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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
02 November 2017 (02.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/189200 A1

(51) International Patent Classification:
E21B 23/00 (2006.01) *E21B 43/116* (2006.01)
E21B 33/134 (2006.01) *E21B 43/119* (2006.01)
E21B 41/00 (2006.01) *E21B 43/26* (2006.01)

(21) International Application Number:
PCT/US2017/026127

(22) International Filing Date:
05 April 2017 (05.04.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/329,690 29 April 2016 (29.04.2016) US

(71) Applicant *(for all designated States except US)*: **EXXONMOBIL UPSTREAM RESEARCH COMPANY** [US/US]; (EMHC-E2-4A-296), 22777 Springwoods Village Parkway, Spring, TX 77389 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **TOLMAN, Randy, C.** [US/US]; 25625 Richards Road, Spring, TX 77386 (US). **MORROW, Timothy, I.** [US/US]; 9806 Moonscape View, Humble, TX 77396 (US). **KINN, Timothy, F.** [US/US]; 2718 Barclay Lake Lane, Spring, TX 77388 (US). **SPIECKER, P., Matthew** [US/US]; 3303 Waters Edge Dr., Manvel, TX 77578 (US).

(74) Agent: **BAKUN, Estelle, C.** et al.; Exxonmobil Upstream Research Company, (CMHC-E2-4A-296), 22777 Springwoods Village Parkway, Spring, TX 77389 (US).

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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: SYSTEM AND METHOD FOR AUTONOMOUS TOOLS

(57) Abstract: Autonomous tools for use in tubular members associated with managing hydrocarbons. The autonomous tools are at least partially fabricated from a dissolvable material, which is configured to dissolve in the fluid within the tubular member. The autonomous tool includes one or more components that determine the location of the autonomous tool within the tubular member and actuate the actuatable tool component once a predetermined or selected location has been reached within the tubular member.

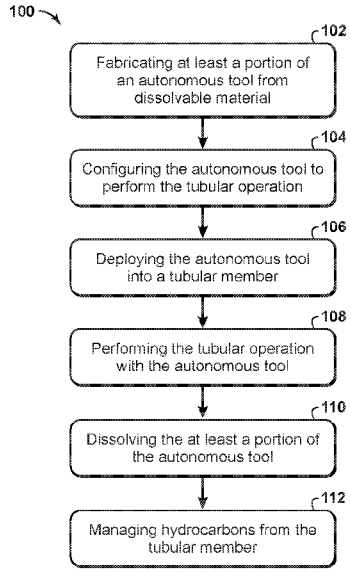

FIG. 1

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[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

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

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

Published:

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

SYSTEM AND METHOD FOR AUTONOMOUS TOOLS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 62/329690 filed April 29, 2016, the entirety of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present techniques relate to the field of autonomous tools. In particular, the present techniques involve autonomously performing tubular operations, such as perforating and/or treating subterranean formations to enhance production of hydrocarbons from subsurface formations. More specifically, the present techniques provide a method and system for perforating, isolating, and/or treating an interval or multiple intervals without need of a wireline or other running string and performing such tubular operations with an autonomous tool that has at least a portion of the autonomous tool fabricated from a dissolvable material.

BACKGROUND

[0003] This section is intended to introduce various aspects of the art, which may be associated with exemplary embodiments of the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0004] In the drilling of oil and gas wells, a wellbore is formed using a drill bit that is attached to the end of a drill string. The drill bit and drill string are used to form a wellbore within a subsurface region by removing rock and other materials. After drilling to a predetermined depth, the drill string and drill bit are removed from the wellbore. The resulting wellbore forms an open space within the subsurface formation.

[0005] Once the wellbore is formed, one or more sets of casing string are installed in the wellbore. The casing strings are lowered into the wellbore and are secured together to form the one or more sets of casing strings. An annular area is thus formed between the one or more sets of casing strings and the surrounding formations. Then, cementing operations may be conducted to fill the annular area with cement, which forms a cement sheath. The combination of cement and casing strengthens the wellbore and facilitates the isolation of the formations fluids behind the one or more sets of casing strings.

[0006] If several casing strings are utilized, the casing strings typically have progressively smaller diameters. Thus, the process of drilling, installing casing strings and cementing the

different diameters of casing strings is repeated several or even multiple times until the depth of the well has reached a predetermined level. The final string of casing, which is referred to as a production casing, is cemented into place near the surface of the formation. In some instances, the production casing may have a liner, which is a casing string that is not tied back to the surface, but is secured from the lower end of the preceding casing string.

[0007] To provide access to hydrocarbons in the subsurface formation, one or more tubular operations (e.g., completion operations or processes) may be performed within the wellbore. For example, the production casing and the associated cement may be perforated at desired levels. The perforations are lateral holes that are shot through the casing strings and the cement sheath surrounding the casing strings to provide a path for hydrocarbons to flow into the wellbore. Following the perforations, the subsurface formation is fractured to provide flow paths through the subsurface formation. The hydraulic fracturing may include injecting fracturing fluid (e.g., viscous fluids that are usually shear thinning, non-Newtonian gels or emulsions) into the subsurface formation at high pressures and rates that the reservoir rock of the subsurface formation fails and forms a network of fractures. The fracturing fluid is typically mixed with a granular proppant material, such as sand, ceramic beads, or other granular materials. The proppant serves to hold the fracture(s) open after the hydraulic pressures are released. The combination of fractures and injected proppant increases the flow capacity of the treated portion of the subsurface region.

[0008] As another tubular operation, one or more acidizing operations may be performed to further stimulate the subsurface formation and to clean the near-wellbore regions downhole within the subsurface formation. The acidizing operations may include injecting an acid solution down the wellbore and through the perforations. The use of an acidizing fluid is particularly beneficial when the subsurface formation includes carbonate rock. In such tubular operations, the acidizing operations may involve injecting a concentrated formic acid or other acidic composition into the wellbore, and directing the acid solution into selected zones of interest. The acid solution dissolves the carbonate material, thereby opening porous channels through the hydrocarbons to provide flow paths into the wellbore. In addition, the acid solution may further dissolve drilling mud that may have invaded the subsurface formation.

[0009] Further, another tubular operation may include the isolation of various zones for pre-production treatment to treat the intervals in stages. This involves the use of diversion methods. In petroleum industry terminology, “diversion” means that injected fluid is diverted from entering one set of perforations so that the fluid primarily enters only one selected zone of interest. Where multiple zones of interest are to be perforated, the tubular operations may

involve that multiple stages of diversion be carried out. The diversion methods may include mechanical devices (e.g., bridge plugs, packers, down-hole valves, sliding sleeves, and baffle/plug combinations); ball sealers; particulates (e.g., sand, ceramic material, proppant, salt, waxes, resins, or other compounds); chemical systems (e.g., viscosified fluids, gelled fluids, foams, or other chemically formulated fluids); and limited entry methods.

[0010] Examples of such techniques are provided in U.S. Patent Nos. 6,394,184; 6,543,538; 7,357,151; and 7,467,778; which are referred to and incorporated herein by reference in their respective entirety. The documents describe various techniques for running a bottom hole assembly ("BHA") into a wellbore, and then creating fluid communication between the wellbore and various zones of interest. The BHA may include mechanically actuated, re-settable axial position locking devices, or slips; an inflatable packer or other sealing mechanism; perforating guns; a casing collar locator; and a translating assembly, such as a string of coiled tubing, conventional jointed tubing, a wireline, an electric line, or a downhole tractor. The perforating guns may further have associated charges. The translating assembly may provide a mechanism for moving the BHA within the wellbore from the surface and may provide electrical signals to the perforating guns. The electrical signals cause the charges to detonate, thereby forming perforations at the location that the perforating guns are positioned. This location is based on the judgment from the operator of the wireline equipment.

[0011] To enhance operations, such techniques utilize friable tools to perform various operations. For example, U.S. Patent Application Publication Nos. 20130062055; 20130062072; 20130255939; 20140131035, which are referred to and incorporated herein by reference in their respective entirety, describe autonomous units and methods for downhole, multi-zone perforation and fracture stimulation for hydrocarbon production. These autonomous units may be fabricated into tools and may be fabricated from a friable material, such as ceramic or some other frangible material. The autonomous tools are utilized to be dropped or pumped down hole. Upon completion of the desired activity, the tool breaks apart to create small chards of material, which are not intended to obstruct the wellbore. The chards may fall to bottom of the wellbore, may be pumped into the formation, or may flow out of the well during production. However, certain tools may not be fabricated from ceramic materials economically and/or may be difficult to reliably reduce to sufficiently small fragments via explosives. These tools may be made from materials that do not break-up appropriately and/or have the potential to plug a perforation channels. With the use of two or more autonomous tools in a single well, the potential exists to hinder operations with the accumulation of debris, which is problematic.

[0012] Accordingly, there remains a need in the industry for apparatus, methods, and systems that provide enhancements to performing tubular operations. The present techniques overcomes the drawbacks of conventional approaches by using autonomous tools that include at least a portion of the components being formed from a dissolvable material. In particular, the present techniques may include, but are not limited to, autonomous tools having special connections between friable tools and/or internal components, such as electronic boards, retention devices, packing or filler for shock absorption, and the like, being at least partially fabricated from dissolvable materials.

SUMMARY

[0013] In one or more embodiments, an assembly and method describes an autonomous tool for use in tubular operations. The autonomous tool includes an actuatable tool component configured to perform a tubular operation; a location component configured to determine a location of the autonomous tool within a tubular member; and an on-board controller configured to send an actuation signal to the actuatable tool component when a predetermined location has been reached within the tubular member. The actuatable tool component, the location component, and the on-board controller are arranged to be deployed together in the tubular member as a single autonomous tool; the actuatable tool component is configured to autonomously perform the tubular operation in response to the actuation signal; and at least a portion of the actuatable tool component, the location component, and the on-board controller are fabricated from a dissolvable material configured to dissolve when subjected to tubular conditions.

[0014] Further, in one or more other embodiments, a method for performing a tubular operation is described. The method includes: deploying an autonomous tool into a tubular member, wherein at least a portion of the autonomous tool is fabricated from dissolvable material and the autonomous tool is configured to autonomously perform the tubular operation; autonomously performing the tubular operation with the autonomous tool; dissolving the at least a portion of the autonomous tool that is fabricated from dissolvable material; and managing hydrocarbons from the tubular member.

[0015] Moreover, in certain embodiments, the autonomous tool may include two or more actuatable tool components. Each of the two or more actuatable tool components may be configured to perform a specific tubular operation, which may be performed in a specific sequence. The on-board controller may communicate instructions to the two or more actuatable tool components to manage sequence of tubular operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] So that the present techniques can be better understood, certain drawings, charts, graphs and/or flow charts are appended hereto. It is to be noted, however, that the drawings illustrate only selected embodiments of the inventions and are therefore not to be considered limiting of scope, for the present techniques may admit to other equally effective embodiments and applications.

[0017] Figure 1 is an exemplary flow chart of a method for utilizing an autonomous tool having at least a portion formed from a dissolvable material in accordance with an embodiment of the present techniques.

[0018] Figure 2 is an exemplary autonomous tool for use in tubular operations in accordance with an embodiment of the present techniques.

[0019] Figure 3 is a side view of an exemplary autonomous tool for a wellbore plugging operation in accordance with an embodiment of the present techniques.

