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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 August 2007 (23.08.2007)

PCT

(10) International Publication Number
WO 2007/094900 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/US2007/000536

(22) International Filing Date: 9 January 2007 (09.01.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/772,067 10 February 2006 (10.02.2006) US

(71) Applicant *(for all designated States except US)*: **EXXONMOBIL UPSTREAM RESEARCH COMPANY** [US/US]; P.O. BOX 2189, Corp-URC-SW348, Houston, TX 77252-2189 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **DALE, Bruce, A.** [US/US]; 7122 Hidden Trails Court, Sugar Land, TX 77479 (US). **CLINGMAN, Scott, R.** [US/US]; 2139 Mcclendon Street, Houston, TX 77030 (US). **YEH, Charles, S.** [US/US]; 9511 Merlins Oaks Court, Spring, TX 77379 (US). **ROSENBAUM, Darren, F.** [US/QA]; 60 AI TAMEEN STREET, Qatar Navigation Building, Doha (QA). **ASMANN, Marcus** [US/US]; 11605 Island Manor Street, Pearland, TX 77584 (US). **MENDEZ-SANTIAGO, Janette** [US/US]; 5806 Larchleaf Lane, Richmond, TX 77469 (US).

(74) Agents: **BROWN, Adam, P.** et al.; EXXONMOBIL UPSTREAM RESEARCH COMPANY, P.O. Box 2189, Houston, TX 77252-2189 (US).

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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

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

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

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FLEXIBLE WELL COMPLETIONS

(57) Abstract: A method of completing a well is described. The well may be a producing well or an injection well. In one embodiment, the method includes identifying technical issues associated with a well; selecting a technology to address each technical issue; defining criteria for each selected technology to determine when to deploy the selected technology in the well, wherein each selected technology remains dormant until the criteria are met; and integrating the technologies into a well completion profile stored in. memory and utilized in the deployment of the technologies into the well. The method provides the ability to proactively address technical issues to reduce workovers and interventions for a well.

WO 2007/094900 A2

FLEXIBLE WELL COMPLETIONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/772,067, filed 10 February 2006.

BACKGROUND

[0002] This section is intended to introduce the reader to various aspects of art, which may be associated with exemplary embodiments of the present invention, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with information to facilitate a better understanding of particular aspects of the present invention. Accordingly, it should be understood that these statements are to be read in this light, and not necessarily as admissions of prior art.

[0003] The production of hydrocarbons, such as oil and gas, has been performed for numerous years. To produce these hydrocarbons from a subsurface formation or basin, one or more wells may be distributed above the subsurface formation to provide access to the subsurface formation. In the wells, tools and equipment, which are generally installed into a well during a completion phase, are utilized to produce hydrocarbons from the wells. In this phase, the tools and equipment are actively utilized to manage the flow of hydrocarbons from the subsurface formation to the surface. Accordingly, by utilizing these tools and equipment, companies produce hydrocarbons from the reserves in the subsurface formations. Further, it may also be desirable to inject water, treatment fluids, or other materials into the well utilizing the tools and equipment indicated above in the completion phase.

[0004] As the demand for hydrocarbons continues to grow, additional challenges are encountered in developing subsurface formations. For instance, to produce hydrocarbons from some subsurface formations, long-

interval completions and/or multilateral technology may be utilized to provide access to multiple subsurface formations with a single well. The use of a long-interval completion may reduce development costs and justify access to certain subsurface formations. In particular, the long-interval completion may justify access to subsurface formations located in remote areas or in deepwater environments.

[0005] However, wells with long, multiple-interval completions typically encounter a number of technical issues that may limit or stop production of the hydrocarbons from the subsurface formation. That is, the extended depth of these wells increases the probability of encountering multiple technical issues, while operating the well over a period of time. These technical issues may reduce productivity, cause mechanical damage to the subsurface/surface equipment, or end production for the well.

[0006] If data is available, these specific technical issues may be compensated for in the design and planning phases. With this approach, each technical issue is typically addressed individually. Unfortunately, the personnel designing a completion may require accurate data to address the technical issues that may be encountered over the life of the well. The lack of data and/or uncertainties in the accuracy of the data precludes reliable predictions, often resulting in completion designs that limit production or require repeated interventions or workovers to maintain a certain level of production. That is, typical well completions can not react to problems encountered during its operation, which results in relying on a well strategy that utilizes remedial interventions or workovers to address problems with the well.

[0007] Some techniques related to designing completion architectures have been disclosed. For example, U.S. Patent Application No. 2002/0177955 discloses a method and apparatus for performing well planning and "general-level" design such as well depth, angle, position, divergence, etc. The patent also discloses use of inflow control devices and valves to

allow operator intervention if an event such as a gas breakthrough should occur. However, the patent fails to disclose the use of technologies that proactively address wellbore issues by remaining dormant until needed and fails to teach the selection and use of a variety of wellbore technologies to address the plurality of technical issues that can and do arise in well completions.

[0008] Accordingly, the need exists for a method or mechanism that may enhance the operation of a well by handling multiple technical issues concurrently, while reducing potential interventions and workovers. Also, the method or mechanism may be proactive instead of reactive by installing technology in the completion initially to enable an automated or instantaneous response to technical issues during the operation of the well.

SUMMARY OF INVENTION

[0009] In one embodiment, a method of completing a well is disclosed. The method includes identifying technical issues associated with a well. Then, a technology is selected for each identified technical issue to address at least one of the technical issues. Further, a set of criteria is defined for each selected technology to determine when to employ the selected technology in the well because each selected technology may remain dormant until the set of criteria are met. Finally, the technologies are integrated into a well completion profile and utilized in the deployment of the technologies into the well to produce hydrocarbons. Some of the technical issues include: the presence of water in the wellbore, formation of a sand bridge, rupture of a primary sand screen, and the presence of hydrocarbons in the well. The well may be a producing well or an injection well.

[0010] In a second embodiment, a method of completing a well is disclosed. The method includes identifying at least three technical issues associated with a well; identifying at least three technologies, wherein each of the technologies addresses at least one of the technical issues; defining

criteria for each of the technologies to determine when to employ the specific technology in the well; and integrating the technologies into a well completion profile for the deployment of the technologies into the well, wherein at least one of the technologies remains dormant until the criteria is met for that specific technology. The well may be a producing well or an injection well.

[0011] In a third embodiment, a method of producing hydrocarbons is disclosed. The method includes identifying technical issues associated with a well; determining one or more technologies to address each technical issue; creating a well completion profile that includes the technologies to address the plurality of technical issues; and producing hydrocarbons from the well based on the well completion profile. The well completion profile may be stored in the memory of a processor based device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The foregoing and other advantages of the present technique may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0013] FIG. 1 is an exemplary well in accordance with certain aspects of the present techniques;

[0014] FIG. 2 is an exemplary flow chart of a flexible well completion profile in accordance with aspects of the present techniques;

[0015] FIG. 3 is an exemplary flow chart of the creation of the flexible well completion profile of FIG. 2 in accordance with aspects of the present techniques;

[0016] FIG. 4 is an exemplary embodiment of a well completion based on a flexible well completion profile in accordance with certain aspects of the present techniques; and

[0017] FIG. 5 is an alternative exemplary embodiment of a well completion based on a flexible well completion profile in accordance with certain aspects of the present techniques.

