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(54) **DOWNHOLE TOOLS, SYSTEMS AND METHODS OF USING**

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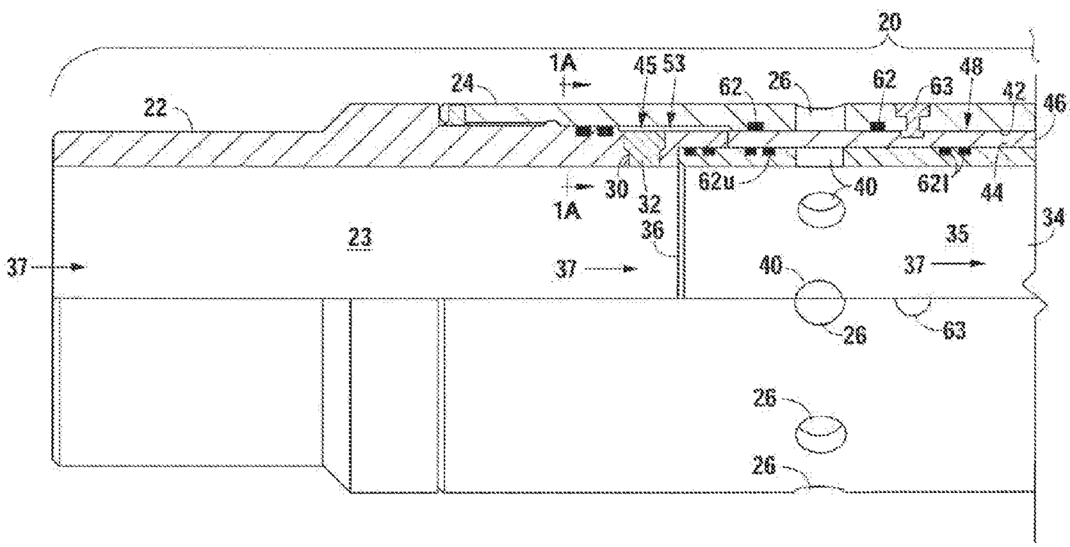
(57) **ABSTRACT**

A downhole tool comprising a nested sleeve preventing fluid communication between the interior of the tool and the exterior of the tool is provided. The downhole tool is actuated when fluid pressure is communicated from the interior of the tool to a first surface the nested sleeve, moving the nested sleeve such that it no longer prevents fluid communication from the interior to the exterior. Devices and methods for controlling the flow of fluid to the first surface of the nested sleeve are provided including fluid control devices such as burst disks, indexing sleeves and ratchet assemblies. In certain embodiments, the nested sleeve may be engaged with a slot system such that the nested sleeve moves along a path defined by such slot until the tool is actuated.



