(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 135 854 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.03.2017 Bulletin 2017/09

(21) Application number: **15460053.0**

(22) Date of filing: **24.08.2015**

(51) Int Cl.:
E21B 10/42 *(2006.01)* ***E21B 10/54*** *(2006.01)*
E21B 17/14 *(2006.01)* ***E21B 31/03*** *(2006.01)*
E21B 10/60 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(71) Applicants:
- **Politechnika Gdanska**
  80-233 Gdansk (PL)
- **Przedsiebiorstwo Cemet Ltd, Sp. z o.o.**
  80-051 Gdansk (PL)

(72) Inventors:
- **Szewczuk, Pawel**
  09-200 Sierpc (PL)
- **Bolewski, Lukasz**
  81-572 Gdynia (PL)
- **Lubinski, Jacek**
  81-388 Gdynia (PL)
- **Szkodo, Marek**
  80-172 Gdansk (PL)
- **Karpinski, Bartlomiej**
  09-200 Sierpc (PL)
- **Kmiec, Mateusz**
  80-462 Gdansk (PL)
- **Antoszkiewicz, Michal**
  10-757 Olsztyn (PL)

(74) Representative: **Budzinski, Slawomir**
JWP Rzecznicy Patentowi
Dorota Rzazewska sp.j.
Sienna Center
Ul. Zelazna 28/30
00-833 Warszawa (PL)

(54) WELLBORE REAMING TOOL

(57) The invention relates to a drilling tool (1) for maintaining a borehole and for cutting rock material, comprising a hollow elongated body (2) in a form of a pipe, provided with a plurality of cutting blades (3) arranged around the body (2) in such a way that they protrude from the external surface of the body (2). The tool is characterised in that the cutting blades (3) are shaped as bands (4), the ends of which are connected to the body (2), and the central part of the cutting blades (3) between the ends protrudes from the body (2), wherein the cutting blades (3) are grouped into sets (5) arranged on the periphery of the body and placed one above the other, and angularly offset relative to each other; each cutting blade (3) in the set (5) is remote from the axis of the body (2) of the drilling tool (1) by a dimension larger than the dimension of the distance from the axis of the body (2) of the cutting blade (3) located directly under it; the body (2) is provided with slots (6) connecting the interior of the body (2) to its external surface and arranged radially under the cutting blades (3), and not connected to the cutting blades (3); under the sets of the cutting blades (4), there is a lateral channel (11) through which the drilling fluid along with the cut rock material flow.

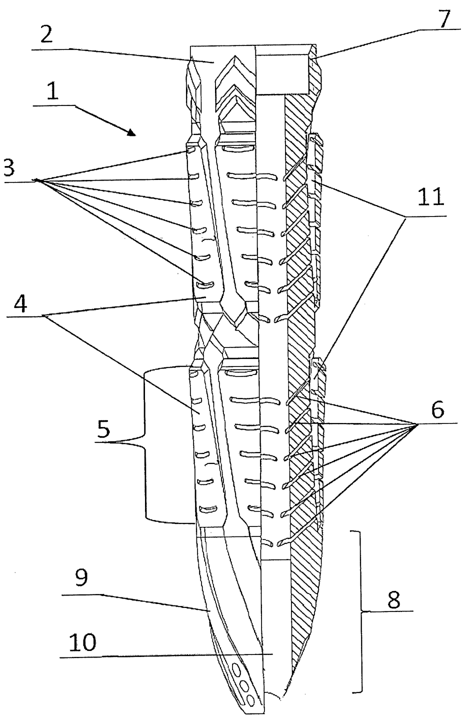

Fig. 2

EP 3 135 854 A1

Description

[0001] The object of the invention is a drilling tool for maintaining a borehole and for cutting rock material.

[0002] Obtaining hydrocarbons by means of directional holes consists of a series of complex operations. The first of them is to drill a hole. This phase is followed by geophysical research on geometry condition of the raw borehole. Then, casing pipes are introduced into the borehole, which ensure stability and sealing of the borehole. Because of the forces inside the hole, present under the ground, and diversity of drilled rocks, the borehole begins to change its geometry immediately after the withdrawal of the drill. Therefore, there is a risk of capturing the casing pipes by rock layers tightening around and reducing the diameter of the hole. In addition, a swelling packet clay material is deposited on the surface of the casing pipes and prevents conducting a proper cementing operation. To prevent such a scenario, a number of methods are used:

- forcing a reciprocating movement and/or rotational movement of the cemented casing string,
- selection of optimal parameters of fluid,
- use of leading, buffering and washing fluids,
- use of packers,
- use of mud cake scrapers and centralisers,
- tools such as guide-shoe, reamer-shoe.

[0003] From the point of view of the invention, the latter are important. These tools are placed at the beginning of a casing string and have a drillable, substantially conical nose and abrasive elements which are made of materials highly resistant to abrasion processes, for example sintered carbides. Usually, they have, in their lower part, openings to allow proper execution of cementing and to ensure a steady flow of drilling fluid. The tool is intended to cut or abrade the rock material from the walls of the hole in places where the hole has a diameter smaller than the designed one. After introducing the pipes together with the tool and cementing the space between the hole wall and the casing string, a nose cone of the tool is drilled in order to allow subsequent steps of the hole exploration. These tools are produced by international concerns, such as Weatherford, Downhole Products or Halliburton.