DETAILED DESCRIPTION

[0018] In the following detailed description, the specific embodiments of the present invention will be described in connection with its preferred embodiments. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be illustrative only and merely provides a concise description of the exemplary embodiments. Accordingly, the invention is not limited to the specific embodiments described below, but rather, the invention includes all alternatives, modifications, and equivalents falling within the true scope of the appended claims.

[0019] Some embodiments of the present techniques relate to a method and mechanism for enhancing hydrocarbon well completions to facilitate well operations. Well operations may include production of hydrocarbons, injection operations, and other activities known to those of skill in the art. Under some aspects of the present techniques, the design of a completion configuration is managed as a well completion profile that accounts for potential technical issues in the producing environment during the life of the well. That is, the well completion profile is utilized to enhance production, injection, or other activities by designing the well completion to account for various technical issues expected to impact these activities. Accordingly, tools may be deployed into a well and remain dormant until specific events activate the tools. The tools provide a flexible mechanism for managing the well on a foot-per-foot basis. As a result of this proactive method, interventions and workovers may be reduced to enhance the operation of the well.

[0020] The present techniques may utilize different types of well completions, such as an open-hole completion or a cased-hole completion, to access a subsurface formation. With a cased-hole completion, a production casing string is set adjacent to the subsurface formation. Then, the production casing string is perforated to provide a fluid flow path from the subsurface formation to the production casing string. The production casing string supports the walls of the wellbore and controls the flow of fluids through specific perforations. Alternatively, with an open-hole completion, no production casing string is placed adjacent to the subsurface formation. As a result, the open-hole completion may experience more technical issues because it does not provide same level of fluid inflow control and wellbore support as a cased-hole completion. Accordingly, to clarify aspects of the present techniques, an open-hole completion is utilized for exemplary purposes, as discussed below in FIG. 1.

[0021] Turning now to the drawings, and referring initially to FIG. 1, an exemplary well **100** in accordance with certain aspects of the present techniques is illustrated. In the exemplary well **100**, a wellbore **102** penetrates the surface **104** to a subsurface formation **106**. As may be appreciated, the subsurface formation **106** may include various layers of rock that may or may not include hydrocarbons or zones of fluids, which are collectively referred to as zones. In this example, the subsurface formation **106** includes a first zone **108**, a second zone **110**, a third zone **112**, a fourth zone **114**, and a fifth zone **116**.

[0022] Various casing strings may be installed into the wellbore **102** to provide access to the subsurface formation **106**. For example, a surface casing string **120** may be installed from the surface **104** to a specific location beneath the surface **104**. Within the surface casing string **120**, an intermediate or production casing string **122** may be utilized to provide support for walls of the wellbore **102**. The production casing string **122** may extend down to a depth near the subsurface formation **106**. The surface and

production casing strings **120** and **122** may be cemented into a fixed position within the wellbore **102** to provide further support.

[0023] In some embodiments of the present techniques, equipment and tools may be connected from the surface **104** to positions near the subsurface formation **106**. As an example, the well **100** may include a tree **124** located over the wellbore **102** at the surface **104**. The tree **124** may be coupled to various tools **126a-126d** via a production tubing or workstring **128** and a control cable **130**. The production tubing **128** may extend through the tools **126** or be coupled to specific tools **126**. This connectivity may be based upon the specific configuration of the tools **126** utilized in the wellbore **102**. Similarly, the control cable **130** may be connected to one or more of the tools **126** to provide control signals and sensory data to monitoring equipment (not shown) that tracks the conditions within the wellbore **102**.

[0024] Other equipment may also be utilized to manage various zones within the wellbore **102**. For instance, packers, such as packer **136**, may be utilized to isolate the wellbore annulus from other zones within the wellbore **102**. In a similar manner, a safety valve **132** may also be utilized to block the flow of fluid from a specific point to the surface **104**. In particular, the safety valve **132** may be utilized to prevent the abnormal flow of fluids from reaching the surface **104**. That is, the safety valve **132** may control the flow of fluids in the production tubing **128**, while being controlled by sensors (not shown) or the control cable **130**.

[0025] Because open-hole completions generally have higher production rates with lower drilling and completion costs, these types of completions are frequently utilized to develop subsurface formations. However, the open-hole completions are not designed to concurrently manage multiple technical issues that the well could face over its lifetime. Generally, the technical issues of open-hole completions are addressed when they occur through remedial actions, such as a workover or intervention, and

are not proactively evaluated to determine technical solutions for potential technical issues that may be encountered concurrently.

[0026] The problem with open-hole completions is further compounded by accessing subsurface formations with a long-interval completion. As noted above, these well completions typically encounter multiple technical issues because of the length and complexity of the completion. Unlike short single zone/single interval completions, long-interval completions may access multiple hydrocarbon zones with a single well, such as well **100**. Because of its length or complex geology, the long-interval completions may encounter multiple technical issues that limit production rates and/or lead to numerous interventions/workovers over the lifetime of the well. The technical issues present in a long-interval completion may include sand production, early water breakthrough, early gas breakthrough, cross flow and/or other similar problems. As a result, the well may have productivity reduced, mechanical damage to the subsurface/surface equipment, and/or a loss of production.

[0027] For example, the well **100** may produce sand during its operation. The sand production may result in subsurface equipment damage, fill-ins or cave-ins of the wellbore **102**. As a result, remedial action, such as a workover or intervention, may be performed to clean out the well before production from the subsurface formation **106** is resumed. This problem is further complicated with the well being in a remote location, such as a deep-water environment or remote location, which also increases the cost of the remedial actions.

[0028] Further, the remedial actions may only provide a partial solution to the technical issue. For example, in addition to sand production, a well may experience water breakthrough in the well. The water breakthrough may result in another remedial action to plug the interval or zone that is producing water. This remedial action may include setting a bridge plug inside a sand screen within the wellbore **102**. However, this bridge plug may simply slow down the water from the problem zone because the wellbore annulus remains

in communication with the water producing zone, if the annulus has not collapsed. If the trouble zones can not be controlled or shut-off, the well's productivity is compromised because the equipment on the surface may be limited by the amount of water, gas or sand that it can process. In this situation, the excess sand may damage equipment, while excess water may make the well non-economical because the oil production may have to be reduced. As such, sand production and water breakthrough in an open-hole completion may result in two or more interventions to resolve the problem or may even result in the abandonment of the well.

[0029] As another approach to managing technical issues within a portion of the wellbore **102**, flow control valves and zonal isolation devices may be utilized to manage the flow of unwanted fluids from a specific zone. These devices provide large or "macro scale" control of water or gas by shutting off or limiting the water of gas from the appropriate zones. That is, the flow control valves and zonal isolation devices block an entire zone to prevent the flow of the water or gas from that zone or limit the flow of water or gas from that zone. As a result, the oil or gas from those specific zones of the subsurface formation may be lost or production may be severely limited.

[0030] To address these different issues, the present techniques provide a mechanism that proactively adapts the well completion profile to address multiple technical issues without operator intervention, as discussed in greater detail in FIG. 2. FIG. 2 is an exemplary flow chart of a well completion process in accordance with aspects of the present techniques. In this flow chart, which is generally referred to by the reference numeral **200**, multiple technical issues may be identified for a well, such as well **100** of FIG. 1. Then, a well completion profile may be developed for the well to address the technical issues in a proactive manner. In particular, the well completion profile may be utilized to deploy various technologies within the well to operate the well in an efficient manner.

