US 20090308588A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2009/0308588 A1**

Howell et al. (43) **Pub. Date: Dec. 17, 2009**

(54) **METHOD AND APPARATUS FOR EXPOSING A SERVICING APPARATUS TO MULTIPLE FORMATION ZONES**

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(21) Appl. No.: **12/139,604**

(22) Filed: **Jun. 16, 2008**

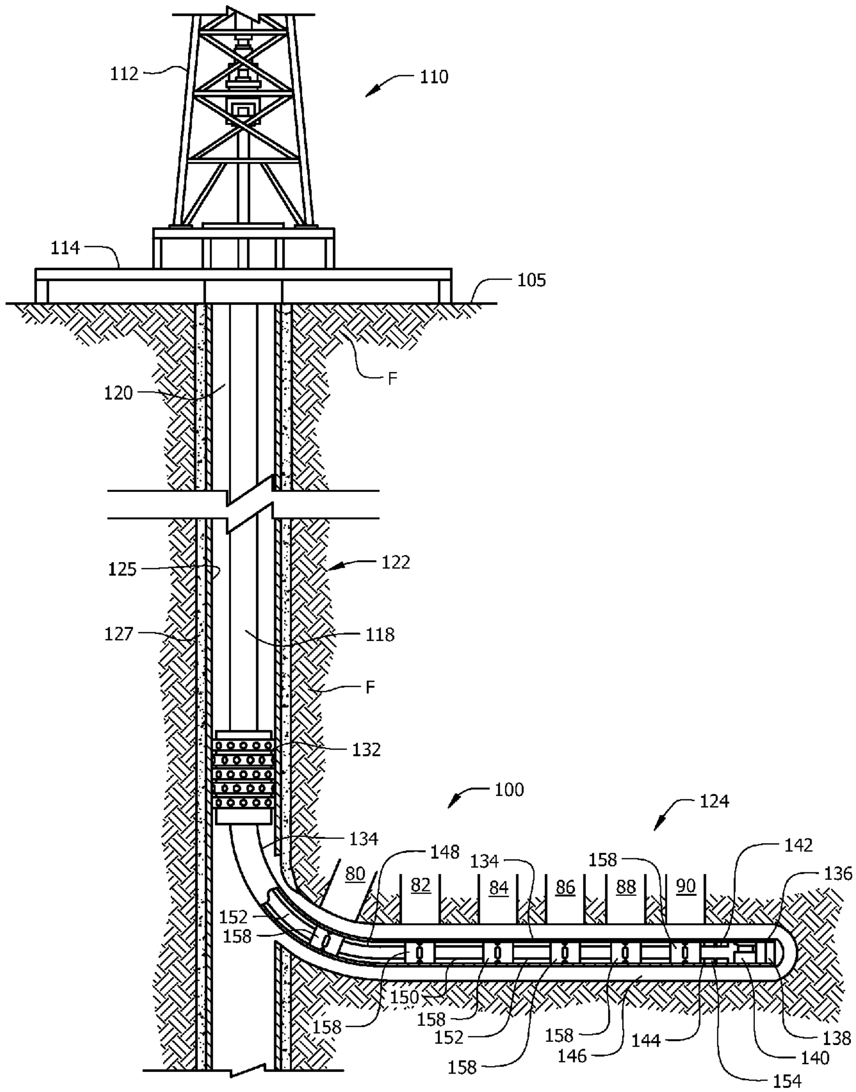
Publication Classification

(51) **Int. Cl.**
E21B 4/04 (2006.01)
E21B 34/06 (2006.01)

(52) **U.S. Cl.** **166/66.4**; 166/373

(57) **ABSTRACT**

A well bore servicing apparatus comprising an first sleeve slidably disposed in a tubing section, an second sleeve slidably disposed in the first sleeve, an indexing slot disposed on one of the outer sleeve and inner sleeve, and a control lug disposed on the other of the outer sleeve and the inner sleeve to communicate with the indexing slot, and an expandable seat disposed in the inner sleeve to receive a plurality of obturating members. A well bore servicing apparatus comprising a work string, a tubing section coupled to the work string, a plurality of sleeve assemblies disposed in the tubing section, and a plurality of seats for receiving an obturating member, one seat disposed in each of the sleeve assemblies, wherein the plurality of seats are substantially the same size.



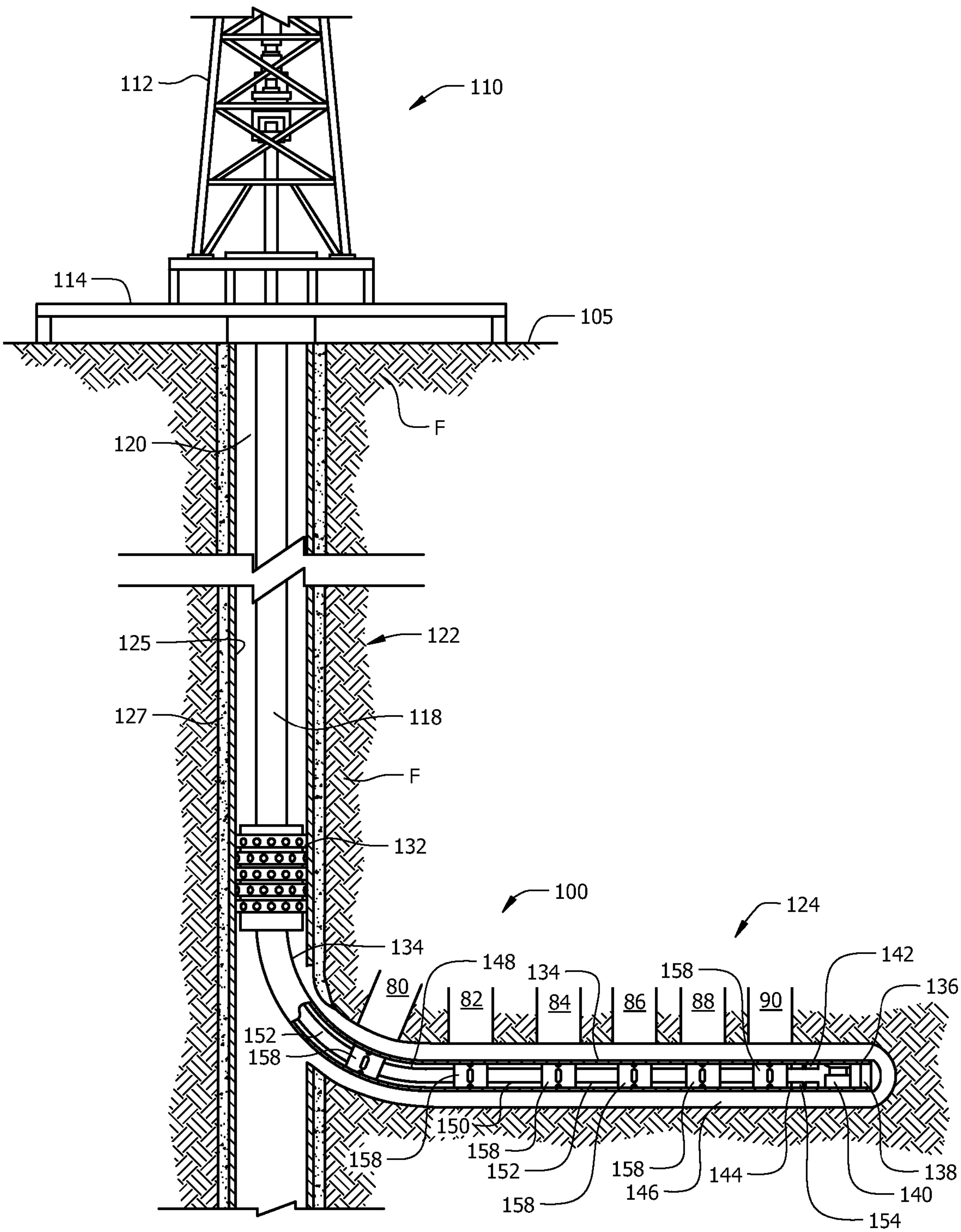

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FIG. 1

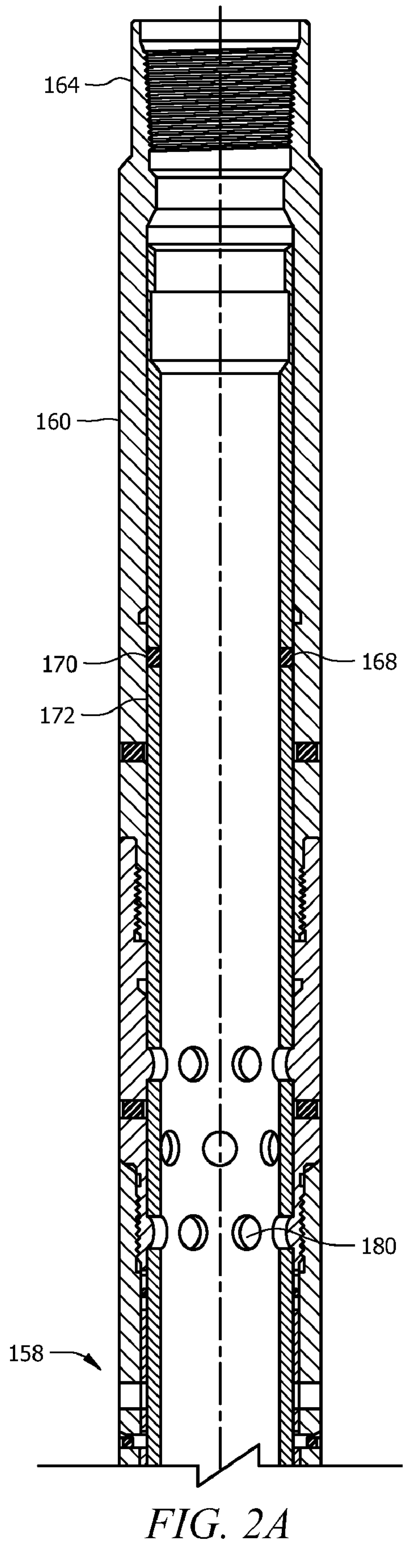
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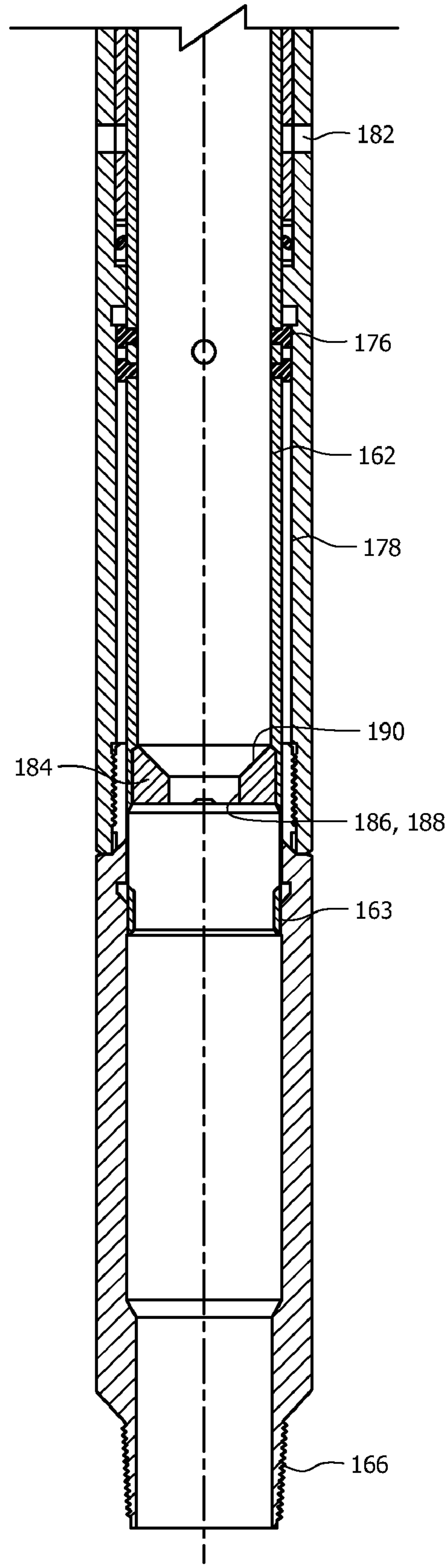
FIG. 2A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186, 188
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FIG. 2B