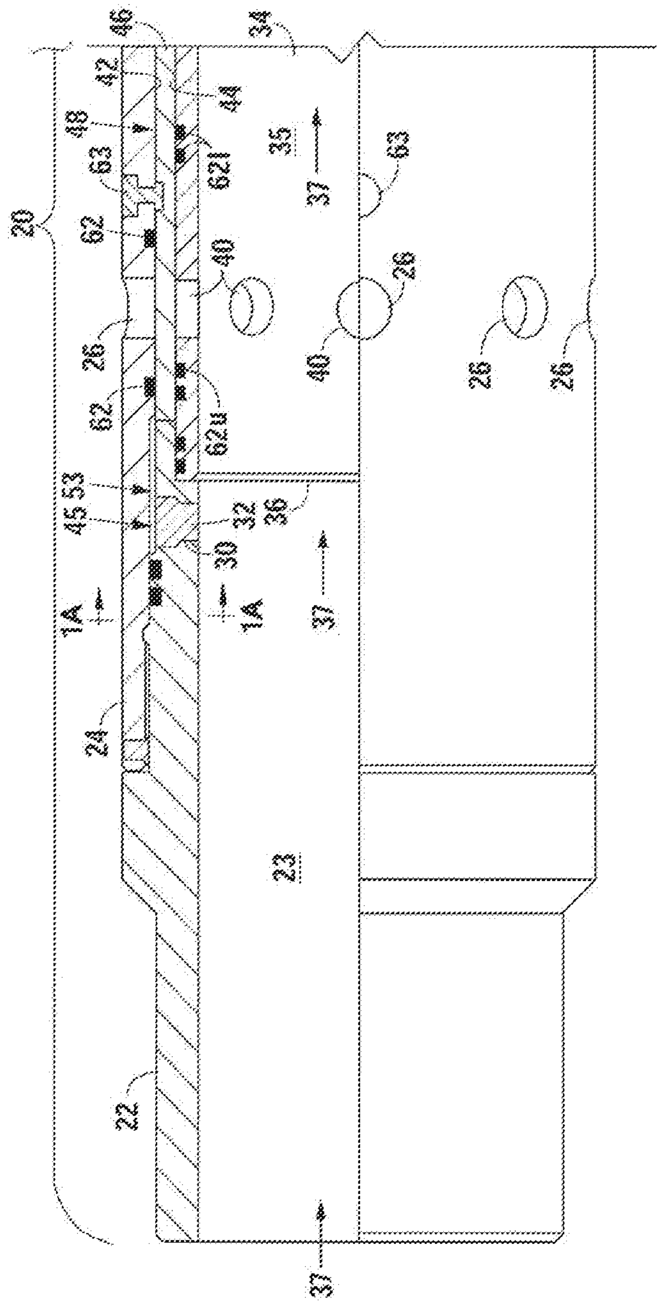


Fig. 1

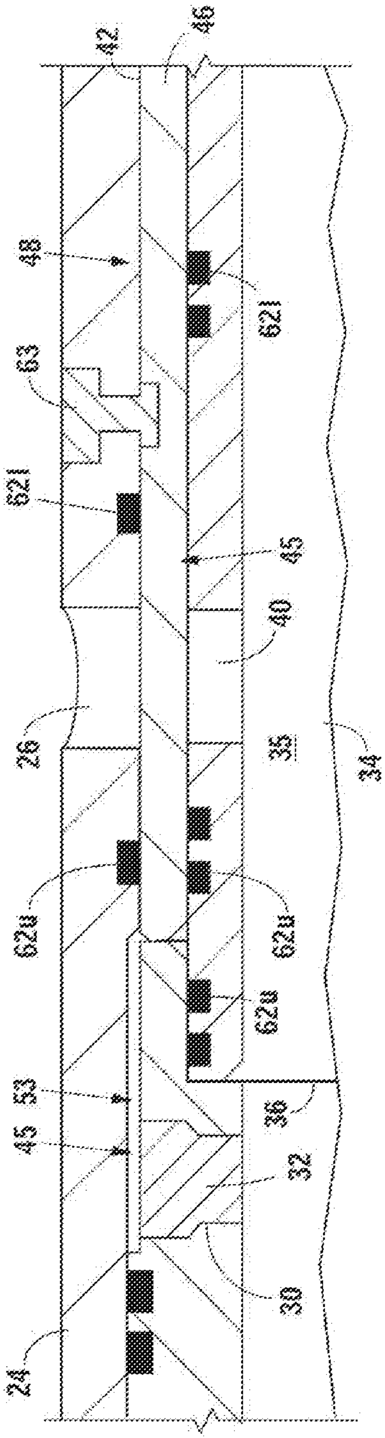


Fig. 1A

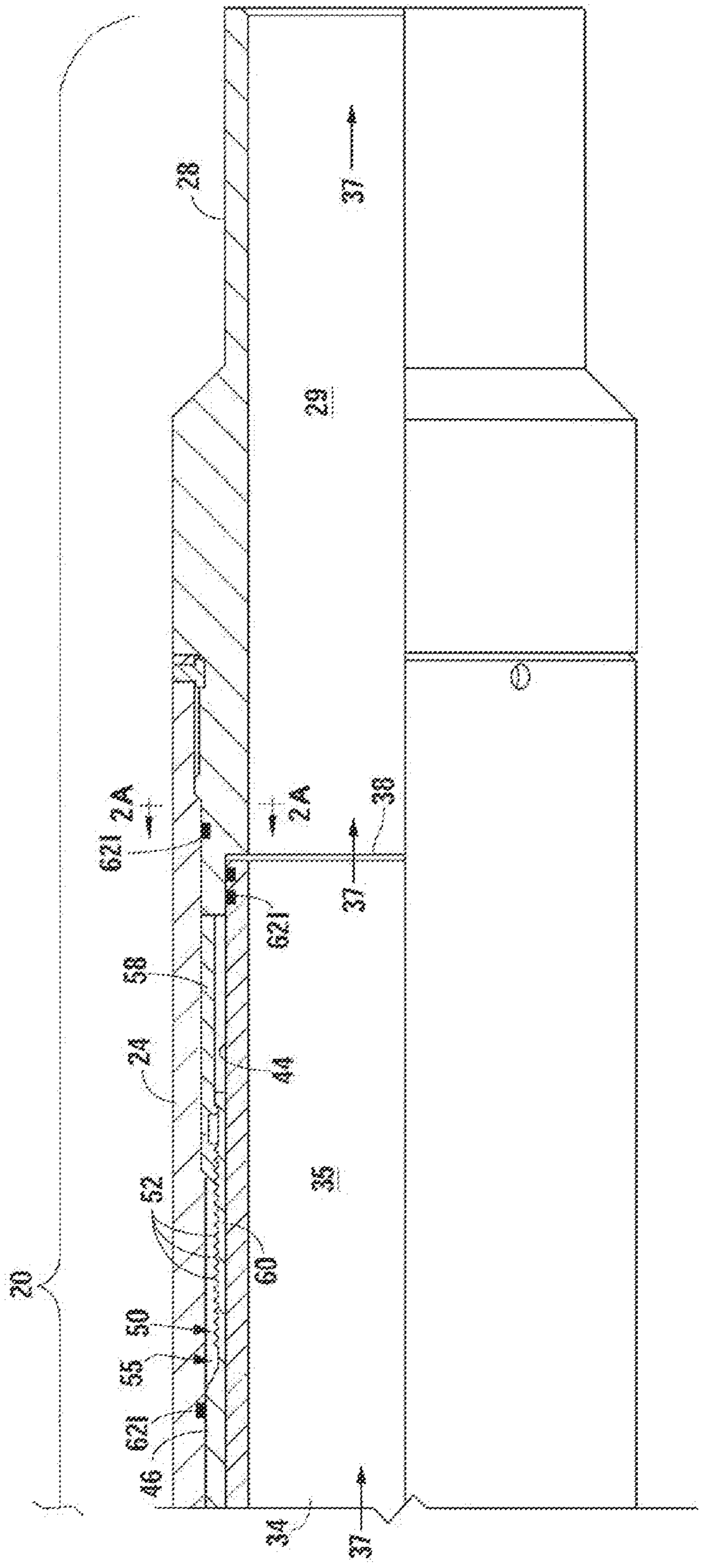


Fig. 2

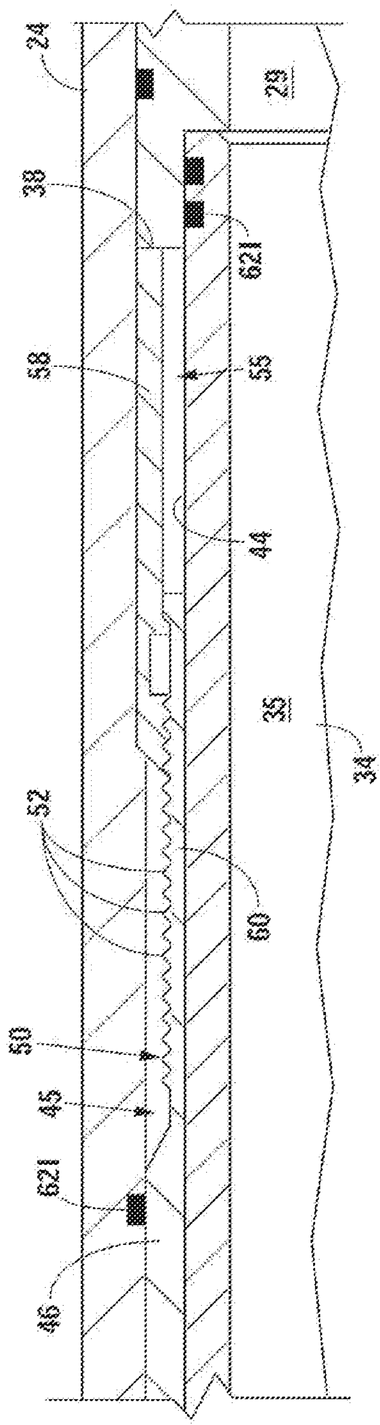


Fig. 2A

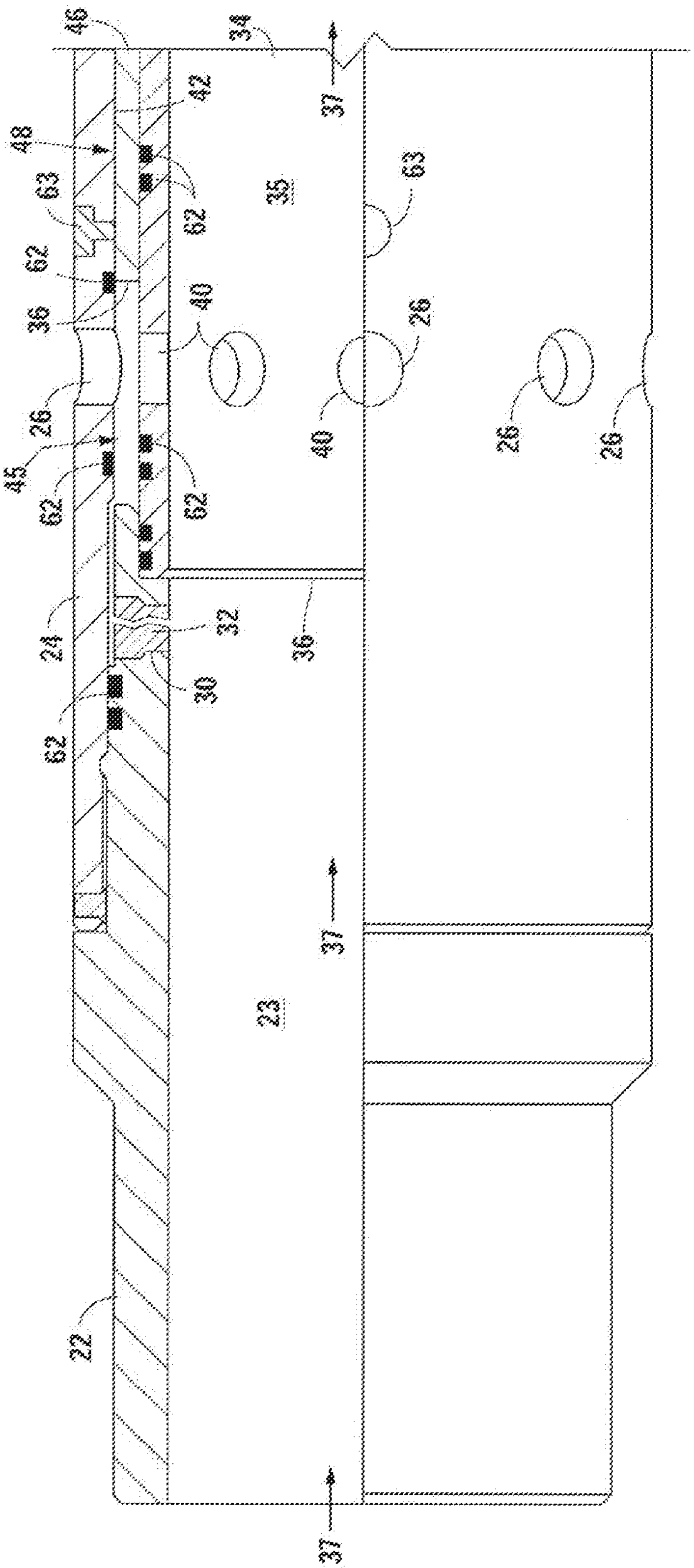


Fig. 3

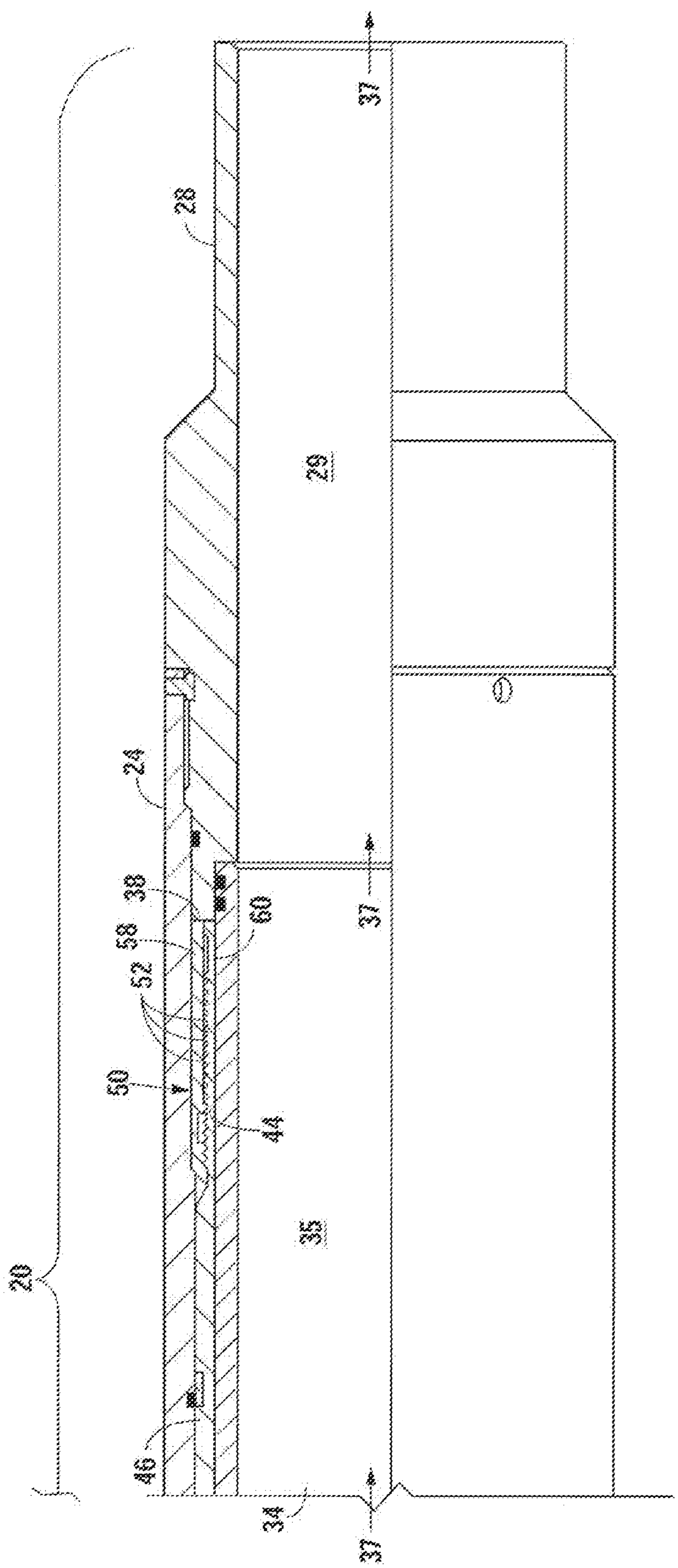


Fig. 4

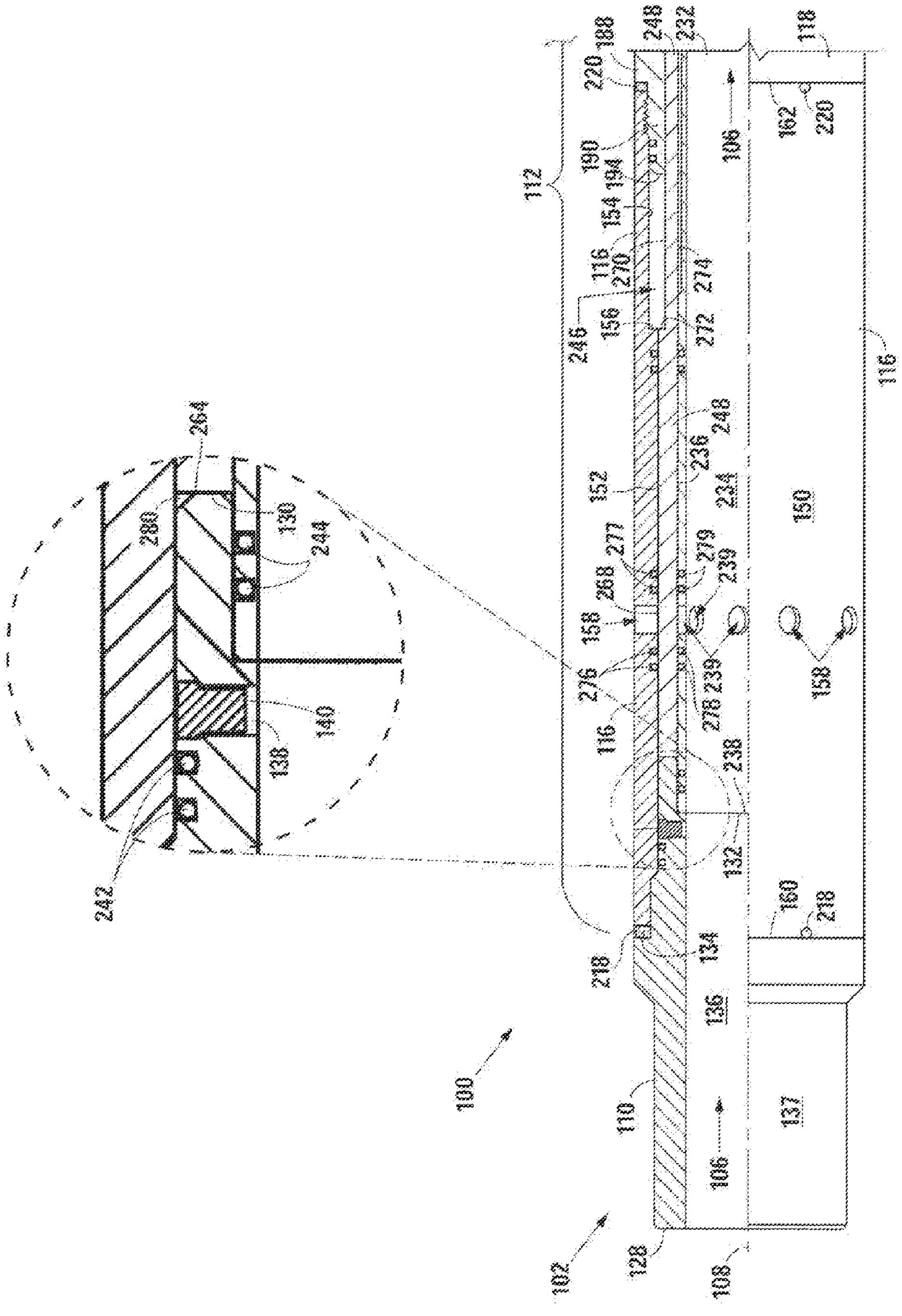

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Fig. 5A

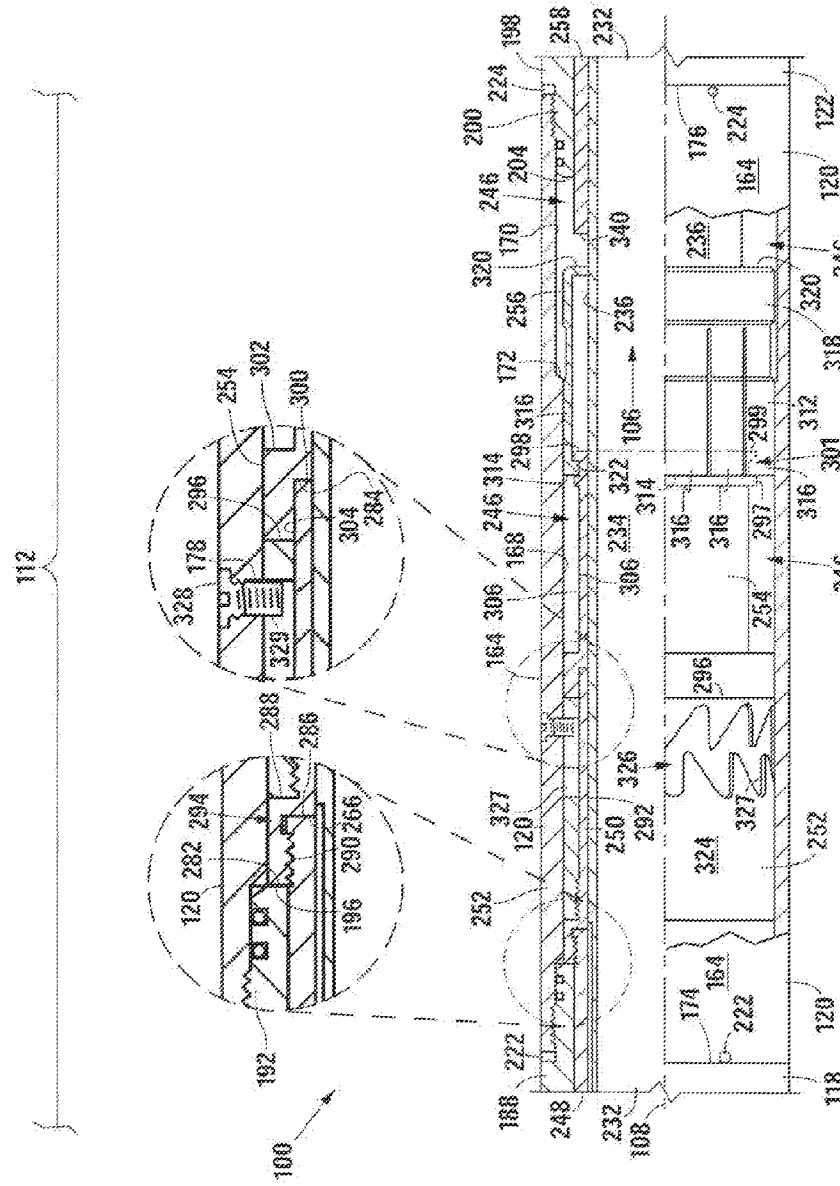

Fig. 5B

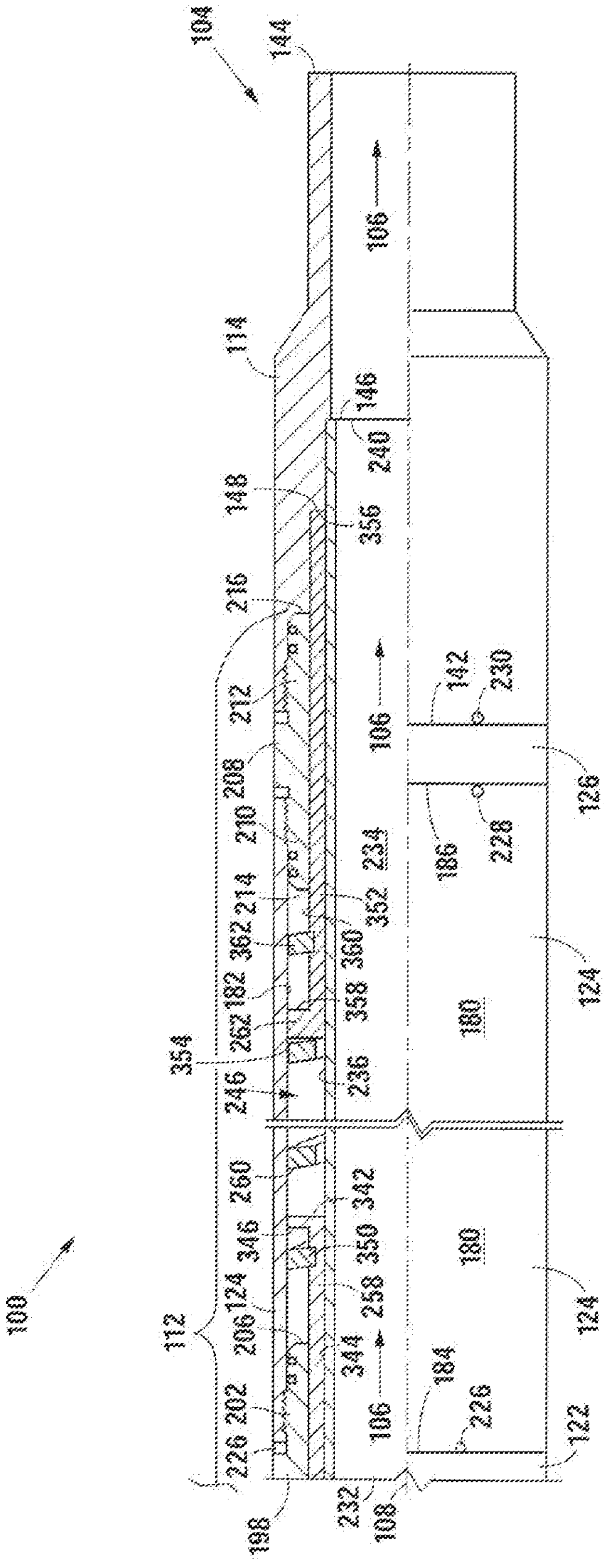
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Fig. 5C

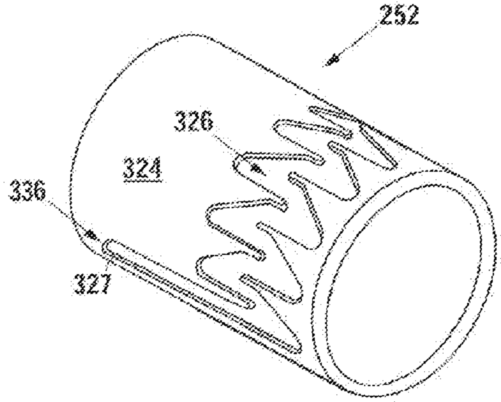
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Fig. 6A

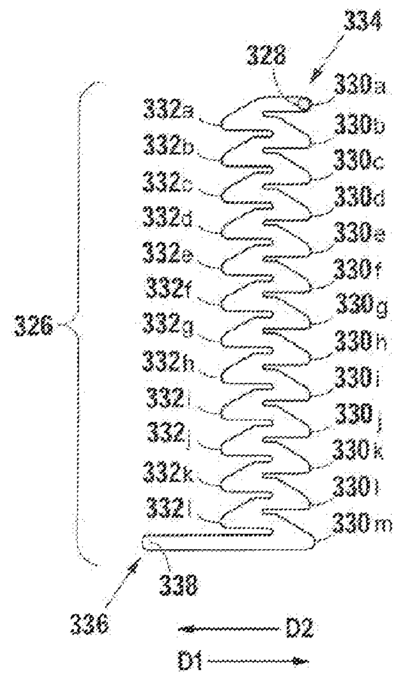
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Fig. 6B

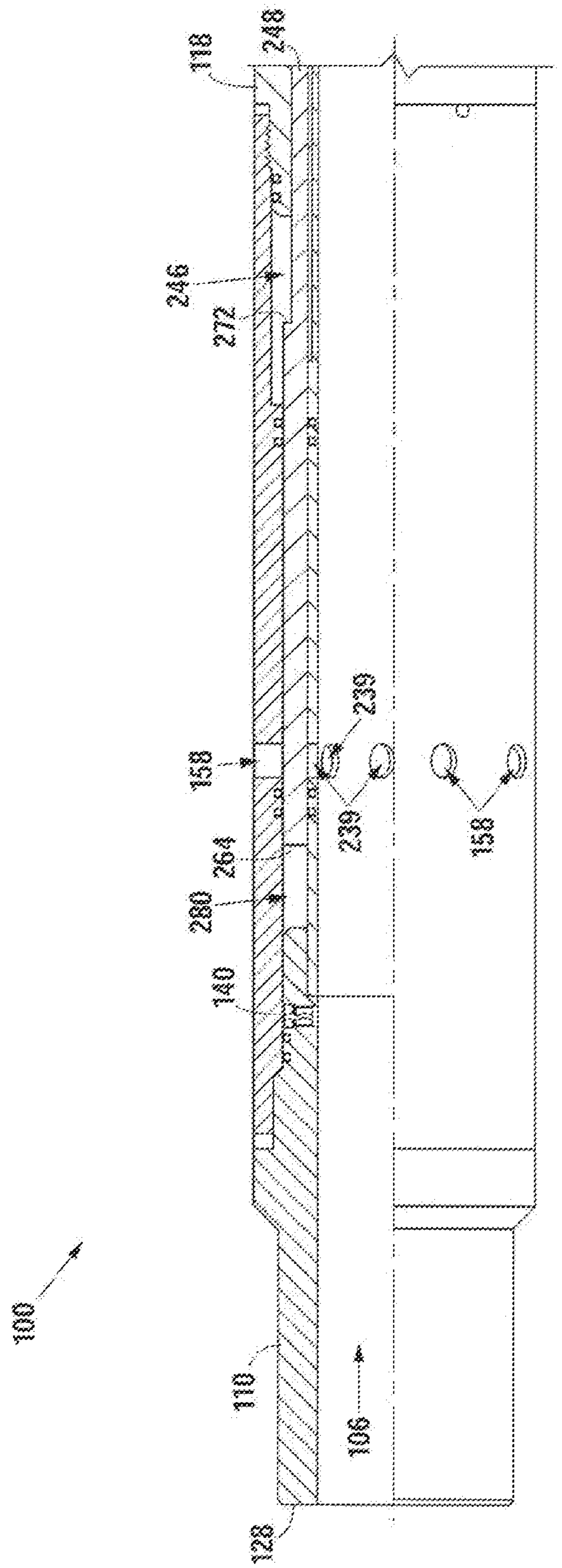

Fig. 7A

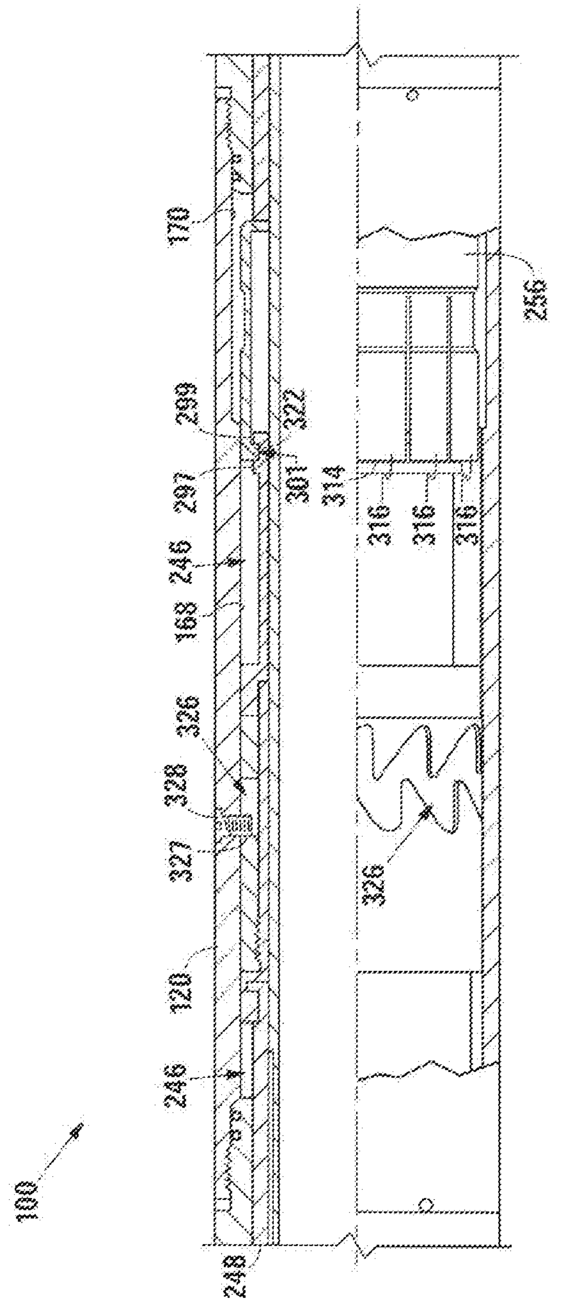
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Fig. 7B

