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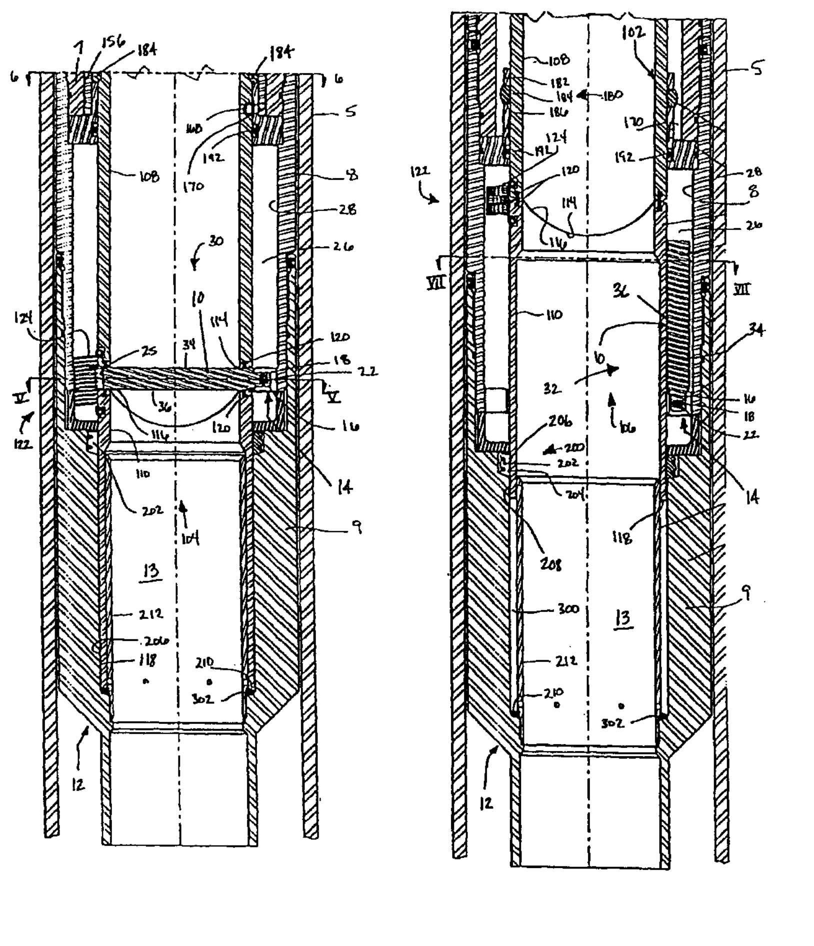
(54) Title: DOWNHOLE VALVE



(57) Abstract: The invention is a downhole valve (100) that includes a body (12), a flow tube assembly (102) that includes an upper tube member (108) and a lower tube member (110), and a flapper valve (10). The flapper valve (10) is pivotally attached to the body (12) and is positioned between the upper tube member (108) and the lower tube member (110) when the flapper valve (10) is in a closed position that blocks fluid flow in an internal bore of the body (12). The flapper valve (10) is moved from the closed position to an open position in response to an upward movement of the upper tube member (108) and the lower tube member (110). When the flapper valve (10) pivots to the open position, the lower tube member (110) moves adjacent to and forms a seal with the upper tube member (108), forming an unobstructed internal bore.

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DOWNHOLE VALVE

This application claims priority from United States Provisional Patent Application No. 60/165,680, filed November 16, 1999.

BACKGROUND OF THE INVENTION

Prior to the commencement of production in a wellbore, it is important to test the integrity and the connections of downhole equipment and tubing. Leaks, faulty connections, or faulty equipment can lead to hydrocarbon losses during production and potentially dangerous and life-threatening situations for operators at the surface of a well. To lessen the danger, a pressure test is normally performed in which the tubing (*e.g.*, production tubing) or drillpipe is pressurized from the surface and any leaks or faulty connections are detected by a loss of pressure as measured by a gauge also located at the surface. To successfully accomplish this test, the tubing or drillpipe must be plugged at some point downhole and be sealed from a selected formation.

The types of devices previously used to plug the tubing or pipe downhole include closed formation tester valves and tubing tester valves. Flapper valves have also been utilized for such a purpose, as illustrated in U.S. Patent Nos. 4,134,455 issued to Read, 4,694,903 issued to Ringgenberg, 5,137,090 issued to Hare et al., and 5,188,182 issued to Echols et al. The flapper valves disclosed in the above referenced patents are generally designed to seal against pressure adjacent the upper side (*e.g.*, pressure from the uphole side) of the flapper valve.

The ability to seal against both uphole and downhole pressure is important because pressure may accumulate in the wellbore underneath the downhole plug. Therefore, it is desirable that a flapper valve be capable of withstanding not only pressure on its upper side generated by the pressure tests, but also pressure on its underside generated by the production fluids or downhole environment.

Additionally, pressure tests are typically conducted several times in sequence, generally each time additional tubing or drillpipe has been added to a drillstring and inserted downhole. The flapper valve must maintain its sealing engagement to the relevant tubing or drillpipe throughout each of the pressure tests in order to preserve the accuracy of each test. Once the pressure tests are completed and the wellbore is ready for production, it is necessary to remove, at least partially, the downhole valve or plug in order to pass other downhole tools through the drillpipe or tubing, or to allow production fluids to flow up to the surface through the tubing or drillpipe. It is preferable to completely remove the downhole valve or plug from the bore of the tubing or drillpipe so that the downhole tools and production fluids can pass and flow freely and without obstruction.

Attempts have been made to design a downhole plug that provides for a clear bore when the valve is opened. However, most plugs (such as those in the aforementioned patents) include parts (*e.g.*, valve seats or internal tubing) that remain in the bore after the flapper has been removed or opened. Parts that remain in the bore may obstruct the passage of tools and the flow of fluids through the bore. It is therefore desirable to provide a downhole valve which enables the complete removal of the flapper valve from the bore of the relevant body at the appropriate time and which leaves such bore free of obstructions after use.

SUMMARY OF THE INVENTION

One aspect of the invention is a downhole valve comprising a body and a flow tube assembly positioned within the body. The flow tube assembly comprises an upper tube member and a lower tube member. A flapper valve is operatively attached to the flow tube assembly and is adapted to move from a closed position to an open position. When the flapper valve is in the closed position, the flapper valve is sealingly positioned between the upper and lower tube members. When the flapper valve is moved to the open position, the flapper valve is enclosed in a recess in the body. The movement of the flapper valve is in response to an upward movement of the upper and lower tube members so that after the flapper valve is enclosed in the recess, the upper and lower tube members move into a cooperative engagement with each other to form a substantially unobstructed internal bore.

Another aspect of the invention is a method of retractably sealing a bore of a body. The method comprises pivotally attaching a flapper valve to the body. A top surface of the flapper valve sealingly engages an upper tube member when the flapper valve is in a closed position. A bottom surface of the flapper valve sealingly engages a lower tube member when the flapper valve is in the closed position. The flapper valve is moved from the closed position to an open position in response to a plurality of pressure cycles by slidably moving the upper tube member and the lower tube member upward until the flapper valve is enclosed in a recess in the body and the upper tube member cooperatively engages the lower tube member.

Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric view of a flapper valve in an embodiment of the invention.

Figure 2A is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in a closed position and a flow tube assembly in a valve sealing position.

Figure 2B is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in a closed position and a flow tube assembly in a valve sealing position.

Figure 3A is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 3B is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 4 is a schematic view of indexer slot sets of an indexing system of an embodiment of the invention.

Figure 5 is a cross-sectional view taken along line V—V of Figure 2B.

Figure 6 is a cross-sectional view taken along line VI—VI of Figure 2B.

Figure 7 is a cross-sectional view taken along line VII—VII of Figure 3B.

Figure 8 is a cross-sectional view taken along line VIII—VIII of Figure 2A.

Figure 9A is a cross-sectional view of an embodiment of the retractable valve with the flapper valve in a closed position and the flow tube assembly in a valve sealing position.

Figure 9B is a cross-sectional view of an embodiment of the retractable valve with the flapper valve in a closed position and the flow tube assembly in a valve sealing position.

Figure 9C is a cross-sectional view of an embodiment of the retractable valve with the flapper valve in a closed position and the flow tube assembly in a valve sealing position.

Figure 9D is a cross-sectional view of an embodiment of the retractable valve with the flapper valve in a closed position and the flow tube assembly in a valve sealing position.

Figure 9E is a cross-sectional view of an embodiment of the retractable valve with the flapper valve in a closed position and the flow tube assembly in a valve sealing position.

Figure 10A is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 10B is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 10C is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 10D is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 10E is a cross-sectional view of an embodiment of a retractable valve with a flapper valve in an open position and a flow tube assembly in a tube engaging position.

Figure 11 is a cross-sectional view of a flapper valve of an embodiment of the invention.

Figure 12 is a cross-sectional view of a flapper valve of an embodiment of the invention.

Figure 13 is a schematic view of the indexer slot sets and ratchet slots of an indexing system of an embodiment of the invention.

Figure 14 is a cross-sectional view taken along line XIV—XIV of Figure 9B.

Figure 15 is a cross-sectional view taken along line XV—XV of Figure 9C.

Figure 16 is a cross-sectional view taken along line XVI—XVI of Figure 9D.

DETAILED DESCRIPTION

Description of an Embodiment of the Downhole Valve

A flapper valve of an embodiment of the invention is generally illustrated as reference numeral **10** in Figures 1-8. In one aspect of the invention, the flapper valve **10** is part of a downhole or retractable valve **100**. Referring to Figure 2B, the flapper valve **10** acts to control a flow of fluids through an internal bore **13** of a flapper housing **8** disposed within a well casing **5**. The flapper housing **8** is a part of a tool body **12** of the retractable valve **100**. Referring to Figures 2B and 5, the flapper valve **10** is pivotally connected to the flapper housing **8** with a pivoting mechanism **14**. In an embodiment of the invention, pivoting mechanism **14** comprises an extension (**16** in Figure 5) on the flapper valve **10**, an extension passageway (**18** in Figure 2B) defined through the extension (**16** in Figure 5), a flapper housing passageway (**20** in Figure 5), and a pivoting pin **22**.

Referring to Figure 2B, a recess **26** is defined on an inside surface **28** of the flapper housing **8**. The recess **26** extends axially along the flapper housing inside surface **28** and houses the extension (**16** in Figure 5) of the flapper valve **10**. As best shown in Figure 5, the flapper housing passageway **20** is defined laterally through the flapper housing **8** on either side of the recess **26**. The extension **16** is received within the recess **26** so that the flapper housing passageway **20** is axially aligned with the extension passageway **18**. The pivoting pin **22** is positioned within the axially aligned flapper housing passageway **20** and the extension passageway **18**. In an embodiment of the invention, the cross-sectional areas of the flapper housing passageway **20** and of the extension passageway **18** may be slightly larger than the cross-sectional diameter of the pivoting pin **22**. In an embodiment of the invention, the cross-sectional shape of the flapper housing passageway **20** and of the extension passageway **18** may be elliptical. Flapper valve **10** is able to pivot about pivoting pin **22**.

The pivoting mechanism (**14** in Figure 2B) enables the flapper valve **10** to pivot from a closed position (**30** in Figure 2B) to an open position (**32** in Figure 3B). In the closed position (**30** in Figure 2B), the flapper valve **10** prohibits any flow of fluids through the internal bore **13** of the flapper housing **8** and the tool body **12**. In the open position (**32** in Figure 3B), the flapper valve **10** permits an unobstructed flow of fluids through the internal bore **13** of the flapper housing **8** and the tool body **12**.

Referring to Figure 1, the flapper valve **10** may be arcuate in shape and comprises a top surface **34**, a bottom surface **36**, and an outer perimeter **25**. The top surface **34** and the bottom surface **36** both have a curvature. In an embodiment of the invention, the flapper valve **10** is formed so that at least portions of the top surface **34** and the bottom surface **36** adjacent the outer perimeter **25** have the same curvature. In another embodiment of the invention, the entire top surface **34** and bottom surface **36** have the same curvature. Having "uniform" or "substantially the same" curvature may also include geometries where the flapper valve **10** has a uniform axial width or a uniform axial length at least along its outer perimeter **25**.

In another embodiment of the invention (shown in Figure 11), a flapper valve **438** is similarly arcuate in shape and has a substantially uniform curvature of its top surface **442** and its bottom surface **444**. In contrast to the flapper valve (**10** in Figure 1) of the previous embodiment, the flapper valve **438** comprises a perimeter portion **445** where a top perimeter surface **441** and a bottom perimeter surface **443** of the perimeter portion **445** are substantially perpendicular to a longitudinal axis of the tool body (**12** in Figure 9A). The substantially flat top perimeter surface **441** is adapted to engage a bottom surface **114A** of an upper tube member **108A** and the substantially perpendicular bottom perimeter surface **443** is adapted to engage a top surface **116A** of the lower tube member **110A**. The substantially perpendicular top **441** and bottom **443** perimeter surfaces may further comprise a sealing device (not shown) (such as, for example, an elastomer gasket, an elastomer seal, or a similar device) to assist in forming a sealing engagement with the upper **108A** and lower **110A** tube members. Further, the bottom surface **114A** of the upper tube member **108A** and the top surface **116A** of the lower tube member **110A** may be adapted to sealingly engage the top perimeter surface **441** and the bottom perimeter surface **443**, respectively, of the flapper valve **438**.

In another embodiment of the invention (shown in Figure 12), a perimeter portion **472** of a flapper valve **471** is arcuate in shape and has a substantially uniform curvature. However, in this embodiment, a top perimeter surface **478** and a bottom perimeter surface **480** of the perimeter portion **472** subtend an angle **482** with respect to a line **484** perpendicular to a longitudinal axis of a tool body (**400** in Figure 9A). The angle **482** may be, for example, 10 degrees, and the angle **482** of the top perimeter surface **478** and the bottom perimeter surface **480** helps support the upper tube member **108A**, the flapper valve **471**, and the lower tube member **110A** when an internal bore **401** of the tool body (**400** in Figure 9A) is pressurized. The upper perimeter surface **478** and the lower perimeter surface **480** may likewise be provided with a sealing device (not shown) as described in the previous embodiment. Further, the upper tube member **108A** and the lower tube member **110A** may be adapted to sealingly engage the top perimeter surface **478** and the bottom perimeter surface **480** so that the sealing engagement accommodates the angle **482**. For example, a bottom surface **114B** and a top surface **116B** may be angled to match the angle **482** formed on the flapper valve **471**.

As shown in Figures 2A and 2B, the retractable valve **100** in an embodiment of the invention comprises a flow tube assembly **102** disposed within the tool body **12**. The flow tube assembly **102** is operatively connected to the flapper valve (**10** in Figure 2B). The tool body **12** generally comprises an upper sub **6**, an upper middle sub **7**, the flapper housing **8**, and a lower sub

9, each interconnected as shown in Figures 2A and 2B. However, the tool body **12** can be formed from one integral member or from any number of subsections and still be within the scope of the invention. For purposes of clarity and brevity, each of the subparts of the tool body **12** (including the upper sub **6**, the upper middle sub **7**, the flapper housing **8**, and the lower sub **9**) will generally be referred to generally as the tool body **12**.