[0004] From British patent specification no. GB 2482703, a tool in a form of a bit for maintaining or expanding a borehole is known. This tool has a form of a hollow pipe which is placed in the borehole in which this tool is moved along this hole. The tool further comprises means constituting blades and openings which are connected to the interior of the tool in the form of a pipe and are located axially in the front of the blade. The removed material can be directed to the interior of the pipe, and the openings can have a form of slots and have an edge which constitutes a blade.

[0005] The stability of the borehole is affected by parameters such as:

- weight of the drilling fluid,
- ECD (Equivalent Circulating Density) during the circulation of the hole,
- salinisation of the drilling fluid, and stabilisers of swelling clays,
- pH of the drilling fluid,
- hydrodynamic and dynamic effect of the nozzles of the drill bit and underreamer,
- presence of swelling clays.

[0006] In the drilling technology, there is a phenomenon of stability changes (swelling of smectite/illite clays) of the hole as a function of time. This translates into the quality of the cemented sections of the piping. The situation requires solving encountered problems by means of new techniques and technologies. One of the risks, to which too little attention has been paid so far, is the phenomenon of directional expansion of swelling clays.

[0007] In the course of exploration and development activities, openings drill through different types of rock with varying physical and chemical properties. Argillaceous rocks (mudstones, claystones, shales) composed of different kinds of clay minerals are among the most frequent rocks. The percentage of mixed packet minerals and illites increases with depth, usually gradually, and the amount of smectites decreases. The Silurian, Ordovician and Cambrian deposits are dominated by illites. Also mixed packet minerals, often containing smectites. Their main structural unit is a film comprising two inwardly facing tetrahedral plates with a central octahedral plate containing aluminum. The layers may extend in two directions but bonds between the films are weak and have a perfect cleavage allowing water and other molecules to be absorbed between the films, resulting in directional expansion. Based on existing information, the occurrence of swelling clays in the Ordovician, Silurian, Devonian, Carboniferous and Jurassic profiles was found. In many situations, the borehole is relatively stable, i.e. its dimensions remain substantially unchanged for several hours. However, this is largely dependent on geological conditions. The main obstacle during drilling and cementing processes are geological conditions prevailing in the holes. One of the main problems is related to the swelling of clay formations, as indicated above. This leads to narrowing of the hole clearance, and consequently to its occlusion.

[0008] The main problem with devices enlarging the hole diameter used so far in the oil drilling industry, is cutting the excavated rock material. Attempts to completely wash it out prove to be ineffective, and additionally lead to escalating changes in geometry of the hole.

[0009] The rock material, exhibiting a high viscosity, is deposited on the surface of the pipes, thereby preventing correct bonding of cement. Accumulation thereof leads to formation of local blockages, which causes formation of channels in the introduced cement paste.

[0010] The aim of the invention is to develop a drilling tool without the disadvantages of known tools.

[0011] According to the invention, a drilling tool for maintaining a borehole and for cutting rock material, comprising a hollow elongated body in a form of a pipe, the body being provided with a plurality of cutting blades arranged around the body in such a way that they protrude from the external surface of the body, is characterised in that:

- the cutting blades are shaped as bands the ends of which are connected to the body, and the central part of the cutting blades between the ends protrudes from the body, wherein the cutting blades are grouped into sets arranged on the periphery of the body and placed one above the other, and angularly offset relative to each other,
- each cutting blade in the set is spaced from the axis of the body of the drilling tool by a dimension larger than the dimension of the distance from the axis of the cutting blade body located directly under it,
- the body is provided with slots connecting the interior of the body to its external surface, which are arranged radially under the cutting blades and not connected to the cutting blades,
- under the sets of the cutting blades, there is a lateral channel through which the drilling fluid along with the cut rock material flow.

[0012] Preferably, the cutting blades are configured to discharge and fragmentise the cut rock material.

[0013] Also preferably, a connection with the lateral channel is formed between the slots in the body of the drilling tool in order to obtain an optimal fragmentising flow of the cut rock material (ejector effect).

[0014] Also preferably, the cutting blades are grouped into two levels of arranged on the periphery of the body, arranged one above the other and offset from each other by an angle of 0° to 45°.

[0015] Preferably, each set on one level comprises four cutting blades, wherein the sets of cutting blades are arranged on the periphery of the drilling tool every 90°.

[0016] Also preferably, each set on one level comprises six cutting blades, wherein six sets of cutting blades on one level are arranged symmetrically on the periphery of the drilling tool.

[0017] Also preferably, the cutting blades in each set are offset from the cutting blades located directly under it by an angle of 5° to 25°.

[0018] Also preferably, it is provided in its upper part with a thread for connecting the drilling tool to casing pipes.

[0019] Also preferably, it ends in a base made of a cuttable material.

[0020] Also preferably, directional channels are made in the base for optimal flow of the drilling mud.

[0021] Also preferably, inlet openings are made in the base for the flow of the drilling mud.

[0022] The object of the invention is presented in embodiments in the drawing, in which:

- Fig. 1 shows a drilling tool in a side view,
- Fig. 2 shows a drilling tool in a partial cross-section,
- Fig. 3 shows a drilling tool in its frontal view,
- Fig. 4 shows a drilling tool in a side view of a portion showing the cutting blades,
- Fig. 5 shows the flow of drilling fluid and excavated material during the operation of a drilling tool,
- Fig. 6 shows a schematic diagram of a drilling tool operating as an ejector,
- Fig. 7 shows computer simulations of drilling fluid flowing through a drilling tool.

[0023] As shown in an embodiment of the invention in Fig. 1, Fig. 2 and in Fig. 4 of the drawing, a drilling tool 1 for maintaining a borehole and for cutting rock material comprises an elongated body 2 in a form of a pipe. The external surface of the body 2 of the drilling tool 1 is provided with a series of cutting blades 3 arranged around the body 2 in such a way that the cutting blades 3 protrude from the external surface of the body 2.