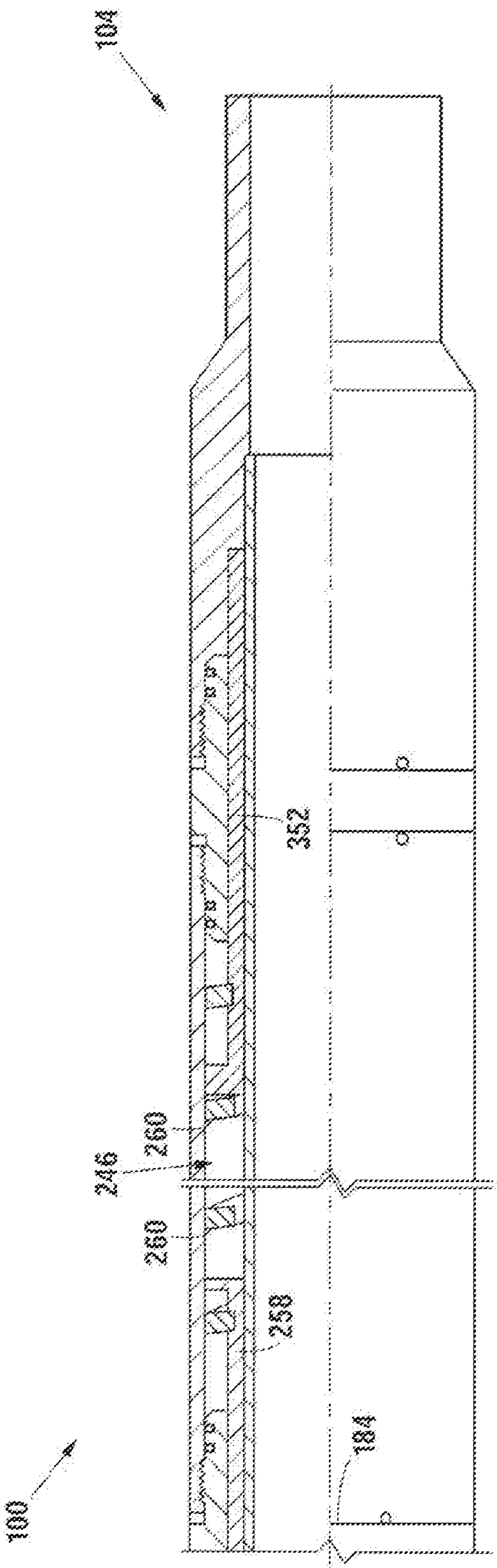

Fig. 7C

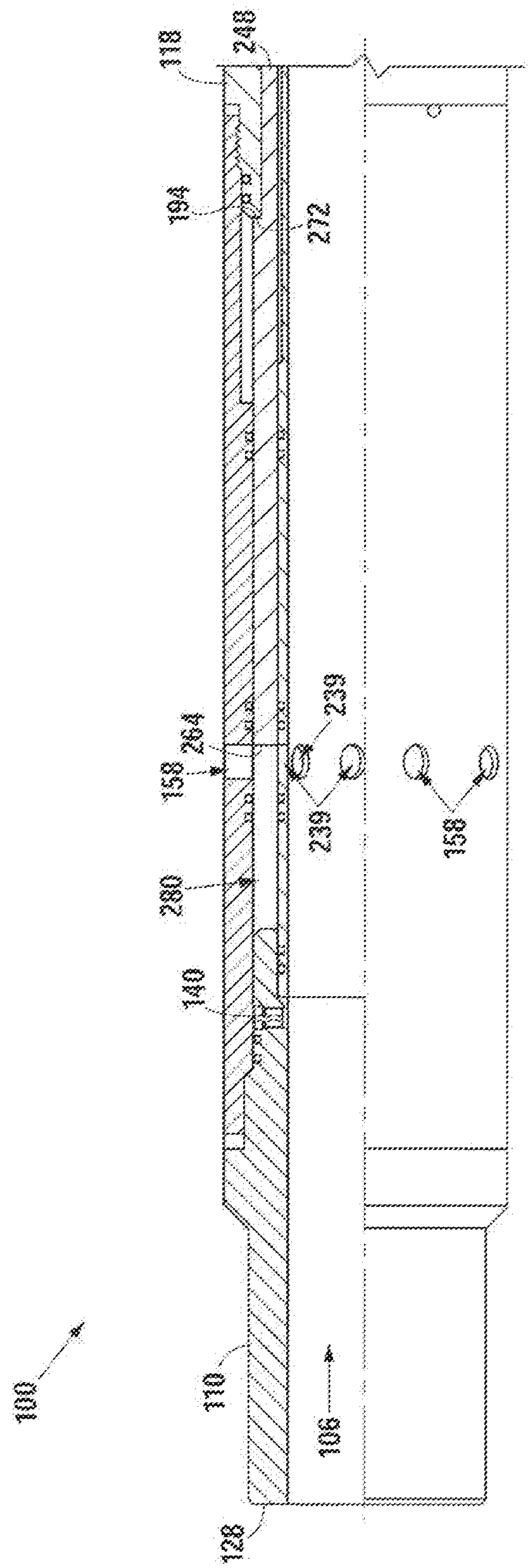

Fig. 8A

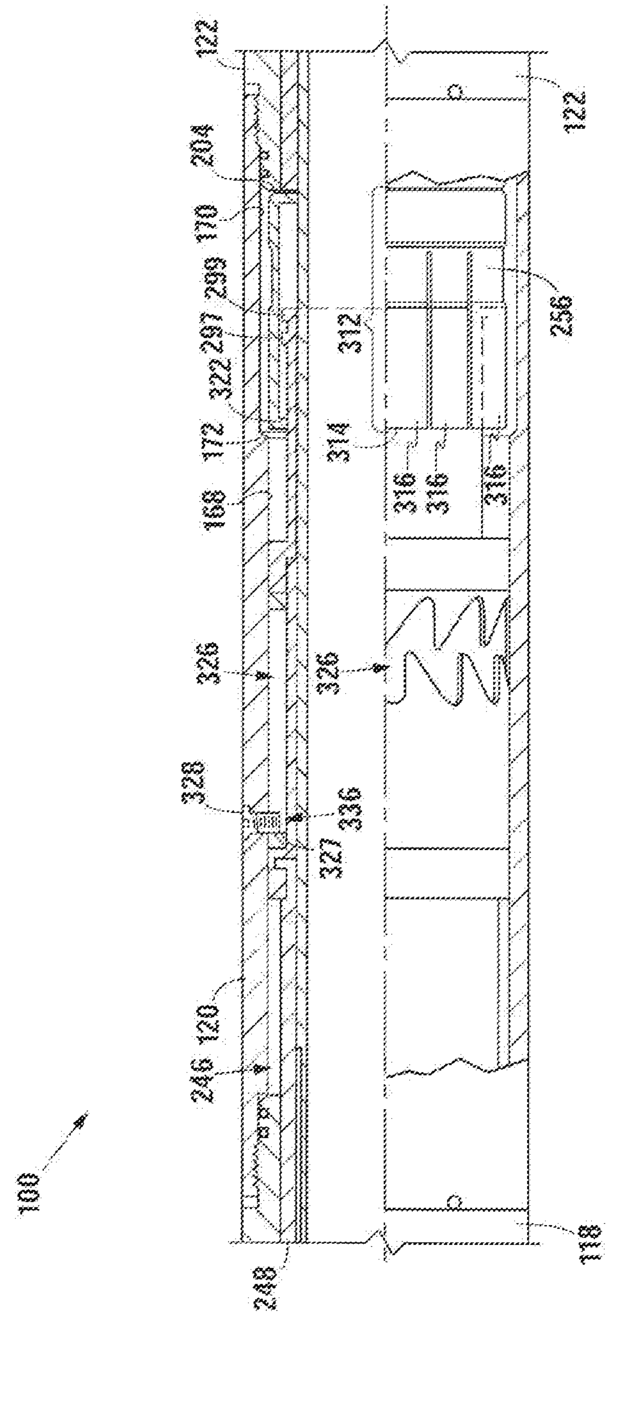
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Fig. 8B

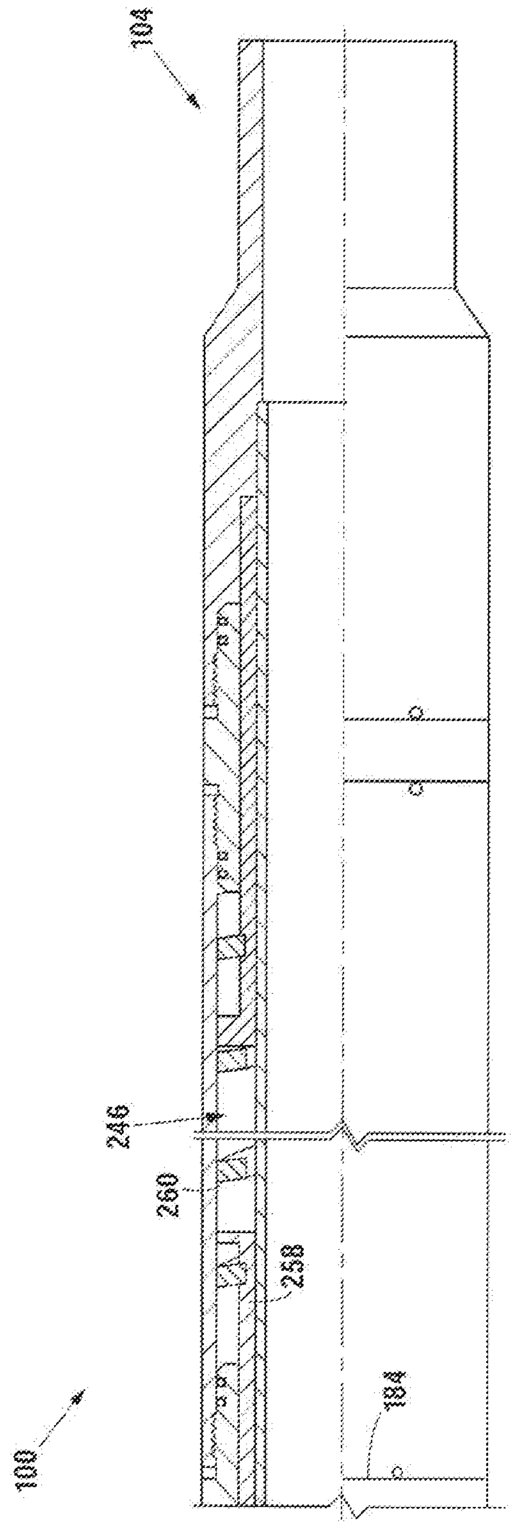

Fig. 8C

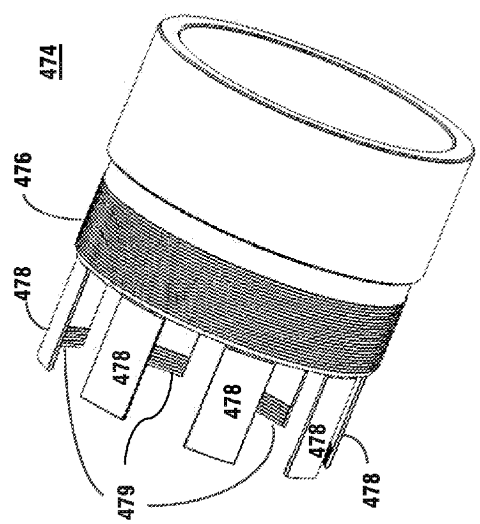

Fig. 9B

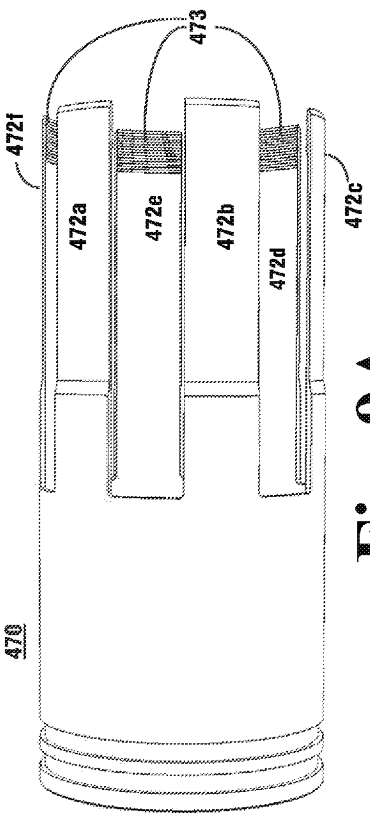

Fig. 9A

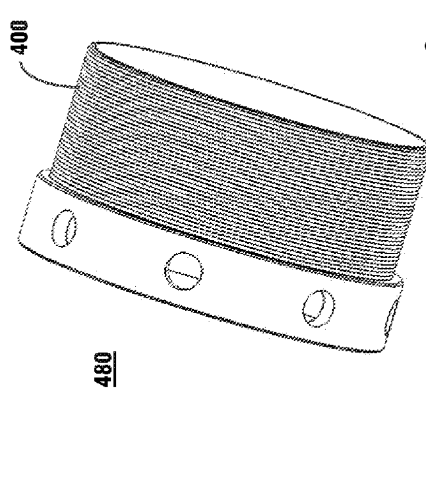

Fig. 9C

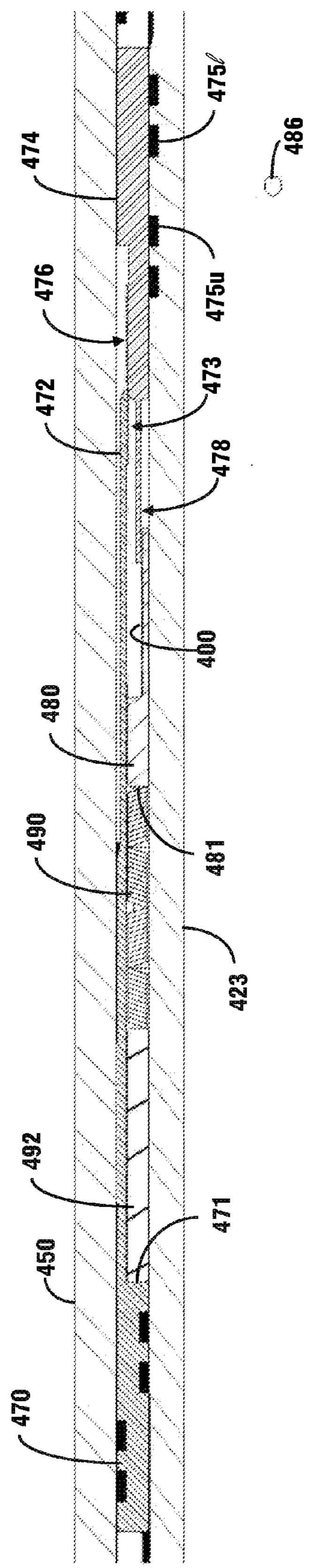
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Fig. 10

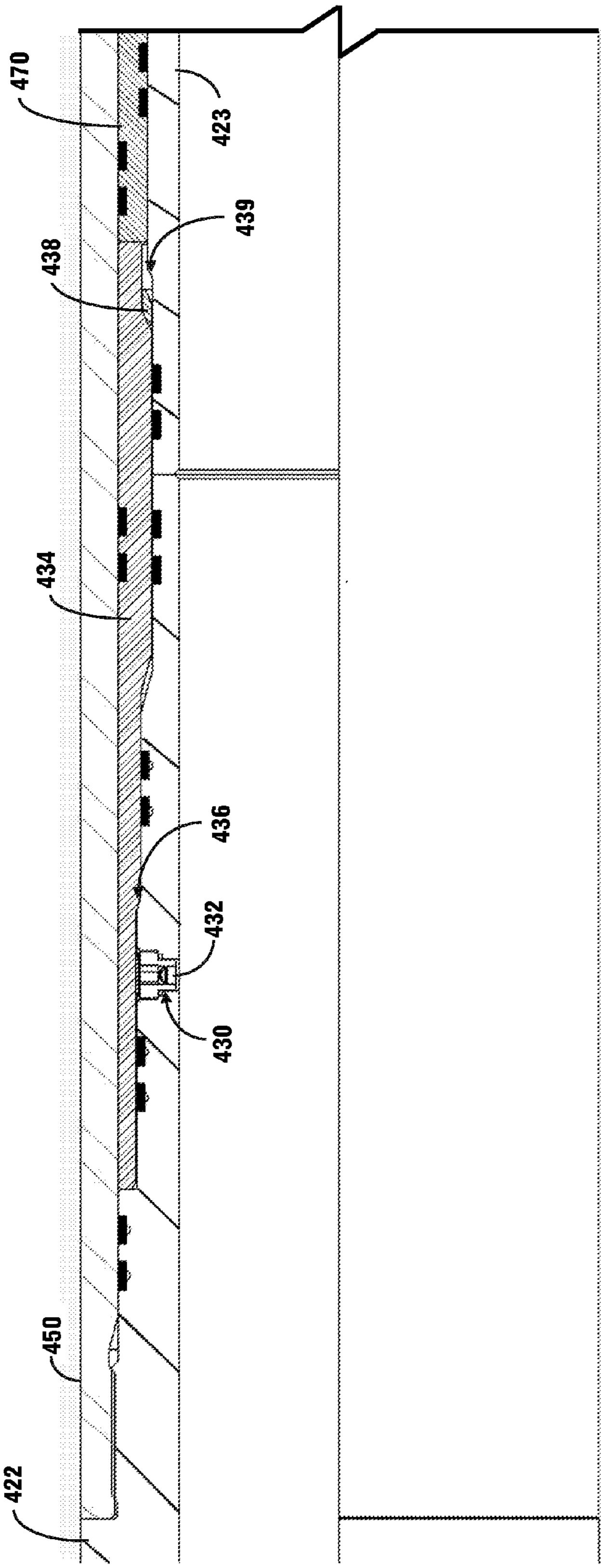

Fig. 11A

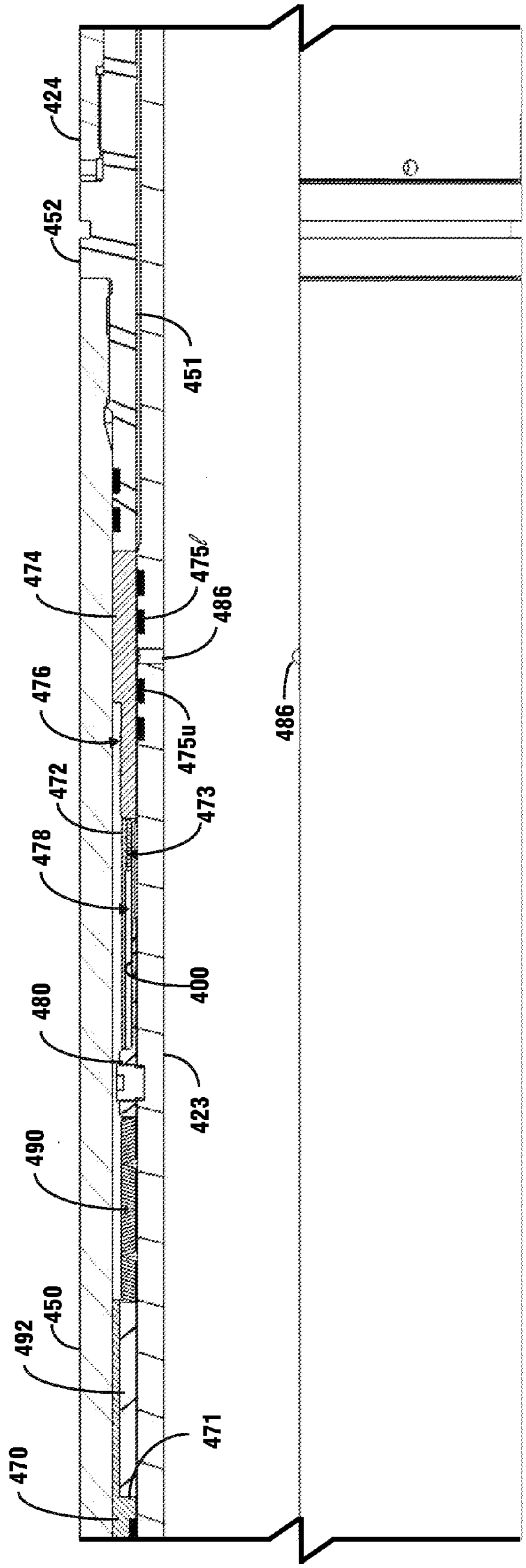
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Fig. 11B

