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(54) **Monitoring well effluent plunger lift operations**

(57) Well effluent plunger lift operations, wherein a plunger (1) cyclically moves up and down through a hydrocarbon fluid production well to remove solid, viscous and/or liquid well effluent deposits (13) therefrom, are monitored by a fiber optical Distributed Vibration Sensing (DVS) assembly (16,17) which is arranged along at least part of the length of the wellbore(3) and is configured to monitor the movement of the plunger (1), well effluents and/or deposits (13) by monitoring vibrations (40), which may be triggered by thermal events, such as temperature differences between gaseous well effluents, deposits (13) and/or the plunger (1), and/or acoustic events, such as noise resulting from a motion and/or position of the plunger (1) and/or of the deposits (13) within the wellbore (3).

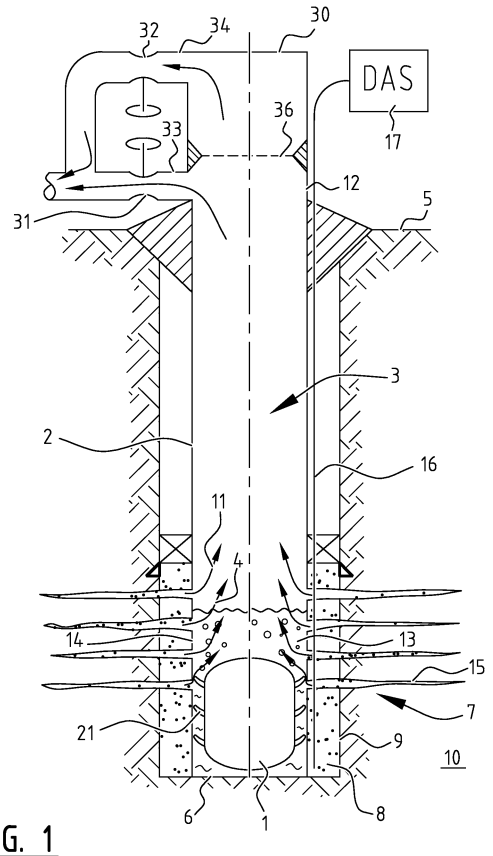

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method and system for monitoring well effluent plunger lift operations, wherein a plunger moves cyclically up and down through an underground wellbore to remove well effluent deposits therefrom.

[0002] Various techniques exist to monitor, control and/or optimize well effluent plunger lift operations.

[0003] A known plunger lift optimizing technique is described in SPE paper 71083 "Plunger-lift optimization by monitoring and analyzing well high frequency acoustic signals, tubing pressure and casing pressure", which paper was presented in May 2001 by J McCoy and L Rowlan at the SPE Rocky Mountain Petroleum Conference in Keystone, Colorado, USA.

[0004] US patent 6,634,426 discloses a method for optimizing plunger lift operations by "Counting Collars", wherein acoustic noise generated when the plunger passes an irregular tubing joint is monitored using an acoustic sensor in the wellhead assembly, which sensor also counts the number of joints passed by the plunger to determine the depth of the plunger in the well. This known technique requires the presence of irregular tubing joints and cannot be used in wells equipped with coiled production tubing assemblies.

[0005] US patent application 20120323493 discloses the use of magnetic detectors in a wellhead assembly for detecting plunger arrival.

[0006] US patent application 20120193091 discloses the use of a sound-generating plunger to monitor plunger velocity in the wellbore.

[0007] Other techniques for monitoring and optimizing well effluent plunger lift operations are disclosed in US patent applications 20080164024 , 20040129428, 20020074118, 20070261845, 20090200020 and 20080202746 .

[0008] The known techniques for monitoring and optimizing well effluent plunger lift operations require use of complex downhole monitoring equipment with limited and rather inaccurate plunger detection ranges and which do not provide accurate information about the location of the plunger at any depth in the well and/or the requirement and/or efficiency of the removal of liquid and/or solid deposits by the plunger.

[0009] Thus, there is a need for an improved technique for monitoring and/or optimizing well effluent lift operations that provides accurate information about the location of the plunger at substantially any depth in the well, even if the well is equipped with a coiled production tubing,

[0010] Furthermore there is a need for an improved technique to accurately monitor the requirement and/or efficiency of the removal of liquid, viscous and/or solid deposits by well effluent plunger lift operations.

SUMMARY OF THE INVENTION

[0011] In accordance with the invention there is provided a method for monitoring well effluent plunger lift operations wherein well effluent deposits are removed from a hydrocarbon fluid production well by a plunger that cyclically moves up and down through the wellbore, the method comprising:

- arranging a fiber optical Distributed Vibration Sensing(DVS) assembly along at least part of the length of the wellbore; and
- inducing the fiber optical DVS assembly to record vibrations indicative of at least one of the following vibration triggering events:

    a) a motion and/or position of the plunger within the wellbore;
    b) a motion of the plunger through a fluid interface and/or along an irregular surface, such as a curvature and/or a joint between a pair of adjacent well tubulars;
    c) an approach or arrival of the plunger at a bottom or a wellhead of the wellbore;
    d) a motion of the hydrocarbon fluid and/or well effluent deposits through the wellbore;
    e) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in the wellbore;
    f) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in a well effluent inflow region at the bottom of the wellbore;
    g) a motion of the hydrocarbon fluid through an annular space between the plunger and the wellbore;
    h) a motion of the hydrocarbon fluid passing from the annular space between the plunger and the wellbore through an accumulation of the well effluent deposits above the plunger;
    i) a variation and/or interruption of motion of the hydrocarbon fluid and/or of the well effluent deposits in the annular space and/or other parts of the well;and/or j) a temperature difference between the well effluent deposits, the produced hydrocarbon fluid and/or the plunger.

