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(54) **A cooling apparatus of a downhole tool**

(57) A cooling apparatus (12) of a downhole tool (9, 11) comprises a turbine (13) driven by a drilling fluid (10) circulating in the downhole tool (9, 11), and a thermodynamic cooler (18). The cooling apparatus (12) further comprises a mechanical arrangement (19) driven by the turbine (13). The mechanical arrangement (19) couples the turbine (13) and the thermodynamic cooler (18) such that the thermodynamic cooler (18) is mechanically driven by the turbine (13).

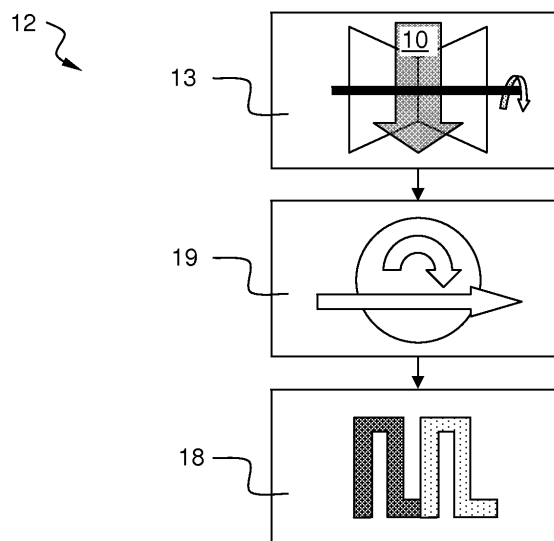


FIG. 3

Description

[0001] FIELD OF THE INVENTION

[0002] The invention relates to a cooling apparatus for a downhole tool and in particular, but not exclusively to a drilling environment.

[0003] BACKGROUND OF THE INVENTION

[0004] Figure 1 schematically shows a typical onshore hydrocarbon well with surface equipment 1, which is located above a hydrocarbon geological formation 2 after some well-bore 3 drilling operations have been carried out.

[0005] A first portion 4 of the well-bore is a cased portion. A casing string 5 has been run into this first portion of the well-bore. Cementing operations have been carried out, in this first portion, for sealing the annulus (i.e. the space between the well-bore 3 and the casing string 5). A second portion 6 of the well-bore is an open bore hole. A third portion 7 of the well-bore is a sensibly horizontal lateral bore hole.

[0006] Typically, the surface equipment 1 comprises a plurality of mud tanks and mud pumps, a derrick, a drawworks, a rotary table, a power generation device and various auxiliary devices, etc, which are well known in the oilfield industry domain. A drill string 8 couples the surface equipment with a downhole tool, for example a drilling assembly 9. The drilling assembly comprises a drill bit. The drill string and the drilling assembly comprise an internal conduit through which a drilling fluid 10 circulates.

[0007] The downhole tool may further comprise a logging assembly 11 for performing logging while drilling or measurement while drilling. Typically, the logging assembly comprises various sensors, detectors, power units, and processing units comprising numerous electronic components. The downhole tool further comprises a cooling apparatus 12 for cooling down the electronic components below their conventional maximum operating temperature in order to avoid any failure during operation. The cooling apparatus 12 may be based on thermodynamic machines, for example mechanical vapor compression cycles, Stirling engine, inverse Brayton cycle, sorption cycles, etc... Typically, these systems are driven by an electric motor. The electrical power may be supplied by either a battery or an alternator turbine. Generally, an alternator turbine is driven by the drilling fluid circulating inside the internal conduit of the drill string. Such an alternator turbine and drilling assembly are preferred because of the high power output.

[0008] Figure 2 is a block diagram schematically showing a typical system for cooling electronic components in the downhole tool. The cooling apparatus 12 comprises a turbine 13, an alternator 14 and appropriate electronic circuits 15 and 16, an electrical motor 17, and a thermodynamic cooler 18. The turbine 13 is coupled to the alternator 14 and, both form an electrical energy generator. The turbine 13 rotates when the drilling fluid 10 is circulated within the drill string and downhole tool. Thus, the

alternator 14 driven by the turbine 13 generates an alternative signal, which is delivered to the power supply 15. The power supply 15 may comprise a rectification module (e.g. a Graetz bridge) coupled to a power converter (e.g. a rectifier and a step-down converter). The power supply 15 delivers an electrical power under the form of a rectified and stepped-down signal (voltage and/or current) suitable for the operation of a motor driving unit 16 connected to an electrical motor. The electrical motor 17 drives the thermodynamic cooler 18, for example by alternately compressing/decompressing a fluid, the decompressed fluid being the "cold" source of the thermodynamic cooler.