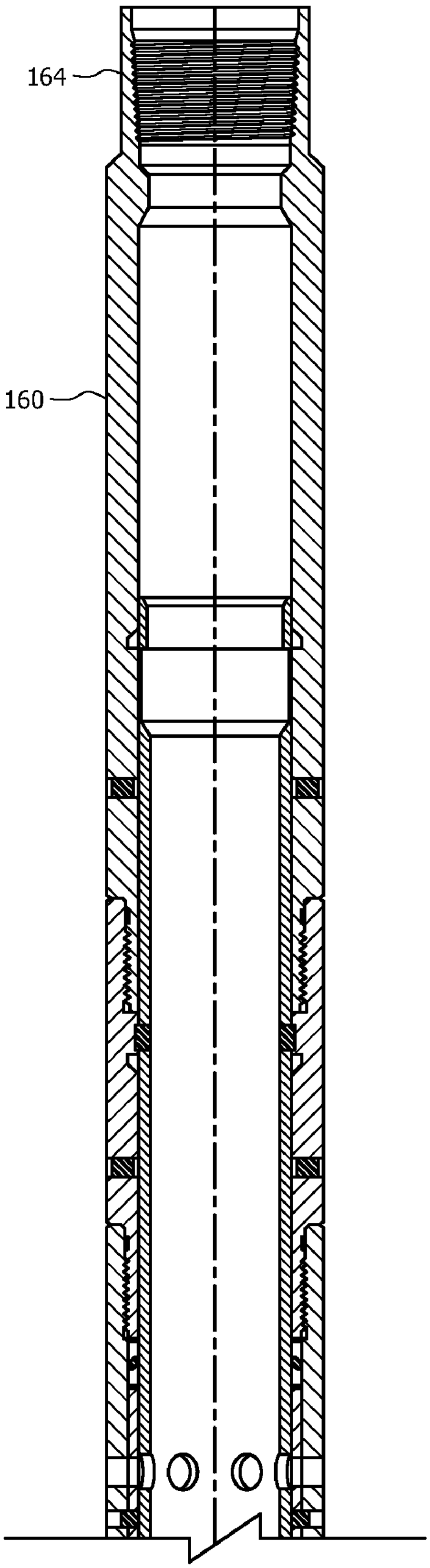

FIG. 3A

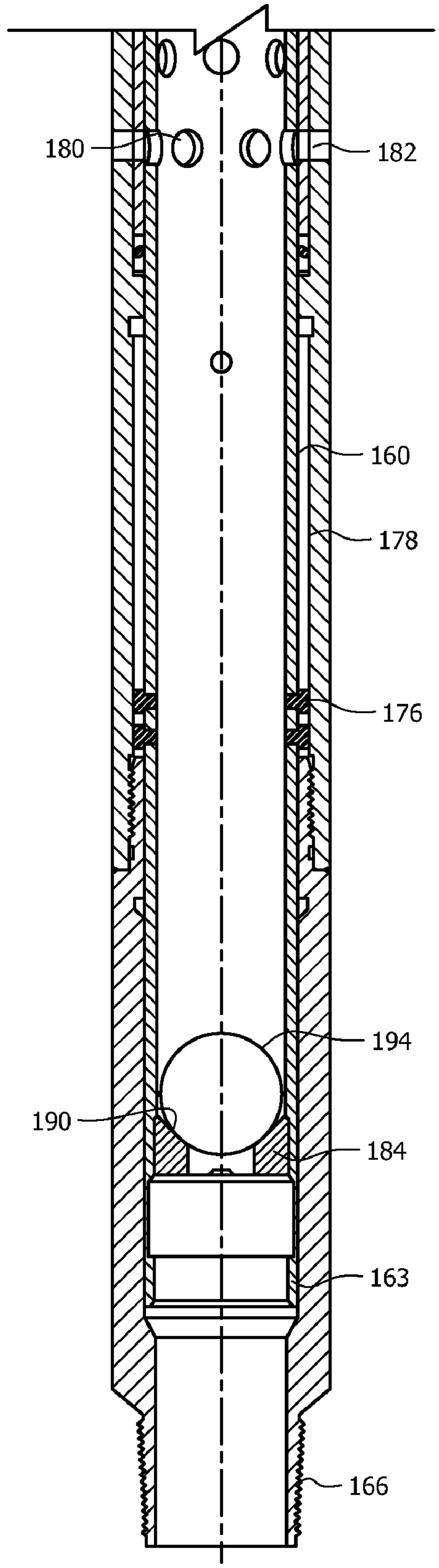

FIG. 3B

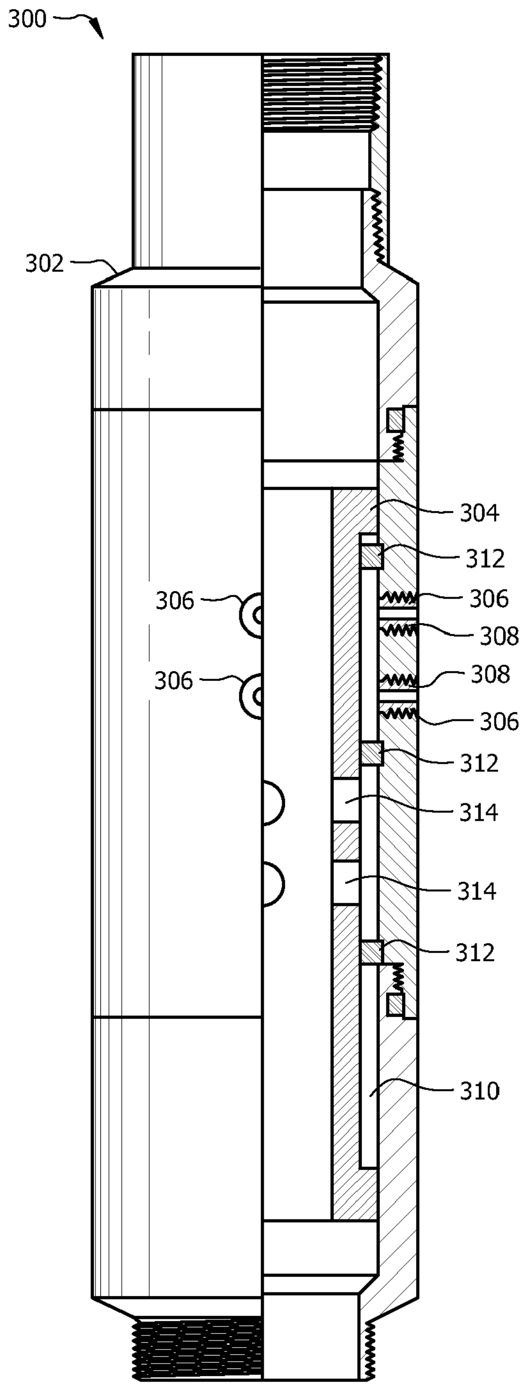
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FIG. 4A

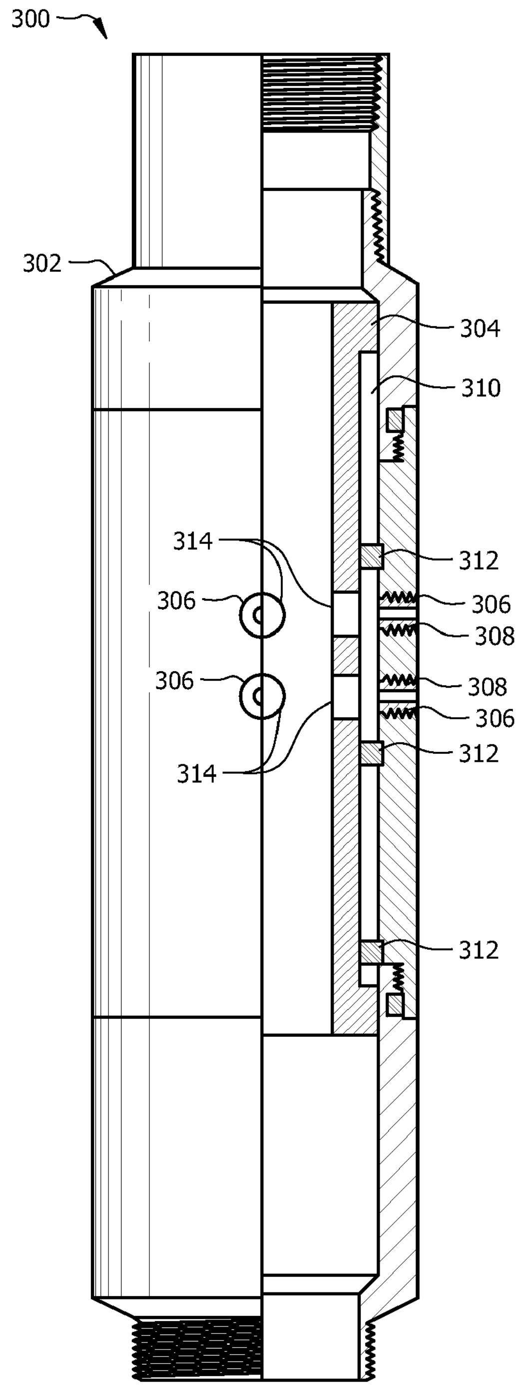
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FIG. 4B