[0024] The cutting blades 3 are shaped as bands 4 connected to the body 2 of the drilling tool 1 in such a way that the ends of the bands 4 are connected to the body 2, and in the central part between the ends of the bands 4 they protrude from the body 2 so that they are at a larger distance from the axis of the drilling tool 1 than the external surface of the drilling tool 1.

[0025] The cutting blades 3 are grouped into sets 5 of cutting blades 3 so that in each set 5, the cutting blades 3 are placed one above the other, and the sets 5 can be angularly offset relative to each other. This angular offset of the cutting blades 3 can vary within a range of 0° to 45°, wherein the offset value depends on many factors, such as, for example, size of the drilling tool 1 generally meant as its diameter, type of rock material in which the borehole is drilled, depth of the borehole, and many others. In an embodiment of the invention shown in Fig. 1, this offset does not occur, i.e. it equals zero.

[0026] Each cutting blade 3 in the set 5 is spaced from the axis of the body 2 of the drilling tool 1 by a dimension larger than the dimension of the distance from the axis of the body 2 of the cutting blade 3 located directly under it. Such a solution causes that the cutting blade 3 located above, collects a further layer of rock material the cutting blade 3 located below was unable to collect.

[0027] In the body 2 of the drilling tool 1, elongated slots 6 are made, extending radially relative to the body 2, connecting the interior of the body 2 of the drilling tool 1 to its external surface. The slots are not connected to the cutting blades 3 but, as shown in Fig. 5, they are located under the bands 4 of the cutting blades 3.

[0028] The bands 4 of the cutting blades 3, in their central part extending between the ends connecting the bands 4 to the body 2 of the drilling tool 1, form, in each set 5 of the cutting blades 3, a lateral channel 11 extending in parallel to the axis of the drilling tool 1 substantially on the external surface of the body 2 and under the bands 4 of the cutting blades 3.

[0029] The cutting blades 3 on the body 2 of the drilling tool 1 are configured so that their operation causes fragmentation and discharging the cut rock material towards the heel of the borehole.

[0030] In the preferred embodiment of the invention, shown in Fig. 1, Fig. 2, Fig. 3 and in Fig. 4, the cutting blades 3 are grouped into sets 5 arranged on the periphery of the body 2 of the drilling tool 1 and placed one above the other, wherein in each set, there are six cutting blades 3, and and on one level around the body 2 of the drilling tool 1, six sets 5 of the cutting blades 3 are arranged. The sets 5 of the cutting blades 3 are therefore arranged every 60°. Of course, in other embodiments, the number of sets 5 of the cutting blades 3 both horizontally and on the periphery of the body 2 of the drilling tool 1, depending on the destination, can vary.

[0031] Also, the angular offset of the cutting blades 3 in the set 5 in relation to the cutting blades 3 located directly under them can vary and amount 5° to 25°, wherein in the embodiment shown in Fig. 1, it amounts to 6°.

[0032] In order to connect to a set of pipes used to maintain the borehole, the drilling tool 1 is provided with a thread 7 at its upper end. In an embodiment shown in Fig. 2, the thread 7 is an internal thread but it is obvious that in other embodiments the thread may be formed outside the drilling tool 1.

[0033] The drilling tool 1 ends in a base 8 made of a cuttable material. In the base 8, directional channels 9 are made for optimal flow of the drilling fluid. The base 8 also has inlet openings 10 for the drilling fluid. After completion of its task, the base 8 of the drilling tool 1 may be drilled.

[0034] The principle of operation of the drilling tool 1, according to the invention, is based on a solution innovative on a global scale, which allows cutting the rock material, and then fragmentising it and discharging it onto the surface out of the borehole. The very idea of operation can be compared to the calibrator known from the engineering industry, which, however, uses the principle of operation of the ejector for removing the cut material from the cutting zone. It is this innovation that provides the developed tool with significant advantages over analogous structures.

[0035] Fig. 6 schematically shows the principle of operation of the ejector, relating to the drilling tool, according to the invention. In Fig. 6, it can be seen that in the negative pressure zone, formed in the narrowing of the space into which a fluid, in this case a drilling fluid, is forced, the sucked rock material, cut by the cutting blades 3 of the drilling tool 1, is captured and accelerated.

[0036] This phenomenon is shown in more detail in Fig. 5 in relation to the drilling tool 1 according to this embodiment. The slots 6 connecting the interior of the body 2 of the drilling tool 1 to its external surface correspond to the negative pressure zone of Fig. 6. Directly above the slots 6 the bands 4 of the cutting blades 3 are arranged, thereby forming, in each set 5 of the cutting blades 3, lateral channels 11 in which the rock material cut by the cutting blades 3 in the resulting borehole is accelerated. This capturing and accelerating of the rock material leads to its further fragmentising at the edges of the cutting blades 3 and preventing formation of deposits on the casing pipes which could disturb the process of their cementing.

[0037] The proposed solution allows the use of high velocity gradients in the vicinity of the cutting blade 3 for precise fragmentation of the cut material and discharging it up the hole along with the drilling fluid. Appropriate fragmentation of the cut material is essential as it prevents formation of so-called mud cakes. This translates into proper cementing of the hole and into environmental safety and return on investment. It is worth noting that the drilling tool 1, according to the invention, does not have any moving parts, which contributes to its reliability.

