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(54) Title: METHOD FOR PROVIDING POWER TO SLIDING SLEEVE SYSTEMS AND/OR OTHER DOWNHOLE DEVICES FOR MULTI-STAGE FRACTURING

(57) Abstract: A multi-zone fracturing system includes at least one device having a power terminal, a central battery receptacle in a wellbore, a coiled tubing, wireline, and/or pump-down battery pack seated in the central battery receptacle, and an electrical connection between the central battery receptacle and the power terminal for transmitting power from the battery pack to the device. Methods of supplying power for multi-zone fracturing systems are also provided.

METHOD FOR PROVIDING POWER TO SLIDING SLEEVE SYSTEMS AND/OR OTHER DOWNHOLE DEVICES FOR MULTI-STAGE FRACTURING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. Section 119(e) to U.S. Provisional Patent Application No. 62/028,011, filed July 23, 2014, and titled “Method for Providing Power to Sliding Sleeve Systems and/or Other Downhole Devices for Multi-Stage Fracturing,” the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present application is related to providing power to sliding sleeve systems and other downhole devices for use in multi-stage fracturing applications.

BACKGROUND

[0003] The vast majority of tight stacked gas sand, tight stacked oil sand, gas shale, and liquids-rich shale developments currently being undertaken by the upstream oil and gas industry require stage fracturing (“stage-frac”) completion processes. Multi-stage fracturing processes involve a single continuous or multiple sequential pumping processes to treat multiple points along a completion interval.

[0004] By far, the majority of these developments use the “Plug n' Perf” stage-frac method because there is a need for cemented production casing completions and a desire to have a large number of fracture initiation points in order to maximize the volume of low permeability hydrocarbon-bearing reservoir rock contacted by the horizontal wellbore and associated hydraulic fracture network. In addition, the “Plug n’ Perf” method is commonly used because there is already significant industry experience and infrastructure to accommodate the completions method. A number of suitable multi-stage fracturing systems exist in the industry today. For instance, a multi-stage fracturing system can include ball-drop actuated frac sleeves, a pressure actuated sleeve, articulated or collapsible ball seats, a downhole tool actuation triggered by a control line or radio frequency identification (RFID), and dissolvable frac balls and plugs. Each frac sleeve may contain a downhole battery to provide power for actuation of the ball seat and/or triggering the frac sleeve to open and/or close at the right time. These frac sleeves may sometimes be referred to as electronic programmable frac sleeves. In certain instances, a permanent control line is installed in the annulus of the production casing and borehole and extends from the surface to the last frac sleeve nearest to the end of the well in order to supply power to each of the programmable frac sleeves which require a certain amount of electrical energy to initiate the opening or closing action of each sleeve.

[0005] In some scenarios, the power needed to control the multi-stage fracturing system may be compromised. For instance, the power in the downhole batteries of a frac sleeve may become too weak to actuate the tool functions after an extended period of time (i.e., more than six months for wells batch drilled and completed from multi-well pad sites), thus causing concern that insufficient battery power will be available in each frac sleeve when it is time to "wake" the tools up (i.e., with a pressure pulse) in preparation for commencing multi-stage frac operations on the well. Alternatively, power can be compromised if the permanent control line installed between the surface and the frac sleeves becomes severed or otherwise compromised. In some well architectures, the need for a production liner (rather than a long string of production casing from surface to the well's total depth (TD)) may make a connection of each frac sleeve to surface via the control line not mechanically feasible.

[0006] Therefore, there exists a need for one or more systems that can provide power to multi-stage fracturing tools requiring a downhole power supply.

SUMMARY

[0007] The present disclosure relates to providing power to sliding sleeve systems and other downhole devices for use in multi-stage fracturing applications. In an example embodiment, a multi-zone fracturing assembly for a wellbore includes a tubular structure positioned within the wellbore and defining an internal bore, wherein the tubular structure includes a plurality of sections for hydraulic fracturing. Each section includes a sliding sleeve disposed in the bore and being movable from a closed condition to an open condition. The sliding sleeve includes a power terminal. The multi-zone fracturing assembly further includes a central battery receptacle positioned in the wellbore, a battery pack seated in the central battery receptacle, and an electrical connection between the central battery receptacle to each power terminal. The battery pack supplies power to each sliding sleeve by way of the electrical connection to provide power for telemetry systems (e.g., RFID receivers) and/or actuation

devices (e.g., atmospheric chambers or wave springs) to trigger movement of the sliding sleeve from a closed condition to an open condition.

[0008] In another example embodiment, a method of supplying power to a multi-zone fracturing system for a wellbore includes disposing a multi-zone fracturing assembly in the wellbore, wherein the multi-zone fracturing assembly includes at least one device requiring power. The at least one device includes a power terminal. The method further includes disposing a central battery receptacle in the wellbore, wherein the central battery receptacle is electrically connected to the power terminal. Further, the method includes deploying a battery pack through the wellbore and seating the battery pack within the central battery receptacle. The method also includes transmitting power from the battery pack to the at least one device via the electrical connection.

[0009] In yet another example embodiment, a multi-zone fracturing assembly for a wellbore includes a tubular structure positioned within the wellbore and defining an internal bore, wherein the tubular structure comprises a plurality of sections for hydraulic fracturing. Each section includes at least one component requiring power for actuation, wherein each section includes a power terminal. The multi-zone fracturing assembly further includes a central battery receptacle positioned in the wellbore and a battery pack seated in the central battery receptacle. The multi-zone fracturing assembly also includes an electrical connection between the central battery receptacle to each power terminal, wherein the battery pack supplies power to each component by way of the electrical connection to actuate the component.