[0031] The flow chart begins at block **202**. At block **204**, technical issues that are predicted or expected to be present are identified. The identification of technical issues may be based on sample well cores that are provided from the wellbore **102**, modeling tools, similar experiences with other wells, or a combination of these techniques. The identified technical issues may include gravel placement, reliable screen running, water or gas breakthrough, screen reliability, flow impairment, flow control, zonal isolation, and/or intervention. With the technical issues identified, a well completion profile may be created, as shown in block **206**.

[0032] The well completion profile may include selecting one or more technologies to address each of the technical issues. It should be noted that one or more technologies may be available to address a technical issue. "Technical issues" are problems that are specific in nature, but include uncertainty as to their timing, location and magnitude during the lifetime of a well. Technical issues can generally be addressed by a particular apparatus, system, or process, called a "technology." Examples of technologies that address technical issues are shown below in Table 1.

Table 1. Technical Issues and Technologies

Reference Number	Technical Issue	Example Technology	Technology	Technology Description
1	Gravel placement	A) Alternate path (External Shunt Tubes)	A) Dormant - Shunt tubes are not utilized until a bridge is formed forcing the fluid to flow through the shunt tubes to access any annulus space below the bridge that is not or partially packed with sand or gravel.	A) External shunt tubes are placed adjacent to primary tubing to allow, fluids, such as slurry, to bypass annular bridges. For further details, please refer to U.S. Patent Nos. 4,945,991 and 5,868,200, which are examples of external shunt tubes and hereby incorporated by reference.
		B) Alternate Path (Internal Shunt Tubes)	B) Dormant - Shunt tubes are not utilized until a sand bridge is formed forcing the fluid to flow through the internal shunt tubes to access any annulus space below the sand bridge that is not or partially packed with sand or gravel.	B) Internal shunt tubes are placed within the primary tubing to allow, fluids, such as slurry, to bypass annular bridges. For further details, please refer to U.S. Patent Nos. 5,515,915 and 6,220,345, which are examples of internal shunt tubes and hereby incorporated by reference.

Reference Number	Technical Issue	Example Technology	Technology	Technology Description
		C) Direct Shunt Pumping	C) Active or Dormant: Slurry is directly injected into the uppermost shunt tubes and exit through shunt nozzles to pack the well annulus (active mode); As the well annulus around the uppermost shunt tubes is packed, slurry is diverted further downstream along the shunt tubes (from dormant to active mode) to continue packing well annulus below the packed section.	C) Direct pumping of fluids, such as slurry or gravel, into shunt tubes to pack the wellbore. For further details, please refer to U.S. Patent No. 5,113,935, which is an example of direct shunt pumping and hereby incorporated by reference.
2	Reliable Screen Running	A) Completion packing process	A) Active or Dormant: The completion packing process is a method of running sand screens into a well without damaging the screens. The process is considered active when wellbore stability is an issue and / or high concentration of solids is present in drill-in / completion fluids.	A) Open-hole gravel pack installation procedure that ensures reliable screen running and pack placement. For further details, please refer to International Publication No. 2004/079145, which is an example and hereby incorporated by reference.
		B) Composite Base Pipe Screen	B) Active or Dormant: The composite base pipe screen is utilized to filter sand from fluids in the well. The light weight composite character is considered active when drag forces would prevent successful running of standard screens.	B) Reduced screen weight by utilizing composite base pipe screen that mitigates drag during screen running.
3	Water Break-through	Swellable polymers	Dormant - The swellable polymer remains inactive until water contacts the polymer.	Polymer incorporated into sand control screen or gravel that swells on contact with water to provide water shut-off. For further details, please refer to U.S. Patent Application, entitled "Conformance Control Through Stimulus-Responsive Materials" by Scott R. Clingman et al. filed February 10, 2006, which is an example and hereby incorporated by reference.
4	Screen Reliability	Redundant screening	Dormant - Redundant sand screens are not filtering sand from fluids until a rupture of the primary sand screen.	Filtering tool with redundant sand control to improve reliability and longevity. For further details, please refer to International Publication No. 2004/094784, which is an example and hereby incorporated by reference.

Reference Number	Technical Issue	Example Technology	Technology	Technology Description
5	Flow impairment	Filtercake removal process	Active or Dormant - The filtercake removal process is a method of removing filtercake from the wellbore. The technology is considered dormant if the filtercake was successfully removed prior to deploying this technology. The technology would still be utilized since the operator may not be certain where and how much the filtercake has been removed.	Filtercake removal method (mechanical or chemical) after running screens and prior to or during pack placement. For further details, please refer to U.S. Patent No. 5,333,689 and U.S. Patent Publication Nos. 20040014606 and 20040106525, which are examples and hereby incorporated by reference.
6	Flow control	Flow control device	Active or Dormant - The flow control device manages the flow of fluids in different settings. Considered dormant technology when combined with swellable polymer technology or when set to automatically respond to wellbore inflow/outflow changes.	Fixed or variable flow controls devices provide the ability to regulate the inflow/outflow and cross flow profiles of a well. These flow control devices may include Reslink's ResFlow™, Reslink's ResInject™, Weatherford's FloReg™, Baker's Equalizer™ or other similar products.
7	Zonal isolation	Swellable packer	Dormant - –the swellable packer does not expand to isolate zone until hydrocarbons or water interact with swellable packer.	Packer that swells on contact with hydrocarbon or water and provides annular isolation for open-hole completions. As an example, the Easywell's Constrictor™ or SwellPacker™ are exemplary packers that swells on contact with hydrocarbons. SWELLFIX manufactured by RUMA swells in water for water management during either well production or well injection.

From the available technologies of Table 1, one or more technologies may be selected as part of the well completion profile, which is discussed further in FIG. 3. It should also be noted that these technologies may be incorporated into a flexible well completion profile for production, injection, other operations, or some combination thereof. Based on the selected technologies, various combinations of the technologies may be integrated together, on a case-by-case basis, to design a well completion profile that enhances productivity, while reducing the potential for interventions/workovers.

[0033] In blocks **208** and **210**, the various technical solutions of the well completion profile may be deployed to produce the hydrocarbons from the well. At block **208**, the selected technologies that represent the technical solutions may be deployed into specific locations of the wellbore. Then, at least some of the selected technologies may be utilized to produce hydrocarbons from the well, as shown in block **210**. Accordingly, the process ends at block **212**.

[0034] Beneficially, the present techniques provide a proactive mechanism to address multiple technical issues without operator intervention. In the present techniques, the design of a completion is configured to proactively adapt the well completion profile to changes in the producing environment, such as geologic/reservoir uncertainties such as early water or gas breakthrough, for example. That is, the well completion profile may be developed to integrate various technologies to address technical issues during the installation of, design of, and production from the well completion. By managing the production of hydrocarbons from the subsurface formation **106** as a well completion profile, interventions and workovers may be reduced or eliminated for the well. However, it should be noted that the present techniques are fully compatible with standard intervention techniques known to those of skill in the art, such as, for example, a subsea intervention module (SIM), some embodiments of which are disclosed in U.S. Patent No. 6,488,093.

[0035] Further, as noted in Table 1, the selected technologies may either be active or remain dormant until certain criteria are met to active the technology. That is, tools, which incorporate the technologies, may be deployed into or adjacent to the wellbore **102** to provide selected technologies that address specific technical issues expected or predicted to occur during the life of the well. Some of these technologies may be active technologies that perform the specific function that they are designed to perform. As an example of active technologies, an inflow control device is an active technology because it manages the flow of fluids regardless of its settings or

configuration. Also, a safety valve is an active technology that operates in multiple configurations and performs its specific function when it is installed.