The flow tube assembly **102** is concentrically and slidably disposed within the internal bore **13** of the tool body **12**. Based on its sliding engagement within tool body **12** and its operative connection to the flapper valve (**10** in Figure 2B), the flow tube assembly **102** typically operates in two positions corresponding to the closed (**30** in Figure 2A) and open (**32** in Figure 2B) positions of the flapper valve (**10** in Figure 2B). When the flapper valve (**10** in Figure 2B) is in the closed position (**30** in Figure 2B), the flow tube assembly (**102** in Figure 2B) is in a valve sealing position (**104** in Figure 2B). When the flapper valve (**10** in Figure 3B) is in the open position (**32** in Figure 3B), the flow tube assembly (**102** in Figure 3B) is in a tube engaging position (**106** in Figure 3B).

The flow tube assembly **102** preferably comprises a upper tube member (**108** in Figure 2B) and a lower tube member (**110** in Figure 2B), each of which is concentrically and slidably disposed within the internal bore **13** of the tool body **12**. The upper tube member (**108** in Figure 2B) includes a top end (**112** in Figure 2A) and a bottom end (**114** in Figure 2B). The lower tube member (**110** in Figure 2B) also includes a top end (**116** in Figure 2B) and a bottom end (**118** in Figure 2B). The first (**108** in Figure 2B) and second (**110** in Figure 2B) tube members are arranged so that the upper tube member bottom end (**114** in Figure 2B) is proximate the lower tube member top end (**116** in Figure 2B) and so that the upper tube member bottom end (**114** in Figure 3B) is capable of abutting and/or mating with the lower tube member top end (**116** in Figure 3B).

As previously shown in Figure 2B, when the flapper valve **10** is in the closed position **30**, the flow tube assembly **102** is in the valve sealing position **104**. In the valve sealing position **104**, the flapper valve **10** is sealingly engaged on its top surface **34** and on its bottom surface **36** by the flow tube assembly **102** so that the flapper valve **10** prohibits flow of fluids through the internal bore **13** of the tool body **12**. In an embodiment of the invention, the flapper valve top surface **34** is sealingly engaged by the upper tube member **108**, preferably by the upper tube member bottom end **114**. Further, the flapper valve bottom surface **36** is sealingly engaged by the lower tube member **110**, preferably by the lower tube member top end **116**. The flapper valve **10** is preferably constructed so that the outer perimeter **25** of the flapper valve **10** is intermediate (*e.g.*, clamped between) the upper tube member **108** and the lower tube member **110** when the flapper valve **10** is in the closed position **30**.

In an embodiment of the invention, the upper tube member bottom end **114** and the lower tube member top end **116** each include a sealing element **120** around their respective perimeters. The sealing elements **120** aid the sealing engagement of the upper tube member bottom end **114** to the flapper valve top surface **34** and the sealing engagement of the lower tube member top end **116** to the flapper valve bottom surface **36**. In order to sealingly engage the flapper valve top surface **34**, the upper tube member bottom end **114** has substantially the same shape (*e.g.*, curvature) as the flapper valve top surface **34**. Thus, the upper tube member bottom end **114** also defines an arcuate shape and sealingly engages the flapper valve top surface **34**. Similarly, in order to sealingly engage the flapper valve bottom surface **36**, the lower tube member top end **116** has substantially the same shape as the flapper valve bottom surface **36**. Therefore, the lower tube member top end **116** also defines an arcuate shape and sealingly engages the flapper valve bottom surface **36**.

Referring to Figure 2B, an embodiment of the retractable valve **100** also comprises a biasing mechanism **122**. When the flapper valve **10** is in the closed position **30**, the biasing mechanism **122** assists in maintaining the sealing engagement between the upper tube member bottom end **114** and the flapper valve top surface **34**, and between the lower tube member top end **116** and the flapper valve bottom surface **36**. In one embodiment, the biasing mechanism **122** comprises at least one spring **124**. One end of each spring **124** is attached to the upper tube member **108** proximate the upper tube member bottom end **114**. The other end of each spring **124** is attached to the lower tube member **110** proximate the lower tube member top end **116**. The springs **124** bias the upper tube member **108** towards the lower tube member **110** so that the flapper valve **10** is compressed between them. In one embodiment, three springs **124** are disposed around the perimeters of upper tube member **108** and lower tube member **110**. The three springs **124** may be disposed, for example, at 90, 180, and 270 degrees around the perimeter of the tube members **108**, **110** from the azimuthal position of the pivot pin **22** as shown, for example, in Figure 5.

Referring to Figure 3B, when the flapper valve **10** is in the open position **32**, the flow tube assembly **102** is in the tube engaging position **106**. In the tube engaging position **106**, the flapper valve **10** pivots about the pivot pin **22** and is housed within the recess **26** of the tool body **12**, leaving the internal bore **13** of the tool body **12** unobstructed. Also in the tube engaging position **106**, the upper tube member bottom end **114** is cooperatively engaged to the lower tube member top end **116**.

Referring to Figure 7, the arcuate shape of the flapper valve **10** enables the flapper valve **10** to fit within the recess **26** of the tool body **12**. The flapper valve **10** may be further formed so that its axial width (or “thickness”) is not larger than the radial width of recess **26** so that the flapper valve **10** can be fully housed within the recess **26**. When housed in the recess **26**, the flapper valve bottom surface **36** is adjacent the flow tube assembly (**102** in Figure 2A) (specifically, the lower tube member (**110** in Figures 3B and 7)) and the flapper valve top surface **34** is adjacent the tool body **12** (specifically, the flapper housing **8**).

The upper tube member bottom end (**114** in Figure 2B) has substantially the same arcuate shape as the flapper valve top surface (**34** in Figure 2B), and the lower tube member top end (**116** in Figure 2B) has substantially the same arcuate shape as the flapper valve bottom surface (**36** in Figure 2B). Moreover, the curvatures of the flapper valve top surface (**34** in Figure 2B) and the flapper valve bottom surface (**36** in Figure 2B) are typically selected to be substantially the same (*e.g.*, the axial length or width of the flapper valve (**10** in Figure 2B) is substantially uniform at least along the outer perimeter (**25** in Figure 1)). This geometric arrangement enables the upper tube member bottom end (**114** in Figure 2B) to cooperatively engage the lower tube member top end (**116** in Figure 2B) around their entire perimeters when the flapper valve (**10** in Figure 2B) is in the open position (**32** in Figure 3B) and housed within the recess (**26** in Figure 3B). Sealing elements (**120** in Figure 3B) that may be arranged around the perimeters of both the upper tube member bottom end (**114** in Figure 3B) and the lower tube member top end (**116** in Figure 3B) help form a sealing engagement between the upper (**108** in Figure 3B) and lower (**110** in Figure 3B) tube members.

In an embodiment of the invention, the retractable valve **100** also comprises an actuating mechanism (**150** in Figure 2A) that causes, after receiving an appropriate stimulus, the flapper valve (**10** in Figure 2B) to pivot from the closed position (**30** in Figure 2B) to the open position (**32** in Figure 3B) and the flow tube assembly (**102** in Figure 2B) to slide from the valve sealing position (**104** in Figure 2B) to the tube engaging position (**106** in Figure 3B). An appropriate stimulus may include, for example, a pressurization of fluid in the internal bore (**13** in Figure 2A) (*e.g.*, a pressure pulse or "cycle" may be generated by turning a surface pump on and off or by varying a surface pump rate) of the retractable valve **100**. In an embodiment of the invention, the actuating mechanism (**150** in Figure 2B) causes the flapper valve (**10** in Figure

2B) to move from the valve sealing position (**104** in Figure 2B) to the tube engaging position (**106** in Figure 3B) after the last of a pre-determined number of pressure cycles has been experienced by the retractable valve **100**. The actual operation of the retractable valve **100**, including the movement of the flapper valve (**10** in Figure 2B) from the closed (**30** in Figure 2B), valve sealing position (**104** in Figure 2B) to the open (**32** in Figure 3B), tube engaging position (**106** in Figure 3B) will be described in detail below.

Referring to Figure 2A, in an embodiment of the invention, the actuating mechanism **150** comprises an indexing system **152** responsive to a predetermined number of pressure cycles in, for example, the internal bore **13** of the retractable valve **100**. Indexing systems that can be used with an embodiment of the invention are known in the art and include, for example, j-slot mechanisms and ratchet mechanisms. The indexing mechanism **152** may be disposed, as shown in Figure 2A, intermediate the tool body **12** and the flow tube assembly **102**. The indexing system **152** generally comprises at least one indexer leg **158** and a sliding indexer sleeve **156**. In an alternative embodiment (not shown), the indexer legs **158** may extend directly from the tool body **12**. In another embodiment, as shown in Figure 2A, the indexer legs **158** may extend from a stationary indexer sleeve **154** through the tool body **12**. The stationary indexer sleeve **154** is cooperatively attached to the tool body **12** and generally surrounds the flow tube assembly **102**. The sliding indexer sleeve **156** is slidably disposed intermediate the tool body **12** and the flow tube assembly **102**. Each indexer leg **158** is typically biased inwardly by a leg spring **160** into a series of indexer slot sets **162** defined on the sliding indexer sleeve **156**. As best shown in Figure 4, the number of indexer slot sets **162** corresponds to a selected number of pressure cycles that may be performed before the actuating mechanism (**150** in Figure 2A) causes the flapper valve (**10** in Figure 2A) to pivot from the closed position (**30** in Figure 2B) to the open position (**32** in Figure 3B) and the flow tube assembly (**102** in Figure 2A) to slide from the valve sealing position (**104** in Figure 2B) to the tube engaging position (**106** Figure 3B). Referring again to Figure 2A, an indexer spring **164** is disposed between a tab **166** on the flow tube assembly exterior surface **103** and the sliding indexer sleeve **156**. The indexer spring **164** functions to bias the sliding indexer sleeve **156** to its appropriate position, as will be discussed in detail below.

Additionally (referring to Figures 2A and 6), an embodiment of the invention further comprises a securing mechanism **180** that further aids in maintaining the flapper valve (**10** in Figure 2B) in the closed position (**30** in Figure 2B) and the flow tube assembly in the valve sealing position (**104** in Figure 2B) until the last of the pre-determined number of pressure cycles has been completed. The securing mechanism **180** typically comprises an annular member **182** with a plurality of dogs **184**. The annular member **182** is securely disposed between the flow tube assembly **102** and the sliding indexer sleeve **156** when the flapper valve (**10** in Figure 2B) is in the closed position (**30** in Figure 2B), and between the flow tube assembly **102** and tool body **12** when the flapper valve (**10** in Figure 3B) is in the open position (**32** in Figure 3B). The plurality of dogs **184** are disposed within a plurality of dog holes **186** in the annular member **182**, and the plurality of dogs **184** extend into slots **188** formed on the exterior surface **103** of the flow tube assembly **102**.

Referring to Figure 3B, in an embodiment of the invention, a guide sleeve **212** is disposed concentrically between the tool body **12** and the lower tube member **110** so that the lower tube member **110** is intermediate the tool body **12** and the guide sleeve **212** within an annular space **300**. The guide sleeve **212** is typically attached to the tool body **12** and acts to guide the lower tube member **110** during the sliding motion thereof. Further, a face seal **302** is disposed within the annular space **300** on a lip **210** defined on the tool body **12**. When the flapper valve **10** is in the closed position (**30** in Figure 2B) and the flow tube assembly (**102** in Figure 2B) is in the valve sealing position (**104** in

Figure 2B), the lower tube member bottom end (**118** in Figure 2B) typically abuts and sealingly engages the face seal **302**. The face seal **302** prevents pressure downhole of the flapper valve (**10** in Figure 2B) from causing fluid in the internal bore (**13** in Figure 2B) to seep into any annular spaces behind, for example, the lower tube member (**110** in Figure 2B) and into, for example, the recess (**26** in Figure 2B).

Referring to Figures 2B and 3B, several tube seals **192** are located throughout the flow tube assembly **102** and the tool body **12** in order to sealingly engage the flow tube assembly **102** and to support the sliding movement of the flow tube assembly **102** in relation to the tool body **12**. For example, a tube seal (**192** in Figure 2A), disposed on a shoulder (**190** in Figure 2A) defined on the tool body (**12** in Figure 2A), sealably engages the upper tube member (**108** in Figure 2A). Another tube seal (**192** in Figure 3B), disposed on the annular member (**182** in Figure 3B), also sealably engages the upper tube member (**108** in Figure 3B).

Several indexer seals (**193** in Figures 2A and 3A) are also included on the sliding indexer sleeve (**156** in Figure 2A) in order to sealingly engage the flow tube assembly (**102** in Figure 2A) and to support sliding movement of the sliding indexer sleeve (**156** in Figure 2A) in relation to the tool body (**12** in Figure 2A) and to the flow tube assembly (**102** in Figure 2A). For example, an indexer seal (**193** in Figure 3A), disposed on the surface of sliding indexer sleeve (**156** in Figure 3A) proximate the flow tube assembly (**102** in Figure 3A) sealingly engages the upper tube member (**108** in Figure 3A). Another indexer seal (**193** in Figure 3A), disposed on the surface of sliding indexer sleeve (**156** in Figure 3A) proximate the tool body (**12** in Figure 3A), sealingly engages the upper middle sub (**7** in Figure 3A).

Operation of an Embodiment of the Downhole Valve

The following description details an example of the operation of an embodiment of the downhole or retractable valve **100**. The operation described below occurs when the retractable valve **100** is placed in a downhole environment to test, for example, the sealing integrity of production tubing, well liners, etc. The description is not intended to limit the scope of the invention because the retractable valve **100** would operate equally well when testing, for example, an above ground pipeline. The retractable valve **100** also operates equally well in both vertical, slanted, or horizontal arrangements and, therefore, is useful in both vertical and directional wells.

Referring to the embodiment shown in Figures 1-8, when the retractable valve **100** is positioned in a tubing string or in drillpipe, the flapper valve **10** is usually in the closed position **30**, and the flow tube assembly **102** is therefore in the valve sealing position **104**. The flow tube assembly **102** is maintained in its position by several features including the indexing system **152** and the securing mechanism **180**. In addition, the lower tube member bottom end **118** is in contact with the face seal **302**.

The flapper valve **10** is sealingly engaged on its top surface **34** by the upper tube member bottom end **114** and on its bottom surface **36** by the lower tube member top end **116**, and the biasing mechanism **122** compresses the flapper valve **10** between them. Since the flapper valve **10** completely obstructs the internal bore **13** of the tool body **12**, the flapper valve **10** prohibits any flow of fluids therethrough. Moreover, since the flapper valve **10** is sealingly engaged on both its top surface **34** and its bottom surface **36** and is prevented from pivoting in any direction by its contact with the upper **108** and lower **110** tube members, the flapper valve **10** may withstand pressure on both its top side **34** and its bottom side **36** without pivoting from its closed position **30**.