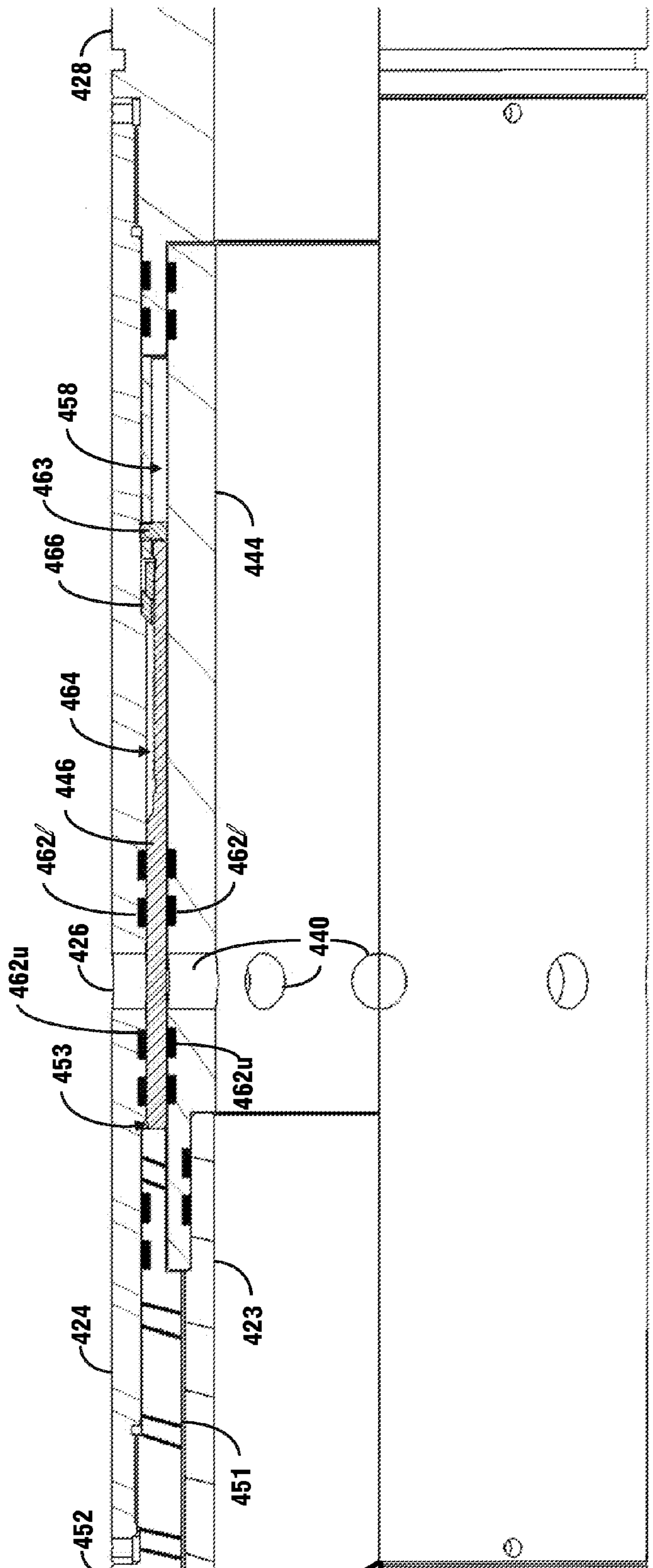
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Fig. 11C

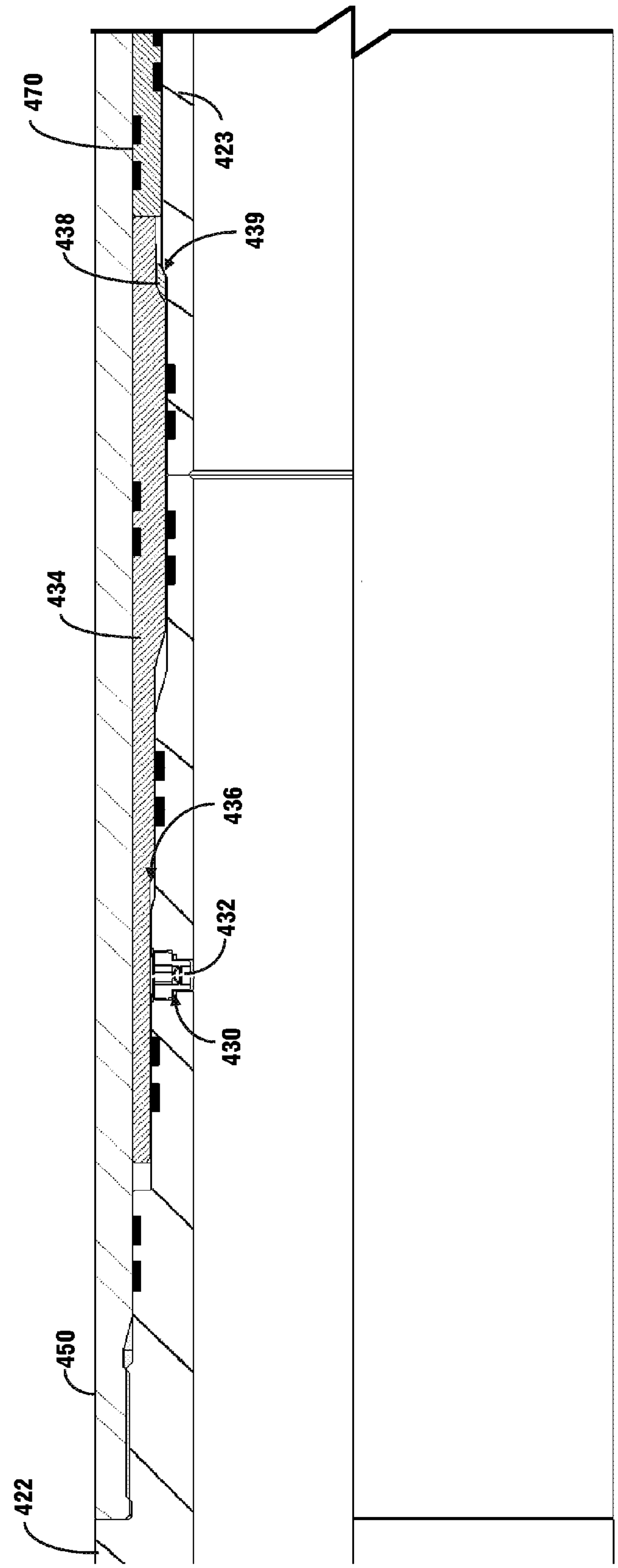

Fig. 12A

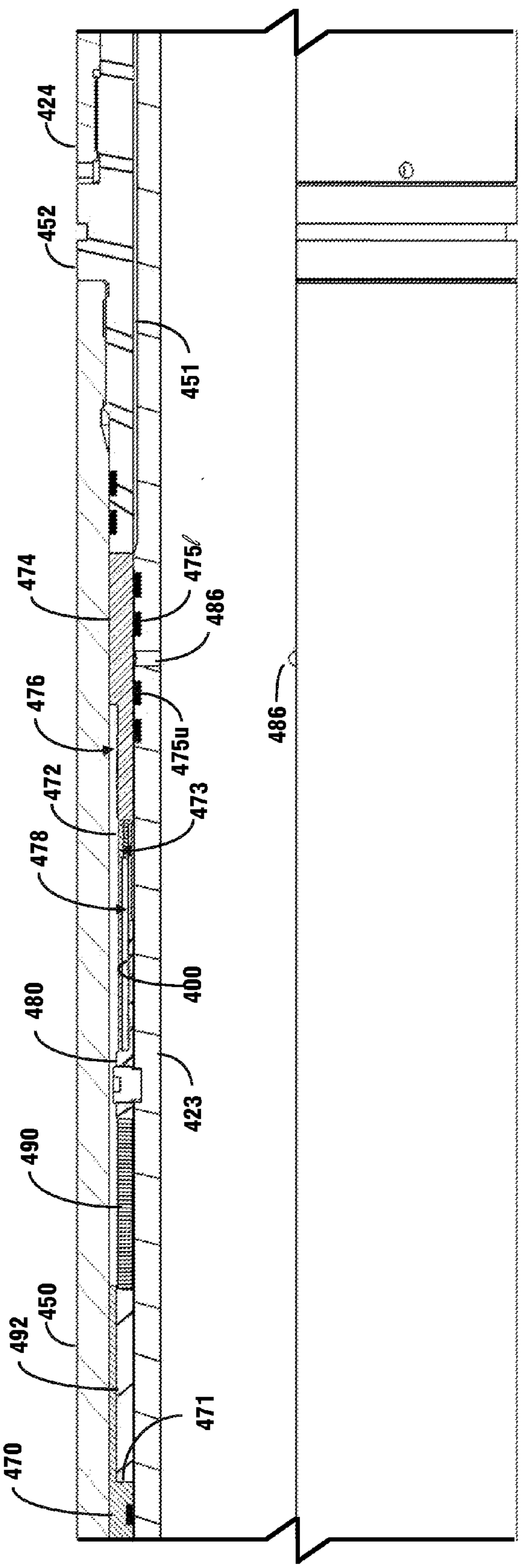
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Fig. 12B

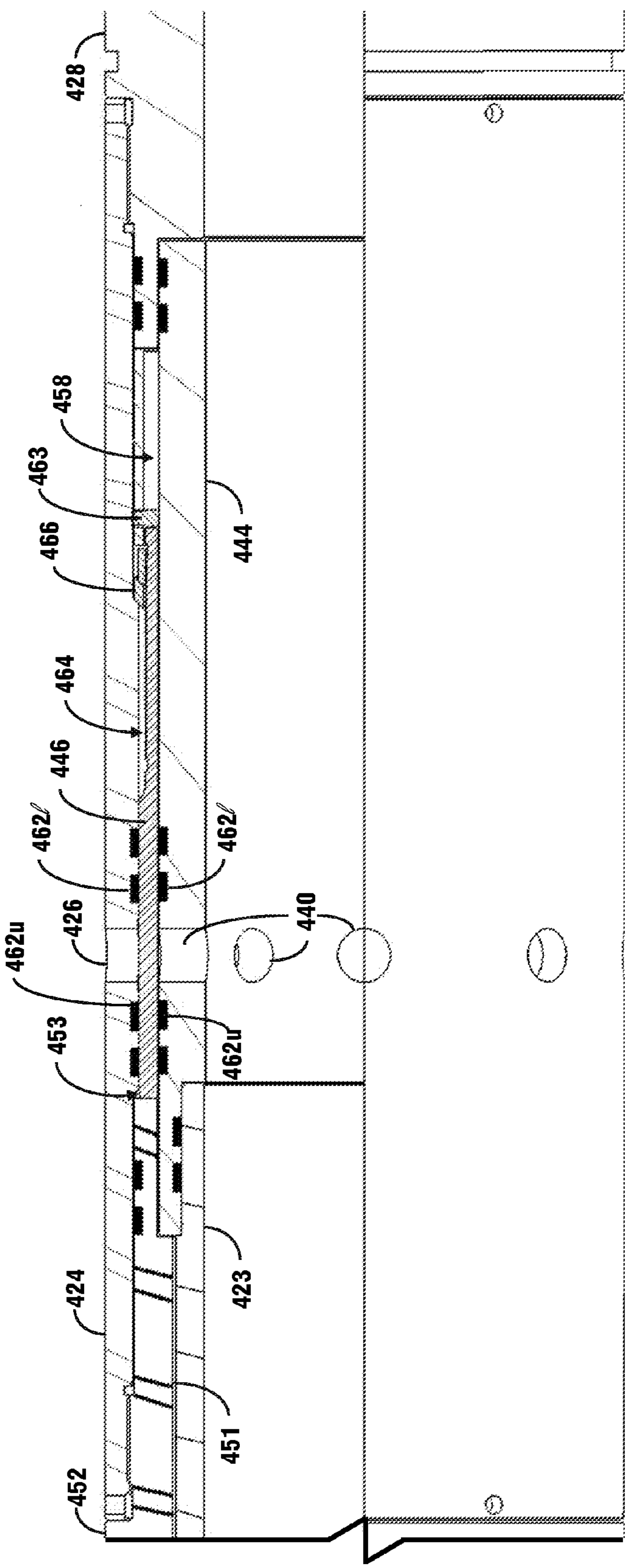
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Fig. 12C

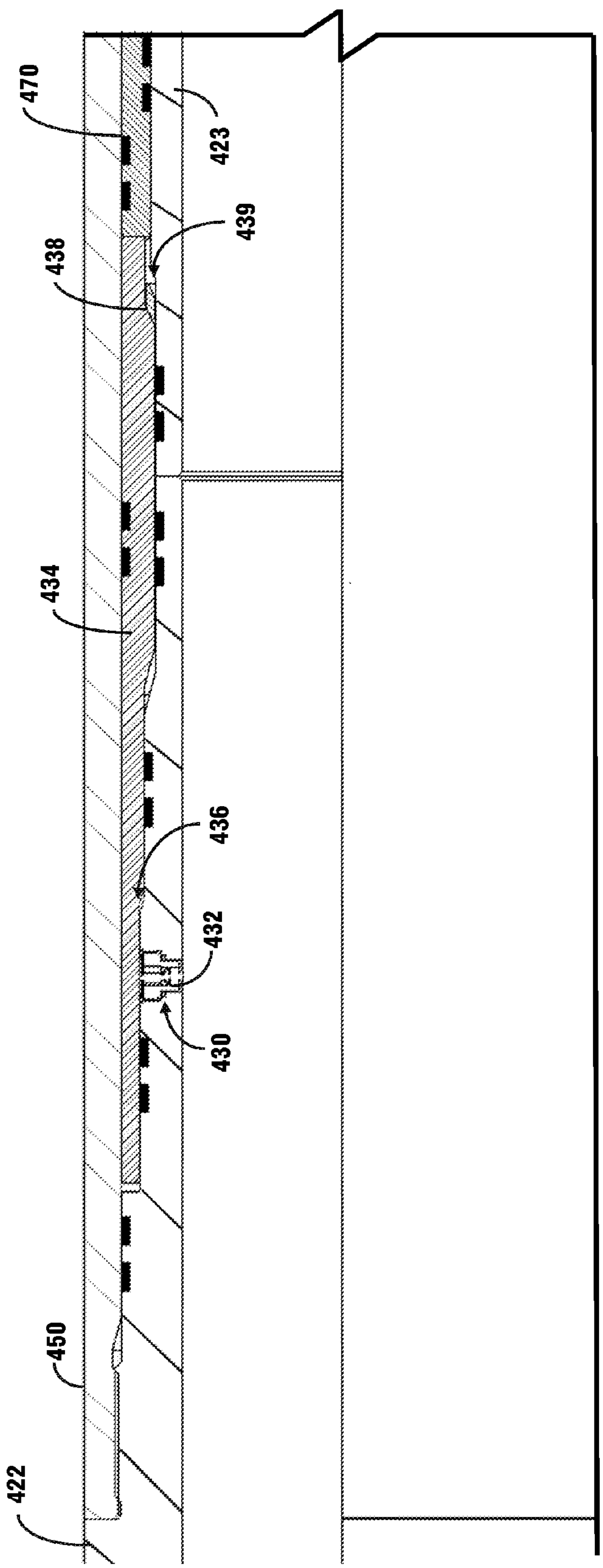

Fig. 13A

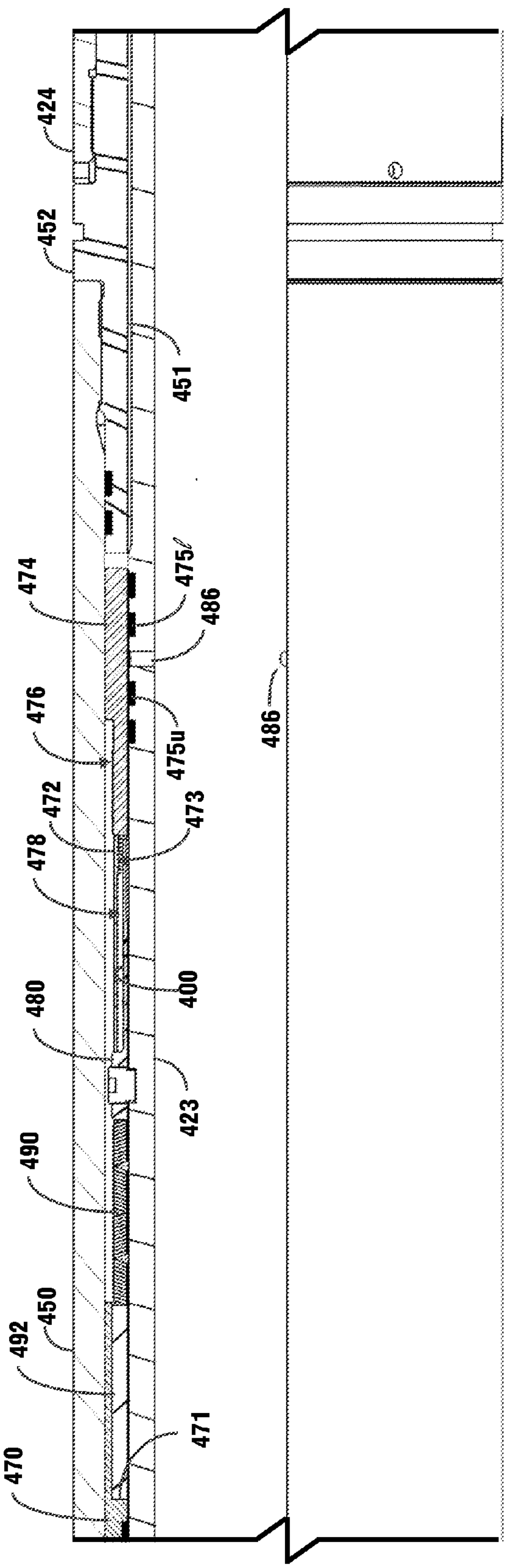
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Fig. 13B

