



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.05.2011 Bulletin 2011/18

(51) Int Cl.:
E21B 47/022^(2006.01) G01V 3/26^(2006.01)

(21) Application number: **09174667.7**

(22) Date of filing: **30.10.2009**

(84) Designated Contracting States:
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 SE SI SK SM TR
Designated Extension States:
AL BA RS

(72) Inventors:
• **Hallundbaek, Jørgen**
3230, Græsted (DK)
• **Francke, Mathias**
2830, Virum (DK)

(71) Applicant: **Welltec A/S**
3450 Allerød (DK)

(74) Representative: **Hoffmann Dragsted A/S**
Rådhuspladsen 16
1550 Copenhagen V (DK)

(54) **Magnetic ranging system for controlling a drilling process**

(57) The invention relates to a ranging system (1) for controlling a drilling process downhole. The ranging system has a longitudinal direction and comprises a drilling tool (2) for drilling a first borehole (3), the drilling tool having a tool axis (4) and comprising a magnetic field

source (5) generating a magnetic field (6) and having a magnetic field source axis (7). In addition, the ranging system comprises a sensing tool (8) arranged in a second borehole (9) for measuring the magnetic field by means of a sensor unit (10). The magnetic field source axis is substantially parallel to the tool axis.

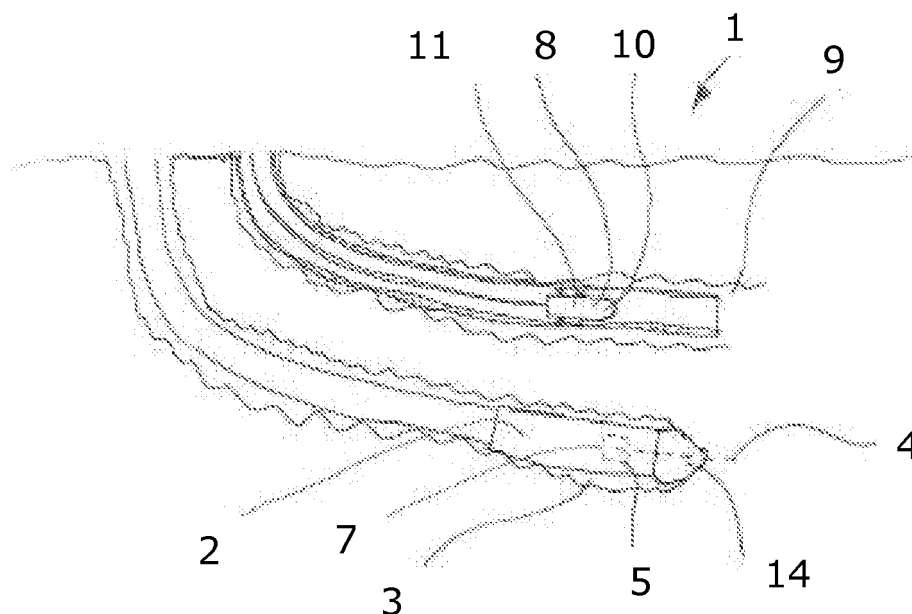


Fig. 1

DescriptionTechnical field

[0001] The present invention relates to a ranging system for controlling a drilling process downhole. The ranging system has a longitudinal direction and comprises a drilling tool for drilling a first borehole, the drilling tool having a tool axis and comprising a magnetic field source generating a magnetic field and having a magnetic field source axis. In addition, the ranging system comprises a sensing tool arranged in a second borehole for measuring the magnetic field by means of a sensor unit.

Background

[0002] When drilling into the formation of an existing well or borehole, it is very important to know the distance to the existing well or borehole while drilling. In some cases, the purpose is to meet the existing well or borehole at a certain position and, in other cases, the purpose is to drill a new borehole at an exact distance to the existing borehole or well with, ensuring that the distance between the two is substantially the same along a certain stretch.

[0003] Known tools comprise different solutions to determine this distance. The tools are used to detect magnetic fields for the purpose of determining the distance. Some tools use current in a wire in the existing borehole while others use a magnet rotating in the drilling head.

