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(54) **DOWNHOLE TOOL HAVING SLIPS SET BY STACKED RINGS**

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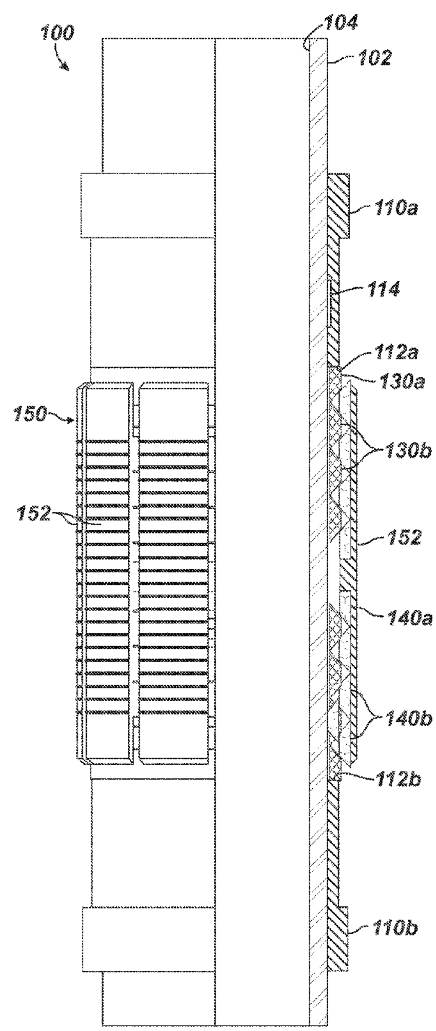
(57) **ABSTRACT**

An apparatus installs downhole in a surrounding tubular. A first shoulder on a mandrel of the apparatus is movable toward a second shoulder. A plurality of stacked rings are disposed about the mandrel and are spaced between the first and second shoulders. A first of the stacked rings decreases in spacing in response to the movement of the first shoulder toward the second shoulder, and a second of the stacked rings expands outward from the mandrel in response to the decrease in spacing. A slip disposed on the stacked rings is movable away from the mandrel toward the surrounding tubular in response to the outward expansion. The apparatus can be a plug, a bridge plug, a fracture plug, a packer, a permanent packer, a retrievable packer, a sump packer, and a sealbore packer. Additionally, the apparatus can include a completion assembly with packer and screen supported on the mandrel.



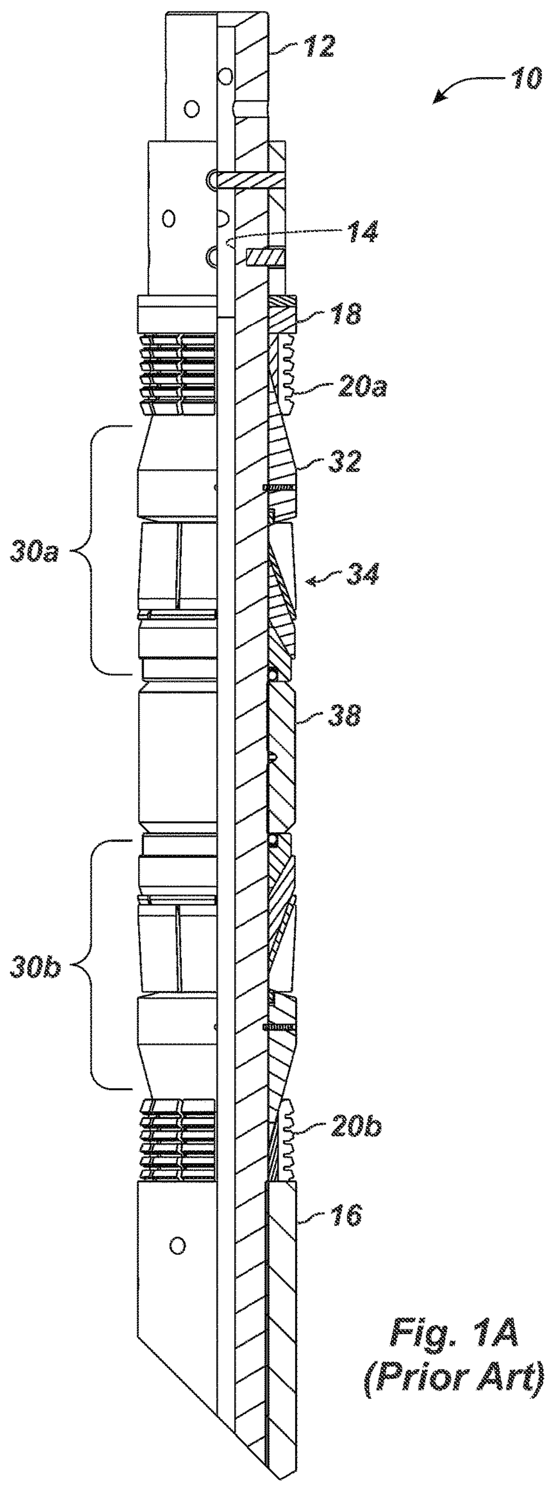


Fig. 1A
(Prior Art)

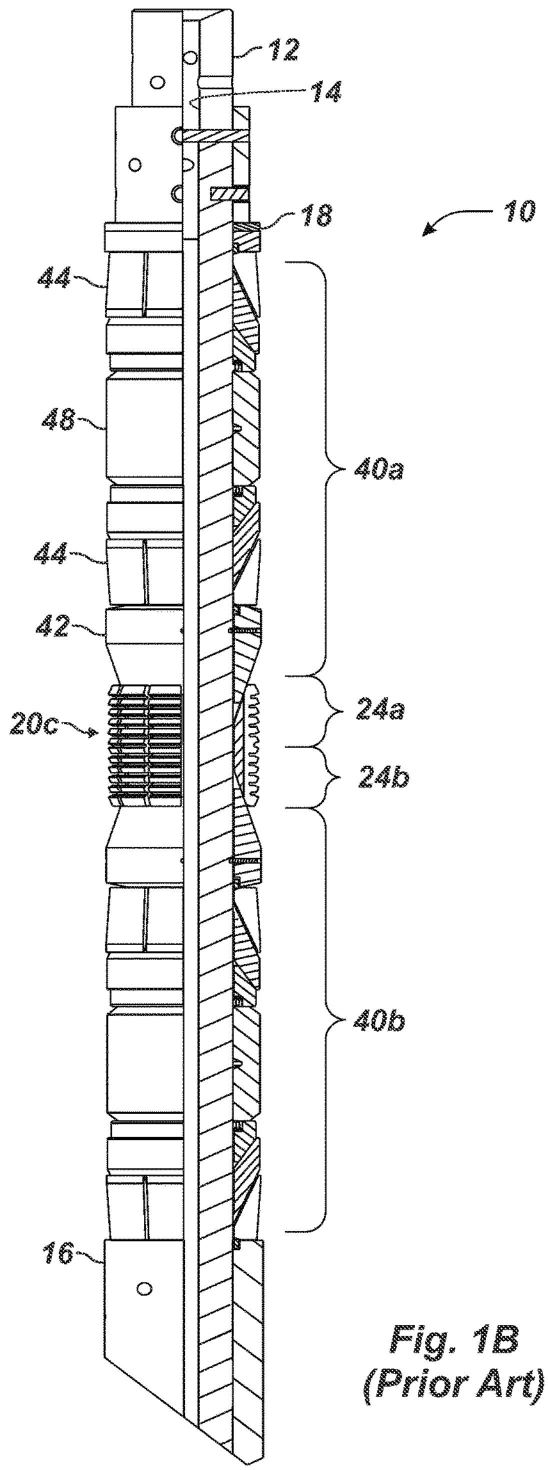


Fig. 1B
(Prior Art)

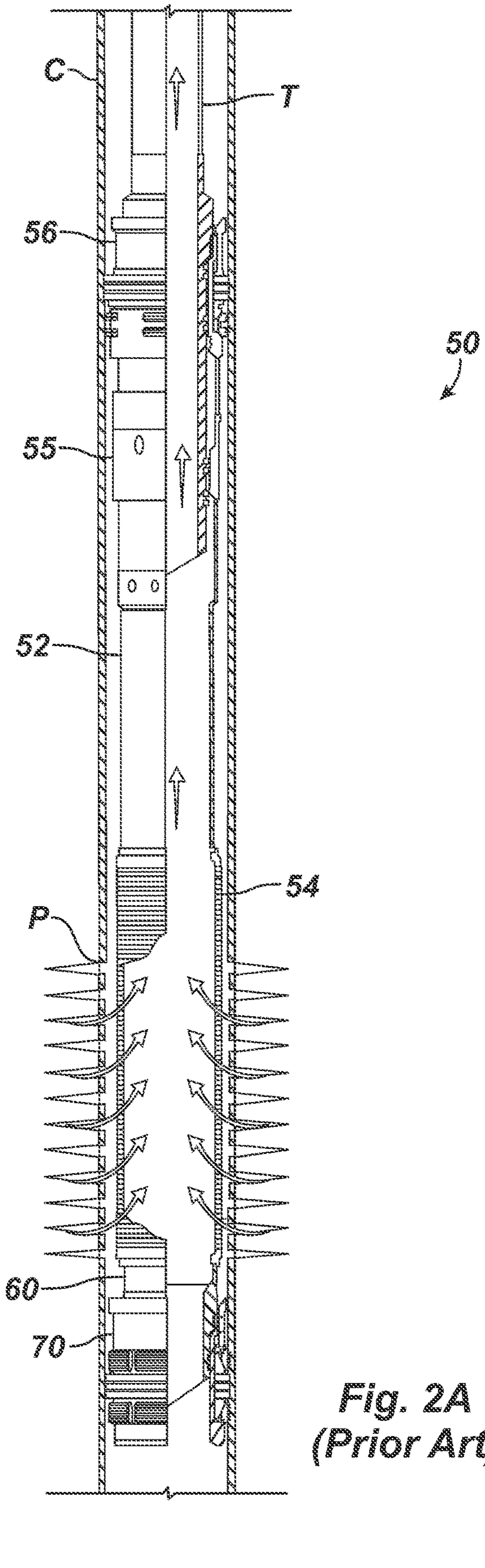


Fig. 2A
(Prior Art)

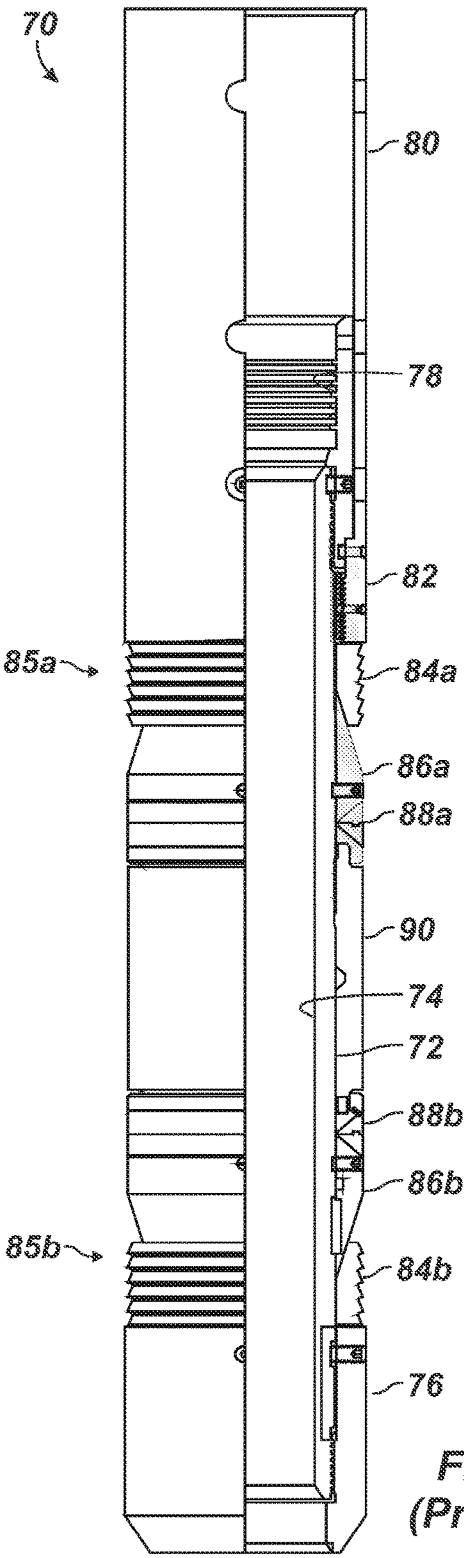


Fig. 2B
(Prior Art)