[0012] The method may further comprise optimizing the plunger lift operation and associated production of hydrocarbon fluid and well deposits in response to the acoustic signals recorded by the fiber optical Distributed Vibration Sensing (DVS)assembly relating to at least one of the vibration triggering events a)-j).

[0013] The hydrocarbon production well may be a natural gas production well and the fiber optical Distributed Vibration Sensing(DVS) assembly may comprise an optical fiber which extends along at least a substantial part of length of the wellbore, and is in acoustic contact with,

an outer surface of a production tubing through which a multiphase well effluent mixture comprising natural gas and at least some liquid, viscous and/or solid well effluent components, such as water, condensates, wax, asphaltenes, precipitates and/or solid particles, are produced, and the plunger moves cyclically up and down through the production tubing to remove any well effluent deposits comprising the liquid, viscous and/or solid components from the interior of the production tubing.

[0014] Optionally, the production tubing comprises a permeable inflow region above a bottom of the well and the wellhead comprises a lubricator located above a well effluent outlet provided with a production choke and the plunger is cyclically moved up and down between the bottom of the well and the lubricator.

[0015] In such case the cyclic motion of the plunger may comprise the following phases:

- an unloading phase during which the plunger is pushed in upward direction through the production tubing towards the wellhead by the pressure of the well effluents in the section of the production tubing below the plunger;
- an afterflow phase during which the plunger is located in the lubricator above the well effluent outlet, while well effluents are produced through the well effluent outlet; and
- a shut-in phase during which production of well effluents is interrupted and the plunger is released from the lubricator and is allowed to descend through the production tubing to the bottom of the well.

[0016] During at least part of the unloading phase the production of well effluents may be controlled by varying the opening of the production choke in response to information provided by the DVS assembly about the location and upward velocity of the plunger through the production tubing.

[0017] The fiber optical Distributed Vibration Sensing (DVS) assembly may be configured to monitor a location of a liquid-gas interface above a deposition of well effluents in the production tubing by monitoring noise associated by migration of the plunger and/or natural gas through the deposition and/or any temperature differences between the plunger, the natural gas and the deposition and the thus monitored location of the liquid-gas interface may be subsequently used as an input to a production choke control system to control the position of the production choke and the position and movement of the plunger within the production tubing, and/or to optimize the liquid unloading phase of the well, and/or a duration of the after-flow phase during which the plunger is arranged in a surface lubricator in the wellhead above the production choke and and/or a duration of the shut-in phase during which the production choke is closed and the plunger falls from the wellhead to a bottom of the well.

[0018] In accordance with the invention there is further provided a system for monitoring well effluent plunger lift operations wherein well effluent deposits are removed from a hydrocarbon fluid production well by a plunger that cyclically moves up and down through the wellbore, the system comprising:

- a fiber optical Distributed Vibration Sensing(DVS) assembly arranged along at least part of the length of the wellbore, which fiber optical DVS assembly is configured to record vibrations indicative of at least one of the following vibration triggering events:

  a) a motion and/or position of the plunger within the wellbore;
  b) a motion of the plunger along an irregular surface, such as a curvature and/or a joint between a pair of adjacent well tubulars;
  c) an approach or arrival of the plunger at a bottom or a wellhead of the wellbore;
  d) a motion of the hydrocarbon fluid and/or well effluent deposits through the wellbore;
  e) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in the wellbore;
  f) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in a well effluent inflow region at the bottom of the wellbore;
  g) a motion of the hydrocarbon fluid through an annular space between the plunger and the wellbore;
  h) a motion of the hydrocarbon fluid passing from the annular space between the plunger and the wellbore through an accumulation of the well effluent deposits above the plunger;
  i) a variation and/or interruption of motion of the hydrocarbon fluid and/or of the well effluent deposits in the annular space and/or other parts of the well;and/or j) a temperature difference between the well effluent deposits, the produced hydrocarbon fluid and/or the plunger.

[0019] The system may further comprise means for optimizing the plunger lift operation and associated production of hydrocarbon fluid and well deposits in response to the vibrations recorded by the fiber optical Distributed Vibration Sensing (DVS)assembly relating to at least one of the vibration triggering events a)-j).

[0020] Furthermore, the plunger may comprise an acoustic source that is configured to transmit an acoustic noise that is detectable by the fiber optical Distributed Vibration Sensing (DVS) assembly.

[0021] The Distributed Vibration Sensing (DVS) assembly may be configured to monitor acoustic events with frequencies of less than 50 Hz, optionally frequencies of less than 20 Hz, in particular frequencies below 10 Hz.

[0022] These and other features, embodiments and advantages of the method and/or system 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.

[0023] Similar reference numerals in different figures denote the same or similar objects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Figure 1 is a schematic longitudinal sectional view of a wet gas production well in which a well cleaning plunger has been lowered to the bottom of the well;
Figure 2 is a schematic longitudinal sectional view of the wet gas production well of Figure 1 during an unloading phase wherein the well cleaning plunger is pushed towards the wellhead and thereby lifts solid and liquid well deposits from the well;
Figure 3 is a schematic longitudinal sectional view of the wet gas production well of Figures 1 and 2 during an afterflow phase wherein the well cleaning plunger is located in a lubricator within the wellhead assembly; and
Figure 4 is a schematic longitudinal sectional view of the wet gas production well of Figures 1-3 during a shut-in phase wherein production is interrupted to allow the cleaning plunger to descend back from the wellhead to the bottom of the well.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

[0025] Figures 1-4 show a hydrocarbon fluid production well that is cleaned by a plunger lift well cleaning operation wherein a plunger 1 is moved up and down through a production tubing 2 within the wellbore 3 to lift liquid and solid deposits 4 to hydrocarbon fluid processing facilities (not shown) at the earth surface 5.