[0009] For example document US6134892 describes such a system for cooling electronic components in the downhole tool of a drill string through which a drilling fluid flows. The power for the electrical system, including the electronic components and the thermoelectric coolers, is supplied by the turbine alternator, which is driven by the drilling mud. The turbine alternator may be of the axial, radial or mixed flow type. Alternatively, the alternator could be driven by a positive displacement motor driven by the drilling mud, such as a Moineau-type motor.

[0010] The hereinbefore described cooling systems are complex as they require electrical energy generation and transformation.

[0011] SUMMARY OF THE INVENTION

[0012] It is an object of the invention to propose a cooling apparatus for a downhole tool that overcomes at least one of the drawbacks of the prior art, in particular an improved cooling apparatus which do not used electrical power.

[0013] One aspect of the invention relates to a cooling apparatus of a downhole tool comprising a turbine driven by a drilling fluid circulating in the downhole tool, a thermodynamic cooler, and a mechanical arrangement driven by the turbine, the mechanical arrangement coupling the turbine and the thermodynamic cooler such that the thermodynamic cooler is mechanically driven by the turbine.

[0014] Advantageously, the mechanical arrangement comprises an actuating cam transforming a rotation of the turbine into an oscillating movement in the thermodynamic cooler.

[0015] Advantageously, the thermodynamic cooler is a Stirling cooler comprising a linear piston coupled to the actuating cam.

[0016] Advantageously, the mechanical arrangement comprises a shaft drive transforming a rotation of the turbine into a circular movement in the thermodynamic cooler.

[0017] Advantageously, the thermodynamic cooler is a compressor coupled to a heat exchanger.

[0018] Advantageously, the compressor is chosen in the group of compressor comprising the Wankel type compressor, the screw compressor, the scroll compressor, the liquid ring pump, and the membrane pump.

[0019] Another aspect of the invention relates to a

downhole tool comprising a cooling apparatus according to the invention.

[0020] Still another aspect of the invention relates to a method comprising: driving a turbine by a drilling fluid circulating in the downhole tool, and coupling, by a mechanical arrangement, the turbine and a thermodynamic cooler such that the thermodynamic cooler is mechanically driven by the turbine.

[0021] The direct turbine driven thermodynamic cooling for downhole use is simple and reliable compared to prior art systems. The rotation of the hydraulic turbine driven by the drilling fluid is directly converted to proceed a thermodynamic cycle. Advantageously, the mechanical work of the hydraulic turbine mechanically powers the thermodynamic cooler instead of generating and transforming electric power generated by an alternator coupled to the turbine.

[0022] BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The present invention is illustrated by way of example and not limited to the accompanying figures, in which like references indicate similar elements:

- Figure 1 schematically shows a typical onshore hydrocarbon well location;
- Figure 2 is a block diagram schematically representing a cooling apparatus for a downhole tool according to the prior art;
- Figure 3 is a block diagram schematically representing a cooling apparatus for a downhole tool according to the invention;
- Figure 4 schematically shows a first exemplary embodiment of the cooling apparatus of Figure 3; and
- Figure 5 schematically shows a second exemplary embodiment of the cooling apparatus of Figure 3.

[0024] DETAILED DESCRIPTION OF THE INVENTION

[0025] Figure 3 is a block diagram schematically representing a cooling apparatus 12 for a downhole tool (9 and 11 shown in Figure 1). For example, the cooling apparatus 12 may be positioned closely to the logging assembly (11 shown in Figure 1) in order to efficiently cooled down the electronic components of the logging tool.

[0026] The cooling apparatus 12 comprises a turbine 13, a mechanical arrangement 19 and a thermodynamic cooler 18. Advantageously, the thermodynamic cooler 18 is coupled to the electronic components, or the printed circuit board comprising the electronic components, or the detector/sensor. The turbine 13 is driven by the drilling fluid 10 circulating in the internal conduit of the downhole tool. The mechanical arrangement 19 is driven by the turbine 13. The mechanical arrangement 19 couples the turbine 13 and the thermodynamic cooler 18. Thus,

the thermodynamic cooler 18 is mechanically driven by the turbine 13.