[0004] In prior art tools, the magnet in the drilling head needs to rotate in order to be able to detect the magnetic field and thus the distance of the drilling head in relation to a known position. Sometimes, however, the drilling heads stops, making it impossible to detect the magnetic field and thus determine the distance and the drilling direction of the drilling head.

[0005] In regard to tools using current in a wire in a existing borehole, the magnetic field sensing device is positioned in the drilling tool. Since the drilling head of the drilling tool is driven by high-pressurised fluid delivered through the drill string, transmittal of data from the measurements conducted by the sensing device is very difficult. These tools produce waves in the fluid as a means of communicating data, which is a very slow means of communication and may moreover inhibit the drilling process.

Description of the invention

[0006] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art and provide an alternative ranging system able to determine the distance of the drilling tool to an existing well or borehole and even the three-dimensional position and orientation of the drilling head in order to control the drilling tool while drilling.

[0007] It is an additional object to provide an improved ranging system capable of determining the distance to an existing borehole or well, even when the drilling tool or the drilling string is not rotating.

[0008] The above objects, together with numerous other objects, advantages, and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a ranging system for controlling a drilling process downhole, the ranging system having a longitudinal direction and comprising:

- a drilling tool for drilling a first borehole, the drilling tool having a tool axis and comprising a magnetic field source generating a magnetic field (6) and having a magnetic field source axis, and
- a sensing tool arranged in a second borehole for measuring the magnetic field by means of a sensor unit,

wherein the magnetic field source axis is substantially parallel to the tool axis.

[0009] Furthermore, the magnetic field source axis may be substantially coincident with the tool axis.

[0010] In addition, the magnetic field source may be an electromagnet or a permanent magnet.

[0011] The sensor unit may comprise at least two magnetometers measuring the strength of the magnetic field.

[0012] According to one embodiment, the second borehole may be an existing borehole.

[0013] In another embodiment, the sensor unit and/or the drilling tool may be driven by a driving unit.

[0014] The ranging system may further comprise a positioning tool for determining the position of the sensing tool in the second borehole or the position of the drilling tool in the first borehole.

[0015] This sensing tool may also have means for controlling the position of the sensing tool.

[0016] The magnetic field source may have a through hole, allowing fluid for driving a drilling head of the drilling tool to pass through the magnetic field source.

[0017] The ranging system may also comprise a calculation unit for processing strength measurements of the magnetic field measured by the sensing tool.

[0018] In addition, the ranging system may comprise a second drilling tool, and the sensing tool may be arranged in or in connection with the second drilling tool so that the first drilling tool comprises the magnetic field source and the second drilling tool comprises the sensing tool.

[0019] The invention further relates to a method for using the ranging system according to the invention, comprising the steps of:

- drilling the first borehole in one drilling direction,
- inserting the sensing tool into the second borehole,
- measuring the strength of the magnetic field while drilling, and
- calculating a relative position of the drilling tool in relation to the sensing tool while drilling.

[0020] Furthermore, the method may comprise the step of calculating the direction of the drilling head.

[0021] In addition, the method may comprise the step of adjusting the drilling direction based on the calculated relative position of the drilling tool in relation to the sensing tool.

[0022] Finally, the invention relates to any use of the ranging system according to the invention.

Brief description of the drawings

[0023] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which

Fig. 1 shows a cross-sectional view of a ranging system according to the invention arranged in two boreholes downhole,

Fig. 2 shows a partly cross-sectional view of the drilling tool, and

Fig. 3 shows the magnetic field source in perspective.

[0024] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

Detailed description of the invention

[0025] The present invention relates to a ranging system 1 for controlling a drilling process downhole, the ranging system having a longitudinal direction. When drilling a borehole, it is very important to be able to control the drilling direction and to know the orientation of the drilling head to ensure that the borehole is positioned at the predetermined position. When using steam assisted gravity drainage (SAGD) to exploit the oil out of the ground, two boreholes must be drilled having substantially the same distance from each other along almost all of their horizontal extension to ensure that the steam penetrates the formation along almost the entire horizontal extension of the boreholes.