[0038] In relation to the drilling tool 1, according to the invention, computer simulations with the use of CFD (Ansys Fluent) tool were conducted, which showed that the flow of the drilling mud in appropriately profiled openings and channels inside the cutting blades 3 induces the occurrence of pressure anomalies, as illustrated in Fig. 7. A special form of the so-called hydrodynamic paradox was used herein. Thereby, a zone of lower pressure under the cutting blades 3 in lateral channels 11 was obtained, allowing suction of the cut rock material, and then its fragmentation through transverse flow of the drilling fluid.

Claims

1. A drilling tool (1) for maintaining a borehole and for cutting rock material, comprising a hollow elongated body (2) in the form of a pipe, the body (2) being provided with a plurality of cutting blades (3) arranged around the body (2) in such a way that they protrude from the external surface of the body (2), **characterised in that**

   - the cutting blades (3) are shaped as bands (4), the ends of which are connected to the body (2), and the central parts of the cutting blades (3)

between the ends protrude from the body (2), wherein the cutting blades (3) are grouped into sets (5) arranged on the periphery of the body and placed one above the other, and angularly offset relative to each other,
- each cutting blade (3) in the set (5) is spaced from the axis of the body (2) of the drilling tool (1) by a dimension larger than the dimension of the distance from the axis of the body (2) of the cutting blade (3) located directly under it,
- the body (2) is provided with slots (6) connecting the interior of the body (2) to its external surface and arranged radially under the cutting blades (3), and not connected to the cutting blades (3),
- under the sets of the cutting blades (4), there is a lateral channel (11) through which the drilling fluid along with the cut rock material flow.

2. The drilling tool, according to claim 1, **characterised in that** the cutting blades (3) are configured to discharge and fragmentise the cut rock material.

3. The drilling tool, according to claim 1, **characterised in that** a connection with the lateral channel (11) is formed between the slots (6) in the body (2) of the drilling tool (1) in order to obtain an optimal fragmentising flow of the cut rock material (ejector effect).

4. The drilling tool, according to claim 1, **characterised in that** the cutting blades (3) are grouped into two levels of sets (5) arranged on the periphery of the body (2), arranged one above the other and offset relative to each other by an angle of 0° to 45°

5. The drilling tool, according to claim 1, **characterised in that** each set (5) on one level comprises four cutting blades (3), wherein the sets (5) of the cutting blades (3) are arranged on the periphery of the drilling tool (1) every 90°.

6. The drilling tool, according to claim 1, **characterised in that** each set (5) on one level comprises six cutting blades (3), wherein six sets (5) of the cutting blades (3) on one level are arranged symmetrically on the periphery of the drilling tool (1).

7. The drilling tool, according to claim 1, **characterised in that** the cutting blades (3) in the set (5) are offset relative to the cutting blades (3) located directly under them by an angle of 5° to 25°.

8. The drilling tool, according to claim 1, **characterised in that** in its upper part it is provided with a thread (7) for connecting the drilling tool (1) to casing pipes.

9. The drilling tool, according to claim 1, **characterised in that** it ends in a base (8) made of a cuttable material.

10. The drilling tool, according to claim 7, **characterised in that** directional channels (9) are made in the base (8)for optimal flow of the drilling fluid.

11. The drilling tool, according to claim 7, **characterised in that** inlet openings (10) are made in the base (8)for the flow of the drilling fluid.