[0027] Figure 4 schematically shows a first exemplary embodiment of the cooling apparatus 12. In this example, the mechanical arrangement 19 comprises an actuating cam 20. The actuating cam 20 may be a swash-plate consisting of a disk attached to a shaft, and a cam follower. The actuating cam 20 transforms the rotation movement 21 of the turbine 13 into an oscillating movement 22 which drives the thermodynamic cooler 18. The thermodynamic cooler 18 is a Stirling cooler 23 comprising a linear piston 24 coupled to the cam follower of the actuating cam 20. The oscillating movement of the linear piston is used to proceed a thermodynamic cycle in the Stirling cooler. The thermodynamic cycle creates a temperature difference which is used to efficiently cool down the electronic components of the downhole tool.

[0028] Figure 5 schematically shows a second exemplary embodiment of the cooling apparatus 12. In this example, the mechanical arrangement 19 comprises a shaft drive 25. The shaft drive 25 transforms the rotation movement 21 of the turbine 13 into a circular movement 26 which drives the thermodynamic cooler 18. The thermodynamic cooler 18 is a compressor 27 coupled to a heat exchanger 28. The compressor 27 may be a Wankel type compressor, a screw compressor, a scroll compressor, a liquid ring pump, or a membrane pump. The circular movement of the compressor is used to proceed a thermodynamic cycle in the heat exchanger. The thermodynamic cycle creates a temperature difference which is used to efficiently cool down the electronic components of the downhole tool.

[0029] Though the invention has been described in relation with a particular example of onshore hydrocarbon well location, it will also be apparent for a person skilled in the art that the invention is applicable to offshore hydrocarbon well location.

[0030] The drawings and their description hereinbefore illustrate rather than limit the invention.

Any reference sign in a claim should not be construed as limiting the claim. The word "comprising" does not exclude the presence of other elements than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such element.

Claims

1. A cooling apparatus (12) of a downhole tool (9, 11), the cooling apparatus comprising:
 - a turbine (13) driven by a drilling fluid (10) circulating in the downhole tool (9, 11);
 - a thermodynamic cooler (18); and
 - a mechanical arrangement (19) driven by the turbine (13), the mechanical arrangement (19) coupling the turbine (13) and the thermodynamic

ic cooler (18) such that the thermodynamic cooler (18) is mechanically driven by the turbine (13).

2. The cooling apparatus (12) of claim 1, wherein the mechanical arrangement (19) comprises an actuating cam (20) transforming a rotation movement (21) of the turbine (13) into an oscillating movement (22) in the thermodynamic cooler (18). 5

3. The cooling apparatus (12) of claim 2, wherein the thermodynamic cooler (18) is a Stirling cooler comprising a linear piston (24) coupled to the actuating cam (20). 10

4. The cooling apparatus (12) of claim 1, wherein the mechanical arrangement (19) comprises a shaft drive (25) transforming a rotation movement (21) of the turbine (13) into a circular movement (26) in the thermodynamic cooler (18). 15

5. The cooling apparatus (12) of claim 4, wherein the thermodynamic cooler (18) is a compressor (27) coupled to a heat exchanger (28). 20

6. The cooling apparatus (12) of claim 5, wherein the compressor (27) is chosen in the group of compressor comprising the Wankel type compressor, the screw compressor, the scroll compressor, the liquid ring pump, and the membrane pump. 25

7. A downhole tool (9, 11) comprising a cooling apparatus (12) according to anyone of the claims 1 to 6. 30

8. A method for cooling a downhole tool (9, 11), the method comprising: 35
 - driving a turbine (13) by a drilling fluid (10) circulating in the downhole tool; and
 - coupling, by a mechanical arrangement (19), the turbine (13) and a thermodynamic cooler (18) such that the thermodynamic cooler (18) is mechanically driven by the turbine (13). 40

