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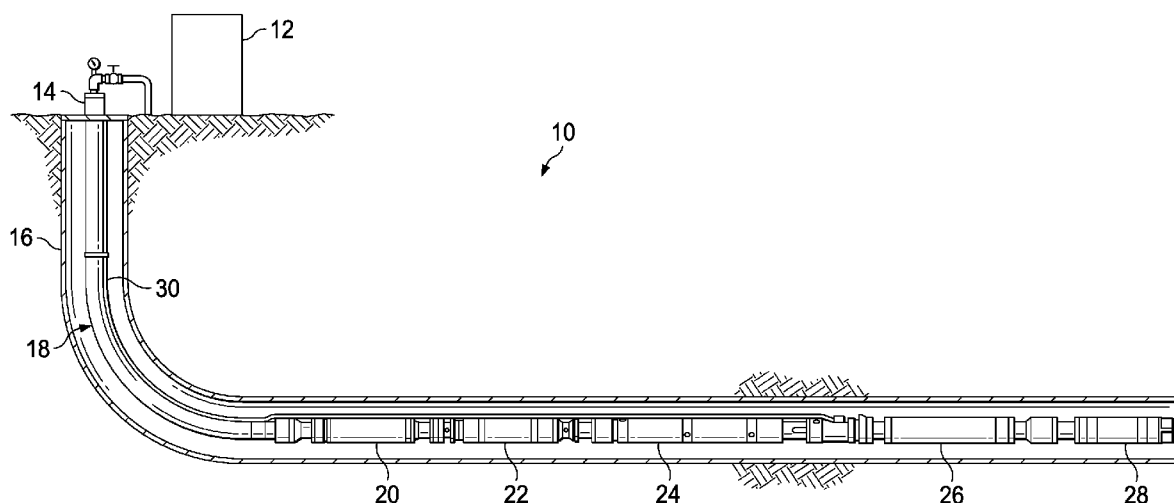


FIG. 1

(57) Abstract: A system for orienting and positioning a downhole ESP string in a deviated well includes a downhole ESP string, an accelerometer, and a data acquisition system. The string includes an intake port. The accelerometer is coupled to the string and measures the orientation of the intake port and the orientation of the string with respect to the vertical. The data acquisition system receives the orientation data, determines an offset value, and causes an adjustment in the orientation of the section. The string is oriented so that the intake port is on the bottom of the string facing towards the floor of the well and the intake port is positioned within the well where a deviation from a vertical path to a horizontal path takes place.



ELECTRICAL SUBMERSIBLE PUMP (ESP) STRING AND ESP ORIENTATION SYSTEM

BACKGROUND

[0001] The present disclosure relates, in general, to directional drilling and the downhole application of artificial lift system to access a well reservoir and, in particular, to a system and method of controlling the orientation of an Electrical Submersible Pump (ESP) string when accessing a well reservoir from a horizontal position.

[0002] Directional drilling technologies in the oil and gas industries have advanced production by allowing operators to drill horizontally through production zones, reaching reservoirs where vertical access is limited, e.g. under cities. The directional drilling technologies also allow for the production of multiple wells from a centralized surface location. This horizontal or deviated drilling has created new challenges for artificial lift suppliers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] For a more complete understanding of the features and advantages of the present disclosure, reference is now made to the detailed description along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0004] FIG. 1 is an illustration of a well pumping station and deviated well and ESP string positioned therein, in accordance with certain example embodiments;

[0005] FIG. 2A is an illustration of a downhole electric submersible pump string with an accelerometer and data acquisition configuration, in accordance with certain example embodiments;

[0006] FIG. 2B is an illustration of a section of the pump string having intake and discharge ports and a particular accelerometer arrangement, in accordance with certain example embodiments; and

[0007] FIG. 3A is an illustration of string section having an accelerometer, according to certain example embodiments;

[0008] FIG. 3B is an illustration of a data acquisition algorithm for causing the control of the orientation of a downhole electric submersible pump string, according to certain example embodiments; and

[0009] FIG. 4 is a block diagram depicting a computing machine and system applications, in accordance to certain example embodiments.

DETAILED DESCRIPTION

[0010] While the making and using of various embodiments of the present disclosure are discussed in detail below, it should be appreciated that the present disclosure provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative and do not delimit the scope of the present disclosure. In the interest of clarity, not all features of an actual implementation may be described in the present disclosure. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming but would be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0011] Deviated wells are sometimes required to access reservoirs where vertical access is not an option. The path of oil and gas fluids through horizontal casing behaves differently than in traditional vertical applications. Because of the change in fluid stream dynamics, Electrical Submersible Pump (ESP) design can benefit from understanding pump or system landing orientation. In a horizontal flow stream, reservoirs fluids (gas and liquid) are more easily separated that can form two parallel or laminar flow paths. Understanding the orientation of an ESP string at its landing position can aid production operators in their ability to avoid gas by placing the pump's intake port in a down position, or lowest position, to take advantage of the earth's gravitational effects to separate the fluids from the gas and by placing the discharge ports on the top, or highest position, in order to eject gas away from the liquid stream.

[0012] Referring to FIG. 1, illustrated is a well pumping station that includes a deviated well and ESP string positioned therein, in accordance with certain example embodiments, denoted generally as 10. The site includes a control center 12, a well head 14, well casing 16, and ESP string 18. In this embodiment, the ESP string 18 includes a pump 20, a gas separator 22, a seal 24, a motor 26, and a string section 28 that includes a data acquisition system. A Motor Lead Extension (MLE) 30 runs from the motor 26 to the control center 12. In this application, the well is deviated enough that the ESP string 18 runs along a horizontal with the earth's surface or stated differently parallel with the earth's surface. The well's deviation is used to take advantage of earth's gravitational effects so that fluid pumped from a reservoir can be more effectively separated. In an embodiment, the string 18 includes ports, e.g. intake ports or discharge ports. In this particular embodiment, the gas separator 22 includes intake and discharge ports. In order to take advantage of earth's gravitational effects, the position of the string 18 is oriented so that the ports are positioned on top and/or bottom of the string. This can significantly improve the function of the pump 20 and motor 26.