[0010] These and other aspects, objects, features, and embodiments will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0012] FIG. 1A illustrates a multi-stage fracturing system that includes a pump down battery pack according to an example embodiment;

[0013] FIG. 1B illustrates a multi-stage fracturing system that includes a battery pack lowered using coiled tubing, a wireline-conveyed tractor device, or another similar device according to an example embodiment;

[0014] FIG. 2 illustrates the multi-stage fracturing system of FIG. 1A with a pressure actuated sleeve opened, but prior to initiating the battery pump down operation according to an example embodiment;

[0015] FIG. 3 illustrates the system of FIG. 1A after deployment of the pump down battery pack having a flow through by-pass and then deployment of ball seat of the frac sleeve according to an example embodiment;

[0016] FIG. 4 illustrates a frac ball that is deployed toward the ball seat of the frac sleeve of the system of FIG. 3 by pumping proppant-free displacement fluid into the pressure-actuated toe sleeve according to an example embodiment;

[0017] FIG. 5 illustrates the system of FIG. 4 with the frac ball positioned on the ball seat of the frac sleeve which has then been opened by applying pressure applied against the frac ball and after deployment of ball seat of frac sleeve according to an example embodiment;

[0018] FIG. 6 illustrates the system of FIG. 5 with a frac ball that is deployed toward the ball seat of the frac sleeve according to another example embodiment;

[0019] FIG. 7 illustrates the system of FIG. 6 with the frac ball positioned on the deployed ball seat of the frac sleeve according to an example embodiment;

[0020] FIG. 8 illustrates the system of FIG. 1A with frac balls positioned on respective deployed ball seats according to an example embodiment; and

[0021] FIG. 9 illustrates the wellbore of FIG. 8 with degraded or dissolved frac balls according to an example embodiment.

[0022] The drawings illustrate only example embodiments and are therefore not to be considered limiting in scope. The elements and features shown in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the example embodiments. Additionally, certain dimensions or placements may be exaggerated to help visually convey such principles. In the drawings, reference numerals designate like or corresponding, but not necessarily identical, elements.

DETAILED DESCRIPTION OF THE EXAMPLE EMBODIMENTS

[0023] The systems and methods of the present application include a multi-stage fracturing system having a central battery receptacle for receiving a battery pack via a pump-down, a wireline-conveyance, or coiled tubing-conveyance operation for providing power to sliding sleeve systems for use in multi-stage fracturing applications and other downhole devices. These devices can include electronic programmable frac sleeves, which are triggered using one or more of a number of different telemetry systems (e.g., RFID, electro-magnetic (EM), magnetic counters, and acoustic), RFID receiver subs, EM transmitting and receiving subs, downhole pressure/temperature gauges, and/or other downhole tools and sensors requiring power which are related to the stage-frac completion. Furthermore, these downhole devices requiring power may be deployed in wells permanently or on a temporary basis. The battery pack can be used as a contingency option to address an event where a power source in each frac sleeve or other downhole device requiring power is not sufficient to operate the tool as designed or as an alternative to configuring each device requiring power with permanent downhole batteries for power. The battery pack can also support other systems like downhole pressure/temperature or other recording devices built into the battery pack or elsewhere in the frac string/liner.

[0024] In the following paragraphs, particular embodiments will be described in further detail by way of example with reference to the drawings. In the description, well-known components, methods, and/or processing techniques are omitted or briefly described. Furthermore, reference to various feature(s) of the embodiments is not to suggest that all embodiments must include the referenced feature(s).

[0025] FIG. 1A illustrates a multi-stage fracturing system that includes a pump down battery pack 106 according to an example embodiment. In some example embodiments, the multi-stage fracturing system of FIG. 1A includes the pump down battery pack 106, a pressure actuated sleeve 110, ball-drop actuated frac sleeves 112-122, and articulated or collapsible ball seats 132-142, which are commanded to deploy using one of a variety of wireless telemetry options such as RFID, EM, acoustic, or magnetic ball counter or via an electronic, hydraulic or fiber optic control line from surface. The multi-stage fracturing system may also include dissolvable frac balls as explained below.

[0026] Generally, each frac sleeve 112-122 is electrically coupled together and wired to a central battery receptacle 108 located near the toe or end of a wellbore 102. The receptacle 108 is run with the casing along with the frac sleeves 112-122. The receptacle 108 has a small internal diameter restriction to allow for seating the battery pack 106. The receptacle 108 has a large bypass 150 to allow passage of a cement wiper plug and fluid to flow therethrough. In general, the size of the bypass 150 is larger than shown in FIG. 1A to allow passage of a cement wiper plug and fluid to flow therethrough. In some example embodiments, the central battery receptacle 108 has a fixed internal profile for receiving the battery pack 106. Alternatively, the receptacle 108 may have an internal profile for receiving the battery pack 106 that is deployed after installation in the wellbore 102.

[0027] In certain exemplary embodiments, each frac sleeve 112-122 is wired together using a wiring 124 via an insulated and protected conduit located in the annulus defined by a casing or a liner defining an internal bore 104 and the wellbore 102. The wiring 124 used to electrically connect the frac sleeve 112-122 may or may not extend to the surface at the top of the wellbore 102. In some example embodiments, an electrical connection between each frac sleeve 112-122 and the central power receptacle 108 can be made using wiring through the casing or liner itself. The wiring 124 can daisy chain between the battery and/or power inlet of each frac sleeve 112-122 and the central battery receptacle 108. The central battery receptacle 108 is configured to receive the battery pack 106 for providing power to the frac sleeves 112-122 and any other downhole devices that need power. The battery pack 106 may also have a bypass to allow fluid to flow therethrough after seating the battery pack 106 into the receptacle 108.

[0028] In certain exemplary embodiments, the pump-down battery pack 106 is a high capacity battery pack. In some alternative embodiments, a battery pack conveyed via wireline and/or coiled tubing may be used instead of the pump-down battery pack 106 without departing from the scope of this disclosure. The battery pack 106 can be designed to be left in the wellbore 102 permanently or can be designed to be retrieved, i.e., via a coil tubing retrieval tool. In addition, the system could be designed to stack multiple batteries to provide additional power to the frac sleeves 112-122 and/or other downhole electronic equipment that is electrically connected to the central power receptacle 108. In certain embodiments, it may be advantageous to position the central battery receptacle 108 at a location other than near the toe of a horizontal well (for instance, near the build section of a horizontal well), which could receive retrievable battery packs for recharging permanent batteries in certain downhole tools, such as in each frac sleeve 112-122. It may also be beneficial to include more than one battery receptacle 108 in a horizontal well as a contingency in the event the receptacle located near the toe of the wellbore 102 becomes compromised.

[0029] After running the production casing or liner and just prior to rigging up the frac pumping equipment, the battery pack 106 can be conveyed into the wellbore 102 using a pump-down operation. As described below with respect to FIG. 1B, in some alternative embodiments, the battery pack 106 can be conveyed into the wellbore 102 using a wireline conveyance tool or using coiled tubing. The battery pack 106 is then seated in the central battery receptacle 108 below the first frac sleeve 112 requiring downhole power located near the casing shoe. In certain exemplary embodiments, each frac sleeve 112-122 is associated with a unique radio frequency identification (RFID) code or other unique identification protocols associated with other options for telemetry commands to and from the surface to the downhole tools (e.g. 2-way through-earth EM).