[0036] However, some of the tools may be dormant because the tools include technologies that remain inactive or dormant until certain criteria are met, as noted above. For example, redundant screening is a technology that remains dormant because the redundant sand screens are not actively filtering sand from the fluids within the wellbore. The technology becomes active only when the primary sand screen is ruptured or damaged and the redundant screens are utilized to filter sand from the subsurface formation fluids. Similarly, for the alternate path technology, shunt tubes are not utilized until a bridge is formed forcing the fluid to flow through the shunt tubes to access the annulus space below the bridge that is not packed with sand or gravel. As such, the shunt tubes remain dormant until pressure increases to force the fluid to flow through the shunt tubes. The creation of the flexible well completion profile is further explained in FIG. 3.

[0037] FIG. 3 is an exemplary flow chart of the creation of the flexible well completion profile of FIG. 2 in accordance with certain aspects of the present techniques. In this flow chart, which is generally referred to by the reference numeral **300**, multiple technical issues may be identified for a well, such as the well **100** of FIG. 1. Then, a technology, which may be a tool or process, may be developed for each specific technical issue during a design phase of the well completion. The selected technologies are analyzed to determine whether the integrated technologies may be combined to enhance well production.

[0038] The flow chart begins at block **302**. In blocks **304-310**, a first technical issue may be addressed by a selected technology. At block **304**, a first technical issue is identified in a manner similar to the block **204** of FIG. 2. At block **306**, one or more technologies may be identified to address the technical issue. It should be noted that one or more technologies may be available to address the technical issue, as discussed above in Table 1. From

the available technologies, one or more technologies may be selected to resolve the first technical issue, as shown in block **308**. The selection of a technology may be based on the general knowledge of the technical issue. For example, water breakthrough may be expected, but the specific time and location is not known. Accordingly, the flexible well completion profile may use this general knowledge to address the problem in a proactive manner without operator intervention. With the first or selected technology, criteria may be established to activate the selected technology, as shown in block **310**. The activation of the technology may be based on input from a sensor, a signal from a monitoring device, an automatic response to certain conditions in the wellbore, or any combination thereof.

[0039] As shown in blocks **312-316**, another technical issue may be analyzed, which is similar to the discussion of blocks **304-310** above. In block **312**, another technical issue may be identified. Then, one or more technologies may be identified to address the technical issue in block **314**. At block **316**, another technology is selected to address the technical issue.

[0040] At block **318**, the previously selected technologies are compared to the currently selected technology for the other technical issue to determine if the technologies are compatible. The previously selected technologies may be the first technology, other technologies previously selected in this process, or other technologies installed within the wellbore. That is, some technologies may not be designed to interact with each other. As a specific example in open-hole gravel pack completion, use of a conventional packer for zone isolation may be unsuitable with external shunt screen due to its complex geometry. Accordingly, modifications of the technologies may be performed to ensure a compatible and reliable design. If the technologies are incompatible, then another technology is selected in block **316**. However, if the technologies are compatible, then the criteria to activate the selected technology is established in block **320**, which may be similar to the discussion of block **310**.

[0041] Once another technology has been selected for the other technical issue, a determination is made if other technical issues are to be addressed, as shown in block **322**. If another technical issue is to be addressed, then another technical issue is identified in block **312**. However, if no other technical issues are to be addressed, the flexible well completion profile may be saved, as shown in block **324**. The saving of the flexible well completion profile may include storing the well completion profile in the memory of a processor-based system, such as computer system or database, for example. Accordingly, the process ends at block **326**.

[0042] Based on the selected technologies in the flexible well completion profile, various combinations of technologies may be integrated together to address any number of technical issues for a well completion. These selected technologies may be integrated, on a case-by-case basis, to design a well completion that enhances productivity, while reducing the potential for interventions or workovers by an operator. That is, the flexible well completion manages the production of hydrocarbons as a well completion profile rather than a single event or issue during the life of the well. Accordingly, because of the flexibility of the well completion profile, the potential number of configurations that may be utilized together is limited by available technologies.

[0043] As a general example, several technologies may be combined based on the technical issues to be addressed in the well completion. These various configurations are shown below in Table 2 for a well completion.

Table 2. "Well Completion Profile" Examples

		Technology Reference Number								
Concept Number	Flexible Well Concept	1A	1B	1C	4	2A	5	3	6	7
1	Gravel placement; Reliable Screen Running; Screen Reliability	X			X	X				
2	Gravel placement; Reliable Screen Running; Screen Reliability		X		X	X				
3	Gravel placement; Reliable Screen Running; Flow Impairment			X	X		X			
4	Concept No. 1 plus Water Breakthrough	X			X	X		X		
5	Concept No. 1 plus flow control and zonal isolation	X			X	X			X	X
6	Concept No. 1 plus zonal isolation	X			X	X				X
7	Concept No. 2 plus water breakthrough		X		X	X		X		
8	Concept No. 2 plus flow control and zonal isolation		X		X	X			X	X
9	Concept No. 2 plus zonal isolation		X		X	X				X
10	Concept No. 3 plus water breakthrough			X	X		X	X		
11	Concept No. 3 plus flow control and zonal isolation			X	X		X		X	X
12	Concept No. 3 plus zonal isolation			X	X		X			X

As shown in Table 2, a flexible well concept may include various technical issues to be addressed. Based on the technical issues, different technologies, which are referenced by technology reference numbers of Table 1, are selected to be included as part of the well completion profile. Accordingly, these exemplary configurations integrate the technologies to manage the production of hydrocarbons in an efficient manner from the well.

[0044] As a specific example, during the design phase, sand control, shale instability, screen erosion, flow impairment from filtercake and water breakthrough may be the technical issues identified for the well. Based on these technical issues, the associated technologies may include alternate path, completion packing process, redundant screening, filtercake removal process, swellable polymers and swellable packer. Of these selected technologies, alternate paths, redundant screening device, swellable polymer and swellable packer are dormant technologies, while the completion packing process and filtercake removal process are active technologies utilized within the well.

[0045] Advantageously, the flexible completion profile does not require precise knowledge of the technical issues, such as the location and specific details about the technical issue. Indeed, the adaptive nature of the flexible well completion utilizes the selected technologies, when certain criteria are met. That is, the selected technology may remain dormant, until an event satisfies the criteria established for the selected technology. As a result, remedial activities, such as workovers and interventions, may be reduced or eliminated for the specific well.

[0046] Further, the present technique provides a flexible mechanism for managing a well in specific portions of a zone, instead of the entire zone. For instance, the present technique may block portions of a zone that is producing water or gas, while retaining the capability to produce oil within the remaining portions of the zone. This functionality may be provided by utilizing a technology, such as swellable polymers, for example, that activate automatically based on certain criteria being detected or present within the wellbore **102**. In this manner, the reserves from the zone may be recovered, while preventing or reducing the production of water or gas. Exemplary embodiments of a well completion based on the well completion profile is discussed in greater detail in FIGs. 4 and 5.

[0047] FIG. 4 is an exemplary embodiment of a well completion in accordance with certain aspects of the present techniques. In this embodiment **400**, various technologies, such as alternate path, swellable polymers, inflow control devices and redundant screening, are utilized to address three potential technical issues associated with the zones **108-116**. As noted above, some of these technologies may remain dormant until certain events activate the technologies during the operation of the well.