[0013] In an embodiment, accelerometer sensors are mounted at different positions along the string 18, e.g. near the separator 22 and the string section 28. During installation, the accelerometer sensors are used to understand the orientation of the string 18 in order to install the string 18 more efficiently and effectively. The benefit of knowing the orientation of the string 18 provides the installers with the ability to rotate the string 18 as it is being lowered into the well hole together with the understanding of the incline for final landing placement. Orientation data from the sensor gives the installer the ability to apply more or less torque to the string 18 as it is being assembled at the well head when lowering the equipment to keep the equipment properly orientated. In an embodiment, data from the accelerometer sensors are used by the data acquisition system to cause the position of the string 18 to be oriented in a manner

so that intake ports are positioned facing toward the bottom of the well casing 16 and discharge ports are facing toward the top of the well casing 16. Furthermore, the sensors ability to communicate the degree of tilt of the string 18 relative to the vertical allows the installer the ability to land the ESP's intake in the area where the deviation from vertical to horizontal takes place. Landing an ESP in such a position puts the intake or intake stinger in optimal position for gas avoidance by taking advantage of the well bore's natural separation where the liquid has the opposing forces of inertia verses gravity. This section of the well bore has the largest accumulation of liquid on the lower side of the casing.

[0014] Referring now to FIG. 2A and FIG. 2B, illustrated is downhole ESP string 18 with an accelerometer sensor configuration and data acquisition section, in accordance with certain example embodiments. In an embodiment, accelerometer sensors are mounted on the string 18. For example, section 28 with accelerometer sensors is mounted to motor 26 at a pre-determined cue or designated spot that is used to indicate the orientation of the motor based on feedback data from the accelerometer sensor. In an embodiment, sensors are mounted on the gas separator 22 at a cue or i.e. a designated location on a section of the string that is used to indicate the orientation of the separator 22 based on feedback data from the accelerometer. It should also be understood that separator 22 can also simply be a section with only intake ports 32 and no discharge ports 34, or obviously both intake ports 32 and discharge ports 34. As previously stated, the placement of the accelerometer sensors according to the cues before the string is placed in the well casing 16 allows for more accurate positioning of the string 18 in the well casing 16 so that the ports are oriented in a favorable direction during rest, i.e. its final landing spot, and the string 18 is placed in optimal location in the well.

[0015] As can be seen in FIG. 3A, separator 22 is mounted with an accelerometer sensor 202. The placement of the sensor 202 at a pre-determined location, i.e. a cue, is used to

understand the orientation of the separator, e.g., during installation. The accelerometer sensor 202 is a 3-axis accelerometer defined by axis x, y, and z. A static g measurement from the z-axis provides the amount of verticality of the full vertical tilt of the ESP string 18 relative to the earth's gravity (g). For example, when the ESP string 18 is vertical, or approximately vertical, output of the accelerometer sensor 202 can be determined to be equal to 1g, or approximate thereto, and when the ESP string 18 is horizontal, or approximately vertical, the output of the ESP string 18 can be determined to equal to 0g, or approximate thereto.

[0016] With respect to the separator 22, the intake orientation, i.e. rotational about the ESP string 18, as processed by the data acquisition system, uses static g from the x and y axis, with at least one of the two axis aligned during sensor-motor assembly so that an axis is aligned with the port intake 32 feature and the sensor housing during sensor motor assembly. A visible orientation marking, i.e. a cue, can be on the sensor 202 indicating the x or y axis position and the indication can be used to orient the port intake 32. For example, if the x axis is aligned with the pump intake and the pump intake and ESP string 18 is installed in a horizontal position in a well, i.e. z axis = 0g static, then x axis will read 1g if pump intake is aligned at top of the ESP string 18, or will read -1g if on bottom, and 0g if on side.

[0017] In an embodiment, the accelerometer sensor 202 is placed at a cue so that feedback data from the sensor 202 indicates the angular orientation, i.e. magnitude and direction, of the interface for the MLE 30. The accelerometer sensor 202 is placed at a cue on the gas separator 22, e.g. in alignment with the port, so that feedback data from the sensor 202 indicates the angular orientation of the ports. Stated slightly differently, the accelerometer sensor 202 provides feedback data that is used by a data acquisition system, see computing machine of Fig. 4, to determine the roll (x) and pitch (y) in relation to yaw (z) or any combination thereof. This information is used by the data acquisition system to determine the orientation of the string 18,

including the incline, calculate an offset value based on a desired orientation value, and cause the orientation of the string 18 or section thereof to be adjusted in response. Although, calculation of the offset value can be an option, depending on the application.

[0018] Referring now to FIG. 3B, illustrated is a data acquisition algorithm for causing the control of the orientation of a downhole electric submersible pump string, according to certain example embodiments. The algorithm begins at block 204 where a data acquisition system monitors for feedback signals from at least one accelerometer sensor 202 and transmits the accelerometer data for processing, at block 206. In an embodiment, the data acquisition system includes multiple downhole sections, e.g. an accelerometer 202 and data acquisition configuration at section 28 and motor 26 and an accelerometer 202 and data acquisition configuration at the gas separator 22. Alternatively, there may be only an accelerometer 202 at the gas separator 22 and an accelerometer 202 and data acquisition configuration at the motor 26 and section 28. The communications interface of the data acquisition system can be wired or wireless, depending on the accelerometer 202 and data acquisition system configuration. In an embodiment, the data acquisition system may include a downhole system section and another section above the well, e.g. in the control center 12.

[0019] At block, 208, the data acquisition system determines the orientation by identifying the accelerometer sensor 202 and calculating an offset value based on a desired orientation value associated with the mounted accelerometer sensor 202 and the measurement provided by the sensor 202. The desired orientation value can be a default value that indicates proper angular alignment of the accelerometer axes. The data acquisition system then generates an orientation adjustment command and calculated offset value and sends the command for processing. The command can also include an identifier identifying the accelerometer sensor 202. The offset value can be used by a well site operator to adjust the orientation of the string 18, e.g. to align

the ports, and/or place the string 18 at a particular location, e.g. at the location where there is a transition from a vertical to horizontal path, in the well casing 16, either manually or automatically. In an embodiment, the data acquisition system can determine the orientation of the string 18 and determine if the ports are positioned incorrectly and the string 18 is tilted incorrectly, as compared to desired orientation data, and send the orientation adjustment command and calculated offset value when required. Stated slightly differently, the data acquisition system can receive the measurements from the sensor 202, determine an offset value from the measurements, compare the offset value with a predetermined threshold value, and send the value to the control center 12 if the value exceeds the desired orientation value by the predetermined threshold. It should be understood, the use of the term accelerometer throughout the specification can mean the use of an accelerometer and magnetometer.