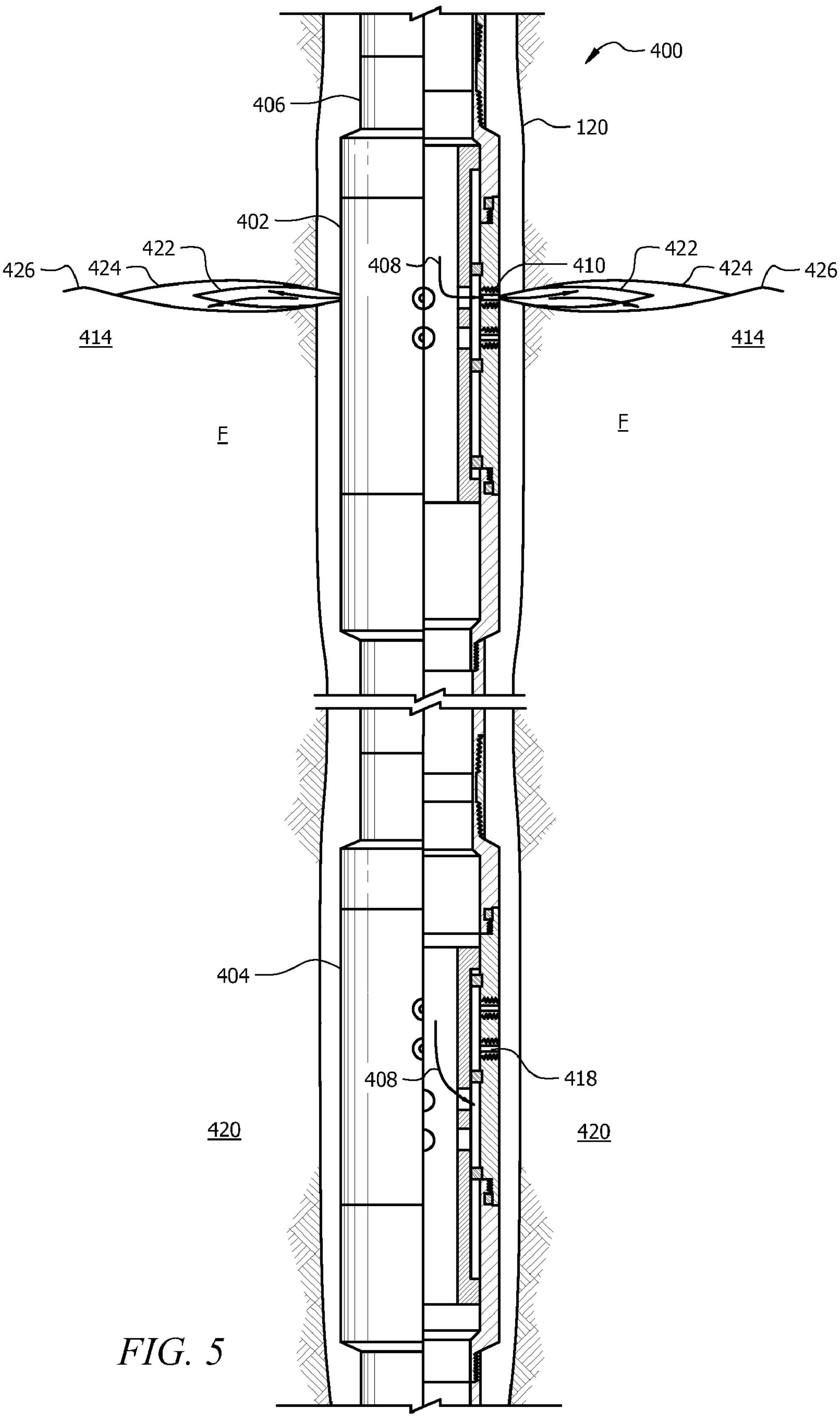
400
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FIG. 5