[0048] In FIG. 4, the fluids from the subsurface formation **106** may flow from the zones **108-116** through tools **404** and **406** into the production tubing **128** in the completion interval. As discussed above in FIG. 1, the production packer **136** may seal the annulus formed between the production casing string **122** and the production tubing **128** from the completion interval. For this example, the zones **108**, **112**, and **116** are rock layers that include hydrocarbons, and may be referred to as pay zones. Further, the zones **110** and **114** are rock layers that do not include hydrocarbons, and these layers may form barrier or buffer zones. As such, the hydrocarbons in the pay zones **108**, **112**, and **116** may flow through the tools **404** and **406** into the production tubing **128**.

[0049] The alternate path technology is deployed within the wellbore **102** as part of the tools **402a**, **402b**, and **402c**, which may be collectively referred to as tools **402**. As noted above in Table 1, the alternate path technology includes external or internal shunt tubes adjacent to sand screen to provide a redundant path for slurry to bypass annular bridges. Each of the tools **402** includes a shunt pipe **410** with different nozzles, such as nozzles **412a**, **412b** and **412c**. During gravel pack placement, the tools **402** may remain dormant when the fluid, such as gravel slurry, flows through the annulus between the screens **404a-404b** and the walls of the wellbore **102**, the tools **402** may be activated by the formation of a sand bridge in the annulus that forces the gravel slurry through the shunt pipe **410** and nozzles **412a**, **412b** and **412c**. As such, the tools **402** may include a dormant

technology that is placed within a well completion, but not utilized until sand bridges are formed within the wellbore **102**.

[0050] Another technology that may be deployed into the wellbore **102** may be redundant screening technology. The redundant screening technology addresses sand screen reliability issues and may be deployed as redundant screens within tools **404a** and **404b**, which may be collectively referred to as tools **404**. Again, as noted above in Table 1, the tools **404** provide redundant sand screens to improve reliability and longevity of sand filtering screens that may be damaged by erosion. Each of the tools **404** include a first sand screen **414** adjacent to the walls of the wellbore **102** and a second sand screen **416** along the flow path **418** from the first sand screen **414** to the production tubing **128**. With this technology, the first sand screen **414** is active because it prevents sand from flowing into the production tubing **128**, but the second sand screen **416** is dormant because it is not actively filtering sand from the fluids entering the wellbore **102**. However, the second sand screen **416** may automatically become active when a failure, such as a puncture or rupture of the first sand screen **414** occurs. Thus, the tools **404** may be a dormant technology placed within a well completion, but not utilized until a specific event, such as a rupture of the first sand screen **414** has occurred.

[0051] The final technologies utilized in this embodiment are swellable polymers along with an inflow control device in a tool **406**. In this tool **406**, the swellable polymer technology addresses water breakthrough issues, while the inflow control device may be adjusted to manage the flow of fluids through the tool **406** into the production tubing **128**. This tool **406** has a sleeve **428** with an opening that engages with different ports **422**, **424** and **426** to manage the flow of fluids from the zone **116**. Based on the location of the sleeve **428** relative to the port **422**, **424** and **426**, different configurations or settings may control the amount of fluid that enters the tool **406**. For instance, in an open configuration, the sleeve **428** may permit fluid to flow through the port **422**. In a choked or restricted configuration, the sleeve **428** may permit fluids to flow

through the port **424**. In a closed configuration, the sleeve **428** may prevent the flow of fluids to the production tubing **128**. The sleeve **428** may be adjusted to the various ports **422**, **424** and **426** based on a comparison of a value determined from monitors or sensors associated with the wellbore and a predetermined or set value. In addition to the sleeve **428** and ports **422**, **424** and **426** of the inflow control device, a polymer may be disposed adjacent to the ports **422**, **424** and **426** to swell on contact with water. This polymer may be utilized to provide a water shut-off functionality to the tool **406**. As such, the tool **406** utilizes technology that remains dormant until water is detected in the wellbore **102**.

[0052] FIG. 5 is an alternative exemplary embodiment of a well completion in accordance with certain aspects of the present techniques. In this embodiment **500**, the technologies of FIG. 4 are again utilized in the tools **402**, **404** and **406** of the well completion with the exception of the swellable polymers. In addition to those technologies, the swellable packer technology, such as, for example, SWELLPACKER™ by Easywell, may be utilized to address an additional technical issue of zonal isolation. It should be noted that the zones **108-116**, tools **402**, **404** and **406**, production casing string **122**, production tubing **128**, and production packer **136** may function similar to the discussion above. Accordingly, if the pay zones **108**, **112**, and **116** are rock layers that contain hydrocarbons and the buffer zones **110** and **114** are rock layers that do not contain hydrocarbons, then the hydrocarbons in the zones **108**, **112**, and **116** may operate similar to the discussion above.

[0053] As an additional technology, the swellable packer technology may be deployed into the wellbore **102** as a first swellable packer **502** and a second swellable packer **504**. The swellable packers **502** and **504** are utilized along with the tools **402**, **404** and **406** to divide the completion interval into different production sections, which may correspond to the zones **108**, **112** and **116**. As noted above in Table 1, the swellable packers **502** and **504** expand on contact with hydrocarbons and provide annular isolation for open-hole completions. In this example, the swellable packer **502** along with the

production packer **136** isolate the fluids in zone **108** to force the fluids to follow the fluid flow path **418**. The swellable packers **502** and **504** isolate the fluids in zone **112** to force the fluids to follow the fluid flow path **506**. Finally, the swellable packer **504** forces the fluids in zone **116** to follow the fluid flow path **420**. Because the swellable packers **502** and **504** do not expand until the hydrocarbons contact the swellable packers **502** and **504**, they may be considered a dormant technology that is placed within a well completion, but not utilized until hydrocarbons are present.

[0054] It should also be noted that a well completion profile may be developed to address the technical issues facing a cased-hole completion under the present techniques. For instance, the well completion profile may include gravel pack along with other technologies to address technical issues associated with a well. The creation of the well completion profile may be performed in a similar manner to the discussion above relating to open-hole completion. It should be appreciated that the selection, integration and deployment of technologies within the cased-hole well may be different from the use of these technologies within an open-hole completion. Regardless, the well completion profile may be utilized to proactively address technical issues to reduce workovers and interventions for a well.

[0055] While the present techniques of the invention may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed above have been shown by way of example. However, it should again be understood that the invention is not intended to be limited to the particular embodiments disclosed herein. Indeed, the present techniques of the invention are to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

CLAIMS

What is claimed is:

1. A method of completing a well comprising:

identifying a plurality of technical issues associated with a well;

selecting a plurality of technologies, wherein each selected technology of the plurality of technologies addresses at least one of the plurality of technical issues;

defining a set of criteria for each selected technology to determine when to deploy the selected technology in the well, wherein each selected technology remains dormant until the set of criteria are met; and

integrating the plurality of technologies into a well completion profile for use in the deployment of the plurality of technologies into the well.

2. The method of claim 1 comprising producing hydrocarbons from the well.

3. The method of claim 1, wherein the plurality of technical issues comprises at least three technical issues.

4. The method of claim 1 comprising identifying for each of the plurality of technical issues one of a plurality of technologies to address the associated technical issue.