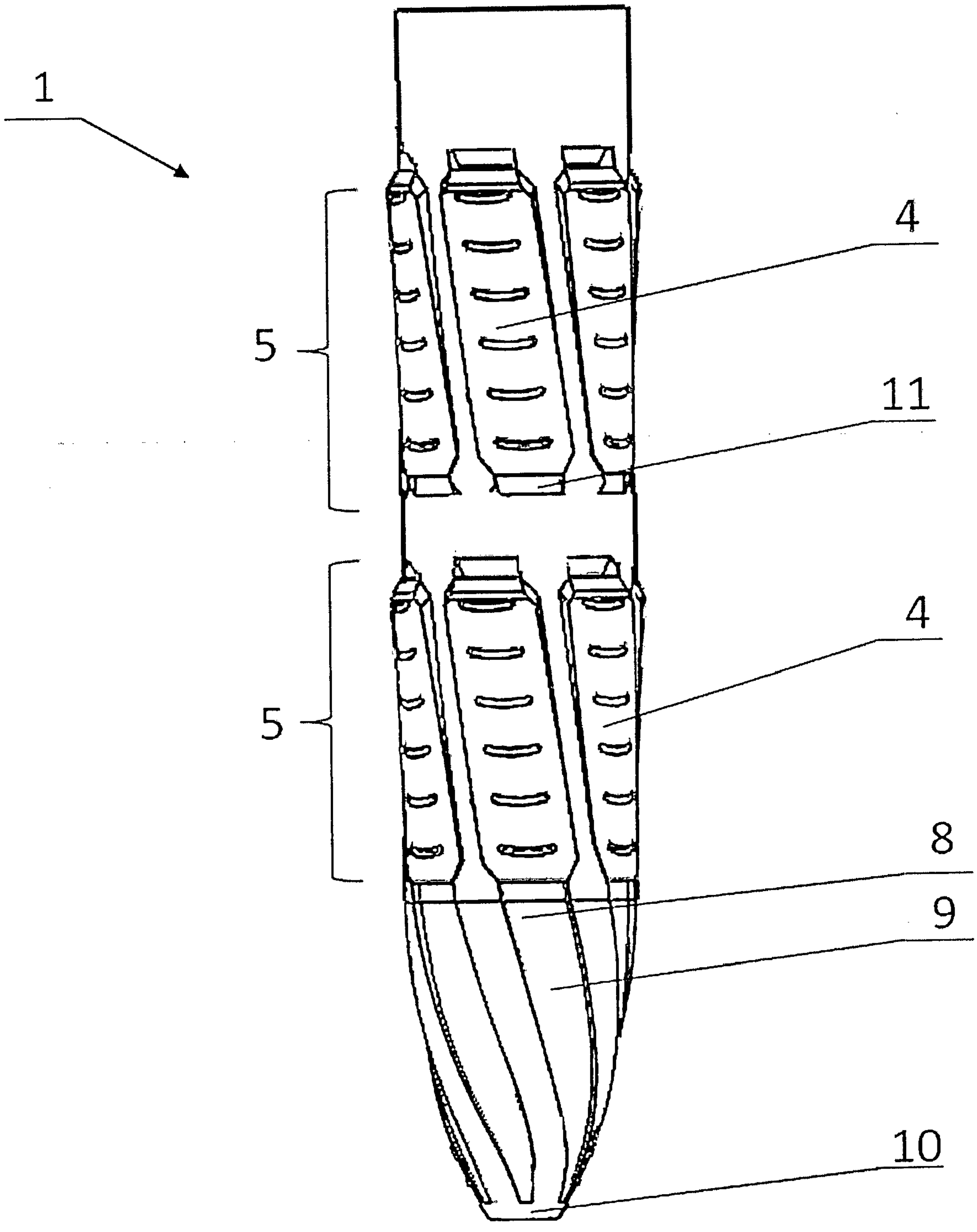

Fig. 1

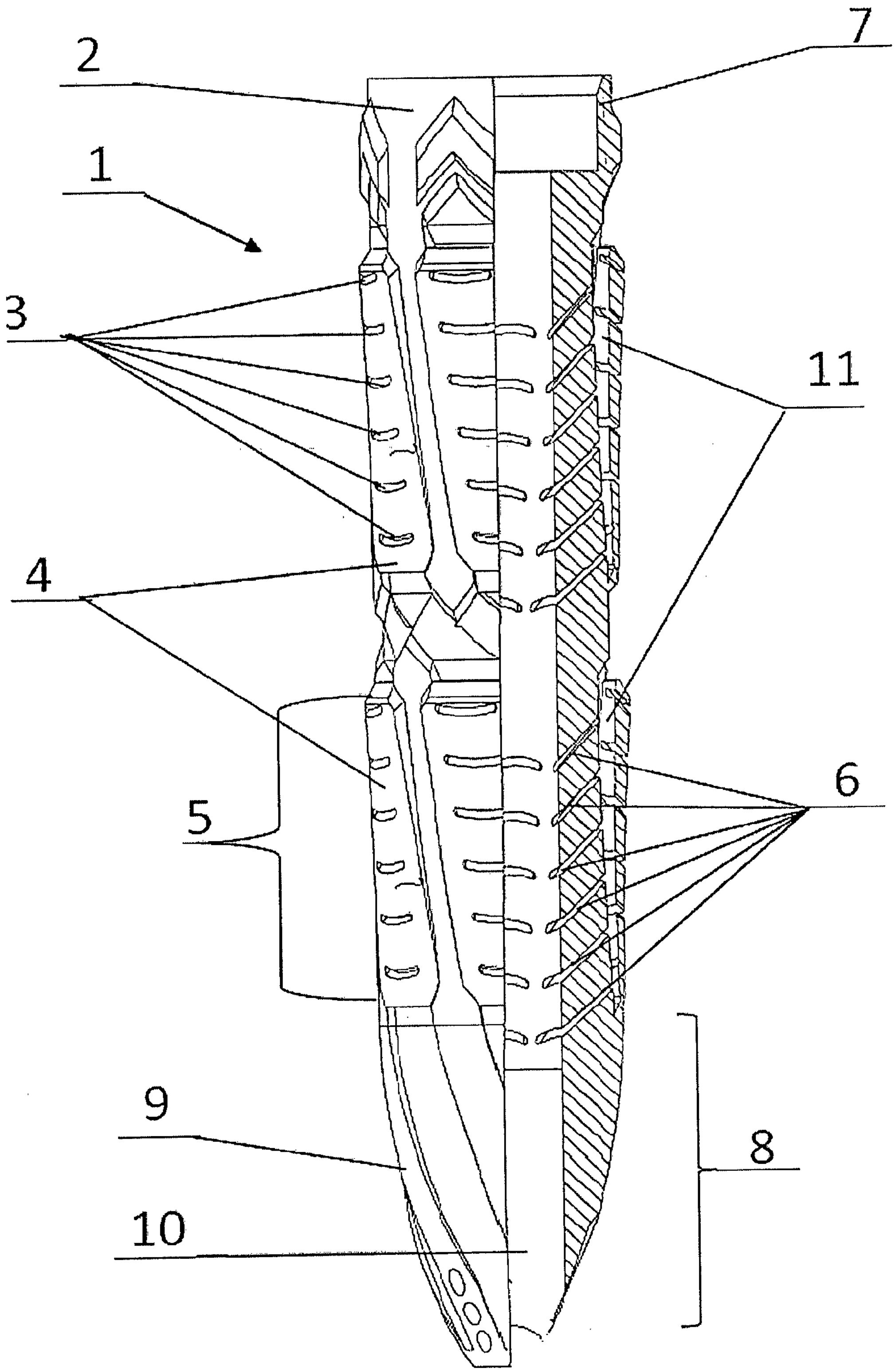

Fig. 2