[0026] The ranging system comprises a drilling tool 2 for drilling a new borehole near an existing borehole as shown in Fig. 1. The drilling tool 2 comprises a drilling head 14 for drilling into the formation, and it further comprises a magnetic field source 5 generating a magnetic field 6, which can be detected by the sensing tool 8 in order to determine the distance between the drilling tool 2 and the sensing tool 8 while drilling and to determine the orientation of the drilling head. In order to ensure that the boreholes are drilled in the predetermined position, one of the drilling tool or the sensing tool may also have a positioning tool.

[0027] The ranging system 1 may also be used while drilling two new boreholes. When drilling two boreholes at substantially the same time, the magnetic field source 5 is arranged in one drilling tool 2 and the sensor unit 10 of the sensing tool 8 is arranged in, or in connection with, another drilling tool 2. By processing the measurements conducted by the sensor unit 10, the drilling direction of the drilling tools 2 can be adjusted to ensure that the distance between the two boreholes remains substantially the same. In order to ensure that the boreholes are positioned in the predetermined position, one of the drilling tools 2 may comprise a positioning tool which is able to determine the position of the drilling tools in relation to the starting point or another known position.

[0028] In Figs. 1 and 2, the drilling tool 2 has a tool axis 4 and the magnetic field source 5 has a magnetic field source axis 7 which is substantially coincident with the tool axis 4. When having substantially coincident axes, the magnetic field source 5 and thereby the drilling tool 2 do not have to rotate in order for the sensor unit 10 to conduct measurements. In prior art tools, the conducting of measurements is dependent on the magnetic field source rotating while conducting the measurements.

[0029] When the drilling tool 2 and thereby the drilling process stops, for instance if the drilling tool 2 has broken down,

the sensing tool 8 of the present invention is still capable of sensing the magnetic field 6 and thus of continuing to conduct measurements because the magnetic field source axis 7 is parallel to the tool axis 4.

[0030] The magnetic field source 5 may be any suitable electromagnet or permanent magnet. By using an electromagnet, the north and south poles can switch, and the sensor unit 10 is thereby able to conduct measurements, without interference from the earth magnetic field.

[0031] The sensor unit 10 comprises at least two magnetometers and, in Fig. 1, the sensing tool 8 has three magnetometers, enabling it to calculate an exact position and direction of the drilling head 14 in relation to the sensing tool as well as the direction in which the drilling head 14 is drilling. Each magnetometer measures the strength of the magnetic field 6 as three vectors.

[0032] When the distance is increased or decreased, the drilling direction of the drilling head 14 is adjusted so that the distance becomes the same again, and the drilling direction is then restored.

[0033] In Fig. 1, the sensing tool 8 comprises a driving unit 11 for driving the tool in the longitudinal direction of the second borehole 9. The sensing tool 8 may comprise means 12 for adjusting the position of the sensing tool, enabling the sensing tool to move back and forth in the borehole to be as close as possible to the drilling tool.

[0034] The drilling tool 2 may also comprise a driving tool if the drilling process is not performed by means of coiled tubing or drill pipes.

[0035] In Fig. 1, the first borehole 3 is the borehole to be drilled, and the second borehole 9 is an existing borehole, but may also be a well or another kind of hole in the formation.

[0036] As can be seen in Figs. 2 and 3, the magnetic field source 5 has a through hole 13, allowing high-pressurised fluid running in the centre of the drilling tool for driving the drilling head 14 of the drilling tool 2 to pass through the magnetic field source 5 without being diverted and thereby lose energy. This is especially convenient when the drilling tool 2 is driven by pressurised fluid through drill pipes or coiled tubing.

[0037] In order to calculate the distance between the drilling head 14 and the sensing tool 8 and the orientation of the drilling head based on the measurements, the ranging system 1 comprises a calculation unit 15 for processing strength measurements of the magnetic field 6 measured by the sensor unit 10.