5. The method of claim 1 comprising configuring the plurality of technologies to operate in a single production zone of the well.

6. The method of claim 5 comprising configuring at least one of the plurality of technologies to automatically activate within the single production zone when the set of criteria are met.

7. The method of claim 6, wherein the set of criteria for the at least one of the plurality of technologies is the presence of water within the wellbore.

8. The method of claim 6, wherein the set of criteria for the at least one of the plurality of technologies is the formation of an annular sand bridge.

9. The method of claim 6, wherein the set of criteria for the at least one of the plurality of technologies is the rupture of a primary sand screen.

10. The method of claim 6, wherein the set of criteria for the at least one of the plurality of technologies is the presence of hydrocarbons in the well.

11. The method of claim 1 comprising:

determining a value from a monitor associated with the well; and

comparing the value to the set of criteria to determine whether to activate one or more of the plurality of technologies.

12. The method of claim 1 comprising configuring each of the plurality of technologies to deploy automatically when the set of criteria are met.

13. The method of claim 1 comprising combining the plurality of technologies together for placement adjacent to a subsurface formation within the well.

14. The method of claim 1, wherein the well is one of a production well or an injection well.

15. The method of claim 1, wherein the well completion profile is stored in the memory of a processor based device.

16. A method of completing a well comprising:

identifying at least three technical issues associated with a well;

identifying at least three technologies, wherein each of the at least three technologies addresses at least one of the at least three technical issues;

defining a set of criteria for each of the at least three technologies to determine when to activate a specific technology for the completion of the well;

integrating the at least three technologies into a well completion profile for use in the deployment of at least one of the at least three technologies into the well, wherein the at least one of the at least three technologies remains dormant until the set of criteria is met for that specific technology; and

utilizing at least one of the at least three technologies to facilitate production of hydrocarbon natural resources from the well.

17. The method of claim 16, wherein the well completion profile is created prior to the production of hydrocarbon natural resources from the well.

18. The method of claim 16, wherein the well completion profile is created for a well that has previously produced hydrocarbon natural resources from the well.

19. The method of claim 16 comprising:

completing the well with the at least three technologies;

determining a value from the well associated with a first technology of the at least three technologies;

comparing the value to the set of criteria to determine whether to activate the first technology; and

producing hydrocarbon natural resources from the well with the first technology activated.

20. The method of claim 16, comprising configuring each of the plurality of technologies to activate automatically when the set of criteria are met.

21. The method of claim 16, wherein a first technical issue comprises water breakthrough, a second technical issue comprises gravel placement, and a third technical issue comprises rupture of a primary screen.

22. The method of claim 16, wherein a first technical issue comprises water breakthrough and a second technical issue comprises flow impairment.

23. The method of claim 16, wherein a first technical issue comprises rupture of a primary screen, a second technical issue comprises gravel placement, and a third technical issue comprises zonal isolation.

24. The method of claim 16, wherein a first technical issue comprises zonal isolation and a second technical issue comprises water breakthrough.

25. The method of claim 16, wherein a first technical issue comprises water breakthrough and a second technical issue comprises flow control.

26. The method of claim 16, wherein the well is one of a production well or an injection well.

27. The method of claim 16, wherein the well completion profile is stored in the memory of a processor based device.

28. A method of producing hydrocarbons comprising:

identifying a plurality of technical issues associated with a well;

determining one or more technologies to address each of the plurality of technical issues;

creating a well completion profile that includes the technologies to address the plurality of technical issues; and

producing hydrocarbons from the well based on the well completion profile.

29. The method of claim 28, wherein at least one of the technologies remains dormant until a specific event occurs.

30. The method of claim 28 comprising defining criteria to activate each of the technologies.

31. The method of claim 28 comprising disposing the technologies adjacent to a subsurface formation within the well.

32. The method of claim 28, wherein the well completion profile is utilized to proactively deploy technologies into a well prior to specific technical issues being present in the well.