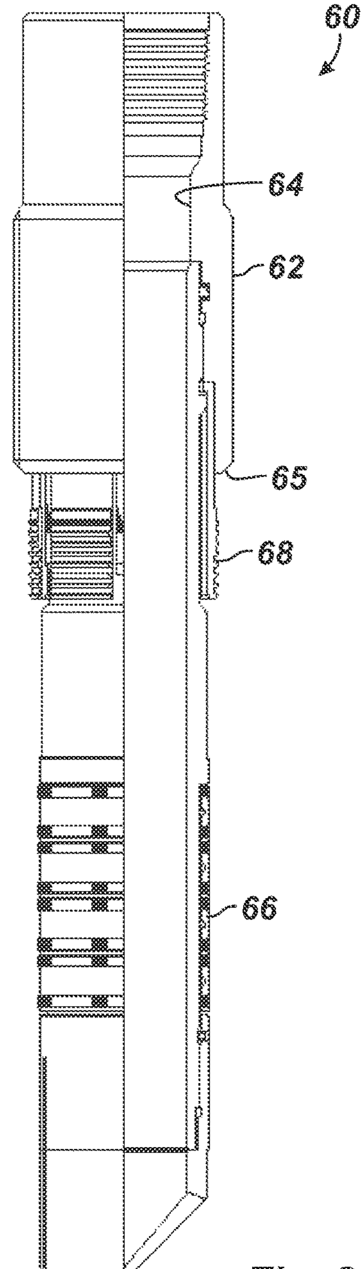


Fig. 2C
(Prior Art)

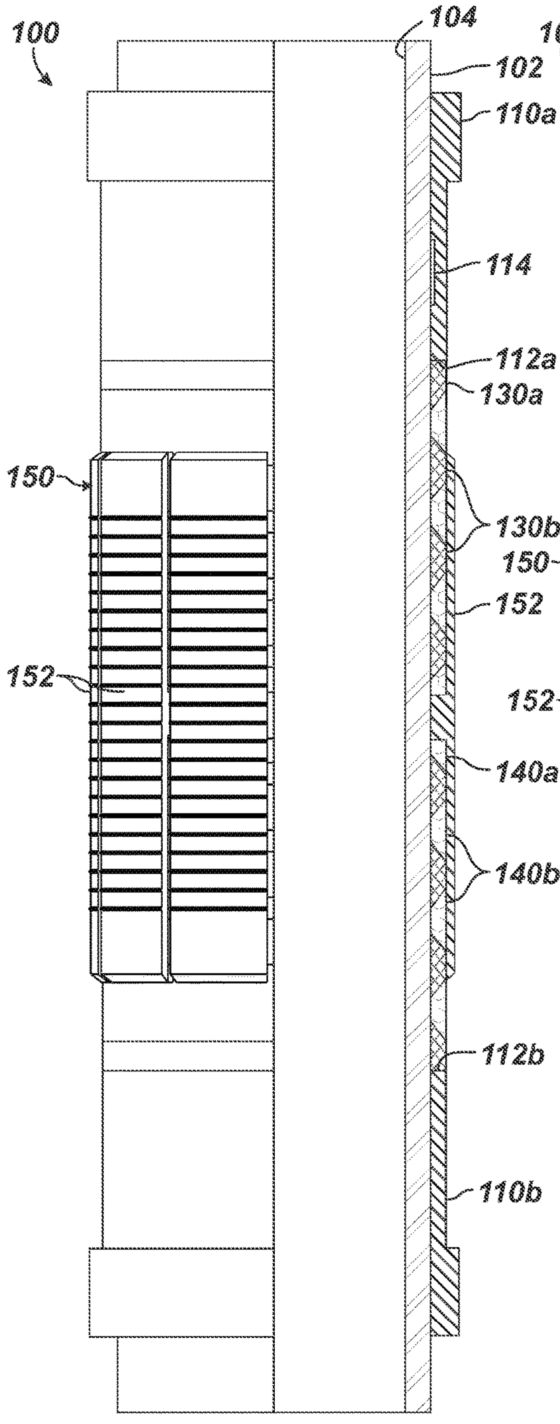

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Fig. 3A

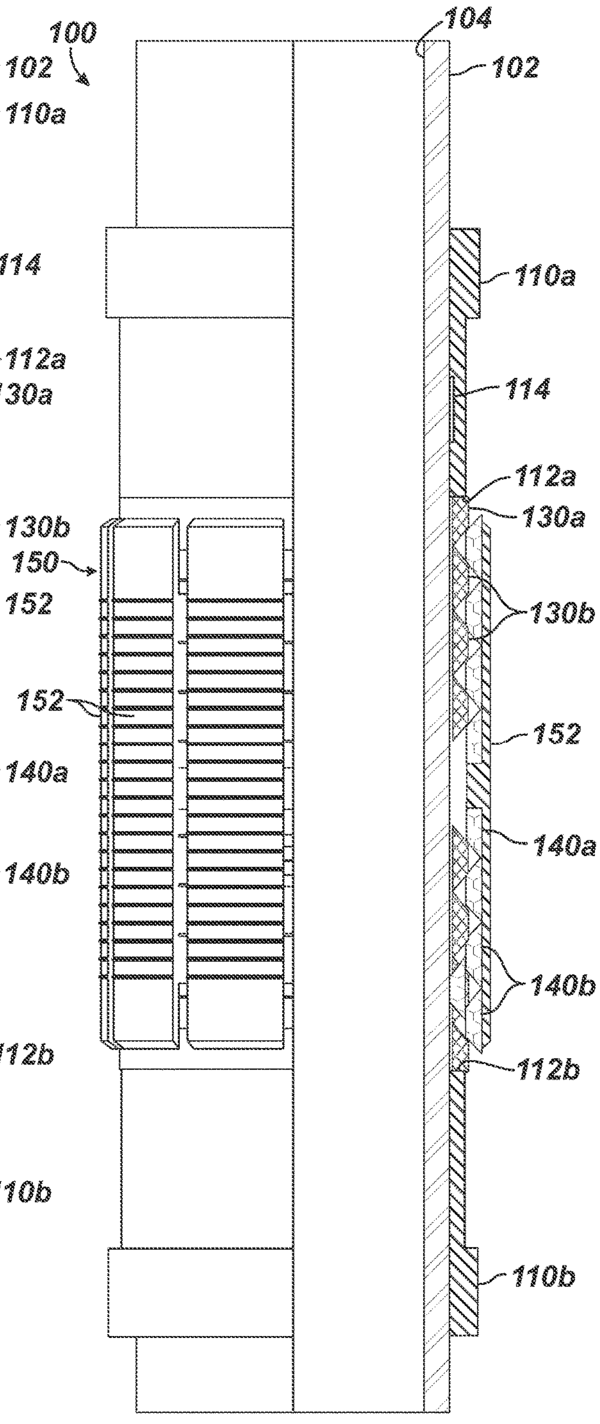
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Fig. 3B

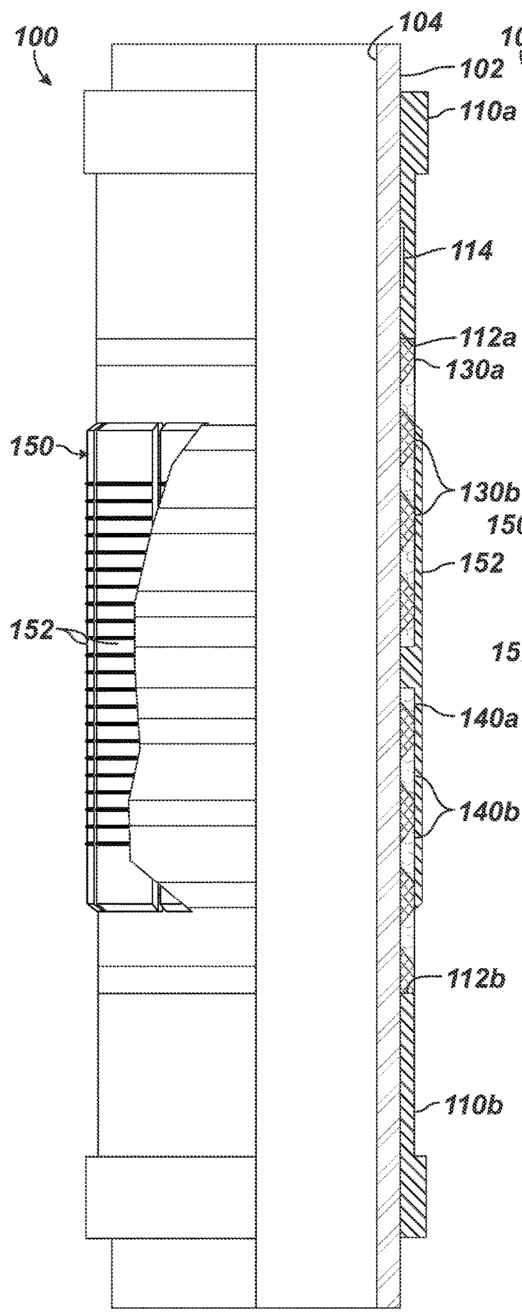
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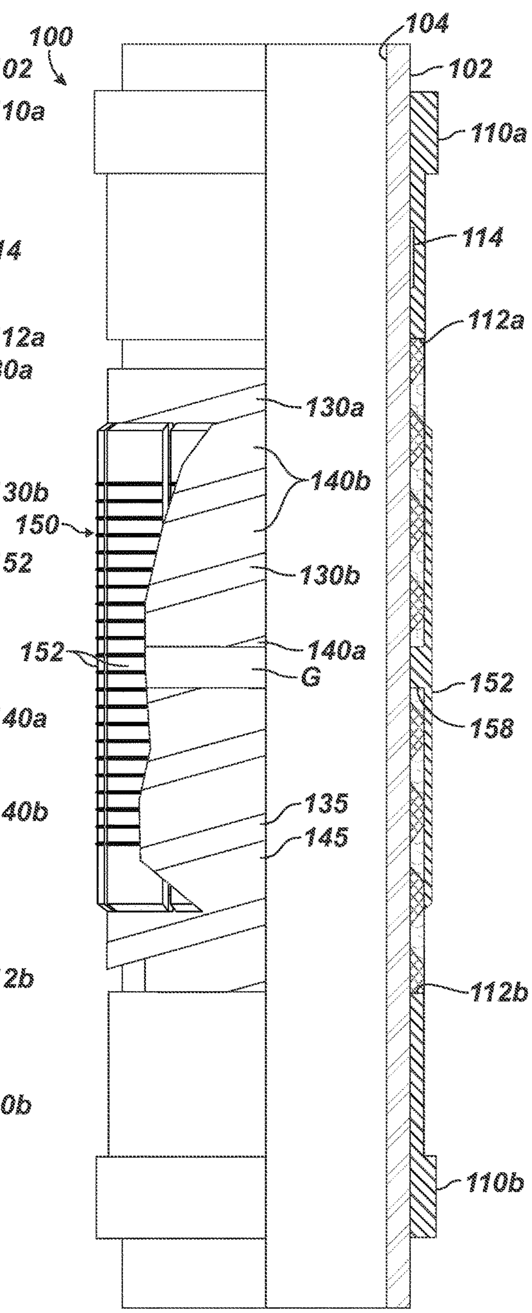
Fig. 3C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110b