[0026] In Figure 1 the plunger 1 is located at the bottom 6 of the wellbore 3 below a perforated well effluent influx zone 7 in which the perforations 15 have been shot through the production tubing 2, and through the gravel pack 8, the well casing or liner 9 and the surrounding hydrocarbon bearing formation 10 to permit influx, as illustrated by arrows 11 of a multiphase mixture of well effluents comprising natural gas and solid and/or liquid components, such as water, condensates, wax, asphaltenes and/or other precipitates and/or formation particles, such as rock, sand and/or clay particles, flow into the production tubing 2.

[0027] At least a fraction of the solid and/or liquid components may be dragged by the flux of natural gas illustrated by arrows 11 to the wellhead 12 and at least another fraction of the solid and/or liquid components may accumulate in a gradually increasing pool 13 of well deposits through which natural gas bubbles 14 travel in upward direction as illustrated by arrows 11.

[0028] A fiber optical Distributed Vibration Sensing (DVS) cable 16 is bonded to the outer surface of the production tubing 2 and is connected to a DVS interrogation assembly 17, which is configured to monitor vibrations resulting from acoustic and/or thermal events within the wellbore 3, such as the noise generated by the flux of natural gas bubbles 14 through the pool 13 of well deposits.

[0029] If the DVS interrogation assembly 17 indicates that the level of the pool 13 of well deposit reaches a level at which production of natural gas is inhibited then the production choke 31 may be fully opened so that the well effluents drag the plunger 1 to surface.

[0030] Figure 2 shows the well onloading phase during which the thus released plunger 1 is further pushed up, as illustrated by arrow 20, by the flux of well effluents 11 through the production tubing 2 and thereby also pushes the pool 13 of well deposits up towards the wellhead 12.

[0031] The plunger 1 may or may not be equipped with fins 21 that may not fully seal off the annular space between the plunger 1 and the inner surface of the production tubing 2, so that a residual fraction of the produced natural gas still migrates as gas bubbles 14 through the annular space and the pool of well deposits 13 above the plunger, thereby allowing the DVS interrogation assembly 17 to monitor the upward migration and size of the pool of well deposits 13 as it is pushed by the plunger 1 towards the wellhead 12.

[0032] The DVS interrogation assembly 17 is also configured to monitor acoustic events associated with the upward movement of the plunger 1 through the production tubing 2, such as the scratching of the fins 21 and/or other parts of the outer surface of the plunger 1 along the inner surface and/or tubing joints of the production tubing 2, and/or whistling noise generated by the residual fraction of natural gas flowing through any remaining gaps between the fins 21 and/or other parts of the outer surface of the plunger 1 and the inner surface of the production tubing 2.

[0033] Figure 3 shows the well during an afterflow phase during which the plunger 1 is located within a lubricator 30 in the wellhead assembly 12.

When the plunger 1 reaches the wellhead assembly 12 there is the risk that its upward velocity is too high and that the plunger 1 and wellhead assembly 12 are damaged by the impact of the collision between the plunger 1 and wellhead assembly 12.

[0034] To avoid such collision and associated damage the DVS interrogation assembly 17 monitors the position and upward velocity of the plunger 1 and induces, if the upward velocity of the plunger is too high when it approaches the wellhead assembly 12, a gradual closing of the production choke 31 and/or bypass valve 32 at the wellhead outlet conduits 33 and 34, thereby reducing the flux of well effluents 35 and the associated upward velocity of the plunger 1.

[0035] Once the plunger 1 is located within the lubricator 30 in the wellhead assembly 12 the bypass valve 32 and a lubricator valve 36 are closed, so that the lubricator 30 is isolated from the wellbore 3 and may be opened to retrieve the plunger 1 from the well for maintenance, inspection or replacement wherein the plunger 1 may be cleaned, worn fins 21 may be replaced and/or a spring and/or bladder actuated plunger release mechanism may be re-activated.

[0036] During the afterflow phase production of well effluents is continued and a pool 13 of well deposits starts again to accumulate at the bottom 6 of the well. When the upper level 37 of the pool 13 reaches the lower perforations 15 gas bubbles will migrate through the pool 13, and the associated noise will be detected by the DVS interrogation assembly 17.

[0037] After such detection the production choke 31 is closed and the lubricator valve 36 is opened to allow the plunger 1 to be lowered by gravity forces to the bottom 6 of the wellbore 3 as illustrated in Figure 4.

[0038] When the plunger 1 descends through the wellbore 3 noise 40 will be generated by friction between the fins 21 and/or other parts of the outer surface of the plunger 1 and the inner surface of the tubing 3 tubing joints and/or perforations 15. This noise 40 is monitored by the fiber optical DVS cable 16 and associated DVS interrogation assembly 17, so that the position and downward motion of the plunger 1 are accurately monitored. Once the DVS interrogation assembly 17 indicates that the plunger 1 reaches the bottom 6 of the wellbore 3 the production choke 31 or bypass valve 32 is opened so that well effluent production is re-started and the produced well effluents drag the plunger 1 to surface.

[0039] The plunger 1 may be equipped with an acoustic source, such as a whistle and/or battery powered microphone that transmits a noise 40 that can be accurately monitored by the fiber optical DVS cable 16 and associated DVS interrogation assembly 17.

[0040] It will be understood that a skilled person may identify other features, embodiments and advantages of the method and system according to the present invention that are not identified in this specification. For example, the DVS cable may be embedded in a cement annulus surrounding the well casing or liner 9 instead of an annular space between the production tubing 2 and well casing or liner 9.