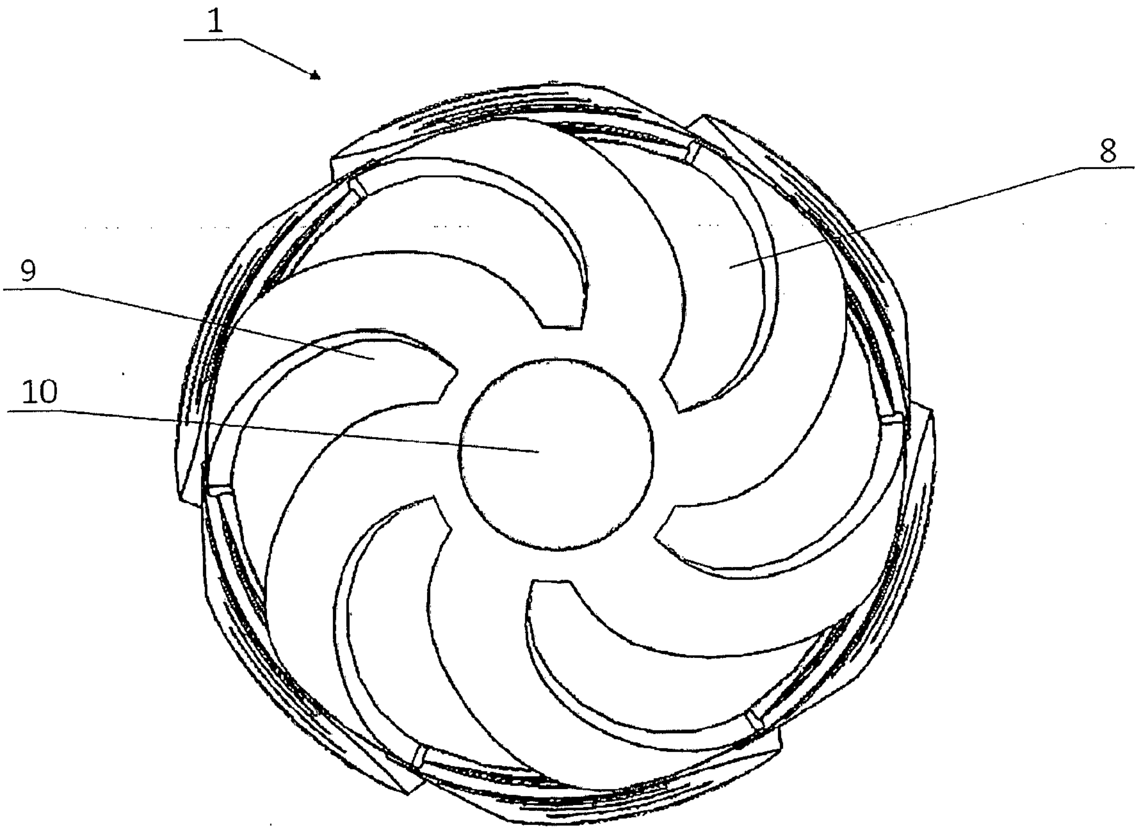

Fig. 3

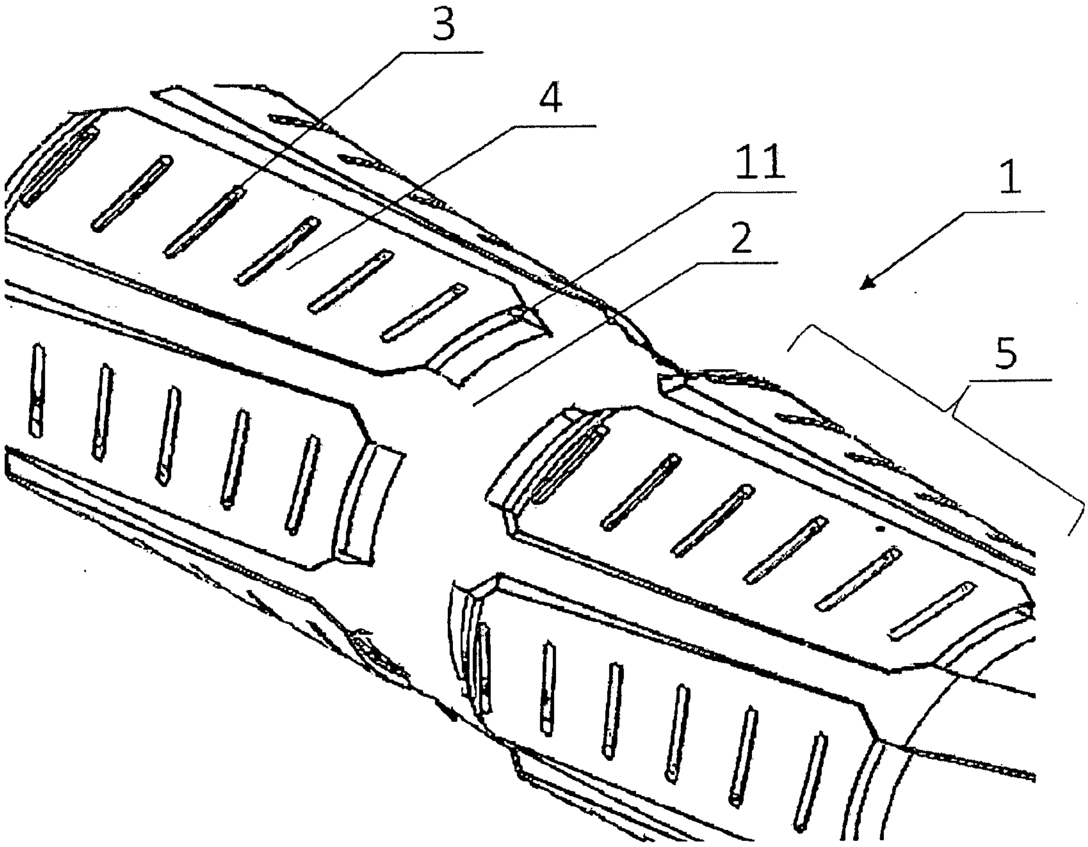

Fig. 4

