(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 January 2015 (29.01.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/013136 A1

(51) International Patent Classification:
E21B 43/12 (2006.01) *F04B 47/06* (2006.01)

(21) International Application Number:
PCT/US2014/047242

(22) International Filing Date:
18 July 2014 (18.07.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/952,100 26 July 2013 (26.07.2013) US

(71) Applicant: **BAKER HUGHES INCORPORATED** [US/US]; P.O. Box 4740, Houston, TX 77210 (US).

(72) Inventors: **TETZLAFF, Steven, K.**; 10304 E. 92nd Pl N, Owasso, OK 74055 (US). **ADAMS, Dan, L.**; 4850 E 484 Rd., Claremore, OK 74019 (US). **MAY, Dewayne**; 3817 S 199 E Ave, Broken Arrow, OK 74014 (US). **DINKINS, Walter, R.**; 1600 W. Durham Ct., Broken Arrow, OK 74011 (US). **PYRON, Steven, W.**; 3509 S. Richmond Ave., Tulsa, OK 74135 (US).

(74) Agent: **HENDRYX, Thomas, N.**; Baker Hughes Incorporated, Intellectual Property Counsel, P.O.Box 4740, Houston, TX 77210-4740 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: LIVE WELL STAGED INSTALLATION OF WET CONNECTED ESP AND RELATED METHOD

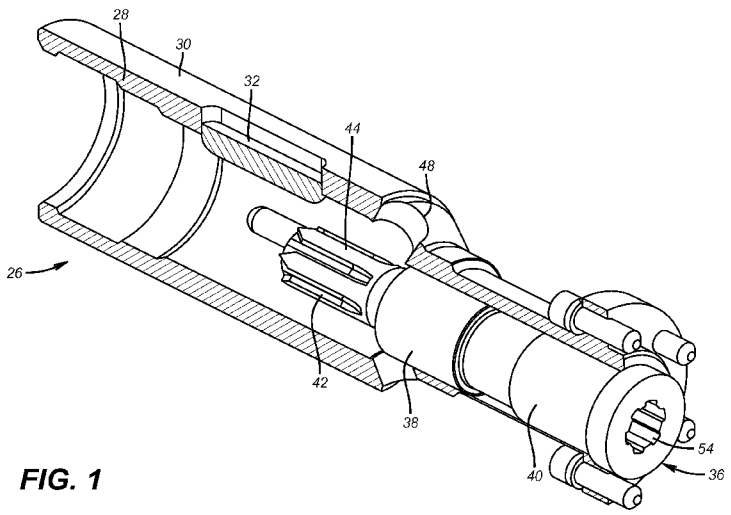

FIG. 1

(57) Abstract: An ESP assembly is broken into subassemblies to fit through a lubricator for live well deployment. A lifting device has a shaft transmission feature and associated housing rotational lock for use at the top of the first subassembly and to be left in position for engagement of the next assembly. The subassemblies can be delivered on wireline or slickline. A wet connect can be at the lower end of the initial subassembly to connect to a cable run alongside the production tubing. The ESP subassemblies all are interconnected in the live well and function as they would if assembled at the surface. The ability to break down the assembly and run it in segments lets the components fit through a length limited lubricator for live well deployment.

WO 2015/013136 A1

LIVE WELL STAGED INSTALLATION OF WET CONNECTED ESP AND RELATED METHOD

Inventors: Steven K. Tetzlaff; Dan L. Adams; Dewayne May;
Walter R. Dinkins and Steven W. Pyron

FIELD OF THE INVENTION

[0001] The field of the invention is installation of electric submersible pumps and more particularly, devices that enable subassembly installation to fit into a lubricator for live well deployment.

BACKGROUND OF THE INVENTION

[0002] Electric submersible pumps (ESP) are used to increase bottom hole pressure to deliver produced fluids to a well surface. These pumps are multistage centrifugal pumps with the number of stages determined by the depth of the ESP and the properties of the pumped fluids and the well configuration. As wells get deeper, with improved drilling technologies, the number of stages needed to achieve desired production has necessarily increased. The additional horsepower to drive the added stages and obtain higher discharge pressures, also by necessity, increased the length of the motor associated with the ESP.