[0020] Referring now to FIG. 4, illustrated is a computing machine 300 and a system applications module 400, in accordance with example embodiments. The computing machine 300 can correspond to any of the various computers, mobile devices, laptop computers, servers, embedded systems, or computing systems presented herein. The module 400 can comprise one or more hardware or software elements, e.g. other OS application and user and kernel space applications, designed to facilitate the computing machine 300 in performing the various methods and processing functions presented herein. The computing machine 300 can include various internal or attached components such as a processor 310, system bus 320, system memory 330, storage media 340, input/output interface 350, a network interface 360 for communicating with a network 370, e.g. cellular/GPS, Bluetooth, or WIFI, and an accelerometer 380, or a magnetometer, or a combination magnetometer and accelerometer.

[0021] The computing machines can be implemented as a conventional computer system, an embedded controller, a laptop, a server, a mobile device, a smartphone, a wearable computer,

a customized machine, any other hardware platform, or any combination or multiplicity thereof. The computing machines can be a distributed system configured to function using multiple computing machines interconnected via a data network or bus system.

[0022] The processor 310 can be designed to execute code instructions in order to perform the operations and functionality described herein, manage request flow and address mappings, and to perform calculations and generate commands. The processor 310 can be configured to monitor and control the operation of the components in the computing machines. The processor 310 can be a general purpose processor, a processor core, a multiprocessor, a reconfigurable processor, a microcontroller, a digital signal processor (“DSP”), an application specific integrated circuit (“ASIC”), a controller, a state machine, gated logic, discrete hardware components, any other processing unit, or any combination or multiplicity thereof. The processor 310 can be a single processing unit, multiple processing units, a single processing core, multiple processing cores, special purpose processing cores, co-processors, or any combination thereof. According to certain embodiments, the processor 310 along with other components of the computing machine 300 can be a software based or hardware based virtualized computing machine executing within one or more other computing machines.

[0023] The system memory 330 can include non-volatile memories such as read-only memory (“ROM”), programmable read-only memory (“PROM”), erasable programmable read-only memory (“EPROM”), flash memory, or any other device capable of storing program instructions or data with or without applied power. The system memory 330 can also include volatile memories such as random access memory (“RAM”), static random access memory (“SRAM”), dynamic random access memory (“DRAM”), and synchronous dynamic random access memory (“SDRAM”). Other types of RAM also can be used to implement the system memory 330. The system memory 330 can be implemented using a single memory module or

multiple memory modules. While the system memory 330 is depicted as being part of the computing machine, one skilled in the art will recognize that the system memory 330 can be separate from the computing machine 300 without departing from the scope of the subject technology. It should also be appreciated that the system memory 330 can include, or operate in conjunction with, a non-volatile storage device such as the storage media 340.

[0024] The storage media 340 can include a hard disk, a floppy disk, a compact disc read-only memory (“CD-ROM”), a digital versatile disc (“DVD”), a Blu-ray disc, a magnetic tape, a flash memory, other non-volatile memory device, a solid state drive (“SSD”), any magnetic storage device, any optical storage device, any electrical storage device, any semiconductor storage device, any physical-based storage device, any other data storage device, or any combination or multiplicity thereof. The storage media 340 can store one or more operating systems, application programs and program modules, data, or any other information. The storage media 340 can be part of, or connected to, the computing machine. The storage media 340 can also be part of one or more other computing machines that are in communication with the computing machine such as servers, database servers, cloud storage, network attached storage, and so forth.

[0025] The applications module 400 and other OS application modules can comprise one or more hardware or software elements configured to facilitate the computing machine with performing the various methods and processing functions presented herein. The applications module 400 and other OS application modules can include one or more algorithms or sequences of instructions stored as software or firmware in association with the system memory 330, the storage media 340 or both. The storage media 340 can therefore represent examples of machine or computer readable media on which instructions or code can be stored for execution by the processor 310. Machine or computer readable media can generally refer to any medium or

media used to provide instructions to the processor 310. Such machine or computer readable media associated with the applications module 400 and other OS application modules can comprise a computer software product. It should be appreciated that a computer software product comprising the applications module 400 and other OS application modules can also be associated with one or more processes or methods for delivering the applications module 400 and other OS application modules to the computing machine via a network, any signal-bearing medium, or any other communication or delivery technology. The applications module 400 and other OS application modules can also comprise hardware circuits or information for configuring hardware circuits such as microcode or configuration information for an FPGA or other PLD. In one exemplary embodiment, applications module 400 and other OS application modules can include algorithms capable of performing the functional operations described by the flow charts and computer systems presented herein.

[0026] The input/output (“I/O”) interface 350 can be configured to couple to one or more external devices, to receive data from the one or more external devices, and to send data to the one or more external devices. Such external devices along with the various internal devices can also be known as peripheral devices. The I/O interface 350 can include both electrical and physical connections for coupling the various peripheral devices to the computing machine or the processor 310. The I/O interface 350 can be configured to communicate data, addresses, and control signals between the peripheral devices, the computing machine, or the processor 310. The I/O interface 350 can be configured to implement any standard interface, such as small computer system interface (“SCSI”), serial-attached SCSI (“SAS”), fiber channel, peripheral component interconnect (“PCI”), PCI express (PCIe), serial bus, parallel bus, advanced technology attached (“ATA”), serial ATA (“SATA”), universal serial bus (“USB”), Thunderbolt, FireWire, various video buses, and the like. The I/O interface 350 can be

configured to implement only one interface or bus technology. Alternatively, the I/O interface 350 can be configured to implement multiple interfaces or bus technologies. The I/O interface 350 can be configured as part of, all of, or to operate in conjunction with, the system bus 320. The I/O interface 350 can include one or more buffers for buffering transmissions between one or more external devices, internal devices, the computing machine, or the processor 320.