Fig. 3D

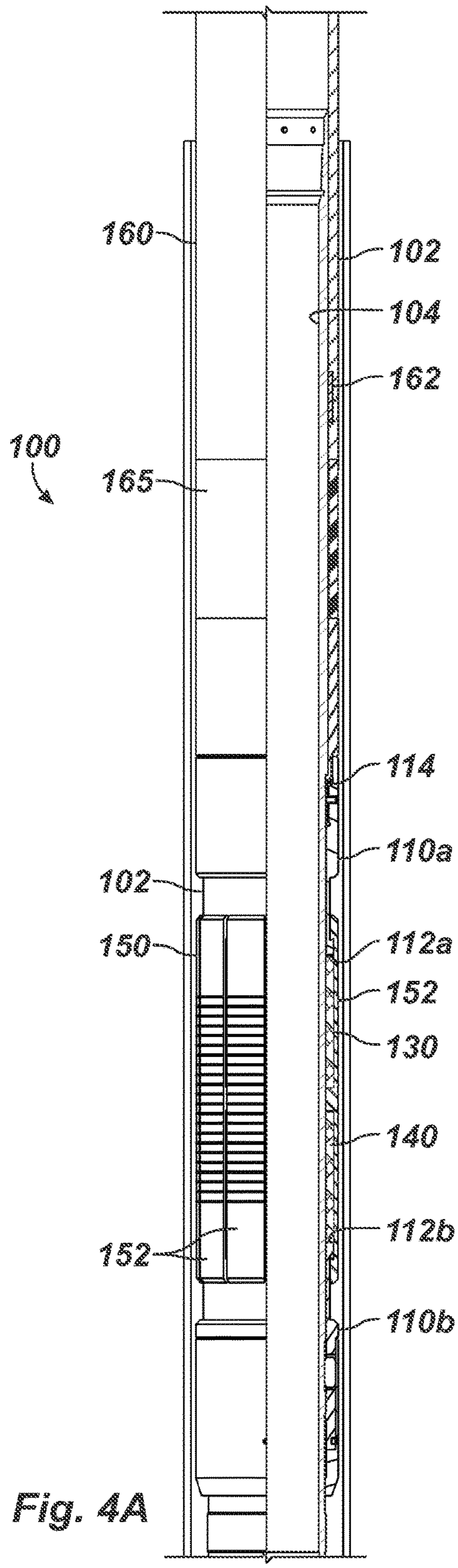
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Fig. 4A

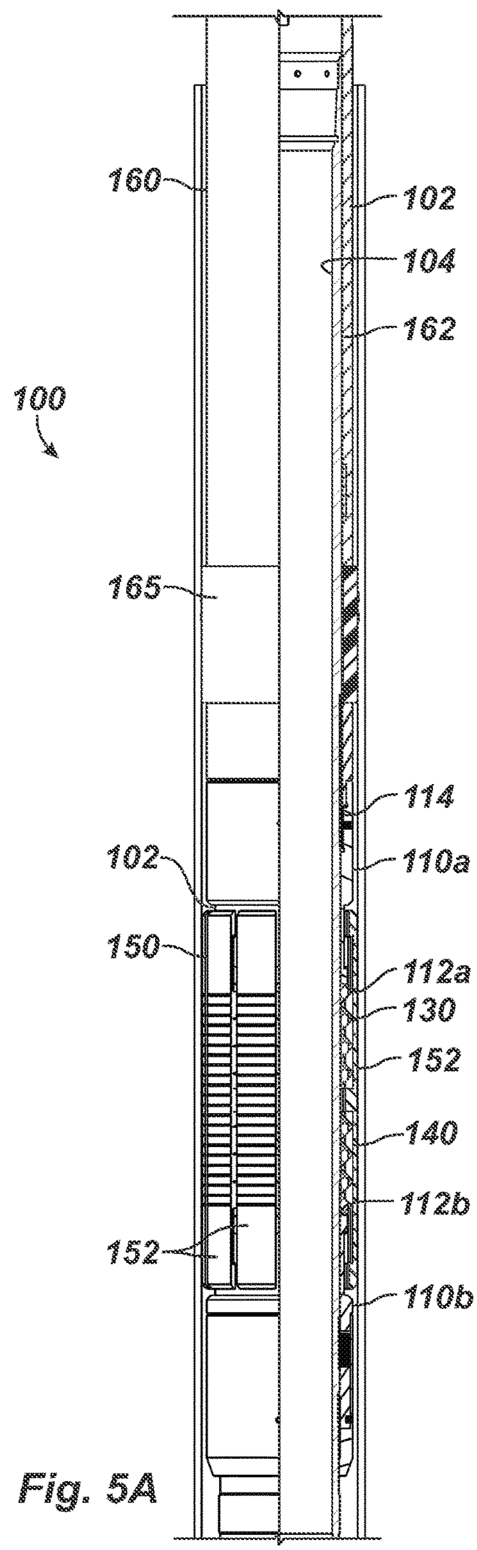
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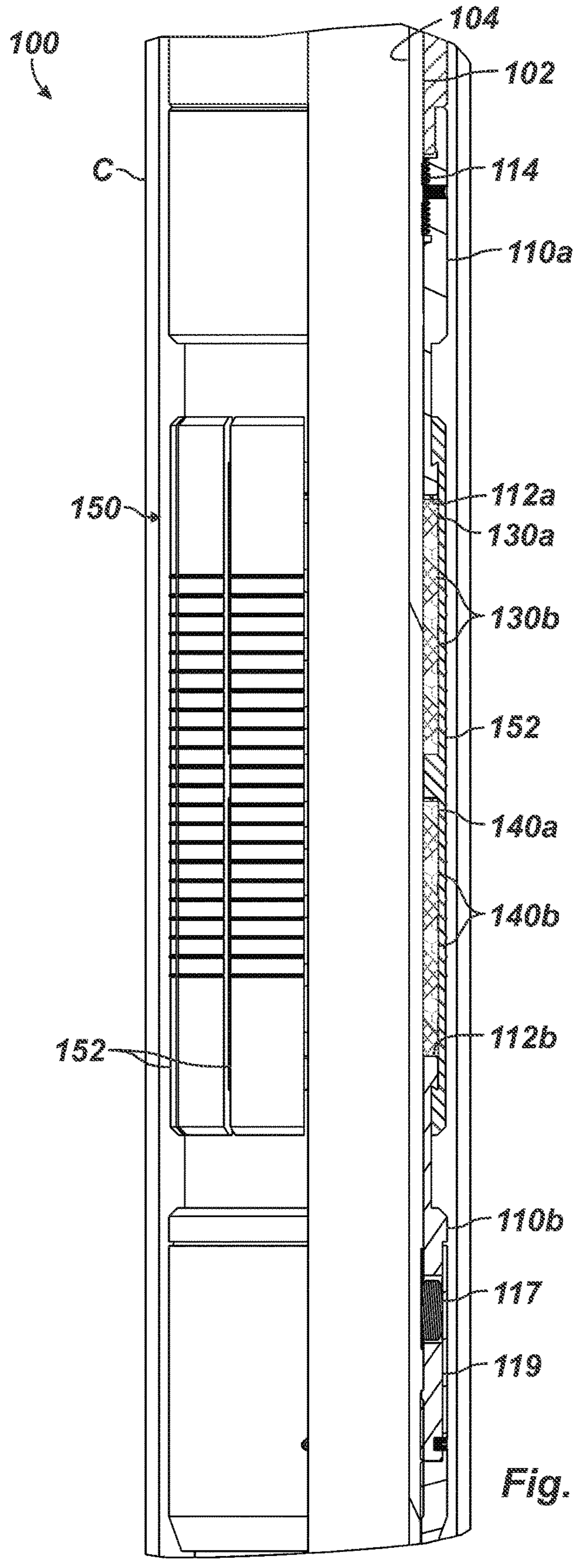
Fig. 5A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110b
117
119

Fig. 4B

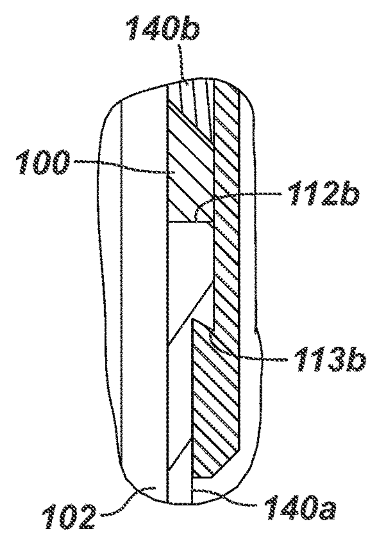
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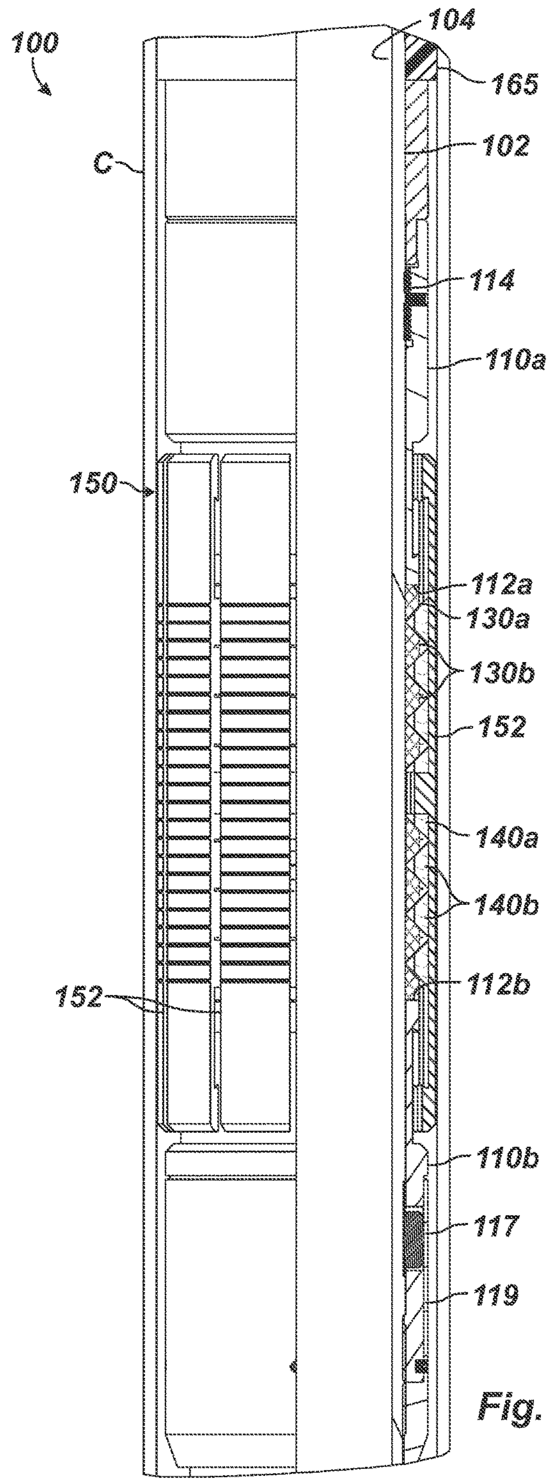
Fig. 4C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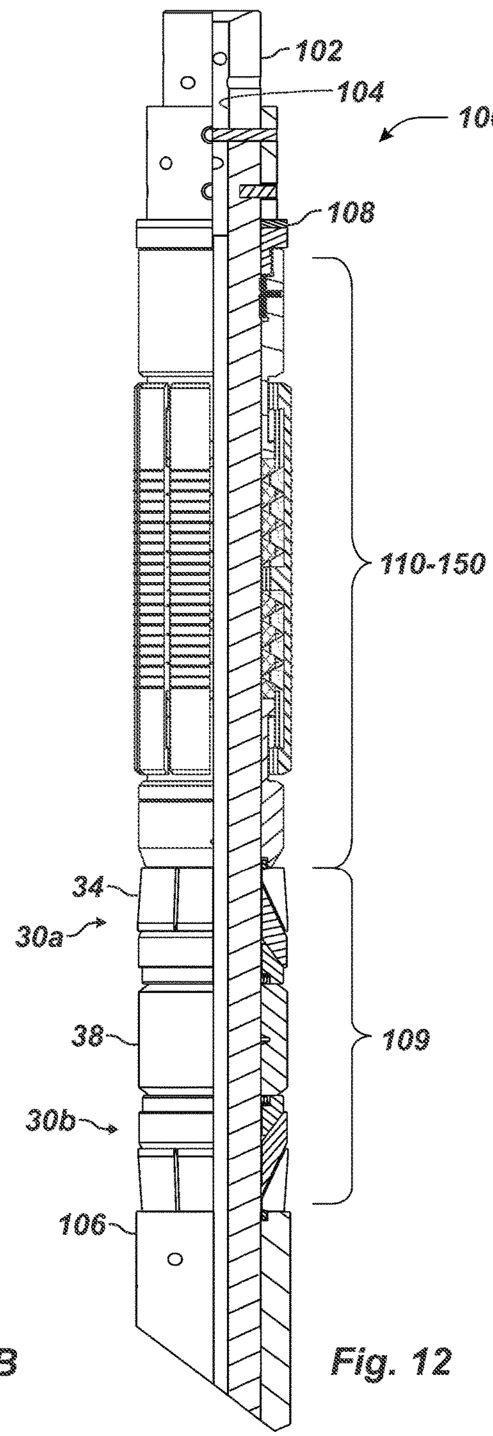
117
119