33. The method of claim 28 comprising configuring the technologies to operate in multiple production zones of the well.

34. The method of claim 28 comprising storing the well completion profile in the memory of a processor based device.

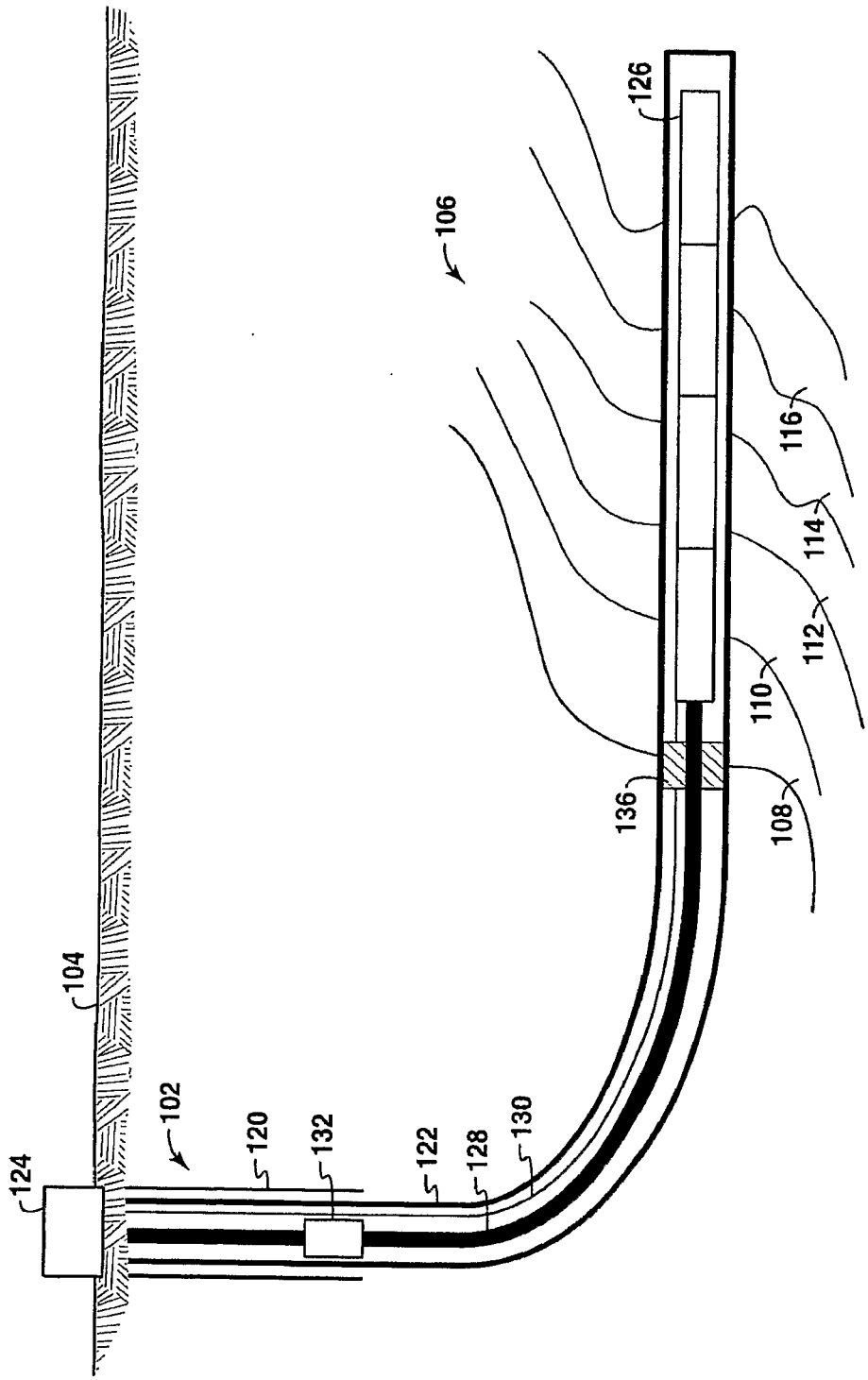


FIG. 1

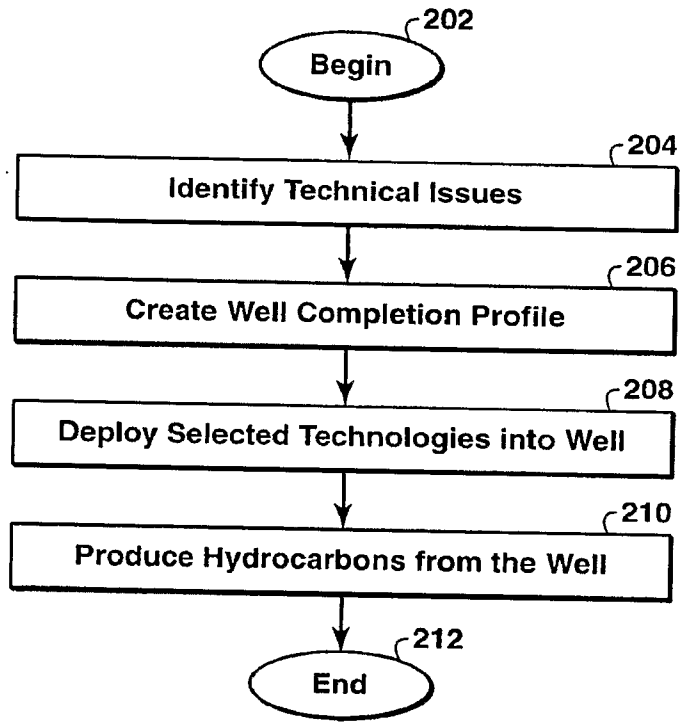

202
Begin
204
Identify Technical Issues
206
Create Well Completion Profile
208
Deploy Selected Technologies into Well
210
Produce Hydrocarbons from the Well
212
End

FIG. 2

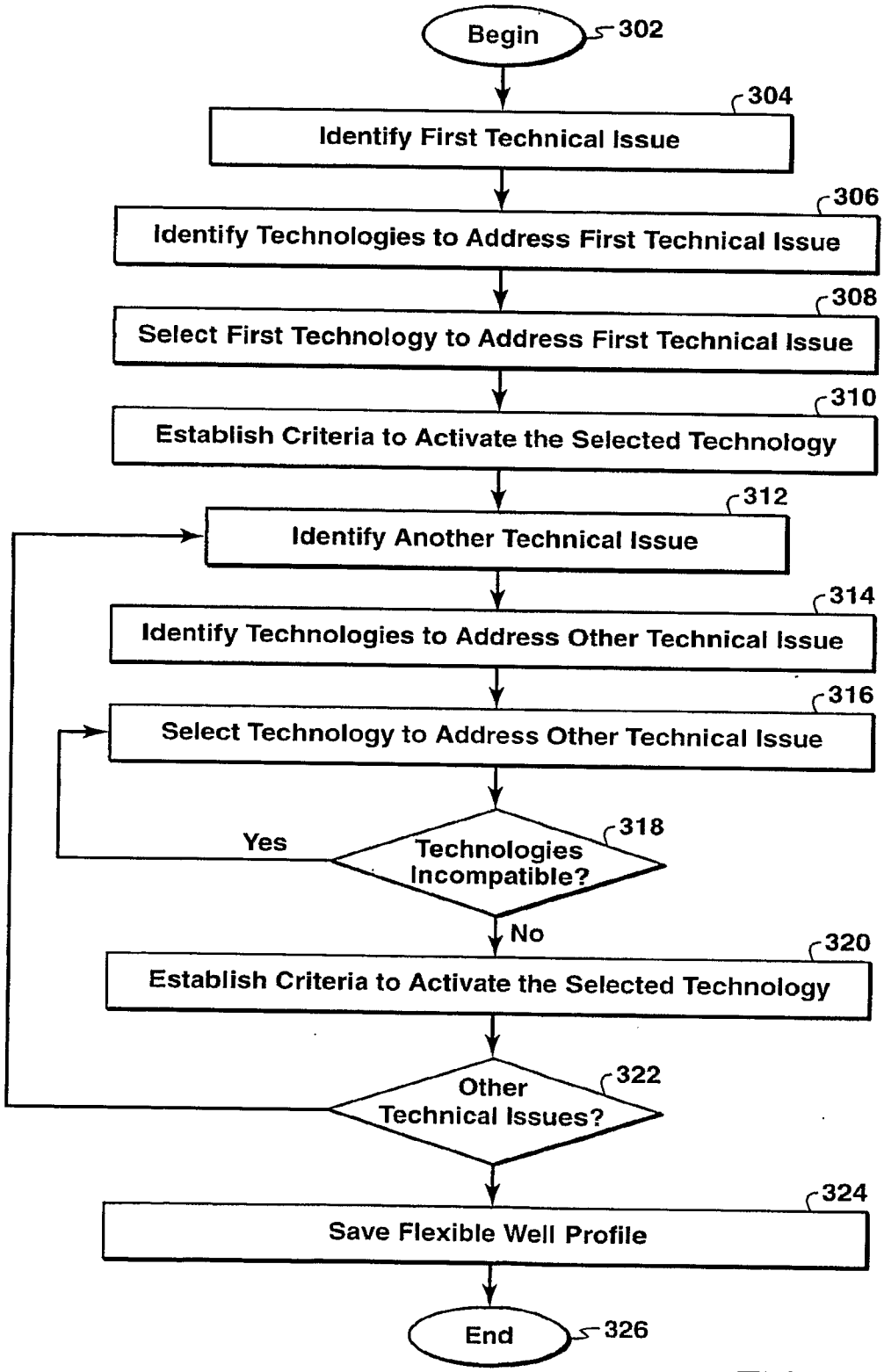

Begin
302
304
Identify First Technical Issue
306
Identify Technologies to Address First Technical Issue
308
Select First Technology to Address First Technical Issue
310
Establish Criteria to Activate the Selected Technology
312
Identify Another Technical Issue
314
Identify Technologies to Address Other Technical Issue
316
Select Technology to Address Other Technical Issue
Yes
Technologies Incompatible?
318
No
320
Establish Criteria to Activate the Selected Technology
Other Technical Issues?
322
324
Save Flexible Well Profile
End
326