[0027] The I/O interface 320 can couple the computing machine to various input devices including mice, touch-screens, scanners, electronic digitizers, sensors, receivers, touchpads, trackballs, cameras, microphones, keyboards, any other pointing devices, or any combinations thereof. The I/O interface 320 can couple the computing machine to various output devices including video displays, speakers, printers, projectors, tactile feedback devices, automation control, robotic components, actuators, motors, fans, solenoids, valves, pumps, transmitters, signal emitters, lights, and so forth.

[0028] The computing machine 300 can operate in a networked environment using logical connections through the NIC 360 to one or more other systems or computing machines across a network. The network can include wide area networks (WAN), local area networks (LAN), intranets, the Internet, wireless access networks, wired networks, mobile networks, telephone networks, optical networks, or combinations thereof. The network can be packet switched, circuit switched, of any topology, and can use any communication protocol. Communication links within the network can involve various digital or an analog communication media such as fiber optic cables, free-space optics, waveguides, electrical conductors, wireless links, antennas, radio-frequency communications, and so forth.

[0029] The accelerometer 380 can be a Micromachined Microelectromechanical Systems (MEMS) accelerometer. The accelerometer 380 can be a single-axis or multi-axis accelerometer to detect magnitude and direction of the string's acceleration as a vector quantity and, therefore

used to sense orientation. The processor 310 can be connected to the other elements of the computing machine or the various peripherals discussed herein through the system bus 320. It should be appreciated that the system bus 320 can be within the processor 310, outside the processor 310, or both. According to some embodiments, any of the processors 310, the other elements of the computing machine, or the various peripherals discussed herein can be integrated into a single device such as a system on chip (“SOC”), system on package (“SOP”), or ASIC device.

[0030] Embodiments may comprise a computer program that embodies the functions described and illustrated herein, wherein the computer program is implemented in a computer system that comprises instructions stored in a machine-readable medium and a processor that executes the instructions. However, it should be apparent that there could be many different ways of implementing embodiments in computer programming, and the embodiments should not be construed as limited to any one set of computer program instructions unless otherwise disclosed for an exemplary embodiment. Further, a skilled programmer would be able to write such a computer program to implement an embodiment of the disclosed embodiments based on the appended flow charts, algorithms and associated description in the application text. Therefore, disclosure of a particular set of program code instructions is not considered necessary for an adequate understanding of how to make and use embodiments. Further, those skilled in the art will appreciate that one or more aspects of embodiments described herein may be performed by hardware, software, or a combination thereof, as may be embodied in one or more computing systems. Moreover, any reference to an act being performed by a computer should not be construed as being performed by a single computer as more than one computer may perform the act.

[0031] The example embodiments described herein can be used with computer hardware and software that perform the methods and processing functions described previously. The systems, methods, and procedures described herein can be embodied in a programmable computer, computer-executable software, or digital circuitry. The software can be stored on computer-readable media. For example, computer-readable media can include a floppy disk, RAM, ROM, hard disk, removable media, flash memory, memory stick, optical media, magneto-optical media, CD-ROM, etc. Digital circuitry can include integrated circuits, gate arrays, building block logic, field programmable gate arrays (FPGA), etc.

[0032] The example systems, methods, and acts described in the embodiments presented previously are illustrative, and, in alternative embodiments, certain acts can be performed in a different order, in parallel with one another, omitted entirely, and/or combined between different example embodiments, and/or certain additional acts can be performed, without departing from the scope and spirit of various embodiments. Accordingly, such alternative embodiments are included in the description herein.

[0033] As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. As used herein, phrases such as “between X and Y” and “between about X and Y” should be interpreted to include X and Y. As used herein, phrases such as “between about X and Y” mean “between about X and about Y.” As used herein, phrases such as “from about X to Y” mean “from about X to about Y.”

[0034] As used herein, “hardware” can include a combination of discrete components, an integrated circuit, an application-specific integrated circuit, a field programmable gate array, or other suitable hardware. As used herein, “software” can include one or more objects, agents, threads, lines of code, subroutines, separate software applications, two or more lines of code or other suitable software structures operating in two or more software applications, on one or more processors (where a processor includes one or more microcomputers or other suitable data processing units, memory devices, input-output devices, displays, data input devices such as a keyboard or a mouse, peripherals such as printers and speakers, associated drivers, control cards, power sources, network devices, docking station devices, or other suitable devices operating under control of software systems in conjunction with the processor or other devices), or other suitable software structures. In one exemplary embodiment, software can include one or more lines of code or other suitable software structures operating in a general purpose software application, such as an operating system, and one or more lines of code or other suitable software structures operating in a specific purpose software application. As used herein, the term “couple” and its cognate terms, such as “couples” and “coupled,” can include a physical connection (such as a copper conductor), a virtual connection (such as through randomly assigned memory locations of a data memory device), a logical connection (such as through logical gates of a semiconducting device), other suitable connections, or a suitable combination of such connections. The term “data” can refer to a suitable structure for using, conveying or storing data, such as a data field, a data buffer, a data message having the data value and sender/receiver address data, a control message having the data value and one or more operators that cause the receiving system or component to perform a function using the data, or other suitable hardware or software components for the electronic processing of data.

[0035] In general, a software system is a system that operates on a processor to perform predetermined functions in response to predetermined data fields. For example, a system can be defined by the function it performs and the data fields that it performs the function on. As used herein, a NAME system, where NAME is typically the name of the general function that is performed by the system, refers to a software system that is configured to operate on a processor and to perform the disclosed function on the disclosed data fields. Unless a specific algorithm is disclosed, then any suitable algorithm that would be known to one of skill in the art for performing the function using the associated data fields is contemplated as falling within the scope of the disclosure. For example, a message system that generates a message that includes a sender address field, a recipient address field and a message field would encompass software operating on a processor that can obtain the sender address field, recipient address field and message field from a suitable system or device of the processor, such as a buffer device or buffer system, can assemble the sender address field, recipient address field and message field into a suitable electronic message format (such as an electronic mail message, a TCP/IP message or any other suitable message format that has a sender address field, a recipient address field and message field), and can transmit the electronic message using electronic messaging systems and devices of the processor over a communications medium, such as a network. One of ordinary skill in the art would be able to provide the specific coding for a specific application based on the foregoing disclosure, which is intended to set forth exemplary embodiments of the present disclosure, and not to provide a tutorial for someone having less than ordinary skill in the art, such as someone who is unfamiliar with programming or processors in a suitable programming language. A specific algorithm for performing a function can be provided in a flow chart form or in other suitable formats, where the data fields and associated functions can be set forth in an

exemplary order of operations, where the order can be rearranged as suitable and is not intended to be limiting unless explicitly stated to be limiting.

