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(54) Title: METHOD AND SYSTEM FOR ENHANCING THE PERFORMANCE OF A WELL TUBULAR EXPANSION ASSEMBLY

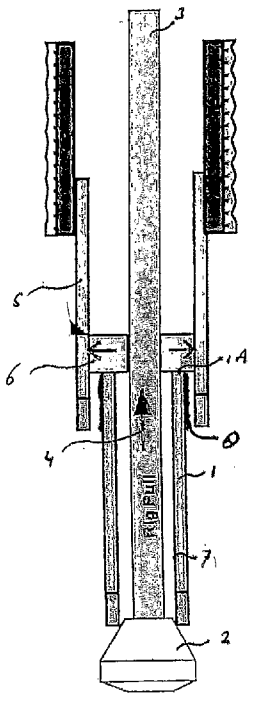


FIG. 1

(57) Abstract: The upward force exerted on an expansion cone (2), which is pulled up by a drill string (3) to expand a well tubular (1), is hydraulically enhanced by: - connecting a bottom plug (10) to a carrier body (11) below the expansion cone (2); - lowering the drill string (3), cone (2), carrier body (11), bottom plug (10) and unexpanded well tubular (1) assembly into a well; - inducing the drill string (3) to pull the expansion cone (2) through a lower edge (13) of the unexpanded well tubular (1) to expand said edge (13) and to subsequently pull the bottom plug (10) into sealing engagement with the expanded edge (13); - releasing the bottom plug (10) from the carrier body (11); - further pulling (F_1) the expansion cone (10) through the well tubular (1) and simultaneously injecting fluid through the drill string(3) below the cone (2) to hydraulically increase (F_2) the upward force ($F=F_1+F_2$) exerted on the expansion cone (2).

WO 2017/001386 A1

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METHOD AND SYSTEM FOR ENHANCING THE PERFORMANCE OF A WELL TUBULAR EXPANSION ASSEMBLY

BACKGROUND OF THE INVENTION

The invention relates to a method and system for enhancing the performance of a well tubular expansion assembly.

A known well tubular expansion assembly and method are disclosed in International patent application WO2012104257.

In this known method a well tubular is expanded by pulling an expansion cone therethrough by drill string pull.

A disadvantage of the known method is that, in particular in deep and/or deviated wells, the drill string pull exerted to the cone may be limited and insufficient to expand an upper end of the tubular within a lower end of a previously installed well tubular.

A further disadvantage of the known method is that it requires use of a top anchor that fixes an upper end of the expanded tubular within a previously installed tubular, which anchor may slip if a large upward force is exerted by the expansion cone to the expanding tubular.

There is a need for and improved method and expandable well tubular wherein the upward force exerted on the expansion cone is hydraulically increased and wherein upward motion of an upper end of a partially expanded well tubular into a previously installed well tubular is inhibited such that forces on a top anchor are reduced.

A known method for placing an expandable bottom plug at the bottom of an expandable well casing is expanded downhole is disclosed in International patent application WO2004/027200. This known method involves a two step installation and expansion process which requires intervention by an operator. There is a need for an improved bottom plug installation and subsequent expansion process that can be performed in one step without intervention of an operator.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a method for enhancing the upward force on an expansion cone which is pulled up by a drill string to expand a well tubular, the method comprising:

- inserting the drill string through the unexpanded well tubular;
- connecting the expansion cone to a lower end of the drill string such that the expansion cone engages a lower edge of the tubular;
- connecting a bottom plug to a carrier body that is suspended below the expansion cone;
- lowering the drill string, cone, bottom plug and the unexpanded well tubular into a well until an upper end of the unexpanded well tubular is co-axially arranged within a lower end of a previously installed tubular;
- pulling the expansion cone by drill string pull through the lower edge of the unexpanded well tubular thereby expanding said lower edge;
- inducing the carrier body to pull the bottom plug into the expanded lower edge and to seal off said lower edge;
- inducing a release joint in the carrier body to release the bottom plug from the carrier body;