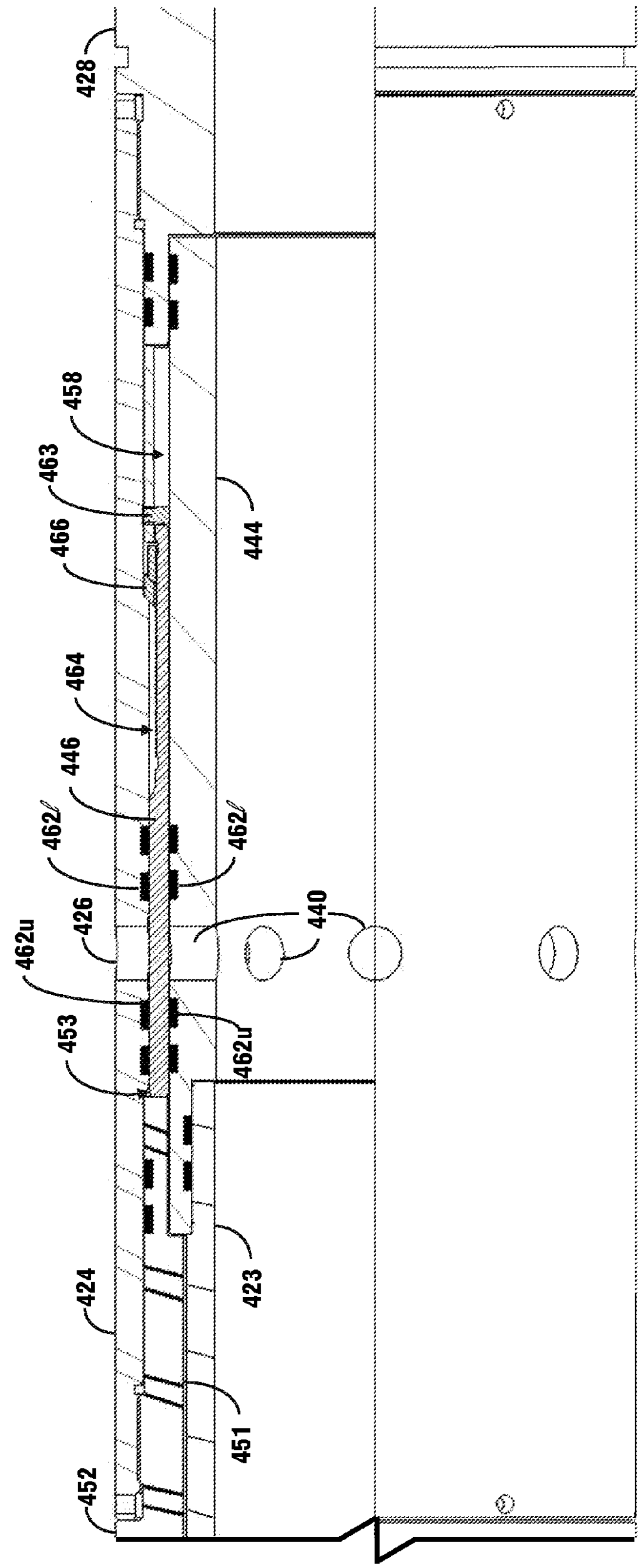
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Fig. 13C

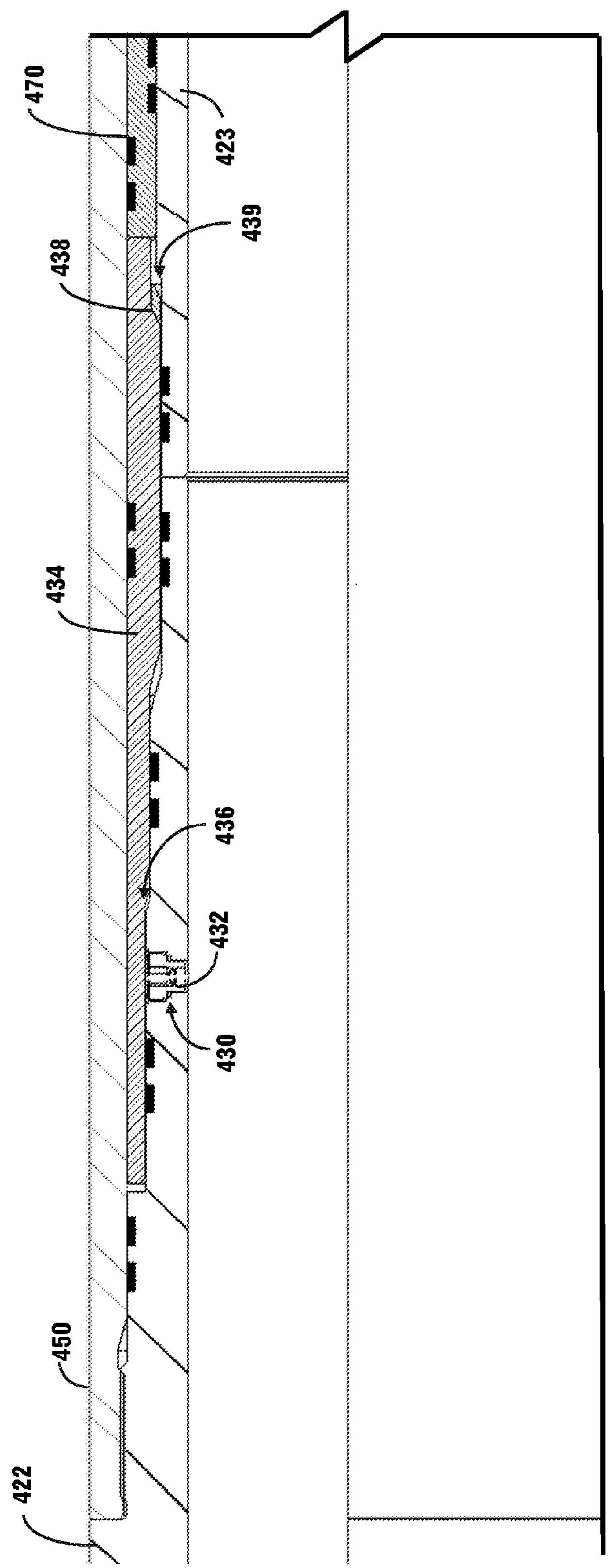

Fig. 14A

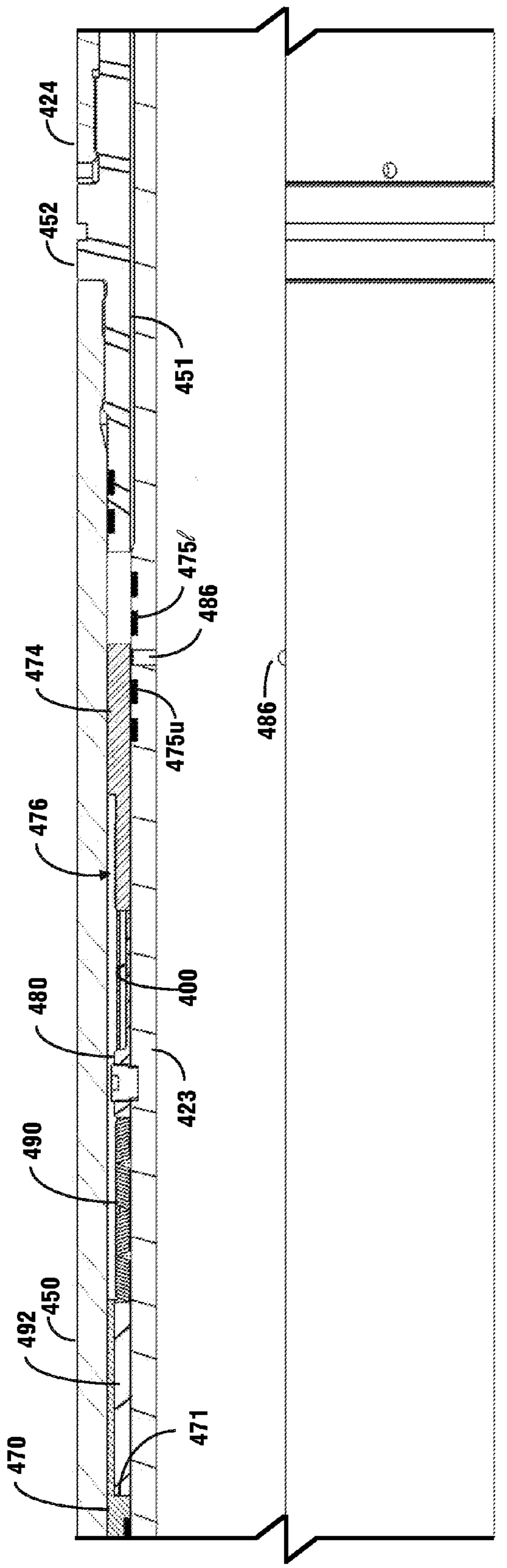
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Fig. 14B

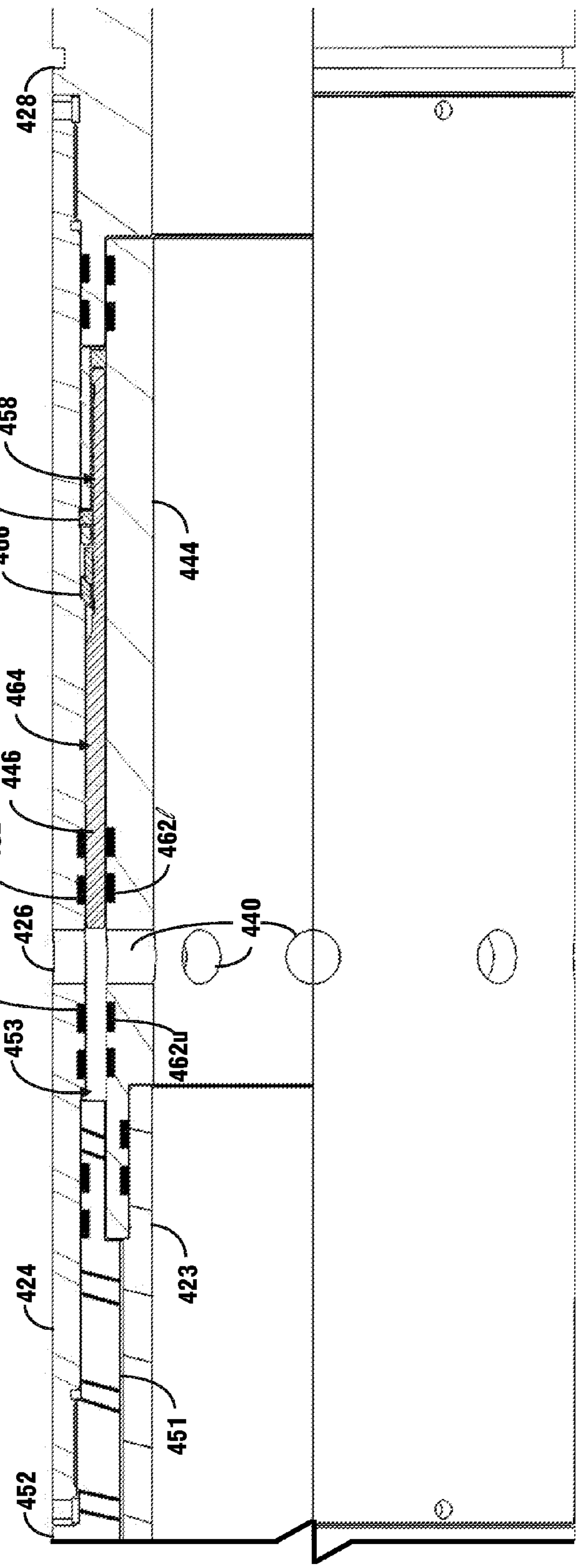
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Fig. 14C

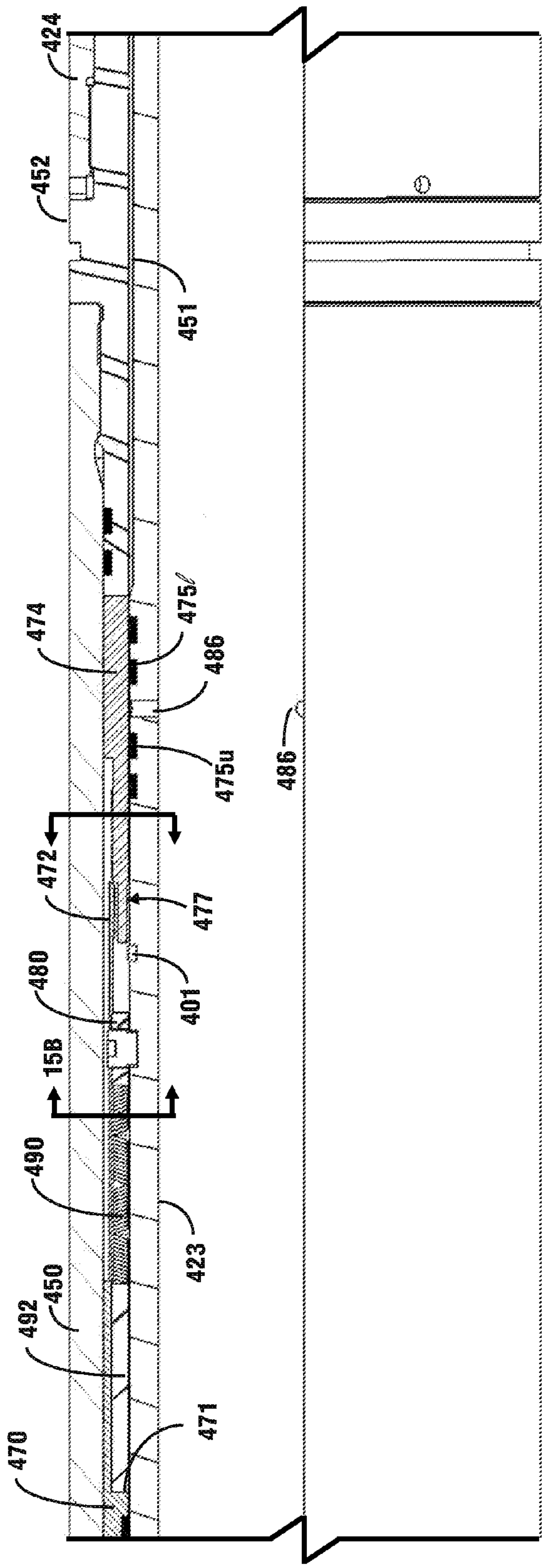
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Fig. 15A

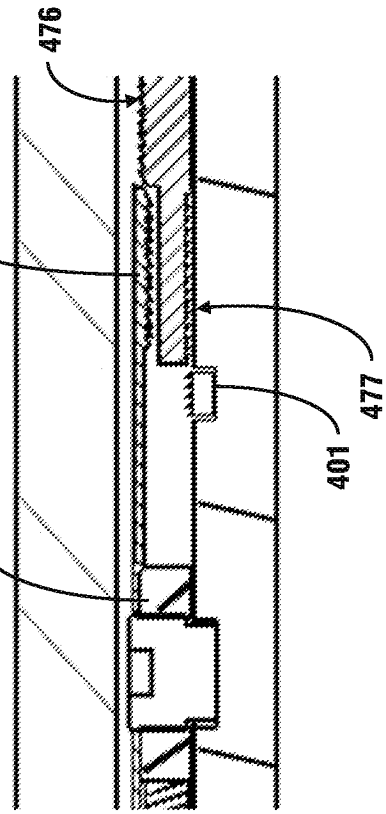

Fig. 15B

DOWNHOLE TOOLS, SYSTEMS AND METHODS OF USING

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application is a continuation in part of U.S. patent application Ser. No. 14/086,900, entitled "Downhole Tool", which claims the benefit of U.S. Provisional Application Ser. No. 61/729,264, filed Nov. 21, 2012, entitled "Downhole Tool," each of which is incorporated by reference herein.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND

[0003] 1. Field of the Invention

[0004] The described embodiments and invention as claimed relate to oil and natural gas production. More specifically, the invention as claimed relates to a downhole tool used to selectively activate in response to fluid pressure.

[0005] 2. Description of the Related Art

[0006] In completion of oil and gas wells, tubing is often inserted into the well to function as a flow path for treating fluids into the well and for production of hydrocarbons from the well. Such tubing may help preserve casing integrity, optimize production, or serve other purposes. Such tubing may be described or labeled as casing, production tubing, liners, tubulars, or other terms. The term "tubing" as used in this disclosure and the claims is not limited to any particular type, shape, size or installation of tubular goods.

[0007] To fulfill these purposes, the tubing must maintain structural integrity against the pressures and pressure cycles it will encounter during its functional life. To test this integrity, operators will install the tubing with a closed "toe"—the end of the tubing furthest from the wellhead—and then subject the tubing to a series of pressure tests. These tests are designed to demonstrate whether the tubing will hold the pressures which it will experience during use.

[0008] One detriment to these pressure tests is the necessity for a closed toe. After pressure testing, the toe must be opened to allow for free flow of fluids through the tubing so that further operations may take place. While formation characteristics, cement, or other factors may still restrict fluid flow, the presence of such factors do not alleviate the desirability or necessity for opening the toe of the tubing. Commonly, the toe is opened by positioning a perforating device in the toe and either explosively or abrasively perforating the tubing to create one or more openings. Perforating, however, requires additional time and equipment that increase the cost of the well.

[0009] Furthermore, current methods of opening the toe with hydraulic pressure limit the pressure test to pressures below the highest pressure the tubing will experience, to a maximum period of time, to a single test, or some combination of the above. This is particularly true in cemented environments where the inside of the tool is exposed to a cement slurry that contains particulate solids and which will ultimately harden.

[0010] Therefore, there exists a need for an improved method of opening the toe of the tubing after it is installed and pressure tested. The present disclosure describes improved devices and methods for opening the toe of tubing installed in a well. Some embodiment tools according to the present disclosure allow the pressure test to be conducted at the full burst pressure rating of the device, and allow sequential pressure tests to be performed. The devices and methods may also be readily adapted to other locations in the well and for other use in tools other than toe valves.

SUMMARY

[0011] The described embodiments of the present disclosure address the problems associated with the closed toe required for pressure testing tubing installed in a well. Further, in one aspect of the present disclosure, a chamber, such as a pressure chamber, air chamber, or atmospheric chamber, is in fluid communication with at least one surface of the shifting element of the device. The chamber is isolated from the interior of the tubing such that fluid pressure inside the tubing is not transferred to the chamber. A second surface of the shifting element is in fluid communication with the interior of the tubing. Application of fluid pressure on the interior of the tubing thereby creates a pressure differential across the shifting element, applying force tending to shift the shifting element in the direction of the pressure chamber, atmospheric chamber, or air chamber.

[0012] In a further aspect of the present disclosure, the shifting element is encased in an enclosure such that all surfaces of the shifting element opposing the chamber are isolated from the fluid, and fluid pressure, in the interior of the tubing. Upon occurrence of some pre-determined event—such as a minimum fluid pressure, the presence of acid, or electromagnetic signal—at least one surface of the shifting element is exposed to the fluid pressure from the interior of the tubing, creating differential pressure thereacross. Specifically, the pressure differential is created relative to the pressure in the chamber, and applies a net force on the shifting element in a desired direction. Such force activates the tool.

[0013] While specific predetermined events are stated above, any event or signal communicable to the device may be used to expose at least one surface of the shifting element to pressure from the interior of the tubing.