[0041] It will also be understood that a skilled person may make modifications to the fiber optical DVS plunger lift monitoring method and system according to the invention that do not go beyond the inventive concept described herein and that the non-limiting examples described with reference to the accompanying drawings therefore do not limit the scope of the accompanying claims.

Claims

1. A method for monitoring well effluent plunger lift operations wherein well effluent deposits are removed from a hydrocarbon fluid production well by a plunger that cyclically moves up and down through the wellbore, the method comprising:

   - arranging a fiber optical Distributed Vibration Sensing(DVS) assembly along at least part of the length of the wellbore; and
   - inducing the fiber optical DVS assembly to record vibrations indicative of at least one of the following vibration triggering events:

     a) a motion and/or position of the plunger within the wellbore;
     b) a motion of the plunger along an irregular surface, such as a curvature and/or a joint between a pair of adjacent well tubulars;
     c) an approach or arrival of the plunger at a bottom or a wellhead of the wellbore;
     d) a motion of the hydrocarbon fluid and/or well effluent deposits through the wellbore;
     e) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in the wellbore;
     f) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in a well effluent inflow region at the bottom of the wellbore;
     g) a motion of the hydrocarbon fluid through an annular space between the plunger and the wellbore;
     h) a motion of the hydrocarbon fluid passing from the annular space between the plunger and the wellbore through an accumulation of the well effluent deposits above the plunger;
     i) a variation and/or interruption of motion of the hydrocarbon fluid and/or of the well effluent deposits in the annular space and/or other parts of the well;and/or
     j) a temperature difference between the well effluent deposits, the produced hydrocarbon fluid and/or the plunger.

2. The method of claim 1, wherein the method further comprises optimizing the plunger lift operation and associated production of hydrocarbon fluid and well deposits in response to the vibrations recorded by the fiber optical Distributed Vibration Sensing (DVS)assembly relating to at least one of the vibration triggering events (a)-(j).

3. The method of claim 2, wherein the hydrocarbon production well is a natural gas production well and the fiber optical Distributed Vibration Sensing(DVS) as-

sembly comprises an optical fiber which extends along at least a substantial part of length of the wellbore, and is in acoustic contact with, an outer surface of a production tubing through which a multiphase well effluent mixture comprising natural gas and at least some liquid, viscous and/or solid well effluent components, such as water, condensates, wax, asphaltenes, precipitates and/or solid particles, are produced, and the plunger moves cyclically up and down through the production tubing to remove any well effluent deposits comprising the liquid, viscous and/or solid components from the interior of the production tubing.

4. The method of claim 3, wherein the production tubing comprises a permeable inflow region above a bottom of the well and the wellhead comprises a lubricator located above a well effluent outlet provided with a production choke and the plunger is cyclically moved up and down between the bottom of the well and the lubricator.

5. The method of claim 4, wherein the cyclic motion of the plunger comprises the following phases:

- an unloading phase during which the plunger is pushed in upward direction through the production tubing towards the wellhead by the pressure of the well effluents in the section of the production tubing below the plunger;
- an afterflow phase during which the plunger is located in the lubricator above the well effluent outlet, while well effluents are produced through the well effluent outlet; and
- a shut-in phase during which production of well effluents is interrupted and the plunger is released from the lubricator and is allowed to descend through the production tubing to the bottom of the well.

6. The method of claim 5, wherein at least during at least part of the unloading phase the production of well effluents is controlled by varying the opening of the production choke in response to information provided by the DVS assembly about the location and upward velocity of the plunger through the production tubing.

7. The method of claim 6, wherein the production choke is gradually at least partially closed if the DVS assembly indicates that the plunger reaches an upper part of the production tubing in the vicinity of the wellhead, thereby reducing the velocity of the plunger as it enters the wellhead and lubricator.

8. The method of claim 7, wherein the fiber optical Distributed Vibration Sensing (DVS) assembly is configured to monitor a location of a liquid-gas interface above a deposition of well effluents in the production tubing by monitoring noise associated by migration of natural gas through the deposition and the thus monitored location of the liquid-gas interface is subsequently used as an input to a production choke control system to control the position of the production choke and the position and movement of the plunger within the production tubing, and/or to optimize the liquid unloading phase of the well, and/or a duration of the after-flow phase during which the plunger is arranged in a surface lubricator in the wellhead above the production choke and and/or a duration of the shut-in phase during which the production choke is closed and the plunger is lowered from the wellhead to a bottom of the well.

9. The method of any one of claims 1-8, wherein the plunger comprises an acoustic source that transmits an acoustic noise that is detected by the fiber optical Distributed Vibration Sensing (DVS) assembly.

10. A system for monitoring well effluent plunger lift operations wherein well effluent deposits are removed from a hydrocarbon fluid production well by a plunger that cyclically moves up and down through the wellbore, the system comprising:

- a fiber optical Distributed Vibration Sensing(DVS) assembly arranged along at least part of the length of the wellbore, which fiber optical DVAS assembly is configured to record vibrations indicative of at least one of the following vibration triggering events:

  a) a motion and/or position of the plunger within the wellbore;
  b) a motion of the plunger along an irregular surface, such as a curvature and/or a joint between a pair of adjacent well tubulars;
  c) an approach or arrival of the plunger at a bottom or a wellhead of the wellbore;
  d) a motion of the hydrocarbon fluid and/or well effluent deposits through the wellbore;
  e) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in the wellbore;
  f) a motion of the hydrocarbon fluid through an accumulation of the well effluent deposits in a well effluent inflow region at the bottom of the wellbore;
  g) a motion of the hydrocarbon fluid through an annular space between the plunger and the wellbore;
  h) a motion of the hydrocarbon fluid passing from the annular space between the plunger and the wellbore through an accumulation of the well effluent deposits above the plunger;

i) a variation and/or interruption of motion of the hydrocarbon fluid and/or of the well effluent deposits in the annular space and/or other parts of the well;and/or
j) a temperature difference between the well effluent deposits, the produced hydrocarbon fluid and/or the plunger.