- further pulling the expansion cone by drill string pull through at least a substantial part of the lower tubular; and
- simultaneously injecting fluid through the interior of the drill string through a fluid discharge opening below the expansion cone into a space between the bottom plug and the expansion cone thereby hydraulically pushing the expansion cone through the lower tubular and increasing the upward force exerted to the expansion cone;

and wherein the expanded lower edge of the well tubular has an inwardly curved shape and the bottom plug comprises:

- a sealing ring that is configured to sealingly engage said edge; and
- self-locking teeth that snap into the inner surface of said inwardly curved edge when the bottom plug is pulled into the lower edge.

The fluid injection through the interior of the drill string may be continued when the expansion cone is pulled through the upper end of the lower tubular into the lower end of the previously installed upper tubular and the drill string pull and pressure of the fluid injected through the drill string may be adjusted on the basis of a monitored longitudinal movement of the expansion cone through the well tubular and a ration between downward hydraulic force exerted on the bottom plug and upward force exerted by the expansion cone on the tubular expanded thereby.

An advantage of the method according to the invention over the method known from International patent application WO2004/027200 is that the bottom plug is positioned in the bottom of the expanded well tubular by letting it shoulder against the bottom end

face of the tubular whereby the bottom plug is mechanically set by overpul to the expansion string. This enables the setting of the plug while the tubular string is being expanded, wherein the pipe expansion and shouldering, anchoring and sealing of the plug is performed in a single operational step without requiring intervention by an operator.

After expansion of the well tubular the bottom plug may be drilled out and the expanded well tubular may then form another previously installed well tubular through which a subsequent well tubular is inserted and expanded in accordance with the method according to the inventon, which process may repeated several times to generate a MOnoDiameter(MOD) well hydrocarbon fluid production well with a substantially constant internal diameter through which, after completion of the well, a larger flux of crude oil, natural gas and/or another hydrocarbon fluid may be produced than through conventional telescoping wells.

In accordance with the invention there is further provided a tubular expansion assembly comprising

- a bottom plug connectable to a carrier body below the expansion cone;
- means for connecting the expansion cone to a lower end of a drill string and to pull the expansion cone by drill string pull into a lower edge of an unexpanded well tubular thereby expanding said lower edge;
- a release joint in the carrier body adapted to release the bottom plug from the carrier body when the bottom plug is pulled into the expanded lower edge of the lower tubular; and
- a fluid discharge opening near a lower end of the expansion cone into for injecting fluid through the drill string and expansion cone into a space between

the bottom plug and the expansion cone thereby hydraulically pushing the expansion cone through the expanding well tubular and increasing the upward force exerted the expansion cone, and wherein the expanded lower edge of the well tubular has an inwardly curved shape and the bottom plug comprises:

- a sealing ring that is configured to sealingly engage said edge; and
- self-locking teeth that snap into the inner surface of said inwardly curved edge when the bottom plug is pulled into the lower edge.

These and other features, embodiments and advantages of the method and expandable well tubular according to the invention are described in the accompanying claims, abstract and the following detailed description of non-limiting embodiments depicted in the accompanying drawings, in which description reference numerals are used which refer to corresponding reference numerals that are depicted in the drawings.

Similar reference numerals in different figures denote the same or similar objects. Objects and other features depicted in the figures and/or described in this specification, abstract and/or claims may be combined in different ways by a person skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 shows how a well tubular is expanded by puling an expansion cone therethrough;

Fig 2 shows how the upper end of the well tubular is expanded within a lower end of an previously installed well tubular after completion of the expansion process;

Fig.3 shows that the expansion assembly according to the invention is provided with a bottom plug suspended below the expansion cone; and

Fig.4 shows how the upward force exerted on the expansion cone is increased by pumping fluid between the expansion cone an bottom plug after pulling the bottom plug into sealing engagement with a lower edge of the expanded well tubular.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

Figure 1 shows how a lower well tubular 1 is expanded by moving an expansion cone 2 therethrough. The expansion cone is connected to a drill string 3 that is pulled up, as illustrated by arrow 4, whilst the upper end 1A of the lower tubular is maintained in a fixed position within a previously installed upper well tubular 5 by a radially expanded top anchor assembly 6.