[0014] In a further aspect, the downhole tool comprises an inner sleeve with a plurality of sleeve ports. A housing is positioned radially outwardly of the inner sleeve, with the housing and inner sleeve partially defining a space radially therebetween. The space, which is preferably annular, is occupied by a shifting element, which may be a shifting sleeve. A fluid path extends between the interior flowpath of the tool and the space. A fluid control device, which is preferably a burst disk, occupies at least a portion of the fluid path.

[0015] When the toe is closed, the shifting sleeve is in a first position between the housing ports and the sleeve ports to prevent fluid flow between the interior flowpath and exterior of the tool. A control member is installed to prevent or limit movement of the shifting sleeve until a predetermined internal tubing pressure or internal flowpath pressure is reached. Such member may be a fluid control device which selectively permits fluid flow, and thus pressure communication, into the annular space to cause a differential pressure across the shifting sleeve. Any device, including, without limitation, shear pins, springs, and seals, may be used provided such device allows movement of the shifting element, such as shifting sleeve, only after a predetermined internal tubing pressure or other predetermined event occurs. In a preferred embodiment, the fluid control device will permit fluid flow into the

annular space only after it is exposed to a predetermined differential pressure. When this differential pressure is reached, the fluid control device allows fluid flow, the shifting sleeve is moved to a second position, the toe is opened, and communication may occur through the housing and sleeve ports between the interior flowpath and exterior flowpath of the tool.

[0016] In a further aspect of the present disclosure, an alternative embodiment nested sleeve assembly may comprise a fluid control device that is a separate nested sleeve blocking the fluid passageway to the upper pressure chamber, also referred to as the inlet chamber. This second nested sleeve functions as a trigger sleeve because movement of the trigger sleeve to its open position permits fluid flow to the inlet chamber and thereby permits actuation of the sliding sleeve. Further, the trigger sleeve may be connected directly to an indexing assembly such that the trigger sleeve only moves to the open position after a desired number of pressure cycles, permitting fluid flow to the shifting sleeve so that the necessary pressure differential across the shifting sleeve may be created in order to open the shifting sleeve.

[0017] In a further aspect of the present disclosure, alternative indexing assemblies are disclosed. A ratcheting indexing assembly may be used such that increased fluid pressure, acting on a pressure sleeve or piston, advances a ratchet assembly in communication with a trigger element. An opposing force, which may be a spring, causes the piston to move in the opposite direction, retracting the ratchet assembly. When the ratchet assembly has moved a necessary distance through the passage of a plurality of cycles, the trigger element is actuated.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0018] FIGS. **1-2** are partial sectional side elevations of an embodiment in the closed position.

[0019] FIGS. **1**A & **2**A are enlarged views of sections of FIGS. **1** & **2** respectively.

[0020] FIGS. **3-4** are partial sectional side elevations of an embodiment in the open position.

[0021] FIGS. **5**A-**5**C are partial sectional side elevations that collectively show a second embodiment of the tool in the closed position.

[0022] FIGS. **6**A-**6**B show features of the slotted member of the second embodiment.

[0023] FIGS. **7**A-**7**C are partial sectional side elevations that collectively show the second embodiment in a shifted position.

[0024] FIGS. **8**A-**8**C are partial sectional side elevations that show the second embodiment in an open position.

[0025] FIGS. **9**A-**9**C are views of certain components of a nested ratchet system according to the present disclosure.

[0026] FIG. **10** is a partial side elevation of one embodiment of a telescoping nested ratchet assembly according to the present disclosure.

[0027] FIGS. **11**A-**11**C are partial side elevations showing one embodiment tool with a telescoping nested ratchet assembly in the run in position.

[0028] FIGS. **12**A-**12**C are partial side elevations showing an embodiment tool with the telescoping ratchet assembly during the high pressure portion of a pressure cycle.

[0029] FIGS. **13**A-**13**C are partial side elevations showing an embodiment tool after a complete pressure cycle.

[0030] FIGS. **14**A-**14**C are partial side elevations showing an embodiment tool after the trigger has been moved to the open position and the shifting sleeve allowed to open.

[0031] FIGS. **15**A-**15**B are partial side elevations showing an embodiment indexing ratcheting assembly utilizing a ratchet ring and opposing teeth.

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

[0032] When used with reference to the figures, unless otherwise specified, the terms "upwell," "above," "top," "upper," "downwell," "below," "bottom," "lower," and like terms are used relative to the direction of normal production and/or flow of fluids and or gas through the tool and wellbore. Thus, normal production results in migration through the wellbore and production string from the downwell to upwell direction without regard to whether the tubing string is disposed in a vertical wellbore, a horizontal wellbore, or some combination of both. Similarly, during the fracing process, fracing fluids and/or gasses move from the surface in the downwell direction to the portion of the tubing string within the formation.

[0033] FIGS. **1-2** depict an embodiment **20**, which comprises a top connection **22** threaded to a top end of ported housing **24** having a plurality of radially-aligned housing ports **26**. A bottom connection **28** is threaded to the bottom end of the ported housing **24**. The top and bottom connections **22**, **28** have cylindrical inner surfaces **23**, **29**, respectively. A fluid path **30** through the wall of the top connection **22** is filled with a burst disk **32** having a rated pressure that will rupture when a pressure is applied to the interior of the tool **22** that exceeds the rated pressure.

[0034] The embodiment **20** includes an inner sleeve **34** having a cylindrical inner surface **35** positioned between a lower annular shoulder surface **36** of the top connection **22** and an upper annular shoulder surface **38** of the bottom connection **28**. The inner sleeve **34** has a plurality of radially aligned sleeve ports **40**. Each of the sleeve ports **40** is axially aligned with a corresponding housing port **26**. The inner surfaces **23**, **29** of the top and bottom connections **22**, **28** and the inner surface **35** of the sleeve **34** define an interior flowpath **37** for the movement of fluids into, out of, and through the tool. In an alternative embodiment, the interior flowpath **37** may be defined, in whole or in part, by the inner surface of the shifting sleeve.

[0035] Although the housing ports **26** and sleeve ports **40** are shown as cylindrical channels between the exterior and interior of the tool **20**, the ports **26**, **40** may be of any shape sufficient to facilitate the flow of fluid therethrough for the specific application of the tool. For example, larger ports may be used to increase flow volumes, while smaller ports may be used to reduce cement contact in cemented applications. Moreover, while preferably axially aligned, each of the sleeve ports **40** need not be axially aligned with its corresponding housing port **26**.

[0036] The top connection **22**, the bottom connection **28**, an interior surface **42** of the ported housing **24**, and an exterior surface **44** of the inner sleeve **34** define an annular space **45**, which is partially occupied by a shifting sleeve **46** having an upper portion **48** and a lower locking portion **50** having a plurality of radially-outwardly oriented locking dogs **52**. Upper sealing elements **62*u*** and lower sealing elements **62*l*** provide pressure isolation between the inner sleeve **34** and the shifting sleeve. In an alternative embodiment, the interior flowpath **37** may be defined, in whole or in part, by the inner surface of the shifting sleeve **46**.

[0037] The annular space **45** comprises an upper pressure chamber **53**—which may also be called an inlet pressure chamber—defined by the top connection **22**, burst disk **32**, outer housing **24**, inner sleeve **34**, shifting sleeve **46**, and upper sealing elements **62***u*. The annular space **45** further comprises a lower pressure chamber **55** defined by the bottom connection **28**, the ported housing **24**, the inner sleeve **34**, the shifting sleeve **46**, and lower sealing elements **62***l*. In one embodiment, the pressure within the upper and lower pressure chambers **53**, **55** is atmospheric when the tool is installed in a well (i.e., the burst disk **32** is intact).

[0038] A locking member **58** partially occupies the annular space **45** below the shifting sleeve **46** and ported housing **24**. When the shifting sleeve **46** is shifted as described hereafter, the locking dogs **52** engage the locking member **58** and inhibit movement of the shifting sleeve **46** toward the shifting sleeve's first position.

[0039] The shifting sleeve **46** is moveable within the annular space **45** between a first position and a second position by application of hydraulic pressure to the tool **20**. When the shifting sleeve **46** is in the first position, which is shown in FIGS. **1-2**, fluid flow from the interior to the exterior of the tool through the housing ports **26** and sleeve ports **40** is impeded by the shifting sleeve **46** and surrounding sealing elements **62**. Shear pins **63** may extend through the ported housing **24** and engage the shifting sleeve **46** to prevent unintended movement toward the second position, such as during installation of the tool **20** into the well. Although shear pins **63** function in such a manner as a secondary safety device, alternative embodiments contemplate operation without the shear pins **63**. For example, the downhole tool may be installed with the lower pressure chamber **55** containing fluid at a higher pressure than the upper pressure chamber **53**, which would tend to move and hold the shifting sleeve in the direction of the upper pressure chamber.

[0040] To shift the sleeve **46** to the second position (shown in FIG. **3-4**), a pressure greater than the rated pressure of the burst disk **32** is applied to the interior (i.e., flowpath **37**) of the tool **20**, which may be done using conventional techniques known in the art. This causes the burst disk **32** to rupture and allows fluid to flow through the fluid path **30** to the annular space **45**. In some embodiments, the pressure rating of the burst disk **32** may be lowered by subjecting the burst disk **32** to multiple pressure cycles. Thus, the burst disk **32** may ultimately be ruptured by a pressure which is lower than the burst disk's **32** initial pressure rating.

[0041] Following rupture of the burst disk **32**, the shifting sleeve **46** is no longer isolated from the fluid flowing through the inner sleeve **34**. The resultant increased pressure on the shifting sleeve **46** surfaces in fluid communication with the upper pressure chamber **53** creates a pressure differential relative to the atmospheric pressure within the lower pressure chamber **55**. Such pressure differential across the shifting sleeve causes the shifting sleeve **46** to move from the first position to the second position shown in FIG. **3-4**, provided the force applied from the pressure differential is sufficient to overcome the shear pins **63**, if present. In the second position, the shifting sleeve **46** does not impede fluid flow through the housing ports **26** and sleeve ports **40**, thus allowing fluid flow between the interior flow path **37** and the exterior of the tool. As the shifting sleeve **46** moves to the second position, the locking member **58** engages the locking dogs **52** to prevent subsequent upwell movement of the sleeve **46**.

[0042] The arrangement of a housing with an inner sleeve therein and shifting sleeve between the housing and inner sleeve may be referred to as a nested sleeve assembly. In some embodiments, the shifting sleeve **46** of a nested sleeve assembly has pressure surfaces, such as the opposing ends of the shifting sleeve **46**, isolated from the interior flowpath **37** and any fluid or fluid pressure therein. A fluid control device, such as a burst disk **32** disposed in a fluid path **30** from the interior flowpath **37** to the annular space **45**, or other mechanism may be included to allow fluid communication between the interior flowpath and at least one of the pressure surfaces.

[0043] The downhole tool may be placed in positions other than the toe of the tubing, provided that sufficient internal flowpath pressure can be applied at a desired point in time to create the necessary pressure differential on the shifting sleeve. In certain embodiments, the internal flowpath pressure must be sufficient to rupture the burst disk, shear the shear pin, or otherwise overcome a pressure sensitive control element. However, other control devices not responsive to pressure may be desirable for the present device when not installed in the toe.

[0044] The downhole tool as described may be adapted to activate tools associated with the tubing rather than to open a flow path from the interior to the exterior of the tubing. Such associated tools may include a mechanical or electrical device that signals or otherwise indicates that the burst disk or other flow control device has been breached. Such a device may be useful to indicate the pressures a tubing string experiences at a particular point or points along its length. In other embodiments, the device may, when activated, trigger release of one section of tubing from the adjacent section of tubing or tool. For example, the shifting element may be configured to mechanically release a latch holding two sections of tubing together. Any other tool may be used in conjunction with, or as part of, the tool of the present disclosure provided that the inner member selectively moves within the space in response to fluid flow through the flowpath. Numerous such alternate uses will be readily apparent to those who design and use tools for oil and gas wells.

[0045] FIGS. **5A-5C** together show an alternative embodiment 100 having a first end **102**, a second end **104**, and a cylindrical flowpath **106** having a longitudinal axis **108** extending between the first end **102** and the second end **104**. While the flowpath **106** through the embodiment 100 provides access to the tool exterior at the first end **102** and second end **104**, the flowpath **106** is radially separated, relative to the axis **108**, from the exterior by a top connection **110**, a housing assembly **112**, and a bottom connection **114**. The housing assembly **112** comprises a ported housing **116**, a first housing connector **118**, a collet housing **120**, a second housing connector **122**, a spring housing **124**, and a third housing connector **126**. Each of the ported housing **116**, collet housing **120**, and spring housing **124** is a tubular body.

[0046] Referring specifically to FIG. **5A**, the top connection **110** has a first annular end surface **128**, a second annular end surface **130**, and first and second annular shoulder surfaces **132**, **134** longitudinally positioned between the first and second annular end surfaces **128**, **130**. The top connection **110** further has a cylindrical inner surface **136** adjacent the first end surface **128**, a first shoulder surface **132** that defines a portion of the flowpath **106**, and an outer surface **137** adjacent the first end surface **128** and second end surface **130**. A fluid path **138** extends radially from the inner surface **136** to the outer surface **137**. The fluid path **138** is occupied with a fluid control device, such as a burst disk **140**, that will rupture when a pressure is applied to the flowpath **106** that exceeds a rated pressure.

[0047] The ported housing **116** has a cylindrical outer surface **150**, a cylindrical first inner surface **152**, a cylindrical second inner surface **154**, an annular shoulder surface **156** separating the first inner surface **152** and the second inner surface **154**, and a plurality of circumferentially-aligned, radially-oriented housing ports **158** extending between the outer surface **150** and the first inner surface **152**. The ported housing **116** further has first and second annular end surfaces **160**, **162** adjacent to the outer surface **150**. The first end surface **160** is adjacent to the first inner surface **152**, and the second end surface **162** is adjacent to the second inner surface **154**.

[0048] Referring to FIG. **5**B, the collet housing **120** has an outer cylindrical surface **164**, a cylindrical first inner surface **168**, a cylindrical second inner surface **170**, a partially-conical shoulder surface **172** separating the first and second inner surfaces **168**, **170**, and first and second annular end surfaces **174**, **176**. The diameter of the first inner surface **168** is less than the diameter of the second inner surface **170**. A pin hole **178** extends through the collet housing **120** between the first inner surface **168** and the outer surface **164**.

[0049] Referring to FIG. **5**C, the spring housing **124** has a cylindrical outer surface **180**, a cylindrical inner surface **182**, and first and second annular end surfaces **184**, **186** adjacent to the outer and inner surfaces **180**, **182**. The bottom connection **114** has a first annular end surface **142**, a second annular end surface **144**, and first and second annular shoulder surfaces **146**, **148** longitudinally positioned between the first and second annular end surfaces **184**, **186**.

[0050] Each of the first housing connector **118**, second housing connector **122**, and third housing connector **126** are identically constructed. As shown in FIG. **5**A-**5**B, the first housing connector **118** has an annular body portion **188** and first and second annular ends **190**, **192** extending away from the body portion **188** terminating in first and second annular end surfaces **194**, **196**, respectively. As shown in FIG. **5**B-**5**C, the second housing adaptor **122** has an annular body portion **198** and first and second annular ends **200**, **202** extending away from the body portion **198** and terminating in first and second annular end surfaces **204**, **206**, respectively. As shown in FIG. **5**C, the third housing adaptor **126** has a body portion **208** and first and second annular ends **210**, **212** extending away from the body portion **208** and terminating in first and second annular end surfaces **214**, **216**, respectively.

[0051] Referring back to FIG. **5**A, the ported housing **116** is fixed to the top connection **110** with a first set of circumferentially aligned screws **218** and to the first end **190** of the first housing connector **118** with a second set of circumferentially aligned screws **220**. As shown in FIG. **5**B, the collet housing **120** is connected to the second end **192** of the first housing connector **118** with a third set of circumferentially aligned screws **222** and the first end **200** of the second housing connecter **122** with a fourth set of circumferentially aligned screws **224**. As shown in FIG. **5**C, the spring housing **124** is connected to a second end **202** of the second housing connector **122** with a fifth set of circumferentially-aligned screws **226** and to the first end **210** of the third housing connector **126** with a sixth set of circumferentially-aligned screws **228**. The bottom connection **114** is connected to the second end **212** of the third housing connector **126** with a seventh set of circumferentially aligned screws **230**.

[0052] Referring again collectively to FIGS. **5**A-**5**C, an inner sleeve **232** is longitudinally fixed between, and relative to, the top connection **110** and the bottom connection **114**. The inner sleeve **232** has a cylindrical inner surface **234** that defines a portion of the flowpath **106**, a cylindrical outer surface **236**, and first and second annular end surfaces **238**, **240**. The first annular end surface **238** is positioned adjacent to the first shoulder surface **132** of the top connection **110**. The second end surface **240** is positioned adjacent to the first shoulder surface **146** of the bottom connection **114**. The inner sleeve **232** has a plurality of radially-aligned sleeve ports **239** extending between inner surface **234** and the outer surface **236**. Each of the sleeve ports **239** is axially aligned with a corresponding housing port **158** of the ported housing **116**.

[0053] Annular sealing elements **242** are positioned radially between the top connection **110** and the ported housing **116**. Annular sealing elements **244** are positioned radially between the inner sleeve **232** and the top connection **110**.

[0054] The top connection **110**, housing assembly **112**, inner sleeve **232** and bottom connection **114** together define an annular space **246** radially positioned relative to the longitudinal axis **108** between the flowpath **106** and the exterior of the embodiment 100. The annular space **246** is occupied by a shifting sleeve **248**, a bearing sleeve **250**, a slotted member **252**, a collet retainer **254**, a collet **256**, a first spring bearing **258**, a coil spring **260**, and a second spring bearing **262**.

[0055] Referring specifically to FIG. **5**A, the shifting sleeve **248** is a tubular body coaxially aligned with the inner sleeve **232** around the longitudinal axis **108**. The shifting sleeve **248** has a first annular end surface **264**, a second annular end surface **266** (see FIG. **5**B), a first outer surface **268** having a first diameter, a second outer surface **270** having a second diameter less than the first diameter, an annular shoulder surface **272** separating the first and second outer surfaces **268**, **270**, and a cylindrical inner surface **274**. The inner surface **274** is closely fitted to the outer surface **236** of the inner sleeve **232**. The first end surface **264** is adjacent to the second end surface **130** of the top connection **110**. Annular sealing elements **276**, **277** are positioned radially between the shifting sleeve **248** and the ported housing **116** on either side of the housing ports **158**. Annular sealing elements **278**, **279** are positioned radially between the shifting sleeve **248** and the inner sleeve **232** on either side of the sleeve ports **239**.

[0056] An annular chamber **280** intersects with the annular space **246** and the fluid path **138**. As shown in FIG. **5**A, the chamber **280** is the space defined by the top connection **110**, sealing elements **242**, **244**, **276**, **278**, the burst disk **140**, inner sleeve **232**, and the shifting sleeve **248**.