[0030] In some example embodiments, once the battery pack is released, a wireline conveyance tool can verify if the battery pack 106 is properly seated in the central battery receptacle 108, if each frac sleeve 112-122 has been successfully connected to power from the battery pack 106, and/or if a control line is effectively installed to transmit to the frac sleeve 112-122. If multiple battery receptacles or landing sites have been run in the casing string or production liner, the process to seat a retrievable battery pack could including selecting which battery receptacle will be used. In this way, if a frac sleeve's connection to the lowermost receptacle becomes damaged or otherwise compromised, power could possibly be reestablished using a different battery receptacle located further towards the surface of the well (for instance, near the build section of the horizontal well). Utilizing a code interrogation logging device in the wireline conveyance tool allows a user to know the unique RFID, EM or other unique code programed within a certain frac sleeve, its location, as well as its operational status. This would allow the operator to run the programmable frac sleeves 112-122 in any order and still provide verification of the unique code position for each sleeve prior to stimulation, as long as each frac sleeve was programmed using unique codes prior to running the sleeves in the hole.

[0031] In certain exemplary embodiments, each frac sleeve 112-122 has a power terminal to make an electrical connection for receiving power. In some example embodiments, the electrical connections between the power terminal of each frac sleeve 112-122 and the central power receptacle 108 may utilize inductive coupling technology in order to avoid splicing wires and sealing electrical connection points at each sleeve. Furthermore, electrical connections between the battery pack 106 and the central power receptacle 108 could also be made using electromagnetic coupling (induction) or via a simple plug-in device. In certain embodiments, a direct current (DC) may be converted to an alternating current (AC) to facilitate inductive coupling.

[0032] The multi-stage fracturing system of the present application can also include a wireline conveyed recharging instrument pumped or tractored into the well in order to re-energize rechargeable downhole batteries that may be included in one or more of the frac sleeves 112-122 independently or re-energize the battery pack 106 seated in the central power receptacle 108, for example, using electromagnetic inductive coupler technology.

[0033] FIG. 1B illustrates a multi-stage fracturing system that includes a battery pack lowered using coiled tubing, a wireline-conveyed tractor device, or another similar device according to an example embodiment. The system of FIG. 1B is similar to the system of FIG. 1A except that, in FIG. 1B, the battery pack 106 and the receptacle 108 are below (to the right of) all frac sleeves 112-122 and 140. To illustrate, the frac sleeve 140 may be the same type of frac sleeve (e.g., a ball-drop actuated frac sleeve) as the frac sleeves 112-122 instead of a pressure actuated frac sleeve such as the frac sleeve 110 of FIG. 1A. For example, the battery pack 106 may provide power to the frac sleeve 140 via the wiring 124 for enabling communication protocols from surface and actuation of the deployment of the ball seat of the frac sleeve 140 or actuation of a device that opens frac sleeve 140 (e.g., triggering exposure of an atmospheric chamber of hydrostatic pressure driving a piston to slide the sleeve open).

[0034] After running the production casing or liner and just prior to rigging up the frac pumping equipment, the battery pack 106 of FIG. 1B can be conveyed into the wellbore 102 using a wireline conveyance tool and/or using coiled tubing. In certain exemplary embodiments, the wireline conveyance tool may have RFID/logging capability. The battery pack 106 is then seated in the central battery receptacle 108 below the first frac sleeve 112 requiring downhole power located near the casing shoe. The wireline and/or coiled tubing conveyance methods are alternatives to the pump-down method described with respect to FIG. 1A. In some example embodiments, the wireline and coiled tubing conveyance methods may provide some benefits including better control on the speed of conveyance, larger battery size, assurance of depth, and reduced risk of damage when the battery pack 106 is carefully and slowly seated in the central battery receptacle 108. In some example embodiments, the battery pack 106 could be conveyed into the wellbore 102 and seated into the central battery receptacle 108 using coiled tubing having electric line contained within the inside of the coiled tubing. If wireline is not available within the coil tubing, interrogation of the function of downhole tools could be made using downhole memory tools with the coil tubing bottomhole assembly. Also, the setting/releasing of the battery pack 106 into the central battery receptacle 108 could be done using a pressure-actuated triggering device. In certain exemplary embodiments, each frac sleeve 112-122, 140 of FIG. 1B is associated with a unique radio frequency identification (RFID) code or other unique identification protocols associated with other options for telemetry commands to and from the surface to the downhole tools (e.g. 2-way through-earth EM).

[0035] After the battery pack 106 is attached to the receptacle 108, the battery pack 106 may provide power to the sleeves 112-122, 140 in a similar manner described with respect to the system of FIG. 1A.

[0036] FIG. 2 illustrates the multi-stage fracturing system of FIG. 1A with the pressure actuated sleeve 110 opened, but prior to initiating the battery pump down operation according to an example embodiment. The bypass 150 of the receptacle 108 allows for the pressure actuated sleeve 110 to be opened by providing a flow path to the frac sleeve 110. Referring to FIGS. 1A and 2, generally, each programmable frac sleeve 112-122 is designed such that its ball seat 132-142 can be deployed on command via a unique telemetry signal initiated from an action at surface at the proper time in the stage-frac process. RFID technology can be used for such telemetry commands, but other telemetry systems known by those skilled in the art could also be used. Once the frac sleeves 112-122 have been deployed in the wellbore 102, which may be cemented or uncemented, the frac process initiates out the pressure actuated toe sleeve 110. In general, a unique surface command can trigger the deployment of each ball seat 132-142 via electromagnetic, RFID tags embedded in a frac ball or frac fluid, via electronic ball counters, or via a copper wire communication to IP addressable micro-switch in the frac sleeves 112-122 to trigger exposure of an atmospheric chamber of hydrostatic pressure, a spring, or other potential energy device to drive a piston in order to deploy the ball seat.

[0037] FIG. 3 illustrates the system of FIG. 1A after deployment of the pump down battery pack 106 having a flow through by-pass and then deployment of ball seat 132 of the frac sleeve 112 according to an example embodiment. For example, the battery pack 106 may provide power to frac sleeve 112 via the wiring 124 for enabling communication protocols from surface and actuation of the ball seat 132 deployment.