[0003] In order to deploy ESPs in live wells utilizing wire line, the pump assembly has to pass through a lubricator. A lubricator is mounted on the well head at the surface. There are installations where the lubricator length is limited by the derrick height. Other installations may limit the lubricator length based on safety concerns or policy. Lubricator assemblies contain valves at opposed ends that can be sequentially operated to introduce the ESP components into the live well, such as with a wireline or slickline, when the bottom valve is opened and the wireline or slickline is delivered through a sealed connection near the top of the lubricator. Another more recent development is to mate a wet connect device on the lower end of the ESP assembly with the other half of the connection that is connected to a cable, run alongside the tubing that will convey the pumped fluids to the surface. This type of power / instrumentation connection has also added to the overall length of the assembly. Since there is a finite limit to the height of the lubricator supported in the derrick, or limited for safety reasons, it has become a problem

to get extended length, higher horsepower, ESP assemblies inserted into live wells.

[0004] It should be noted that coiled tubing, continuous rod and jointed rod or tubing could also be utilized to deploy these ESP systems with and without lubricator type equipment. While the lubricator type applications allow these installs on live wells, the same equipment can be used on wells that have been pressure equalized / neutralized or killed.

[0005] The present invention addresses this problem with a solution that allows the overall ESP assembly to be broken down into subassemblies that will fit in a lubricator for staged deployment and final system assembly, at the downhole fixture located at or near the bottom of the production tubing. This downhole fixture being the socket portion of the wet connection device. Once run into the well, these staged subassemblies function as though the entire assembly was put together at the surface, as could be done before when the assemblies had smaller motors and fewer stages.

[0006] Those skilled in the art will better appreciate the various aspects of the invention from a review of the detailed description of the preferred embodiment and the associated drawings while understanding that the full scope of the invention is to be determined by the appended claims.

SUMMARY OF THE INVENTION

[0007] An ESP assembly is broken down into subassemblies to fit within a lubricator where a safe working length is required for live well deployment. A lifting device has a shaft transmission feature and associated housing rotational lock for use at the top of the first subassembly which is left in position for engagement of the next assembly. The subassemblies can be delivered on wireline or slickline. A wet connect can be at the lower end of the initial subassembly to connect to a cable run alongside the production tubing. The ESP subassemblies all are deployed and interconnected in the live well and function as they would if assembled at the surface. The ability to break down the assembly and run it in segments lets the components fit through a length limited lubricator for live well deployment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a perspective view of the lift device to run in the first subassembly into production tubing;

[0009] FIG. 2 shows the production tubing in cased hole, in section, illustrating the wet connect and screen at the lower end of the production tubing;

[0010] FIG. 3 illustrates the first subassembly to be run into the production tubing with the other half of the wet connect at its lower end;

[0011] FIG. 4 is a section view of the lift sub used at the top of the assembly in FIG. 2 to run it into the production tubing to mate with the wet connect at the lower end of the production tubing;

[0012] FIG. 5 is the next subassembly to be run into the production tubing and includes the pump and lower end shaft extension to mate into the lift sub shown in FIG. 4 that is left in the production tubing;

[0013] FIG. 6 is the last subassembly that includes a seal assembly for the production tubing;

[0014] FIG. 7 is an anchor mounted above the seal assembly of FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] Referring to FIG. 2, a borehole is shown with casing **10** although an open hole is an alternative. Production tubing **12** is run into the casing **10** and supports at its lower end a half **14** of a wet connection of a type known in the art. A cable for power and communication between the surface and the wet connect **14** is schematically illustrated. The assembly in FIG. 2 has the other half of the wet connect **20** at its lower end and is referred to as the socket portion of the wet connect. When the halves **14** and **20** make electrical contact such a condition is sensed at the surface through the cable **16**. The assembly is retained by the lift device **26** that is shown in more detail in FIGS. 1 and 4. As shown in FIG. 1 there is a lift profile **28** where a slickline or wireline can be releasably attached in a manner known in the art. Apart from that there are anti-rotation lugs **32** in the housing **30** that are engaged by splines **34** shown at the lower end of FIG. 5 on the crossover assembly **35**. Once crossover assembly **35** is landed onto lift device **26**, axial load from the pump, **46** is transferred from 4-3, through **35**, **26** and ultimately to the thrust bearing inside **24**.

[0016] Thus, in operation, the housing **30** does not rotate but the shaft coupling assembly **36** turns. Assembly **36** is supported on bearings **38** and **40** and has a male end **42** with spline **44** to engage a pump shaft that is not shown

that extends out the lower end of the ESP **46** shown in FIG. 5. One or more openings **48** are provided in housing **30** to allow solids or other debris to pass out of the housing **30** when it is run in with the assembly shown in FIG. 3. The remainder of the assembly in FIG. 3 is a lower portion of a motor module module **22** that is rotationally locked at **50** to the remainder of the motor assembly **22** and **24**.