[0020] Figure 4 is a side view of an exemplary autonomous tool for a wellbore perforating operation in accordance with an embodiment of the present techniques.

[0021] Figure 5 is an exemplary flow chart of a method for utilizing an autonomous tool having two or more actuatable tool components, wherein the autonomous tool has at least a portion formed from a dissolvable material in accordance with an embodiment of the present techniques.

[0022] Figures 6A, 6B and 6C are a side view of a portion of a wellbore and the subsurface formation near the wellbore for different stages of deployment of the autonomous tool in in accordance with an embodiment of the present techniques.

DETAILED DESCRIPTION

[0023] In the following detailed description section, specific embodiments of the present techniques are described. 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 for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described below, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0024] Unless otherwise explained, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. The singular terms "a," "an," and "the" include plural referents unless the context clearly indicates otherwise. Similarly, the word "or" is intended to include "and" unless

the context clearly indicates otherwise. The term "includes" means "comprises." All patents and publications mentioned herein are incorporated by reference in their entirety, unless otherwise indicated. In case of conflict as to the meaning of a term or phrase, the present specification, including explanations of terms, control. Directional terms, such as "upper," "lower," "top," "bottom," "front," "back," "vertical," and "horizontal," are used herein to express and clarify the relationship between various elements. It should be understood that such terms do not denote absolute orientation (e.g., a "vertical" component can become horizontal by rotating the device). The materials, methods, and examples recited herein are illustrative only and not intended to be limiting.

[0025] As used herein, the terms “ceramic” or “ceramic material” may include oxides such as alumina and zirconia. Specific examples include bismuth strontium calcium copper oxide, silicon aluminum oxynitrides, uranium oxide, yttrium barium copper oxide, zinc oxide, and zirconium dioxide. “Ceramic” may also include non-oxides such as carbides, borides, nitrides and silicides. Specific examples include titanium carbide, silicon carbide, boron nitride, magnesium diboride, and silicon nitride. The term “ceramic” also includes composites, meaning particulate reinforced combinations of oxides and non-oxides. Additional specific examples of ceramics include barium titanate, strontium titanate, ferrite, and lead zierconate titanate.

[0026] As used herein, “dissolvable material” means materials that dissolve or break apart under certain tubular condition. The dissolvable materials may include the classes of polymers, metals or composites that dissolve or break apart under certain tubular conditions (e.g., certain pressure ranges, certain temperature ranges and certain chemistry ranges, such as concentrations of certain compounds that may be present within a wellbore) and rendering the material small enough to not interfere with tubular operations. For example, if the dissolvable material is a polymer material, it may undergo a hydrolysis reaction with the reaction products going into solution (e.g., by the polymer material interacting with formation water, which may be in a specific range or concentration for the water). As another example, if the dissolvable material is a metal, it may undergo galvanic reactions with the resulting products being reduced in size and/or going into solution. Further, as yet another example, if the dissolvable material is a polymer material, it may undergo a reaction with the reaction products going into solution within a certain temperature range. By way of example, a ball sealer may be fabricated from a dissolvable material, which may be configured to dissolve in five days, five weeks, or five months.

[0027] As used herein, the term "fluid" refers to gases, liquids, and combinations of gases and liquids, as well as to combinations of gases and solids, combinations of liquids and solids, and combinations of gases, liquids, and solids.

[0028] As used herein, the term "formation" refers to any definable subsurface region. The formation may contain one or more hydrocarbon-containing layers, one or more non-hydrocarbon containing layers, an overburden, and/or an underburden of any geologic formation.

[0029] As used herein, the term "friable" means any material that may be crumbled, powderized, fractured, shattered, or broken into pieces, often preferably small pieces. The term "friable" also includes frangible materials such as ceramic. It is understood, however, that in many of the apparatus and method embodiments disclosed herein, components described as friable, may alternatively be comprised of drillable or millable materials, such that the components are destructible and/or otherwise removable from within the wellbore.

[0030] As used herein, the term "gas" refers to a fluid that is in its vapor phase at 1 atmosphere (atm) and 15°C (Celsius).

[0031] As used herein, the term "hydrocarbon" refers to an organic compound that includes primarily, if not exclusively, the elements hydrogen and carbon. Hydrocarbons may also include other elements, such as, but not limited to, halogens, metallic elements, nitrogen, oxygen, and/or sulfur. Hydrocarbons generally fall into two classes: aliphatic, or straight chain hydrocarbons, and cyclic, or closed ring hydrocarbons, including cyclic terpenes. Examples of hydrocarbon-containing materials include any form of natural gas, oil, coal, and bitumen that can be used as a fuel or upgraded into a fuel.

[0032] As used herein, the term "hydrocarbon fluids" refers to a hydrocarbon or mixtures of hydrocarbons that are gases or liquids. For example, hydrocarbon fluids may include a hydrocarbon or mixtures of hydrocarbons that are gases or liquids at formation conditions, at processing conditions or at ambient conditions (15°C and 1 atm pressure). Hydrocarbon fluids may include, for example, oil, natural gas, coalbed methane, shale oil, pyrolysis oil, pyrolysis gas, a pyrolysis product of coal, and other hydrocarbons that are in a gaseous or liquid state.

[0033] As used herein, the term "millable" is somewhat synonymous with the term "drillable," and both refer to any material that with the proper tools may be drilled, cut, or ground into pieces within a wellbore. Such materials may include, for example, aluminum, brass, cast iron, steel, ceramic, phenolic, composite, and combinations thereof. The terms may be used substantially interchangeably, although milling is more commonly used to refer to the

process for removing a component from within a wellbore while drilling more commonly refers to producing the wellbore itself.

[0034] As used herein, the term “oil” refers to a hydrocarbon fluid containing primarily a mixture of condensable hydrocarbons.

[0035] As used herein, the terms "produced fluids" and "production fluids" refer to liquids and/or gases removed from a subsurface formation, including, for example, an organic-rich rock formation. Produced fluids may include both hydrocarbon fluids and non-hydrocarbon fluids. Production fluids may include, but are not limited to, oil, natural gas, pyrolyzed shale oil, synthesis gas, a pyrolysis product of coal, carbon dioxide, hydrogen sulfide and water (including steam).

[0036] As used herein, the term “production casing” includes a liner string or any other tubular member fixed in a wellbore along a zone of interest.

[0037] As used herein, the term "subsurface" refers to geologic strata occurring below the earth's surface.

[0038] As used herein, the term "wellbore" refers to a hole or void in the subsurface made by drilling or insertion of a conduit into the subsurface. A wellbore may have a substantially circular cross section, or other cross-sectional shapes. As used herein, the term "well", when referring to an opening in the formation, may be used interchangeably with the term "wellbore."

[0039] As used herein, “tubular conditions” refers to the range of pressures, temperatures, and chemistry within a wellbore and/or tubular member, such as a conduit and/or pipe. For example, tubular conditions within a wellbore typically include temperatures between 26 °C to 150 °C for temperatures (Bottom Hole Temperatures) and pressures between 100 pounds per square inch (psi) and 25,000 psi. Further, the chemistry within a tubular member and/or wellbore may include different quantities of hydrocarbons, water (H_20), carbon dioxide (CO_2), nitrogen (N_2) and hydrogen sulfide (H_2S). The water chemistry includes properties, such as pH, presence of dissolved ions like chlorides, sulfates, etc.

[0040] As used herein, the terms “zone” or “zone of interest” refers to a portion of a formation containing hydrocarbons. Alternatively, the formation may be a water-bearing interval.

[0041] Persons skilled in the technical field will readily recognize that in practical applications of the disclosed methodology, it is partially performed on a processor based device (e.g., on-board controller or a logic control device), typically a suitably programmed processor based device. Further, some portions of the detailed descriptions which follow are presented in terms of procedures, steps, logic blocks, processing and other symbolic representations of

operations on data bits within a computer or processor memory. These descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. In the present application, a procedure, step, logic block, process, or the like, is conceived to be a self-consistent sequence of steps or instructions leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, although not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a process based device.

[0042] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present application, discussions utilizing the terms such as "processing" or "computing", "calculating", "comparing", "determining", "displaying", "copying," "identifying," "storing," "adding," "applying," "executing," "maintaining," "updating," "creating," "constructing" "generating" or the like, refer to the action and processes of a process based device, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the processor based device memories or registers or other such information storage, transmission or display devices.

[0043] Autonomous tools are configured to be dropped or pumped into a wellbore. The majority of the bulk material may be made from ceramic or some other frangible material, as described in U.S. Patent Application Publication No. 20130062055, which is incorporated by reference herein in its entirety. Upon completion of the desired tubular operation or activity (e.g., perforating, cutting, setting plug, etc.), the autonomous tool may break apart and create small chards of material that do not obstruct the wellbore. These chards then settle to the bottom of the wellbore, are pumped into the formation, or flow out of the well during production. Yet, some components or parts may not be made from ceramic materials economically. These materials may be made from materials that do not break-up appropriately or have the potential to plug perforations. Further, in horizontal sections of the wellbore, the chards may settle over the lower portion of the wellbore, which may hinder access to this portion of the wellbore. Accordingly, the number of autonomous tool used in a single well increases potential issues by accumulating a significant amount of debris within the wellbore.

[0044] Beneficially, the use of dissolvable materials in the autonomous tools may enhance economics and performance by reducing the cost and increasing the functionality of the autonomous tool, enhancing reliably by ensuring that the autonomous tool fragments are ultimately reduced sufficiently in size and/or eliminate the need for explosives to reduce the tool to fragments, which may be desirable in locations where there are restrictions on the use of explosives. Functionality may also be enhanced by use of less dense materials, which enhance the flow or pump down characteristics of the autonomous tool. Lighter materials or an overall less dense autonomous tool may flow in the "center line" of fluids under turbulent conditions. This condition significantly improves the timing and reliability of estimation of the tool on target. Also, the synergies between using two or more materials together in an autonomous tool may further enhance the operations. For example, using dissolvable materials for certain parts or components may be more economical as compared to frangible materials because it may lessen the cost of manufacture significantly. Also, if the parts or components have the ability to dissolve into wellbore fluids, the accumulation of materials in the well may be lessened or mitigated. The integration of these materials may also provide enhanced production capability because the flow paths that provide fluid communication with the formation are not obstructed (e.g., tubular conduits and/or the perforation passages are not restricted to flow or lessen pressure drops). In addition, materials that may plug off flow control devices may be removed from the well by solution or captured by being pumped back into the formation (e.g., during flow back operations), which further lessens operating expenses.

[0045] The present techniques involve the use of autonomous tools that are fabricated to have at least a portion made of a dissolvable material. Accordingly, the present techniques disclose processes and systems for performing tubular operations (e.g., well operations) in subsurface formations in an enhanced manner. As noted above, the use of autonomous tools involves deploying autonomous tools into the wellbore that are not retrieved or guided by surface based equipment (e.g., wireline or other such manual guidance equipment). As such, the autonomous tools have to be transformed after the tubular operation is performed to not interfere or to lessen interference with subsequent tubular operations. While the autonomous tool may be fabricated from other materials, such as frangible and/or friable materials, at least a portion of the autonomous tool may be fabricated from a dissolvable material in the present techniques. The frangible and/or friable materials may become tiny shards when broken-up with explosives and may be pumped into the formation, flow back to surface, or settle to the bottom of the well without economic impact or impact on future well intervention operations

(e.g., production logging), while the dissolvable materials may be dissolve into the fluids within the wellbore.