11. The system of claim 10, wherein the system further comprises means for optimizing the plunger lift operation and associated production of hydrocarbon fluid and well deposits in response to the acoustic signals recorded by the fiber optical Distributed Vibration Sensing (DVS)assembly relating to at least one of the acoustic signal triggering events (a)-(j).

12. The system of claim 11, wherein the hydrocarbon production well is a natural gas production well and the fiber optical Distributed Vibration Sensing(DVS) assembly comprises an optical fiber which extends along at least a substantial part of length of the wellbore, and is in acoustic contact with, an outer surface of a production tubing through which a multiphase well effluent mixture comprising natural gas and at least some liquid, viscous and/or solid well effluent components, such as water, condensates, wax, asphaltenes, precipitates and/or solid particles, are produced, and the plunger moves cyclically up and down through the production tubing to remove any well effluent deposits comprising the liquid, viscous and/or solid components from the interior of the production tubing.

13. The system of any one of claims 10-12, wherein the plunger comprises an acoustic source that is configured to transmit an acoustic noise that is detectable by the fiber optical Distributed Vibration Sensing (DVS) assembly.

14. The system of any one of claims 10-13, wherein the Distributed Vibration Sensing (DVS) assembly is configured to monitor acoustic events with frequencies of less than 50 Hz, optionally frequencies of less than 20 Hz.