When the expansion cone 2 reaches the top anchor assembly 6 the top anchor assembly needs to be retracted and pulled up by the expansion cone as illustrated in Fig.2 and then upward motion of lower tubular 1 needs to prevented by friction between the outer surface of the lower tubular an the inner surface of the upper tubular 5. Such upward motion or slip may be inhibited by roughening an upper section 8 of the outer surface of the lower well tubular 1 and or providing said upper section with a high friction coating 6.

Optionally an inner surface of the lower tubular 1 is coated with a lubricating coating 7 to lubricate the longitudinal movement of the cone 2 therethrough.

Figure 3 shows that the expansion assembly according to the invention is provided with an

expandable bottom plug 10 suspended at a carrier body 11 below the expansion cone 2. The lower end of the carrier body 11 is provided with a self-releasing joint 12, which disconnects the bottom plug 10 from the carrier body 11 when the bottom plug is pulled into a lower edge 13 of the expanded tubular as illustrated in Fig.4.

Figure 4 shows how the upward force F exerted on the expansion cone 2 is increased by pumping, as illustrated by arrows 14, pressurized fluid through the drill string 3 and a fluid discharge port 15 below the cone 2 into a space 16 between the expansion cone 2 and bottom plug 10 and into the bottom plug 10 to expand the plug 10 and simultaneously pulling the expanded bottom plug 10 into sealing engagement with the lower edge 13 of the expanded well tubular 1 to provide a hydraulic force F_2 that supplements the mechanical force F_1 exerted by the drill string pull on the cone 2. The hydraulic force F_2 and mechanical force F_1 jointly push the cone 2 up through the expanding tubular 1, which is particularly relevant when the upper part of the expanding tubular 1 is expanded within the lower end of a previously installed tubular 5 in which case both tubulars 1 and 5 may be expanded into a sealing engagement as illustrated in Figure 3.

Figures 3 and 4 also show that a top anchor 17 may be expanded against the inner surface of the previously installed tubular 5 to inhibit upward movement of the lower tubular 1 during the expansion process. It will be understood that if the downward force F_2 exerted by the injected pressurized fluid 14 via the bottom plug 10 on the expanded tubular 1 is larger than the upward mechanical force F_1 exerted by drill string pull on the

cone and expanding tubular 1 there is no need to use a top anchor 17.

It will be understood from the foregoing that the method and well tubular according to present invention are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein.

The particular embodiments disclosed above are illustrative only, as the present invention may be modified, combined and/or practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein.

Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below.

It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined and/or modified and all such variations are considered within the scope of the present invention as defined in the accompanying claims.

While any methods, systems and/or products embodying the invention are described in terms of "comprising," "containing," or "including" various described features and/or steps, they can also "consist essentially of" or "consist of" the various described features and steps.

All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number

and range encompassed within the broader range of values.

Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

Moreover, the indefinite articles "a" or "an", as used in the claims, are defined herein to mean one or more than one of the element that it introduces.

If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be cited herein by reference, the definitions that are consistent with this specification should be adopted.

CLAIMS:

1. A method for enhancing the upward force on an expansion cone which is pulled up by a drill string to expand a well tubular, the method comprising:

- inserting the drill string through the unexpanded well tubular;

- connecting the expansion cone to a lower end of the drill string such that the expansion cone engages a lower edge of the tubular;

- connecting a bottom plug to a carrier body that is suspended below the expansion cone;

- lowering the drill string, cone, bottom plug and the unexpanded well tubular into a well until an upper end of the unexpanded well tubular is co-axially arranged within a lower end of a previously installed tubular;