[0046] The dissolvable materials include classes of polymers, metals or composites that dissolve or break apart under "friable action" (e.g., performed by the tool) as well as under tubular conditions, which may render the pieces small enough so as not to interfere with tubular operations. For example, the dissolvable materials may include polylactic acid (PLA), polyglycolic acid (PGA), polydioxone (PDO), polycaprolactone (PCL), alloys and other polymers or dissolvable metal materials. The dissolvable materials, which may be non-frangible materials, may dissolve naturally over time at tubular conditions. Further, the dissolvable materials (e.g., dissolvable polymers) may be provided in a variety of strengths and decomposition capabilities for many different applications. For example, the dissolvable material may dissolve at different rates and/or may dissolve in different tubular conditions (e.g., as a result of exposure to concentrations of a specific compound, exposure to certain temperatures, or exposure to certain pressures).

[0047] The autonomous tool may include one or more components with each component being a single element or including one or more parts. In particular, the one or more components may include a control logic system or component (e.g., on-board controller), a location or depth determination device or component, an actuatable tool component, such as a perforating component, a shockwave component, a pipe cutting component, a dump bailing component, a setting tool component to set bridge plugs, and/or any other suitable components. One or more parts and/or one or more components of the autonomous tools may be fabricated from the dissolvable material. For example, circuit boards, seals, and/or environmental protection casing may be fabricated from the dissolvable material. As another example, a setting tool component for bridge plug application or the crossover connections to a jet cutting charge for casing or tubing may be fabricated from the dissolvable material. Also, the dissolvable material may be used to fabricate control circuit boards for control logic, and/or parts of the safety control systems or components, such as the housing for addressable switches. At least a portion of the autonomous tool may include one or more parts in a component, may include one or more components and even may include fabricating the entire autonomous tool from the dissolvable material. For example, the autonomous tools may include a ceramic tool body and the threaded connectors made of dissolvable material (e.g., a metal material or polymer). As a further example, the dissolvable material may be used to fabricate seals and/or sealing devices, such as O-rings, gaskets, bulk heads, etc. In addition, the dissolvable material may be used for connection devices between dissimilar materials.

[0048] In one or more embodiments, the autonomous tool may be utilized in a method to enhance the tubular operations. For example, an autonomous tool may be fabricated, wherein at least a portion of the autonomous tool is from dissolvable material. Then, the autonomous tool may be configured to perform one or more tubular operations, which may involve coupling various components together and programming the different components to perform the one or more tubular operations. Once configured, the autonomous tool is deployed into the wellbore. The deploying the autonomous tool may include pumping, using gravitational pull, using a tractor, or any combinations thereof. Once deployed, the autonomous tool may perform the tubular operation. Following the performance of the tubular operation, at least a portion of the autonomous tool may dissolve based on the tubular conditions (e.g., wellbore conditions). Then, hydrocarbons may be produced from the subsurface region.

[0049] To further enhance tubular operations, the autonomous tool may include various components coupled together and configured to activate within a predetermined sequence of tubular operations. For example, the two or more autonomous components may be configured to be deployed as a single autonomous tool. As an example, the autonomous tool may include an on-board controller (e.g., a logic control device or processor controlled device) that is combined with a perforating gun component and a bridge plug component. The on-board controller may be configured to measure speed and depth with a processor running an algorithm that calculates speed and depth for the perforating gun component and the bridge plug component. Once the perforating gun component reaches a pre-determined location, the perforating gun component may initiate an action, such as perforating the wellbore, and then the bridge plug component may initiate an action, such as setting a bridge plug. In such a configuration, a dissolvable material may be used to deploy an autonomous tool at a specific depth or after exposure to the conditions within the wellbore for a specific amount of time. In this manner, two or more autonomous tool components may be deployed into the wellbore as a single autonomous tool (e.g., an autonomous assembly) and the dissolvable material may be utilized to maintain the specific sequential order of tubular operations (e.g., well operations) for the wellbore.

[0050] In one or more embodiments, the present techniques may be used to deploy a single autonomous tool, which includes a set of two or more autonomous tool components. The single autonomous tool may perform multiple tubular operations via a single deployment. For example, the autonomous tool may stimulate multiple target zones or regions via a single deployment of the autonomous tool. The autonomous tool may provide a mechanism for selective placement of each stimulation treatment for each individual zone to enhance well

productivity. Also, the autonomous tool may provide diversion between zones to ensure each zone is treated per design and previously treated zones are not inadvertently damaged. Further, the autonomous tool may provide a mechanism for stimulation treatments to be pumped at high flow rates to facilitate efficient and effective stimulation. As such, the autonomous tool may enhance tubular operations, such as multi-zone stimulation techniques and the associated hydrocarbon recovery from subsurface formations that contain multiple stacked subsurface intervals. With the ability to use dissolvable material in the autonomous tool string, non-friable parts may act as "shock absorbers" or bulk heads protecting other friable parts from being inadvertently affected by the need to break apart or "fry" a section of the component or tool at individual stages of operation during the operation of the autonomous tool within the wellbore. An example may include perforating multiple stages or zones separated by distance in one run. As one perforating gun in a first perforating gun component is utilized (e.g., shot), a need exists to protect the remaining perforating gun components until each of the remaining perforating gun components have reached the depth or location for utilization. By utilizing dissolvable materials to separate the perforating gun components, multiple operations may be performed, while not contaminating the tubular with debris that is not "fry" or go into solution over time.

[0051] As an example, the autonomous tool may include a packer component disposed on the lower or bottom of the autonomous tool and a perforating gun component disposed above the packer component. Once the autonomous tool is dropped into the wellbore, an on-board controller of the autonomous tool may be configured to activate the packer component at a specific depth or location. Once activated, the packer component may form a plug within the wellbore and the on-board controller may be configured to activate the perforating gun component. The perforating gun component may fire within the section of the wellbore to form perforations that may then be treated with sand. This process may be repeated by deploying another autonomous tool or deploying one or more perforating gun components and one or more packer components from the remaining portion of the autonomous tool. Then, the series of plugs may dissolve over time and no milling operation is required and no separate operation is needed to place plugs within the wellbore.

[0052] As yet another example, the autonomous tool may include an on-board controller (e.g., a logic control device) that is combined with a first perforating gun component and a second perforating gun component. The on-board controller may be configured to calculate the location of the first perforating gun component and the second perforating gun component. Once the autonomous tool reaches a pre-determined location, the first perforating gun component may separate from the second perforating gun component, which may initiate a

timer for the respective perforating gun components to perform the perforating operations. In such a configuration, a dissolvable material may be used to couple the perforating gun components and may separate after exposure to the conditions within the wellbore (e.g., the tubular conditions) for a specific amount of time. In this manner, two or more perforating gun components may be deployed into the wellbore as a single autonomous tool (e.g., an autonomous assembly) and the dissolvable material may be utilized to maintain the specific sequential order of tubular operations (e.g., well operations) for the wellbore. Further, each perforating gun component may include a ballast member, which is utilized to adjust the movement of the perforating gun component down the wellbore.

[0053] As an example, the present techniques may be utilized with multiple zone stimulation techniques, such as Just-In-Time-Perforating™ ("JITP") process, as described in U.S. Patent No. 6,543,538, which is incorporated by reference herein in its entirety. In these techniques, the process may involve: using a perforating device, perforating at least one interval of one or more subterranean formations traversed by a wellbore; pumping treatment fluid through the perforations and into the selected interval without removing the perforating device from the wellbore; deploying or activating an item or substance in the wellbore to removably block further fluid flow into the treated perforations; and repeating the process for at least one more interval of the subterranean formation. Using dissolvable materials for the JITP components may lessen recovery operations of the tool string.

[0054] Further, in other embodiments, the autonomous tool may include a shockwave component. The shockwave component may be a fabricated tool component, as described in U.S. Patent Serial Nos. 62/262034, 62/262036, 62/263069, which are each incorporated by reference herein in their entirety. The shockwave component may include a collar locator system, one or more rope socket devices, one or more primer cord carrier devices, one or more addressable switches, one or more connector subs and one or more sealing devices, one or more setting tool parts to set bridge plugs, and/or any other suitable parts. The use of dissolvable materials in the shockwave component provides a mechanism to mitigate the problem of having to recapture the tool. For example, if one or more parts of shockwave components are at least partially fabricated from dissolvable materials, which may also include frangible or friable materials as well, any shards that do not dissolve may be pumped out into the formation, flow back to surface, or settle to the bottom of the well without economic impact to production or impact on future tubular operations. The use of dissolvable material may be used in the fabrication of a carrier bar, an addressable switch sub, a rope socket and other such parts. The

dissolvable materials (e.g., polymers) may involve a variety of strengths and decomposition capabilities for many different applications.

[0055] Beneficially, the present techniques provide a more efficient completion process. First, the use of autonomous tools remove the reliance on wireline-conveyed or tubing-conveyed tools, which are difficult to run though a lubricator and limit the pump rates. Further, without the surface equipment (e.g., cranes, wireline equipment and coil tubing units), the expense of the operation and risks to personnel may be lessened, which lessens the overall economics of extraction operations. Further, various risks are avoided or mitigated by changing the overall approach because wireline failures and/or subsequent fishing operations may not be utilized with certain embodiments of the present techniques.

[0056] In one or more embodiments, the present techniques may include an autonomous tool that includes various components with at least a portion of the autonomous tool being fabricated from a dissolvable material. For example, the autonomous tool may include an actuatable tool component; a location component for sensing the location of the actuatable tool component within a wellbore or other tubular member based on a physical signature (e.g., a pressure sensor and/or casing collar locator); and an on-board controller configured to transmit an actuation signal to the actuatable tool component when the location component has determined that a selected or predefined location of the actuatable tool component has been reached based on the physical signature. The actuatable tool component is configured to be actuated to perform a well or tubular operation in response to the actuation signal. The actuatable tool component, the location component, and the on-board controller are together dimensioned and arranged to be deployed in the wellbore or other tubular member as an autonomous tool. The tubular member may be a wellbore constructed to produce hydrocarbon fluids or a pipeline transporting fluids. Further, the actuatable tool component, the location component, and the on-board controller may be coupled together and/or disposed within a housing. The housing and/or the coupling mechanism may include a frangible material or a dissolvable material. The actuatable tool component may be, for example, a fracturing plug, a bridge plug, a cutting tool, a casing patch, a cement retainer, or a perforating gun.

[0057] In certain embodiments, the autonomous tool may include a location component (e.g., location controller or position controller). The location component may be a separate component from an on-board controller, or may be integrally included within the on-board controller. The location component may be configured to determine the location of the autonomous tool or a component within the wellbore or tubular member (e.g., to sense or identify the location of the actuatable tool or a component within a tubular member). The

location component may determine the location or position within the tubular member (e.g., within the casing string of the wellbore) based on a physical signature provided along the tubular member. For example, the location component may be a casing collar locator, and the physical signature may be formed by the spacing of collars along the tubular member. As the different casing collars are identified by the collar locator, the location of the autonomous tool is determined relative to a predetermined casing collar location. As another example, the location component may be a radio frequency antenna, and the physical signature may be formed by the spacing of identification tags along the tubular member. As the identification tags are identified by the radio frequency antenna, the location of the autonomous tool is determined relative to a predetermined identification tag location. Further, as yet another example, the location component may be a pressure sensor, and the physical signature may be formed by the pressure changes within the tubular member. As the pressure reaches a predetermined threshold, the location of the autonomous tool is determined relative to a predetermined pressure identifier. Moreover, the location component may include two or more sensing devices spaced apart along the autonomous tool, which may be two of more of casing collar locators, radio frequency antenna, pressure sensor and any combination thereof. As a specific example, for two sensing devices, the first sensing device may be disposed lower than the second sensing device relative to the direction of travel into the tubular member. The first sensing device may be referred to as the lower sensing device and the second sensing device may be referred to as the upper sensing device. In this configuration, the signatures formed by the different sensing devices may be used to determine the location of the autonomous tool and/or to validate the location of the autonomous tool (e.g., by comparing the determined locations).