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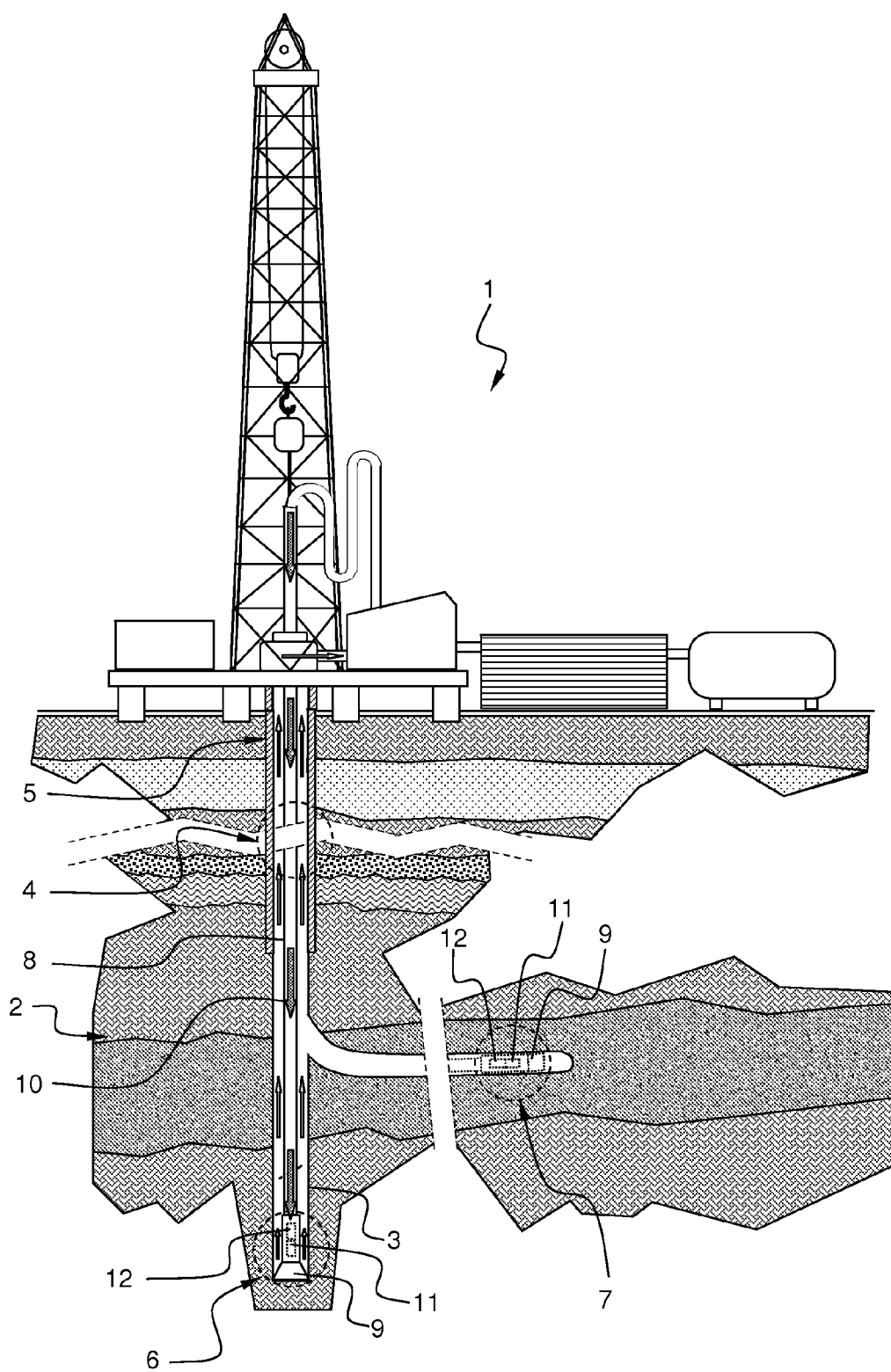