[0038] The position of the magnet, relative to the sensor, r , is calculated as the solution to a minimisation problem. The expression for the field of a magnetic dipole in vector notation is:

$$\mathbf{B} = \frac{\mu}{4\pi} \left(\frac{3(\mathbf{d} \cdot \mathbf{r})\mathbf{r}}{r^5} - \frac{\mathbf{d}}{r^3} \right)$$

where μ is the permeability, $\mathbf{d}$ is the dipole vector, $\mathbf{r}$ is the position vector, and r is the length of the position vector. This can be rearranged into:

$$-\frac{\mu}{4\pi} \mathbf{d} = r^3 \left(\mathbf{B} - \frac{3}{2r^2} (\mathbf{r} \cdot \mathbf{B}) \mathbf{r} \right).$$

[0039] If the field is measured at two different places, the dipole vector can be eliminated from the above equation and the following expression emerges:

$$\|\mathbf{r}\|^3 \left(\mathbf{B} - \frac{3}{2\|\mathbf{r}\|^2} (\mathbf{r} \cdot \mathbf{B}) \mathbf{r} \right) = \|\mathbf{r} + \mathbf{s}\|^3 \left(\mathbf{B} - \frac{3}{2\|\mathbf{r} + \mathbf{s}\|^2} ((\mathbf{r} + \mathbf{s}) \cdot \mathbf{B}) (\mathbf{r} + \mathbf{s}) \right)$$

which has r as the only variable and where $\mathbf{s}$ is the relative position between the two measurements. The position of the magnet with respect to the sensor, $\mathbf{r}$, can be found by minimisation of a residual based on the equation above, the expression thus being:

$$r = \arg \min_r \left\| \|r\|^2 \left(B - \frac{3}{2\|r\|^2} (r \cdot B) r \right) - \|r + s\|^2 \left(B - \frac{3}{2\|r + s\|^2} ((r + s) \cdot B) (r + s) \right) \right\|$$

5

[0040] After finding the relative position of the magnet, the dipole vector can be calculated directly by insertion into equation 1.

10 **[0041]** By fluid or well fluid is meant any kind of fluid which may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By gas is meant any kind of gas composition present in a well, completion, or open hole, and by oil is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil, and water fluids may thus all comprise other elements or substances than gas, oil, and/or water, respectively.

[0042] By a casing is meant any kind of pipe, tubing, tubular, liner, string, etc. used downhole in relation to oil or natural gas production.

15 **[0043]** In the event that the tools are not submersible all the way into the casing, a downhole tractor can be used to push the tools all the way into position in the well. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

20 **[0044]** Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

25 1. A ranging system (1) for controlling a drilling process downhole, the ranging system having a longitudinal direction and comprising:

- 30 - a drilling tool (2) for drilling a first borehole (3), the drilling tool having a tool axis (4) and comprising a magnetic field source (5) generating a magnetic field (6) and having a magnetic field source axis (7), and
- a sensing tool (8) arranged in a second borehole (9) for measuring the magnetic field by means of a sensor unit (10),

wherein the magnetic field source axis is substantially parallel to the tool axis.

35 2. A ranging system according to claim 1, wherein the magnetic field source axis is substantially coincident with the tool axis.

3. A ranging system according to claim 1 or 2, wherein the magnetic field source is an electromagnet or a permanent magnet.

40 4. A ranging system according to any of the preceding claims, wherein the sensor unit comprises at least two magnetometers.

5. A ranging system according to claim 4, wherein the magnetometers measure the strength of the magnetic field.

45 6. A ranging system according to any of the preceding claims, wherein the second borehole is an existing borehole.

7. A ranging system according to any of the preceding claims, wherein the sensor unit and/or the drilling tool is driven by a driving unit (11).

50 8. A ranging system according to any of the preceding claims, further comprising a positioning tool for determining the position of the sensing tool in the second borehole or the position of the drilling tool in the first borehole.

55 9. A ranging system according to any of the preceding claims, wherein the sensing tool has means (12) for controlling the velocity or position of the sensing tool.