[0058] In other embodiments, the autonomous tool may include an on-board controller, as one of the components. The on-board controller may be configured to transmit or send an actuation signal to the actuatable tool component when the location component has identified the selected location within the tubular member and/or when the on-board controller has determined that a specific time period has elapsed. The on-board controller may include a clock or timing mechanism that determines the amount of time that elapses between sensing different signatures (e.g., sensing different tags, collars, wireless transmitter signals or depths) as the autonomous tool traverses the tubular member. The autonomous tool, or specifically the on-board controller, may be configured or programmed to determine the velocity of the autonomous tool at a given time based on the distance between signatures (e.g., comparing the signature from the lower sensing device and the signature of the upper sensing device, or

dividing the distance traveled between sensors by the elapsed time between the signatures. The position of the autonomous tool may then be determined by one or more of calculating the location of the autonomous tool relative to the signatures (e.g., tags as sensed by either the lower or the upper sensing device), and calculating the velocity of the autonomous tool as a function of time.

[0059] The actuatable tool component of the autonomous tool may include different components to perform specific tubular operations. For example, the actuatable tool component may be a perforating gun component. The perforating gun component may be fabricated from at least a portion of dissolvable material and may be configured to fire shots (e.g., from a detonation device) along the selected location to produce perforations into the associated casing string and cement sheath at that selected location. As another example, the actuatable tool component may be a ball sealer component. The ball sealer component may be configured to release a plurality of ball sealers to block flow through any perforations at a selected locations. The ball sealer component may be configured to release the ball sealers before the perforating operations are performed or simultaneously therewith. In yet another example, the actuatable tool component may be a fracturing plug component. The fracturing plug component may include a fracturing plug having an elastomeric element for creating a fluid seal upon being actuated. The fracturing plug component may also be configured to detect a selected location along the wellbore for setting and may be configured to actuate one or more slips and a sealing element are together actuated to set the fracturing plug assembly. Further still, in another example, the actuatable tool component may be a setting component that include a set of slips for holding the autonomous tool in the wellbore. In this configuration, the setting component may be configured to activate the slips to be set in the wellbore at the selected location. Moreover, the actuatable tool component may be a fracturing plug, a shockwave component, a cement retainer, or a bridge plug. The autonomous tool also has a setting tool for setting the autonomous tool.

[0060] In yet other embodiments, the present techniques may include methods for performing tubular operations (e.g., wellbore completion operation) with a working line that does not provide any communication between the autonomous tool and surface equipment. As an example of this configuration, the wellbore is constructed to produce hydrocarbon fluids from a subsurface formation or to inject fluids into a subsurface formation. The method includes deploying an autonomous tool into the wellbore, which may be deployed via a working line (e.g., a slickline, a wireline, or an electric line). The autonomous tool includes at least a portion of it being fabricated from a dissolvable material. Further, the method may

include removing the working line after the autonomous tool is set in the wellbore. Moreover, the autonomous tool may include a location component for sensing the location of the actuatable tool component within the wellbore based on a physical signature provided along the wellbore. Also, the on-board processor may be configured to transmit or send an actuation signal to the actuatable tool component when the location component has determined a selected location of the actuatable tool component based on the physical signature. The actuatable tool component is configured to perform the tubular operation in response to the actuation signal. The present techniques may be further understood with reference to the Figures 1 to 6C below.

[0061] Figure 1 is an exemplary flow chart 100 of a method for utilizing an autonomous tool having at least a portion formed from a dissolvable material in accordance with an embodiment of the present techniques. In this flow chart 100, the method may be used to autonomously perform tubular operations. In particular, the method utilizes an autonomous tool having at least a portion formed from a dissolvable material. The dissolvable material may provide shock resistant connections, pressure bulk heads, fixtures and/or electrical boards with enhanced shock resistance, for example. The method provides potentially lower cost, enhances reliably by ensuring tool fragments are reduced to acceptable size or dissolved, provides an alternative to ceramic materials (e.g., which are difficult to fabricate components, such as joints between components).

[0062] The method begins at block 102. In block 102, an autonomous tool is fabricated having at least a portion of the autonomous tool being formed from dissolvable material. The autonomous tool may include an actuatable tool component (e.g., perforating gun component, ball sealer component, fracturing plug component, setting component, fracturing plug component, cement retainer component, bridge plug component, shockwave component and any combination thereof), a location component and an on-board controller. Further, the autonomous tool may also include a housing that is utilized to enclose one or more components and to isolate one or more components from fluids within the tubular member. Also, the dissolvable material may include materials, such as polylactic acid (PLA), polyglycolic acid (PGA), polydioxone (PDO), polycaprolactone (PCL), alloys, and the like. At block 104, the autonomous tool is configured to perform a tubular operation. Configuring the autonomous tool may include programming the components to perform specific operations or functions (e.g., perform the tubular operation at a specific location) or within a specific time period, to determine the location of the autonomous tool and/or to actuate the actuatable tool component. Further, configuring the autonomous tool may include coupling various components together to communicate with each other and/or to be secured together to form the autonomous tool.

[0063] Once the configuration is completed, the autonomous tool may be used in the tubular member to perform the tubular operations, as shown in blocks 106, 108 and 110. At block 106, the autonomous tool is deployed into the tubular member. The deployment of the autonomous tool may include pumping, using gravitational pull, using a tractor, or combinations thereof. Further, the deployment may involve the use of a working line (e.g., a slickline, a wireline, or an electric line). At block 108, autonomous tool performs the tubular operation. The tubular operation may include perforating, cutting, setting a plug or seal, and other well operations. Then, once the tubular operation is performed, at least a portion of the autonomous tool dissolves, as shown in block 110. The dissolving of the at least a portion of the autonomous tool may involve dissolving parts, fixtures, connections, tubular, bulk heads and/or parts of an actuating tool component. Further, at least a portion of the remaining autonomous tool may be broken apart to create small chards of material, which are not intended to obstruct the tubular member. The chards may fall to bottom of the tubular member, may be pumped out of the tubular member (e.g., into the formation), and/or may flow out of the well during production. The at least a portion of the remaining autonomous tool may be fabricated from a frangible material. The frangible material may include ceramic, phenolic, composite, cast iron, brass, aluminum, or combinations thereof.

[0064] Once the tubular operation is completed, the hydrocarbons may be managed from the tubular member, as shown in block 112. This management may include resuming passing hydrocarbons through a pipeline or further processing the hydrocarbon downstream of the tubular member. Further, the management of the hydrocarbons may include extracting or producing the hydrocarbon from the subsurface formation and the well.

[0065] Beneficially, the present techniques may lessen operating costs and may lessen operational delays in performing the tubular operations. For example, the tubular operations may not involve operations utilized to capture tools, recover tools and/or couple or decouple tools from a wireline, as performed with conventional wireline based tubular operations. Further, as another example, the present techniques may be utilized to lessen the equipment utilized in the tubular operations, such as hollow steel carriers, depth location equipment and connections used to attach devices or tools to a wireline umbilical and/or detach devices or tools to a wireline umbilical.

[0066] As may be appreciated, the present techniques may include autonomous tools that are have one or more components secured together and configured to communicate with each other. The components may include processor based devices in certain configurations, such as an on-board controller and a logic control device, which are configured to perform certain

functions. Accordingly, the components, methodologies, and other aspects of the present techniques can be implemented as software, hardware, firmware or any combination of the three. Of course, wherever a component or subcomponent of the present techniques is implemented as software, the component can be implemented as a standalone program, as part of a larger program, as a plurality of separate programs, as a statically or dynamically linked library, as a kernel loadable module, as a device driver, and/or in every and any other way known now or in the future to those of skill in the art of computer programming. Additionally, the present techniques are in no way limited to implementation in any specific operating system or environment.

[0067] For example, Figure 2 is an exemplary autonomous tool 200 for use in tubular operations in accordance with an embodiment of the present techniques. The autonomous tool may include an on-board controller 202 that communicates with an actuatable tool component 204 and a location component 206. The components may communicate via a physical mechanisms (e.g., wires) or may communicate via wireless mechanisms (e.g., radio wave transmissions). Further, the autonomous tool 200 may also include a housing 208 that is utilized to enclose one or more components, such as components 202, 204 and 206 for this exemplary configurations. The housing 208 may be utilized to isolate components from fluids within the tubular member.

[0068] The on-board controller 202 may be configured to manage the tubular operations. The on-board controller 202 may include a processor, memory accessible by the processor and a set of instructions stored on the memory that are configured to communicate with the other components, such as actuatable tool component 204 and a location component 206, to receive location data and provide instructions, such as notifications or signals to the other components. The on-board controller 202 may be configured to calculate from the location data, depth, time and/or velocity when the actuatable tool component 204 should be activated or may be configured to deploy additional actuatable tool component, if necessary. For example, the on-board controller 202 may be configured to transmit or send an actuation signal to the actuatable tool component 204 when the location component 206 has identified the selected location within the tubular member (e.g., from a wireless transmitter within the tubular member) and/or when the on-board controller 202 has determined that a specific time period has elapsed. The on-board controller 202 may include a clock or timing mechanism (not shown) that determines the amount of time that elapses between sensing different signatures (e.g., sensing different tags, collars, or depths) as the autonomous tool traverses the tubular member. The on-board controller 202 may also be configured to calculate the velocity of the autonomous tool at a

given time based on the distance between location data or signatures (e.g., comparing the signature from the same sensor at two locations or comparing the data from two or more sensors, and then dividing the distance traveled between location data (e.g., distance travelled) by the elapsed time between the signatures.

[0069] The actuatable tool component 204 may be configured to perform one or more tubular operations. For example, the actuatable tool component 204 may include perforating gun component, ball sealer component, fracturing plug component, setting component, fracturing plug component, cement retainer component, bridge plug component and any combination thereof, for example.

[0070] The location component 206 may determine or recognize the location of the autonomous tool within the tubular member. The location component 206 may be a separate component from an on-board controller 202, or may be integrally included within or as part of the on-board controller 202. The location component 206 may include a processor, memory accessible by the processor and a set of instructions stored on the memory that are configured to communicate with the other components, such as on-board controller 202, and one or more sensors, such as first sensor 210 and second sensor 212, to receive location data and to provide instructions, such as notifications or signals to the other components, such as on-board controller 202. The location component 206 may utilize a location detection technology to determine the location of the autonomous tool or one of the respective components based on the location detection technology (e.g., sensing different tags, collars, velocity, time and/or depths). As an example, the location component 206 may be configured to determine the location or position within the tubular member (e.g., within the casing string of the wellbore) based on a physical signature provided from identification tags along the tubular member, or by detecting or identifying casing joints or casing collars within the tubular member; by identifying radio frequency tags along the tubular member or by determining the depth of the autonomous tool based on pressure within the tubular member. For example, the location component 206 may be configured to receive location data from sensors 210 and 212 and to determine the location based on that location data. As another example, the location component 206 may be configured to obtain location data that is pressure measurement data from the sensors 210 and 212 and to determine the location based on the pressure within the tubular member at the location. Further, the location component 206 may also include an accelerometer, which is configured to measure acceleration experienced during a freefall. The accelerometer, which may include a gyroscope, may include multi-axis capability to detect

magnitude and direction of the acceleration as a vector quantity. The location component 206 may be configured to calculate the location of the autonomous tool.

