the length, and hence the weight, of the remaining tubular section increases, an upward force may need to be applied to the remaining tubular section to prevent uncontrolled bending or buckling of the wall.

Suitably the remaining tubular section is axially extended at its upper end in correspondence with its downward movement. This is done, for example, by adding tubular portions at the upper end in any suitable manner such as by welding. Alternatively, the remaining tubular section is formed as a coiled tubing that is unreeled from a reel and subsequently inserted into the wellbore. In this way the process of eversion of the tubular element can be continued until a desired length of the tubular element is expanded.

The invention will be described hereinafter in more detail and by way of example, with reference to the accompanying drawing in which:

Fig. 1 schematically shows a lower portion of a first embodiment of the system of the invention;

Fig. 2 schematically shows the first embodiment during cutting of a tubular element in a wellbore; and

Fig. 3 schematically shows a lower portion of a second embodiment of the system of the invention.

In the drawing and the description, like reference numerals relate to like components.

Referring to Figs. 1 and 2, there is shown a system including a wellbore 1 extending into an earth formation 2, and an expandable tubular element in the form of liner 4 extending from surface downwardly into the wellbore 1. The liner 4 has been partially radially expanded by eversion of the wall of the liner whereby a radially expanded tubular section 10 of the liner 4 has been formed, which has an outer diameter substantially equal to the wellbore diameter. A remaining tubular section of the liner 4, in the form of unexpanded liner section 8, extends concentrically within the expanded tubular section 10.

The wall of the liner 4 is, due to eversion at its lower end, bent radially outward and in axially reverse (i.e. upward) direction so as to form a U-shaped lower section 11 of the liner interconnecting the unexpanded liner section 8 and the expanded liner section 10. The U-shaped lower section 11 of the liner 4 defines a bending zone 12 of the liner.

The expanded liner section 10 is axially fixed to the wellbore wall 14 by any suitable anchoring means (not shown), or by frictional forces between the expanded liner section 10 and the wellbore wall 14 resulting from the expansion process. The U-shaped lower section 11 of liner 4 is positioned a short distance above the bottom of the wellbore so that an open-hole wellbore section 13 is defined below the U-shaped lower section 11.

A drill string 20 extends from surface through the unexpanded liner section 8 to the bottom of the wellbore 1, with a jetting head 22 at its lower end. The jetting head 22 comprises a plurality of jetting nozzles 24 and cutting nozzles 26. The jetting nozzles 24 are directed so as to eject fluid jets 28 against the bottom and/or the wall of the wellbore 1. Each fluid jet 28 suitably includes a stream of fluid, e.g. water, with abrasive particles entrained therein. The cutting nozzles 26 are directed radially outward from the jetting head.

The drill string 20 is provided with a guide device 30 having a curved surface portion 32 arranged to transfer a thrust force from the liner 4 to the drill string 20, and to support and guide the U-shaped lower section 11 of the liner 4 during eversion of the liner 4. The guide device 30 is rotatable relative to the drill string 20 about its central longitudinal axis. Furthermore, the guide device 30 is collapsible so as to allow it to pass through the unexpanded liner section 4 (Fig. 2).

In Fig. 3 is shown the second embodiment, which is substantially similar to the first embodiment, except that the cutting head 22 is provided with reamers 33 adapted to ream the wellbore 1 to a nominal diameter substantially equal to the outer diameter of the expanded liner section 10. The reamers 33 are radially retractable to allow the reamers 33 to pass through the unexpanded liner section 4 when in retracted mode.

During normal operation or the first embodiment (Figs. 1 and 2), a lower end portion of the liner 4 is initially everted. That is, the lower end portion is bent radially outward and in axially reverse direction, whereby the U-shaped lower section 11 and a short length of expanded liner section 10 are initiated. Subsequently, the expanded liner section 10 is anchored to the wellbore wall 14 by the anchoring means. Depending on the geometry and/or material properties of the liner 4, the expanded liner section 10 alternatively can become anchored to the wellbore wall automatically by friction forces between the expanded liner section 10 and the wellbore wall 14.

A downward force is then applied to the unexpanded liner section 8 so as to move it gradually downward. As a result, the unexpanded liner section 8 becomes progressively everted whereby the unexpanded liner section 8 is transformed into the expanded liner section 10. The bending zone 12 moves in downward direction during the eversion process at approximately half the speed of downward movement of the unexpanded liner section 8.