10. A ranging system according to any of the preceding claims, wherein the magnetic field source has a through hole (13), allowing fluid for driving a drilling head (14) of the drilling tool to pass through the magnetic field source.

EP 2 317 069 A1

11. A ranging system according to any of the preceding claims, further comprising a calculation unit (15) for processing strength measurements of the magnetic field measured by the sensing tool.

5 12. A ranging system according to any of the preceding claims, further comprising a second drilling tool, the sensing tool being arranged in or in connection with the second drilling tool so that the first drilling tool comprises the magnetic field source and the second drilling tool comprises the sensing tool.

13. A method for using the ranging system according to any of the preceding claims, comprising the steps of:

- 10
- drilling the first borehole in one drilling direction,
 - inserting the sensing tool into the second borehole,
 - measuring the strength of the magnetic field while drilling, and
 - calculating a relative position of the drilling tool in relation to the sensing tool while drilling.

15 14. A method according to claim 13, further comprising the step of:

- adjusting the drilling direction based on the calculated relative position of the drilling tool in relation to the sensing tool.

20 15. Use of the ranging system according to any of the claims 1-12 downhole.

25

30

35

40

45

50

55

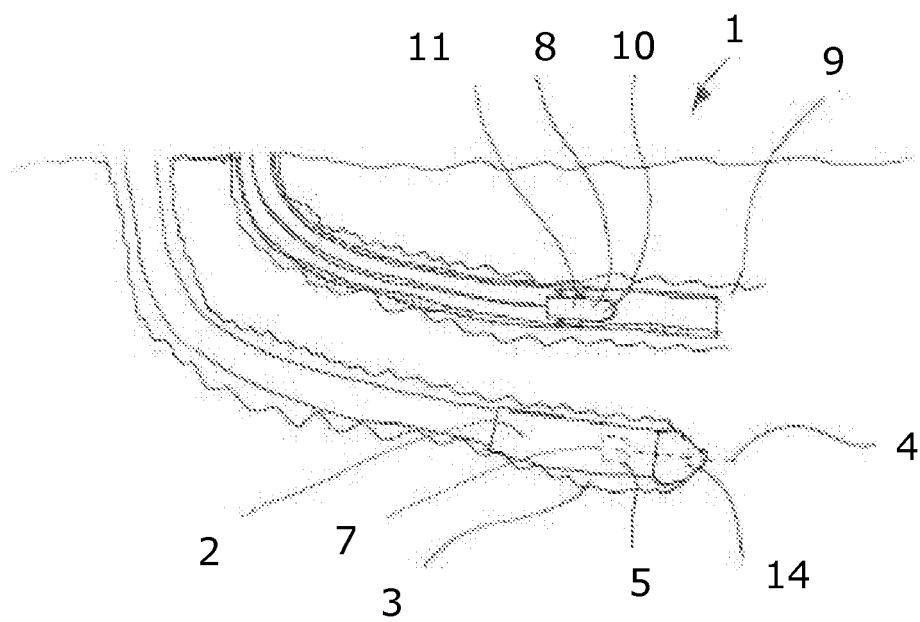


Fig. 1

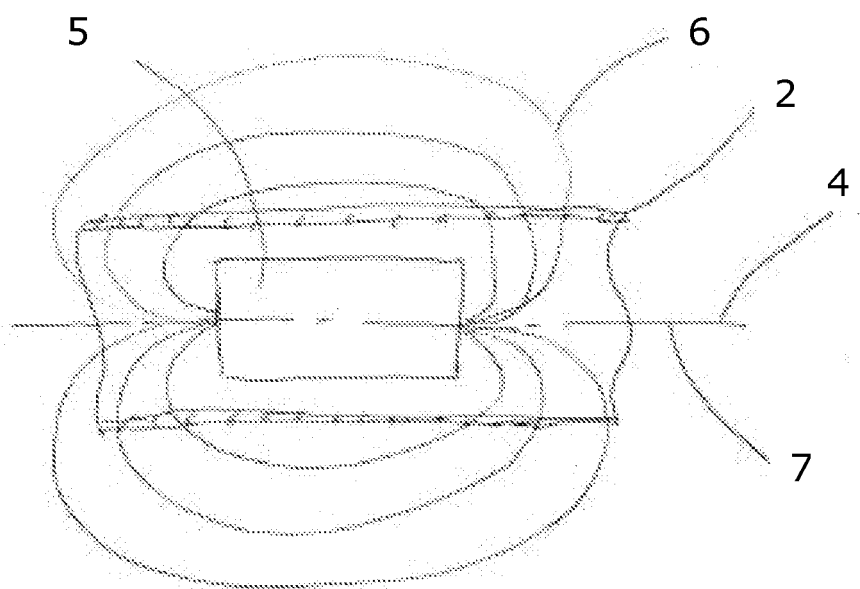


Fig. 2

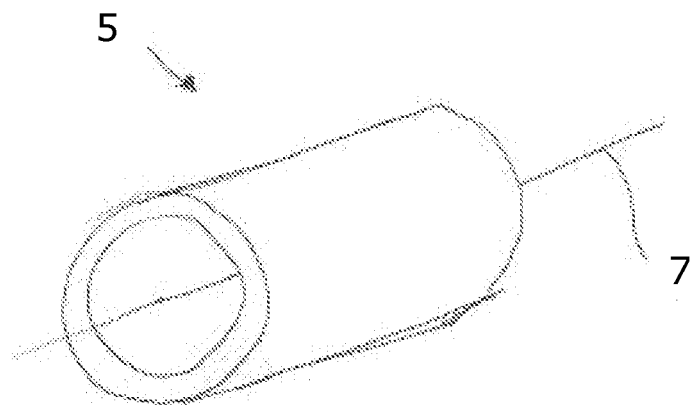


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 09 17 4667