[0071] As an example, the on-board controller 202 may be a computing system, which may be utilized and configured to implement on or more of the present aspects. The computing system may include a processor; memory in communication with the processor; and a set of instructions stored on the memory and accessible by the processor, wherein the set of instructions, when executed, are configured to perform one or more operations that are pre-programed into the device. The dissolvable components, which may include the mother board, clips and/or other hardware, lessen any debris that has to be removed from the tubular member for ongoing operations and lessen the potential for any negative impact to fluid conductivity for ongoing tubular operations.

[0072] Figure 3 is a side view of an exemplary autonomous tool 300 as may be used for tubular operations within a wellbore. In this view, the autonomous tool 300 is a fracturing plug assembly, which may be used to perform the tubular operation in a wellbore completion. The autonomous tool 300 may be deployed within a string of production casing, which is formed from a plurality of joints that are threadedly connected at collars. The autonomous tool 300 is exposed to injection of fluids, which may be include high pressures and temperatures within the typical environment of the wellbore completion. Also, the autonomous tool 300 may involve a pre-actuated position (e.g., used for deployment) and an actuated position (e.g., used once actuated). Further, the autonomous tool 300 forms a plug body and include various components, such as the location component 308, an on-board controller 310, and an actuatable tool component, which includes an elastomeric sealing element 302, a set of slips 304, and a setting tool 306.

[0073] The actuatable tool component includes different parts that perform specific functions for the autonomous tool. For example, the elastomeric sealing element 302 is mechanically expanded in response to a shift in a sleeve or other means as is known in the art. The slips 304 also ride outwardly from the body along wedges (not shown) spaced radially around the outer portion of the autonomous tool 300. Preferably, the slips 304 are also urged outwardly along the wedges in response to a shift in the same sleeve or other means as is known in the art. The slips 304 extend radially to "bite" into the tubular member, such as the casing, when actuated, securing the autonomous tool 300 in position. The setting tool 306 actuates the slips 304 and the elastomeric sealing element 302 and translates them along the wedges to contact the surrounding casing. In the actuated position, the elastomeric sealing element 302 is expanded, as shown along the arrow 312, into sealed engagement with the surrounding

production casing (not shown), and the slips 304 are also expanded into mechanical engagement with the surrounding production casing (not shown). The sealing element 302 has a sealing ring, while the slips 304 have grooves or teeth that interact with the inner diameter of the casing.

[0074] The location component 308 is configured to sense or identify the location of the autonomous tool 300 within the production casing. Accordingly, the location component 308 may be configured to detect collars, object, tags or pressures within the wellbore and may be configured to generate a signature associated with the location of the autonomous tool 300 (e.g., depth signals in response to the determined location). For example, the location component 308 may be a casing collar locator that senses the location of the casing collars as it moves down the production casing; a radio frequency detector that detects radio frequency identification tags; a pressure sensor that detects pressures within the wellbore; and/or any combination of these different techniques. As another example, the location component 308 may include two or more of these techniques to provide verification or redundancy for the location identification. In particular, the location component 308 may include a casing collar locator and a pressure sensor that are used to compare the respective locations that may be identified within the wellbore.

[0075] The on-board controller 310 is utilized to manage the tubular operation. For example, the on-board controller 310 is configured to process the depth signals received from the location component 308. In one configuration, the on-board controller 310 may be configured to compare the received depth signals with a pre-determined signature associated with one or more objects. The predetermined signature may be a previously performed casing collar log, which is performed before deploying the autonomous tool 300 to determine the spacing of the casing collars; may be a diagram providing information concerning the spacing of tags; and/or may be a diagram of predetermined pressure measurements. Then, the depth of the autonomous tool 300 may be calculated based at least partially on the comparison. Further, the on-board controller 310 is configured to transmit a signal to activate the actuatable tool component when it determines that the autonomous tool or specifically the component has reached a particular depth or predetermined location. As an example, the activation of the autonomous tool 300 may include sending signals to the setting tool 306 to stop moving the autonomous tool through the tubular member, and to set the slips 304 and the elastomeric sealing element 302 in the tubular member at the desired depth or location.

[0076] Figure 4 is a side view of an exemplary autonomous tool 400 for a wellbore perforating operation in accordance with an embodiment of the present techniques. Similar to

Figure 3, the autonomous tool 400 may be deployed within a string of casing, which is formed from a plurality of joints that are threadedly connected at collars. The autonomous tool 400, which may include a perforating gun and other associated equipment, is exposed to various fluids within the wellbore, which may be include high pressures and temperatures within the typical environment of the wellbore. Also, the autonomous tool 400 may involve a pre-actuated position (e.g., used for deployment) and an actuated position (e.g., used once actuated). In particular, the autonomous tool 400 may include various components, such as a first location component 404 and a second location component 408, an on-board controller 410, and an actuatable tool component, which includes a fishing neck 402, a perforating gun 406, and a ball sealer carrier 412.

[0077] The actuatable tool component may be parts for a perforating gun assembly that is configured to form perforations through the tubular member and portions of the surrounding formation. The fishing neck 402 may be dimensioned and configured to function as the male portion to a mating downhole fishing tool (not shown). The fishing neck 402 provides a mechanism to retrieve the autonomous tool 400 if it becomes stuck in the casing or fails to detonate. The perforating gun 406 may be a select fire gun that fires, for example, 16 shots. The perforating gun 406 has an associated charge that detonates to cause shots to be fired from the perforating gun 406 into the surrounding casing, as shown by arrow 414. The perforating gun 406 may include one or more shaped charges distributed along the length of the perforating gun 406 and oriented according to desired specifications. The charges are preferably connected to a single detonating cord to ensure simultaneous detonation of all charges. Examples of suitable perforating guns include the Frac Gun™ from Schlumberger, and the G-Force® from Halliburton. Further, the ball sealer carrier 412 may be disposed at the lower portion of the autonomous tool 400. The ball sealer carrier 412 may be configured to release the ball sealers (not shown) when the perforating gun 406 is actuated. Alternatively, the ball sealer carrier 412 may be configured to release the ball sealers (not shown) when a timer on the on-board controller 410 has elapsed a period of time (e.g., shortly before the perforating gun 406 is fired, concurrently therewith or simultaneously therewith). The released ball sealers may be used to seal perforations that have been formed at a lower depth or location in the wellbore. These ball sealers may be fabricated from the dissolvable material.

[0078] Similar to the location component 308 of Figure 3, the first location component 404 and the second location component 408 may operate in a similar manner. The location components 404 and 408 may determine the location of the autonomous tool 400 and generate one or more depth signals in response. While one location component may be utilized, the

autonomous tool 400 may include two location components, as a further enhancement to the tubular operations. The use of two location components may be utilized to verify the location between the first location component 404 with the second location component 408 or to calculate a combined location from the two location components 404 and 408. Further, the location component 404 and 408 may utilize the same location techniques (e.g., casing collar locators; radio frequency detectors or pressure sensors) or may be a combination of different location techniques. For example, if the tubular operation involves more precision, the casing collar locator or radio frequency detector may be the first location component 404, while the pressure sensor may be the second location component 408.

[0079] Also, the on-board controller 410 may operate in a similar manner to the on-board controller 310 of Figure 3. The on-board controller 410 may process the depth signals generated by one or more of the location components 404 and 408 using appropriate logic and power units. In one configuration, the on-board controller 410 may compare the generated depth signals with a pre-determined physical signature, as discussed above. Further, the on-board controller 410 may be configured to activate the actuatable tool component when it determines that the autonomous tool 400 has reached at a depth that is the selected or predetermined location, which is performed using appropriate on-board processing. As an example, the on-board controller 410 may activate a detonating cord that ignites the charge associated with the perforating gun component 406 to initiate the perforation of the production casing at a desired depth or location. Further, the on-board controller 410 may activate the ball sealer carrier 412 to release the ball sealers (not shown) prior to igniting the detonating cord for the perforating gun component 406 or at the same time the detonating cord is ignited. The actuation of the actuation tool component may be result in the destruction of the autonomous tool, which may be fabricated form at least a portion of dissolvable material and the remaining portion may be fabricated from a friable material. As an example, the detonation may result in the materials that the autonomous tool 400 is fabricated from becoming a part of the proppant mixture injected into fractures in a later completion stage.

[0080] To further enhance the process, a single autonomous tool may include two or more actuatable tool components to perform two or more tubular operations with a single deployment. For example, two or more actuatable tool components may be configured to deploy at different locations and may be configured to delay activation to perform a specific sequence of tubular operations. By way of example, Figure 5 is an exemplary flow chart 500 of a method for utilizing an autonomous tool having two or more actuatable tool components, wherein the autonomous tool has at least a portion formed from a dissolvable material in

accordance with an embodiment of the present techniques. In this flow chart 500, the method may be used to autonomously perform multiple tubular operations in a specific sequence. In particular, the method utilizes an autonomous tool having two or more actuatable tool components, wherein each of two or more actuatable tool components perform a specific tubular operations.

[0081] The method begins at block 502. In block 502, an autonomous tool is fabricated having two or more actuatable tool components, which are each configured to perform a respective tubular operation. At least a portion of the autonomous tool is formed from strategic placement of dissolvable components for the desired effect. The two or more actuatable tool component may include perforating gun component, ball sealer component, fracturing plug component, setting component, fracturing plug component, cement retainer component, bridge plug component and any combination thereof. The autonomous tool may also include one or more location components and one or more on-board controllers, which may be dedicated to each of the actuatable tool components or utilized for the actuatable tool components. Further, the autonomous tool may also include a housing that is utilized to enclose one or more components and to isolate one or more components from fluids within the tubular member. At block 504, the autonomous tool is configured to perform the sequence of tubular operations. Similar to block 104 of Figure 1, the configuring the autonomous tool may include programming the components to perform specific operations or functions (e.g., perform the tubular operation at a specific location) or within a specific time period, to determine the location of the autonomous tool and/or to actuate the actuatable tool component.

[0082] Once configured, the autonomous tool may be used in the tubular member to perform the sequence of tubular operations, as shown in blocks 506, 508, 510, 512, 514 and 516. At block 506, the autonomous tool is deployed into the tubular member. Similar to block 106 of Figure 1, the deployment of the autonomous tool may include pumping, using gravitational pull, using a tractor, or combinations thereof. At block 508, autonomous tool determines if the first location has been reached. If the first location has not been reached, the autonomous tool continues to monitor the location within the tubular member. However, if the first location has been reached, the autonomous tool may actuate the first actuatable tool component, as shown in block 510. The actuating the first actuatable tool component may include detaching or separating the first actuatable tool component from the remaining actuatable tool components (e.g., the second actuatable tool component). Then, the autonomous tool determines if the second location has been reached in block 512. If the second location has not been reached, the autonomous tool continues to monitor the location within

the tubular member. However, if the second location has been reached, the autonomous tool may perform the sequence of tubular operations, as shown in block 514. This may involve actuating the second actuatable tool component. For example, the sequence of tubular operations may include the first actuating tool component releasing ball sealers and then the second actuating tool component perforating the tubular member at the second location. Then, once the sequence of tubular operations are performed, the at least a portion of the autonomous tool dissolves, as shown in block 516. The dissolving of the at least a portion of the autonomous tool may be performed in a similar manner to block 110 of Figure 1.