15. The system of claim 14, wherein the DVS is configured to monitor acoustic events with frequencies below 10 Hz.

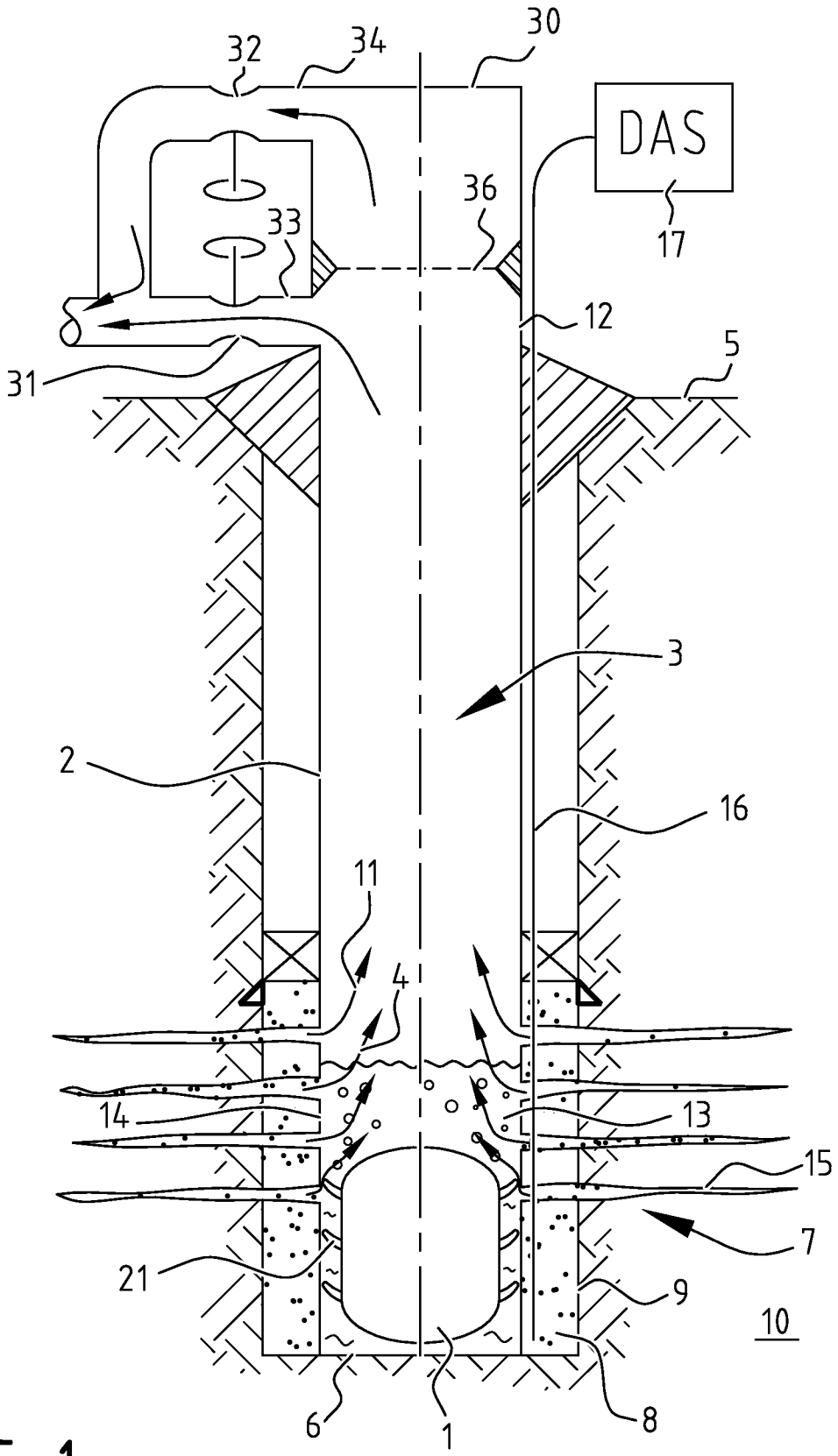

FIG. 1

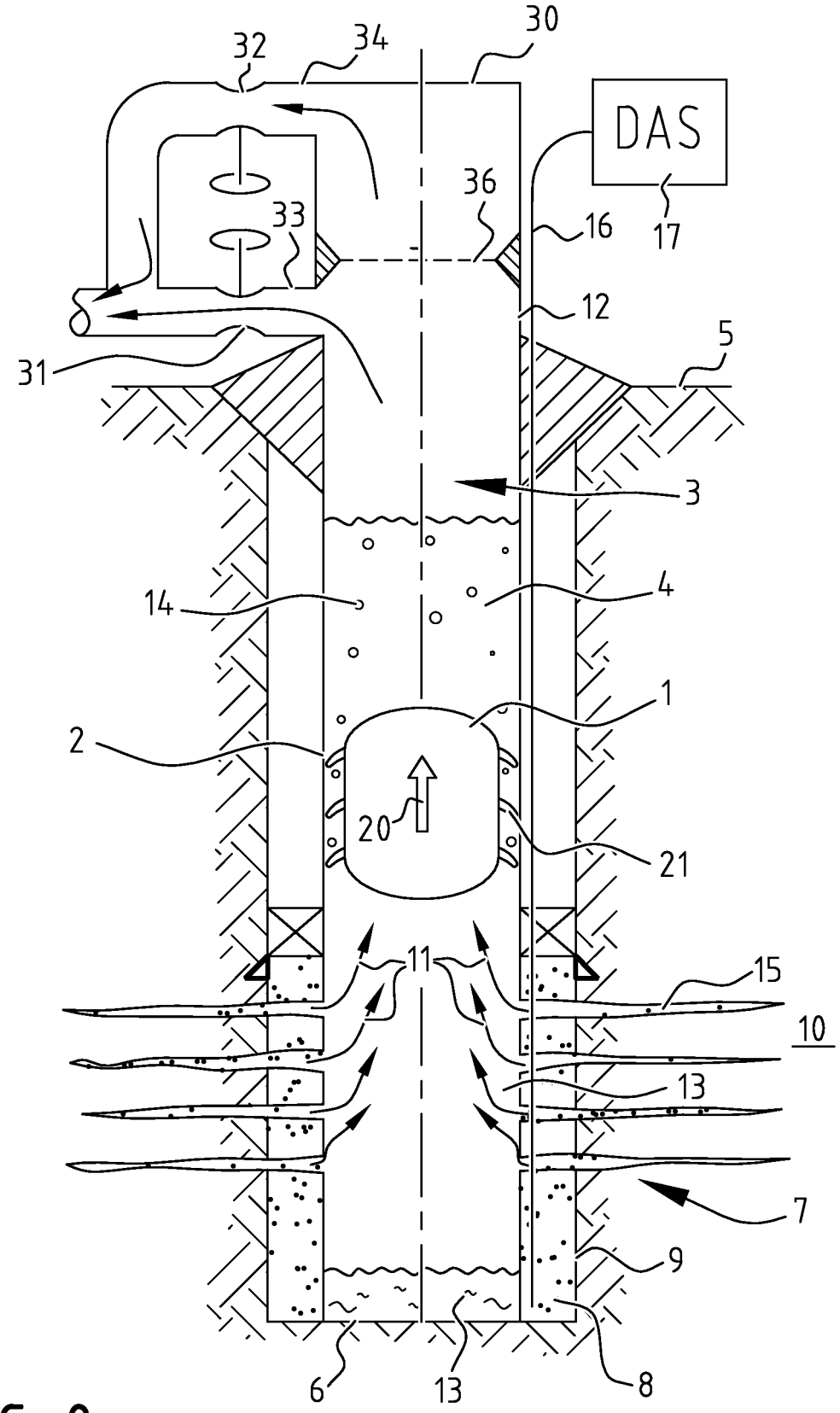

FIG. 2

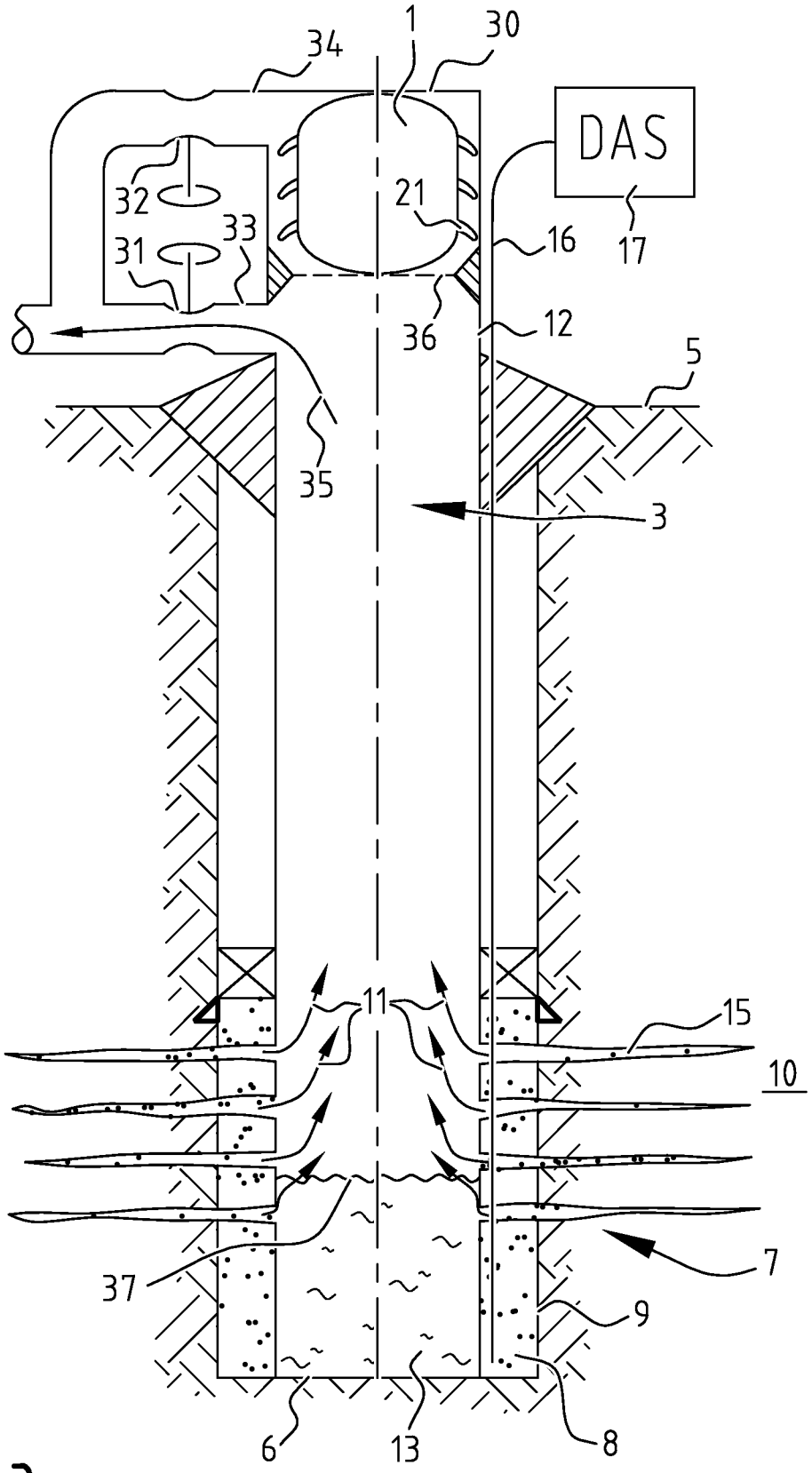

FIG. 3

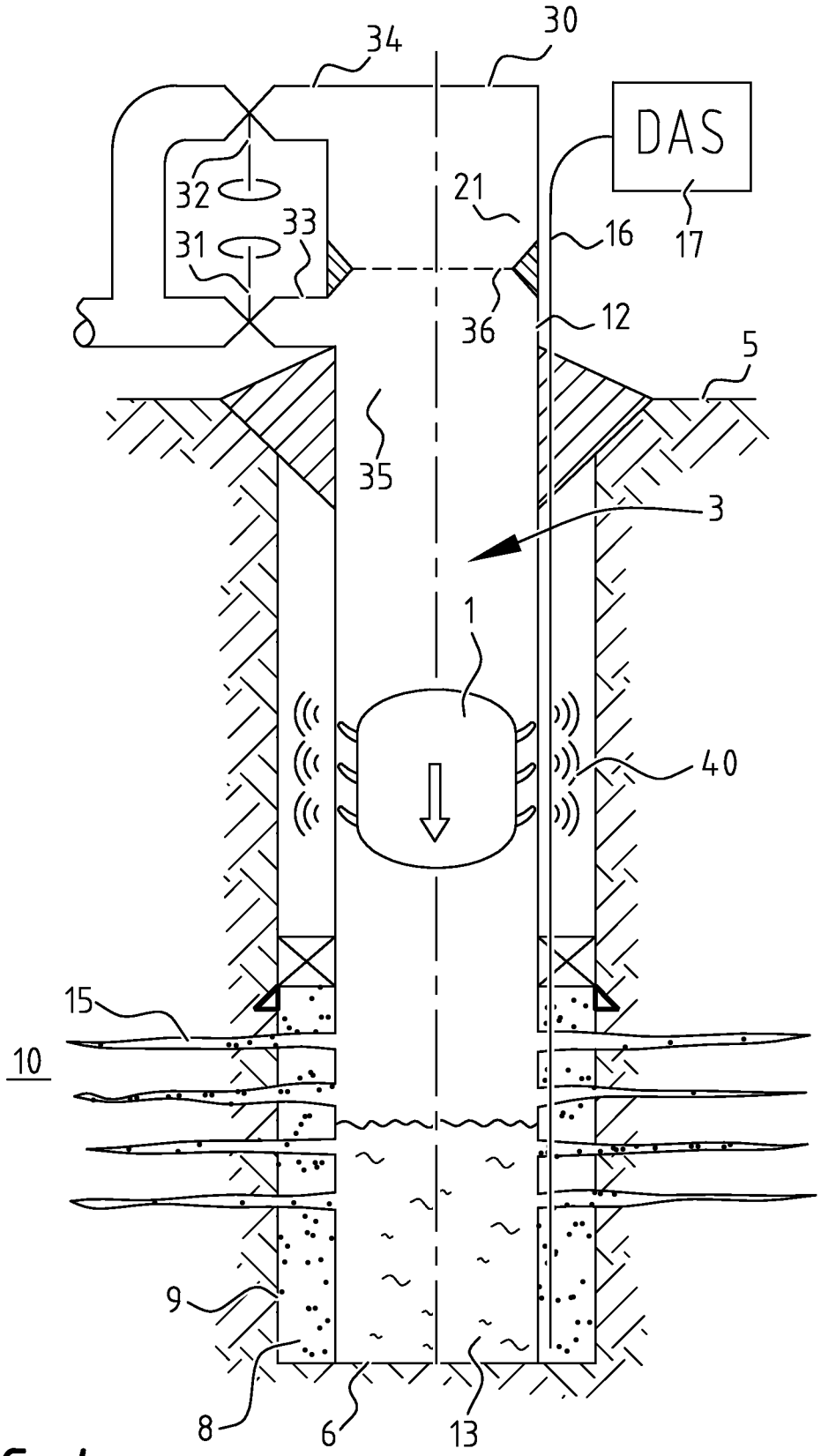

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 6297

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 2011/088462 A1 (SAMSON ETIENNE M [US] ET AL) 21 April 2011 (2011-04-21) * figures 1-2 * * paragraphs [0001] - [0002], [0017] - [0018], [0020] - [0022], [0024], [0030] - [0031] * * paragraphs [0034], [0036] - [0039], [0041] - [0042], [0044] - [0045], [0052], [0059] * * paragraphs [0062], [0066], [0073], [0089], [0094], [0099] * -----	1-15	INV. E21B47/00 E21B47/12 ADD. E21B43/12 E21B47/10
A	Halliburton: "Fiberwatch services", , 31 December 2012 (2012-12-31), pages 1-2, XP007922646, Retrieved from the Internet: URL:http://www.halliburton.com/public/pe/contents/Data_Sheets/web/H/H07778.pdf [retrieved on 2014-04-15] * page 1, column 1, lines 1-5 * * page 2, column 1, lines 12-15 * -----	1,10	
A	US 2012/092960 A1 (GASTON GRAHAM [US] ET AL) 19 April 2012 (2012-04-19) * figure 1 * * paragraphs [0003], [0011], [0013], [0023] - [0026], [0052] - [0053] * -----	1,10,14, 15	
	-/--		

TECHNICAL FIELDS SEARCHED (IPC)
E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 April 2014	Brassart, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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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	Halliburton: "Artificial Lift systems and the 5P's", , 14 November 2012 (2012-11-14), pages 1-6, XP007922645, Retrieved from the Internet: URL:http://halliburtonblog.com/artificial-lift-and-the-5-ps/ [retrieved on 2014-04-15] * page 3 *	1,10	