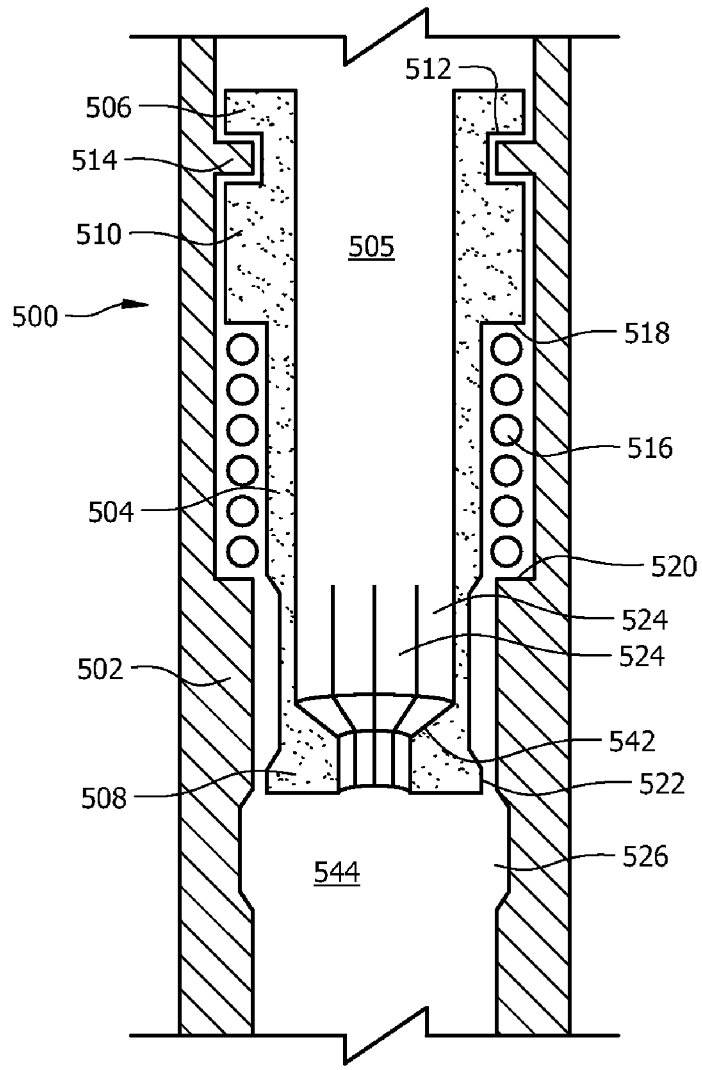

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FIG. 6A

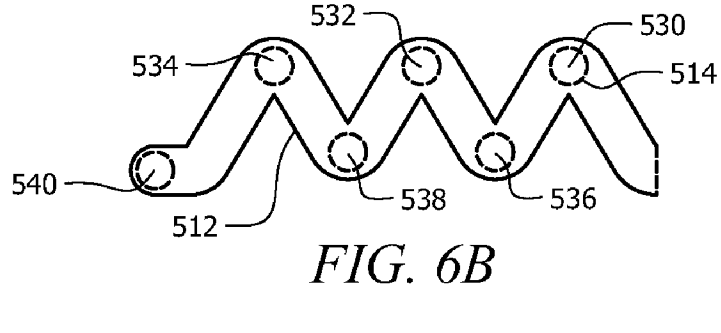

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FIG. 6B

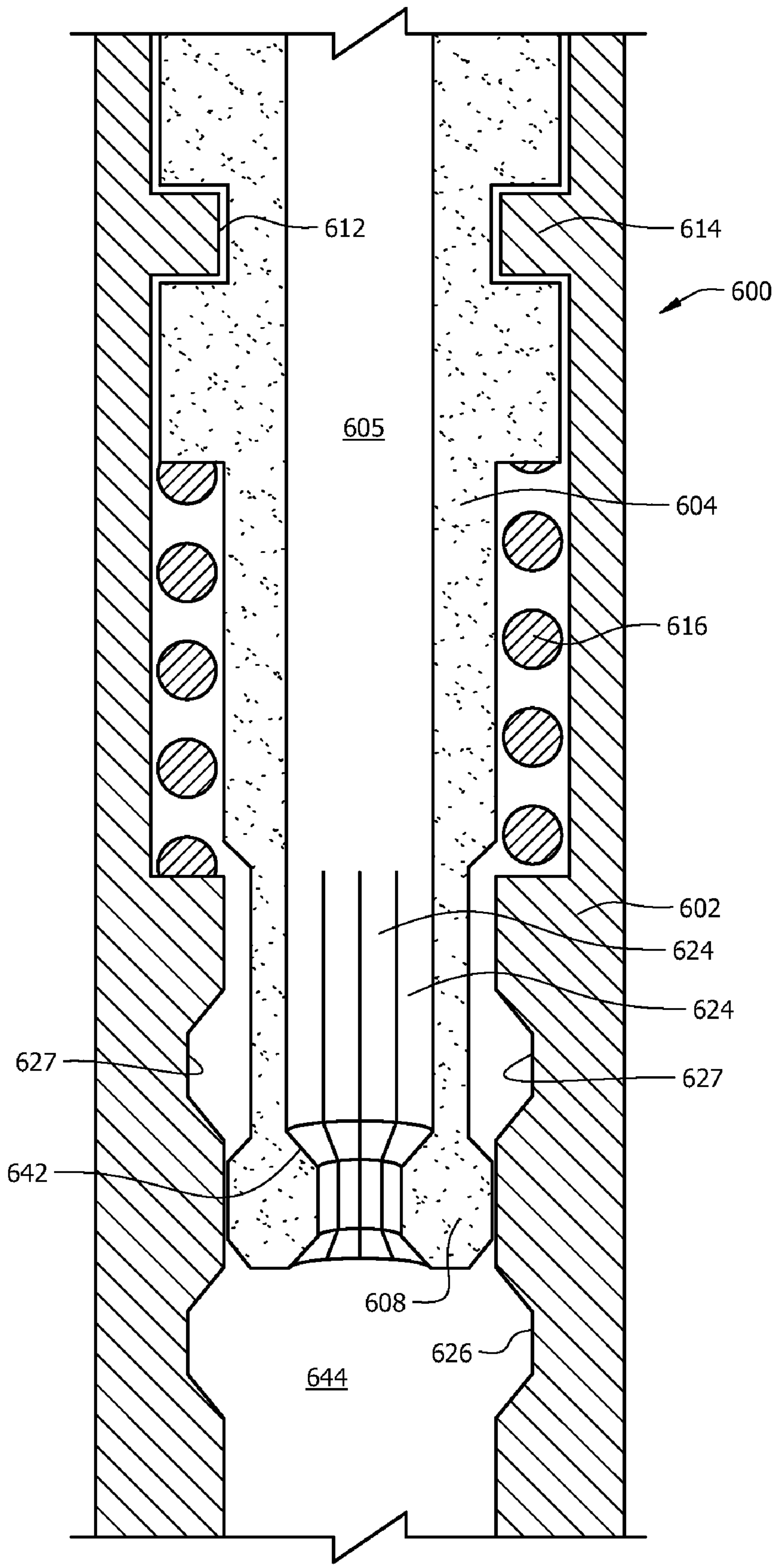

FIG. 7

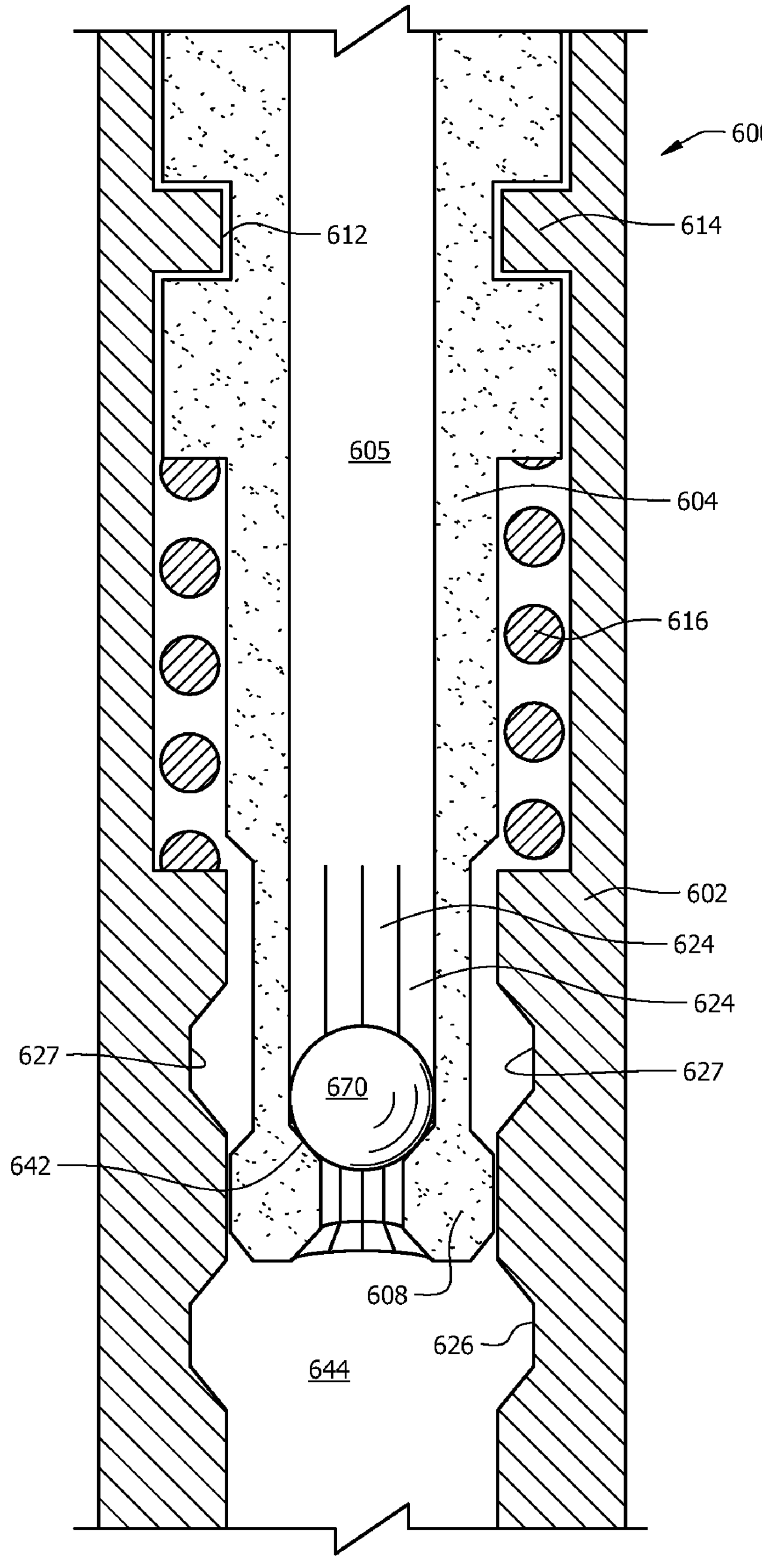

FIG. 8

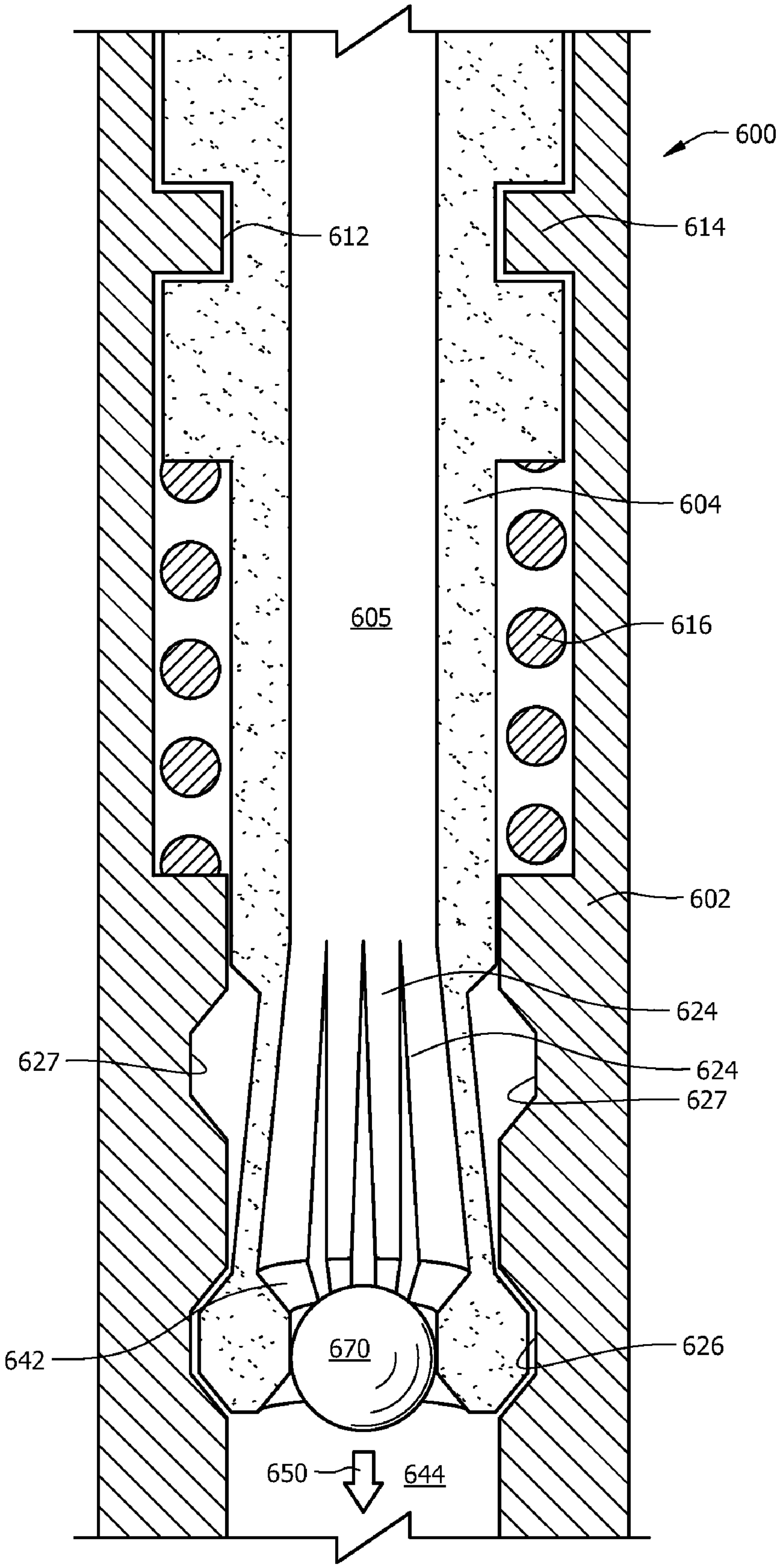

FIG. 9

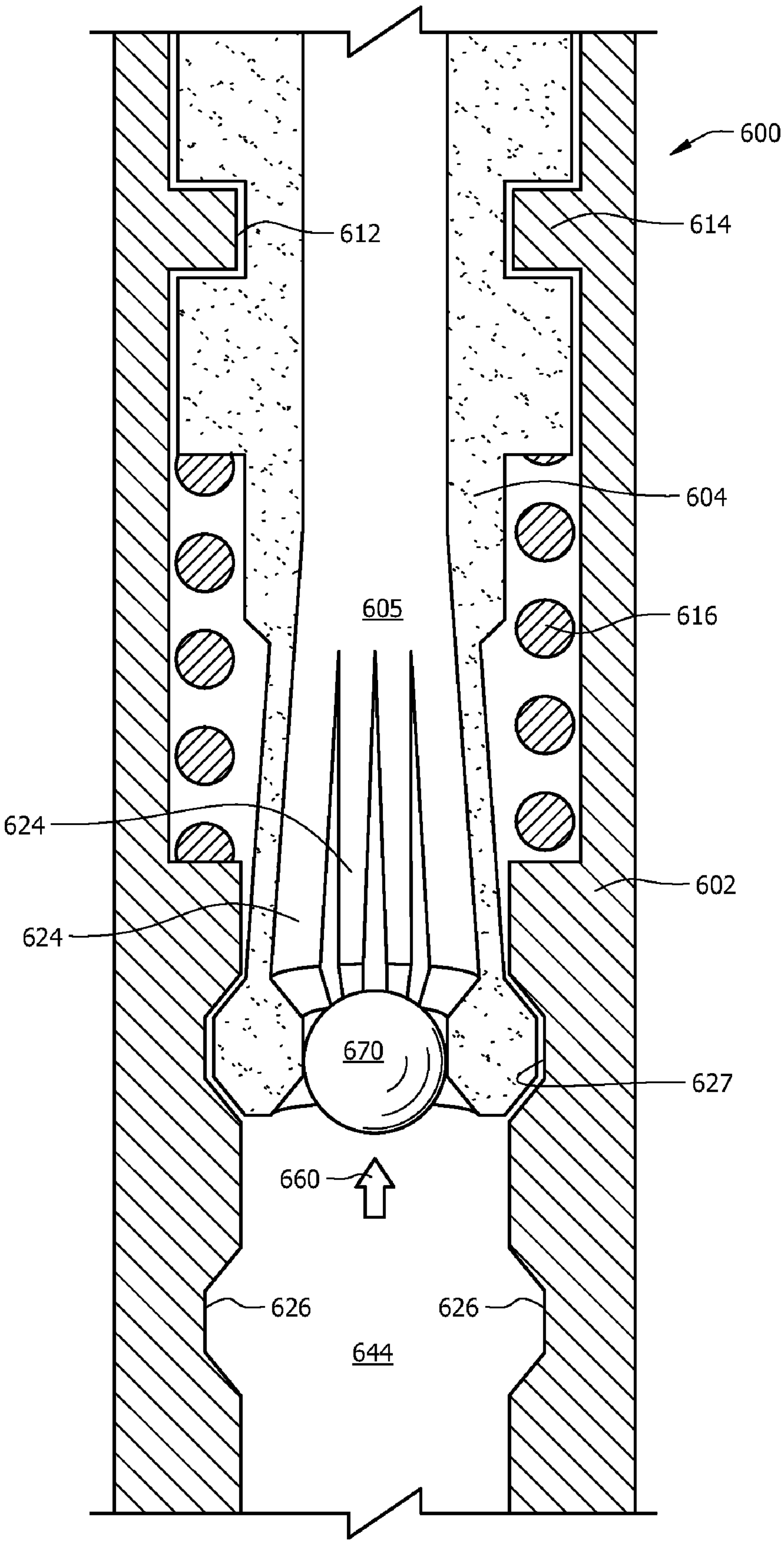

FIG. 10

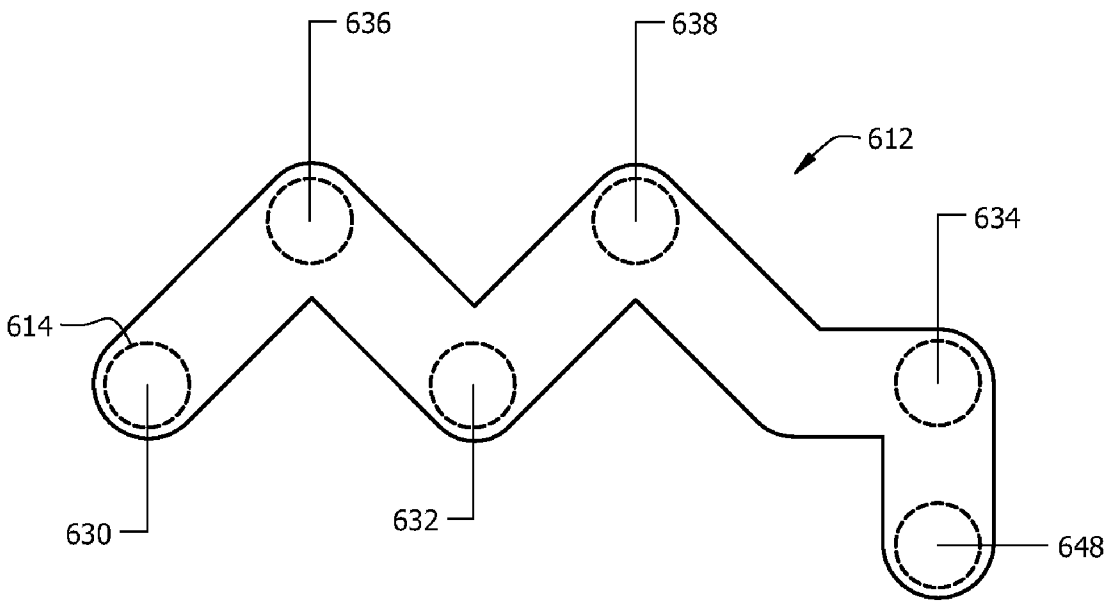

FIG. 11

METHOD AND APPARATUS FOR EXPOSING A SERVICING APPARATUS TO MULTIPLE FORMATION ZONES

BACKGROUND

[0001] Hydrocarbon-producing wells often are stimulated by hydraulic fracturing operations, wherein a fracturing fluid may be introduced into a portion of a subterranean formation penetrated by a well bore at a hydraulic pressure sufficient to create or enhance at least one fracture therein. Stimulating or treating the well in such ways increases hydrocarbon production from the well. The fracturing equipment may be included in a completion assembly used in the overall production process.

[0002] In some wells, it may be desirable to individually and selectively create multiple fractures along a well bore at a distance apart from each other, creating multiple "pay zones." The multiple fractures should have adequate conductivity, so that the greatest possible quantity of hydrocarbons in an oil and gas reservoir can be drained/produced into the well bore. When stimulating a formation from a well bore, or completing the well bore, especially those well bores that are highly deviated or horizontal, it may be advantageous to create multiple pay zones with a series of actuatable sleeve assemblies disposed in a downhole tubular. The actuatable sleeve assemblies are also referred to as stimulation sleeves, or casing or tubing windows.

[0003] A stimulation sleeve may include a section of tubing having holes or apertures pre-formed in the tubing, and a sliding sleeve movable relative to the tubing section. The sliding sleeve also includes apertures alignable with the apertures in the tubing section. Upon actuation of the stimulation sleeve, such as by ball drop or other obturating member interference, the sliding sleeve moves and the sliding sleeve apertures are aligned with the tubing section apertures. This exposes the reservoir to the interior of the tubing string, and vice versa. The flow path created between the reservoir and the tubing string through the stimulation sleeve can be used for fracturing or production operations. The apertures in the tubing section may include jet forming nozzles to provide a fluid jet into the formation, causing tunnels and fractures therein.

[0004] While the stimulation sleeve just described is one embodiment, other embodiments of actuatable sleeve assemblies may be used in series along a downhole tubular to communicate with multiple pay zones during fracturing or completion operations. To selectively actuate each successive sleeve assembly, differently sized balls or other obturating members are released into the tubing string. Each sleeve assembly includes a ball seat having a different inner diameter. The sleeve assembly having the largest ball seat is disposed furthest uphole, or closest to the surface of the well, while each successive sleeve assembly below the initial assembly includes an incrementally decreasing ball seat diameter. Thus, smaller balls may be released into the tubing string to pass through the larger diameter ball seats and selectively actuate the lower sleeve assemblies. Subsequently, incrementally larger sized balls are released into the tubing string to actuate each successive sleeve assembly in ascending order up the well.