- pulling the expansion cone by drill string pull through the lower edge of the unexpanded well tubular thereby expanding said lower edge;

- inducing the carrier body to pull the bottom plug into the expanded lower edge and to seal off said lower edge;

- inducing a release joint in the carrier body to release the bottom plug from the carrier body;

- further pulling the expansion cone by drill string pull through at least a substantial part of the lower tubular; and

- simultaneously injecting fluid through the interior of the drill string through a fluid discharge opening below the expansion cone into a space between the bottom plug and the expansion cone thereby hydraulically pushing the expansion cone through the lower tubular and increasing the upward force exerted to the expansion cone; and

wherein the expanded lower edge of the lower tubular has an inwardly curved shape and the bottom plug comprises:

- a sealing ring that is configured to sealingly engage said inwardly curved edge; and
- self-locking teeth that snap into the inner surface of said inwardly curved edge when the bottom plug is pulled into the lower edge.

2. The method of claim 1, wherein the fluid injection through the interior of the drill string is continued when the expansion cone is pulled through the upper end of the lower tubular into the lower end of the previously installed upper tubular.

3. The method of claim 1 or 2, wherein the drill string pull and pressure of the fluid injected through the drill string are adjusted on the basis of a monitored longitudinal movement of the expansion cone through the well tubular and a ration between downward hydraulic force exerted on the bottom plug and upward force exerted by the expansion cone on the tubular expanded thereby.

4. The method of any one of claims 1-3, further comprising locking the upper end of the unexpanded well tubular to the previously installed tubular by a top anchor assembly and retracting the top anchor assembly when the expansion cone reaches said upper end.

5. The method of any one of claims 1-4, wherein after expansion of the well tubular the bottom plug is drilled out and the expanded well tubular forms the previously installed well tubular through which a subsequent well tubular is inserted and expanded in accordance with the method according to any one of claims 1-5.

6. The method of claim 5, wherein the process of expanding a subsequent well tubular, drilling out the bottom plug and expanding yet another subsequent well tubular is repeated several times to generate a MOnoDiameter(MOD) wellbore with a substantially constant internal diameter.

7. The method of any one of claims 1-6, wherein the expanded and previously installed well tubulars form part of a casing or liner assembly of a hydrocarbon fluid production well through which, after completion of the well, crude oil, natural gas and/or another hydrocarbon fluid is produced.

8. A tubular expansion assembly for use in the method according to any one of claims 1-7, comprising

- a bottom plug connectable to a carrier body below the expansion cone;
- means for connecting the expansion cone to a lower end of a drill string and to pull the expansion cone by drill string pull into a lower edge of an unexpanded well tubular thereby expanding said lower edge;
- a release joint in the carrier body adapted to release the bottom plug from the carrier body when the bottom plug is pulled into the expanded lower edge of the lower tubular; and
- a fluid discharge opening near a lower end of the expansion cone into for injecting fluid through the drill string and expansion cone into a space between the bottom plug and the expansion cone thereby hydraulically pushing the expansion cone through the expanding well tubular and increasing the upward force exerted the expansion cone; and

wherein the expanded lower edge of the well tubular has an inwardly curved shape and the bottom

plug comprises:

- a sealing ring that is configured to sealingly engage said edge; and

- self-locking teeth that snap into the inner surface of said inwardly curved edge when the bottom plug is pulled into the lower edge.