[0038] FIG. 4 illustrates a frac ball 402 that is deployed toward the ball seat 132 of the frac sleeve 112 of the system of FIG. 3 by pumping proppant-free displacement fluid into the pressure-actuated toe sleeve 110 according to an example embodiment. In some example embodiments, the frac ball 402 may have an RFID tag number (e.g., tag #2). The frac ball 402 may be dissolvable or degradable to allow fluid to travel to the surface as explained below.

[0039] FIG. 5 illustrates the frac ball 402 positioned on the ball seat 132 of the frac sleeve 112 according to an example embodiment. Referring to FIGS. 4 and 5, using the flowpath created down the casing from surface through the bypass in the pump down battery 106 and out the previously opened pressure-actuated frac sleeve 110, the frac ball 402 is pumped down and lands on the electronically deployed ball seat 132 of the frac sleeve 112. As the frac ball 402 having a particular RFID tag (e.g., tag #2) passes by the frac sleeve 114, the ball seat 134 may be deployed as shown in FIG. 5. The battery back 106 may provide power to the frac sleeve 114 via the wiring 124 to enable communications to and from the surface (e.g., for telemetry commands and/or tool status and diagnostics reporting) and triggering deployment of the ball seat 134. After the frac ball 402 is positioned on the ball seat 132, pressuring up against the frac ball 402 opens the frac sleeve 112.

[0040] In some example embodiments, during the displacement of the frac stage, which is pumped through the ball-drop frac sleeve 112, a signal may be sent (for instance, via a unique RFID tag embedded within the dissolvable frac ball 402) triggering a mechanism to form the ball seat 134 within the programmable frac sleeve 114 having the deployable ball seat 134 above and adjacent to the frac sleeve 112. In certain exemplary embodiments, the mechanism to form the ball seat 134 includes opening a valve such that hydrostatic pressure floods an atmospheric pressure chamber that drives a piston to collapse the ball seat 134. In other embodiments, the mechanism includes a pneumatic chamber activated by a valve opening that then drives a piston to collapse the ball seat 134. In yet another embodiment, the mechanism includes a fuse comprised of Kevlar or other high strength material that is designed to release the kinetic energy of a spring that drives the ball seat 134 to deploy upon receiving the unique RFID triggering command. A combination of these methods could be used to permit simultaneously or scheduled opening of multiple valves and isolating previously open valves with a single RFID triggering command and/or the frac ball 402. RFID technology can be used for such telemetry commands, but other telemetry systems known by those skilled in the art could also be used.

[0041] FIG. 6 illustrates a frac ball 602 that is deployed toward the ball seat 134 of the frac sleeve 114 according to an example embodiment. As illustrated in FIG. 6, as the frac ball 602 travels toward the ball seat 134 of the frac sleeve 114, the frac ball 602 typically pumped down the well using proppant-free displacement fluid displaces slurry into the frac sleeve 112. The slurry as well as other fluid is pushed past the deployed ball seat 134 of the frac sleeve 114 toward the frac sleeve 112. The frac ball 602 may have an RFID tag number (e.g., tag #3). The frac ball 602 may be dissolvable or degradable to allow fluid to travel to the surface as explained below.

[0042] FIG. 7 illustrates the frac ball 602 positioned on the ball seat 134 of the frac sleeve 114 according to an example embodiment. The ball seat 136 of the frac sleeve 116 is already deployed as shown in FIG. 7. In some example embodiments, the ball seat 136 may have been deployed in a similar manner described with respect to the ball seat 134 of the frac sleeve 114. The frac ball 602 is positioned on the ball seat 134, and the frac ball 702 is positioned on the ball seat 136. In some example embodiments, triggering of ball seat deployments and enabling the related telemetry commands from surface is performed using power from the battery pack 106.

[0043] FIG. 8 illustrates frac balls 402, 602, 702, 802, 902 positioned on respective ball seats 132, 134, 136, 140, 142 according to an example embodiment. As illustrated in FIG. 8, the ball seats 132, 134, 136, 140, 142 are deployed. The power to actuate the electronic programmable frac sleeves (e.g., by deploying the ball seats 132, 134, 136, 140, 142 at the desired time during the stage-frac process) may be provided by the battery pack 106 via the wiring 124. In some example embodiments, one or more ball seats (e.g., ball seat 138 of the frac sleeve 118) may be intentionally left collapsed. Because all of the frac balls 402, 602, 702, 802, 902 and ball seats 132, 134, 136, 140, 142 (upon collapse) are exactly the same size, a large number of frac stages may be deployed in the wellbore 102. In general, dissolvable frac balls having exactly the same size as previous pumped frac balls may be pumped to land on the first frac sleeve having a previously collapsed ball seat. The frac process described above may be repeated as a very efficient continuous pumping operation until all of the frac stages are completed, at which time the frac balls are designed to degrade or dissolve with time and temperature to allow the wellbore to be flowed back as shown in FIG. 9 without a post frac millout operation.

[0044] It is contemplated that the frac sleeves 112-122 in FIG. 1A could be configured for use in applications where only a single frac entry point is required or desired for each discrete frac stage or where multiple frac entry points are preferred for a discrete frac stage.

[0045] The multi-stage fracturing system of the present application is advantageous over conventional frac systems for a number of reasons. For instance, power is available from the pump-down battery pack 106 even after the battery energy stored in each frac sleeve 112-122 is not sufficient to operate the tool. Also, using a pump down battery pack 106 as a contingency power system to downhole batteries in each programmable frac sleeve 112-122 and/or in the event of a control line failure on systems that have control line running to each frac sleeve 112-122 from surface. The pump-down battery will facilitate batch drilling and completion operations from multi-well pad sites, where the duration from the time the programmable frac sleeves 112-122 are run to when the tools are activated for frac work could exceed the capabilities of downhole batteries run as a component within each programmable frac sleeve (e.g., duration of several months to more than a year).

[0046] In addition, the present system can be incorporated with downhole monitoring, and more specifically, a telemetry package can be added to the system that would be coupled with the battery pack 106 and physically recovered at the end of a job to obtain downhole data at one or more places in the horizontal wellbore. Alternatively, a sampling of data (due to low communications baud rates) could be transmitted to surface during the fracturing operation. This could be facilitated by more advanced or powerful telemetry package at the battery pack locations or at more favorable locations along the path connected by wiring 124.

[0047] A pump-down battery pack 106 could recharge existing batteries located within each sleeve 112-122 so that control line failures during hydraulic fracturing operations do not impact operations.