[0005] Such a tubing assembly with successive diameter sleeves tends to restrict the inner diameter of the flow bore through the tubing string with the lower, smaller diameter sleeves, thereby also restricting the flow rates and treatment pressures that can be achieved with the tubing assembly. Further, a successive diameter system limits the number of sleeve assemblies that can be disposed in the tubing string because the flow bore of the tubing string has a limited number of incremental diameters between the maximum diameter of the flow bore and the minimum diameter that can still achieve treatment pressure flow rates. To achieve desirable results in the aforementioned treatment and production processes, maintaining an inner diameter of the flow bore for flow rates and treatment pressures, and increasing the number of pay zones is needed. The present disclosure includes embodiments for maintaining an increased or substantially uniform inner diameter of a treatment or completion assembly having stimulation sleeves, and for increasing the number of stimulation sleeves included in the treatment or completion assembly.

SUMMARY

[0006] Disclosed herein is a well bore servicing apparatus comprising an first sleeve slidably disposed in a tubing section, an second sleeve slidably disposed in the first sleeve, an indexing slot disposed on one of the outer sleeve and inner sleeve, and a control lug disposed on the other of the outer sleeve and the inner sleeve to communicate with the indexing slot, and an expandable seat disposed in the inner sleeve to receive a plurality of obturating members.

[0007] Also disclosed herein is a well bore servicing apparatus comprising a work string, a tubing section coupled to the work string, a plurality of sleeve assemblies disposed in the tubing section, and a plurality of seats for receiving an obturating member, one seat disposed in each of the sleeve assemblies, wherein the plurality of seats are substantially the same size.

[0008] Further disclosed herein is a method of servicing a well bore comprising disposing a tubing section in the well bore, positioning the tubing section adjacent a plurality of formation zones, passing a first obturating member through a first moveable sleeve, catching the first obturating member in a second moveable sleeve to actuate a sleeve assembly adjacent a first formation zone, and catching a second obturating member in the first moveable sleeve to actuate a second sleeve assembly adjacent a second formation zone, wherein the first and second obturating members are substantially the same size.

[0009] Further disclosed herein is a method of servicing a well bore comprising placing a tubing section in the well bore via a work string, and actuating a plurality of sleeve assemblies in the tubing section with same-size obturating members.