[0057] Referring to FIG. **5**B, the second end surface **266** of the shifting sleeve **248** is adjacent to the bearing sleeve **250**, which has a first annular end surface **282** and a second annular end surface **284**, an inner shoulder surface **286**, and an outer shoulder surface **288**. The inner shoulder surface **286** is adjacent to and separates first and second cylindrical inner surfaces **290**, **292**, of the bearing sleeve **250**. The second inner surface **292** is closely fitted to the outer surface **236** of the inner sleeve **232**. The first inner surface **290** has a larger diameter than the second inner surface **292** and defines, with the adjacent portion of the inner sleeve **232**, an annular space **294** in which the second end surface **266** of the shifting sleeve **248** contacts the inner shoulder surface **286**. The first annular end surface **282** is in contact with the second end surface **196** of the first housing connector **118**.

[0058] The second annular end surface **284** of the bearing sleeve **250** is fitted to the collet retainer **254**. The collet retainer **254** has a first annular end surface **296** and a second annular end surface **298**, an inner shoulder surface **300**, and an outer shoulder surface **302**. The inner shoulder surface **300** is adjacent to and separates first and second inner cylindrical surfaces **304**, **306**. The second inner surface **306** is closely fitted to the outer surface **236** of the inner sleeve **232**. The first inner surface **304** has a larger diameter than the second inner surface **306** and, with the adjacent portion of the inner sleeve **236**, defines an annular space into which the second end surface **284** of the bearing sleeve **250** is fitted and contacts the inner shoulder surface **300**.

[0059] First and second annular retaining members **297**, **299** define a circumferential retaining groove **301** proximal to the second end surface **298** of the collet retainer **254**. The second retainer member **299** coterminates with the second end surface **298** of the collet retainer **254**.

[0060] The collet **312** is positioned around the second end surface **298** of the collet retainer **254**. The collet **312** has a first end **314** coterminating with the ends of collet fingers **316**, an annular body **318**, and an annular end surface **320** opposing the first end **314**. Each collet finger **316** extends from the annular body **318** toward the outer shoulder surface **302** of the retainer **254** and terminates in an inwardly-extending shoulder **322** that coterminates with the first end **314**. The fingers **316** are in contact with, and inhibited from radial expansion away from the retainer **254** by, the first inner surface **168** of the collet housing **120**. The inwardly-extending shoulder **322** is positioned in the retaining groove **301** defined by the collet retainer **254**.

[0061] The annular slotted member **252** is positioned around the bearing sleeve **250** and longitudinally between the outer shoulder surface **288** of the bearing sleeve **250** and the first end surface **296** of the collet retainer **254**. The slotted member **252** has an outer surface **324** and a slot **326** formed in the outer surface **324**. A pin, such as torque pin **328**, extends through the pin hole **178** in the collet housing **120** and has a terminal end **329** positioned in the slot **326**. The slotted member **252** is concentrically aligned with the axis **108**.

[0062] As shown in FIG. **6**A-**6**B, the slot **326** is a continuous path defined by a slot sidewall **327** and extending circumferentially around, and formed in, the outer surface **324** of the slotted member **252**. The slot **326** is formed of a repeated pattern of longitudinally-aligned first positions **330***a-m* and longitudinally aligned intermediate positions **332***a-l*. A first end **334** of the slot **326** terminates in the first position **330***a*. A second end **336** of the slot **326** terminates with a second position **338**. The intermediate positions **332***a-l* are longitudinally between the first positions **330***a-m* and the second position **338**.

[0063] The slot **326** is shaped so that when the torque pin **328** is in one of the first positions **330***a-m* and the slotted member **252** moves in a first longitudinal direction D**1** relative to the pin **328**, the torque pin **328** moves toward the adjacent intermediate position. If the torque pin **328** is in the first position **330***m* and the slotted member **252** moves in the first direction D**1**, the pin **328** moves toward the second position **338**. When the torque pin **328** is in a intermediate position, such as the intermediate position **332***a,* and the slotted member **252** moves in a second longitudinal direction D**2** toward the first end **102** of the embodiment 100, the torque pin **328** moves toward the next adjacent first position, first position **330***b.*

[0064] Referring back to FIG. **5**B-**5**C, the first spring bearing **258** has an annular first end surface **340**, an annular second end surface **342**, and an inner cylindrical surface **344** closely fitted to the outer surface **236** of the inner sleeve **232**. The first spring bearing **258** is coaxially aligned with the inner sleeve **232**. An annular shoulder surface **346** is positioned longitudinally between the first end surface **340** and the second end surface **342**. As shown in FIG. **5**B, a portion of the first spring bearing **258** is positioned radially between the inner sleeve **232** and the second housing connector **122** and extends past the first end surface **204** of the second housing connector **122** toward the collet **312**.

[0065] As shown in FIG. **5**C, the coil spring **260** is positioned in the annular space **246** longitudinally between the second housing connector **122** and the third housing connector **126**, and radially between the inner sleeve **232** and the spring housing **124**. The coil spring **260** has a first end **350** positioned between the second end surface **206** of the second housing connector **122** and the shoulder surface **346** of the first spring bearing **258**. The first end **350** of the spring **260** is fixed to, and moves longitudinally with, the first spring bearing **258**.

[0066] A second spring bearing **352** is positioned in the annular space **246**, and has a first annular end surface **354** and a second annular end surface **356**. An annular shoulder surface **358** is positioned between the first annular surface **354** and the second annular surface **356**. The second spring bearing **352** has a cylindrical outer surface **360** positioned radially between the third housing adaptor **126** and the inner sleeve **232**. The coil spring **260** has a second end **362** positioned longitudinally between the shoulder surface **358** of second spring bearing **352** and the third housing connector **126**.

[0067] FIGS. **5**A-**5**C collectively show the embodiment 100 as it may be run into a wellbore, with the second end **104** being located downwell of the first end **102**. In this run-in configuration, the pressure in the chamber **280** is atmospheric and the burst disk **140** is intact. As shown in FIG. **5**B, the end surface **320** of the collet **312** is spaced a distance from the first end surface **204** of second housing connector **122**, and the first end **314** of the collet **312** is around a portion of the collet retainer **254**. The first end **314** of the collet **312** is positioned radially within first inner surface **168** of the collet housing **120**. The shoulder **322** is positioned in the retaining groove **301**, resulting in the collet **312** having a fixed longitudinal relationship with the collet retainer **254**. The end **329** of torque pin **328** is positioned in the slot **326** in a first position, such as the first position **330***a* (see FIG. **6**). The coil spring **260** is urging the first spring bearing **258** toward the first end **102** of the embodiment 100, which in turn urges the collet **312**, collet retainer **254**, bearing sleeve **250**, and shifting sleeve **248** toward the first end **102** of the embodiment.

[0068] As shown in FIG. **5**A, the shifting sleeve **248** is moveable within the annular space **246** between a first position and a second position (as will be described with reference to FIGS. **8**A-**8**C) by application of hydraulic pressure to the chamber **280**. When the shifting sleeve **248** is in the first position, fluid flow from the flowpath **106** to the exterior of the embodiment through the housing ports **158** and sleeve ports **239** is impeded by the shifting sleeve **248** and surrounding sealing elements **276**-**279**.

[0069] Referring to FIG. **5**A, to move the shifting sleeve **248**, a pressure greater than the rated pressure of the burst disk **140** is applied to the flowpath **106** to rupture burst disk **140** and establish a fluid communication path from the flow path **106** to the chamber **280** through the fluid path **138**. Fluid is inhibited from exiting the chamber **280** between the various elements of the embodiment 100 by sealing elements **242**, **244**, **276**, **278**.

[0070] After the rupture of the burst disk **140**, the resultant increased pressure on the first end surface **264** of the shifting sleeve **248** creates a pressure differential relative to the expansive force exerted by the coil spring **260** and the pressure in the remaining portions of the annular space **246**, which causes the shifting sleeve **248** to move toward the second end **104** of the embodiment 100. Because of the longitudinally-fixed relationship of the bearing sleeve **250**, slotted member **252**, collet retainer **254**, and collet **312** relative to the shifting sleeve **248**, these elements are also moved toward the second end **104**, provided the force applied from the pressure differential is sufficient to move these elements and overcome the increasing magnitude of the force resulting from increased compression of the spring **260** under Hooke's law. While the slotted member **252** is longitudinally fixed relative to the bearing sleeve **250** and the collet retainer **254**, the slotted member **252** is rotatable around the bearing sleeve **250**, subject to the positioning of the torque pin **328** within the slot **326**.

[0071] FIGS. **7**A-**7**C collectively show the embodiment with the shifting sleeve **248** and related components in a shifted position. In this position, the torque pin **328** is in one of the first positions of the slot **326**. The volume of the chamber **280** is larger than as shown in FIG. **5**A because of displacement of the first end surface **264** of the shifting sleeve **248**. The collet fingers **316** remain inhibited from radial expansion by the first inner surface **168** of the collet housing **120**. Movement past the shifted position shown in FIG. **7**A-**7**C is limited by, inter alia, the position of the torque pin **328** within the slot **326**, which is in an intermediate position with the pin **328** in contact with the slot sidewall **327**. The coil spring **260** exerts an expansive force on the first and second spring bearings **258**, **352**, urging the shifting sleeve **248** toward the top connection **110**, but the shifting sleeve **248**, slotted member **252**, collet retainer **254**, collet **256**, bearing sleeve **250**, and first spring bearing **258** are shifted towards the second end **104** into the intermediate position on slot **326** by the fluid pressure in chamber **280**.

[0072] Following a pressure increase within the flowpath **106**, and therefore chamber **280**, sufficient to move the shifting sleeve **248** to the shifted position, the pressure may thereafter be decreased to a magnitude at which the expansive force of the spring **260** moves the first spring bearing **258**, collet **312**, collet retainer **254**, bearing sleeve **250**, and shifting sleeve **248** to the first position of FIG. **5**A-**5**C. This decrease in pressure marks the end of the pressure cycle.

[0073] FIGS. **8**A-**8**C collectively show the embodiment 100 with the shifting sleeve **248** and related components in the second position. As shown in FIG. **8**A, the first end surface **264** of the shifting sleeve **248** is positioned longitudinally between the housing ports **158** and the first housing connector **118**, which allows a fluid communication path between the exterior and the flowpath **106** through the housing ports **158**, sleeve ports **239**, and chamber **280**. The shoulder surface **272** of the shifting sleeve **248** is adjacent to first end surface **194** of the first housing connector **118**. As shown in FIG. **8**B, the torque pin **328** is in the second end **336** of the slot **326**. Movement of the collet **312** toward the second end **104** is limited by the first end surface **204** of the second housing connector **122**. Second end **336** may be referred to as the actuated position of the slotted member. Any of the first positions **330***a-m* and the intermediate positions **332***a-l* may be referred to as a non-actuated position and any two or more collectively referred to as non-actuated positions.

[0074] The first end **314** of the collet **312** has moved past the shoulder surface **172** into the larger-diameter section defined by the second inner surface **170**, which allows collet fingers **316** to radially expand as the collet retainer **254** moves further toward the second housing connector **122**. This allows the retaining members **297**, **299** to move past the finger shoulders **322**, which terminates the fixed longitudinal relationship between the collet retainer **254** and the collet **312**. Subsequent movement of the collet **312** toward the top connection **110** is inhibited by engagement of the collet fingers **316** with the shoulder surface **172**. After this disengagement, the expansive force of the spring **260** is no longer translated to the shifting sleeve **248** through the collet **312** as described with reference to FIGS. **7**A-**7**C.

[0075] One advantage of this embodiment over the embodiment described with reference to FIGS. **1**-**4** relates to applications in which the well operator may desire to test the tubing string at pressures near the rated pressure of the burst disk **140**. Although the burst disk **140** has a rated pressure at which it is intended to rupture, it may rupture unintentionally before the rated pressure within the flowpath **106** is obtained. The closer the test pressure to the rated pressure, the more likely an unintentional rupture of the burst disk **140** that would result in a premature actuation of the embodiment shown in FIGS. **1**-**4**, which may leave the tubing string inoperable for the intended application.

[0076] In addition, the embodiment 100 may be particularly useful for applications in which the tubing pressure will be tested multiple times prior to the desired actuation of the tool. Generally, the more frequently the burst disk **140** (or any device intended to fail at a predetermined rating) is subject to increased pressures that approach the rated pressure, the increased likelihood of failure of the burst disk **140** at a pressure lower than the rated pressure.

[0077] In either of these cases, the embodiment 100 inhibits unintended opening of the establishment of a fluid communication path and the exterior as follows. In the run-in configuration of FIG. **5**A-**5**C, the torque pin **328** is located in a first position other than position **330***m*. Thus, it will take at least one pressure cycle, with each cycle resulting in an increase in pressure and a decrease in pressure, before the embodiment 100 will actuate, with each cycle requiring a sufficient pressure to overcome the expansive force of the spring **260** and move the shifting sleeve **248** and related elements to the position shown in FIG. **8**A-**8**C. For example, in applications where the well operator desires to cycle pressure within the tubing string a predetermined number of cycles prior to actuation of the tool, the torque pin **328** is positioned in a corresponding first position to require at least the predetermined number of pressure cycles plus one additional pressure cycle. In this way, the slotted member **252**, spring **260**, and torque pin **360** function as an indexing assembly, and more specifically a mechanical and pressure responsive indexing assembly, by advancing one increment in response to the predetermined stimulus, that is the increase and decrease in fluid pressure applied the interior flowpath **106**.

[0078] As a specific example, assume the burst disk **140** of the embodiment 100 has a rated burst pressure of 10,200 psi and the well operator desires to cycle the pressure to 10,000 psi three times to test the tubing string as a whole. In this scenario, the embodiment 100 is configured with the torque pin **328** positioned in the first position **330***i*. In the event the burst disk **140** does not rupture during any of the three test pressure cycles, the burst disk will rupture when intended upon application of a pressure of at least 10,200. The embodiment 100 will then be actuated to the position shown in FIG. **8**A-**8**C with an additional four pressure cycles, with each increase in pressure causing movement of the shifting sleeve **248** to the position shown in FIG. **7**A-**7**C and each decrease in the pressure allow the return of the shifting sleeve **248** to the position shown in FIG. **5**A-**5**C by the coil spring **260**.

[0079] If, however, the burst disk **140** inadvertently ruptures during one of the three pressure-testing cycles, the embodiment 100 prevents inadvertent movement of the shifting sleeve **248**. Because the torque pin **328** is initially positioned in first position **330***i*, even if the pressure is sufficient to move the shifting sleeve **248** during one or more of the three test pressure cycles following inadvertent failure of the burst disk **140**, the embodiment 100 will not actuate until at least the fourth pressure cycle.

[0080] For example, if the burst disk **140** ruptures during the first pressure test cycle and the pressure is sufficient to move the shifting sleeve **248** to the shifted position shown in FIG. **7**A-**7**C, upon conclusion of the first pressure test cycle, the shifting sleeve **248** returns to the first position of FIG. **5**A-**5**C as torque pin **328** advances to the next first position, which in this example is first position **330***j*. During the subsequent two pressure cycles, torque pin **328** again advances to the next first positions **330***k* and **330***l*, such that the next pressure cycle will cause the embodiment 100 to actuate to the position shown in FIG. **8**A-**8**C.

[0081] Devices according to the present disclosure may comprise a trigger sleeve as the fluid control device. The trigger sleeve of the illustrated embodiment may be connected with an indexing assembly, such as the slotted indexing assembly of FIGS. **5**-**8**, wherein the indexing assembly is connected to a trigger sleeve preventing fluid communication between the interior flowpath and the upper chamber until a number of pressure cycles occur. In such embodiment, the shifting sleeve remains in the first position until the tool is actuated.

[0082] FIGS. **9**-**10** illustrate another embodiment indexing assembly comprising a ratchet and a spring. A second ratchet assembly serves as a retaining element, applying force to prevent the trigger sleeve from "backing up" during operation. The ratchets of FIGS. **9**-**10** are arranged such that the indexing assembly telescopes in, or compresses, as the index assembly is cycled. It will be appreciated that, although the ratcheting assembly illustrated in the figures telescopes in, ratchet assemblies that telescope out, or expand, may also be used and are within the scope of present disclosure.

[0083] Indexing assemblies according to the embodiments of FIGS. **9**-**10** may comprise a pressure sleeve, an indexing sleeve, and a retaining element. The components of such embodiments may be arranged in a nested fashion such that the assembly telescopes, either elongating or shortening, through each pressure cycle. FIGS. **9**A, **9**B, and **9**C illustrate certain embodiments of such a pressure sleeve, indexing sleeve, and retaining element, respectively. As more fully described with respect to FIG. **10**, the pressure sleeve, indexing sleeve, and retaining elements in FIGS. **9**A-C may be assembled into an opposing nested ratchet assembly which shortens (e.g. telescopes down) a defined amount during each pressure cycle. Such an opposing nested ratchet assembly may cause or permit actuation of an associated tool when the assembly is shortened by a defined amount (e.g. when a trigger sleeve is moved a sufficient distance that it no longer prevents fluid communication through a passageway).

[0084] The pressure sleeve **470** shown in FIG. **9**A comprises a collet having a body and collet fingers **472**. Each collet finger has a series of pawl teeth **473** adjacent or near to its tip. The indexing sleeve **474** has a body and an indexing rack **476** comprising a series of ridges or teeth configured to engage the indexing pawl teeth **473** of the pressure sleeve **470**. In the illustrated embodiment, the indexing sleeve **474** is also a collet with a series of retaining collet fingers **478** having retaining pawl teeth **479**. A retaining sleeve **480** has a retaining rack **400** with teeth opposing and configured to engage retaining pawl teeth **479**.

[0085] FIG. **10** shows the pressure sleeve, indexing sleeve, and retaining sleeve as they might be assembled with other components into an opposing nested ratchet assembly usable in a downhole tool. The embodiment downhole tool in FIG. **10** comprises a housing **450** and an inner sleeve **423** with an annular space therebetween. A nested ratcheting indexing assembly is positioned within the annular space and isolated from fluid inside the tool (e.g. in the interior flowpath) as well as any fluid exterior to the housing **450**. The embodiment nested ratcheting assembly has a pressure sleeve **470** which engages spring stack **490** at pressure sleeve shoulder **471**. Spring stack **490** engages a retaining shoulder **481** on retaining sleeve **480** such that spring stack **490** is positioned between pressure sleeve **470** and retaining sleeve **480**. Collet fingers **472** pass around spring stack **490** and the retaining sleeve **480** such that indexing pawl teeth **473** are positioned adjacent to indexing rack **476** of indexing sleeve **472**. Retaining collet fingers **478** of indexing sleeve **474** extend towards retaining sleeve **400** such that retaining pawl teeth **479** are positioned adjacent to retaining rack **400**. The indexing pawl teeth **473** and indexing rack **476** may comprising an indexing ratchet. The retaining pawl teeth **479** and retaining rack **400** may comprise a retaining ratchet.