[0017] Item **24** is the seal section component. This component provides an equalization function between the well bore pressures seen at depth and the internal pressure of the ESP components **46**, **58** and **60**. In addition to providing pressure equalization, the seal component **24** also handles axial thrust to the ESP system created by the driven pump assembly **46** while the system is energized. The seal component **24** also protects the motor **22**, **24** and connection plug **20** from well bore fluid contamination. It is important to note that the assembly of FIG. 3 must all be part of the same staged installation as they are all serviced / filled with a synthetic type of dielectric oil.

[0018] The motor shaft extends From 22 through 24 to end **52** where an end spline meshes into the female splined connection **54** shown in FIG. 1. The pump shaft, not shown is a female end that slips over the male end shaft **42** with splines **44**. In essence the lift device **26** serves as a coupling between the seal shaft at end **52**, and the pump crossover 35 shaft to the pump intake shaft not shown that passes through ports 66 to the shaft in pump 46 that is not shown.

[0019] Once the assembly of FIG. 2 has been deployed into the production tubing **12** of FIG. 1 and the wet connect portions **14** and **20** are communicating the wireline or slickline or other conveyance supporting the lift device **26** is released and the wireline or slickline is retrieved to the surface to allow the assembly of FIG. 5 to be picked up and run into a live well through a lubricator that is not shown. In essence FIG. 5 is the ESP **46** that has a polished bore receptacle and an internal lifting profile not shown near its upper end **56**. The lifting profile allows running in the ESP **46** and the crossover assembly **35** in one trip through the lubricator. The wireline or slickline is again released so that another trip into the production tubing can be made with the sealing assembly **58,** then anchor assembly **60** that can be run in on a separate wire line run. Projections **62** positioned on the exterior and

adjacent interior polished bore receptacle act to centralize the assembly. The anchor **60** holds the assembly shown in FIGS. 3-7 inside the production tubing **10** to keep the assembled components fixed against the wet connection **14** at the lower end of the production tubing **10**.

[0020] Those skilled in the art will appreciate the fact that the problem of limited length in a lubricator is addressed by the present invention that breaks down an overlong assembly into stages that are short enough to load into a lubricator with a length limit of about 25 meters allowing the assembly to be put together in the live well while still maintaining the safety systems that are there to prevent loss of well control. The first break location is at the motor drive shaft which is run in with the lift device **26** in a way that the motor shaft is already coupled to the lift device that is left in the hole after the first trip to deliver the assembly of FIG. 2. After making contact with the wet connect **14** already at the bottom of the production tubing **10** the conveyance such as wireline or slickline is removed and the assembly of FIG. 5 including the ESP **46** is lifted and deployed. The pump shaft that is not shown connects to spline **44** on the lift sub shaft **42**. The conveyance is again released leaving exposed the polished bore receptacle on the top end **56** of the FIG. 5 assembly. The seal assembly **58** can be run in with the anchor **60** or separately. A seal assembly at the lower end of **58** registers with the polished bore receptacle that is not shown. Externally, the seal assembly **58** divides the suction and discharge sides of the EPSP **46**. Suction from the formation enters through screen **64** shown in FIG. 1 and passes through inlets **66** shown in FIG. 5. Discharge flow from the ESP **46** passes through the sealing assembly **58** and the anchor **60** on up to the surface through the production tubing **12**.

[0021] The problem that limits placement of ESP in a live well at depths where the length of the ESP and motor exceed the lubricator length is solved with the present invention. While the break locations in the ESP assembly can be selected at different component connections doing the breaking up at the connection of the motor shaft to the pump shaft allows more efficient use of the available length in these limited length lubricators. The incorporation of a shaft connector in the lift sub also allows having the break in the assembly at the connection between the motor and pump shafts. The other components above just push together and are finally anchored by anchor **60**. As the

operating depth and pressure output demanded from ESPs increases the ability to get the entire assembly into a live well will no longer be limited by lubricator length can no longer be a limiting factor. Indeed in the deeper applications where more pump stages and motor horsepower are required would mean such assemblies could not be run into a live well without significant risks of blowout. The method of the present invention allows the safe downhole assembly in a live well of long ESPs that are wet connected in the hole.

[0022] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

We claim:

1. A method of assembling an electric submersible pump (ESP) assembly in a live well that in the aggregate is longer than an available lubricator, comprising:

assembling subassemblies that are shorter than the lubricator at the surface of a borehole;

running in said subassemblies into the borehole through the lubricator;

assembling said subassemblies to each other in the borehole.