Further, because the cross-sectional areas (which may be, for example, elliptical) of the extension passageway **18** and the flapper housing passageway **20** are slightly larger than the cross-sectional area of the pivoting pin **22**, the flapper valve **10** may experience some small axial movement without affecting the sealing engagement between the flapper valve **10** and the upper **108** and lower **110** tube members. The ability of the flapper valve **10** to compensate for the small axial movement helps the flapper valve **10** compensate for pressure changes both uphole and downhole. The securing mechanism **180** provides support for absorbing any load generated by pressurization of the tool body **12**, particularly if a higher pressure is present on the top surface **34** (*e.g.*, the uphole side) of the flapper valve **10**.

Once the retractable valve **100** is properly positioned in the tubing string or drillpipe, an operator may conduct pressure testing of downhole equipment. For purposes of discussion, the sequence of events produced by one pressure cycle will be explained. However, the indexing system **152** may operate a plurality of times after a plurality of pressure cycles are experienced before actuating the flapper valve **10** to the open position **32** and moving the flow tube assembly **102** to the tube engaging position **106**. The sequence of events produced by one pressure cycle is typically repeated until a selected number of pressure cycles (*e.g.*, five pressure cycles in the embodiment shown in Figures 1-8) is achieved. The events that occur after achieving the selected number of pressure cycles will also be described below.

Referring to Figure 2B, the internal bore **13** of the tool body **12** is pressurized (*e.g.*, by a surface pump such as a surface mud pump or a cement pump) in a first pressure cycle. Because the flapper valve **10** is in the closed position **30**, the flapper valve **10** will prohibit any flow of pressurized fluids through the internal bore **13**. The pressurized fluids may, however, exit the internal bore **13** through an indexer port **168** that is formed through the flow tube assembly **102** (and through the annular member **182**) and that provides fluid communication between the internal bore **13** and an indexer chamber **170**. The indexer chamber **170** is at least partially defined in one embodiment by the sliding indexer sleeve **156** and by the annular member **182** and the sliding indexer sleeve **156**.

As the pressure is increased in the internal bore **13**, the pressure also increases in the indexer chamber **170** due to the fluid communication provided by indexer port **168**. Before any indexing motion is initiated, the sliding indexer sleeve **156** is held in place by the cooperative engagement of the indexer legs **158** and the indexer slot sets **162**. As best shown in Figure 4, each slot set **162** includes slots **172A-172E** and slots **174A-174E**. Prior to the commencement of each pressure cycle, each indexer leg **158** is disposed within, for example, slot **172A** of the corresponding slot set **162**. The sliding indexer sleeve **156** remains stationary until the pressure in the internal bore **13** (and indexer chamber **170**) is increased to a level that generates sufficient pressure so that the sliding indexer sleeve **156** slides upward (*e.g.*, uphole) and compresses the indexer spring **164**. The upward movement of the sliding indexer sleeve **156** compresses the indexer spring **164** and also causes each indexer leg **158** to move from the slot **172A** to slot **174A** of the relevant slot set **162**. The upward movement of the sliding indexer sleeve **156** typically further comprises a rotation of the sliding indexer sleeve **156** with respect to the tool body **12** as each indexer leg **158** advances from slot to slot. The rotation of the sliding indexer sleeve **156** may be either clockwise or counterclockwise with respect to the tool body **12**, and the direction of rotation is not intended to limit the invention.

When the first pressure cycle is complete and the pressure is decreased within the internal bore **13** and within the indexer chamber **170**, several forces serve to cause the sliding indexer sleeve **156** to slide back towards the indexer chamber **170** and rotates, thereby also causing each indexer leg **158** to move from the slot **174A** to slot **172B** of the slot set **162**. For example, in one embodiment the tool body **12** may include an outlet port **250** that provides fluid communication between the annulus defined between the exterior of the tool body **12** and the well casing **5** and a return chamber **252**. Return chamber **252** is defined between the tool body **12** and the flow tube assembly **102** and from shoulder **190** to the sliding indexer sleeve **156**. The pressure within the return chamber **252** acts on sliding indexer sleeve **156** and opposes the pressure within the indexer chamber **170**. Once the pressure is decreased in the internal bore **13** and in indexer chamber **170**, the pressure in the return chamber **252** will typically be greater than that in the indexer chamber **170** and will cause the sliding indexer sleeve **156** to slide back towards indexer chamber **170** and rotate. The indexer spring **164** may also assist in biasing the sliding indexer sleeve **156** back toward its original position, particularly in cases when the pressure at the indexer spring **164** side of the sliding indexer sleeve **156** is the same or less than the pressure in the indexer chamber **170**.

In another embodiment, as shown in Figure 8, a nitrogen charge **256** may be disposed within the return chamber **252**. At a selected time (*e.g.*, when the pressure is decreased in the internal bore **13** and the sliding indexer sleeve **156** is moving back toward its original position), pressure from the nitrogen charge **256** provides additional force for moving the sliding indexer sleeve **156** back toward its original position (*e.g.*, downhole). In this embodiment, the return chamber **252** is preferably sealed so that the outlet port **250** is typically eliminated or plugged.

The sequence of the subsequent pressure cycles is substantially the same as those previously described as the indexer legs **158** move through slots **172B-172E** and **174B-174E**, until the last of the predetermined number of pressure cycles. The indexing system **152** illustrated in the Figures is designed to allow five pressure cycles, corresponding to the five indexer slot sets **162**, before the flapper valve **10** and the flow tube assembly **102** are actuated and moved into an open position (**32** in Figure 3B). However, a designer may select any number of pressure cycles by appropriately configuring the actuating mechanism **150** and the indexing system **152** to correspond to the chosen number of cycles.

During the last (*e.g.*, the fifth) pressure cycle, the indexer legs **158** are moved from slot **172E** to slot **174E**. After the sliding indexer sleeve **156** has compressed the indexer spring **164** as a result of increased pressure within internal bore **13** and indexer chamber **170**, the pressure is once again decreased within internal bore **13** and indexer chamber **170**. As a result, each indexer leg **158** moves to the last slot **175**. At this point, the retractable valve **100** is not configured to withstand any more pressure cycles without allowing the flapper valve **10** to pivot from its closed position **30** to its open position **32**.

When the operator is prepared to pivot the flapper valve **10** from its closed position **30** to its open position **32**, the operator pressurizes the tool body **12** another time (*e.g.*, a sixth time). The increased pressure in the internal bore **13** and the indexer chamber **170** causes the sliding indexer sleeve **156** to slide toward and compress indexer spring **164**. Concurrently (because there are no more slot sets **162** for the indexer legs **158** to engage), each indexer leg **158** is guided into an indexer outlet groove **176** that enables each of the indexer legs **158** to completely disengage from the indexing system **152**. The disengagement of the indexing system **152** and the continued pressurization of the indexer chamber **170** enables the sliding indexer sleeve **156** to continue its sliding movement and further compress indexer spring **164**. At a certain point during its slide, the sliding indexer sleeve **156** contacts tab **166**, which is disposed on the exterior surface **103** of the flow tube assembly **102**. At another selected point during its slide, the sliding indexer sleeve **156** slides out of abutment with the securing mechanism **180**. As a result, and as illustrated in Figure 3B, the plurality of dogs **184** are no longer secured within their respective slots **188** on the exterior surface **103** of the flow tube assembly **102**. Provided that the pressure in the indexer chamber **170** is high enough, the sliding indexer sleeve **156** continues its upward sliding motion (driven by the pressure) and imparts an upward force on the tab **166**. The upward force applied to the tab **166** forces the flow tube assembly **102** upwards, which force completely disengages the dogs **184** from within the respective slots **188**. The dogs **184** subsequently move outward through the dog holes **186** in the annular chamber **182** and produce a disengagement of the securing mechanism **180**. The disengagement of the securing mechanism **180** enables the flow tube assembly **102** to be carried upward as a result of the upward force provided by the pressure acting on the sliding indexer sleeve **156** and to freely slide within the tool body **12**. The sliding indexer sleeve **156** and the flow tube assembly **102** continue their upward slide until the tab **166** of the upper tube member **108** contacts a shoulder **190** attached to the tool body **12**.

Referring to Figure 3B, the upward movement of the upper tube member **108** causes the lower tube member **110** to also move upwards because the upper **108** and lower **110** tube members are connected by the biasing mechanism **122** and due to the pressure of the internal bore. As a result, the flapper valve **10**, which is positioned between the upper tube member **108** and the lower tube member **110**, is at first also forced upward by the upward movement of the flow tube assembly **102**. The flapper valve **10** then begins to pivot about pivoting pin **22**. During the pivoting motion, the flapper valve **10** first becomes disengaged from the flow tube assembly **102** at the side of flapper valve **10** opposite the pivoting pin **22**. Further upward movement of the flow tube assembly **102** rotates the flapper valve **10** until it is substantially parallel with the longitudinal axis of the tool body **12** and completely disengages from the flow tube assembly **102** and is positioned in the recess **26** of the tool body **12**. At this point, the flapper valve **10** is in its open position **32**. The springs **124** of the biasing mechanism **122** may extend somewhat during the upward slide of the flow tube assembly **102** and assist in rotating the flapper valve **10** from the closed position **30** to the open position **32**.

Referring to Figure 3B, when in the closed position **32**, the flapper valve **10** permits an unobstructed flow of fluids within the internal bore **13** of the tool body **12**. Further, with the flapper valve **10** disengaged from the flow tube assembly **102**, the lower tube member **110** continues to slide upward and is pulled into contact with the upper tube member **108** by the biasing mechanism **122** and the pressure in the internal bore. Because the upper tube member bottom end **114** is formed to cooperatively mate with the lower tube member top end **116** (*e.g.*, because the arcuate shapes of the upper surface **34** and the lower surface **36** of the flapper valve **10** are typically substantially the same), the biasing mechanism **122** helps to bring the upper tube member **108** and the lower tube member **110** into a cooperative engagement. The cooperative engagement between upper tube member **108** and lower tube member **110** is important because it provides for an unobstructed flow of fluids within the internal bore **13**. In the embodiment including sealing elements **120**, the sealing elements provide a cooperative sealing engagement between the upper and lower tube members **108** and **110** thereby preventing leakage of fluid from the internal bore **13**.

In an embodiment of the invention, the flow tube assembly **102** further comprises a locking mechanism (**200** in Figure 3B) that locks the flow tube assembly **102** in the tube engaging position **106**. The locking mechanism (**200** in Figure 3B) typically comprises at least one ratchet member (**202** in Figure 3B) disposed on the tool body **12** and a locking surface (**206** in Figures 2B and 3B) defined on the exterior surface **103** of the flow tube assembly **102**. Each ratchet member (**202** in Figure 3B) includes ratchet member teeth (**204** in Figure 3B) proximate the flow tube assembly **102**. The locking surface (**206** in Figure 3B) includes locking surface teeth (**208** in Figure 3B) that mate with the ratchet member teeth (**204** in Figure 3B).

In the valve sealing position **104** shown in Figure 2B, when the flapper valve **10** is in the closed position **30**, the locking surface (**206** in Figure 2B) is located below the ratchet members (**202** in Figure 2B). During the upward movement of the flow tube assembly **102** from the valve sealing position **104** to the tube engaging position **106**, the locking surface (**206** in Figure 2B) slides toward the ratchet member (**202** in Figure 2B). Once the locking surface teeth (**208** in Figure 3B) are in direct contact with the ratchet member teeth (**204** in Figure 3B), the ratchet member teeth (**204** in Figure 3B) and the locking surface teeth (**208** in Figure 3B) are designed to allow the locking surface (**206** in Figure 3B) to move upward in relation to the ratchet members (**202** in Figure 3B) but to prohibit the locking surface (**206** in Figure 3B) (and flow tube assembly **102**) to move downward (*e.g.*, downhole). Thus, once the lower tube member **110** stops its upward movement, the cooperative engagement of the ratchet member teeth (**204** in Figure 3B) and the locking surface teeth (**208** in Figure 3B) locks the lower tube member **110** (and the flow tube assembly **102**) axially in place.

Additional Embodiments of the Downhole Valve

Another embodiment of the invention is shown in Figures 9A-9E and 10A-10E. Referring to Figure 9A, an embodiment of the invention comprises a downhole valve **399** comprising a tool body **400** and a flow tube assembly **402.** The tool body **400** further comprises an upper sub **405**, an upper middle sub **407**, a middle sub (**409** in Figure 9B), a middle sub (**411** in Figure 9C), a lower middle sub (**413** in Figure 9D), a lower sub (**415** in Figure 9E), and a flapper housing (**448** in Figure 9D). For simplicity and clarity, the subs (**405**, **407**, **409**, **411**, **413**, and **415**) will be referred to as being part of the tool body **400**.

The operation of the downhole valve (**399** in Figure 9A) is similar to the operation of the valve (**100** in Figure 2A) discussed in previous embodiments. However, there are differences that will be discussed in detail below. The downhole valve (**399** in Figure 9A) is generally positioned in a downhole casing string (**404** in Figure 9A) or other tubular string (such as, for example, production tubing). The flow tube assembly (**402** in Figure 9A) is positioned inside the tool body (**400** in Figure 9A) and further comprises an upper tube member (**108A** in Figure 9A) and a lower tube member (**110A** in Figure 9D).

The upper tube member (**108A** in Figure 9A) and the lower tube member (**110A** in Figure 9D) are adapted to sealingly engage a flapper valve (**438** in Figure 9D) when the flapper valve (**438** in Figure 9D) is in a closed position (**446** in Figure 9D). The sealing engagement has been previously described in the discussion of Figures 11 and 12.

The flow tube assembly (**402** in Figure 9A) also comprises an upper spring (**410** in Figure 9A) that is positioned between an upper shoulder (**470** in Figure 9A) formed on the upper tube member (**108A** in Figure 9A) and a bearing assembly (**412** in Figure 9A). The upper spring (**410** in Figure 9A) operates cooperatively as a part of an indexing system (**435** in Figure 9B) by providing an axial force that helps hold an indexer leg (**414** in Figure 9B) of the indexing system (**435** in Figure 9B) in an appropriate slot formed on a sliding indexer sleeve (**416** in Figure 9B). The bearing assembly (**412** in Figure 9A) operates cooperatively as a part of the indexing system (**435** in Figure 9B) by permitting the sliding indexer sleeve (**416** in Figure 9B) to rotate relative to the upper spring (**410** in Figure 9A) when the indexing system (**435** in Figure 9B) is operating. The bearing assembly (**412** in Figure 9A) may comprise a roller bearing, a needle bearing, a pair of thrust washers, or any other bearing known in the art.

Referring to Figure 9B, the indexing system **435** is similar to the indexing system (**152** in Figure 2B) of previous embodiments. The indexing system **435** typically comprises one indexing leg **414** and a sliding indexer sleeve **416**. As shown in Figure 9B, the indexer leg **414** is attached to the tool body **400** (specifically to the middle sub **409**). The attachment may be a fixed attachment (*e.g.*, via a weld, etc.), a removable attachment (*e.g.*, similar to that shown in the previous embodiments), or any other attachment mechanism known in the art. The sliding indexer sleeve **416** is positioned intermediate the tool body **400** and the flow tube assembly **402**. The indexer leg **414** engages the sliding indexer sleeve **416** during the operation of the indexing system **435** enabling the indexer sleeve **416** to slide in an upward direction, thereby compressing the upper spring **410**. As disclosed in previous embodiments, the upward movement of the sliding indexer sleeve **416** typically further comprises a rotation of the sliding indexer sleeve **416** with respect to the tool body **400**.