[0048] Installation of the total system may be simplified because the exact order of how each programmable frac sleeve 112-122 is run (i.e., each sleeve having a unique code for RFID, EM or other communication technology) would not be important since the location of each sleeve having a unique code could be interrogated, for example, via a wireline tool used to run the pump-down battery pack 106. In addition to confirming the location of each programmable frac sleeve 112-122 having a unique RFID code in the wellbore 102, potential equipment problems could be detected and mitigation plans could be developed prior to commencing hydraulic fracture stimulation operations.

[0049] Furthermore, the present system allows the use of production liner systems rather than production casing strings run from surface which could lower cost. However, in cases where production casing is run from surface along with a control line run from surface with connections to each programmable frac sleeve 112-122 for power, the pump-down battery pack 106 could be used as a backup if the control line to surface fails. In addition, the battery pack 106 could be used to power downhole monitoring systems for extended periods after the fracturing operation to accommodate start-up and/or early production operations. In this application, a battery receptacle (similar to the battery receptacle 108) with a sufficiently large bypass area could be located near the heel of the well (< 45° inclination) to facilitate wireline operations without having to pump-down the battery packs. Also, if the battery receptacle 108 is located in the angle build section of the wellbore, the size of the battery pack 106 could be longer and/or larger which would enable the battery pack 106 to have more insulation / protection from the hostile well environment and would also promote better flow characteristics. Furthermore, such battery receptacle 108 located near the heel of the well could be used to accept a retrievable battery pack 106 for recharging existing downhole batteries in frac sleeves 112-122 or other downhole tools prior to initiating stage fracturing operations should a line failure in the lateral occur thus permitting recharging “from above” or “from below” a failure point of the electrical connection caused during installation.

[0050] The present description may also enable the use of lower cost downhole batteries since the pump-down battery pack 106 could be installed immediately before commencement of the fracturing operations. In conventional systems requiring downhole power to operate frac sleeves 112-122, the batteries installed in each frac sleeve 112-122 and run in the well upon the initial running of the production casing or liner must maintain an adequate electric charge at downhole conditions until frac operations commence. The time between initially running the frac sleeves 112-122 with the production casing or liner and initiating hydraulic fracturing operations could be several months up to a year in duration. It is likely these batteries installed in each frac sleeve 112-122 would be more costly to manufacture than a battery pack which is installed in the well immediately before fracturing operations are planned to begin since the electrical energy is not required to be stored over a long period of time in the case of the pump-down battery pack 106.

[0051] Although FIGS. 4-9 are described with respect to the system of FIG. 1A, the descriptions of FIGS. 4-9 are generally applicable to the system of FIG. 1B. Further, although the descriptions of the multi-stage fracturing systems/assemblies of FIG. 1A and 1B are focused on the sleeves 110-122, 140 and the ball seats 132-142, in other embodiments, the battery pack 106 may be used to provide power to other devices without departing from the scope of this disclosure.

[0052] Although some embodiments have been described herein in detail, the descriptions are by way of example. The features of the embodiments described herein are representative and, in alternative embodiments, certain features, elements, and/or steps may be added or omitted. Additionally, modifications to aspects of the embodiments described herein may be made by those skilled in the art without departing from the spirit and scope of the following claims, the scope of which are to be accorded the broadest interpretation so as to encompass modifications and equivalent structures. One of ordinary skill in the art will appreciate that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-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 nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

CLAIMS

1. A multi-zone fracturing assembly for a wellbore, comprising:

a tubular structure positioned within the wellbore and defining an internal bore, wherein the tubular structure comprises a plurality of sections for hydraulic fracturing, each section comprising a sliding sleeve disposed in the bore and being movable from a closed condition to an open condition, wherein the sliding sleeve comprises a power terminal;

a central battery receptacle positioned in the wellbore;

a battery pack seated in the central battery receptacle; and

an electrical connection between the central battery receptacle to each power terminal, wherein the battery pack supplies power to each sliding sleeve by way of the electrical connection to contribute to actuation of the sliding sleeve from a closed condition to an open condition at a desired time during a multi-stage fracturing operation.

2. The multi-zone fracturing assembly of claim 1, wherein the battery pack is a high capacity battery that is pumped down the wellbore from surface with or without a connection to wireline or coiled tubing extending from the surface to the central battery receptacle during installation.

3. The multi-zone fracturing assembly of claim 1, wherein the central battery receptacle is positioned at or near a toe of the wellbore.

4. The multi-zone fracturing assembly of claim 1, further comprising additional central battery receptacles positioned in the plurality of sections.

5. The multi-zone fracturing assembly of claim 1, wherein the battery pack is retrievable.

6. The multi-zone fracturing assembly of claim 1, wherein multiple battery packs may be seated in the central battery receptacle in stacked fashion.

7. A method of supplying power to a multi-zone fracturing system for a wellbore, comprising:

(a) disposing a multi-zone fracturing assembly in the wellbore, wherein the multi-zone fracturing assembly comprises at least one device requiring power, wherein the at least one device comprises a power terminal;

(b) disposing a central battery receptacle in the wellbore, wherein the central battery receptacle is electrically connected to the power terminal;

(c) deploying a battery pack through the wellbore and seating the battery pack within the central battery receptacle; and

(d) transmitting power from the battery pack to the at least one device via the electrical connection.

8. The method of supplying power of claim 7, wherein the battery pack is deployed with a wireline conveyance tool.

9. The method of supplying power of claim 7, further comprising the step of re-energizing the battery packs.

10. The method of supplying power of claim 7, wherein the central battery receptacle is positioned at or near a toe of the wellbore.

11. The method of supplying power of claim 7, further comprising additional central battery receptacles positioned in the plurality of sections.

12. A multi-zone fracturing assembly for a wellbore, comprising:

a tubular structure positioned within the wellbore and defining an internal bore, wherein the tubular structure comprises a plurality of sections for hydraulic fracturing, each section comprising at least one component requiring power for actuation, wherein each section comprises a power terminal;

a central battery receptacle positioned in the wellbore;

a battery pack seated in the central battery receptacle; and

an electrical connection between the central battery receptacle to each power terminal, wherein the battery pack supplies power to each component by way of the electrical connection to actuate the component.

13. The multi-zone fracturing assembly of claim 12, wherein the at least one component is selected from the group consisting of sliding sleeves, shut-off valves inside the internal bore, and downhole sensors.

14. The multi-zone fracturing assembly of claim 12, wherein the central battery receptacle is positioned at or near a build section of the wellbore.