A	US 2002/084071 A1 (MCCOY JAMES N [US] ET AL) 4 July 2002 (2002-07-04) * figures 1,14,40 * * paragraphs [0019], [0020], [0022], [0047], [0073], [0099] - [0100], [0111], [0148] *	1,3,10, 12	
A	US 2013/167628 A1 (HULL JOHN [CA] ET AL) 4 July 2013 (2013-07-04) * paragraphs [0002], [0004], [0048] - [0053], [0100] - [0107], [0134], [0137] - [0143] *	1,10	TECHNICAL FIELDS SEARCHED (IPC)
A	US 2010/207019 A1 (HARTOG ARTHUR H [GB] ET AL) 19 August 2010 (2010-08-19) * figures 1-2 * * paragraphs [0002], [0005], [0016], [0024] *	1,8,10	
A,D	US 2012/193091 A1 (BENDER ROBERT E [US] ET AL) 2 August 2012 (2012-08-02) * figure 1 * * paragraphs [0001], [0013], [0040] - [0042] *	2,7,9,13	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 April 2014	Brassart, P

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 6297

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 2009/200020 A1 (HEARN WILLIAM [US]) 13 August 2009 (2009-08-13) * figures 1-2 * * paragraphs [0003], [0027], [0030] - [0032], [0034] - [0036] * -----	4,5	
A,D	US 2007/261845 A1 (WHITE ARTHUR F [US] ET AL) 15 November 2007 (2007-11-15) * figure 1 * * paragraphs [0004], [0010], [0036], [0039] * -----	7	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	16 April 2014	Brassart, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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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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16-04-2014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011088462 A1	21-04-2011	AU 2010309577 A1	24-05-2012