Referring again to Figure 9B, the operation of the indexing system **435** is similar to that of the previous embodiment. To operate the indexing system **435** when the flapper valve (**438** in Figure 9D) is in the closed position (**446** in Figure 9D), the internal bore **401** of the tool body **400** is pressurized by, for example, a surface pump for a selected number of pressure cycles. When the internal bore **401** is pressurized, the high pressure from the internal bore **401** is transmitted through a port **428** in the upper tube member **108A** and through port **430** in the sliding indexer sleeve **416** into a lower chamber **514**. The high pressure in the lower chamber **514** forces the sliding indexer sleeve **416** upward and rotates the sliding indexer sleeve **416**, thereby compressing the upper spring **410** and starting the indexing process. When the pressure in the internal bore **401** is decreased at the end of a pressure cycle, the pressure in the lower chamber **514** is also decreased. External fluid pressure (which may also be referred to as annular fluid pressure, and which at this point is generally higher than the fluid pressure in the internal bore **401**) may then enter the tool body **400** through a port (**468** in Figure 9A) formed in the tool body **400**. The fluid enters through the port (**468** in Figure 9A) and into an upper chamber (**515** in Figure 9A). The fluid pressure in the upper chamber (**515** in Figure 9A) acts to force the indexer sleeve **416** axially downward and to rotate the sliding indexer sleeve **416** until the indexer leg **414** is seated in an appropriate slot (as will be described in detail below). The upper spring **410** also provides an axially downward (*e.g.*, downhole) force that helps seat the indexer leg **414** in the appropriate slot.

Referring to Figure 9A, the upper chamber **515** is sealed at an upper end by at least one seal **466**. The seal **466** is formed against an outer surface **516** of the upper tube member **108A**. The upper chamber **515** is sealed at a lower end by at least one seal **517**. Referring to Figure 9B, the lower chamber **514** is similarly sealed at a lower end by at least one seal **513** and at an upper end by at least one seal **517**.

As shown in Figure 13, the sliding indexer sleeve comprises a plurality of indexer slots **500A-500G** and **502A-502G**. Each pair of slots (*e.g.*, **500A** and **502A**) correspond to the operation of the indexing system **435** in response to a pressure cycle (as previously defined in the discussion of the other embodiments). For example, Figure 13 shows seven pairs of slots (**500A/502A-500G/502G**) that correspond to seven pressure cycles in the operation of the indexing system **435**. After the seventh pressure cycle has been completed, the indexer leg **414** enters an indexer outlet groove **501** and slides so that the sliding indexer sleeve **416** is disengaged from the indexer leg **414** (thereby permitting the upper tube member **108A** to slidably move in an upward direction and compress upper spring (**410** in Figure 9A)).

Another embodiment of the invention also includes a ratcheting collet mechanism (**490** in Figure 14) that comprises a ratcheting collet (**418** in Figure 14) and a plurality of ratchet slots (**504A-504N** in Figures 13 and 14) in the sliding indexer sleeve (**416** in Figures 13 and 14). In operation, as the sliding indexer sleeve (**416** in Figure 14) rotates relative to the tool body (**400** in Figure 9A) in response to a pressure cycle, the ratcheting collet (**418** in Figure 14) advances from, for example, ratchet slot (**504A** in Figure 13) to ratchet slot (**504B** in Figure 13). Typically, the number of ratchet slots (**504A-504N** in Figure 13) comprises the total number of indexer slots (**500A-500G** plus **502A-502G** in Figure 13). For example, in Figure 13, the embodiment shown is designed to disengage the sliding indexer sleeve **416** after seven pressure cycles. As a result, there are a total of fourteen indexer slots (**500A-500G** plus **502A-502G** in Figure 13) in the sliding indexer sleeve **416**. Therefore, as shown in Figures 13 and 14, there are a total of fourteen ratchet slots **504A-**

504N.

The operation of the ratcheting collet mechanism (**490** in Figure 14) is similar to that of the indexing system (**435** in Figures 9B and 13). For example, when one (*e.g.*, the first) pressure cycle is completed, the indexer leg (**414** in Figure 13) moves from one indexer slot (**500A** in Figure 13) past indexer slot (**502A** in Figure 13) and into indexer slot (**500B** in Figure 13). As the sliding indexer sleeve (**416** in Figure 14) rotates, the ratcheting collet (**418** in Figure 14) correspondingly moves from ratchet slot (**504A** in Figure 14) to ratchet slot (**504C** in Figure 14). The ratcheting collet (**418** in Figure 14) is adapted to prevent the sliding indexer sleeve (**416** in Figure 14) from rotating in the opposite direction of that desired (*e.g.*, the ratcheting collet mechanism (**490** in Figure 14) prevents the sliding indexer sleeve (**416** in Figure 13) from moving downward so that the indexer leg (**414** in Figure 13) cannot move from, for example, indexer slot (**500B** in Figure 13) back to indexer slot (**500A** in Figure 13)). The ratchet slots **504A-504N**, as shown in Figure 14, are designed so that the ratchet collet (**418** in Figure 14) cannot move from, for example, ratchet slot (**504B** in Figure 14) to ratchet slot (**504A** in Figure 14) in a reversed rotation. However, as shown in Figures 13 and 14, after the seventh pressure cycle, the ratchet collet (**418** in Figure 14) enters the indexer outlet groove (**501** in Figures 13 and 14) (along with the indexer leg (**414** in Figure 13)) so that the sliding indexer sleeve (**416** in Figures 13 and 14) may move freely upward.

Referring to Figure 9B, and in a manner similar to that of previous embodiments, the invention further comprises a securing mechanism **421** that helps hold the upper tube member **108A** and the lower tube member **110A** in sealing engagement with the flapper valve **438** until the last of the predetermined number of pressure cycles has been completed. The securing mechanism (**421** in Figure 15) comprises an outer sleeve (**426** in Figure 15) that is slidably disposed intermediate the tool body (**400** in Figure 15) and an inner sleeve (**422** in Figure 15). The inner sleeve (**422** in Figure 15) is positioned intermediate the upper tube member (**108A** in Figure 15) and the outer sleeve (**426** in Figure 15) and includes a plurality of slots (**427** in Figure 15). The outer sleeve (**426** in Figure 15) may also be axially fixed in position with, for example, shear pins (**550** in Figure 15). However, any other similar securing mechanism known in the art may be used. A plurality of dogs (**424** in Figure 15) are positioned in the plurality of slots (**427** in Figure 15), and the dogs (**424** in Figure 15) are also cooperatively positioned in slots (**425** in Figure 15) formed in the upper tube member (**108A** in Figure 15). The dogs (**424** in Figure 9B) axially secure the upper tube member (**108A** in Figure 9B) in place because the dogs (**424** in Figure 9B) operatively connect the upper tube member (**108A** in Figure 9B) to the inner sleeve (**422** in Figure 9B) which is, in turn, secured to the tool body (**400** in Figure 9B) at a shoulder contact point (**429** in Figure 9B).

Referring to Figure 10B, the securing mechanism **421** is designed to release the upper tube member **108A** after the predetermined number of pressure cycles have been completed. In operation, after the predetermined number of pressure cycles (*e.g.*, after the seventh pressure cycle has been completed), the sliding indexer sleeve **416** has moved up so that a lower shoulder **423** of the sliding indexer sleeve **416** has contacted an upper shoulder **420** of the outer sleeve **426**. As the sliding indexer sleeve **416** begins to freely slide upwards, the sliding indexer sleeve **416** (because of the contact between the lower shoulder **423** and the upper shoulder **420**) urges the outer sleeve **426** upward so that the plurality of dogs **424** may move radially outward and out of the slots **425** in the upper tube member **108A**. The upper tube member **108A** is then no longer secured by the securing mechanism **421** and may slide freely upward. The upward movement of the upper tube member **108A** is produced by the upward movement of the sliding indexer sleeve **416** (which is produced by the pressure in the internal bore **401**).

Referring to Figure 9D, the flapper valve **438** of an embodiment of the invention is sealingly engaged in its closed position **446** by a bottom surface **114A** of the upper tube member **108A** and a top surface **116A** of the lower tube member **110A**. Referring to Figures 11 and 12, the bottom surface **114A** and the top surface **116A** may be adapted, for example, to sealingly engage the perimeter portion **472** of the flapper valve **471**. For example, Figure 12 shows that the bottom surface **114B** and the top surface **116B** may be angled to match an angle **482** formed by the top perimeter surface **478** and the bottom perimeter surface **480** of the perimeter portion **472** of the flapper valve **471**. As in the previous embodiment, the flapper valve **438**, the upper tube member bottom surface **114A,** and the lower tube member upper surface **116A** are constructed so that [1] the flapper valve **438** is sealingly engaged in its closed position **446** by the upper tube member bottom surface **114A** and the lower tube member top surface **116A** (see Figure 9D) and [2] the upper tube member bottom surface **114A** is cooperatively engaged to the lower tube member top surface **116A** when the flapper valve is in the open position **520** (see Figure 10D).

Referring again to Figure 9D, the flapper valve **438** further comprises a pivoting mechanism **440** similar to that of the previous embodiments. The pivoting mechanism **440** enables the flapper valve **438** to pivot from the closed position **446** to an open position **520** as shown in Figure 10D. The flapper valve (**438** in Figure 9D) is pivotally attached to the flapper housing (**448** in Figure 9D). In an embodiment of the invention, the flapper housing (**448** in Figure 9D) is typically rotationally secured in place by a pin (**450** in Figure 16) that engages a groove (**451** in Figure 16) on an external surface (**453** in Figure 16) of the flapper housing (**448** in Figure 16). Further, in the embodiment, the flapper housing (**448** in Figure 9D) is typically axially secured in place between a retaining ring (**452** in Figure 9D) and a shoulder (**455** in Figure 9D) of the tool body (**400** in Figure 9D).

When the flapper valve is in the closed position (**446** in Figure 9D), the lower tube member (**110A** in Figure 9D) is held against the flapper valve (**438** in Figure 9D) with the help of the securing mechanism **421** and since the lower tube member (**110A** in Figure 9E) is also wedged between the flapper valve **438** and a shoulder **600** on body **400**. The lower spring (**456** in Figure 9E) is initially at least partially compressed between an intermediate shoulder (**454** in Figure 9E) on the lower tube member (**110A** in Figure 9E) and a shoulder (**458** in Figure 9E) of the tool body (**400** in Figure 9E). After the indexing system (**435** in Figure 9C) has been cycled through the predetermined number of pressure cycles (*e.g.*, seven) and the upper tube member (**108A** in Figure 10D) has moved axially upward, the lower spring (**456** in Figure 10E) begins to extend axially upward.

After the indexing system (**435** in Figure 9C) has been cycled through the predetermined number of pressure cycles, the high pressure in the internal bore (**401** in Figure 10D) acts to move the sliding indexer sleeve (**416** in Figure 10B) and the upper tube member (**108** in Figure 10D) axially upward compressing the upper spring (**410** in Figure 10A). This collective movement is enabled by the engagement between the upper spring (**410** in Figure 10A), the upper shoulder (**470** in Figure 10A) on the upper tuber member (**108A** in Figure 10A), and the sliding indexer sleeve (**416** in Figure 10B). The upward movement of the upper tube member (**108A** in Figure 10A) continues until the upper shoulder (**470** in Figure 10A) of the upper tube member (**108A** in Figure 10A) contacts an upper seal ring (**408** in Figure 10A). At this point, the upper spring (**410** in Figure 10A) is substantially compressed between the sliding indexer sleeve (**416** in Figure 10B) and the upper shoulder (**470** in Figure 10B), and the upper tube member (**108A** in Figure 10A) is in its uppermost position.

In one embodiment, the upper tube member (**108A** in Figure 10A) is locked in this uppermost position by a plurality of upper ratchet members (**432** in Figure 10C) comprising upper ratchet member teeth (**536** in Figure 10C) that are adapted to engage similar upper locking surface teeth (**436** in Figure 10C) formed on the upper tube member (**108A** in Figure 10C). The teeth are formed so that when they are cooperatively engaged they prohibit the upper tube member (**108A** in Figure 10C) from moving downward but enable the upward movement of the upper tube member **108A** until it reaches its uppermost position. With the teeth engaged and the upper tube member **108A** is in its uppermost position, the upper tube member (**108A** in Figure 10C) is substantially secured axially in place.

It is noted that during the upward movement of the upper tube member **108A**, the flapper valve (**438** in Figure 9D) and the lower tube member (**110A** in Figure 9D) are maintained in their respective closed and lower positions by the pressure in the internal bore (**401** in Figure 9D) that induces the upward movement of the sliding indexer sleeve **416** and the upper tube member **108A**. The pressure in the internal bore (**401** in Figure 9D) acts downwardly against the flapper valve (**438** in Figure 9D) and the lower tube member (**110A** in Figure 9D).

Once the upper tube member (**108A** in Figure 10C) is locked in place, the pressure in the internal bore (**401** in Figure 10D) is decreased. After the pressure is decreased so that it provides less downward force on the flapper valve (**438** in Figure 10D) than the upward force provided on the flapper valve (**438** in Figure 10D) and lower tube member (**110A** in Figure 10D) by the lower spring (**456** in Figure 10E), the upward force of the lower spring (**456** in Figure 10D) pushes the lower tube member (**110A** in Figure 10D) and the flapper valve (**438** in Figure 10D) upward. As the upward movement continues, the flapper valve (**438** in Figure 10D) rotates about the pivoting mechanism (**440** in Figure 10D). The rotation of the of the flapper valve (**438** in Figure 10D) moves the flapper valve (**438** in Figure 10D) into a recess (**434** in Figure 10D) in the flapper housing (**448** in Figure 10D) and moves the flapper valve (**438** in Figure 10D) into the open position (**520** in Figure 10D).

Referring to Figure 10D, soon after the flapper valve **438** pivots into the recess **434**, the top surface **116A** of the lower tube member **110A** moves into a cooperative engagement with the bottom surface **114A** of the upper tube member **108A**. The lower spring **456**, which is sliding the lower tube member **110A** axially upward as it expands, forces the lower tube member **110A** against the upper tube member **108A**. As in the previous embodiment, the bottom surface **114A** of the upper tube member **108A** and the top surface **116A** of the lower tube member **110A** are formed to cooperatively mate with each other. Sealing elements (not shown) may also be arranged around the perimeters of both the bottom surface **114A** and the top surface **116A** to help form a sealing engagement.