15. The multi-zone fracturing assembly of claim 12, further comprising additional central battery receptacles positioned in the plurality of sections.

16. The multi-zone fracturing assembly of claim 12, wherein the battery pack is a high capacity battery that is pumped down the well from surface with or without a connection to wireline or coiled tubing extending from the surface to the central battery receptacle during installation.

17. The multi-zone fracturing assembly of claim 12, wherein each component is electrically connected via a daisy chain.

18. The multi-zone fracturing assembly of claim 12, wherein the battery pack is retrievable.

19. The multi-zone fracturing assembly of claim 12, wherein multiple battery packs may be seated in the central battery receptacle in stacked fashion.

20. The multi-zone fracturing assembly of claim 12, wherein the battery pack is rechargeable.

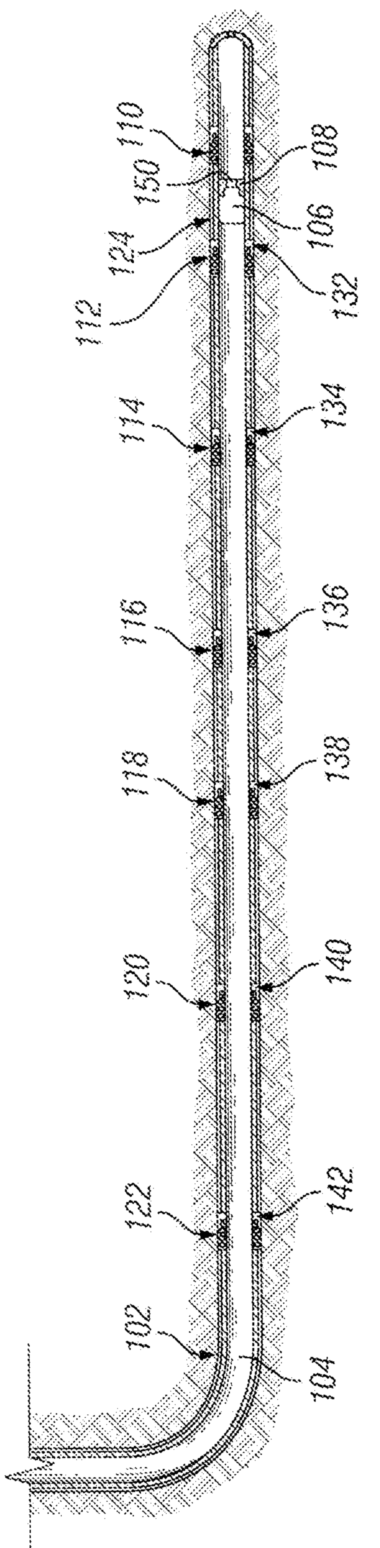
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FIG. 1A

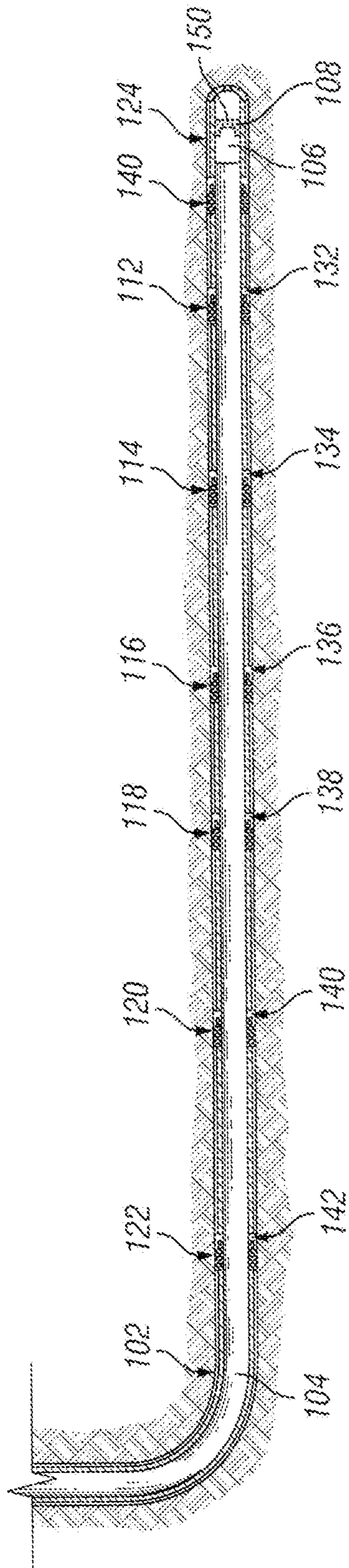
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FIG. 1B