If desired, the mechanical properties and dimensions of the liner 4 can be selected such that the expanded liner section 10 becomes pressed against the wellbore wall 14 as a result of the expansion process so as to seal against the wellbore wall and/or to stabilize the wellbore wall.

Since the length, and hence the weight, of the unexpanded liner section 8 gradually increases, the magnitude of the downward force can be gradually lowered in correspondence with the increasing weight of unexpanded liner section 8. Eventually, the downward force may need to be replaced by an upward force to prevent buckling of liner section 8.

The unexpanded liner section 8 is at its upper end extended in correspondence with its downward movement, for example by adding tubular sections to the liner, or by continuously forming the liner from metal sheet on a reel.

Simultaneously with downward movement of the unexpanded liner section 8 into the wellbore, the drill string 20 is operated to deepen the wellbore bottom by ejecting the fluid jets 28 against the wellbore bottom whereby the drill string is rotated slowly. The drill string 20 thereby gradually moves downward into the wellbore 1. The force applied to the unexpanded liner section 4 is controlled such that the U-shaped section 11 of the liner 4 moves downward at the same speed as the drill string 20 and remains in contact with the curved surface portion 32 of guide device 30 whereby the U-shaped lower section 11 exerts a small thrust force to the drill string 20. With increasing eversion of the liner 4, an increasing portion of the thrust force results from the weight of the unexpanded liner section 8.

Since the jetting head 22 requires only a small thrust force for excavating the wellbore, relative to the thrust force required for drilling with a conventional drill bit, the compressive load in unexpanded liner section 4 can be kept relatively low. It is thereby achieved that the risk of inadvertent buckling of the unexpanded liner section 4 is significantly reduced.

If it is required to cut the unexpanded liner section 4, the guide device 30 is collapsed and the drill string 20 is raised until the cutting nozzles 26 are positioned at the desired cutting level (Fig. 2). Subsequently fluid jets 36 with entrained abrasive particles are jetted through cutting nozzles 26 against the unexpanded liner section 4 thereby cutting the liner section 4.

Normal operation of the second embodiment is substantially similar to normal operation of the first embodiment. In addition, the reamers 33 are kept in expanded mode during drilling with the drill string 20 thereby enlarging the diameter of the wellbore 1 to the nominal diameter.

In a modified version of the second embodiment (not shown), the drill string is at its lower end provided with a conventional pilot drill bit for drilling a pilot bore of relatively small diameter, and the reamers are provided with jetting nozzles to enlarge the borehole to its nominal diameter. Since the jetting nozzles can be precisely controlled with respect to direction and velocity of the fluid jets, the jetting nozzles in the reamers allow accurate drilling of the borehole to its nominal diameter.

When it is required to retrieve the drill string 20 to surface the guide device 30 and the reamers 33 (if present) are radially retracted and the drill string 20 is retrieved through the unexpanded liner section 8.

With the system of the invention, it is achieved that the wellbore is progressively lined with the everted liner directly above the jetting head during the drilling process. As a result, there is only a relatively short open-hole section of the wellbore at all times. The advantages of such short open-hole section will be most pronounced during drilling into a hydrocarbon fluid containing layer of the earth formation. In view thereof, for many applications it will be sufficient if the process of liner eversion during drilling is applied only during drilling into the hydrocarbon fluid reservoir, while other sections of the wellbore are lined or cased in conventional manner. Alternatively, the process of liner eversion during drilling may be commenced at surface or at a selected downhole location, depending on circumstances.

In view of the short open-hole section during drilling, there is a significantly reduced risk that the wellbore fluid pressure gradient exceeds the fracture gradient of the rock formation, or that the wellbore fluid pressure gradient drops below the pore pressure gradient of the rock formation. Therefore, considerably longer intervals can be drilled at a single nominal diameter than in a conventional drilling practice whereby casings of stepwise decreasing diameter must be set at selected intervals.

Also, if the wellbore is drilled through a shale layer, such short open-hole section eliminates possible problems due to a heaving tendency of the shale.

After the wellbore has been drilled to the desired depth and the drill string has been removed from the wellbore, the length of unexpanded liner section that is still present in the wellbore can be left in the wellbore or it can be cut-off from the expanded liner section and retrieved to surface.