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 2008/041626 A1 (CLARK BRIAN [US]) 21 February 2008 (2008-02-21) * paragraphs [0032] - [0036], [0047] - [0053] *	1-15	INV. E21B47/022 G01V3/26
X	US 2009/260879 A1 (CLARK BRIAN [US] ET AL) 22 October 2009 (2009-10-22) * paragraphs [0033], [0034] *	1-3,6-7, 11,13-15	
A	US 5 589 775 A (KUCKES ARTHUR F [US]) 31 December 1996 (1996-12-31) * column 3, line 7 - column 4, line 15 *	1-15	
A	US 2008/275648 A1 (ILLFELDER HERBERT M J [US]) 6 November 2008 (2008-11-06) * paragraphs [0010] - [0011] *	1-15	
A	US 4 933 640 A (KUCKES ARTHUR F [US]) 12 June 1990 (1990-06-12) * column 5, lines 6-24 * * column 6, lines 7-27 *	1-15	
A	US 2008/018334 A1 (REIDERMAN ARCADY [US]) 24 January 2008 (2008-01-24) * paragraph [0041] *	1-15	E21B G01V
A	US 2009/260878 A1 (MORLEY JAN S [US] ET AL) 22 October 2009 (2009-10-22) * abstract *	1-15	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 19 March 2010	Examiner Garrido Garcia, M
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	

1
EPO FORM 1503 03.92 (P04C01)

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

EP 09 17 4667

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.

19-03-2010

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008041626 A1	21-02-2008	BR PI0703272 A CA 2597581 A1 GB 2441033 A	08-04-2008 16-02-2008 20-02-2008
US 2009260879 A1	22-10-2009	WO 2009128990 A2	22-10-2009
US 5589775 A	31-12-1996	CA 2187487 A1	06-06-1997
US 2008275648 A1	06-11-2008	CA 2686716 A1 EP 2153026 A1 WO 2008137097 A1	13-11-2008 17-02-2010 13-11-2008
US 4933640 A	12-06-1990	NONE	
US 2008018334 A1	24-01-2008	WO 2009029850 A2	05-03-2009
US 2009260878 A1	22-10-2009	WO 2009128989 A1	22-10-2009

EPO FORM P0459

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