Fig. 5B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34
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109
38
30b
106

Fig. 12

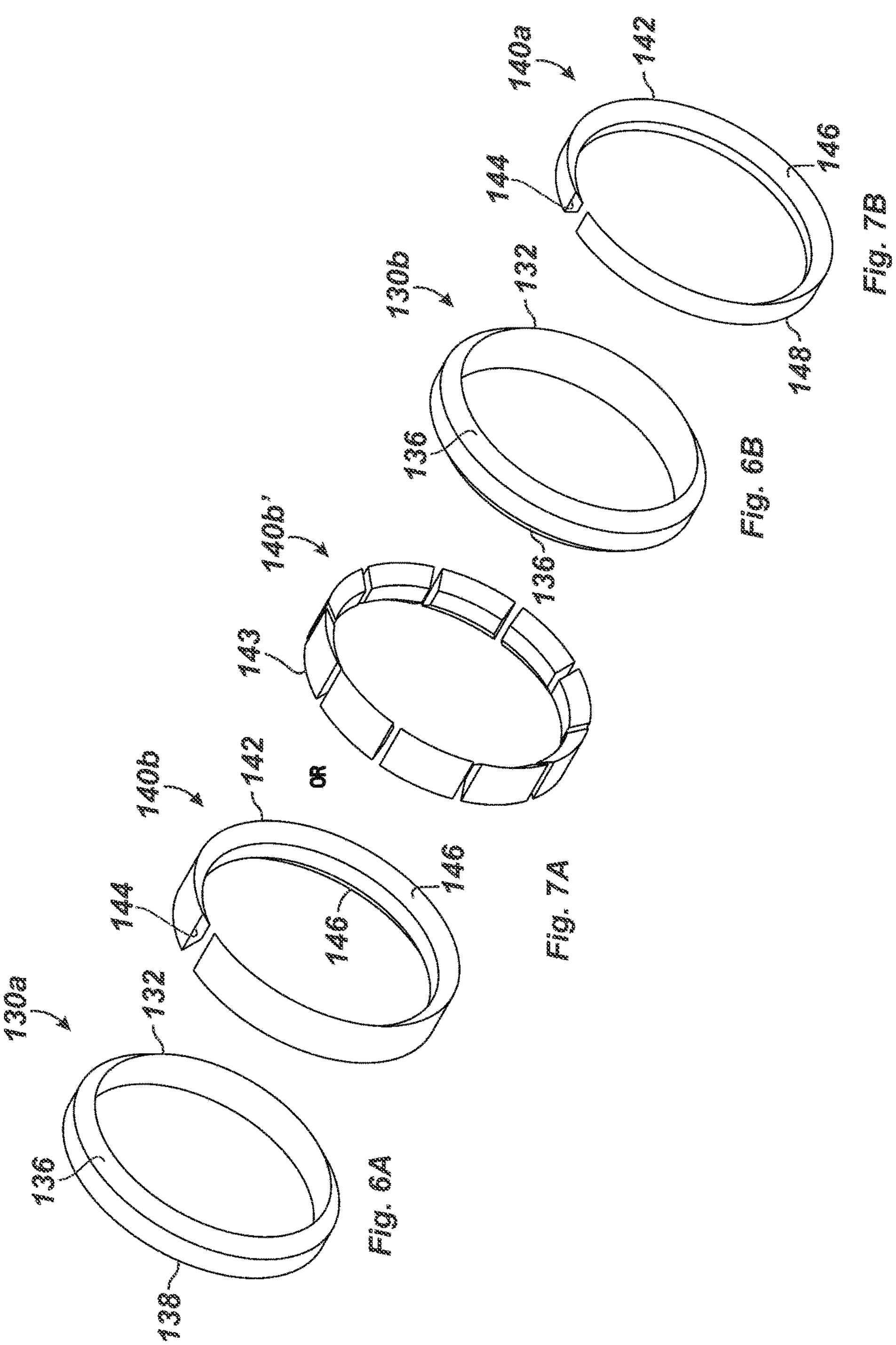

Fig. 6A

Fig. 7A

Fig. 6B

Fig. 7B

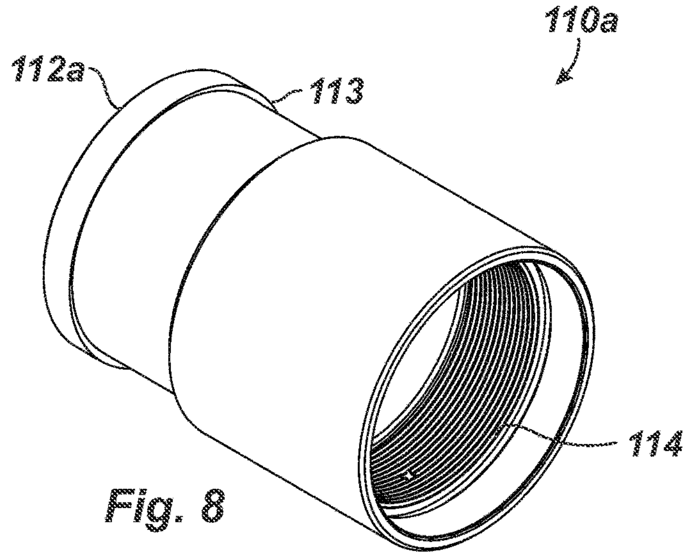

Fig. 8

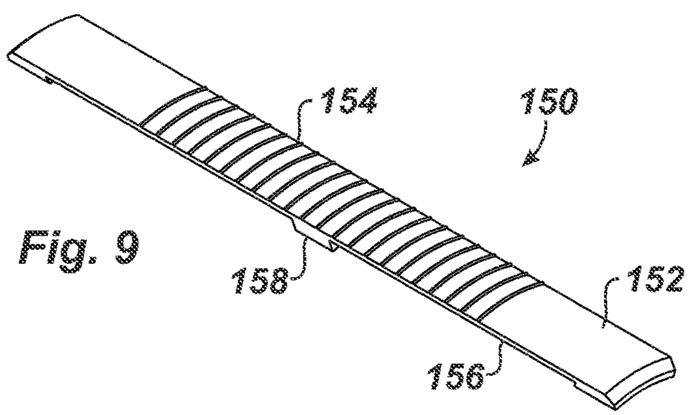

Fig. 9

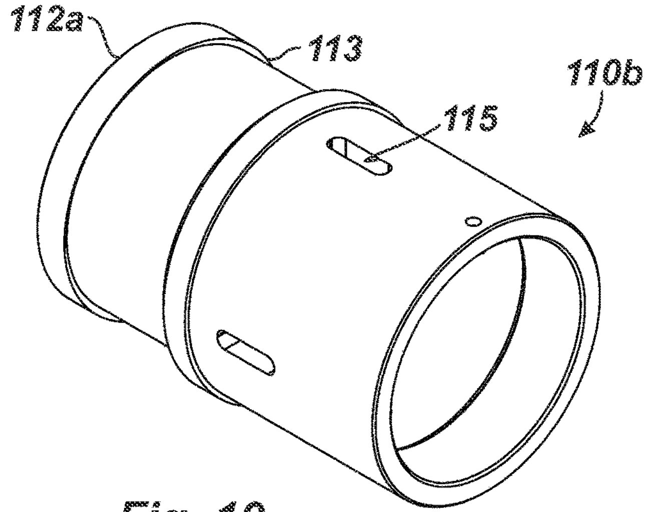

Fig. 10

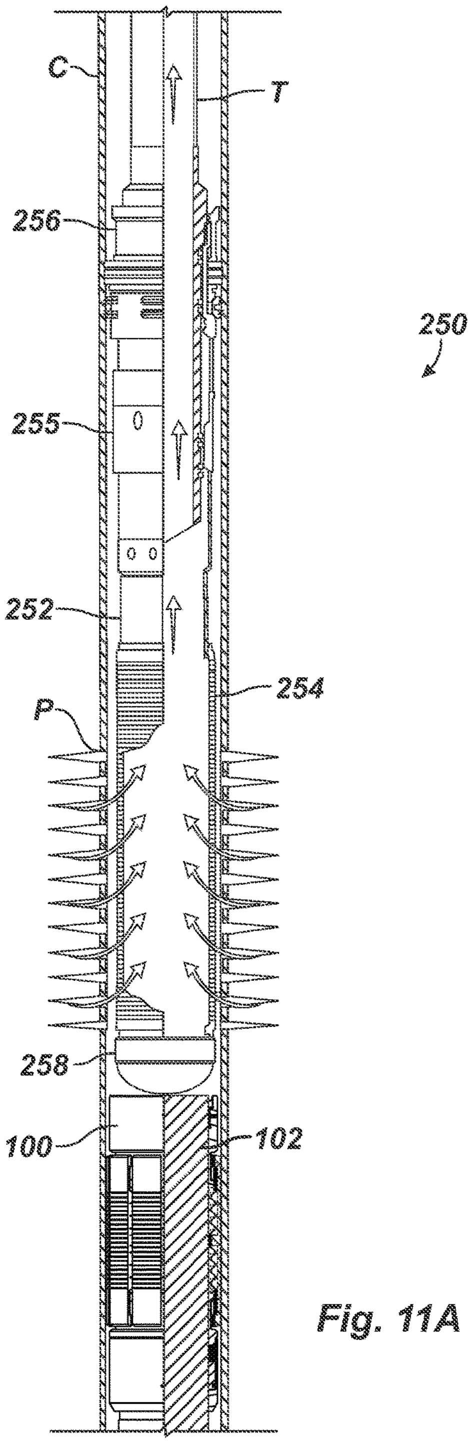

Fig. 11A

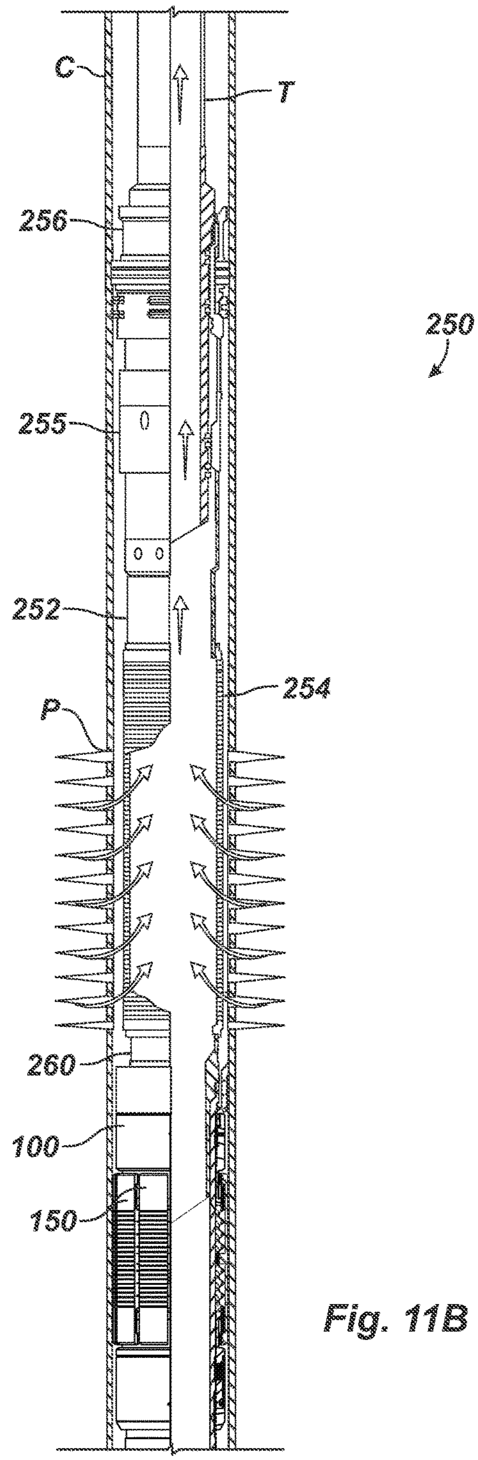

Fig. 11B

DOWNHOLE TOOL HAVING SLIPS SET BY STACKED RINGS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Appl. 62/081,753, filed 19 Nov. 2014, which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to the field of downhole tools, and in particular to downhole tools, such as bridge plugs, frac-plugs, and packers.

BACKGROUND ART

[0003] An oil or gas well includes a wellbore extending into a well to some depth below the surface. Typically, the wellbore is lined with tubulars or casing to strengthen the walls of the borehole. To strengthen the walls of the borehole further, the annular area formed between the casing and the borehole is typically filled with cement to set the casing permanently in the wellbore. Perforating the casing then allows production fluid to enter the wellbore and flow to the surface of the well.

[0004] Downhole tools with sealing elements, such as plugs or packers, are placed within the wellbore to isolate the production fluid or to manage production fluid flow through the well. For example, a bridge plug or a fracture plug placed within the wellbore can isolate upper and lower sections of production zones. Bridge plugs and frac-plugs create a pressure seal in the wellbore to allow pressurized fluids or solids to treat an isolated formation.

[0005] For their part, packers are typically used to seal an annular area formed between two co-axially disposed tubulars within a wellbore. For example, packers may seal an annulus formed between production tubing disposed within wellbore casing. Alternatively, packers may seal an annulus between the outside of a tubular and an unlined borehole. Routine uses of packers include the protection of casing from pressure, both well and stimulation pressures, as well as the protection of the wellbore casing from corrosive fluids. Other common uses include the isolation of formations or leaks within a wellbore casing or multiple producing zones, thereby preventing the migration of fluid between zones. Packers may also be used to hold kill fluids or treating fluids within the casing annulus.

[0006] These types of downhole tools are usually constructed of cast iron, aluminum, or other alloyed metals, but can be made of non-metallic materials, such as composite materials. A sealing member is typically made of a composite or synthetic rubber malleable material that seals off an annulus within the wellbore to prevent the passage of fluids. When the tool is activated, the sealing member is compressed or swells, thereby expanding radially outward from the tool to engage and seal with a surrounding casing or tubular. Conventional bridge plugs, fracture plugs, and packers typically comprise a synthetic sealing member located between upper and lower metallic retaining rings, commonly known as slips, that prevent the downhole tool from moving up or down in the wellbore.

[0007] As noted above, one type of downhole tool is a bridge plug, such as shown in a cutaway view in FIG. **1**A. The bridge plug **10** has a mandrel **12**, about which are disposed various elements typically formed of metal, but can be made of a composite material, such as is described in U.S. Pat. No. 7,124,831. Even when most of the bridge plug **10** is made of composite materials, the two slips **20***a-b* may be made of metal, such as a ductile cast iron.

[0008] As shown, a sealing member **38** and other related elements **30***a-b* are disposed about the mandrel **12**. Axial force through the slips **20***a-b* and the other elements **30***a-b* compress the sealing member **38**, causing it to expand and to seal with the surrounding tubular (not shown). The two slips **20***a-b*, oriented opposite to each other, expand to engage with the surrounding tubular and help retain the downhole tool **10** in place. Boost forces from the sealing member **38** on the slips **20***a-b* increase their holding ability.

[0009] The sealing elements **30***a-b* each include a cone **32** and anti-extrusion rings **34**. When pushed by the push ring **18** in the setting procedures, the first slip **20***a* rides up the cone **32** to be wedged out against the surrounding tubular. At the same time, the slip **20***a* and cone **32** are pushed along the mandrel **12** against the anti-extrusion rings **34** and the sealing element **38**. On the opposite end, the second slip **20***b* similarly rides up its cone **32** as the elements **30***a-b* are pushed against the mule shoe **16** on the end of the mandrel **12**.

[0010] Another downhole tool **10**, such as a bridge plug, is shown in a cutaway view in FIG. **1**B. This tool **10** uses a single bi-directional slip **20**. Instead of confining a single sealing member with two slips, this single slip **20** is confined by two sealing systems **40***a-b*.