FIG. 1 - PRIOR ART

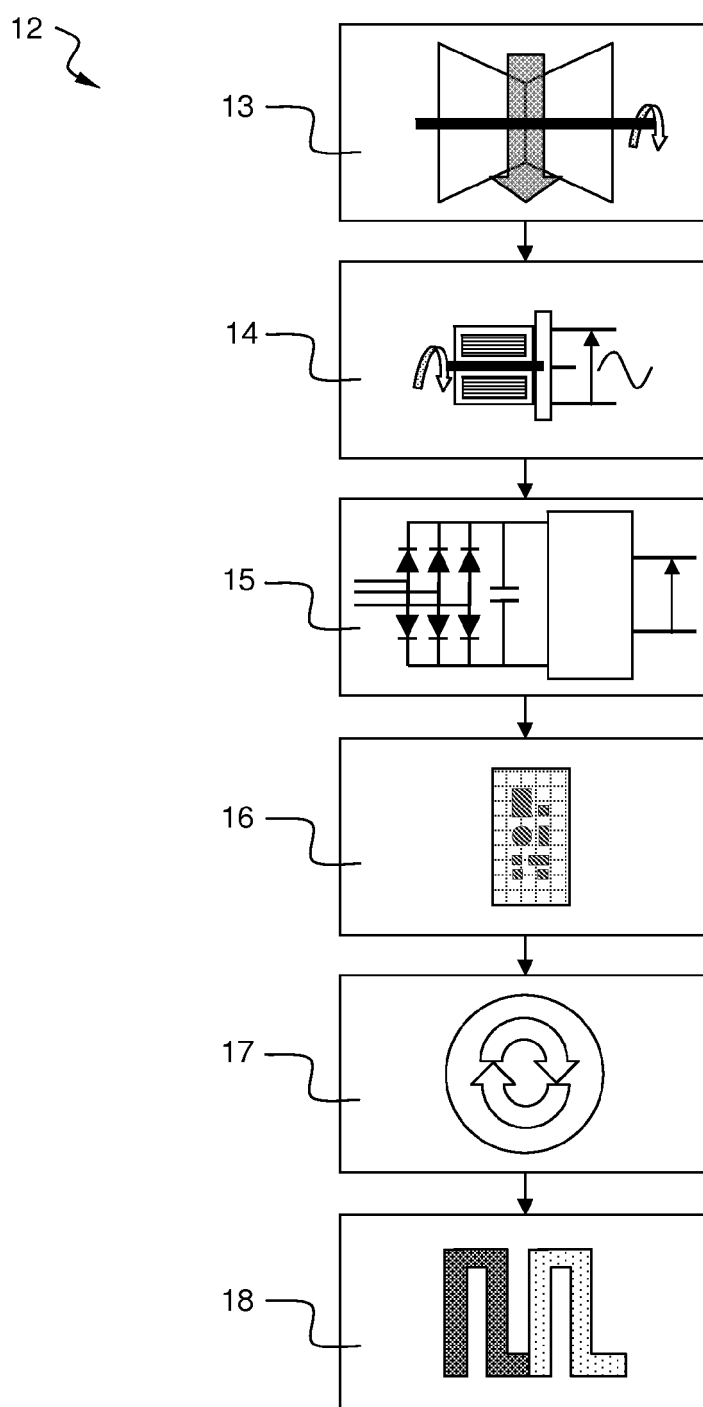


FIG. 2 – PRIOR ART

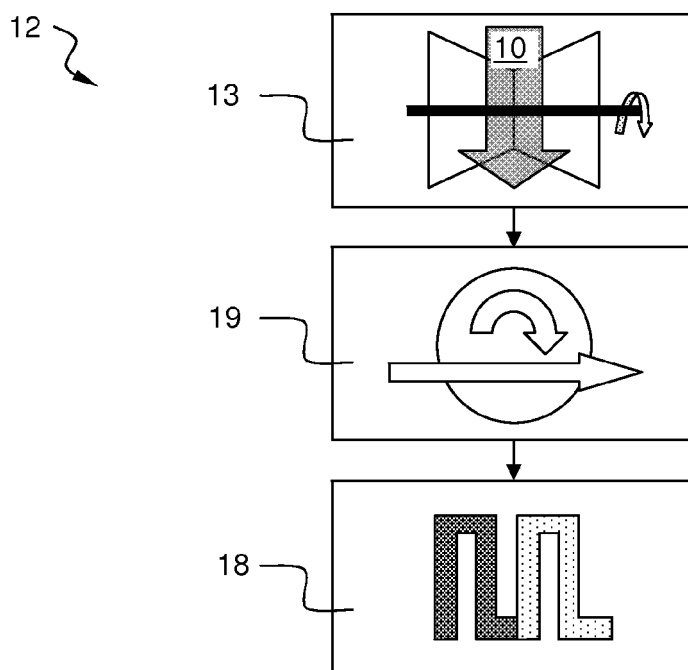


FIG. 3

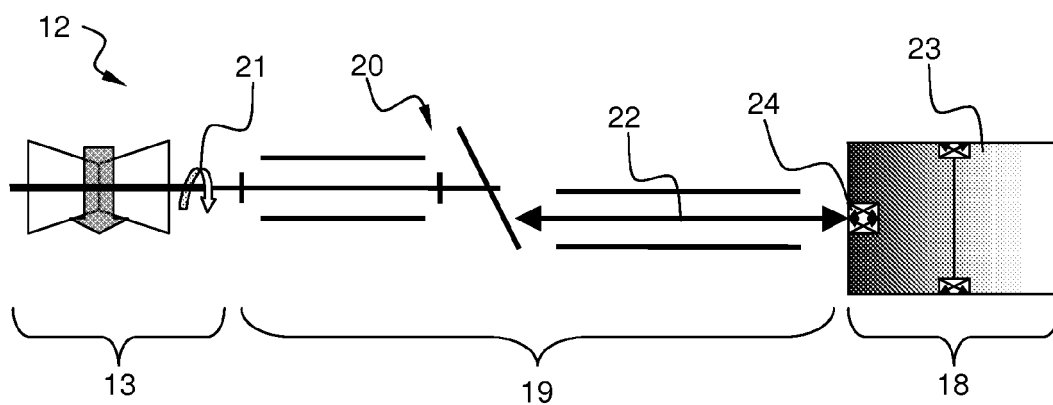


FIG. 4

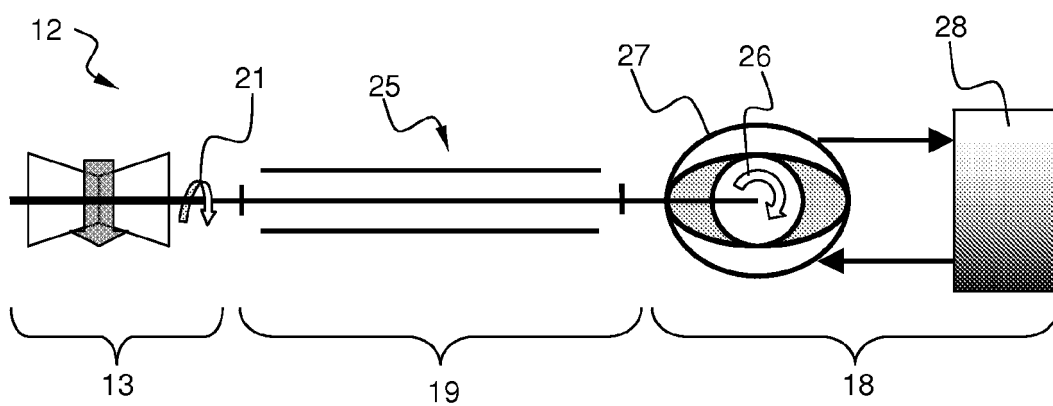


FIG. 5



EUROPEAN SEARCH REPORT

Application Number
EP 09 15 9162

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	US 6 134 892 A (TURNER WILLIAM EVANS [US] ET AL) 24 October 2000 (2000-10-24) * column 4, line 16 - line 48; figure 2 * -----	1-8	INV. E21B36/00
A	US 2006/162931 A1 (MAYES JAMES C [US]) 27 July 2006 (2006-07-27) * paragraph [0039] - paragraph [0040]; claims 1,2,7; figure 2 * -----	1-8	
A	US 2006/117759 A1 (HALL DAVID R [US] ET AL) 8 June 2006 (2006-06-08) * paragraphs [0015], [0104] - [0110]; claims 1,2; figures 2,12-14 * -----	1-8	
A	CA 2 590 566 A1 (SCHLUMBERGER CA LTD [CA]) 18 January 2008 (2008-01-18) * paragraph [0027]; figure 1 * -----	1-8	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			E21B F03B F25B
3	Place of search Munich	Date of completion of the search 15 September 2009	Examiner Strømme, Henrik
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			

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

EP 09 15 9162

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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15-09-2009

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 6134892	A	24-10-2000	US 5931000 A	03-08-1999
US 2006162931	A1	27-07-2006	NONE	
US 2006117759	A1	08-06-2006	NONE	
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6134892 A [0009]