In one embodiment, the lower tube member (**110A** in Figure 10D) is locked in this position by a plurality of lower ratchet members (**460** in Figure 10E) comprising lower ratchet member teeth (**512** in Figure 10E) that are adapted to engage similar lower locking surface teeth (**436** in Figure 10E) . formed on the lower tube member (**110A** in Figure 10E). The teeth are formed so that when they are cooperatively engaged they prohibit the lower tube member (**110A** in Figure 10E) from moving downward but enable the upward movement of the lower tube member (**110A** in Figure 10E) until it moves into cooperative engagement against the upper tube member (**108A** in Figure 10D). When the teeth are engaged and the lower tube member **110A** is in cooperative engagement with upper tube member **108A**, the lower tube member (**110A** in Figure 10E) is substantially secured axially in place.

At this point, the upper spring (**410** in Figure 10A) is substantially compressed, the upper tube member (**108A** in Figure 10A) and the lower tube member (**110A** in Figure 10D) are in a cooperative engagement, and the flapper valve (**438** in Figure 10D) is located in the recess (**434** in Figure 10D). The upper ratchet members (**432** in Figure 10C) and the lower ratchet members (460 in Figure 10C) also lock the upper tube member (**108A** in Figure 10C) and the lower tube member (**110A** in Figure 10E) in place. At this point, the internal bore (**401** in Figure 10D) of the downhole valve (**399** in Figure 10D) is completely free of obstructions and fluids may flow freely within the internal bore (**401** in Figure 10D).

Advantageously, the downhole valve provides a mechanism that provides a bore seal that can withstand both uphole and downhole pressure. The downole valve may be used to pressure test various downhole tubing and connections. After testing, the downhole valve may be actuated (*e.g.*, by pressure cycles or pressure pulses) so that the flapper valve moves from a valve sealing position to an open, tube engaging position. In the tube engaging position, the downhole valve provides a bore that is free of obstructions and that permits free passage of fluids and other tools.

Those skilled in the art will appreciate that other embodiments of the invention can be devised which do not depart from the spirit of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

CLAIMS

What is claimed is:

1. A downhole valve comprising:

a body;

a flow tube assembly positioned within the body, the flow tube assembly further comprising an upper tube member and a lower tube member; and

a flapper valve operatively attached to the flow tube assembly and adapted to pivot from a closed position wherein the flapper valve is sealingly positioned between the upper and lower tube members, to an open position,

wherein the flapper valve is pivoted to the open position and is enclosed in a recess in the body in response to an upward movement of the upper and lower tube members so that the upper and lower tube members move into a cooperative engagement with each other to form a substantially unobstructed internal bore.

2. The downhole valve of claim 1, wherein the flapper valve further comprises:

a top surface;

a bottom surface; and

an outer perimeter.

3. The downhole valve of claim 2, wherein the top surface and the bottom surface of the flapper valve have the same curvature at least proximate the outer perimeter.

4. The downhole valve of claim 2, wherein the top surface and the bottom surface of the flapper valve form an arcuate shape of uniform thickness.

5. The downhole valve of claim 2, wherein the top surface and the bottom surface of the flapper valve form an arcuate shape with at least a uniform thickness proximate the outer perimeter.

6. The downhole valve of claim 2, wherein the top surface of the flapper valve is adapted to sealingly engage a bottom surface of the upper tube member and the bottom surface of the flapper valve is adapted to sealingly engage a top surface of the lower tube member when the flapper valve is the closed position.

7. The downhole valve of claim 2, wherein the outer perimeter of the flapper valve further comprises seals adapted to sealingly engage the upper tube member and the lower tube member.

8. The downhole valve of claim 2, wherein an upper surface of the outer perimeter and a bottom surface of the outer perimeter are angled with respect to a line perpendicular to an internal bore of the body to improve the sealing engagement between the flapper valve and the upper and lower tube members.

9. The downhole valve of claim 8, wherein a bottom surface of the upper tube member and a top surface of the lower tube member are adapted to sealingly engage the angled upper and lower surfaces of the outer perimeter of the flapper valve.

10. The downhole valve of claim 1, wherein a bottom surface of the upper tube member is adapted to cooperatively engage a top surface of the lower tube member when the flapper valve is in the open position.

11. The downhole valve of claim 10, wherein at least one of the bottom surface and the top surface include a sealing element so as to provide a cooperative sealing engagement between the upper and lower tube members.

12. The downhole valve of claim 1, wherein the flapper valve is adapted to operatively move from the closed position to the open position at least partly in response to a plurality of pressurizations of an internal bore of the body.

13. The downhole valve of claim 12, wherein completion of the plurality of pressurizations of the internal bore disengages an indexing mechanism and enables the upper and lower tube members to move upward into the cooperative engagement with each other, wherein the upward movement of the upper and lower tube members enables the movement of the flapper valve from the closed position to the open position to form the substantially unobstructed wellbore.

14. The downhole valve of claim 13, wherein the indexing mechanism comprises a ratchet mechanism that substantially prevents rotational movement of a sliding indexer sleeve in a direction opposite an intended direction of rotation as the sliding indexer sleeve moves upward.

15. The downhole valve of claim 1, wherein the upper tube member and the lower tube member are operatively connected by a biasing mechanism.

16. The downhole valve of claim 15, wherein the biasing mechanism comprises at least one spring.

17. The downhole valve of claim 15, wherein the biasing mechanism forces a bottom surface of the upper tube member against a top surface of the flapper

valve and a top surface of the lower tube member against a bottom surface of the flapper valve when the flapper valve is in the closed position.

18. The downhole valve of claim 15, wherein the biasing mechanism forces a bottom surface of the upper tube member into a cooperative engagement with a top surface of the lower tube member when the flapper valve is in the open position.

19. The downhole valve of claim 1, wherein the flapper valve is pivotally connected to a flapper housing that is axially fixed in relation to the body.

20. The downhole valve of claim 1, wherein the flapper valve is adapted to seal against pressure adjacent both a top surface and a bottom surface of the flapper valve.

21. The downhole valve of claim 1, wherein the upward sliding movement of the upper and lower tube members is induced at least in part by the pressurization of the internal bore of the body.

22. The downhole valve of claim 1, wherein the downhole valve further comprises ratchet members that axially secure the upper tube member and the lower tube member when the flapper valve is in the open position.

23. The downhole valve of claim 1, wherein the upward movement of the upper tube member is induced by the pressurization of the internal bore of the body and the upward movement of the lower tube member is induced by the expansion of a spring.

24. A downhole downhole valve comprising:

a body;

an upper tube member slidably disposed within the body;

a lower tube member slidably disposed within the body; and

a flapper valve pivotally attached to the body and adapted to sealingly engage the upper tube member and the lower tube member when in a closed position,

wherein the flapper valve when in the closed position seals a bore in the body against both uphole and downhole pressure, and

wherein the flapper valve is adapted to move into an open position and is enclosed in a recess in the body in response to an upward movement of the upper and lower tube members so that the upper and lower tube members slidably move into a cooperative engagement with each other to form a substantially unobstructed internal bore.

25. A downhole valve comprising:

a body;

a flow tube assembly positioned within the body, the flow tube assembly further comprising an upper tube member and a lower tube member; and

a flapper valve operatively attached to the flow tube assembly and axially fixed in relation to the body, wherein the flapper valve is adapted to pivot from a closed position wherein the flapper valve is sealingly positioned between the upper and lower tube members, to an open position,

wherein the flapper valve is pivoted to the open position and is enclosed in a recess in the body in response to an upward movement of the upper and lower tube members so that the upper and lower tube members move into a cooperative engagement with each other to form a substantially unobstructed internal bore.

26. A downhole valve comprising:

a body;

a flow tube assembly positioned within the body, the flow tube assembly further comprising an upper tube member and a lower tube member; and

a flapper valve operatively attached to the flow tube assembly and adapted to pivot from a closed position wherein the flapper valve is sealingly positioned between the upper and lower tube members, to an open position,

wherein the flapper valve is pivoted to the open position and is enclosed in a recess in the body in response to an upward movement of the upper tube member and a movement of the lower tube member so that the upper and lower tube members move into a cooperative engagement with each other to form a substantially unobstructed internal bore and the flapper valve is retained in the open position by the lower tube member.

27. The downhole valve of claim 26, wherein the lower tube member also moves upwards.

28. A method of selectively sealing a bore of a body, the method comprising:

pivotally attaching a flapper valve to the body;

sealingly engaging a top surface of the flapper valve with an upper tube member when the flapper valve is in a closed position;

sealingly engaging a bottom surface of the flapper valve with a lower tube member when the flapper valve is in the closed position; and

moving the flapper valve from the closed position to an open position by slidably moving the upper tube member and the lower tube member upward until the flapper valve is enclosed in a recess in the body and the upper tube member cooperatively engages the lower tube member.

29. The method of claim 28, wherein the moving step is at least partly in response to a plurality of pressure cycles.

30. The method of claim 28, further comprising sealing the bore from pressure both uphole and downhole of the flapper valve when the flapper valve is in the closed position.

31. The method of claim 28, further comprising axially securing the upper and lower tube members when they are cooperatively engaged with each other.

32. The method of claim 31, wherein the axially securing step comprises axially securing the upper tube member with a mechanism that is functionally independent from the mechanism that axially secures the lower tube member.

33. The method of claim 28, further comprising axially securing the flapper valve in position relative to the body.

34. The method of claim 28, wherein the upper tube member and the lower tube member slidably move substantially upward from an initial position as the flapper valve moves from the closed position to the open position.

35. The method of claim 29, wherein completing the plurality of pressure cycles disengages an indexing mechanism and allows the upper and lower tube members to move axially upward, wherein the upward movement of the upper and lower tube members moves the flapper valve from the closed position to the open position.

36. The method of claim 28, wherein the upper tube member is moved upward by the continued pressurization of the internal bore of the body.

37. The method of claim 36, wherein the lower tube member is moved upward by the expansion of a spring.

38. The method of claim 37, wherein the spring does not expand until the pressurization of the internal bore is decreased.

39. The method of claim 37, wherein the upper tube member is locked in its uppermost position prior to the movement of the lower tube member.

40. The method of claim 39, wherein the lower tube member is locked in cooperative engagement with the upper tube member using a mechanism that is functionally independent from the mechanism that locks the upper tube member in its uppermost position.

41. The method of claim 28, wherein the cooperative engagement between the upper and lower tube members is a cooperative sealing engagement.

42. A method of selectively sealing a bore of a body, the method comprising:

pivotally attaching a flapper valve to the body;

sealingly engaging a top surface of the flapper valve with an upper tube member when the flapper valve is in a closed position;

sealingly engaging a bottom surface of the flapper valve with a lower tube member when the flapper valve is in the closed position; and

pressurizing the internal bore of the body to move the upper tube member upwards;

expanding a spring to move the lower tube member upwards; and moving the flapper valve from the closed position to an open position in response to the upwards movement of the upper tube member and the lower tube member.

43. The method of claim 42, wherein the expanding step occurs subsequent to the pressurizing step.

44. The method of claim 42, further comprising locking the upper tube member and the lower tube member so that they are cooperatively engaged.

45. The method of claim 44, wherein the locking step occurs when the upper tube member and the lower tube member are in their uppermost positions.

46. The method of claim 44, further comprising locking the upper tube member with a mechanism that is functionally independent from the mechanism used to lock the lower tube member.

47. A downhole valve, comprising:

a body;

a flow tube assembly positioned within the body, the flow tube assembly further comprising an upper tube member and a lower tube member; and

a flapper valve operatively attached to the flow tube assembly and adapted to pivot from a closed position wherein the flapper valve is sealingly positioned between the upper and lower tube members, to an open position,

wherein the flapper valve is pivoted to the open position and is enclosed in a recess in the body in response to the movement of the upper and lower tube members in a single direction so that the upper and lower tube members move into a cooperative engagement with each other to form a substantially unobstructed internal bore.

48. The downhole valve of claim 47, wherein the single direction is the upwards direction.

49. The downhole valve of claim 48, wherein the upper tube member and the lower tube member are locked in their uppermost positions.

50. The downhole valve of claim 47, wherein the upper tube member and the lower tube member are locked following movement in the single direction.

51. A method of selectively sealing a bore of a body, the method comprising:

pivotally attaching a flapper valve to the body;

sealingly engaging a top surface of the flapper valve with an upper tube member when the flapper valve is in a closed position;

sealingly engaging a bottom surface of the flapper valve with a lower tube member when the flapper valve is in the closed position; and

moving the flapper valve from the closed position to an open position by slidably moving the upper tube member and the lower tube member in a single direction until the flapper valve is enclosed in a recess in the body and the upper tube member cooperatively engages the lower tube member.

52. The method of claim 51, wherein the single direction is the upwards direction.

53. The method of claim 52, further comprising locking the upper tube member and the lower tube member in their uppermost positions.

54. The downhole valve of claim 51, further comprising locking the upper tube member and the lower tube member following movement in the single direction.