[0083] Once the sequence of tubular operations are completed, the hydrocarbons may be managed from the tubular member, as shown in block 518. This management may include resuming passing hydrocarbons through a pipeline or further processing the hydrocarbon downstream of the tubular member. Further, the management of the hydrocarbons may include extracting or producing the hydrocarbon from the subsurface formation and the well. Beneficially, the time involved in the production of hydrocarbons may be lessened to enhance the economics of the well investment and development.

[0084] By way of example, the autonomous tool may include a configuration of perforating gun components to perforate multiple target zones or regions and set a bridge plug components to isolate previously treated zones via a single deployment of the autonomous tool. This configuration may be similar to conventional plug and perforate operation, but without the use of wireline and its associated equipment. Accordingly, this configuration may lessen costs and lessen down time associated with spooling in, pump down, and removal of the wire and tool string through a lengthy lubricator. Beneficially, this may lessen total time on location, which lessens the associated costs. Further, the sooner the fracture fluids can be removed from the formation, the less negative impact the fracture fluids may have on the formation, which enhance production.

[0085] Figures 6A, 6B and 6C are a side view 600, 620 and 640 of a portion of a wellbore and the subsurface formation near the wellbore for various stages of deployment of the autonomous tool in accordance with an embodiment of the present techniques. In these views 600, 620, and 640, the autonomous tool 602 may provide a mechanism for selective placement of each perforating gun component 604, 606 and 608 for each individual zone to enhance well productivity.

[0086] Figure 6A is a side view 600 of a portion of a wellbore and the subsurface formation near the wellbore for initial deployment of the autonomous tool. In this view 600, the autonomous tool 602 may include perforating gun components 604, 606 and 608, which are

coupled together as a single autonomous tool for the deployment into the wellbore. The wellbore may include a casing string 610 surrounded by a cement sheath 613. The wellbore is disposed within a subsurface formation including three zones of interest, such as first zone 614, second zone 616 and third zone 618. Further, to assist the identification of the location within the wellbore, various tags, such as tag 612, may be disposed within the wellbore.

[0087] Figure 6B is a side view 620 of a portion of a wellbore and the subsurface formation near the wellbore for a subsequent stage in the tubular operations. In this stage, the first perforating gun component 604 separates from the remaining perforating gun component 606 and 608 to deploy within the first zone of interest 614. In this view 620, the perforating gun components 606 and 608 are coupled together as the remaining actuatable tool components traveling to the lower locations, such as zones of interest 616 and 618.

[0088] Figure 6C is a side view 640 of a portion of a wellbore and the subsurface formation near the wellbore for a final stage in the tubular operations. In this stage, the perforating gun components have detonated to form the perforations 642, 644, and 646 for the respective zones. In particular, the first perforating gun component 604 forms the perforations 642 in the first zone of interest 614, the second perforating gun component 606 forms the perforations 644 in the second zone of interest 616, while the third perforating gun component 608 forms the perforations 646 in the third zone of interest 618.

[0089] As additional enhancements, the autonomous tool may include other actuatable tool components. For example, the additional actuatable tool components may provide diversion between zones of interest 614, 616 and 618 to ensure each zone is treated per design and previously treated zones of interest 614, 616 and 618 are not inadvertently damaged. Further, the autonomous tool may provide a mechanism for stimulation treatments to be pumped at high flow rates to facilitate efficient and effective stimulation. As such, the autonomous tool may enhance tubular operations, such as multi-zone stimulation techniques and the associated hydrocarbon recovery from subsurface formations that contain multiple stacked subsurface intervals. With the use of autonomous tools containing dissolvable materials, surface equipment utilization in a given time period may be enhanced (e.g., high pressure pumping equipment). The enhancement is a result of the lessening or removal of the need or requirement to remove debris along with enhanced capabilities to run more components and perform more tubular operations on a single run with materials that dissolve within the tubular conditions.

[0090] While it will be apparent that the inventions herein described are well calculated to achieve the benefits and advantages set forth above, it will be appreciated that the inventions are susceptible to modification, variation and change without departing from the spirit thereof.

CLAIMS

What is claimed is:

1. An autonomous tool for performing a tubular operation, comprising:

an actuatable tool component configured to perform a tubular operation;

a location component configured to determine a location of the autonomous tool within a tubular member; and

an on-board controller configured to send an actuation signal to the actuatable tool component when a predetermined location has been reached within the tubular member;

wherein:

the actuatable tool component, the location component, and the on-board controller are arranged to be deployed together in the tubular member as a single autonomous tool;

the actuatable tool component is configured to autonomously perform the tubular operation in response to the actuation signal; and

at least a portion of the actuatable tool component, the location component, and the on-board controller are fabricated from a dissolvable material configured to dissolve when subjected to tubular conditions.

2. The autonomous tool of claim 1, wherein the location component is further configured to determine the location of the autonomous tool based on identifying casing collars within the tubular member, wherein the location component is configured to compare a depth signature formed by the spacing of the casing collars along the tubular member, with a predetermined signature generated prior to deployment of the autonomous tool into the tubular member.

3. The autonomous tool according to claim 1, wherein the location component is further configured to determine the location of the autonomous tool based on identifying radio frequency identification tags within the tubular member, wherein the location component is configured to compare a signature formed by the identified radio frequency identification tags within the tubular member, with a predetermined signature generated prior to deployment of the autonomous tool into the tubular member.

4. The autonomous tool according to claim 1, wherein the location component is further configured to determine the location of the autonomous tool based on pressure measurements within the tubular member, wherein the location component is configured to compare a signature formed by the measured pressures within the tubular member, with a predetermined signature generated prior to deployment of the autonomous tool into the tubular member.

5. The autonomous tool according to claim 1, wherein the autonomous tool further comprises a second location component to determine a second location of the autonomous tool within the tubular member, wherein the second location component utilizes a different location detection technology from the location component.

6. The autonomous tool according to claim 1, wherein the autonomous tool self-destructs in response to one of the actuation of the actuatable tool component, the determination of elapsing of a selected period of time by the on-board controller, and any combination thereof.

7. The autonomous tool according to claim 1, wherein the actuatable tool component is a perforating gun component that is substantially fabricated from a dissolvable material.

8. The autonomous tool according to claim 1, wherein the actuatable tool component is a ball sealer component that is substantially fabricated from a dissolvable material.

9. The autonomous tool according to claim 1, wherein the remaining portion of the autonomous tool is fabricated from a friable material or a millable material.

10. The autonomous tool according to claim 1, wherein the autonomous tool further comprises a second actuatable tool component configured to perform a second tubular operation, wherein:

the on-board controller is further configured to send a second actuation signal to the second actuatable tool component when the predetermined location has been reached within the tubular member;

the actuatable tool component, the second actuatable tool component, the location component, and the on-board controller are arranged to be deployed together in the tubular member as a single autonomous tool; and

the second actuatable tool component is configured to autonomously perform the second tubular operation in response to the second actuation signal.

11. The autonomous tool of claim 10, wherein the on-board controller manages the sequence of tubular operations.

12. The autonomous tool according to claim 10, wherein the actuatable tool component is a first perforating gun component and the second actuatable tool component is a second perforating gun component.

13. The autonomous tool according to claim 10, wherein the actuatable tool component is a first perforating gun component and the second actuatable tool component is a bridge plug component.

14. The autonomous tool according to claim 10, wherein the actuatable tool component is a first perforating gun component and the second actuatable tool component is a shockwave component.

15. The autonomous tool according to any of the preceding claims used in a method for performing one or more tubular operations, comprising:

deploying an autonomous tool into a tubular member, wherein at least a portion of the autonomous tool is fabricated from a dissolvable material and the autonomous tool is configured to autonomously perform the one or more tubular operations;

autonomously performing the one or more tubular operations with the autonomous tool;

dissolving the at least a portion of the autonomous tool that is fabricated from the dissolvable material; and

managing hydrocarbons from the tubular member.

16. The method according to claim 15, wherein the autonomous tool comprises:

an actuatable tool component configured to perform a first tubular operation of the one or more tubular operations;

a location component configured to determine a location of the autonomous tool within the tubular member; and

an on-board controller configured to send an actuation signal to the actuatable tool component when a predetermined location has been reached within the tubular member;

wherein:

the actuatable tool component, the location component, and the on-board controller are arranged to be deployed together in the tubular member as a single autonomous tool; and

the actuatable tool component is configured to autonomously perform the tubular operation in response to the actuation signal.

17. The method according to claim 15, further comprising determining the location of the autonomous tool based on identified casing collars disposed along the tubular member.

18. The method according to claim 15, further comprising determining the location of the autonomous tool based on identified radio frequency identification tags within the tubular member.

19. The method according to claim 15, further comprising determining the location of the autonomous tool based on pressure measurements within the tubular member.

20. The method according to claim 17, wherein the determining the location of the autonomous tool further comprises determining the location of the autonomous tool based on two or more location detection technologies.

21. The method according to claim 16, further comprising managing a sequence of the one or more tubular operations with the on-board controller.

22. The method according to claim 16, wherein the autonomous tool further comprises a second actuatable tool component and further comprising performing a second tubular operation with the second actuatable tool component.

23. The method according to claim 15, wherein the autonomously performing the one or more tubular operations with the autonomous tool further comprises performing a first perforating operation with a first perforating gun component of the autonomous tool; and performing a second perforating operation with a second perforating gun component of the autonomous tool.

24. The method according to claim 15, wherein the autonomously performing the one or more tubular operations with the autonomous tool further comprises performing a perforating operation with a perforating gun component of the autonomous tool; and performing a bridging operation with a bridge plug component of the autonomous tool.

25. The method according to claim 15, further comprising self-destructing the autonomous tool in response to one of the actuation of the actuatable tool component, the determination of elapsing of a selected period of time by the on-board controller, and any combination thereof.