[0011] As before, the downhole tool **10** uses a mandrel **12** having the remainder of the downhole tool **10** disposed about the mandrel **12**. The single bi-directional slip **20** resists movement in either axial direction once activated by the sealing systems **40***a-b* to engage with the surrounding tubular.

[0012] To provide sealing with the surrounding tubular, the downhole tool **10** uses the two sealing systems **40***a-b*, one axially on either end of the slip **20**. Each sealing system **40***a-b*, in addition to sealing the downhole tool **10** with the surrounding tubular, also provides boost forces to the slip **20**, increasing its ability to engage with the tubular and hold the downhole tool **10** in place under high pressure.

[0013] Each sealing system **40***a-b* includes a sealing member **48**, which is a malleable, synthetic element. In addition to the sealing member **48**, each sealing system **40***a-b* has a cone **42** and two sets of anti-extrusion rings **44**. Axial force is applied to the sealing systems **40***a-b* and slip **20** using a setting tool (not shown) in a manner similar to that discussed above.

[0014] Another type of downhole tool is a sump packer, which is used to locate the bottom of a screen assembly in a sand control or gravel pack completion. For example, FIG. **2** shows a typical gravel pack completion **50** having a sump packer **70** used for this purpose. Although the sump packer **70** can be used, other packers or plugs (e.g., bridge plug or cement plug) can be used.

[0015] In the cased hole C, the sump packer **70** is installed as a base for the gravel pack completion **50**. The sump packer **70** can be run into the well on electric wireline prior to perforating the casing C. When set, the sump packer **70** positions at a point below the lowest planned perforation P. Typically, the sump packer **70** is a permanent seal bore type of packer, such as Weatherford's UltraPak Sump Packer or the Baker Model "D" or "F" Retainer Production Packer, although a retrievable sealbore packer could be used.

[0016] The sump packer **70** provides access to the bottom of the well C, which can act as a sump for debris left or dropped in the hole. The sump packer **70** also allows logging tools to be run below the producing interval.

[0017] The cased-hole gravel pack completion **50** has a retrievable sealbore packer **56** with a gravel pack extension **52**, a crossover tool **55**, and screen(s) **54** extending therefrom. The completion **50** is deployed into the cased well that has been perforated into the production zone, and the completion **50** at its distal end has a snap-latch assembly **60** that seals into the sump packer **70**. The snap-latch assembly **60** provides a surface indication that the gravel pack completion **50** is properly located in the sump packer **70**. With the completion **50** in place, the upper packer **56** is set, and the crossover tool **55** is manipulated to its various positions to pump the gravel as well as any other treatments. From that point, a tubing string T can install in the upper packer **56** to create a path for production fluid. Then, any of the other desired completion and production operations can be performed.

[0018] FIG. **2**B shows an example of a sump packer **70** according to the prior art. The sump packer **70** includes a mandrel **72** having a polished bore **74**. Inside the mandrel **72**, the top of the bore **74** defines a locating shoulder and square thread **78**. At the other end, lower slips **84***a* rest against the mandrel **72** between a lower setting element **85***b* and the mandrel's distal nose **76**. In an opposing manner, upper slips **84***b* rest against the mandrel **72** between an upper setting element **85***a* and a setting sleeve **80** having a body lock ring **82**. Between the setting elements **85***a-b* is a packing element **90** disposed about the mandrel **72** to be compressed therebetween.

[0019] When the snap-latch assembly **60** as shown in FIG. **2**C is inserted into the sump packer **70** (FIG. **2**B), the assembly's end **66** seals inside the polished bore **74**, latches **68** engage in the square thread **78**, and the upper ledge engages the locating shoulder. The latches **68** have threaded fingers that collapse inward as the assembly **60** contacts the top of the sump packer **70**. When the assembly **60** is fully lowered into the sump packer **70**, the threaded fingers on the latches **68** expand and engage the left-hand square threads **78** in the top of the sump packer **70**. About 2,000 pounds of set down weight may be required to snap into the packer **70**, and about 8,000 to 12,000 pounds may be required to snap out.

[0020] In the setting process, the setting sleeve **80** on the sump packer **70** is then activated and moves downhole, while the body lock ring **82** prevents reverse movement. The setting assembly of the sump packer **70** is compressed by the slips **84***a-b* riding up the ramps of the setting elements' cones **86***a-b* and by the packing element **90** compressing between the setting elements **85***a-b* and expanding outward to the casing. The setting elements **85***a-b* can include anti-extrusion elements **88***a-b* to limit the extrusion of the packing element **90** in the space between the setting elements **85***a-b* and the surrounding casing. This can help assure a good seal in the annulus.