[0036] The above-disclosed embodiments have been presented for purposes of illustration and to enable one of ordinary skill in the art to practice the disclosure, but the disclosure is not intended to be exhaustive or limited to the forms disclosed. Many insubstantial modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The scope of the claims is intended to broadly cover the disclosed embodiments and any such modification. Further, the following clauses represent additional embodiments of the disclosure and should be considered within the scope of the disclosure:

[0037] Clause 1, a system includes a downhole ESP string having a section with at least one of an intake port and a discharge port positioned in the well; an accelerometer coupled to the section of the string for measuring the orientation of the at least one of the intake port and the discharge port and sending port orientation data; and a data acquisition system for receiving the port orientation data and causing an adjustment in the orientation of the section.

[0038] Clause 2, the system of clause 1, wherein the position of the coupled accelerometer is aligned with the position of at least one of the intake and the discharge port.

[0039] Clause 3, the system of clause 1, wherein the section is oriented so that the intake port is on the bottom of the string facing towards the floor of the well.

[0040] Clause 4, the system of clause 1, wherein the section is oriented so that the intake port is on the bottom of the string and the discharge port is on the top of the string facing towards the ceiling of the well.

[0041] Clause 5, the system of clause 1, wherein the data acquisition system further: determines an offset value based on the measuring; and sends the offset value to a well operations center.

[0042] Clause 6, the system of clause 1, wherein data acquisition system further: determines an offset value based on the measuring; compares the offset value with a desired orientation value; and sends the offset value to the well operations center if the offset value exceeds the desired orientation value by a predetermined threshold.

[0043] Clause 7, the system of clause 1, wherein the data acquisition system measures the output from the accelerometer with any combination of x, y, and z axes and determines an angle of degree of tilt relative to a vertical alignment of static 1G of the string during install and rest.

[0044] Clause 8, the system of clause 1, wherein the data acquisition system causes the string to be oriented so that the intake port is facing a bottom surface of the well, wherein the well runs lengthwise in a horizontal direction.

[0045] Clause 9, the system of clause 1, wherein the data acquisition system causes the string to be placed in the well so that the intake port at a place in the well where the deviation from vertical to horizontal takes place.

[0046] Clause 10, a method for orienting a downhole ESP string in a well, the method comprising: positioning a downhole electric submersible pump string having a section with at least one of an intake port and a discharge port in the well; measuring, using an accelerometer coupled to the section of the string, the orientation of the at least one of the intake port and the discharge port and sending port orientation data; and receiving, using a data acquisition system, the port orientation data and causing an adjustment in the orientation of the section.

[0047] Clause 11, the method of clause 10, wherein the position of the coupled accelerometer is aligned with the position of at least one of the intake and the discharge port.

[0048] Clause 12, the method of clause 10, further comprising orienting the section so that the intake port is on the bottom of the string facing towards the floor of the well.

[0049] Clause 13, the method of clause 10, further comprising orienting the section so that the intake port is on the bottom of the string and the discharge port is on the top of the string facing towards the ceiling of the well.

[0050] Clause 14, the method of clause 10, further comprising: determining an offset value based on the measuring; and sending the offset value to a well operations center.

[0051] Clause 15, the method of clause 10, further comprising determining an offset value based on the measuring; comparing the offset value with a desired orientation value; and sending the offset value to the well operations center if the offset value exceeds the desired orientation value by a predetermined threshold.

[0052] Clause 16, the method of clause 11, further comprising measuring, at the data acquisition system, the output from the accelerometer with any combination of x, y, and z axis and determining the angle of degree of tilt relative to a vertical alignment of static 1G of the string during install and rest.

[0053] Clause 17, the method of clause 16, further comprising causing, by the data acquisition system, the string to be oriented so that the intake port is facing a bottom surface of the well, wherein the well runs in a horizontal direction.

[0054] Clause 18, an apparatus for orienting a downhole ESP string in a well, the apparatus comprising: an accelerometer coupled to a section of a downhole electric submersible pump string that measures the orientation of the at least one of an intake port and a discharge port and

sends port orientation data; and a data acquisition system that receives port orientation data and causes an adjustment in the orientation of the downhole electric submersible pump string.

[0055] Clause 19, the apparatus of clause 18, wherein the data acquisition system further: determines an offset value based on the measurement of the orientation of the at least one of an intake port and a discharge port; and sends the offset value to a well operations center.

[0056] Clause 20, the apparatus of clause 18, wherein data acquisition system further: determines an offset value based on the measuring; compares the offset value with a desired orientation value; and sends the offset value to the well operations center if the at least one offset value exceeds the desired orientation value by a predetermined threshold.

[0057] The foregoing description of embodiments of the disclosure has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the disclosure. The embodiments were chosen and described in order to explain the principals of the disclosure and its practical application to enable one skilled in the art to utilize the disclosure in various embodiments and with various modifications as are suited to the particular use contemplated. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the embodiments without departing from the scope of the present disclosure. Such modifications and combinations of the illustrative embodiments as well as other embodiments will be apparent to persons skilled in the art upon reference to the description. It is, therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A system for orienting and positioning a downhole ESP string in a well, the system comprising:

a downhole electric submersible pump string having a section with at least one of an intake port and a discharge port positioned in the well;

an accelerometer coupled to the section of the string that measures an orientation of the at least one of the intake port and the discharge port and sends port orientation data; and

a data acquisition system that receives the port orientation data and causes an adjustment in the orientation of the section.

2. The system of claim 1, wherein the position of the coupled accelerometer is aligned with a position of at least one of the intake and the discharge port.

3. The system of claim 1, wherein the section is oriented so that the intake port is facing towards the floor of the well.

4. The system of claim 1, wherein the section is oriented so that the intake port is on the bottom of the string and the discharge port is on the top of the string facing towards the ceiling of the well.

5. The system of claim 1, wherein the data acquisition system further:
determines an offset value based on the measuring; and
sends the offset value to a well operations center.