MOD 2

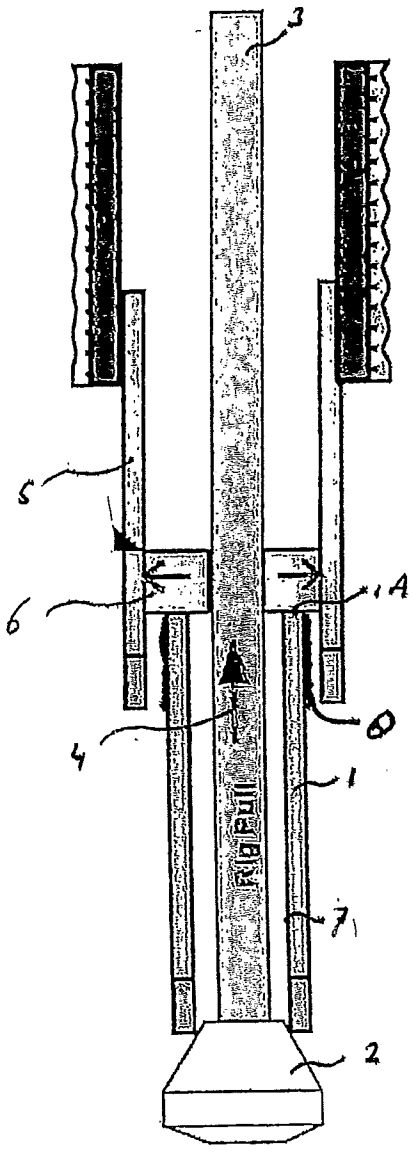


FIG. 1

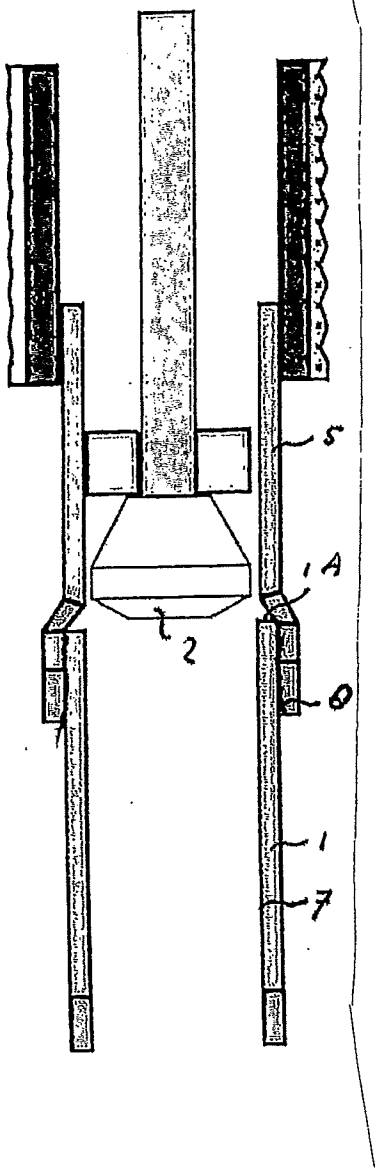


FIG. 2

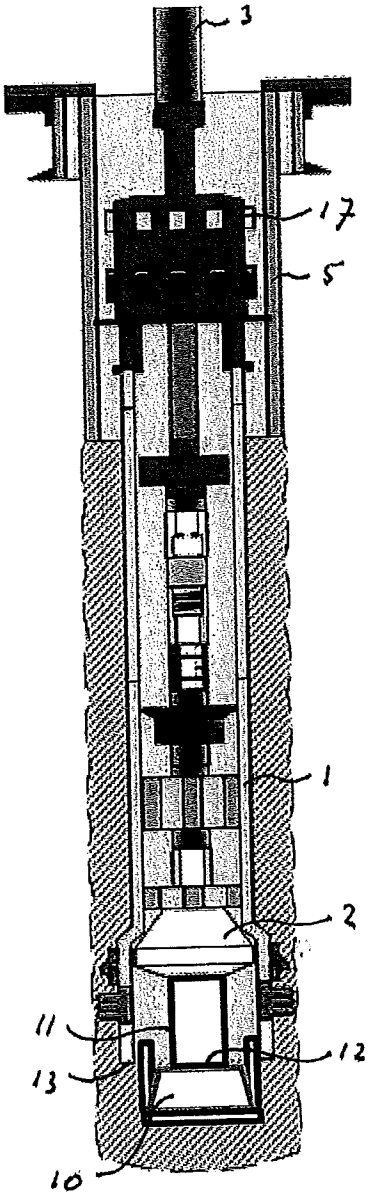


FIG. 3

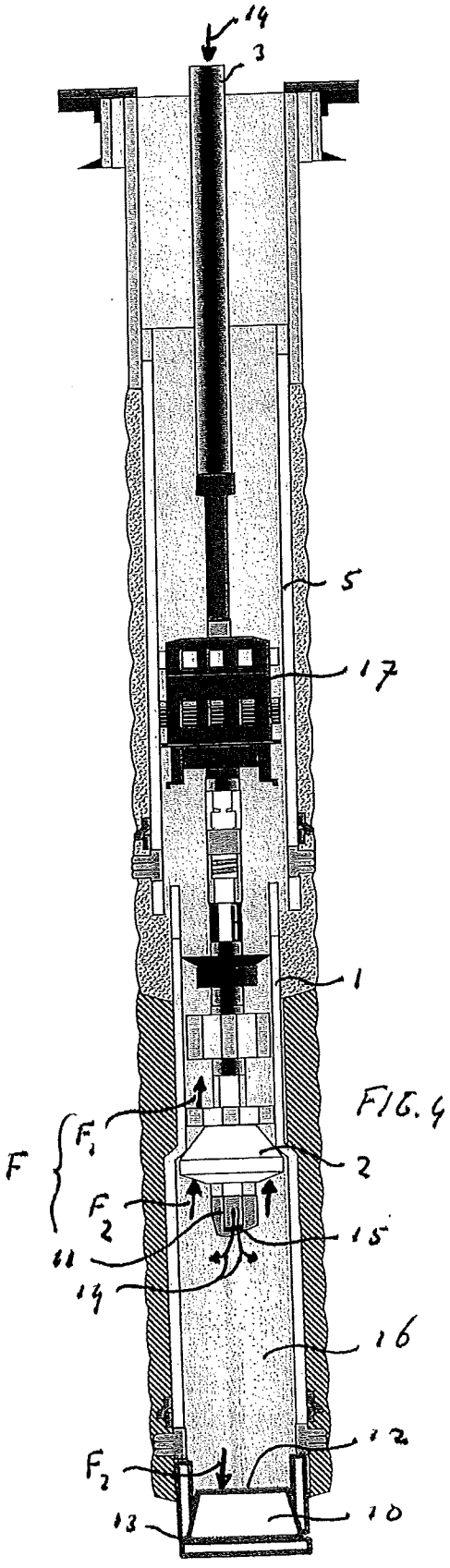


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/064977

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/10
ADD.

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

B. FIELDS SEARCHED

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

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/027200 A2 (ENVENTURE GLOBAL TECHNLOGY [US]; WATSON BROCK WAYNE [US]; BRISCO DAVID) 1 April 2004 (2004-04-01) paragraphs [0013], [0018], [0019], [0020]; figures 1-4	1-8
Y	WO 2004/048750 A2 (SHELL INT RESEARCH [NL]; SHELL CANADA LTD [CA]; BENZIE SCOTT ANTHONY []) 10 June 2004 (2004-06-10) page 8, line 11 - page 9, line 9; figures 4A-4C	1-8
Y	US 6 497 291 B1 (SZARKA DAVID D [US]) 24 December 2002 (2002-12-24) column 3, line 64 - column 4, line 5; figure 8	1-8

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[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent but published on or after the international filing date

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 2016	21/09/2016

Name and mailing address of the ISA/	Authorized officer
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1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/064977

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/251035 A1 (SIMPSON NEIL ANDREW ABERCROMBI [GB] ET AL) 16 December 2004 (2004-12-16) paragraphs [0050] - [0053], [0062], [0065]	1-8
A	WO 2010/059535 A2 (SHELL OIL CO [US]; SHELL INT RESEARCH [NL]; ANDERSON MARK WILSON [NL];) 27 May 2010 (2010-05-27) paragraphs [0015], [0018], [0024]	1-8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/064977

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