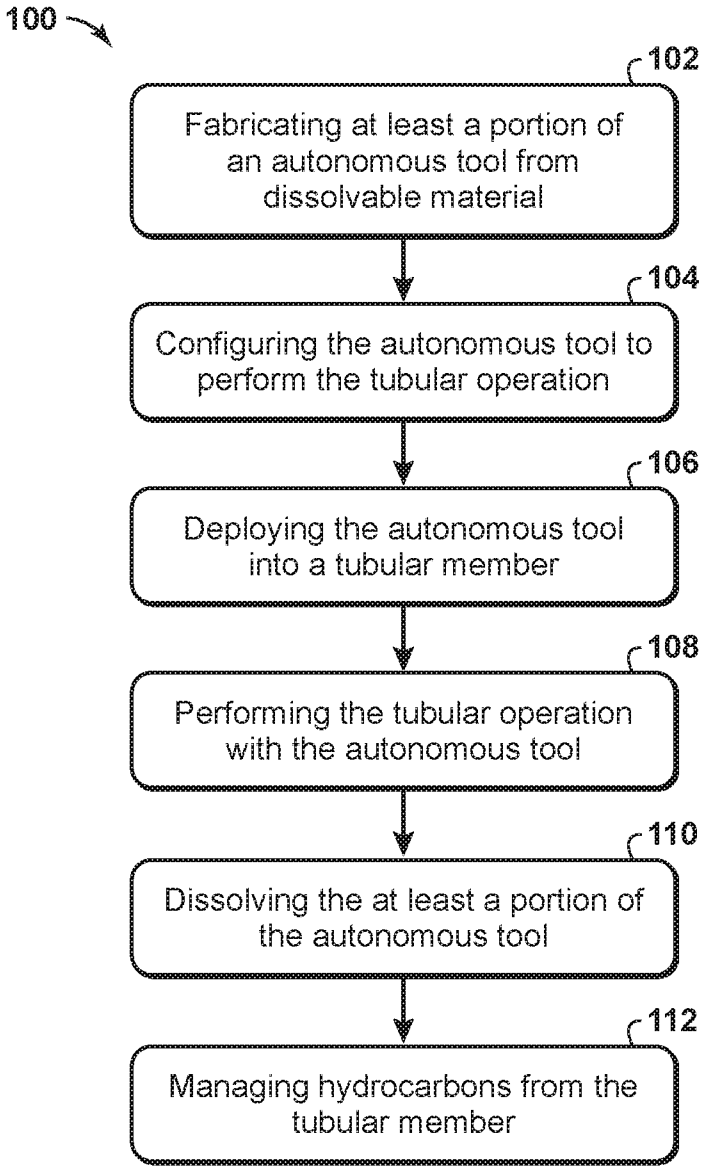
100
102
Fabricating at least a portion of an autonomous tool from dissolvable material
104
Configuring the autonomous tool to perform the tubular operation
106
Deploying the autonomous tool into a tubular member
108
Performing the tubular operation with the autonomous tool
110
Dissolving the at least a portion of the autonomous tool
112
Managing hydrocarbons from the tubular member

FIG. 1

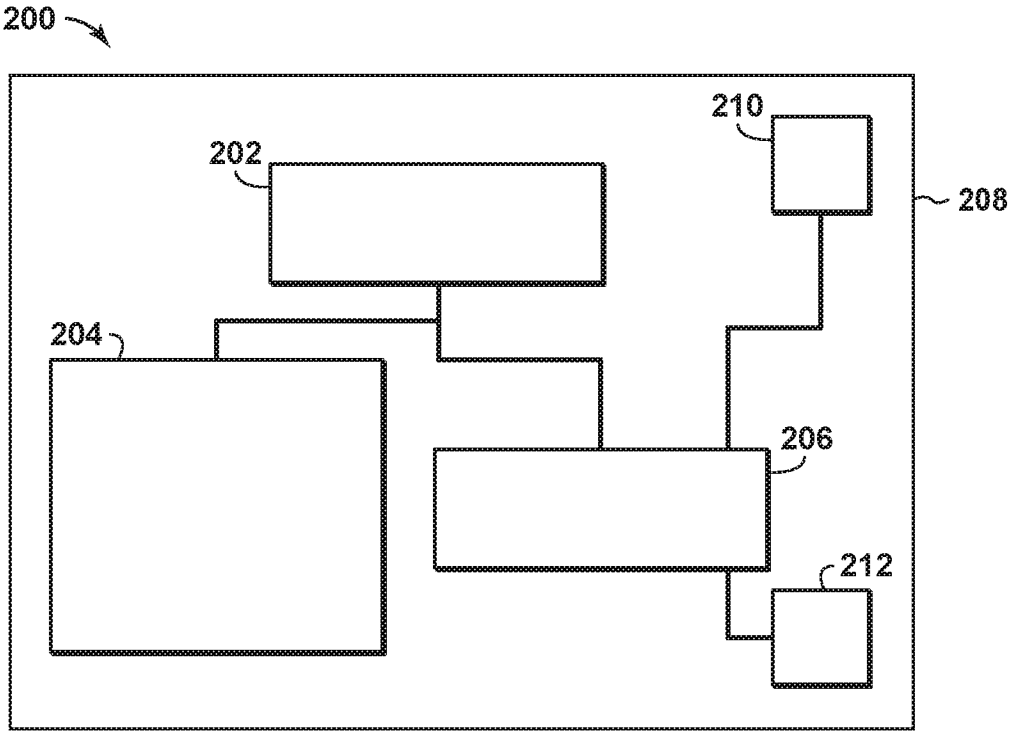

FIG. 2

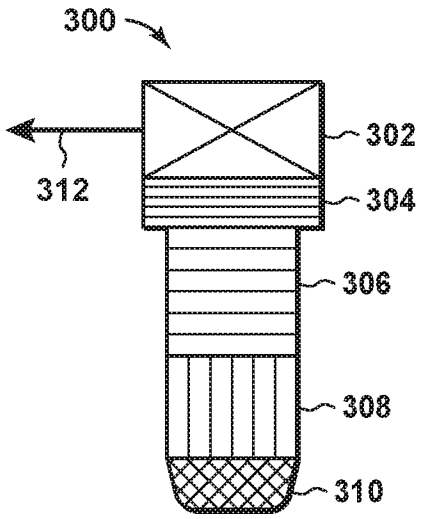

FIG. 3

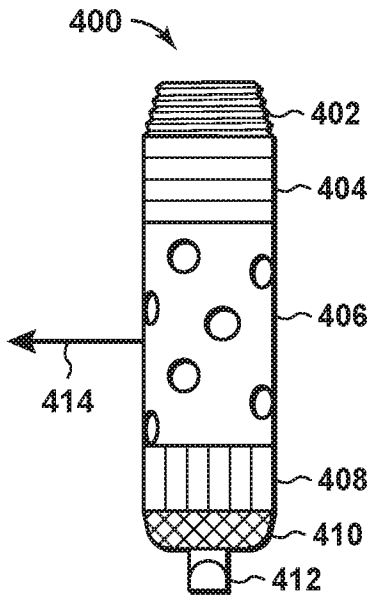

FIG. 4

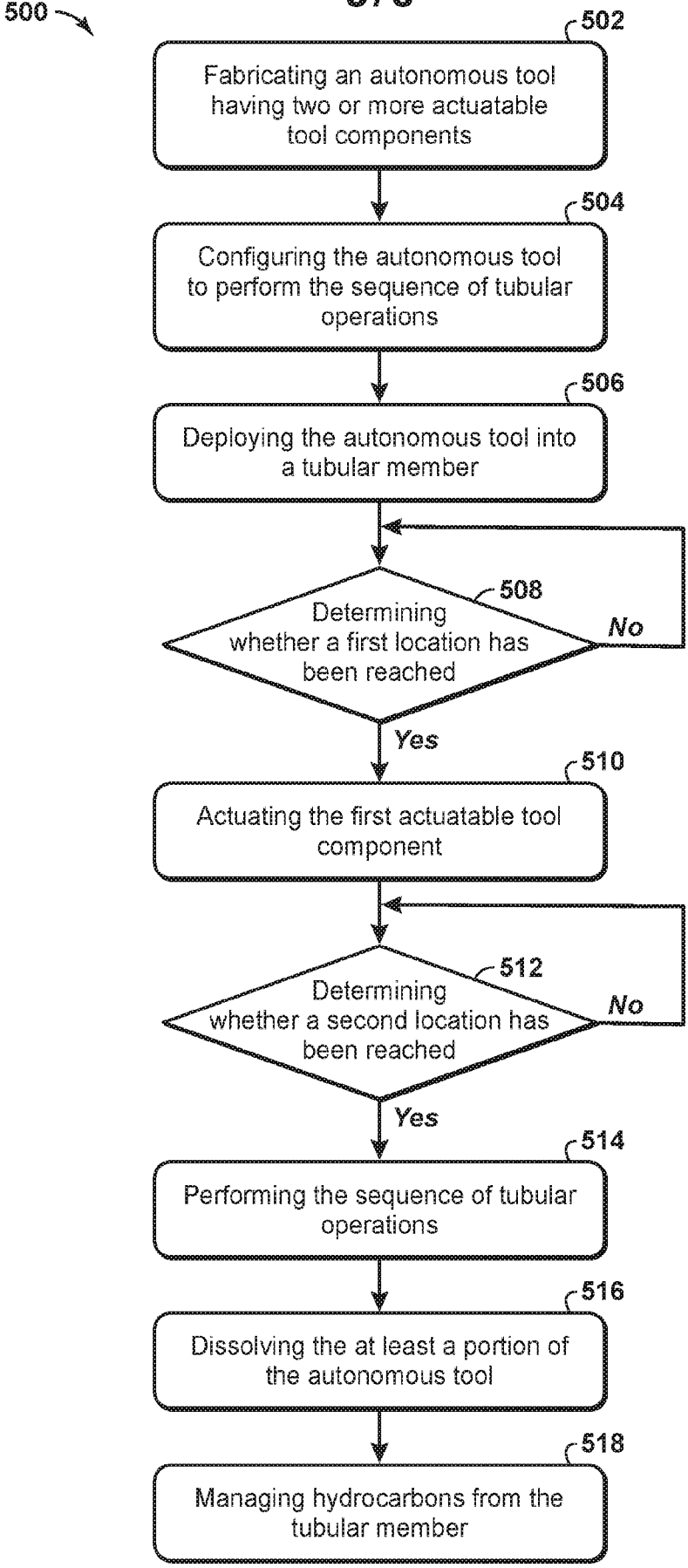
500
502
Fabricating an autonomous tool having two or more actuatable tool components
504
Configuring the autonomous tool to perform the sequence of tubular operations
506
Deploying the autonomous tool into a tubular member
508
Determining whether a first location has been reached
No
Yes
510
Actuating the first actuatable tool component
512
Determining whether a second location has been reached
No
Yes
514
Performing the sequence of tubular operations
516
Dissolving the at least a portion of the autonomous tool
518
Managing hydrocarbons from the tubular member