6. The system of claim 1, wherein data acquisition system further:
determines an offset value based on the measuring;
compares the offset value with a desired orientation value; and
sends the offset value to the well operations center if the offset value exceeds the at
desired orientation value by a predetermined threshold.
7. The system of claim 1, wherein the data acquisition system measures the output
from the accelerometer with any combination of x, y, and z axes and determines an angle of
degree of tilt relative to a vertical alignment of static 1G of the string during install and rest.
8. The system of claim 7, wherein the data acquisition system causes the string to
be oriented so that the intake port is facing a bottom surface of the well, wherein the well runs
lengthwise in a horizontal direction.
9. The system of claim 1, wherein the data acquisition system causes the string to
be placed in the well so that the intake port at a place in the well where the deviation from
vertical to horizontal takes place.
10. A method for orienting and positioning a downhole ESP string in a well, the
method comprising:
positioning a downhole electric submersible pump string having a section with at least
one of an intake port and a discharge port in the well;
measuring, using an accelerometer coupled to the section of the string, the orientation
of the at least one of the intake port and the discharge port and sending port orientation data;
and

receiving, using a data acquisition system, the port orientation data and causing an adjustment in the orientation of the section.

11. The method of claim 10, wherein the position of the coupled accelerometer is aligned with the position of at least one of the intake and the discharge port.

12. The method of claim 10, further comprising orienting the section so that the intake port is on the bottom of the string facing towards the floor of the well.

13. The method of claim 10, further comprising orienting the section so that the intake port is on the bottom of the string and the discharge port is on the top of the string facing towards the ceiling of the well.

14. The method of claim 10, further comprising:
determines an offset value based on the measuring; and
sends the offset value to a well operations center.

15. The method of claim 10 further comprising:
determining an offset value based on the measuring;
comparing the offset value with a desired orientation value; and
sending the offset value to the well operations center if the offset value exceeds the desired orientation value by a predetermined threshold.

16. The method of claim 10, further comprising measuring, at the data acquisition system, the output from the accelerometer with any combination of x, y, and z axis and determining the angle of degree of tilt relative to a vertical alignment of static 1G of the string during install and rest.

17. The method of claim 16, further comprising causing, by the data acquisition system, the string to be oriented so that the intake port is facing a bottom surface of the well, wherein the well runs in a horizontal direction.

18. An apparatus for orienting and positioning a downhole ESP string in a well, the apparatus comprising:

an accelerometer coupled to a section of a downhole electric submersible pump string that measures the orientation of the at least one of an intake port and a discharge port and sends port orientation data; and

a data acquisition system that receives port orientation data and causes an adjustment in the orientation of the downhole electric submersible pump string.

19. The system of claim 18, wherein the data acquisition system further:
determines an offset value based on the measurement of the orientation of the at least one of an intake port and a discharge port; and
sends the offset value to a well operations center.

20. The system of claim 18, wherein data acquisition system further:
determines an offset value based on the measuring;
compares the offset value with a desired orientation value; and
sends the offset value to the well operations center if the at least one offset value
exceeds the desired orientation value by a predetermined threshold.