[0021] As can be seen above, downhole tools, such as packers, plugs, etc., can use a number of different elements systems having slips, setting elements (i.e., cones, anti-extrusion rings, etc.), and packing elements. In one continuing problem associated with conventional element systems of these types of downhole tools, the cones of the element systems can collapse. This can occur, for example, on both permanent and retrievable tools, such as packers. There is also a continuing desire to increase the contact area between the slips and cones of the element systems or at least to further distribute the cone-to-slip load over a larger area.

[0022] Attempts to design a convention downhole tool, such as a packer, capable of handling 10,000-psi or greater cone collapse pressure have been made, and testing has proven these attempts to be unsuccessful. One issue that prevents increased cone collapse pressures one conventional downhole tools is the limitations in the contact area between the slips and the cones when set into the tubular or casing. In some implementations, only a thin annular area exists between the downhole tool and the surrounding tubular that limits how much contact the cone can have to the slip.

[0023] Historically, the problem of increasing the cone collapse pressure has been solved by simply increasing the material strength of the components. Additionally, different slip configurations have been used, such as Halliburton's "barrel" slips, Baker Hughes' tangential slips or wedge slips, or Petrowell's multi-ramp slips. Some examples of different slip configurations are disclosed in U.S. Pat. Nos. 4,311,196; 5,884,699; 5,944,102; 6,302,217; 7,614,449; 7,690,424; and 8,567,510.

[0024] The subject matter of the present disclosure is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE DISCLOSURE

[0025] According to the present disclosure, an apparatus installs in a surrounding tubular. The apparatus has a mandrel, first and second opposing shoulders, a plurality of stacked rings, and a slip. The first and second opposing shoulders are disposed on the mandrel. At least the first opposing shoulders is movable toward the second opposing shoulder. The plurality of stacked rings are disposed about the mandrel and are spaced between the first and second opposing shoulders. First of the stacked rings decrease in spacing in response to the movement of the first opposing shoulder toward the second opposing shoulder, and second of the stacked rings expand outward from the mandrel in response to the decrease in spacing. The slip is disposed about the stacked rings and moves away from the mandrel toward the surrounding tubular in response to the outward expansion.

[0026] The slip can have a number of configurations as disclosed herein. The slip can have an outer surface with wickers for engaging the surrounding tubular. The slip can include a plurality of segments longitudinally arranged relative to the mandrel and disposed about the stacked rings.

[0027] A drive sleeve disposed on the mandrel move the first shoulder. A lock disposed between the drive sleeve and the mandrel can permit movement of the drive sleeve toward the second shoulder, but prevents reverse movement of the drive sleeve. The first shoulder can have a catch at least temporarily holding an end of the slip. For its part, the second shoulder can be a sleeve fixed on the mandrel.

[0028] The second of the stacked rings can be spaced between the first of the stacked rings. The first of the stacked rings can have at least one first ramped edge against which the second of the stacked rings adjacent thereto wedges. The second of the stacked rings can have at least one second

ramped edge wedging against the at least one first ramped edge of the first of the stacked rings adjacent thereto.

[0029] The stacked rings can have a number of configurations, as disclosed herein. The stacked rings can be a full ring element defining a full circumference, a split ring element defining a split, a segmented ring element having a plurality of segments, and the like. Each of the stacked rings can be an individual ring element disposed about the mandrel. Alternatively, each of the stacked rings can be a strip coiled about a portion of the mandrel.

[0030] The stacked rings can include first and second outer rings each having a shoulder disposed adjacent one of the first and second shoulders disposed on the mandrel. The slip can have a central tab on an inner surface disposed toward the mandrel. The stacked rings in this case can include first and second inner rings each having a shoulder disposed adjacent a side of the central tab.

[0031] The spacings in between the stacked rings can expand the second of the stacked rings outward at one of the opposing shoulders before the other opposing shoulder. Also, the stacked rings can have contact angles disposed adjacent one another, and the contact angles can expand the second of the stacked rings outward at one of the opposing shoulders before the other opposing shoulder.

[0032] The apparatus can be a plug, a bridge plug, a fracture plug, a packer, a permanent packer, a retrievable packer, a sump packer, and a sealbore packer. According to the present disclosure, a setting sleeve disposed on the mandrel can compress against a packing element to expand outward toward the surrounding tubular.

[0033] According to the present disclosure, the apparatus disclosed above can further include a completion assembly that installs in the surrounding tubular. A distal end of the completion assembly is supported by the mandrel of the apparatus. In one example, the mandrel defines a throughbore, and the distal end of the completion assembly engages in the throughbore. A latch tool on the distal end can seal in the throughbore of the mandrel and can latching to the mandrel. In another example, the completion assembly can have a bull plug on the distal end. The completion assembly can include a packer disposed at a proximal end, an extension extending from the packer, and a screen disposed on the extension.

[0034] Methods of deploying and setting the apparatus disclosed above can involve deploying the apparatus in the surrounding tubular; and moving at least a first opposing shoulders disposed on the apparatus toward a second opposing shoulder disposed on the apparatus. The method decreases spacing of first of a plurality of stacked rings disposed on the apparatus between the first and second opposing shoulders in response to the movement and expands second of the stacked rings outward from the apparatus in response to the decrease in spacing. A slip disposed about the stacked rings engages toward the surrounding tubular in response to the outward expansion.

[0035] The foregoing summary is not intended to summarize each potential embodiment or every aspect of the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0036] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an implementation of apparatus and methods consistent with the present invention and, together with the detailed description, serve to explain advantages and principles consistent with the disclosed subject matter. In the drawings,

[0037] FIG. **1**A illustrates a partial cross-sectional view of a bridge plug according to the prior art;

[0038] FIG. **1**B illustrates a partial cross-sectional view of another bridge plug according to the prior art;

[0039] FIG. **2**A illustrates a cased-hole gravel pack completion according to the prior art;

[0040] FIG. **2**B illustrates a sump packer according to the prior art in partial cross-section;

[0041] FIG. **2**C illustrates a snap-latch tool according to the prior art in partial cross-section;

[0042] FIGS. **3**A-**3**B illustrate a downhole tool according to the present disclosure in partial cross-section in a run-in condition and a set condition, respectively;

[0043] FIGS. **3**C-**3**D illustrate the downhole tool in partial cross-section revealing different configurations for stacked rings;

[0044] FIG. **4**A illustrates another embodiment of the disclosed downhole tool in partial cross-section in the run-in condition;

[0045] FIG. **4**B illustrates a more detailed view of the disclosed tool in the run-in condition;

[0046] FIG. **4**C illustrates an isolated view of engagement of a setting sleeve with a slip segment on the disclosed tool;

[0047] FIG. **5**A illustrates the disclosed downhole tool in partial cross-section in the set condition;

[0048] FIG. **5**B illustrates a more detailed view of the disclosed tool in the set condition;

[0049] FIG. **6**A illustrates a perspective view of an outer setting ring for the disclosed tool;

[0050] FIG. **6**B illustrates a perspective view of an inner setting ring for the disclosed tool;

[0051] FIG. **7**A illustrates perspectives view of two types of inner expansion rings for the disclosed tool;

[0052] FIG. **7**B illustrates a perspective view of an outer expansion ring for the disclosed tool;

[0053] FIG. **8** illustrates a perspective view of a drive sleeve for the disclosed tool;

[0054] FIG. **9** illustrates a perspective view of a slip segment for the disclosed tool;

[0055] FIG. **10** illustrates a perspective view of a fixed sleeve for the disclosed tool;

[0056] FIG. **11**A illustrates an embodiment of the disclosed tool used as a bridge plug to support a cased-hole gravel pack completion;

[0057] FIG. **11**B illustrates an embodiment of the disclosed tool used as a sump packer to support a cased-hole gravel pack completion; and

[0058] FIG. **12** illustrates the disclosed tool as a bridge plug in partial cross-section.

DESCRIPTION OF EMBODIMENTS

[0059] FIGS. **3**A-**3**B illustrate a downhole tool **100** according to the present disclosure in partial cross-section in a run-in condition. The downhole tool **100** can be configured as a bridge plug, a frac plug, a packer, or any other desired downhole packer tool. In a particular example, the downhole tool **100** can be a permanent sump packer used as a base for a cased-hole gravel pack completion.

[0060] The downhole tool **100** has a mandrel **102**, first and second opposing shoulders **112***a*-*b*, a plurality of stacked rings **130***a*-*b* and **140***a*-*b*, and a slip **150**. The first and second opposing shoulders **112***a*-*b* are disposed on the mandrel **110**, and at least one of the opposing shoulders (e.g., the first shoulder **112***a*) is movable toward the second opposing shoulder **112***b*. These opposing shoulders **112***a-b* can be part of sleeves **110***a-b* disposed on the mandrel **102**. In this context, the first sleeve **110***a* can be a drive sleeve movable along the mandrel **102** toward the second, fixed sleeve **110***b*. (FIG. **6** shows an isolated perspective view of a sleeve **110**.)

[0061] The slip **150** includes a plurality of segments **152** that are axially aligned and disposed about the stacked rings **130***a-b*, **140***a-b*. The exposed surfaces of the slip segments **152** have wickers, teeth, or the like for engaging the surrounding tubular, casing, or the like. The inner surface of the slip segments **152** can have a central tab **158** for stabilizing the segments **152** on the tool **100**. In particular, the central tab **158** has square shoulders that set against adjacent rings (e.g., **140***a*).

[0062] The stacked rings **130***a-b*, **140***a-b* are disposed about the mandrel **102** and are spaced between the first and second opposing shoulders **112***a-b*. The stacked rings **130***a-b*, **140***a-b* decrease in spacing in response to the movement of the first opposing shoulder **112***a* toward the second opposing shoulder **112***b*, and at least some of the stacked rings (e.g., **140***a-b*) expand outward from the mandrel **102** in response to the decrease in spacing.

[0063] In particular, first rings **130***a-b* are disposed about the mandrel **102** and are spaced between the first and second opposing shoulders **112***a-b* of the sleeves **110***a-b*. Second rings **140***a-b* are also disposed about the mandrel **102** as well, but they are spaced in between each of the first rings **130***a-b*. The slip **150** with its segments **152** is disposed on the first and second rings **130***a-b*, and **140***a-b*.

[0064] During activation, the drive sleeve **110***a* is moved toward the fixed sleeve **110***b*. Activation can be achieved in several known ways—some of which are disclosed herein. The first rings **130***a-b* decrease in spacing in response to the movement of the drive sleeve **110***a* toward the opposing sleeve **110***b*, and the second rings **140***a-b* expand outward from the mandrel **102** in response to the decrease in spacing of the first rings **130***a-b*. Finally, the slip segments **152** move away from the mandrel **102** toward the surrounding tubular in response to the outward expansion of the second rings **140***a-b*.

[0065] FIG. **3**C illustrate the downhole tool **100** in partial cross-section revealing how the stacked rings can be configured as individual rings **130***a-b*, **140***a-b* alternatingly stacked on the outside of the mandrel **102**. A gap G is present between inner expansion rings **140***a* where the central tabs **158** of the segments **152** positions.

[0066] An alternative configuration is shown in FIG. **3**D. Here, the stacked rings can be configured as strips **135** and **145** (wires, springs, or the like) alternatingly coiled about the mandrel **102** to form the various rings **130***a-b*, **140***a-b*. The lengths of the strips **135** and **145** may not fully encompass the expanse between the opposition shoulders **112***a-b* so that space can be provided for at least some of the ends of these coiled strips **135** and **145** to accommodate spiraled movement of the strips during activation.