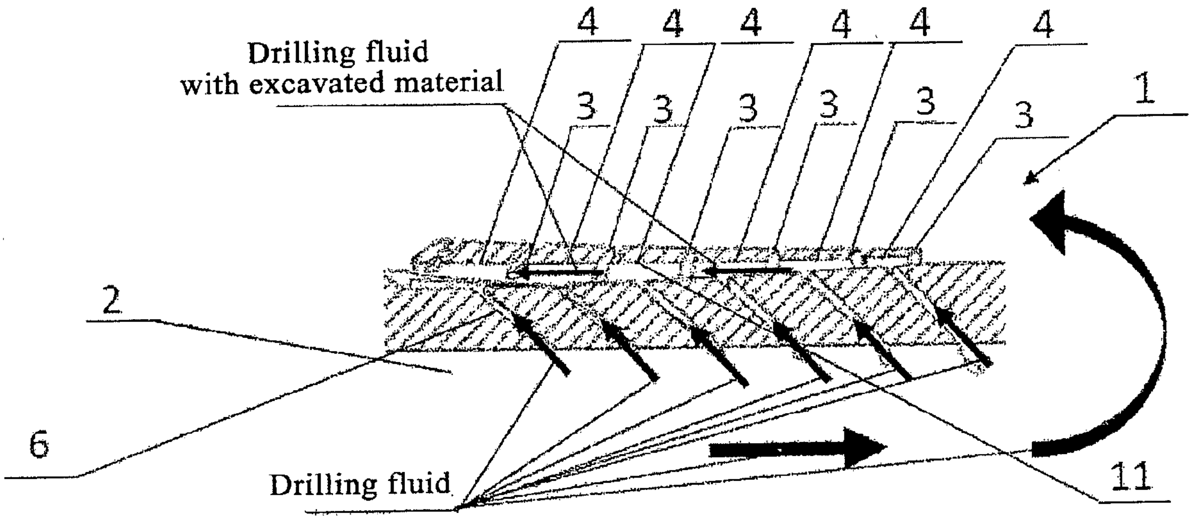
4
4
4
4
4
4
Drilling fluid
with excavated material
3
3
3
3
3
3
1
2
6
Drilling fluid
11