[0010] Further disclosed herein is a method of servicing a well bore comprising disposing a tubing section having a plurality of actuatable sleeve assemblies in the well bore, providing a series of obturating members having substantially the same size to actuate the sleeve assemblies, and successively actuating the sleeve assemblies with the same-size obturating member to successively treat a plurality of formation zones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more detailed description of the embodiments, reference will now be made to the following accompanying drawings:

[0012] FIG. 1 is a schematic, partial cross-section view of a fluid treatment and completion apparatus in an operating environment;

[0013] FIGS. 2A and 2B are cross-section views of a stimulation sleeve in a closed position;

[0014] FIGS. 3A and 3B are cross-section views of the stimulation sleeve of FIGS. 2A and 2B in an open position;

[0015] FIG. 4A is a partial cross-section view of a hydrojetting casing window assembly;

[0016] FIG. 4B is a partial cross-section view of the casing window assembly of FIG. 4A in a shifted open position;

[0017] FIG. 5 is a partial cross-section view of a well completion assembly including embodiments of FIGS. 4A and 4B;

[0018] FIG. 6A is a partial cross-section view of an indexing assembly;

[0019] FIG. 6B is a profile view of an indexing slot of the indexing assembly of FIG. 6A;

[0020] FIG. 7 is a partial cross-section view of an alternative embodiment of an indexing assembly in an initial position;

[0021] FIG. 8 is a partial cross-section view of the indexing assembly of FIG. 7 receiving a dropped ball;

[0022] FIG. 9 is a partial cross-section view of the indexing assembly of FIG. 7 in a release position;

[0023] FIG. 10 is a partial cross-section view of the indexing assembly of FIG. 7 in a return position; and

[0024] FIG. 11 is a profile view of an indexing slot of the indexing assembly of FIG. 7.

DETAILED DESCRIPTION

[0025] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawing figures are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. The present invention is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results.

[0026] Unless otherwise specified, any use of any form of the terms "connect", "engage", "couple", "attach", or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . ". Reference to up or down will be made for purposes of description with "up", "upper", "upwardly" or "upstream" meaning toward the surface of the well and with "down", "lower", "downwardly" or "downstream" meaning toward the terminal end of the well, regardless of the well bore orientation. The term "zone" or "pay zone" as used herein refers to separate parts of the wellbore designated for treatment or production and may refer to an entire hydrocarbon formation or separate portions of a single formation such as horizontally and/or vertically spaced portions of the same formation. The term "seat" as used herein may be referred to as a ball seat, but it is understood that seat may also refer to any type of catching or stopping device for an obturating member or other member sent through a work string fluid passage that comes to rest against a restriction in the passage. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0027] Disclosed herein are several embodiments of a well bore servicing apparatus including multiple sleeve assemblies disposed in a work string that are selectively actuatable to expose different formation zones to an inner fluid passage of the work string at different times. The sleeve assemblies may be sequentially actuated to expose the inner fluid passage to the formation zones such that they are treated at different times in a certain order. The sleeve assemblies may also include an inner indexing assembly allowing the sleeve assemblies to be actuated without loss of the inner diameter of the fluid passage in the work string, and without using multiple sizes of dropped balls. The indexing assembly may include an inner sleeve that is moveable and lockable relative to the moveable sleeve of the sleeve assemblies. The indexing assembly can be manipulated to allow a pre-determined number of obturating members to pass through a seat in the indexing assembly before a selected obturating members is caught in the seat and the indexing assembly is moved to actuate the sleeve assembly. In essence, the indexing assembly is configured to count the number of passing obturating members before actuation. The number of counted obturating members can be adjusted. The counting can be achieved with a J-slot or indexing slot communicating between the inner sleeve of the indexing assembly and the moveable or outer sleeve of the sleeve assembly, and an expandable seat for the obturating member.

[0028] Referring to FIG. 1, a schematic representation of an exemplary operating environment for a fluid treatment or completion apparatus **100** is shown. The apparatus **100** is an exemplary embodiment, and various other embodiments of the apparatus **100** consistent with the teachings herein are included. As depicted, a drilling rig **110** is positioned on the earth's surface **105** and extends over and around a well bore **120** that penetrates a subterranean formation F for the purpose of recovering hydrocarbons. The well bore **120** may be drilled into the subterranean formation F using conventional (or future) drilling techniques. The well bore **120** may extend substantially vertically away from the surface **105** over a vertical portion **122**, or may deviate at any angle from the surface **105** over a deviated or horizontal portion **124**. In some instances, all or portions of the well bore **120** may be vertical, deviated, horizontal, and/or curved.

[0029] At least a portion of the vertical well bore **122** may be lined with casing **125** that may be cemented **127** into position against the formation F in a conventional manner. Alternatively, the horizontal portion **124** may be cased and cemented also, or the operating environment for the apparatus **100** includes an uncased well bore **120**. The drilling rig **110** includes a derrick **112** with a rig floor **114** through which a tubing or work string **118** extends downwardly from the drilling rig **110** into the well bore **120**. The tubing string **118** suspends a representative downhole apparatus **100** to a predetermined depth within the well bore **120** to perform a specific operation, such as perforating a casing, expanding a fluid path therethrough, fracturing the formation F, producing the formation F, or other completion operation. The tubing string **18** may also be known as the entire conveyance above and coupled to the apparatus **100**. The drilling rig **110** is conventional and therefore includes a motor driven winch and other associated equipment for extending the tubing string **118** into the well bore **120** to position the apparatus **100** at the desired depth.

[0030] While the exemplary operating environment depicted in FIG. **1** refers to a stationary drilling rig **110** for lowering and setting the apparatus **100** within a land-based well bore **120**, one of ordinary skill in the art will readily appreciate that mobile workover rigs, well servicing units, such as coiled tubing units, and the like, could also be used to lower the apparatus **100** into the well bore **120**. It should be understood that the apparatus **100** may also be used in other operational environments, such as within an offshore well bore.

[0031] In one embodiment, the apparatus **100** comprises an upper end having a liner hanger **132** such as, for example, a Halliburton VersaFlex® liner hanger, a lower end **136**, and a tubing section **134** extending therebetween. The lower end **136** may have a float shoe **138** and a float collar **140** of a type known in the art connected therein, and other tubing conveyed devices **142**, **144** connected therein. The horizontal well bore **124** and the tubing section **134** define an annulus **146** therebetween. The tubing section **134** includes an interior **148** that defines a flow passage **150** therethrough. In the embodiment shown, an inner string **152** is disposed in tubing section **134** and extends therethrough so that a lower end **154** thereof extends into and is received in a polished bore receptacle **144**. The inner string **152** may be used to carry cement if the completion operation requires cement. Alternatively, cement may not be needed and the tubing section **134** may be without the inner string **152** such that the flow passage **150** is the main flowbore through the apparatus **100**. A plurality of actuatable sleeve assemblies or stimulation sleeves **158** are connected in the tubing section **134**. The stimulation sleeves **158** may be, for example, ball drop activated, Delta Stim® Sleeves available from Halliburton Energy Services, Inc.

[0032] Referring now to FIGS. **2**A and **2**B, the stimulation sleeve **158** comprises an outer housing **160** with an opening sleeve **162** detachably connected therein. The opening sleeve **162** has a lower end **163**. After becoming detached from the housing **160**, the opening sleeve **162** is slidable or movable in the housing **160** as explained in more detail hereinbelow. The outer housing **160** has an upper end **164** and a lower end **166**, both of which are adapted to be directly connected or threaded into a tubing section such that the outer housing **160** makes up a part of the tubing section **134**. The opening sleeve **162** is initially connected to the outer housing **160** with a snap ring **168** which extends into a groove **170** defined on an inner surface **172** of the outer housing **160**. In addition, shear pins extending through the outer housing **160** and into the sleeve **162** may be utilized to detachably connect the sleeve **162** to the outer housing **160**. Guide pins **176** may be threaded or otherwise attached to the sleeve **162** and may be received in axial grooves or axial slots **178** in the housing **160**. The guide pins **176** are slidable in the axial slots **178**, which will prevent relative rotation between the sleeve **162** and the outer housing **160**. The sleeve **162** has a plurality of sleeve or door ports **180** therethrough. The outer housing **160** has a plurality of housing ports **182** defined therein. In the position shown in FIGS. **2**A and **2**B, the sleeve ports **180** are misaligned from the housing ports **182** such that the stimulation sleeve **158** is in a closed position. The sleeve **162** has a seat ring **184** operably associated therewith and is connected therein at or near the lower end **163**. The seat ring **184** has a central opening **186** defining a diameter **188** therethrough, and has a seat surface **190** for engaging an obturating member to be dropped through the tubing string.

[0033] To move the opening sleeve **162** from the closed position to an open position, an obturating member **194**, such as a closing ball shown in FIG. **3**B, is dropped through the tubing string **118** so that it will engage the seat **190** on the seat ring **184**. Although shown as a closing ball, the obturating member **194** may be other closing devices such as plugs and darts that will engage the seat **190** and prevent flow therethrough. Pressure is increased to overcome the holding force applied by the snap ring **168** and the shear pins, thereby moving the opening sleeve **162** to the position shown in FIGS. **3**A and **3**B in which the sleeve ports **180** and the casing ports **182** are aligned to allow for the passage of fluids therethrough.

[0034] Referring now to FIGS. **4**A and **4**B, an exemplary casing window assembly **300** is shown and can be adapted for use as an alternative embodiment of the stimulation sleeve **158**. As used herein, the term "casing window" refers to a section of casing configured to enable selective access to one or more specified zones of an adjacent subterranean formation. A casing window has a window that may be selectively opened and closed by an operator, for example, movable sleeve member **304**. The casing window assembly **300** can have numerous configurations and can employ a variety of mechanisms to selectively access one or more specified zones of an adjacent subterranean formation.

[0035] The casing window **300** includes a substantially cylindrical outer casing **302** that receives a movable sleeve member **304**. The outer casing **302** includes one or more apertures **306** to allow the communication of a fluid from the interior of the outer casing **302** into an adjacent subterranean formation. The apertures **306** are configured such that fluid jet forming nozzles **308** may be coupled thereto. In some embodiments, the fluid jet forming nozzles **308** may be threadably inserted into the apertures **306**. The fluid jet forming nozzles **308** may be isolated from the annulus **310** (formed between the outer casing **302** and the movable sleeve member **304**) by coupling seals or pressure barriers **312** to the outer casing **302**.

[0036] The movable sleeve member **304** includes one or more apertures **314** configured such that, as shown in FIG. **4**A, the apertures **314** may be selectively misaligned with the apertures **306** so as to prevent the communication of a fluid from the interior of the movable sleeve member **304** into an adjacent subterranean formation. The movable sleeve member **304** may be shifted axially, rotatably, or by a combination thereof such that, as shown in FIG. **4**B, the apertures **314** selectively align with the apertures **306** so as to allow the communication of a fluid from the interior of the movable sleeve member **304** into an adjacent subterranean formation. The movable sleeve member **304** may be shifted via the use of a ball drop mechanism.

[0037] Referring now to FIG. **5**, an exemplary well completion assembly **400** includes open casing window **402** and closed casing window **404** formed in a tubing section or conduit **406**. Alternatively, the well completion assembly **400** may be selectively configured such that the casing window **404** is open and the casing window **402** is closed, such that the casing windows **402** and **404** are both open, or such the that casing windows **402** and **404** are both closed.