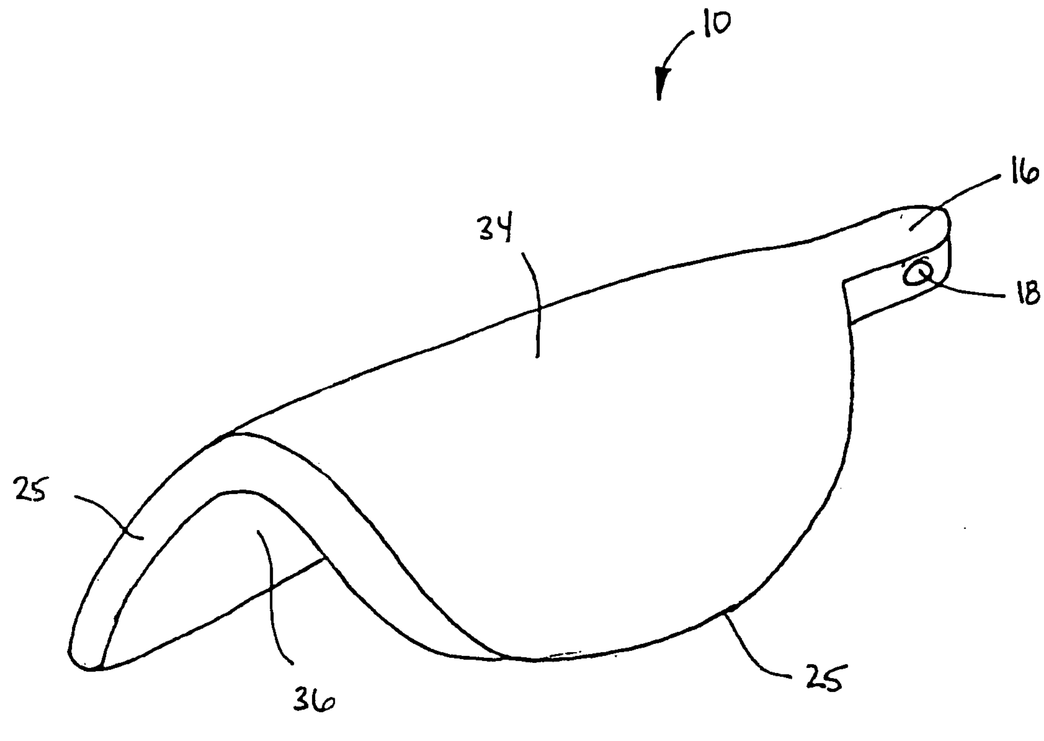

Figure 1

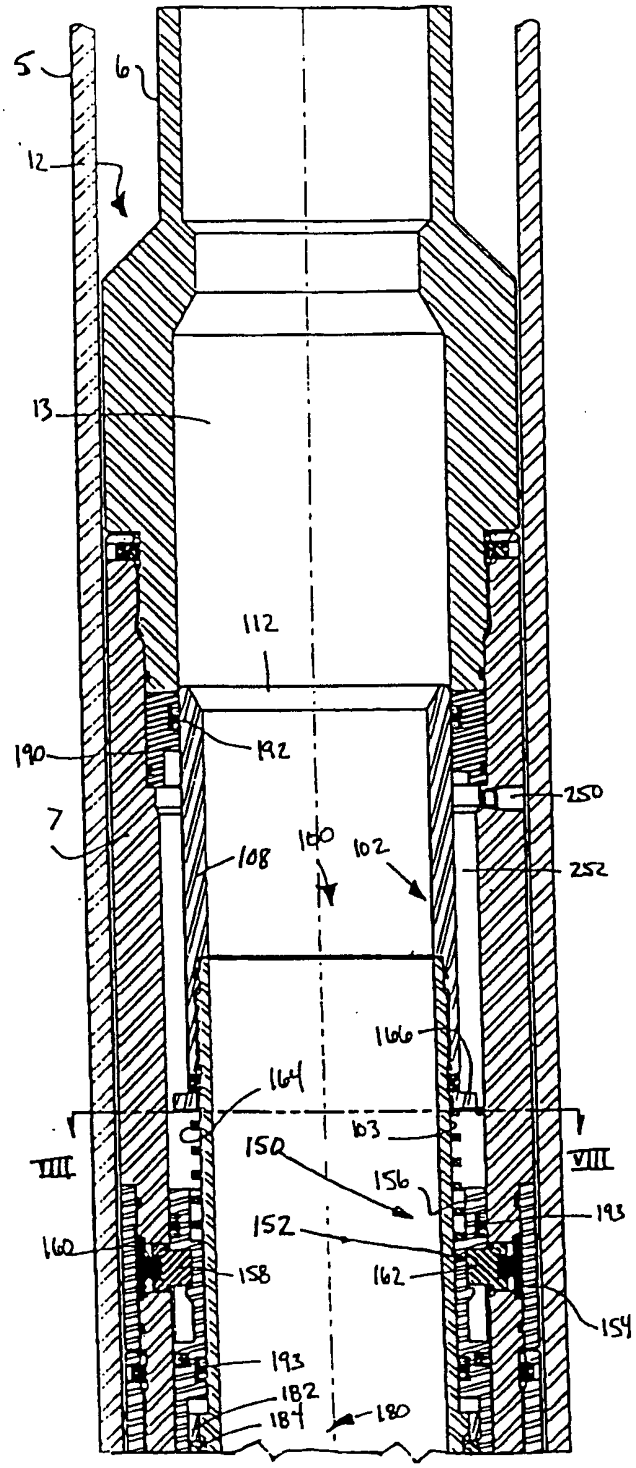
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Figure 2A

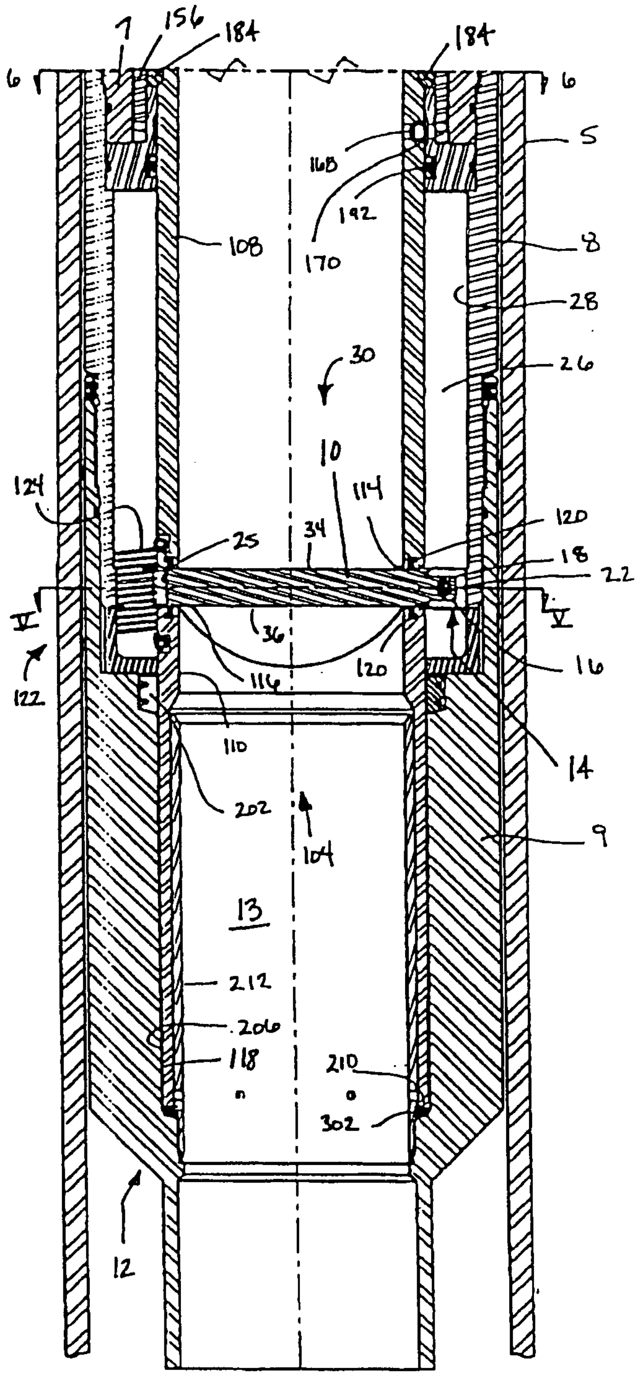
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Figure 2B

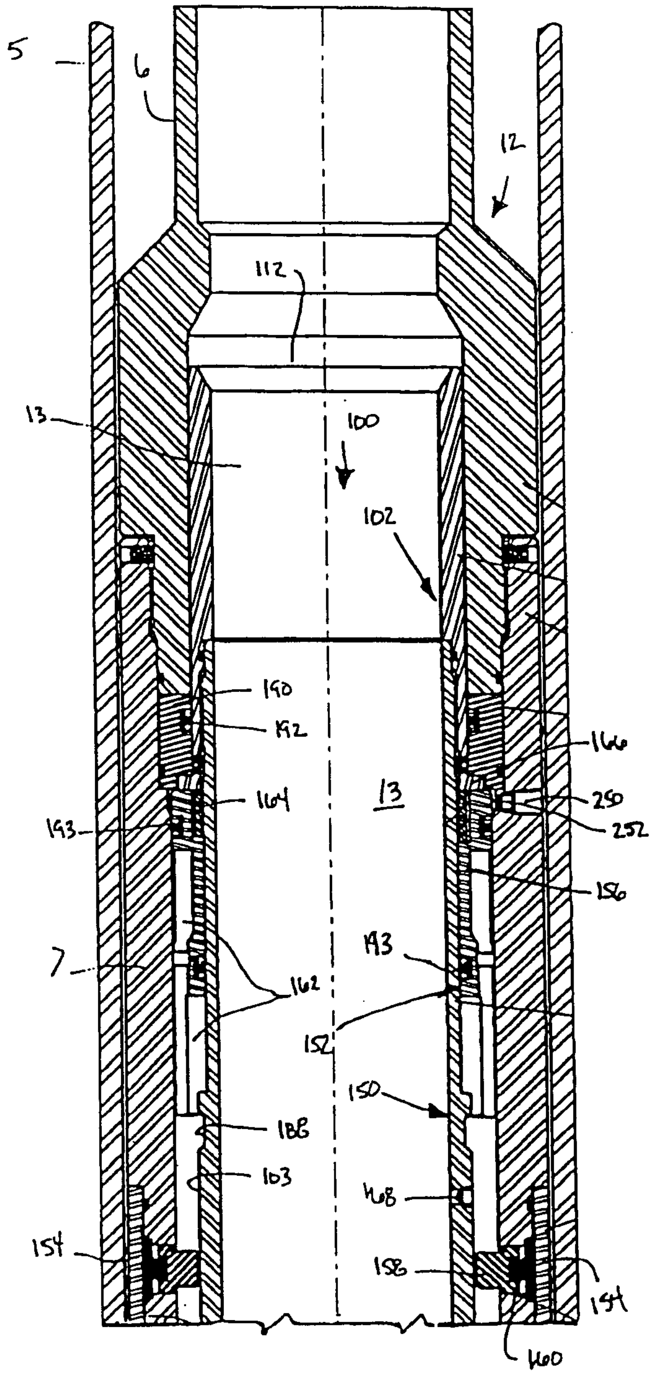
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Figure 3A

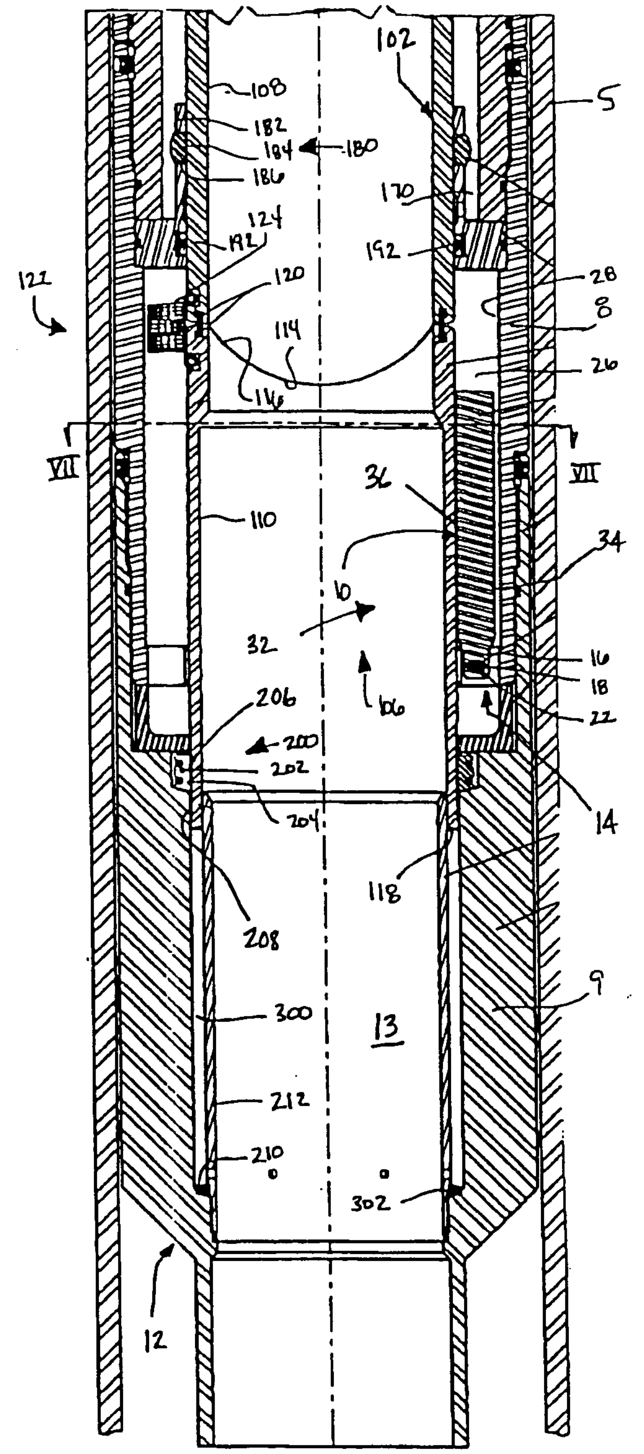
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Figure 3B

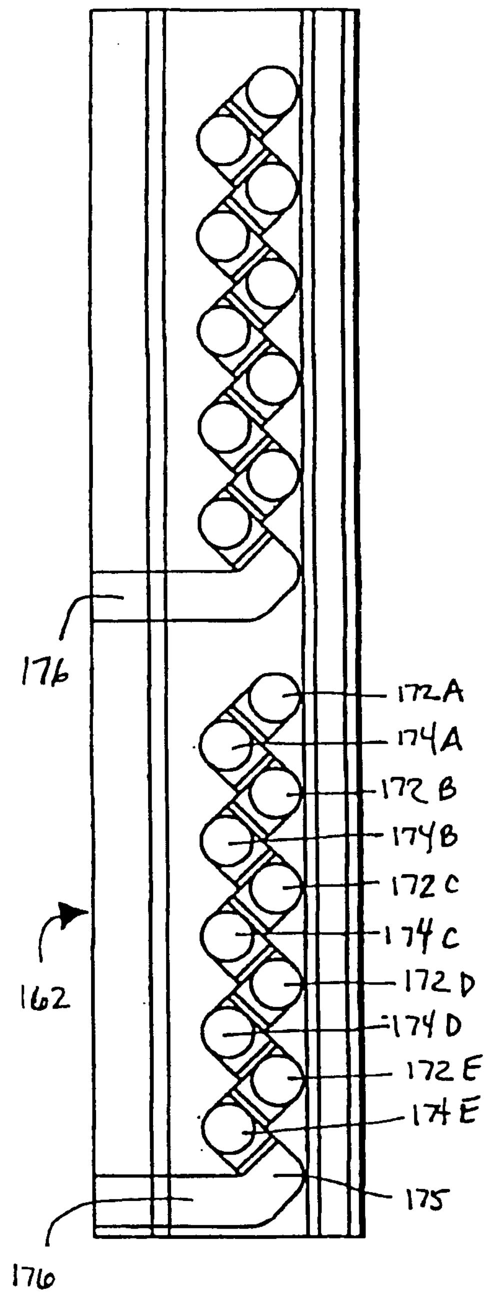
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Figure 4