		CA 2778086 A1	28-04-2011
		EP 2491357 A2	29-08-2012
		US 2011088462 A1	21-04-2011
		US 2013091942 A1	18-04-2013
		WO 2011048373 A2	28-04-2011
US 2012092960 A1	19-04-2012	CA 2815204 A1	26-04-2012
		EP 2630519 A2	28-08-2013
		US 2012092960 A1	19-04-2012
		WO 2012054635 A2	26-04-2012
US 2002084071 A1	04-07-2002	NONE	
US 2013167628 A1	04-07-2013	NONE	
US 2010207019 A1	19-08-2010	NONE	
US 2012193091 A1	02-08-2012	CA 2764651 A1	14-07-2012
		US 2012193091 A1	02-08-2012
US 2009200020 A1	13-08-2009	CA 2552294 A1	13-01-2007
		CA 2714879 A1	13-01-2007
		GB 2428265 A	24-01-2007
		GB 2466739 A	07-07-2010
		US 2007012442 A1	18-01-2007
		US 2009200020 A1	13-08-2009
US 2007261845 A1	15-11-2007	NONE	

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

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Patent documents cited in the description

- US 6634426 A **[0004]**
- US 20120323493 A **[0005]**
- US 20120193091 A **[0006]**
- US 20080164024 A **[0007]**
- US 20040129428 A **[0007]**
- US 20020074118 A **[0007]**
- US 20070261845 A **[0007]**
- US 20090200020 A **[0007]**
- US 20080202746 A **[0007]**

Non-patent literature cited in the description

- **J MCCOY ; L ROWLAN.** Plunger-lift optimization by monitoring and analyzing well high frequency acoustic signals, tubing pressure and casing pressure. *SPE Rocky Mountain Petroleum Conference in Keystone, Colorado, USA,* May 2001 **[0003]**