[0038] A fluid **408** may be pumped down the conduit **406** and communicated through the fluid jet forming nozzles **410** of the open casing window **402** against the surface of the well bore **120** in the zone **414** of the subterranean formation F. The fluid **408** would not be communicated through the fluid jet forming nozzles **418** of the closed casing window **404**, thereby isolating the zone **420** of the subterranean formation F from any well completion operations being conducted through the open casing window **402** involving the zone **414**. The fluid **408** may include any of the embodiments disclosed elsewhere herein.

[0039] In one embodiment, the fluid **408** is pumped through the fluid jet forming nozzles **410** at a velocity sufficient for fluid jets **422** to form perforation tunnels **424**. In one embodiment, after the perforation tunnels **424** are formed, the fluid **408** is pumped into the conduit **406** and through the fluid jet forming nozzles **410** at a pressure sufficient to form cracks or fractures **426** along the perforation tunnels **424**.

[0040] Referring back to FIG. **1**, a plurality of the sleeve assemblies **158** are included in the tubing section **134** of the treatment and completion apparatus **100**. The sleeve assemblies **158** are positioned adjacent the selected zones to be treated, such as the plurality of selected zones **80**, **82**, **84**, **86**, **88** and **90** that may be treated and produced with the methods and apparatus described herein. After work string **118** having apparatus **100** is lowered into well bore **120**, and the apparatus **100** is appropriately set, a first ball or other obturating member may be dropped into the work string **118**. The ball seats in the lowermost sleeve assembly **158** to actuate, as described herein, the sleeve assembly and establish a fluid path to the formation zone **90**. Then, a treatment fluid, such as an acidizing fluid or a fracturing fluid, may be flowed through the work string **118**, the tubing section **134**, the fluid path in the sleeve assembly, and toward the zone **90**. In some embodiments, a high pressure fluid is communicated through the sleeve assembly fluid path to provide a hydrojet stream to the zone **90**. As used herein, high pressure, for example, is generally greater than about 1,000 p.s.i., alternatively greater than about 3,500 p.s.i., alternatively greater than about 10,000 p.s.i., and alternatively greater than about 15,000 p.s.i. Once the selected zone **90** has been treated, a second ball is dropped to engage the sleeve seat in the next sleeve assembly **158** in ascending order, adjacent the zone **88**. When the ball is seated, fluid flow is blocked to the lower sleeve assembly and fluid pressure will increase to actuate the new sleeve assembly. The zone **88** can then be treated. This procedure may be followed to selectively and successively actuate the sleeve assemblies **158** in ascending order, and service any and/or all of the zones **80**, **82**, **84**, **86**, **88**, **90**. Typically, the center opening **186** (FIGS. **2**B and **3**B) in each of the sleeve assemblies **158** is of a diameter **188** such that the balls **194** may pass therethrough to engage the seat sleeves **184** in sleeve assemblies therebelow. Therefore, the seat sleeve diameter **188** will be gradually and incrementally larger from the lowermost seat sleeve through the final seat sleeve in the uppermost sleeve assembly.

[0041] Referring now to FIG. **6**A, an assembly is shown that is adaptable to be used with the various sleeve assembly embodiments described herein. A sliding sleeve sub or indexing assembly **500** includes an outer sleeve **502** and an inner sleeve member **504** disposed therein. For reference purposes, the outer sleeve **502** is analogous to the opening sleeve **162** of FIGS. **2**A-**3**B. The inner sleeve member **504** includes an upper end **506**, a lower end **508** and a flow bore **505** therethrough. The upper end **506** includes an increased diameter portion **510** having an indexing slot or J-slot pattern **512** that receives a control lug **514** disposed on an inner surface of the outer sleeve **502**. The interaction between the lug **514** and the indexing slot **512**, as will be described in more detail hereinbelow, is the primary mode of communication between the outer sleeve **502** and the inner sleeve member **504**. The lower end **508** includes a projection **522** and a series of collet fingers **524**. Disposed between an outer sleeve shoulder **520** and an inner sleeve shoulder **518** is a biasing spring **516**. The inner surface of the outer sleeve **502** also includes a recessed portion **526**.

[0042] Referring next to FIG. **6**B, the indexing slot **512** is shown in an unwrapped or flattened profile view. The indexing slot **512** may also be referred to as a continuous J-slot or a control groove. The indexing slot **512** includes a plurality of biased, reset or stop positions **530**, **532**, **534** and a plurality of release positions **536**, **538** for the lug **514**. The slot **512** also includes a final engagement or actuation position **540**. The indexing slot **512** is disposed about the upper portion of the tube forming the inner sleeve **504**. The indexing slot **512**, in some embodiments, may be a solid member, such as a metal sheet, having a slot or groove formed therein. The indexing slot may be shaped to extend around a cylindrical member, as is shown in FIG. **6**A. In some embodiments described, the lug **514** includes a circular shape from a top view of the lug. The lug may include other shapes, such as an oval or elliptical shape. Furthermore, other control slot operating members may interact with the indexing slot **512** to provide the relationships described herein.

[0043] In operation, the indexing assembly **500** is assembled as shown in FIG. **6**A, with the inner sleeve **504** biased upward by the spring **516** such that the collet fingers **524** and the projection **526** are above the recess **526**. The control lug **514** is initially disposed in one of the stop positions **530**, **532**, **534** and limits the upward movement of the inner sleeve **504**. Preferably, the initial position of the lug **514** is the furthest from the final position **540** to allow the most number of cycles through the indexing slot, though the initial position can be selected to pre-determine the number of cycles through the indexing slot and thus the number of balls that pass through the inner sleeve **504**. A first ball, such as that shown in FIG. **8**, passes through the flow bore **505** and arrives at a seat **542** in the lower end **508**. A pressure buildup above the ball causes the inner sleeve to overcome the biasing force of the spring **516** and move downward, as similarly depicted in FIG. **9**. As the inner sleeve **504** moves downward, the projection **526** slides into the recess **526** and the collet fingers expand into the recess, as shown in FIG. **9**. Simultaneously, the inner sleeve **504** and the indexing slot **512** are guided about the lug **514**, which is stationary on the outer sleeve **502**, such that the lug moves from initial slot **530** to the release position **536**. The ball is then allowed to pass into the flow bore **544** below the inner sleeve **504**. After the ball passes, the pressure on the inner sleeve **504** is relieved the biasing spring moves the inner sleeve **504** upward. At the same time, the inner sleeve **504** and the indexing slot **512** are guided about the lug **514** such that the lug is now placed in the stop position **532**.

[0044] The lug **514** is guided through any number of sets of stop and release positions until the lug **514** reaches the final position **540**. In the final position **540**, vertical movement of the inner sleeve **504** is restricted such that the pressure buildup in the inner sleeve **504** is transferred to the outer sleeve **502** and the overall sleeve assembly is actuated as described herein. For example, when the lug **514** is in the final position **540**, the ball seat **542** acts analogously to the ball seat **190** in the seat ring **184** of FIGS. **2**B and **3**B. The outer sleeve **502** then moves similarly to the sleeve **162** of the sleeve assembly **158**. Thus, the indexing assembly **500** can replace the seat ring **184** arrangement of the sleeve assembly **158** while providing increased flexibility for inner sleeve **504** movement and ball pass-through while the overall sleeve assembly remains unactuated.

[0045] The indexing assembly **500** can be pre-set to count any number of ball pass-throughs. For example, if an indexing assembly **500** is placed in the second lowermost position, wherein another assembly is below it, and it is known that one ball must pass through the indexing assembly **500**, then the assembly is adjusted accordingly. In one embodiment, the indexing slot **512** is simply manufactured to have the initial position **532**, the release position **538**, the reset position **534** and the final position **540**. Therefore, one cycle from position **532** to position **538** to position **534** allows one ball to pass through the indexing assembly **500** before the final position **540** is reached and the sleeve assembly is actuated. In another embodiment, the indexing slot **512** is manufactured to have any number of stop and release positions, and the indexing assembly **500** is assembled such that the initial position of the lug **514** is in the second to last stop position, or position **532**.

[0046] A plurality of indexing assemblies **500** may be disposed in a tubing section in series, such as in the series of stimulation sleeves **158** shown in FIG. **1**. The series of indexing assemblies **500** will include ball seats **542** all having the same unexpanded diameter to receive the same size balls. For example, the diameter of unexpanded ball seat **542** in FIG. **6**A may be 2.75 inches, while the balls may be 3 inches in diameter. Each assembly **500** can be pre-set to catch and release a different number of 3-inch balls such that the series of assemblies will actuate a series of sleeve assemblies **158** or **300** to successively expose the work and tubing strings to different zones of interest **80**, **82**, **84**, **86**, **88**, **90** while passing the same size ball through the plurality of indexing and sleeve assemblies. In alternative embodiments, a first series of indexing and sleeve assemblies is adapted to receive a first size ball while a second series of indexing and sleeve assemblies is adapted to receive a second size ball, thereby further expanding the total number of sleeve assemblies that can be actuated in the well. Alternatively, a third series may be added and so on. For example, a bottom series of four indexing and sleeve assemblies may be adapted to successively actuate upon receiving a series of four 2-inch balls. A next series of four indexing and sleeve assemblies may be adapted to successively actuate upon receiving a series of four 2.25-inch balls. A third series disposed uphole of the second series may be adapted to successively actuate upon receiving a series of four 2.5-inch balls. In this embodiment, a total of twelve indexing and sleeve assemblies can be actuated to expose zones of interest. Further added series will add indexing and sleeve assemblies in increments of four, or however many balls the indexing assembly is designed to catch and release as designed herein.

[0047] In some embodiments, the collet fingers **524** are dipped in stiffening or hardening agents for added strength or resistance. In one embodiment, the collet fingers **524** are at rest in the contracted position shown in FIG. **6**A, and the force of the ball passing through the collet fingers causes them to expand into the recess **526**. These collet fingers **524** may also be referred to as "normally closed" or "normally contracted." In another embodiment, the collet fingers are formed and strengthened to normally be in the expanded position shown in FIG. **9**, such that the collet fingers are forced together as shown in FIG. **6**A and allowed to spread automatically when placed in the position of FIG. **9**. These collet fingers **524** may also be referred to as "normally open" or "normally expanded." In other embodiments, the collet fingers **524** are dipped in an elastomer or other compressible material such that when the collet fingers are contracted as shown in FIG. **6**A, the elastomer coating on one finger will compress against the elastomer coating on an adjacent finger to close the spaces between the fingers and provide a sealed ball seat **542**.