FIG. 5

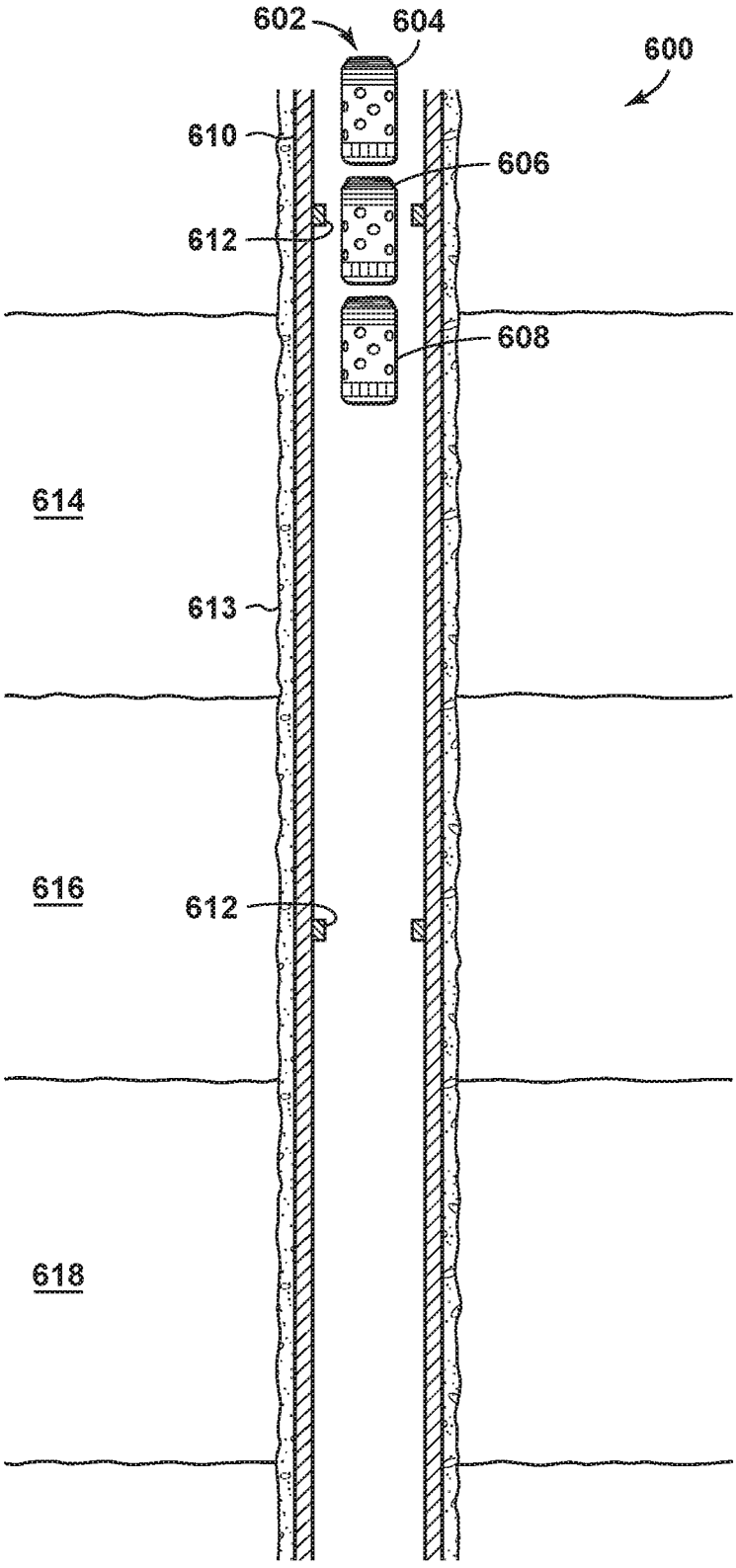

FIG. 6A

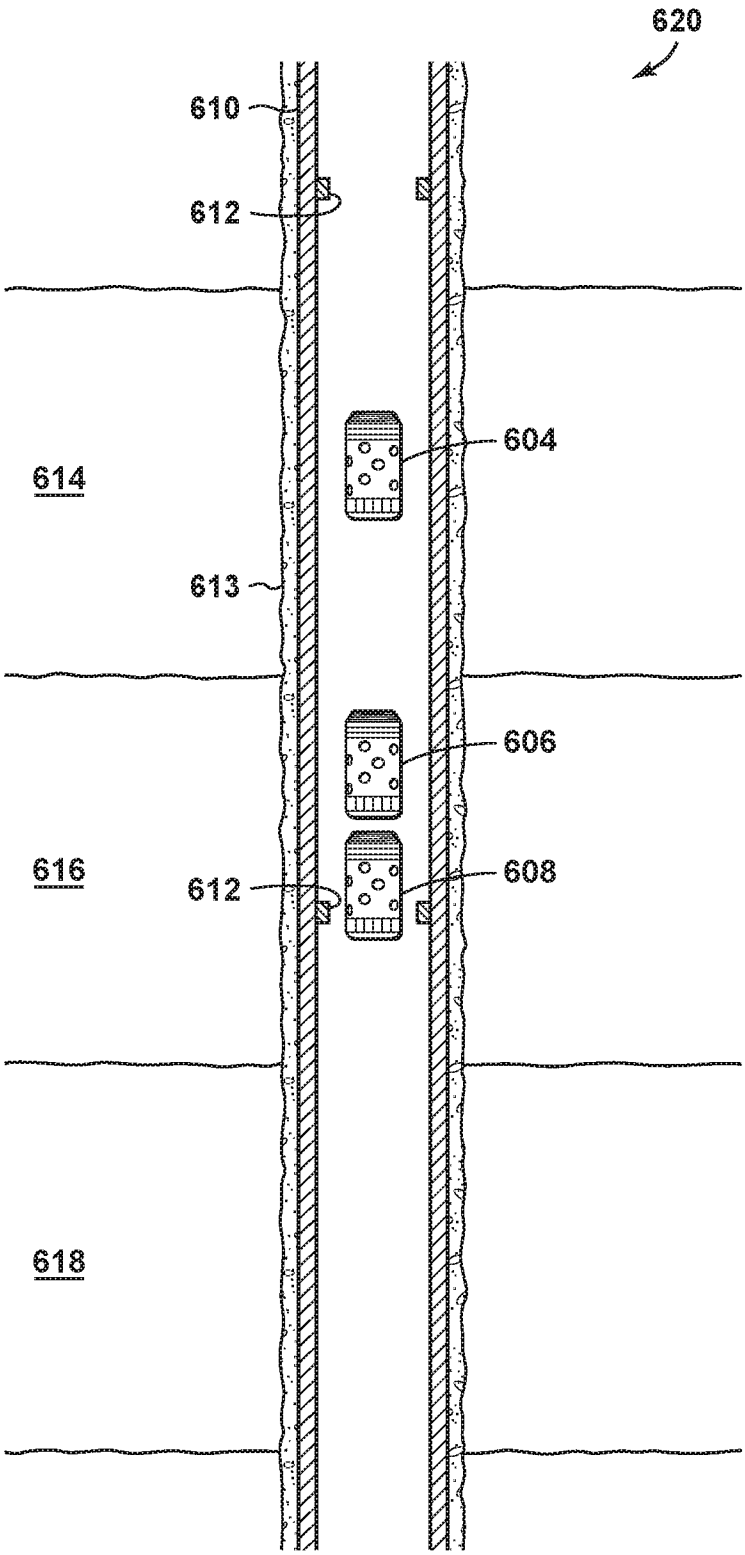

FIG. 6B

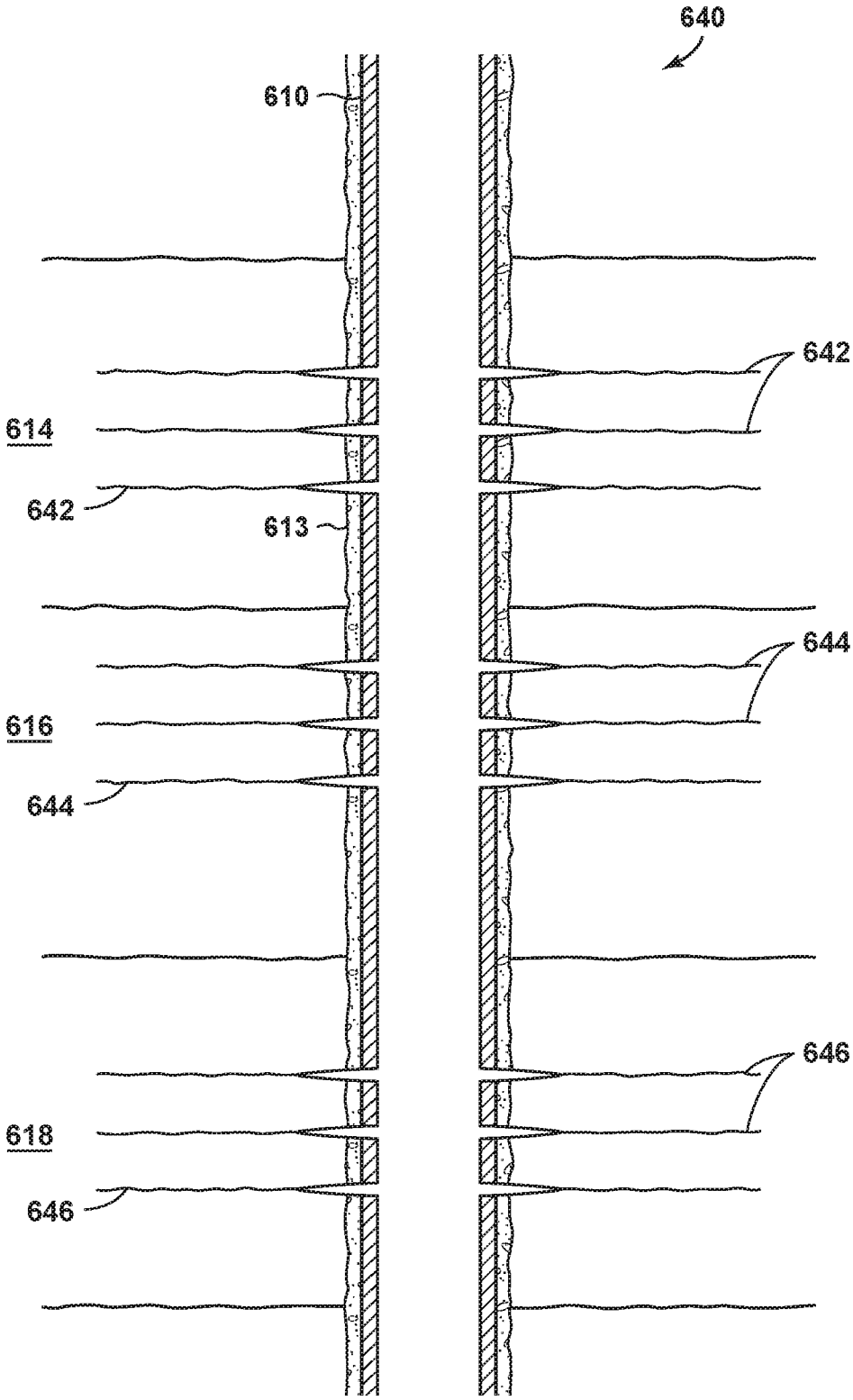

FIG. 6C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/026127

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B23/00 E21B33/134 E21B41/00 E21B43/116 E21B43/119
E21B43/26
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/186672 A1 (SCHLUMBERGER CA LTD [CA]; SCHLUMBERGER SERVICES PETROL [FR]; SCHLUMBER) 20 November 2014 (2014-11-20) figures 1-3 paragraphs [0043] - [0046] paragraphs [0058] - [0059] paragraphs [0064] - [0069] paragraphs [0072] - [0073] paragraphs [0093], [0095] ----- -/--	1-4,6,8, 15-19, 21,25

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 June 2017	13/06/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Altamura, Alessandra

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/026127

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/241824 A1 (BURRIS WESLEY J II [US] ET AL) 3 November 2005 (2005-11-03) figures 1-5,16A-C paragraphs [0032] - [0037] paragraphs [0042] - [0046] paragraphs [0051] - [0057], [0060], [0062] paragraphs [0113] - [0117] paragraph [0133] paragraphs [0150], [0157] - [0161] paragraphs [0172] - [0175] -----	1-7,9-25
X	US 2016/069163 A1 (TOLMAN RANDY C [US] ET AL) 10 March 2016 (2016-03-10) figures 1,2 paragraphs [0028] - [0032], [0036], [0063] paragraphs [0069] - [0082] -----	1,2, 15-17,21

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/026127

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		US 2005241825 A1	03-11-2005
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		US 2005269083 A1	08-12-2005
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		WO 2016039888 A1	17-03-2016