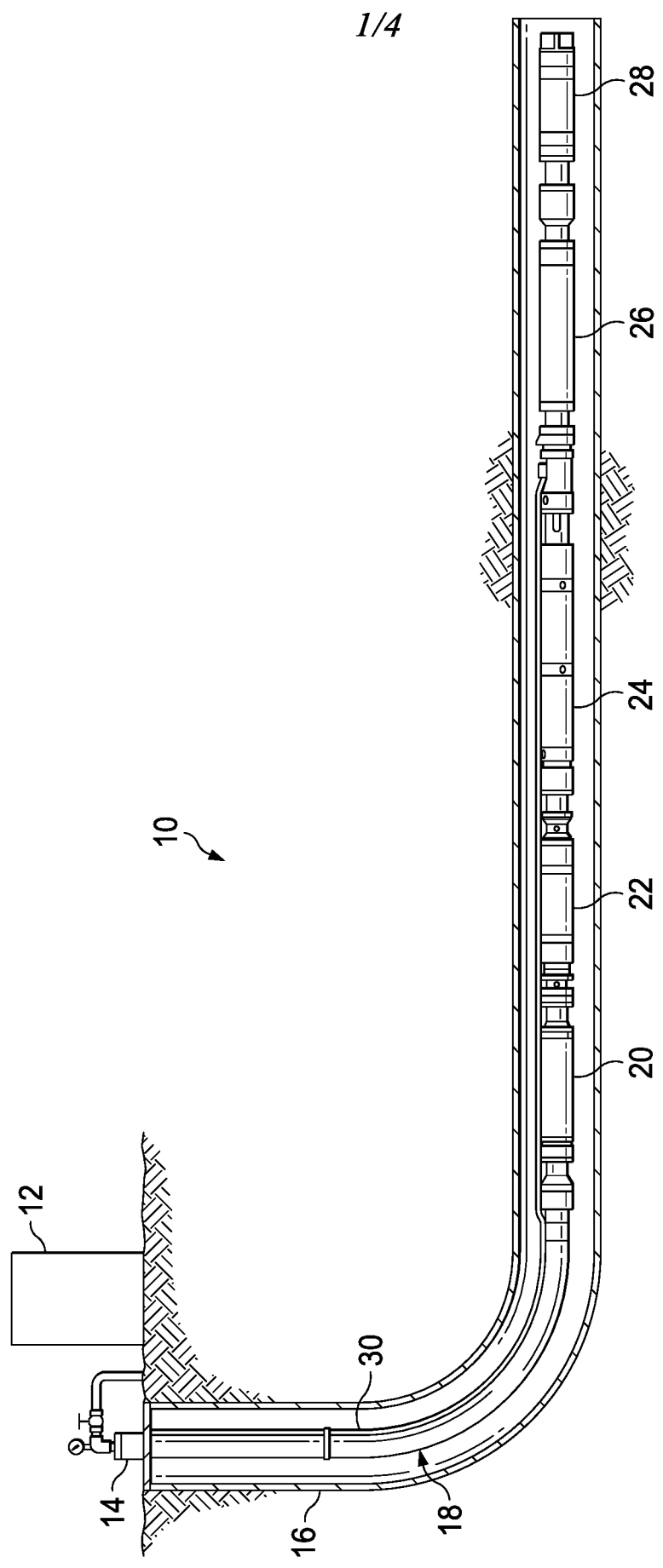
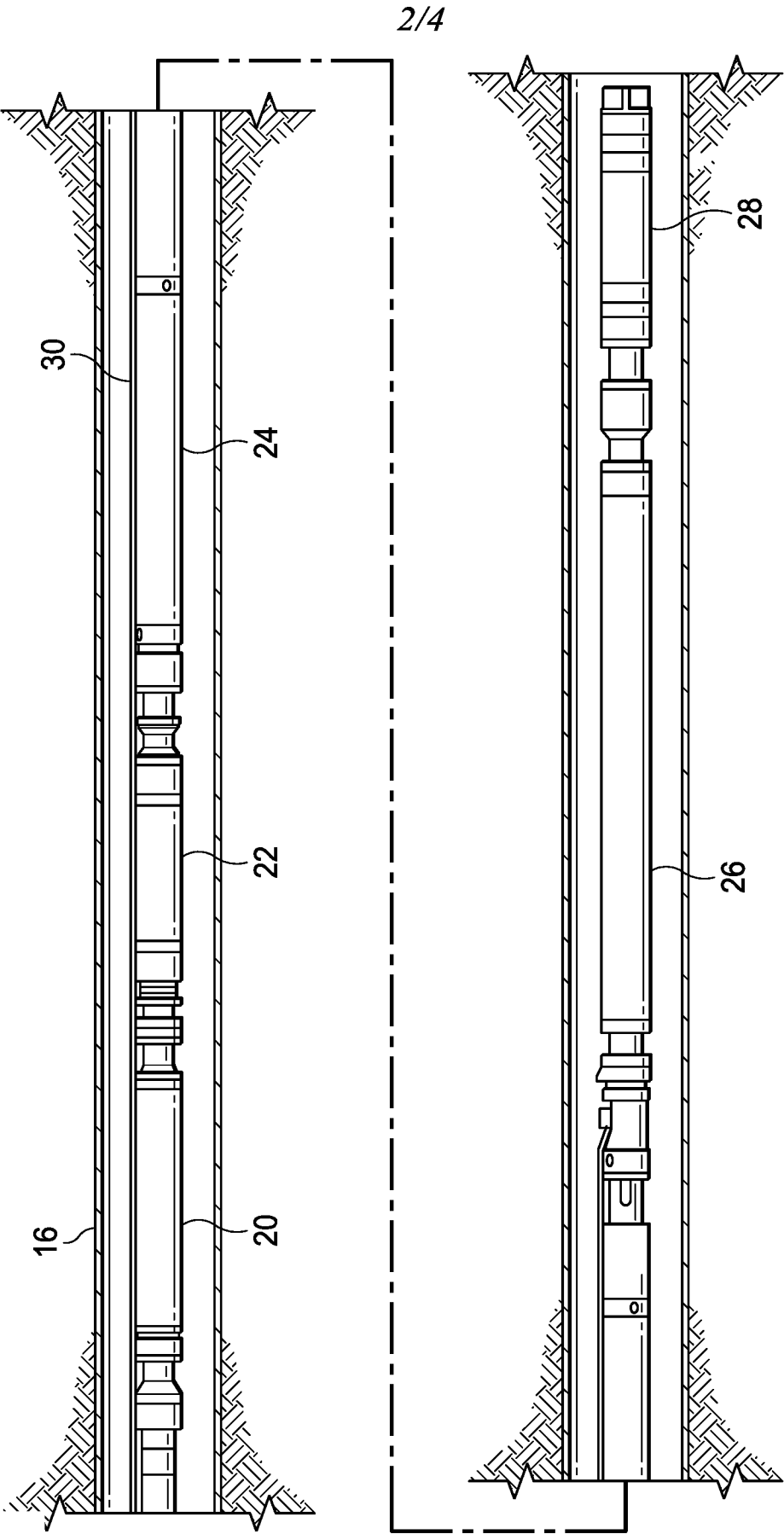
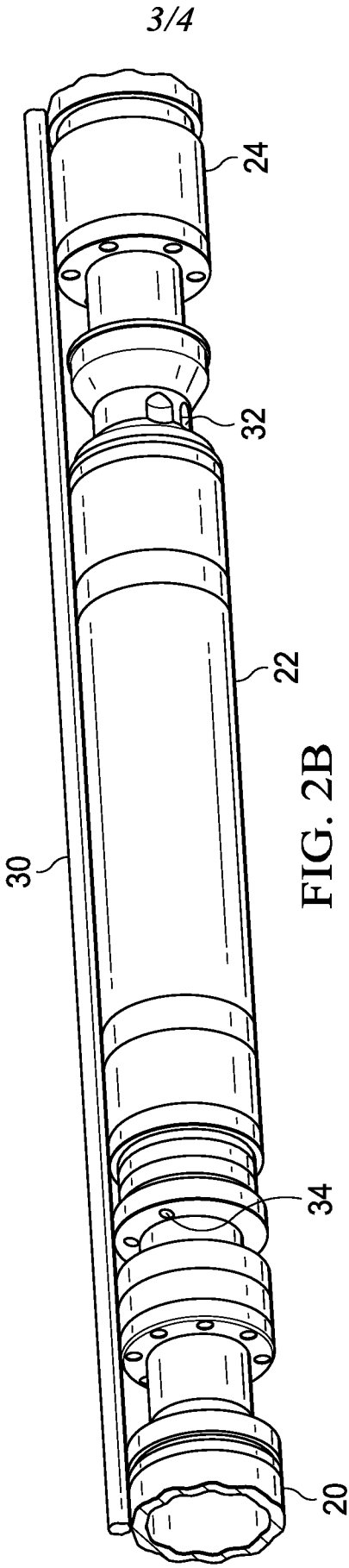