2. The method of claim **1**, comprising:

separating the motor driver from the ESP into separate assemblies.

3. The method of claim **2**, comprising:

using a lift device connected on one end to a motor / seal driveshaft when delivering the motor driver separately from said ESP system.

4. The method of claim **3**, comprising:

providing a connector shaft in said lift device connected on a lower end to said motor shaft.

5. The method of claim **4**, comprising:

rotationally locking said motor shaft to said connector shaft in said lift device.

6. The method of claim **5**, comprising:

engaging a pump shaft of said ESP to an opposite end of said connector shaft when the ESP assembly has passed through the lubricator.

7. The method of claim **6**, comprising:

rotationally locking a housing of said lift device to a housing of said ESP on assembly.

8. The method of claim **7**, comprising:

providing a male spline on an end of said connector shaft that engages the pump shaft and a female spline on the opposite end of said connector shaft that engages said motor shaft.

9. The method of claim **1**, comprising:

initially installing a wet connect adjacent a lower end of a production string in the borehole;

mating to said wet connect with the initial subassembly run into said production tubing.

10. The method of claim **9**, comprising:

running in the initial subassembly with a lift device at its upper end;

leaving said lift device in the production tubing for subsequent connection to the next delivered subassembly.

11. The method of claim **10**, comprising:

delivering subassemblies on wireline or slickline or tubing.

12. The method of claim **10**, comprising:

providing a lifting profile at an upper end of said lifting device.

13. The method of claim **10**, comprising:

using motor driver components as the first delivered subassembly.

14. The method of claim **13**, comprising:

connecting the ESP, as a second subassembly, to the lift device positioned above the first subassembly.

15. The method of claim **14**, comprising:

providing a connector shaft in said lift device to connect a motor shaft to a pump shaft.

16. The method of claim **15**, comprising:

rotationally locking a housing of said ESP pump to a housing on said lift device.