Fig. 5

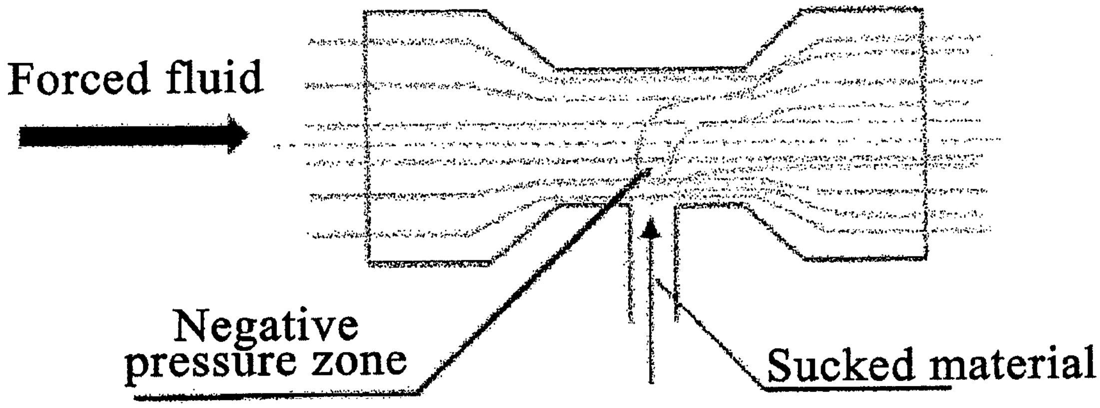

Fig. 6

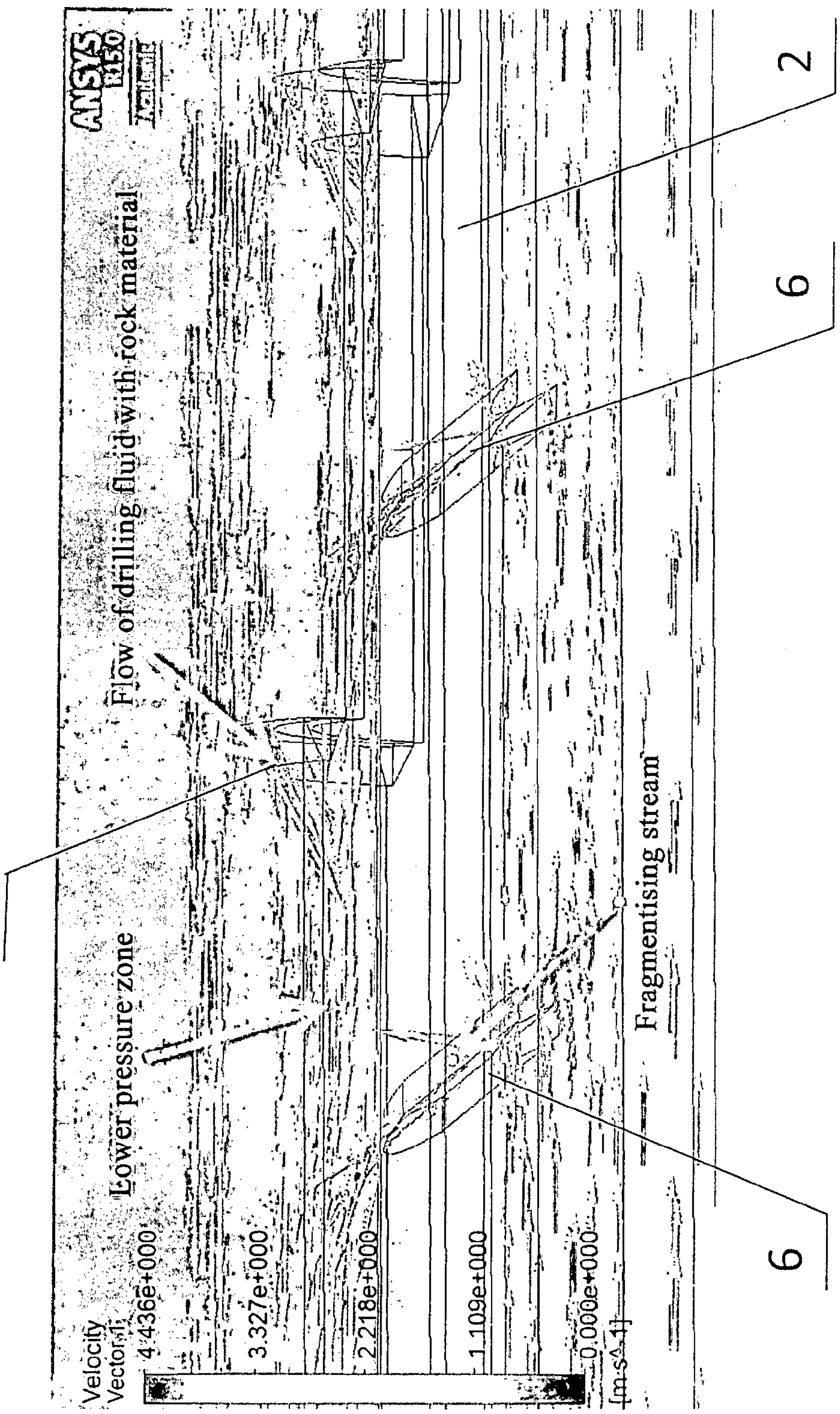
ANSYS
R15.0
Velocity
Vector 1
4.436e+000
3.327e+000
2.218e+000
1.109e+000
0.000e+000
[m s^-1]
Flow of drilling fluid with rock material
Lower pressure zone
Fragmentising stream
2
6
6
6

Fig. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 15 46 0053

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 199 511 A (TIBBITTS GORDON A [US] ET AL) 6 April 1993 (1993-04-06) * figures 1-3, 8 * * column 3, line 59 - column 4, line 66 * * column 6, line 47 - column 7, line 24 * -----	1-8,10, 11	INV. E21B10/42 E21B10/54 E21B17/14 E21B31/03 E21B10/60
X	US 6 527 065 B1 (TIBBITTS GORDON A [US] ET AL) 4 March 2003 (2003-03-04) * figures 3-5 * * column 7, line 6 - column 9, line 6 * -----	1-8,10, 11	
A	US 2002/189863 A1 (WARDLEY MIKE [GB]) 19 December 2002 (2002-12-19) * figures 1-2, 4 * * paragraphs [0012], [0033] * -----	1,9	
A	CN 104 373 059 A (CHINA NAT PETROLEUM CORP; CNPC DRILLING RES INST) 25 February 2015 (2015-02-25) * figure 2 * -----	1	
A	US 2002/020565 A1 (HART STEVEN JAMES [GB] ET AL) 21 February 2002 (2002-02-21) * figure 1 * -----	1	TECHNICAL FIELDS SEARCHED (IPC) E21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	28 January 2016	Brassart, P

CATEGORY OF CITED DOCUMENTS

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

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 46 0053

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-01-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5199511 A	06-04-1993	AU 647651 B2	24-03-1994
		AU 2082092 A	18-03-1993
		CA 2073995 A1	17-03-1993
		DE 69222388 D1	30-10-1997
		EP 0532869 A1	24-03-1993
		US 5199511 A	06-04-1993
US 6527065 B1	04-03-2003	BE 1014353 A5	02-09-2003
		GB 2367312 A	03-04-2002
		IT TO20010837 A1	28-02-2002
		US 6527065 B1	04-03-2003
US 2002189863 A1	19-12-2002	AU 776634 B2	16-09-2004
		AU 2015801 A	03-07-2001
		CA 2393754 A1	28-06-2001
		EP 1242711 A1	25-09-2002
		NO 20022831 A	14-06-2002
		US 2002189863 A1	19-12-2002
		WO 0146550 A1	28-06-2001
CN 104373059 A	25-02-2015	NONE	
US 2002020565 A1	21-02-2002	DE 60100727 D1	16-10-2003
		DE 60100727 T2	22-07-2004
		EP 1182323 A1	27-02-2002
		US 2002020565 A1	21-02-2002
		ZA 200105680 A	06-02-2002

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- GB 2482703 A **[0004]**