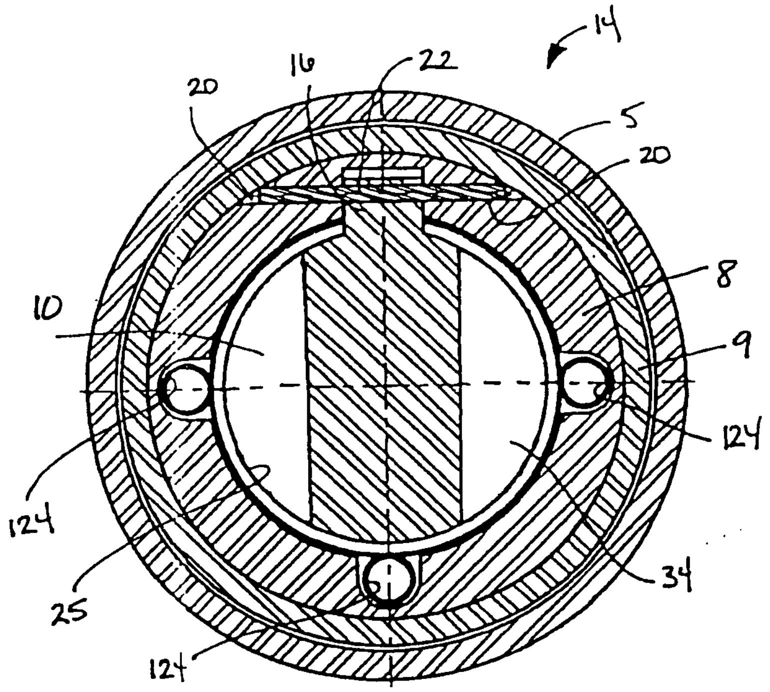

Figure 5

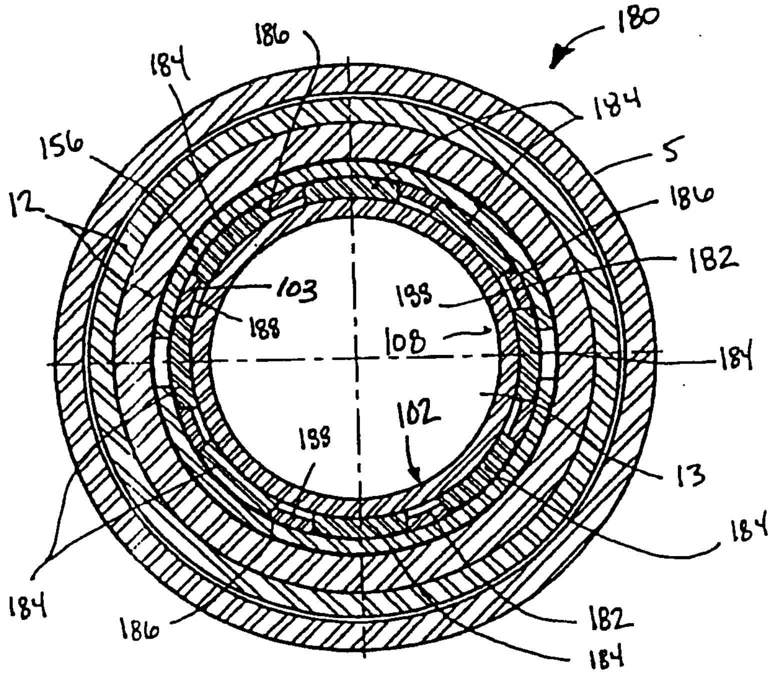

Figure 6

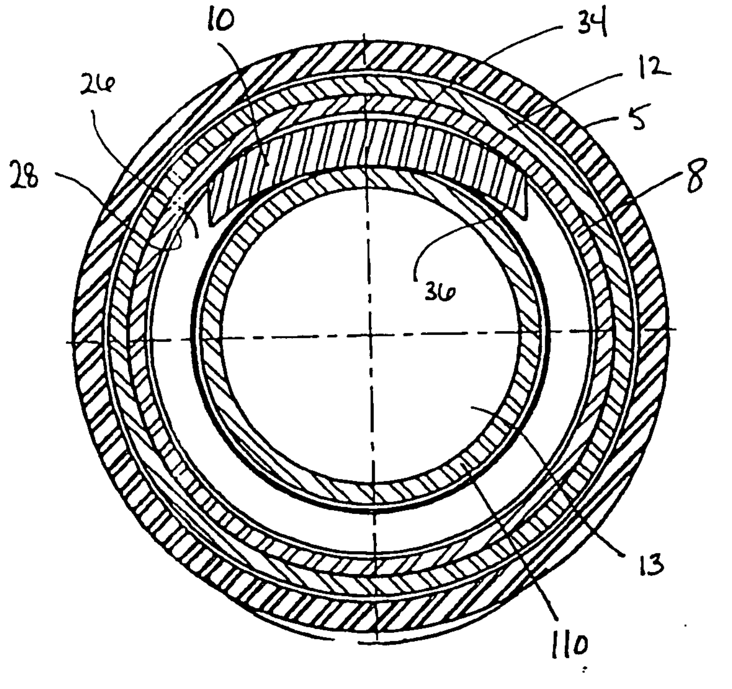

Figure 7

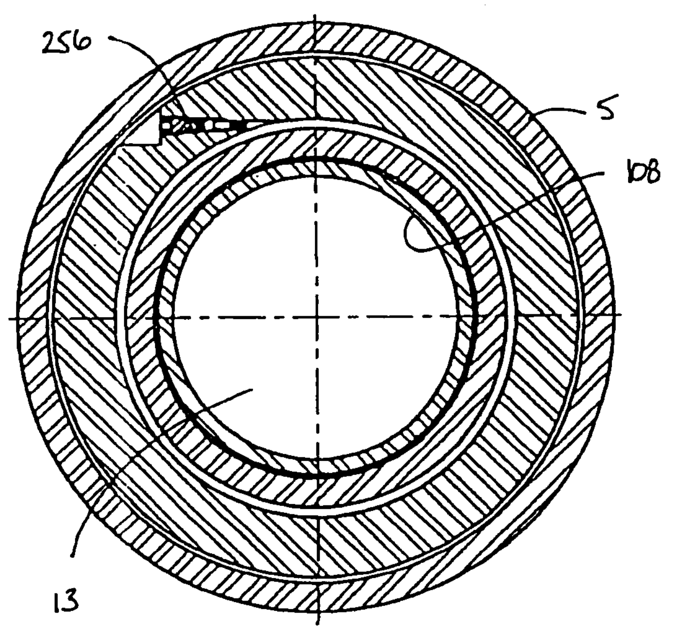

Figure 8

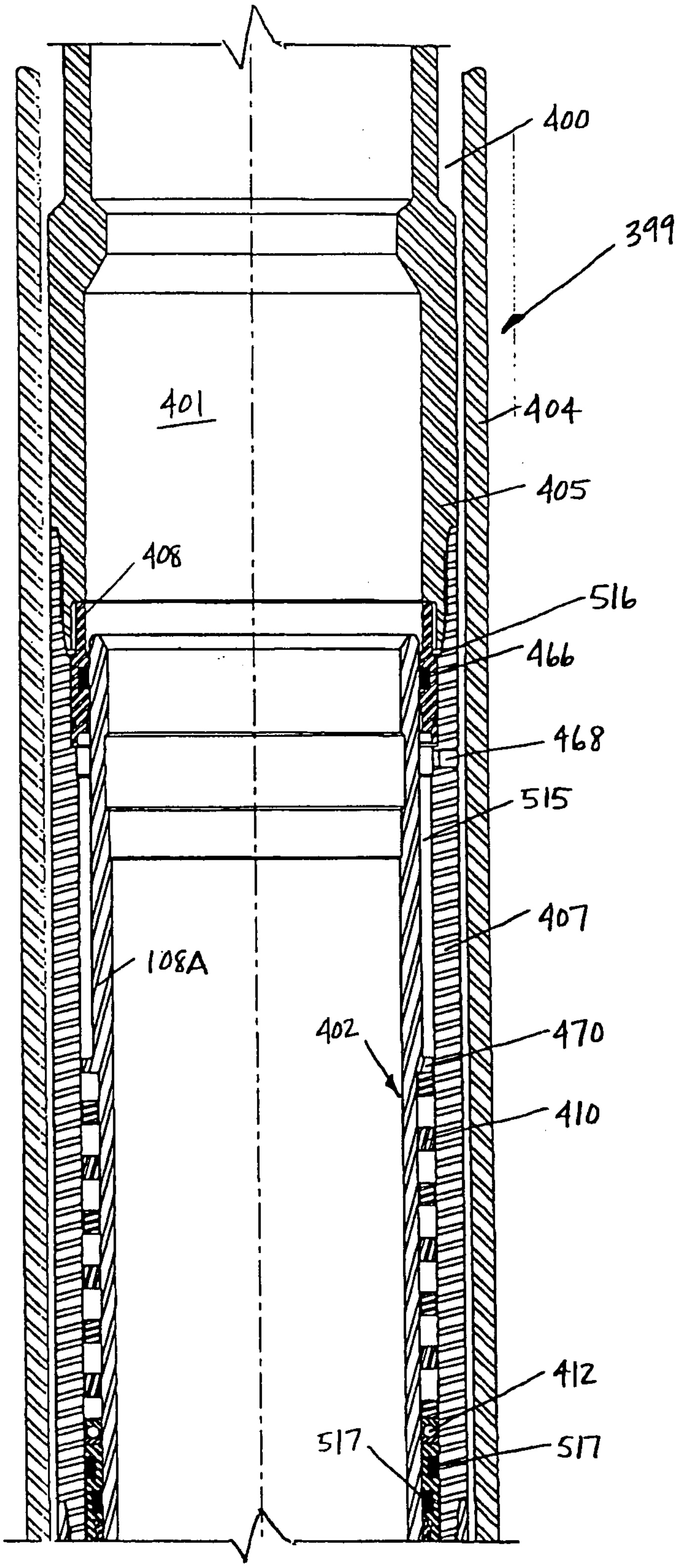
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Figure 9A

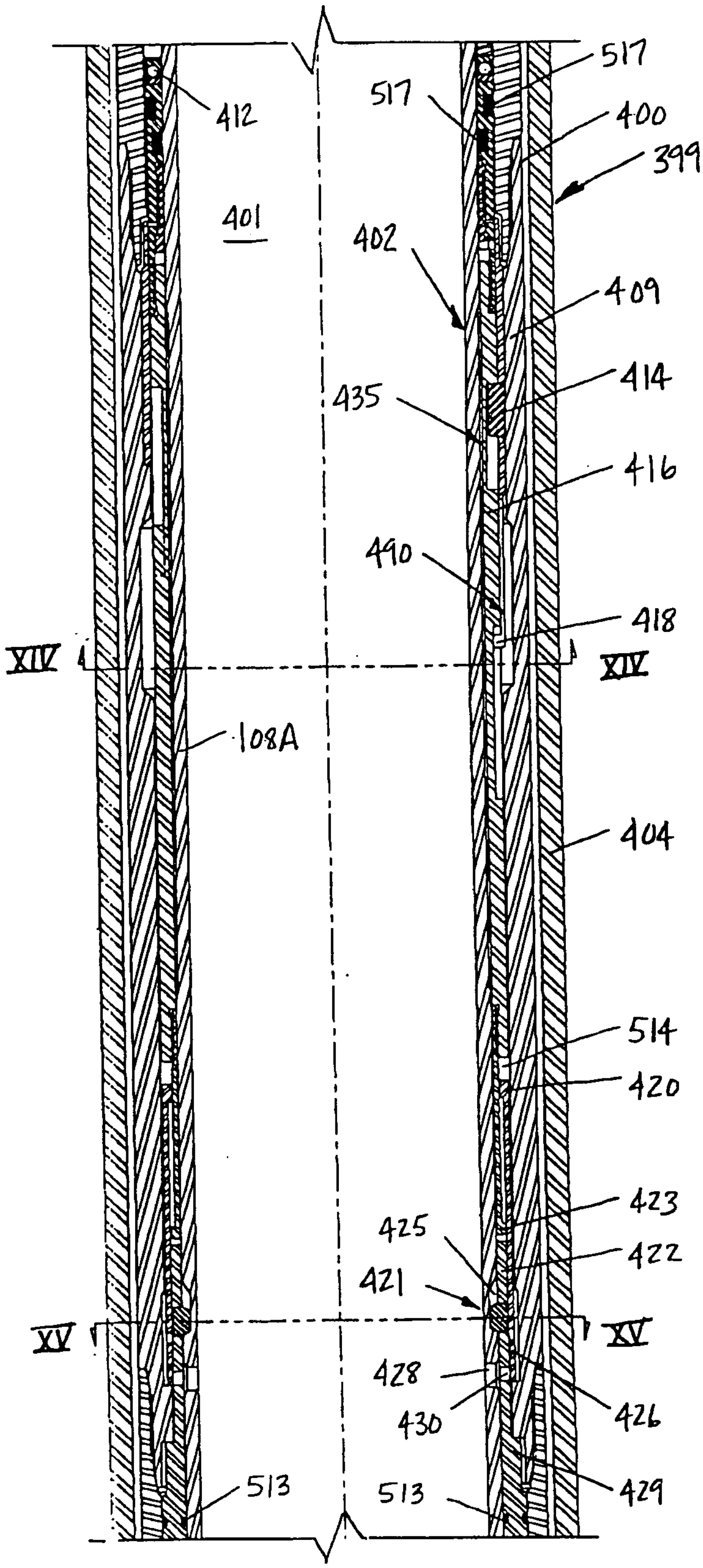
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Figure 9B