[0086] In the illustrated embodiment, spring spacer **492** is positioned between the spring stack **490** and pressure sleeve shoulder **471**. Spring spacer **492** may be of different lengths to accommodate various lengths of spring. Such increased range of acceptable spring lengths provides greater flexibility for selecting a spring, such as spring stack **490**, with a desired compression force over a selected deflection (e.g. stroke length). The spring stack illustrated in FIGS. **10**-**14** comprise belleville springs, which may be selected to provide the desired compression resistance over a relatively short deflection. Further, the stroke length of the belleville spring stack can be increased by placing multiple stacks of parallel belleville springs in series, e.g. opposing orientation, such as is illustrated in FIG. **10** for spring stack **490**. It will be appreciated that while belleville springs may be selected for certain embodiments, springs of any type, such as helical, wave, leaf, or others may be utilized provided that the spring, as installed, applies the desired force as it compresses over the chosen deflection.

[0087] The indexing sleeve **474** of FIG. **10** functions as a fluid control device, e.g. serves a function similar to the burst disk **32** of the embodiment tool in FIG. **1**. A passageway **486** through the inner sleeve **423** connects the interior flowpath of inner sleeve **423** to the annular space between the inner sleeve **423** and the housing **450**. Indexing sleeve **474** is positioned in the annular space adjacent to the passageway **486** and engages seals **475***u* and **475***l* which prevent fluid communication along the radially outward surface of inner sleeve **423**. Thus, indexing sleeve **474** prevents fluid and pressure communication between the passageway **486** and a tool, component or structure adjacent to passageway **486**.

[0088] Details of one embodiment downhole tool with a ratcheting indexing assembly can be seen in FIGS. **11-14**. The pressure sleeve **470**, spring stack **490** with spacer **492**, retainer sleeve **480**, and indexing sleeve **474** are arranged in an annular space between inner sleeve **423** and housing **425** in the fashion described with reference to FIG. **10**. With reference to FIG. **11**A, first connector sub **422**, which may be referred to as a "top sub" for convenience, is connected to housing **450** and abuts an end of inner sleeve **423**. Housing **450** and top sub **422** form an annular space therebetween which is substantially continuous with the annular space between the inner sleeve **423** and housing **450**. Adjacent to pressure sleeve **470** on the end opposite the spring stack **490** is piston **434**, which is positioned in the annular space between the top sub **422** and housing **450** and extends into the annular space between the inner sleeve **423** and housing **450**. A pressure surface **436** of piston **434** is fluidly connected to the interior flowpath of the tool via fluid passageway **430**. Fluid passageway **430** may be occupied by a burst disk **432** which prevents fluid communication through the fluid passageway **430** until the burst disk **432** is ruptured.

[0089] FIG. **11**B illustrates the middle portion of the tool including pressure sleeve **470**, spring stack **490**, retaining sleeve **480** and indexing sleeve **474**, arranged as described with respect to FIG. **10**. The view in FIGS. **11**A-C is rotated around the longitudinal axis of the tool, such that the longitudinal section of FIG. **11**B passes through a gap between two indexing collet fingers **472** as well between two retaining collet fingers **478**. Retaining sleeve **474** is adjacent to a cross over sub **452** which defines an end of the annular space and connects the housing **450** with the ported housing **424** of a nested sleeve valve.

[0090] In the embodiment FIGS. **11-14**, crossover sub **452** connects the indexing element, including the indexing sleeve **474**, with a nested sleeve sliding valve (shown in FIG. **11**C) similar to the valve in FIGS. **1-4**. The nested sleeve assembly generally comprises a ported housing **424**, a ported inner sleeve **444**, with a shifting sleeve **446** in the annular space **464** therebetween. The ends of the annular space are defined by crossover sub **452** and the bottom sub **428**. The shifting sleeve **446** is positioned between sleeve ports **440** of the ported inner sleeve **444** and housing ports **426** of the ported housing **424**. Seals **462***u* and **462***l* prevent fluid communication from the exterior of the tool and the interior flowpath into inlet pressure chamber **453** and outlet pressure chamber **458** as well as preventing fluid communication between the exterior of the tool and interior flowpath around the ends of shifting sleeve **446**. Shifting sleeve **446** may have teeth configured to engage opposing teeth on locking ring **466**. One or more shear pins **463**, or other retaining device, may be in communication with the shifting sleeve to prevent the shifting sleeve from moving until the fluid pressure in the inlet pressure chamber **453** is sufficiently higher than the fluid pressure in outlet pressure chamber that the force across the shifting sleeve **446** created by such pressure differential is sufficient to break the shear pins **463** or otherwise overcome the retaining device.

[0091] It will be appreciated that bottom sub **428** may comprise an outlet conduit, such as, without limitation, the outlet conduits described with respect to FIGS. **6-12** of applicant's U.S. patent application Ser. No. 14/211,122 filed on Mar. 14, 2014 and entitled Downhole Tools, System, and Methods of Using, the disclosure of which is incorporated by reference herein. The inclusion of such an outlet conduit may permit actuation of another tool connected to the outlet conduit via tubing, a flowline, or other device. Further, pressure may be applied to the piston **434** via an inlet conduit, rather than through a passageway, such as passageway **430**. Certain embodiment inlet conduits are also disclosed in FIGS. **6-12** of applicant's U.S. patent application Ser. No. 14/211,133 which are incorporated herein by reference.

[0092] FIGS. **12-14** illustrate the embodiment downhole tool of FIGS. **11**A-C through its cycles of operation. In FIGS. **12**A-B, fluid pressure sufficient to rupture the burst disk is applied to the fluid in the interior flowpath of the tool according to known methods. Rupture of the burst disk permits the fluid, and thereby fluid pressure, to be communicated to the pressure surface **436** of the piston **434**. If the fluid pressure applied to the fluid surface **436** applies sufficient force to overcome the spring stack **490**, the frictional forces against the piston **434** and the pressure sleeve **470**, and any other forces resisting movement of the pressure sleeve **470** or piston **434**, the piston **434** will shift, pushing the pressure sleeve **470** and thereby compressing the one or more springs in the spring stack **490**. The piston **434** and pressure sleeve **470** advance until a stop, such as stop ring **438** engages a barrier such as stop shoulder **439**, limiting travel of the piston **434** and the pressure sleeve **470**. It will be appreciated that the stop shoulder **439**, or similar barrier may not be required in certain embodiments as the retaining shoulder **481** and spring stack **490** may serve as a stop when the spring stack **490** is fully compressed. Engagement of stop shoulder **439** by stop ring **438**, however, may limit the load applied to retaining sleeve **480**, reducing the chance retaining sleeve **480** will fail.

[0093] When the force applied to the pressure sleeve **470** is sufficient for the pressure sleeve **470** to compress the spring stack **490**, the indexing ratchet advances by the same distance that the spring stack **490** has compressed. In the embodiment of FIG. **12**B, indexing collet fingers **472** have advanced relative to the indexing sleeve **474** such that indexing pawl teeth **473** partially overlap with and engage indexing rack teeth **476**. Because indexing sleeve **474** remains engaged with seal **475***l*, inlet pressure chamber **453** remains isolated from the interior flowpath and the shifting sleeve **446** remains in the original closed position shown in FIG. **12**C.

[0094] At this point, the tubing string in which such tool is installed may be subjected to a pressure test by increasing the pressure in the tubing to a desired value. While the test generally should not exceed the burst rating of the downhole tool, the pressure test can be conducted at any acceptable value for any desired length of time. The engagement of stop ring **438**, when present, with stop shoulder **439** holds the force that such pressure test applies and prevents larger force from being transferred to pressure sleeve **470**, spring stack **490** and retaining sleeve **480**.

[0095] Fluid pressure from in the interior flowpath may then be reduced, reducing the force applied to the pressure surface **436** and consequently to the piston **434**. Spring stack **490** will begin to expand, pushing pressure sleeve **470** and piston **434** in the opposite direction and into a neutral position. Such neutral position will be dictated by either the maximum return travel allowed for the piston **434** and pressure sleeve **470** or by the minimum fluid pressure of the cycle. FIG. **13**A shows the piston **434** and pressure sleeve **470** in a neutral position between the piston's **434** and pressure sleeve's **470** initial position (shown in FIG. **11**A) and the advanced position to which they may be forced to advance the indexing ratchet (shown in FIG. **12**A. It will be appreciated that, in the embodiment of FIG. **13**A-B, the neutral position of the pressure sleeve **470** at the beginning of the cycle will affect the stroke length for that cycle.

[0096] Movement of pressure sleeve **470** from an advanced position to the neutral position causes indexing sleeve **474** to advance towards its actuated position, e.g. the open position for the embodiment of FIGS. **11-14**. Specifically, when the indexing ratchet advances, the indexing pawl teeth **473** engages the indexing rack **476** at a more advanced location causing the indexing sleeve **474** to be pulled, via the ratchet, as the pressure sleeve **470** travels to its neutral position. In this way, indexing sleeve **474** moves toward the partially open position as shown in FIG. **13**B.

[0097] Advancement of the indexing sleeve towards the open position may also advance a retaining ratchet, if present. In certain embodiments, such as the embodiment of FIG. **13**B, retaining collet fingers **478** extend from the indexing sleeve **474** towards retaining sleeve **480**. Retaining pawl teeth **479** on retaining collet fingers **478** oppose retaining rack **400** on the retaining sleeve **480**. Thus, advancement of the indexing sleeve **474** towards the open position advances the retaining pawl teeth **479** along the retaining rack **400**, holding, or assisting to hold, the indexing sleeve **474** and preventing its movement back towards the fully closed position. It will be appreciated that mechanisms, including use of frictional force from seals **475***u* and **475***l*, other seals, or other structures for preventing the indexing sleeve from moving towards or returning to the fully closed position may be utilized and are within the scope of the present disclosure.

[0098] With the indexing sleeve only partly open, indexing sleeve remains engaged with seal **475***l*, and therefore the inlet chamber **453** of the nested sleeve valve remains in fluid isolation from the fluid and fluid pressure in the interior of the device. The nested sleeve therefore remains unactuated, in the condition shown by FIG. **13**C.

[0099] Subsequent cycles (e.g. increased force applied on pressure sleeve **470** to compress the spring stack **490** followed by a reduction in such force to allow the spring stack **490** to expand and move the pressure sleeve to a neutral position) progressively move the indexing sleeve **474** towards the actuated position. As illustrated in FIGS. **14**A-C, when the indexing sleeve **474** is moved a sufficient distance that it no longer engages seal **475***l*, fluid communication is established from the interior flowpath through passageway **486**, into channel **451**, and thereby to inlet pressure chamber **453**. Such fluid communication between the interior flowpath with inlet pressure chamber **453** permits the formation of a pressure differential across shifting sleeve **446** which, when the pressure differential reaches a sufficient value as described above, opens the valve by moving the shifting sleeve **446** from the closed to the open position.

[0100] From the foregoing description, considerations for selecting a spring, such as spring stack **490**, stop ring **438**, spring spacer **492**, and other components of the disclosed embodiments become readily apparent. For example, the distance necessary for the indexing sleeve **474** to fully open, e.g. for the end of indexing sleeve **474** to clear seal **475***l* may be correlated with the distance between each of the teeth of the indexing rack **476**. As one example, the teeth of indexing rack **476** may be set 0.060 inches (sixty thousandths of an inch) apart and the indexing sleeve may need to move 1.4 inches to clear seal **475***l*. In such an arrangement, the indexing pawl teeth **473** must advance twenty-four teeth along the indexing rack **476** in order to move the indexing sleeve **474** to the open position. Thus, if six cycles are desired prior to opening the indexing sleeve, each cycle must advance the indexing ratchet an average of four teeth. In many embodiments, such average will be accomplished by setting the indexing ratchet to advance the same number of teeth for each cycle.

[0101] Having determined the number of teeth for advancing the ratchet on each cycle, the stroke length for the indexing assembly may be established by correlating the stroke length with the desired number of teeth to advance with each stroke. In the above example, a stroke length between 0.24 inches and 0.30 inches will advance the indexing ratchet four teeth per cycle, thereby moving indexing sleeve 0.24 inches. Thus, the sum of the stroke lengths for the cycles used to move the indexing sleeve to the open position may be greater than the total distance moved by the indexing sleeve, but, in the illustrated embodiments, the two distances will be correlated through the number of teeth the ratchet assembly advances during each pressure cycle.

[0102] The stroke length may be established by selecting an appropriate stop, such as a stop ring **438** or by allowing full compression of the spring. Further the stroke length may be selected or even changed following installation of the downhole tool in a well by controlling the maximum cycle pressure—such that the spring deflects a known maximum distance based on the load—or by controlling the minimum cycle pressure—such that the spring expands only partially, limiting the available travel for the next cycle—or combinations of all of the above.

[0103] For example, the spring, such as spring stack **490**, may be in a fully expanded condition when the indexing assembly is in the initial condition, e.g. when the tool is installed in a well. Upon rupture of the burst disk, fluid pressure, which may be hydrostatic pressure in the interior flowpath, will apply force to the piston **434**, partially compressing the spring. The stroke length associated with the first cycle will include this initial compression plus further compression from additional fluid pressure applied to advance the piston **434** until a stop, such as full spring compression or engagement of stop ring **438** on stop shoulder **439**, is reached. When the added fluid pressure is removed, the spring will partially expand, remaining partially compressed by the force that the fluid in the interior flowpath continues to exert on the pressure surface **436** of the piston **434**. Such force may be the force from hydrostatic pressure or may be a higher pressure applied to the fluid using known methods. It will be appreciated that this arrangement allows the number of cycles to be increased above the predicted minimum number by applying a minimum cycle pressure that is above hydrostatic pressure and decreasing the stroke length the pressure cycles.

[0104] A fluid pressure in the interior flowpath may also be used in conjunction with the compressive strength of the spring stack **490** to determine a neutral position for the piston **430** and pressure sleeve **470**. In fact, a plurality of neutral positions may be determined based on a range of possible fluid pressures in the interior flowpath. For example, a hydrostatic pressure in the installed tubing string of 1000 psi may advance the selected spring stack 0.1 inches, reducing, in some embodiments, stroke length from approximately one-half inch to approximately 0.4 inches, and reducing the number of teeth advanced from 6 to 5 if the teeth are spaced 0.060 inches apart. Thus, it is necessary to cycle the indexing assembly 5 times rather 4 to move the indexing sleeve a total of 1.26 inches (21 teeth). If the fluid pressure in the interior flowpath is maintained at a higher pressure, the spring remains more compressed, the stroke length is shortened further, and the indexing sleeve **474** advances towards the actuated position less distance for each such cycle. Thus, the number of cycles can be controlled, within a certain range, by using fluid pressure to define the neutral position.

[0105] FIGS. **15**A-**15**B disclose an alternative embodiment ratchet assembly utilized as a retaining element. Pressure sleeve **470**, spring stack **490**, retaining sleeve **480** and indexing sleeve **474** are disposed in an annular space between housing **450** and inner sleeve **423**. Indexing collet fingers **472** are configured to engage indexing rack **476** of indexing sleeve **474**. Indexing sleeve has a retaining rack **477** which is configured to engage retaining ratchet ring **401** as indexing sleeve **474** is pulled over the ratchet ring. It will be appreciated that such a ratchet ring and rack assembly could also be used for the indexing ratchet as well as for the retaining element.

[0106] It will be appreciated that the disclosed embodiments may contain redundant seals and such seals may be included or excluded provided that fluid integrity is maintained as necessary. For example, FIG. **12**A illustrates piston **434** and pressure sleeve **470** without seals shown to be present in FIG. **11**A.

[0107] The present disclosure includes preferred or illustrative embodiments in which specific tools are described. Alternative embodiments of such tools can be used in carrying out the invention as claimed and such alternative embodiments are limited only by the claims themselves. Other aspects and advantages of embodiments according to the present disclosure and the invention as claimed may be obtained from a study of this disclosure and the drawings, along with the appended claims.

We claim:

1. A downhole tool having an exterior, the tool comprising:

a nested sleeve assembly comprising a shifting sleeve, the shifting sleeve having a first position and a second position; and

an indexing assembly in communication with the shifting sleeve, the indexing assembly having an actuated position and at least one non-actuated position;

wherein the indexing assembly advances from the at least one non-actuated position to the actuated position in response to a predetermined stimulus; and

further, wherein the indexing assembly prevents the nested sleeve from moving to the second position when the indexing assembly is in the at least one non-actuated position.

2. The downhole tool of claim **1** wherein the indexing assembly comprises

a pressure sleeve moveable in response to fluid pressure in an interior flowpath of the tool,

a fluid control device,

a spring,

wherein

the spring opposes movement of the pressure sleeve towards the fluid control device

the fluid control device is slidable relative to the pressure sleeve in a first direction and fixed relative to the pressure sleeve in a second direction substantially opposite to the first direction; and

movement of the pressure sleeve in the second direction moves the fluid control device towards an actuated position.

3. The downhole tool of claim **2** wherein the spring opposes movement of the pressure sleeve in the first direction.

4. The downhole tool of claim **1** wherein the indexing assembly comprises a fluid control device.

5. The downhole tool of claim **1** wherein the indexing assembly comprises at least one ratchet assembly.

6. The downhole tool of claim **5**, wherein the at least one ratchet assembly comprises collet fingers having teeth thereon and a sliding sleeve comprising a rack for engaging the teeth.

7. The downhole tool of claim **1** wherein the shifting sleeve remains in the closed position until the indexing assembly reaches the actuated position.

8. A method for actuating a downhole tool, the method comprising flowing a fluid into the downhole tool, the downhole tool comprising:

a nested sleeve assembly having a shifting sleeve and a passageway connecting at least one surface of the shifting sleeve with a flowpath of the downhole tool, the shifting sleeve having a first position and a second position;

an indexing assembly comprising a pressure sleeve, a spring, and a fluid control device;

applying a plurality of fluid pressure cycles to the fluid in the downhole tool; the pressure cycles comprising a high pressure on the fluid sufficient to compress the spring a desired amount and a low pressure on the fluid permitting the spring to return the pressure sleeve to a neutral position;

advancing the indexing assembly a desired stroke length through the plurality of pressure cycles,

moving the fluid control device from a closed position to an open position in response to the plurality of pressure cycles,

9. The method of claim **8** wherein a distance to move the fluid control device from an open position to a closed position is correlated with the sum of the stroke lengths for the plurality of pressure cycles.

10. The method of claim **8** wherein the low pressure is a pressure of above hydrostatic pressure and the desired stroke length is less than the maximum stroke length.

11. The method of claim **7** further comprising flowing cement through tool before the first of said plurality of pressure cycles.

12. The method of claim **8** further comprising a pressure test, wherein the pressure of the fluid in the interior flowpath is increased to a pressure at least as high as the maximum pressure predicted to be applied to a tubing string along which the downhole tool is placed.

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