In case the length of unexpanded liner section is left in the wellbore, there are several options for completing the wellbore. These are, for example, as follows:

A) A fluid, for example brine, is pumped into the annulus between the unexpanded and expanded liner sections so as to pressurise the annulus and increase the collapse resistance of the expanded liner section. Optionally one or more holes are provided in the U-shaped lower section to allow the pumped fluid to be circulated.

B) A heavy fluid is pumped into the annulus so as to support the expanded liner section and increase its collapse resistance.

C) Cement is pumped into the annulus in order to create, after hardening of the cement, a solid body between the unexpanded liner section and the expanded liner section, whereby the cement may expand upon hardening.

D) The unexpanded liner section is radially expanded (i.e. clad) against the expanded liner section, for example by pumping, pushing or pulling an expander through the unexpanded liner section.

In the above examples, expansion of the liner is started at surface or at a downhole location. In case of an offshore wellbore whereby an offshore platform is positioned above the wellbore, at the water surface, it can be advantageous to start the expansion process at the offshore platform. In such process, the bending zone moves from the offshore platform to the seabed and from there further into the wellbore. Thus, the resulting expanded tubular element not only forms a liner in the wellbore, but also a riser extending from the offshore platform to the seabed. The need for a separate riser from is thereby obviated.

Furthermore, conduits such as electric wires or optical fibres for communication with downhole equipment can be extended in the annulus between the expanded and unexpanded sections. Such conduits can be attached to the outer surface of the tubular element before expansion thereof. Also, the expanded and unexpanded liner sections can be used as electricity conductors to transfer data and/or power downhole.

Since any length of unexpanded liner section that is still present in the wellbore after completion of the eversion process, will be subjected to less stringent loading conditions than the expanded liner section, such length of unexpanded liner section may have a smaller wall thickness, or may be of lower quality or steel grade, than the expanded liner section. For example, it may be made of a material having a relatively low yield strength or relatively low collapse rating.

Instead of leaving a length of unexpanded liner section in the wellbore after the expansion process, the entire liner can be expanded with the method described above so that no unexpanded liner section remains in the wellbore. In such case, an elongate member, for example a pipe string, can be used to exert the necessary downward force to the unexpanded liner section during the last phase of the eversion process.

In order to reduce friction forces between the unexpanded and expanded liner sections during the expansion process, suitably a friction reducing layer, such as a Teflon layer, is applied between the unexpanded and expanded liner sections. For example, a friction reducing coating can be applied to the outer surface of the liner before expansion. Such layer of friction reducing material furthermore reduces the annular clearance between the unexpanded and expanded sections, which results in a reduced tendency of the unexpanded section to buckle. Instead of, or in addition to, such friction reducing layer, centralizing pads and/or rollers can be applied between the unexpanded and expanded sections to reduce the friction forces and the annular clearance there-between.

Instead of expanding the expanded liner section against the wellbore wall (as described), the expanded liner section can be expanded against the inner surface of another tubular element already present in the wellbore.

CLAIMS

1. A system for drilling a wellbore into an earth formation, comprising

- an expandable tubular element extending into the wellbore, whereby a lower end portion of the wall of the tubular element extends radially outward and in axially reverse direction so as to define an expanded tubular section extending around a remaining tubular section of the tubular element, the expanded tubular section being extendable by downward movement of the remaining tubular section relative to the expanded tubular section whereby said lower end portion of the wall bends radially outward and in axially reverse direction; and
- a drill string extending through the remaining tubular section, wherein the tubular element and the drill string are arranged for transferring a thrust force from the tubular element to the drill string, and wherein the drill string includes a jetting head for deepening the wellbore by jetting a stream of fluid against the bottom of the wellbore.

2. The system of claim 1, further comprising means for centralising the jetting head in the remaining tubular section.

3. The system of claim 1 or 2, wherein the expanded tubular section has an outer diameter, and wherein the drill string is provided with a reamer for reaming the wellbore to at least the outer diameter of the expanded tubular section.

4. The system of any one of claims 1-3, wherein the remaining tubular section and the drill string are arranged for simultaneous lowering in the wellbore.

5. The system of claim 4, wherein said lower end portion of the wall is arranged for lowering into the wellbore at substantially the same speed as lowering of the drill string during drilling of the wellbore.