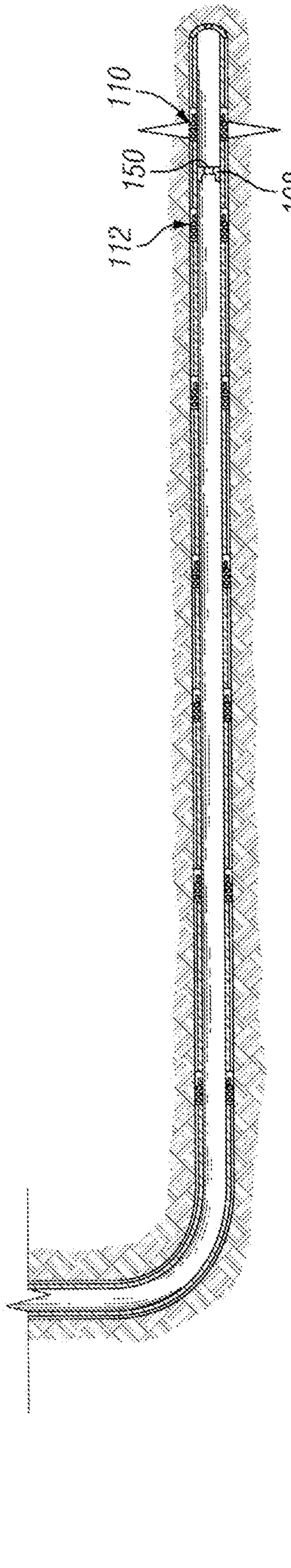

FIG. 2

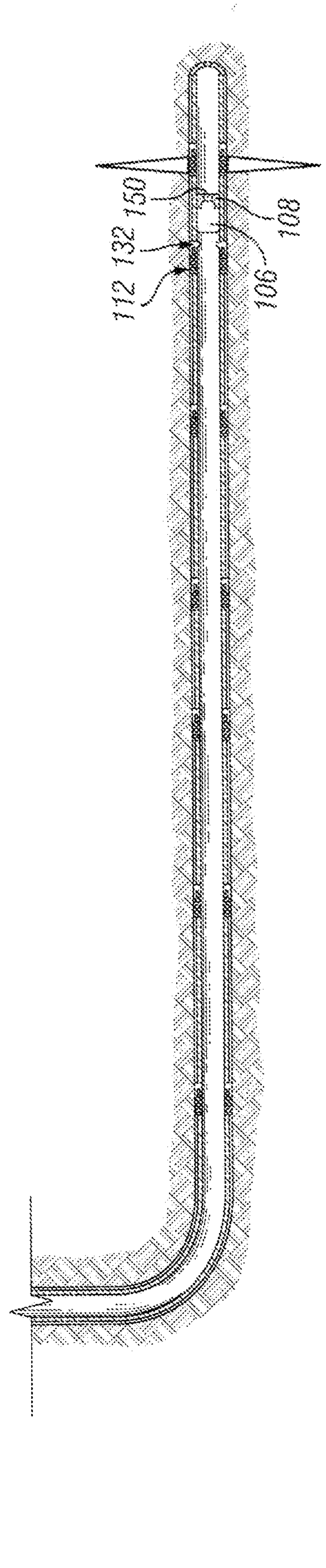

FIG. 3

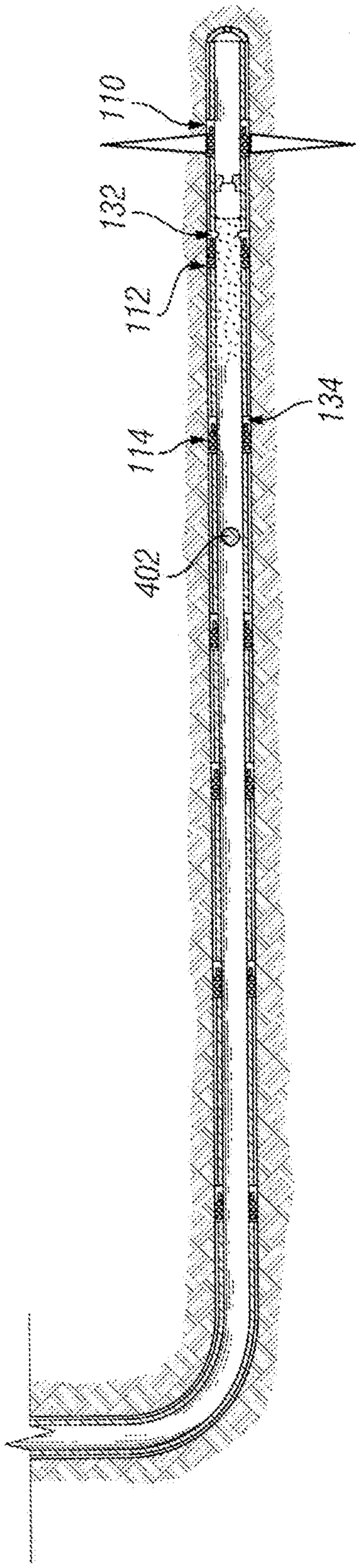

FIG. 4

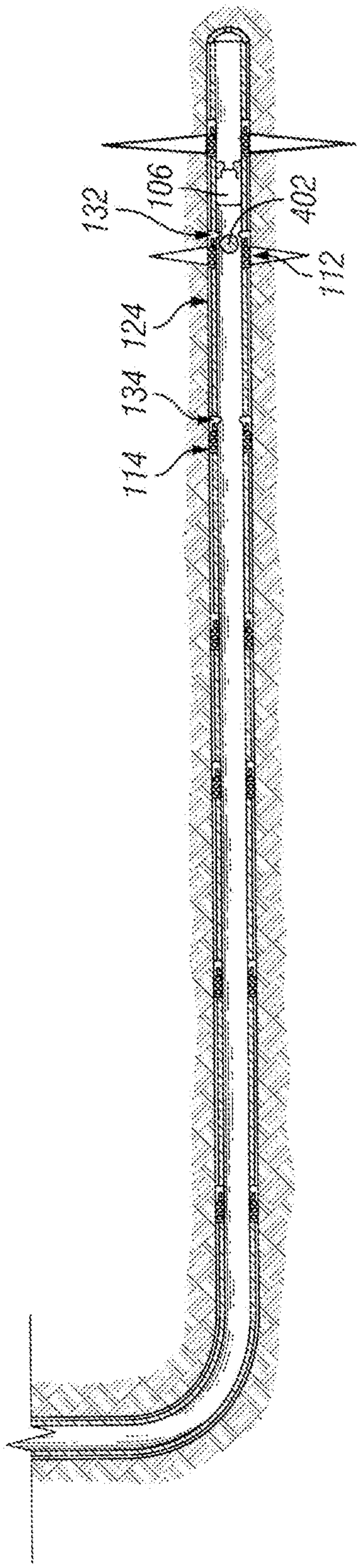

FIG. 5

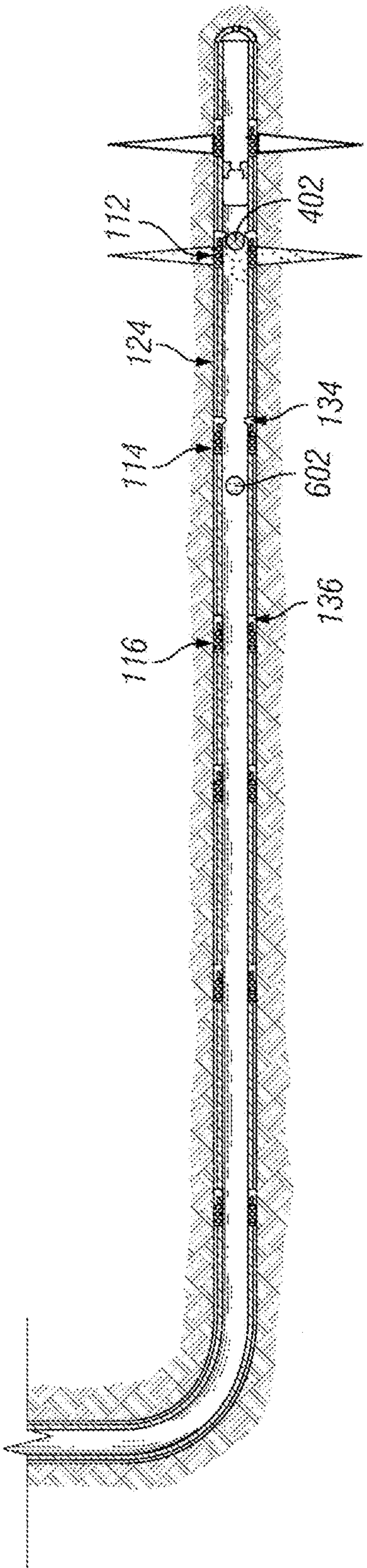
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FIG. 6