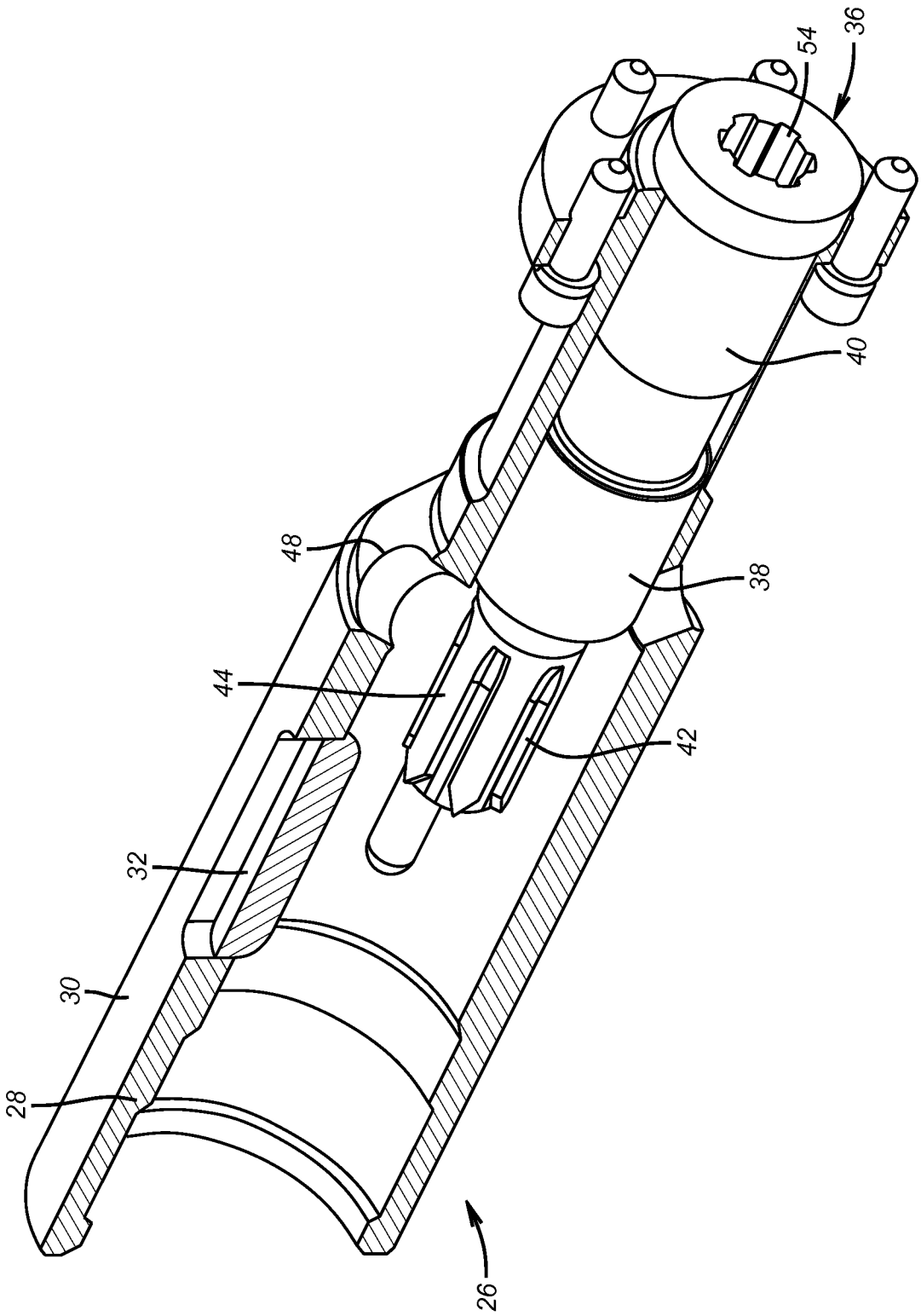

FIG. 1

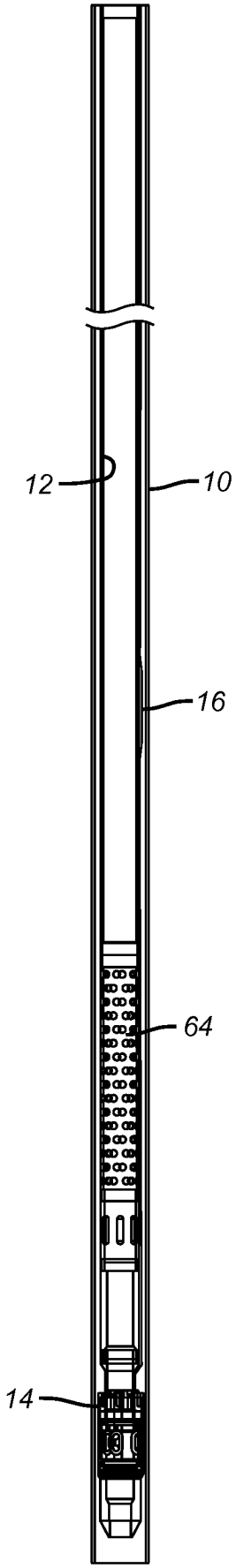

FIG. 2

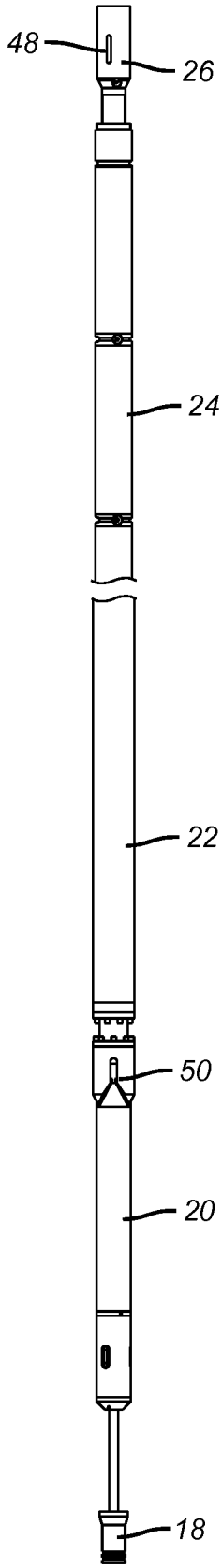

FIG. 3

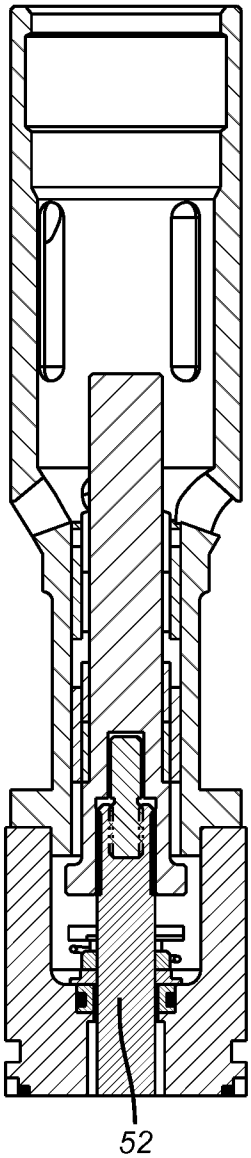

FIG. 4

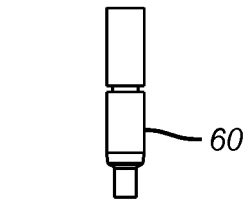

FIG. 7

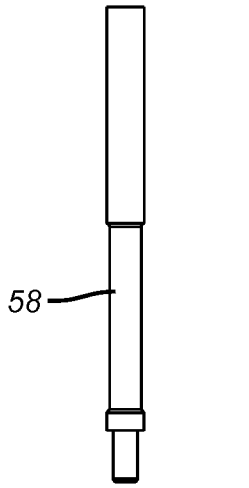

FIG. 6

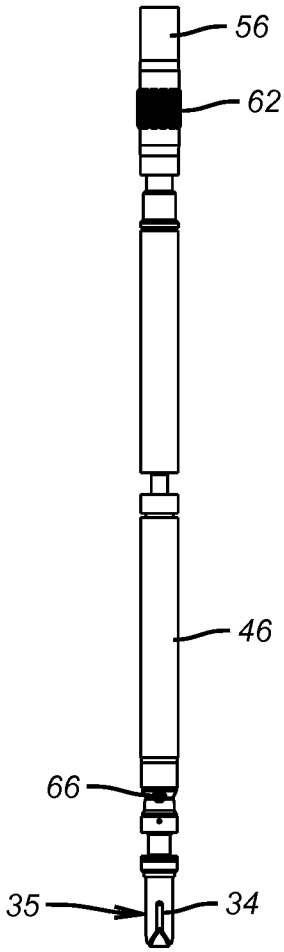

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/047242

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/12(2006.01)i, F04B 47/06(2006.01)i

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 43/12; E21B 33/08; E21B 43/116; E21B 43/00; E21B 19/16; E21B 23/00; F04B 47/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: electric submersible pump, assemble, lubricator, borehole, subassembly, motor driver, lift device, seal, connector, pump, and shaft

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6059042 A (HUBER et al.) 09 May 2000 See abstract; column 9, lines 30-37; column 14, line 1 - column 15, line 33; and figures 2a,9-14.	1-5
A		6-16
A	US 2009-0242191 A1 (WILDMAN et al.) 01 October 2009 See paragraphs [0010]-[0012] and figures 1-3.	1-16
A	US 2003-0116314 A1 (DALLAS, L. MURRAY) 26 June 2003 See paragraphs [0025]-[0026],[0037] and figures 1-4.	1-16
A	US 6056055 A (FALCONER et al.) 02 May 2000 See column 3, line 18 - column 4, line 17 and figures 1-5.	1-16