6. The system of any one of claims 1-5, wherein the wall of the tubular element includes a material susceptible of plastic deformation during said bending of the wall so that the expanded tubular section retains an expanded shape as a result of said plastic deformation.

7. The system of any one of claims 1-6, wherein the remaining tubular section is subjected to an axially compressive force acting to induce said downward movement of the remaining tubular section.

8. The system of claim 7, wherein said axially compressive force results at least partly from the weight of the remaining tubular section.

9. The system substantially as described hereinbefore with reference to the drawings.

Fig.1

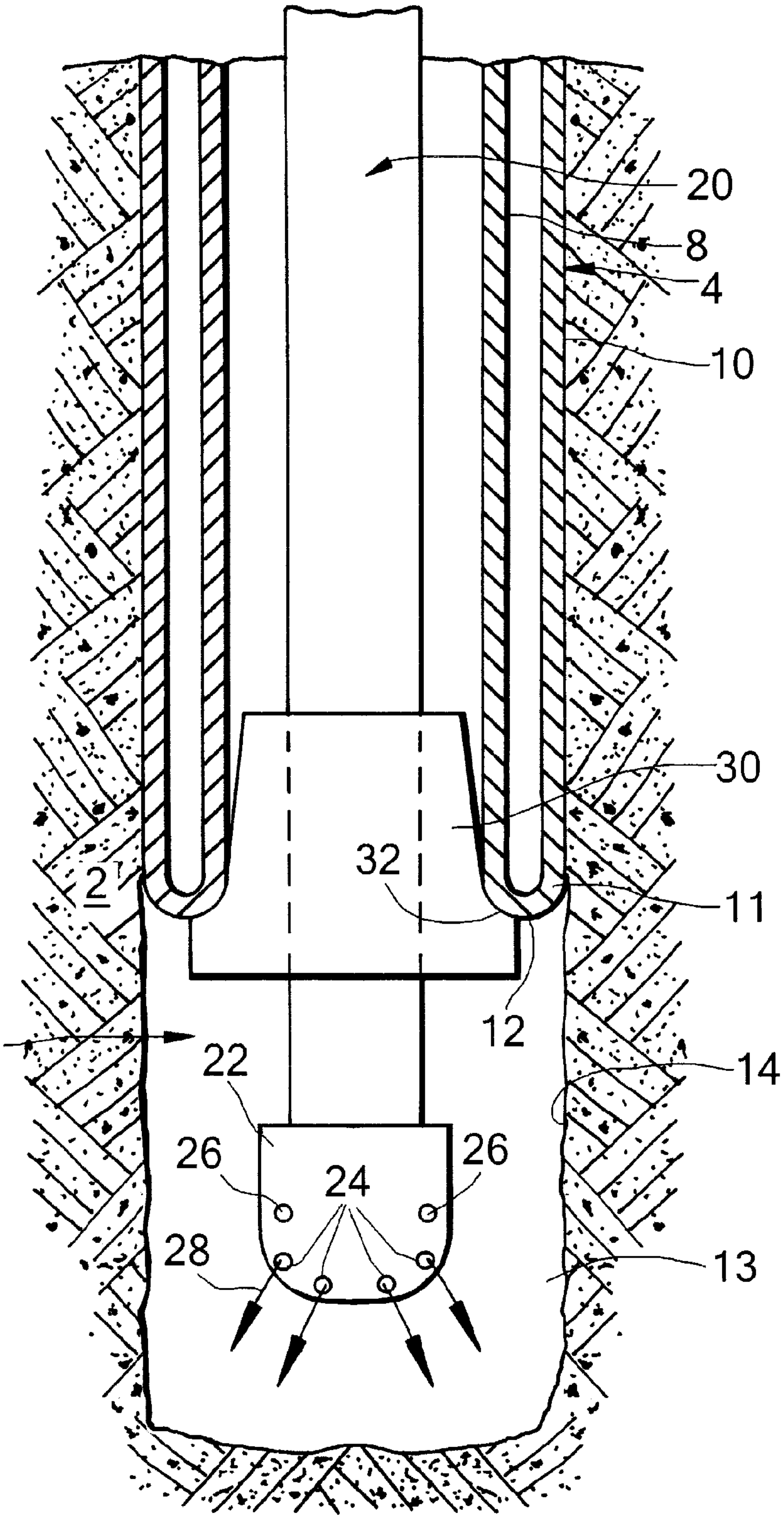


Fig.2

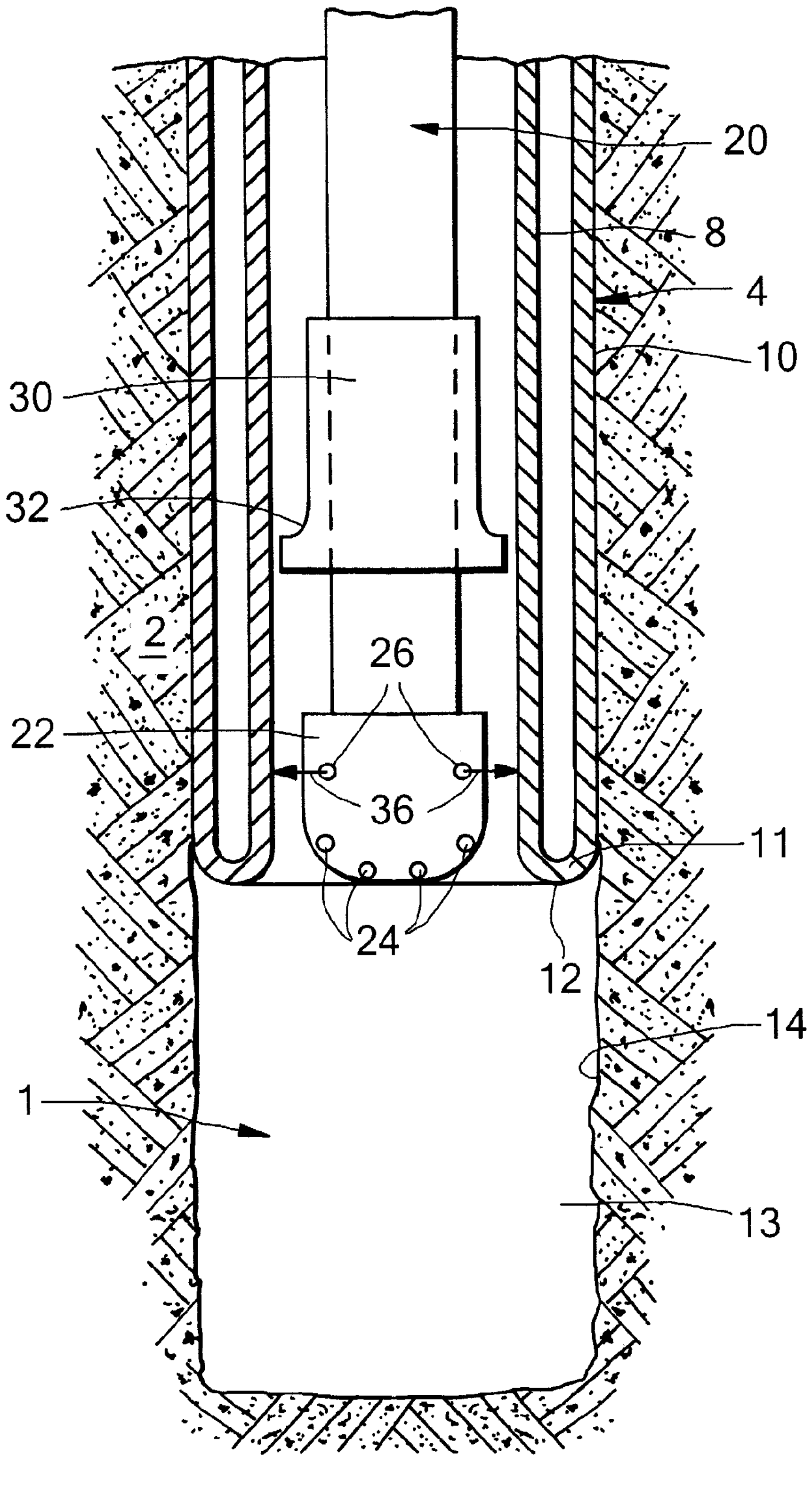
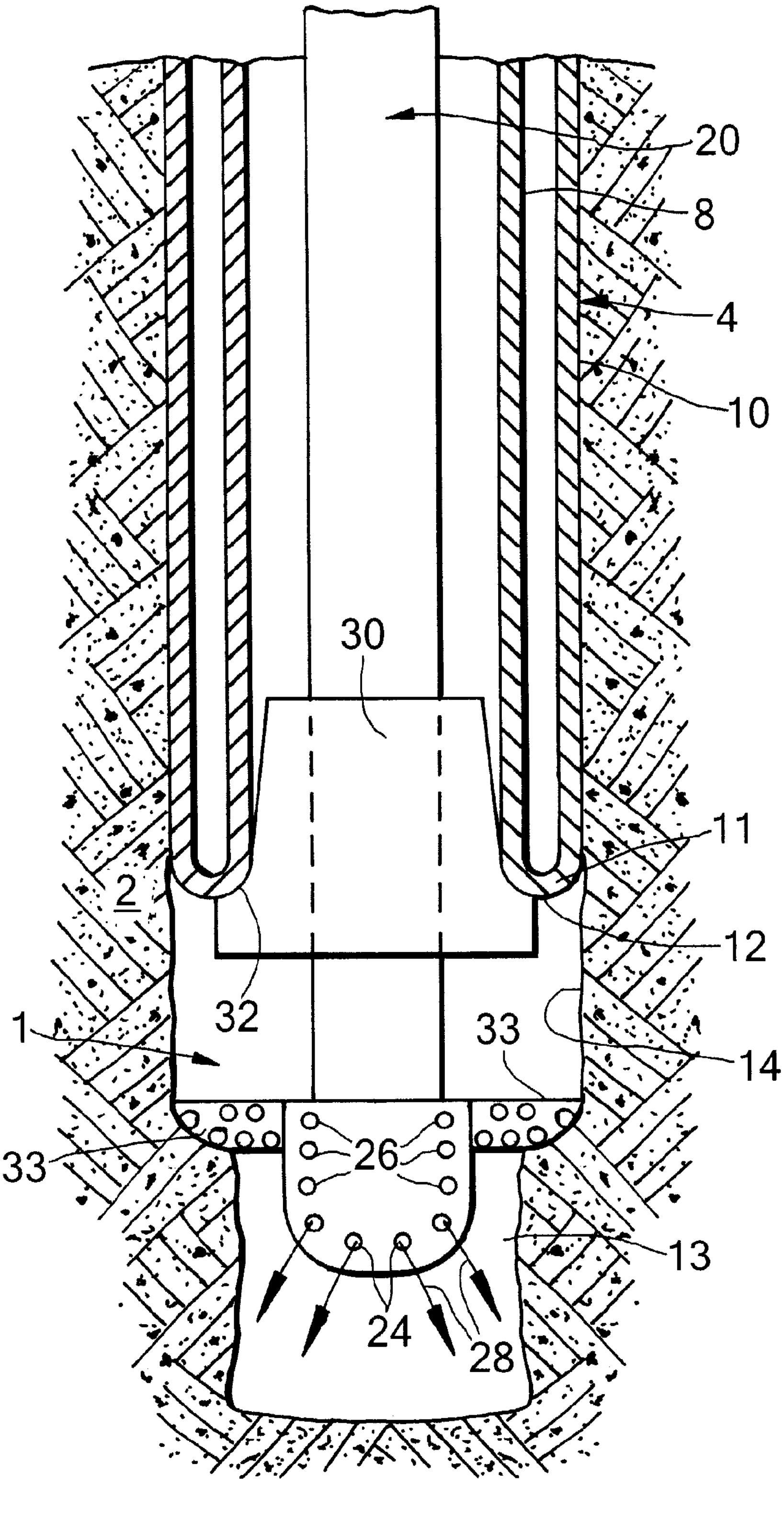


Fig.3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/066994

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B7/20 E21B43/10

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 927 775 A (HILDEBRANDT ALEXANDER B) 8 March 1960 (1960-03-08) the whole document	1-9
A	US 5 803 666 A (KELLER CARL E [US]) 8 September 1998 (1998-09-08) the whole document	1-9
A	US 2007/107941 A1 (FILLIPOV ANDREI G [US] ET AL) 17 May 2007 (2007-05-17) the whole document	1-9
A	US 3 674 100 A (BECKER NORMAN D) 4 July 1972 (1972-07-04) the whole document	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2009	04/02/2009

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/066994

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2927775	A	08-03-1960	NONE	
US 5803666	A	08-09-1998	NONE	
US 2007107941	A1	17-05-2007	NONE	
US 3674100	A	04-07-1972	NONE	