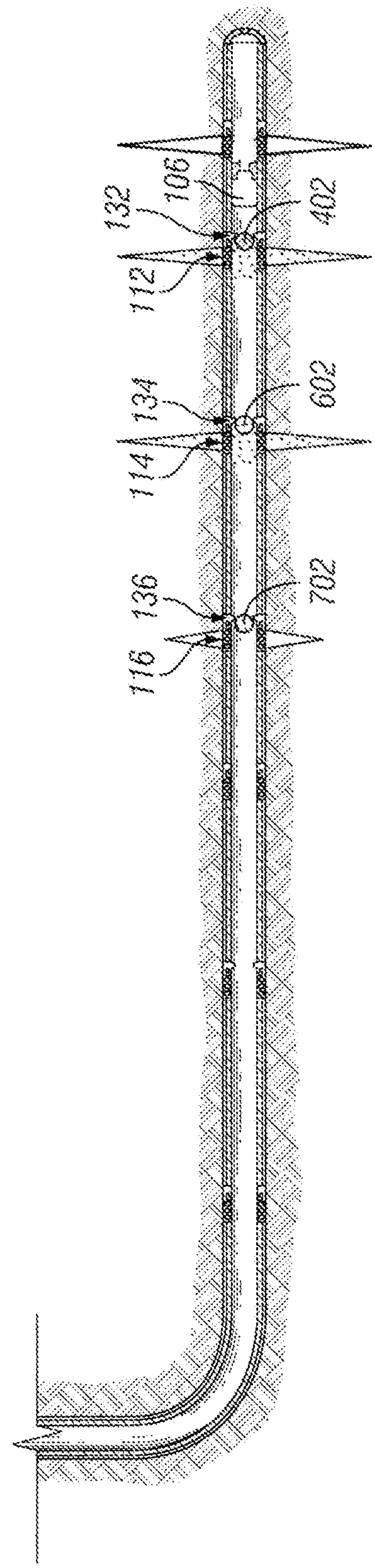
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FIG. 7

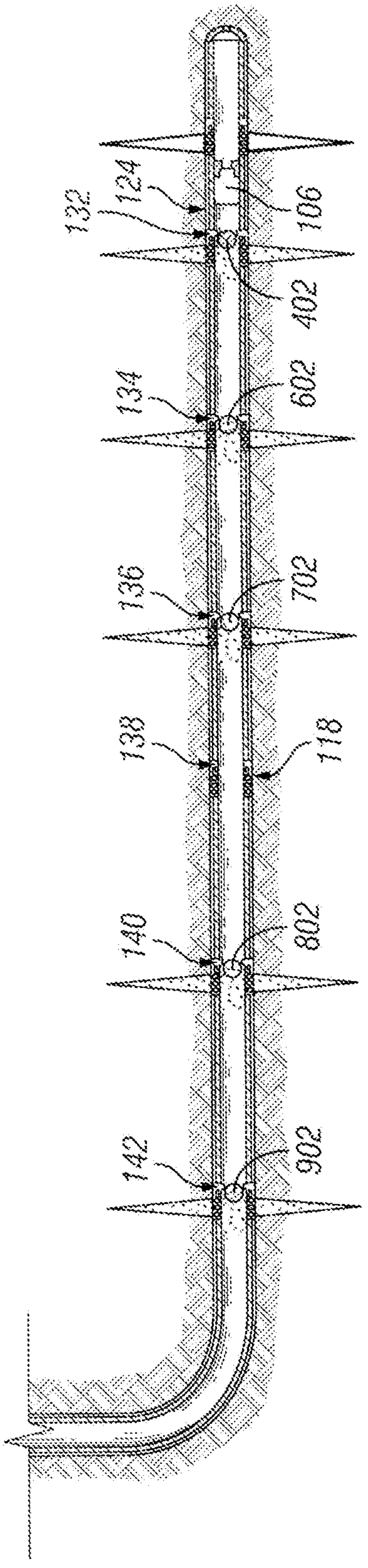

FIG. 8

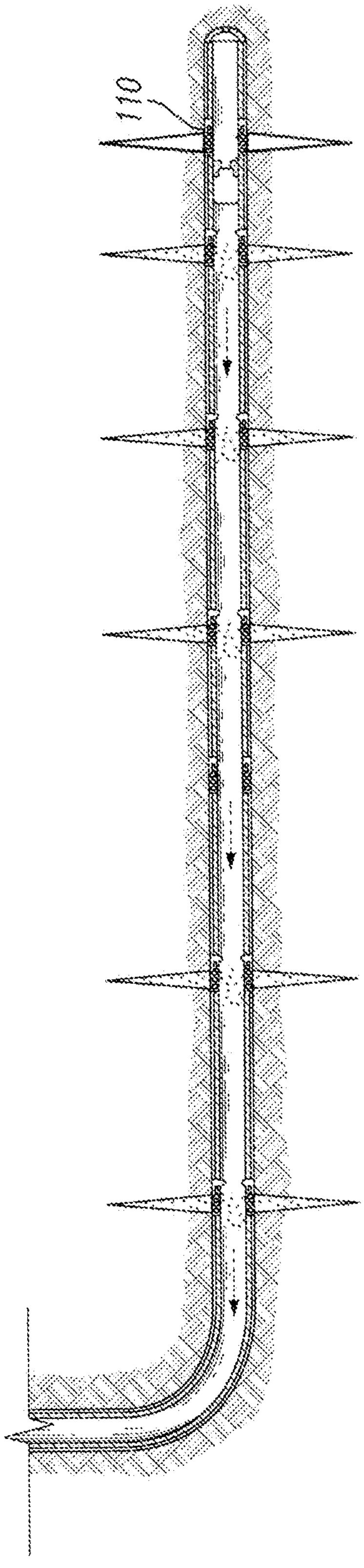

FIG. 9