A	US 6328111 B1 (BEARDEN et al.) 11 December 2001 See claims 1-8 and figures 1-8.	1-16

☐ Further documents are listed in the continuation of Box C.

☒ 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
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 November 2014 (03.11.2014)	**03 November 2014 (03.11.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
CHOI, Hyun Goo
Telephone No. +82-42-481-8288

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/047242

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 06059042 A	09/05/2000	EP 0876546 A1	11/11/1998
		EP 0876546 A1	28/03/2001
		EP 0876546 B1	04/06/2003
		US 5848646 A	15/12/1998
		WO 97-27382 A1	31/07/1997
US 2009-0242191 A1	01/10/2009	US 7845401 B2	07/12/2010
		WO 2009-120578 A2	01/10/2009
US 2003-0116314 A1	26/06/2003	CA 2364151 A1	28/05/2003
		CA 2412911 A1	28/05/2003
		US 6769489 B2	03/08/2004
US 06056055 A	02/05/2000	GB 2326892 A	06/01/1999
US 6328111 B1	11/12/2001	CA 2299580 A1	24/08/2000
		GB 0004399 D0	12/04/2000
		GB 0110252 D0	20/06/2001
		GB 2347156 A	30/08/2000
		GB 2347156 B	20/02/2002
		GB 2359317 A	22/08/2001
		GB 2359317 B	31/07/2002
		NO 20000909 A	25/08/2000
		NO 20033754 A	25/08/2000
		NO 20033755 A	25/08/2000
		NO 20033756 A	25/08/2000
		NO 318702 B1	25/04/2005