[0067] Again, a gap G is present where the central tabs **158** of the segments **152** positions. The strips **135**, **145** at one end of the slip **150** can be coiled in one direction, and the strips **135**, **145** at the other end can be similarly coiled in the same direction. Alternatively, the strips **135**, **145** can be coiled in opposing directions to one another.

[0068] Either of these configurations in FIGS. **3**C-**3**D can achieve the same results during activation. As the opposing shoulders **112***a-b* are brought closer together, the expansion rings **140***a-b* (either as individual rings or parts of a coil) can expand outward and push the slip segments **152** toward the surrounding tubular.

[0069] During activation, a lock **114**, such as a body lock ring or other mechanism, disposed between the drive sleeve **110***a* and the mandrel **102** permits the movement of the drive sleeve **110***a* toward the fixed sleeve **110***b*, but the lock **114** prevents reverse movement of the drive sleeve **110***a*. In this way, the tool **100** will not unset once setting forces cease. Once the tool **100** is activated (i.e., the second rings **140***a-b* are expanded, the slip segments **152** are engaged, etc.), the tool **100** can seal the annulus between the mandrel **102** and the surrounding tubular or casing.

[0070] The downhole tool **100** can be installed in the wellbore with any desired non-rigid system, such as electric wireline or coiled tubing. A setting tool (not shown), such as a Baker E-4 Wireline Setting Assembly commercially available from Baker Hughes, Inc., can connect to an upper portion of the mandrel **102**. Specifically, an outer movable portion of the setting tool is disposed about the outer diameter of the mandrel **102**, abutting the end of the drive sleeve **110***a*. An inner portion of the setting tool can affix to the mandrel **102**. The setting tool and the downhole tool **100** are then run into the well casing to the desired depth where the downhole tool **100** is to be installed.

[0071] To set or activate the downhole tool **100**, the mandrel **102** is held by the wireline, through the inner portion of the setting tool, as an axial force is applied through the outer movable portion of the setting tool to the drive sleeve **110***a*, which transfers axial force from the setting tool to the element system. In particular, the axial force causes the outer portions of the downhole tool **100** to move axially relative to the mandrel **102**. The force asserted against the drive sleeve **110***a* is transmitted by the shoulder **112***a*. An equal and opposite force is asserted by the fixed sleeve **110***b* on the other end of the downhole tool **100**. The force from both ends is transmitted to the element system, which causes the slip **150** and second rings **140***a-b* to expand and set against the surrounding tubular.

[0072] The segments **152** of the slip **150** can be initially interconnected together and may fracture under radial stress. The slip **150** can have a plurality of recessed grooves, allowing the slip segments **152** to fracture along the grooves. Alternatively, the segments **152** may already be independent.

[0073] An outer surface of the slip **150** can include outwardly, extending wickers, comprising serrations or edge teeth. The wickers can be arranged with a first set oriented toward the drive sleeve **110***a*, to resist uphole axial movement, and the wickers can be arranged with a second set oriented toward the fixed sleeve **110***b*, to resist downhole axial movement. Any number, shape, and configuration of wicker can be used as desired.

[0074] When set, the downhole tool **100** can acts as a packer with the slip **150** fixing the tool **100** in place. The stacked contact between the rings **130***a-b*, **140***a-b* and the radial forces they place on the outside of the mandrel **102** and the inside of the slip **150** can also act as a fluid seal in the annular space between the mandrel **102** and the surrounding casing, although the fluid seal for the downhole tool **100** can be provided by a separate packing element (not shown) on the mandrel **102**.

[0075] Any fluid sealing provided at the rings **130***a-b*, **140***a-b* and slip **150** can be achieved by encasing the components in an elastomer. Alternatively, the sealing can be achieved in part by the stacked fit between the rings **130***a-b*, **140***a-b*. If the rings **130***a-b*, **140***a-b* are metallic, then the sealing can be a metal-to-metal seal between the interfacing surfaces. If one or the other of the rings **130***a-b*, **140***a-b* are composed of another malleable or low yield material (e.g., plastic, elastomer, 4140 stainless steel, etc.), then sealing between the stacked rings **130***a-b*, **140***a-b* can be comparably made between the interfacing surfaces. In fact, the splits **144** if present in the expansion rings **140***a-b* can be misaligned, creating a tortuous path capable of sealing. Similarly, if the expansion rings **140***a-b* are composed of a compressible material, then the splits **144** if present in these rings **140***a-b* can close to create the desired sealing. Finally, other forms of sealing, such as an independent packing element or seal, could be used elsewhere on the tool **100** in relation to the slip **150** and stacked rings **130***a-b*, **140***a-b* depending on the implementation.

[0076] Turning now to Figurers **4**A through **10**, details of another embodiment of the disclosed tool **100** are discussed. FIG. **4**A illustrates the disclosed downhole tool **100** along with a setting tool in partial cross-section in the run-in condition, and FIG. **4**B illustrates a more detailed view of the disclosed downhole tool **100** in the run-in condition.

[0077] Similar components have the same reference numbers as in the previous embodiment. Again, the downhole tool **100** has a mandrel **102**, first and second opposing shoulders **112***a-b*, a plurality of stacked rings (i.e., first setting rings **130***a-b* and second expansion rings **140***a-b*), and a slip **150**. At least the first shoulder **112***a* on the drive sleeve **110** is movable toward the second opposing shoulder **112***b* on the fixed sleeve **110***b*.

[0078] As shown, the mandrel **102** can define a throughbore **104**, although this is not strictly necessary depending on the purpose of the tool **100**. In the present context, the tool **100** is shown as a sump packer. Therefore, the mandrel **102** defines a wide cylinder close to the inner dimension of the surrounding casing. Additionally, the mandrel's throughbore **104** can define a wide inner dimension and can be a polished bore, such as used for a sump packer for sealing with a latch assembly.

[0079] The setting rings **130***a-b* are disposed about the mandrel **102** and are spaced between the opposing shoulders **112***a-b* of the sleeves **110***a-b*. The expansion rings **140***a-b* are also disposed about the mandrel **102** as well, but they are spaced in between each of the setting rings **130***a-b*. The slip **150** with its segments **150** is disposed on the rings **130***a-b*, and **140***a-b*.

[0080] The slip **150** includes a plurality of segments **152** that are axially aligned and disposed about the rings **130***a-b*, **140***a-b*. (FIG. **9** shows an isolated perspective view of a segment **152** of the slip **150**). The exposed surfaces of the slip segments **152** have wickers, teeth, or the like for engaging the surrounding tubular. The inner surface of the slip segments **152** can have a central tab **158** for stabilizing the segments **152** on the tool **100**, as will be described below.

[0081] As shown in the detailed view of FIG. **4**C, each end of the opposing shoulders (e.g., **112***b*) can have a catch **113**, tooth, or the like to engage an end of a slip segment **152**. Other ways of fixing the segment **152** can be used, including shear pins, shear screws, frangible bands, etc. The catches **113** on the ends of the segments **152** hold the slip **150** and other elements together during run-in, as shown in FIGS. **4**A-**4**B. This can help prevent premature setting and can retain the slip segments **152** during tripping downhole.

[0082] As noted above, activation of the tool **100** can be achieved in several ways. In the current embodiment as best shown in FIGS. **4**A and **5**A, the mandrel **102** of the tool **100** has a setting sleeve **160** moveably disposed toward the uphole end near the drive sleeve **110***a*. The setting sleeve **160** includes a body lock ring **162** or other mechanism that allows movement of the sleeve **160** toward the drive sleeve **110***a*, but prevents the reverse. A packing element **165** on the setting sleeve **160** can be expanded to seal with the surrounding tubular or casing C. Any of the various types of packing elements can be used, and only a schematic arrangement is shown here. In general, the packing element **165** can include an elastomer for sealing, a cone and wedge ring arrangement, or any other acceptable arrangement.

[0083] As the setting sleeve **160** is freed with downhole movement (by shearing pins or the like), the setting sleeve **160** moves along the mandrel **102** with the sleeve's body lock **162** preventing reverse movement. The packing element **165** expands outward against the casing C, and the setting sleeve **160** moving along the mandrel **102** eventually pushes the drive sleeve **110***a*, which then activates the slip **150**, setting rings **130***a-b*, and expansion rings **140***a-b* to set the slip **150** outward against the casing C.

[0084] In particular and as discussed previously, the drive sleeve **110***a* during activation is moved toward the fixed sleeve **110***b*. (FIG. **8** illustrates a perspective view of the drive sleeve **110***a* for the disclosed tool **100**). Once the drive sleeve **110***a* is moved, the catch **113** near the sleeve's shoulder **112***a* can disengage from the slip segments (**152**), and the shoulder **112***a* can push against the rings (**130***a-b*, **140***a-b*). Meanwhile, the body lock ring **114** on the inside of the drive sleeve **110***a* can engage a threaded surface on the tool's mandrel (**102**) to lock forward progress of the sleeve **110***a*.

[0085] At the opposite end of the tool **100**, the fixed sleeve **110***b*, which is shown in an isolated view in FIG. **10**, allows the rings (**130***a-b*, **140***a-b*) to press against its shoulder **112***b*. Likewise, shifting of the slip segments (**152**) disengages their ends from the catch **113** near this second shoulder **112***b*. Pockets **115** disposed around the outside of the fixed sleeve **110***b* can accommodate anti-rotation lugs (**117**; FIGS. **4**B, **5**B) that engage in outer slots on the mandrel **102** and are covered by a cover (**119**; FIGS. **4**B, **5**B) on the fixed sleeve **110***b*.

[0086] During activation as best shown in FIG. **5**B, the setting rings **130***a-b* decreases in spacing in response to the movement of the drive sleeve **110***a* toward the opposing sleeve **110***b*, and the expansion rings **140***a-b* expand outward from the mandrel **102** in response to the decrease in spacing of the setting rings **130***a-b*. Finally, pushed outward with the expansion rings **140***a-b*, the slip segments **152** move away from the mandrel **102** toward the surrounding casing in response to the outward expansion of the expansion rings **140***a-b*.

[0087] Thus, during activation, the setting and expansion rings **130***a-b*, **140***a-b* begin to make contact, and the setting rings **130***a-b* force the expansion rings **140***a-b* outward due to the incline ramp faces on each setting ring **130***a-b*. In turn, as the expansion rings **140***a*-*b* are forced outward, the outer dimension of the rings **140***a*-*b* makes contact on the slip's inside surfaces to force the slip segments **152** outward to bite into the surrounding casing C.

[0088] Being stacked along the outside of the mandrel **120**, the setting and expansion rings **130***a*-*b*, **140***a*-*b* increase the contact area between the rings **130***a*-*b*, **140***a*-*b* and slip **150**. The stacking of the rings **130***a*-*b*, **140***a*-*b* also distributes load over a larger area outside the mandrel **102** and inside the slip **150**. Additional rings can be stacked to increase the contact area if the slip **150** needs to be qualified for a higher pressure or load.

[0089] Each ring **130***a*-*b*, **140***a*-*b* transfers the applied axial force to radial expansion toward the inner surface of the surrounding casing. The expansion rings **140***a*-*b* flow and expand across the ramped surfaces of the setting rings **130***a*-*b*, applying a collapse load through the setting rings **130***a*-*b* on the mandrel **102**, which helps prevent slippage of the system one activated. The collapse load also prevents the rings **130***a*-*b*, **140***a*-*b* from rotating on the mandrel **102**.