[0048] In an alternative embodiment, the control lug **514** is disposed on the outer surface of the inner sleeve **504** and the indexing slot **512** is disposed on the inner surface of the outer sleeve **502**, i.e., they are switched. In this embodiment, the profile view of FIG. **6**B would be flipped such that the stop positions would be on top and the release positions on bottom, and the final position would be on top.

[0049] With reference to FIG. **7**-**11**, a further embodiment includes an indexing assembly **600** having similar components as the assembly **500**, such as an outer sleeve **602** and an inner sleeve **604**. However, assembly **600** further includes an upper recessed portion **627**. In operation, a ball **670** enters the flow bore **605** and arrives at the seat **642** as shown in FIG. **8**. The pressure buildup above the ball **670** overcomes the biasing force provided by the spring **616** and moves the inner sleeve **604** downward. As shown in FIG. **9**, the collet fingers **624** expand into the recess **626**, either by the force provided by the ball **670** or by the normally open disposition of the fingers, and the ball **670** passes through the fingers **624** and the seat **642** to travel downward **650** through the flow bore **644**. The biasing force of the spring **616** then returns the inner sleeve **604** to the middle position shown in FIG. **8**, readying the indexing assembly **600** to receive another ball **670**. During this process, the lug **614** and indexing slot **612** operate as previously described.

[0050] However, at some point, it may be desirable to return a ball or balls to the surface of the well. A ball may be forced upward along a return path **660** in the flow bore **644** by fluid pressure or other means, and the indexing assembly **600** is adapted to work in reverse wherein the upper recess **627** receives the expanding collet fingers **624** as shown in FIG. **10**. As shown in FIG. **11**, a reserve position **648** is provided in the indexing slot **612** to accommodate the upward movement of the inner sleeve **604** as shown in FIG. **10**. For example, the indexing assembly **600** may be assembled such that the lug **614** is given an initial position **630**. Ball engagement on the seat **642** causes the inner sleeve **604** to move downward, and thus the lug **614** moves upward in the indexing slot **612** to the first release position **636**. The ball **670** passes through the collet fingers **624**, thereby relieving the pressure in the inner sleeve **604**. The biasing spring **616** returns the inner sleeve **604** and the indexing slot **612** to a position placing the lug **614** in a first reset position **632**. Another ball **670** may be cycled through the inner sleeve **604**, placing the lug **614** in a second release position **638**, then in a second reset position **634** which is also the catch position. Position **634** is a catch position because the lug **614** is not allowed to move upward to a position similar to positions **636**, **638**, thereby preventing downward movement of the inner sleeve **604** and release of the ball **670**. The pressure buildup above the ball **670** is transferred to the outer sleeve **602**, which is the slidable sleeve of a larger sleeve assembly as described herein. However, unlike indexing slot **512**, the slot **612** provides an additional position **648** that allows upward movement of the inner sleeve **604** to accommodate the return of the ball **670** shown in FIG. **10**. Once the balls have been returned as described, the well can be produced unobstructed and without intervention to drill out the ball-engaged indexing and sleeve assemblies. In other embodiments, the balls or other obturating members are breakable or dissolvable to remove them from the inner flow bores.

[0051] In other embodiments, the total number of reset and release positions is adjusted to increase or decrease the number of balls the indexing assemblies are designed to catch and release. For example, the indexing slots **512**, **612** are designed to release two balls before catching the third ball. However, additional sets of reset and release positions can be added to increase the number of balls that are released before the final ball is caught.

[0052] The number of zones, indexing assemblies and sleeve assemblies shown herein is not intended to be limiting and is shown only for exemplary purposes. Any desired number of zones may be treated or produced. The plurality of zones will be treated sequentially upwardly. For example, when a sleeve assembly is moved to align openings, dissolving fluid and then treatment fluid may be flowed into the zone to be treated, and the next zone desired to be treated is done so in the manner described. Once the selected zones have been treated, the balls can be flowed back to the surface, as previously described, or drilled out and the well can be produced through each of the selected zones in a manner known in the art.

[0053] In alternative embodiments, the mechanical assemblies **500**, **600** may be similar with the exception of the indexing slots **512**, **612**. The indexing slots **512**, **612** act as counter mechanisms to count the number of balls that pass through the assemblies. While the other elements and components of the assemblies remain similar, the indexing slots **512**, **612** can be replaced by alternative counting mechanisms. The electro-mechanical sliding sleeve assemblies or subs may incorporate electronics, and the counter or reader in the sleeve assembly could be actuated by magnets, RFID tags or other "smarts" in the balls. For example, the sliding sleeve sub can be placed in the open or release position as the normal position. An electronic reader in the inner sleeve electronically counts the magnets or tags in the balls as they pass through the expandable seat, and upon counting a pre-determined number of balls, the sleeve is actuated to move to the closed position. The inner sleeve can be moved to the closed position by a motor or other drive means known in the art. Thus, while the sliding inner sleeve and collet finger arrangement provides the same uniformity of flow bore diameter and ball size, the counting of the balls is accomplished by electronic or electrical means rather than mechanical means, and the inner sleeve is driven not by fluid pressure but by a drive means such as an electro-mechanical actuator. In alternative embodiments, the electro-mechanical actuator can be replaced by pressurized chambers adjacent the inner sliding sleeve. An unpressurized chamber is adjacent and communicates with the inner sleeve, and is separate from a pressurized chamber by a burst disc. Upon an actuation command from the electronic counter, the disc can be burst to expose the unpressurized chamber and thus the inner sliding sleeve to fluid pressure to move the sleeve to its closed position as described herein.

[0054] In addition to servicing, treatment and completion systems, the embodiments of the indexing or sliding sleeve assemblies can be used in other systems. For example, a system including a series open-hole packer can incorporate the indexing or sliding sleeve assemblies for successive actuation of the packers.

[0055] While specific embodiments have been shown and described, modifications can be made by one skilled in the art without departing from the spirit or teaching of this invention. The embodiments as described are exemplary only and are not limiting. Many variations and modifications are possible and are within the scope of the invention. Accordingly, the scope of protection is not limited to the embodiments described, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

What is claimed is:

1. A well bore servicing apparatus comprising:

an first sleeve slidably disposed in a tubing section;

an second sleeve slidably disposed in the first sleeve;

an indexing slot disposed on one of the outer sleeve and inner sleeve, and a control lug disposed on the other of the outer sleeve and the inner sleeve to communicate with the indexing slot; and

an expandable seat disposed in the inner sleeve to receive a plurality of obturating members.

2. The apparatus of claim **1** wherein the lug is disposed within the indexing slot to guide relative movement between the first sleeve and the second sleeve.

3. The apparatus of claim **1** wherein the plurality of obturating members are the same size.

4. The apparatus of claim **2** wherein the indexing slot includes a plurality of stop positions and a plurality of release positions for the lug.

5. The apparatus of claim **4** wherein the plurality of stop positions correspond to a contracted position of the expandable seat and the plurality of release positions correspond to an expanded position of the expandable seat for passing through the plurality of obturating members.

6. The apparatus of claim **1** wherein the expandable seat includes a plurality of collet fingers.

7. The apparatus of claim **6** wherein the collet fingers are normally open.

8. The apparatus of claim **6** wherein the collet fingers are normally closed.

9. The apparatus of claim **6** wherein the collet fingers are dipped or coated.

10. A well bore servicing apparatus comprising:

a work string;

a tubing section coupled to the work string;

a plurality of sleeve assemblies disposed in the tubing section; and

a plurality of seats for receiving an obturating member, one seat disposed in each of the sleeve assemblies;

wherein the plurality of seats are substantially the same size.

11. The apparatus of claim **10** wherein the seats are operable to receive a series of obturating members having substantially the same size.

12. The apparatus of claim **11** wherein the series of obturating members are operable to successively actuate the plurality of sleeve assemblies adjacent multiple formation zones.

13. The apparatus of claim **10** wherein the tubing section having the plurality of sleeve assemblies includes a substantially uniform minimum flow bore diameter over its axial length.

14. The apparatus of claim **10** wherein all sleeve assemblies disposed in the tubing section are actuatable by the same size obturating member.

15. The apparatus of claim **10** further comprising an indexing slot and a corresponding control lug disposed in each of the sleeve assemblies.

16. The apparatus of claim **15** wherein the control lugs communicate with positions in the indexing slot to count the number of obturating members that pass through an inner sleeve assembly.

17. The apparatus of claim **10** further including an electronic counter operable to detect the obturating member.

18. The apparatus of claim **10** further including a drive means coupled to an indexing assembly in each of the sleeve assemblies.

19. The apparatus of claim **11** further comprising an electronic tag in each of the obturating members, an electronic counter in each of an inner sleeve assembly disposed in each of the sleeve assemblies, and an electro-mechanical actuator coupled to the inner sleeves.

20. A method of servicing a well bore comprising:

disposing a tubing section in the well bore;

positioning the tubing section adjacent a plurality of formation zones;

passing a first obturating member through a first moveable sleeve;

catching the first obturating member in a second moveable sleeve to actuate a sleeve assembly adjacent a first formation zone; and

catching a second obturating member in the first moveable sleeve to actuate a second sleeve assembly adjacent a second formation zone;

wherein the first and second obturating members are substantially the same size.

21. The method of claim **20** further comprising passing a plurality of same-size obturating members through the first moveable sleeve and actuating a plurality of sleeve assemblies below the first moveable sleeve with the same-size obturating members.

22. A method of servicing a well bore comprising:

placing a tubing section in the well bore via a work string; and

actuating a plurality of sleeve assemblies in the tubing section with same-size obturating members.

23. The method of claim **22** further comprising pumping a treatment fluid through a flow bore in the tubing section having a substantially uniform inner diameter.

24. The method of claim **22** further comprising maintaining constant flow rates over the axial length of the tubing section having the plurality of sleeve assemblies.

25. The method of claim **22** further comprising maintaining constant treatment pressures over the axial length of the tubing section having the plurality of sleeve assemblies.

26. A method of servicing a well bore comprising:

disposing a tubing section having a plurality of actuatable sleeve assemblies in the well bore;

providing a series of obturating members having substantially the same size to actuate the sleeve assemblies; and

successively actuating the sleeve assemblies with the same-size obturating member to successively treat a plurality of formation zones.

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