FIG. 3

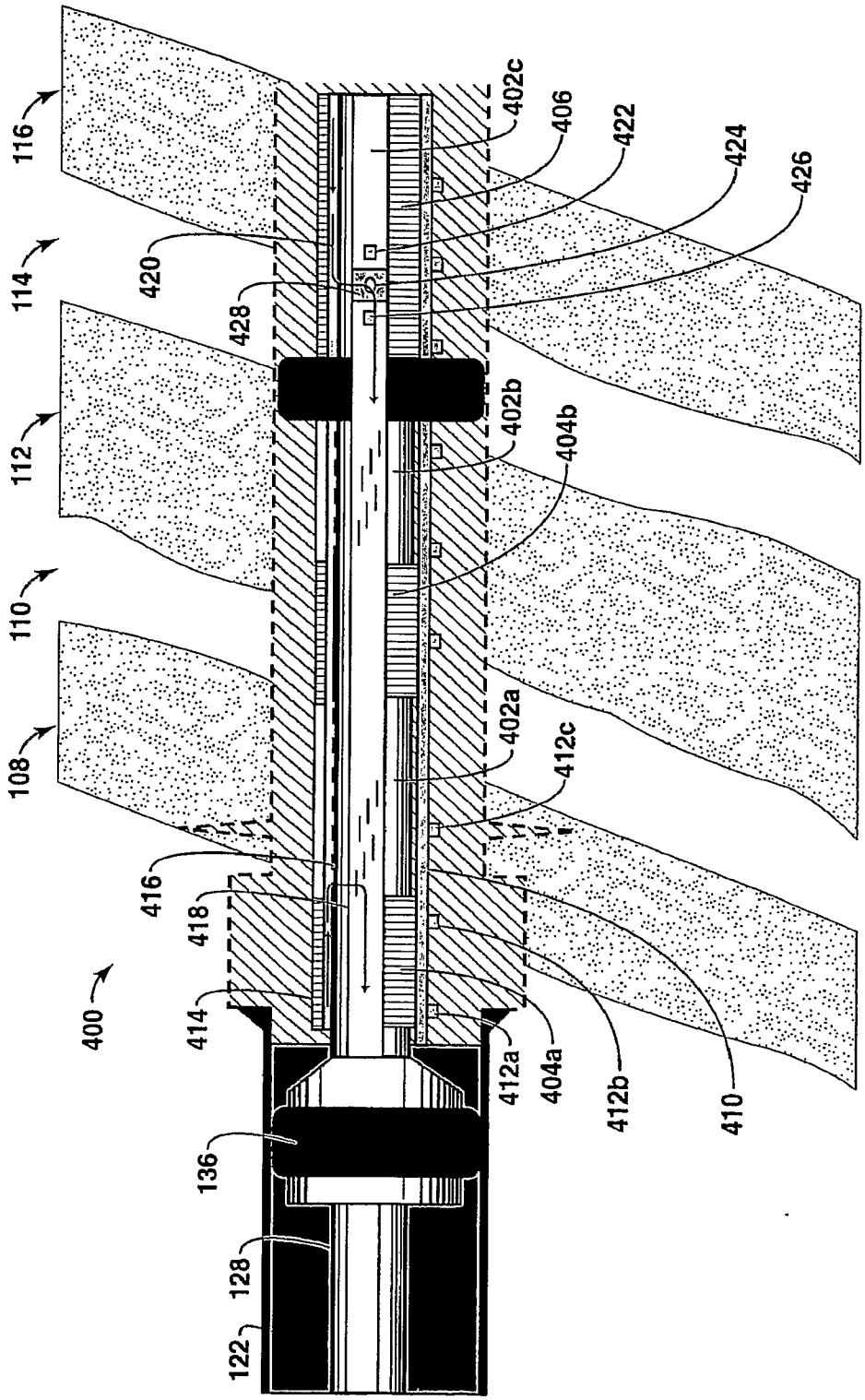

116
114
112
110
108
400
402c
406
422
424
426
420
428
402b
404b
402a
412c
416
418
414
412a
404a
412b
410
136
128
122

FIG. 4

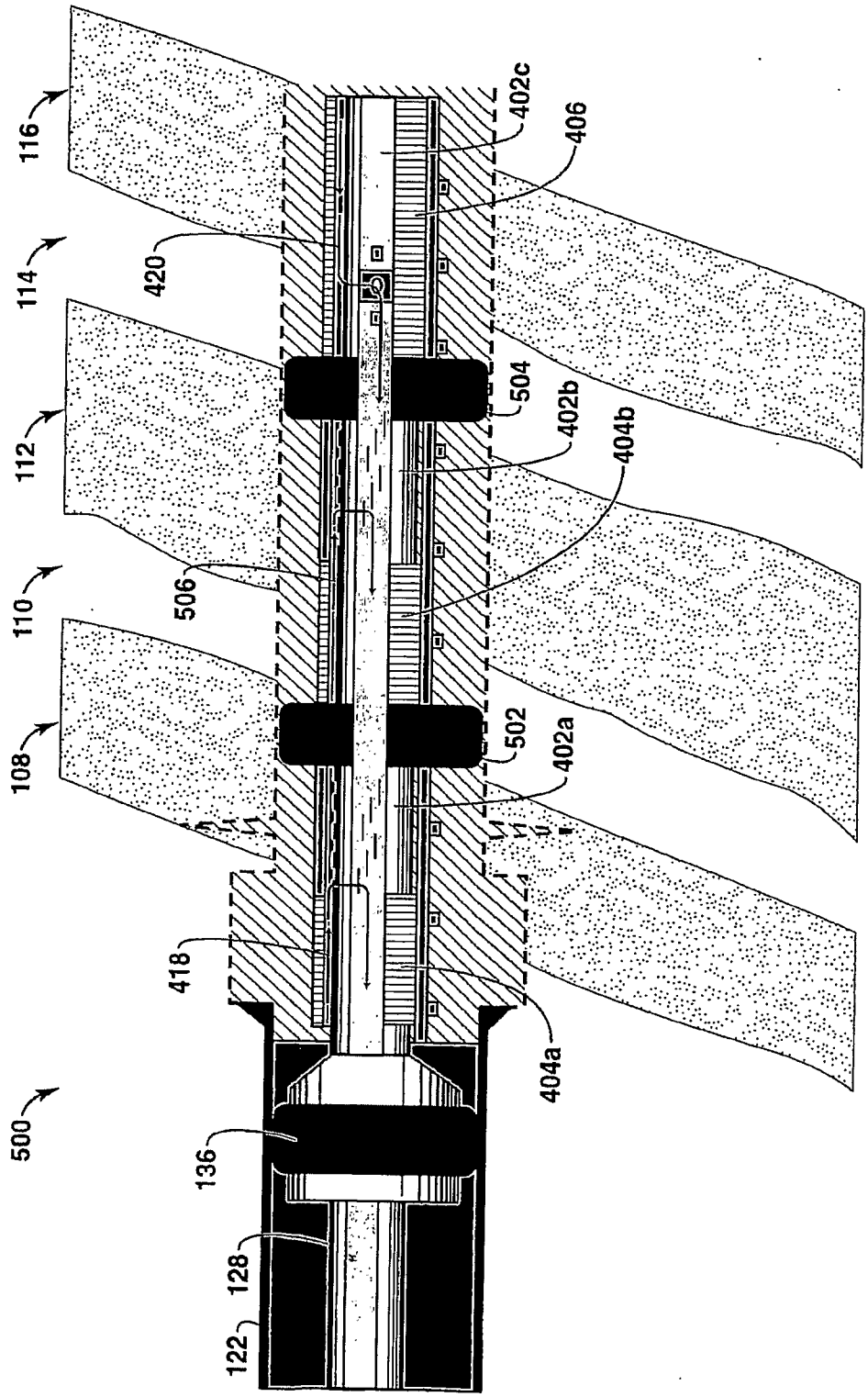

116
114
112
110
108
500
420
506
418
136
128
122
504
502
402c
406
402b
404b
402a
404a

FIG. 5