[0090] As shown in isolated detail in FIGS. **6**A-**6**B, the setting rings **130***a*-*b* can be solid rings **132** that slide onto the outer surface of the mandrel (**102**), although split or even segmented rings could be used. These setting rings **130***a*-*b* can be composed of a rigid material, such as a metal, plastic, etc. The outer ones of these setting rings (i.e., **130***a* in FIG. **6**A) can have shouldered edges **138** for engaging against the opposing shoulders (**112***a*-*b*) of the sleeves (**110***a*-*b*). However, the remaining interior edges **136** of the rest of the setting rings **130***a*-*b* are ramped or sloped outward.

[0091] As shown in isolated detail in FIGS. **7**A-**7**B, the second expansion rings **140***a*-*b* can be split rings **142** having splits **144**. These expansion rings **140***a*-*b* can be composed of a rigid material, such as a metal, plastic, etc. Alternatively, the expansion rings **140***a*-*b* can be composed of compressible/expandable material, such as an elastomer, plastic, etc., and the expansion rings **140***a*-*b* may not include a split.

[0092] The inner ones of these expansion rings (i.e., **140***a* in FIG. **7**B) can have shouldered edges **148** for engaging against the opposing sides of the central tab (**158**) on the slip segments (**152**). However, the remaining interior edges **146** of the rest of the expansion rings **140***a*-*b* are ramped or sloped inward to wedge against the ramped edges **136** on adjacent first rings **130***a*-*b*.

[0093] As an alternative to the split ring, any of the expansion rings **140***b*' can be a segmented ring having a number of segments **143**. This configuration can also be used for any of the other rings **130***a*-*b*, **140***a* disclosed herein.

[0094] The contact angles of the ramped edges **136**, **146** for the rings **130***a*-*b*, **140***a*-*b* can be configured as desired to achieve desired wedging. The contact angles of the edges **136**, **146** can be comparable for both types of rings **130***a*-*b*, **140***a*-*b*, or the angles for the different rings **130***a*-*b*, **140***a*-*b* can be differently configured. Likewise, the angles for the edges **136**, **146** of each ring **130***a*-*b*, **140***a*-*b* can all be similarly configured along the length of the element system from the uphole end of the slip **150** to the downhole end of the slip **150**.

[0095] Alternatively, the contact angles of the edges **136**, **146** can be configured along the length of the elements so that the slip segments **152** initially set outward at their uphole end first and then set toward their downhole end. The reverse configuration could also be used. As an alternative or in addition to the changing angles along the length of the element system, the geometry of the rings **130***a*-*b*, **140***a*-*b* can be different from one end of the element system to the other to create a setting sequence from one end of the slip **150** to the other. In other variations to achieve a desired setting sequence, slots can be added, the materials can differ, thinner cross-sections can be provided, and the like to some of the rings **130***a*-*b*, **140***a*-*b*.

[0096] The disclosed tool **100** can be used in any packer application that requires holding high loads in thin cross-section designs. As noted herein, the disclosed tool **100** can be a plug. To that end, the tool **100** can be used with a completion assembly having a distal end supported by the tool **100**. As depicted in FIG. **11**A, for example, a gravel pack completion **250** can have a retrievable sealbore packer **256** with a gravel pack extension **252**, crossover tool **255**, and screen(s) **254** extending therefrom. At its distal end, the gravel pack completion **250** can have a bull plug **258** disposed at the bottom of the screen(s) **254**.

[0097] Before the completion **250** is deployed, the disclosed tool **100** configured as a bridge plug **100** is set in the casing C at a suitable location using any of the various setting techniques. The completion **50** is then deployed into the cased well, and the bull plug **258** can be supported on the disclosed tool **100** configured as the bridge plug. In this arrangement, the mandrel **102** of the tool **100** may or may not have a flow passage therethrough.

[0098] In another implementation for supporting the gravel pack completion **250**, the disclosed tool **100** can be used as a sump packer. As depicted in FIG. **11**B, the mandrel **102** of the disclosed tool **100** as a sump packer defines a throughbore. As before, the completion **250** can have a retrievable sealbore packer **256** with a gravel pack extension **252**, a crossover tool **255**, and screen(s) **254** extending therefrom. At its distal end, the gravel pack completion **250** can have a snap-latch tool **260** installing in the throughbore **104** of the mandrel **102**. The snap-latch tool **260** has seals sealing in the throughbore **104** of the mandrel **102** and has a latch latching to the mandrel **102**. Although not shown, it will be appreciated that the disclosed tool **100** can have a setting sleeve (e.g., **160**) and other features similar to those discussed above with reference to FIGS. **4**A and **5**A.

[0099] The snap-latch tool **260** provides a surface indication that the gravel pack completion **250** is properly located in the sump packer **100**. With the completion **250** in place, the upper packer **256** is set, and the crossover tool **255** is manipulated to its various positions to pump gravel as well as any other treatments into the annulus and through the perforations. From that point, a tubing string T can install in the upper packer **256** to create a path for production fluid. Then, any of the other desired completion and production operations can be performed.

[0100] Finally, as noted previously, the disclosed tool **100** can be used as a number of downhole packer tools or the like. As an example, FIG. **12** illustrates the disclosed tool **100** as a bridge plug in partial cross-section. The bridge plug **100** has a mandrel **102** having a packing element **109** and setting elements **110**-**150**. The packing element **109** can be disposed on the mandrel **102** near the shoe **106** and can include some conventional components, such as anti-extrusion elements **30***a*-*b* and a packer **38**. The anti-extrusion elements **30***a*-*b* can have various backup rings **34** and the like. The setting elements **110**-**150** are similar to those disclosed herein and can be disposed about the mandrel **102**

between the packing element **109** and a push ring **108**. Setting of the packing element **109** and the setting elements **110-150** can be achieved by axial force applied against the push ring **108** and compressing the components against the shoe **106** on the held mandrel **102**.

[0101] The foregoing description of preferred and other embodiments is not intended to limit or restrict the scope or applicability of the inventive concepts conceived of by the Applicants. More or less rings **130***a-b*, **140***a-b* can be used. The rings **130***a-b*, **140***a-b* can be disposed along a length of the mandrel **102** greater or shorter than the extent of the slip **150**. All of the rings **130***a-b*, **140***a-b* preferably have ramped surfaces, although this is not strictly necessary if the alternating expansion rings **140***a-b* even with a different cross-section can ride up on the setting rings **130***a-b* with a different cross-section.

[0102] It will be appreciated with the benefit of the present disclosure that features described above in accordance with any embodiment or aspect of the disclosed subject matter can be utilized, either alone or in combination, with any other described feature, in any other embodiment or aspect of the disclosed subject matter.

[0103] In exchange for disclosing the inventive concepts contained herein, the Applicants desire all patent rights afforded by the appended claims. Therefore, it is intended that the appended claims include all modifications and alterations to the full extent that they come within the scope of the following claims or the equivalents thereof.

What is claimed is:

1. An apparatus installing downhole in a surrounding tubular, the apparatus comprising:

a mandrel;

first and second shoulders disposed on the mandrel, at least the first shoulder being movable toward the second shoulder;

a plurality of stacked rings disposed about the mandrel and spaced between the first and second shoulders, a first of the stacked rings decreasing in spacing in response to the movement of the first shoulder toward the second shoulder, a second of the stacked rings expanding outward from the mandrel in response to the decrease in spacing; and

a slip disposed on the stacked rings, the slip being movable away from the mandrel toward the surrounding tubular in response to the outward expansion.

2. The apparatus of claim **1**, wherein the apparatus is selected from the group consisting of a plug, a bridge plug, a fracture plug, a packer, a permanent packer, a retrievable packer, a sump packer, and a sealbore packer.

3. The apparatus of claim **1**, wherein the slip comprises an outer surface having wickers engageable with the surrounding tubular.

4. The apparatus of claim **1**, wherein the slip comprises a plurality of segments being arranged longitudinally relative to the mandrel and being disposed about the stacked rings.

5. The apparatus of claim **1**, wherein the first shoulder comprises a drive sleeve disposed on the mandrel and movable thereon.

6. The apparatus of claim **5**, further comprising a lock disposed between the drive sleeve and the mandrel, the lock permitting movement of the drive sleeve toward the second shoulder and preventing reverse movement of the drive sleeve away from the second shoulder.

7. The apparatus of claim **1**, wherein the second opposing comprises a sleeve fixed on the mandrel.

8. The apparatus of claim **1**, wherein the second of the stacked rings is spaced in between the first of the stacked rings, the second of stacked rings expanding outward from the mandrel in response to the decrease in spacing of the first of the stacked rings.

9. The apparatus of claim **8**, wherein the slip is disposed about at least the second of the stacked rings, the slip being movable away from the mandrel toward the surrounding tubular in response to the outward expansion of the second of the stacked rings.

10. The apparatus of claim **1**, wherein the first of the stacked rings comprises at least one first ramped edge against which the second of the stacked rings adjacent thereto wedges.

11. The apparatus of claim **10**, wherein the second of the stacked rings comprises at least one second ramped edge wedging against the at least one first ramped edge of the first of the stacked rings adjacent thereto.

12. The apparatus of claim **1**, wherein the stacked rings comprises at least one of a split ring element defining a split; a segmented ring element having a plurality of segments; a full ring element defining a full circumference; an individual ring element disposed about the mandrel; a strip coiled about a portion of the mandrel; a compressible material; and a rigid material.

13. The apparatus of claim **1**, wherein the stacked rings comprise first and second outer rings each having a third shoulder disposed adjacent one of the first and second shoulders disposed on the mandrel.

14. The apparatus of claim **1**, wherein the slip comprises a central tab disposed on an inner surface of the slip toward the mandrel, and wherein the stacked rings comprise first and second inner rings each having a third shoulder disposed adjacent a side of the central tab.

15. The apparatus of claim **1**, wherein the first shoulder comprises a catch at least temporarily holding an end of the slip.

16. The apparatus of claim **1**, wherein the stacked rings have different spacings between one another, whereby the second of the stacked rings at one of the first and second shoulders expands outward before the second of the stacked rings at the other of the first and second shoulder.

17. The apparatus of claim **1**, wherein the stacked rings have different contact angles disposed adjacent one another, whereby the second of the stacked rings expands outward at one of the first and second shoulders before the second of the stacked rings at the other of the first and second shoulder.

18. The apparatus of claim **1**, further comprising:

a packing element disposed on the mandrel adjacent the first shoulder; and

a setting sleeve disposed on the mandrel adjacent the packing element, the setting sleeve movable on the mandrel toward the first shoulder and expanding the packing element outward toward the surrounding tubular.

19. The apparatus of claim **1**, further comprising a completion assembly installing in the surrounding tubular and having a distal end supported by the mandrel of the apparatus.

20. The apparatus of claim **19**, wherein at least one of:

the distal end engages in a throughbore defined in the mandrel;

the distal end comprises a seal sealing in a throughbore of the mandrel;

the distal end comprises a latch latching to the mandrel; and

the distal end comprises a bull plug.

21. The apparatus of claim **19**, wherein the completion assembly comprises:

a packer disposed toward a proximal end of the completion assembly; and

a screen disposed on the assembly between the packer and the distal end.

22. A method of installing an apparatus downhole in a surrounding tubular, the method comprising:

deploying the apparatus in the surrounding tubular;

moving at least a first shoulder disposed on the apparatus toward a second shoulder disposed on the apparatus;

decreasing spacing of first of a plurality of stacked rings disposed on the apparatus between the first and second shoulders in response to the movement;

expanding second of the stacked rings outward from the apparatus in response to the decrease in spacing; and

engaging a slip disposed on the stacked rings toward the surrounding tubular in response to the outward expansion.

* * * * *