FIG. 1





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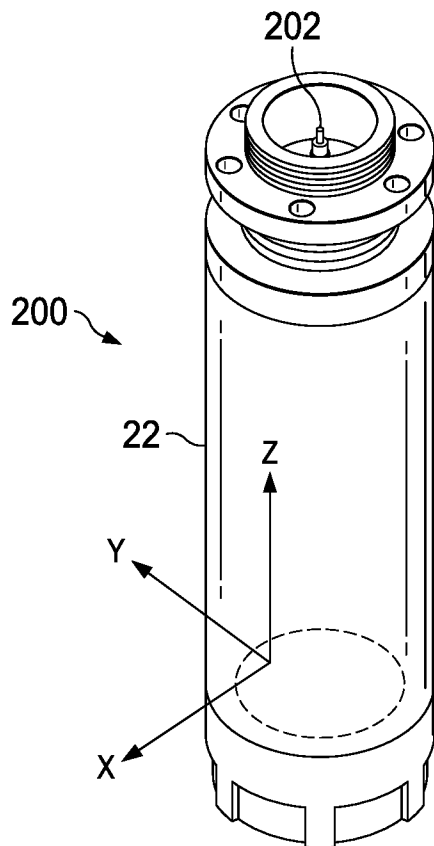


FIG. 3A

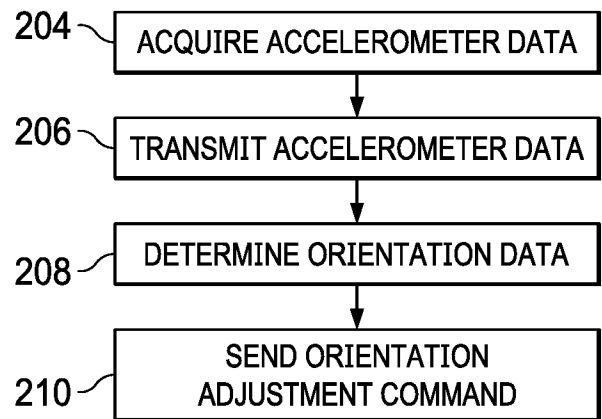


FIG. 3B

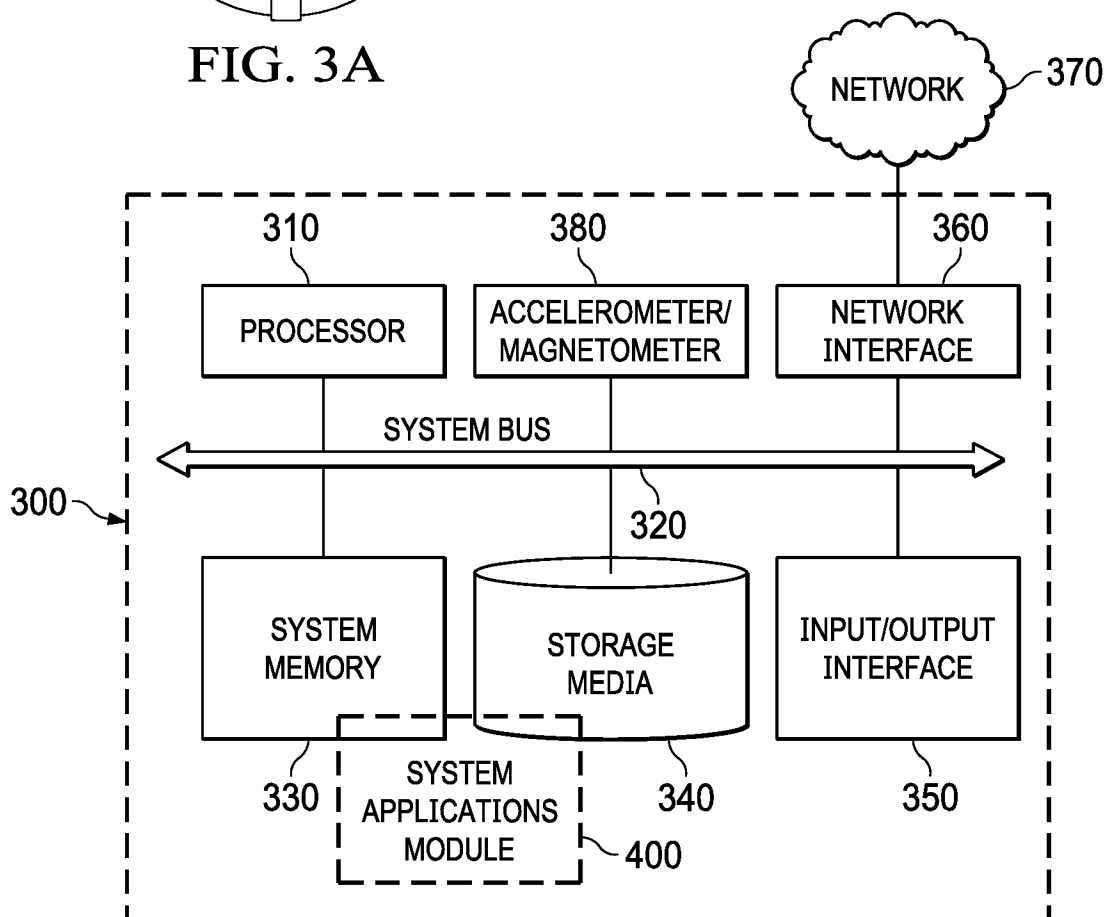


FIG. 4

A. CLASSIFICATION OF SUBJECT MATTER**E21B 43/12(2006.01)i, E21B 47/09(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 43/00; E21B 47/00; E21B 47/024; E21B 47/06; F04B 47/06; F04B 49/06; E21B 47/09

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, intake port, discharge port, accelerometer, orientation, data acquisition system

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0319911 A1 (REID et al.) 23 December 2010 See paragraphs [0023], [0033]-[0034], claims 18, 24, and figures 1A-1C.	1-20
Y	GB 2475074 A (OXFORD MONITORING SOLUTIONS LIMITED) 11 May 2011 See page 7, lines 11-20, page 9, lines 18-26 and figures 1-2.	1-20
A	US 2017-0096889 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 06 April 2017 See paragraph [0183] and figure 19.	1-20
A	US 2005-0173114 A1 (CUDMORE et al.) 11 August 2005 See claim 1 and figure 2.	1-20
A	WO 2016-205100 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION et al.) 22 December 2016 See claim 1 and figure 1.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

24 May 2019 (24.05.2019)

Date of mailing of the international search report

27 May 2019 (27.05.2019)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/048572

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