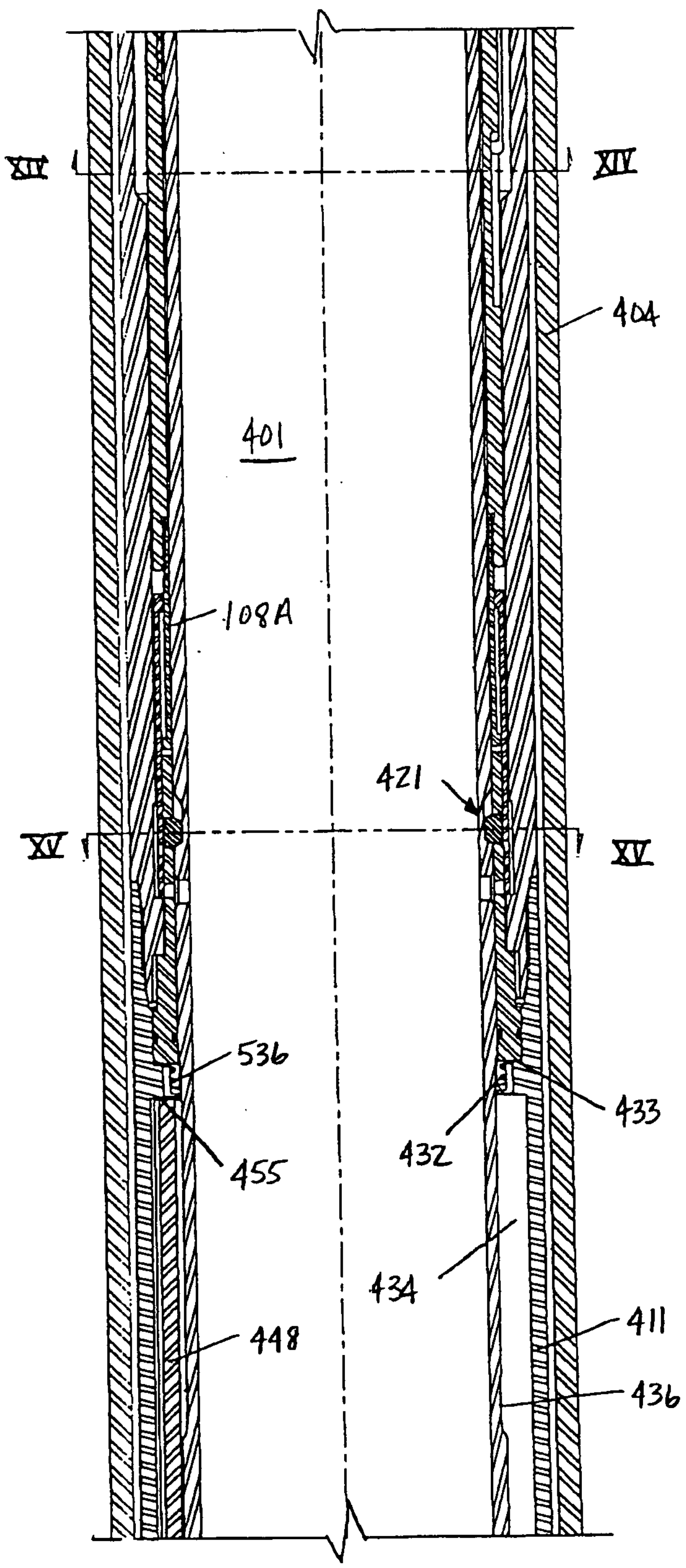

Figure 9C

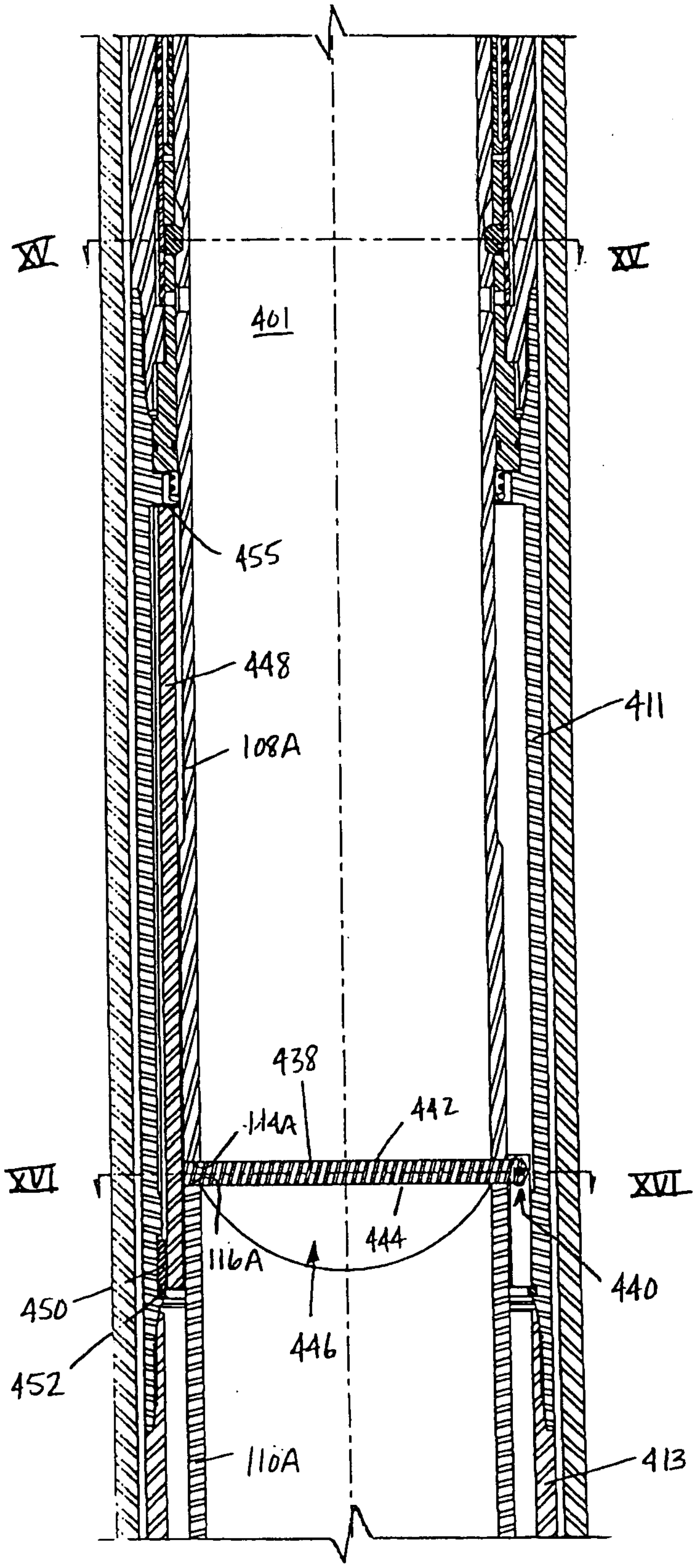
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Figure 9D

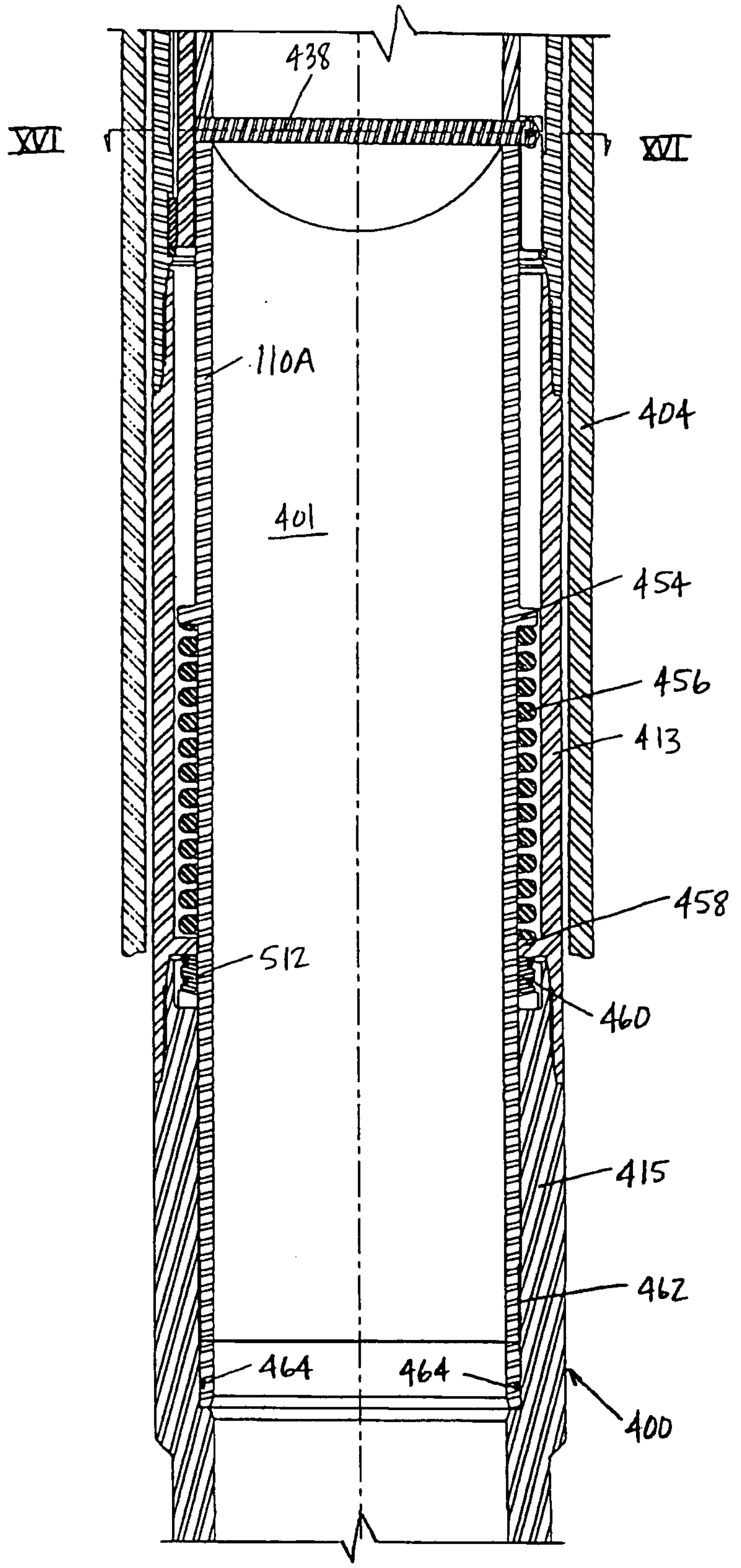
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Figure 9E

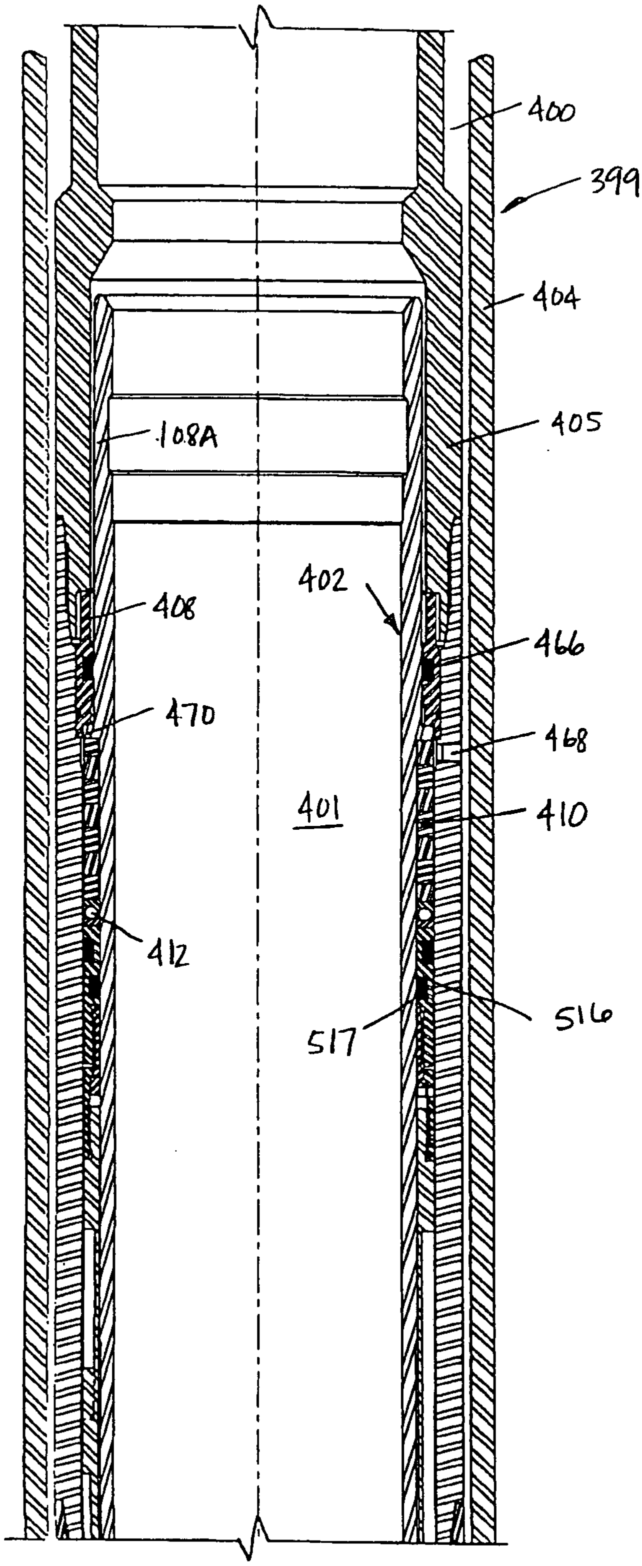

Figure 10A

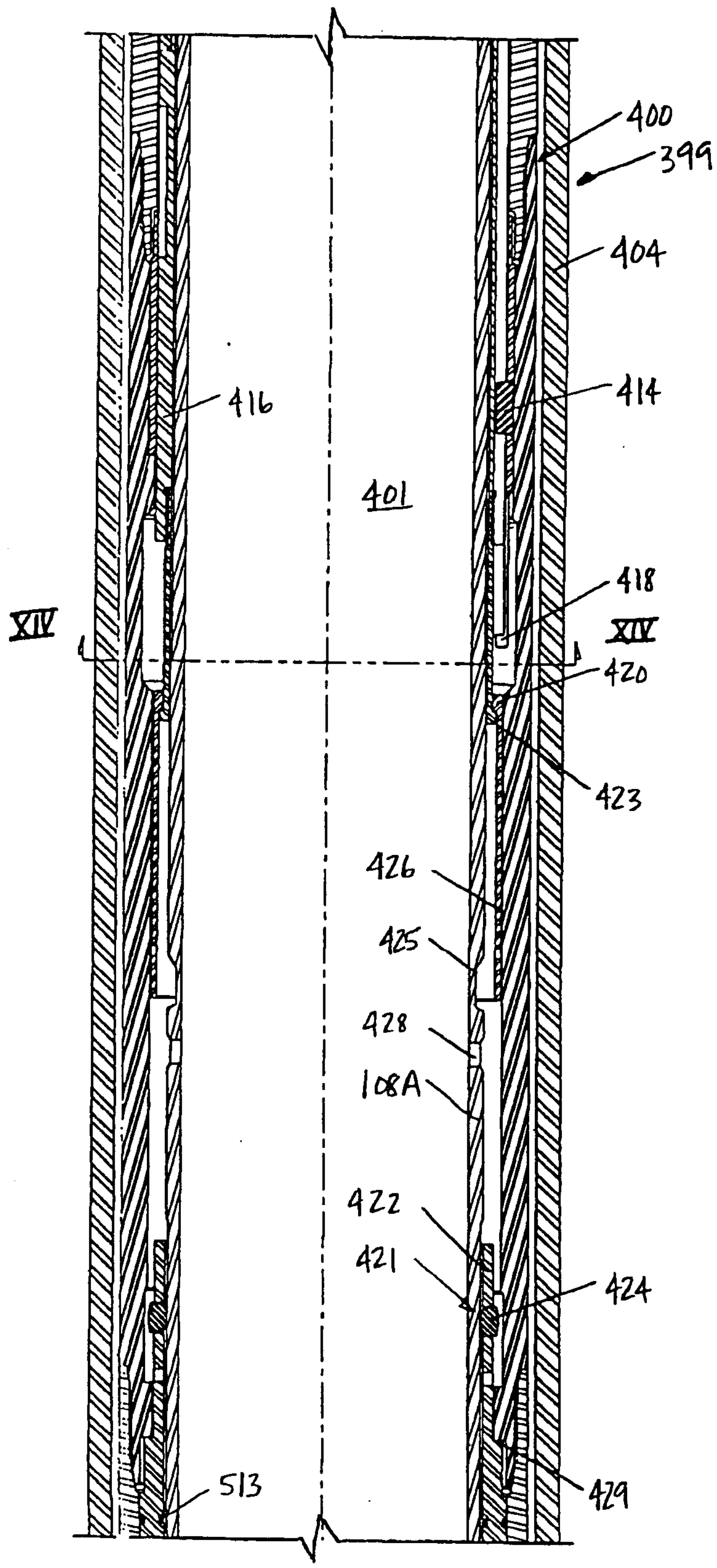
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Figure 10B

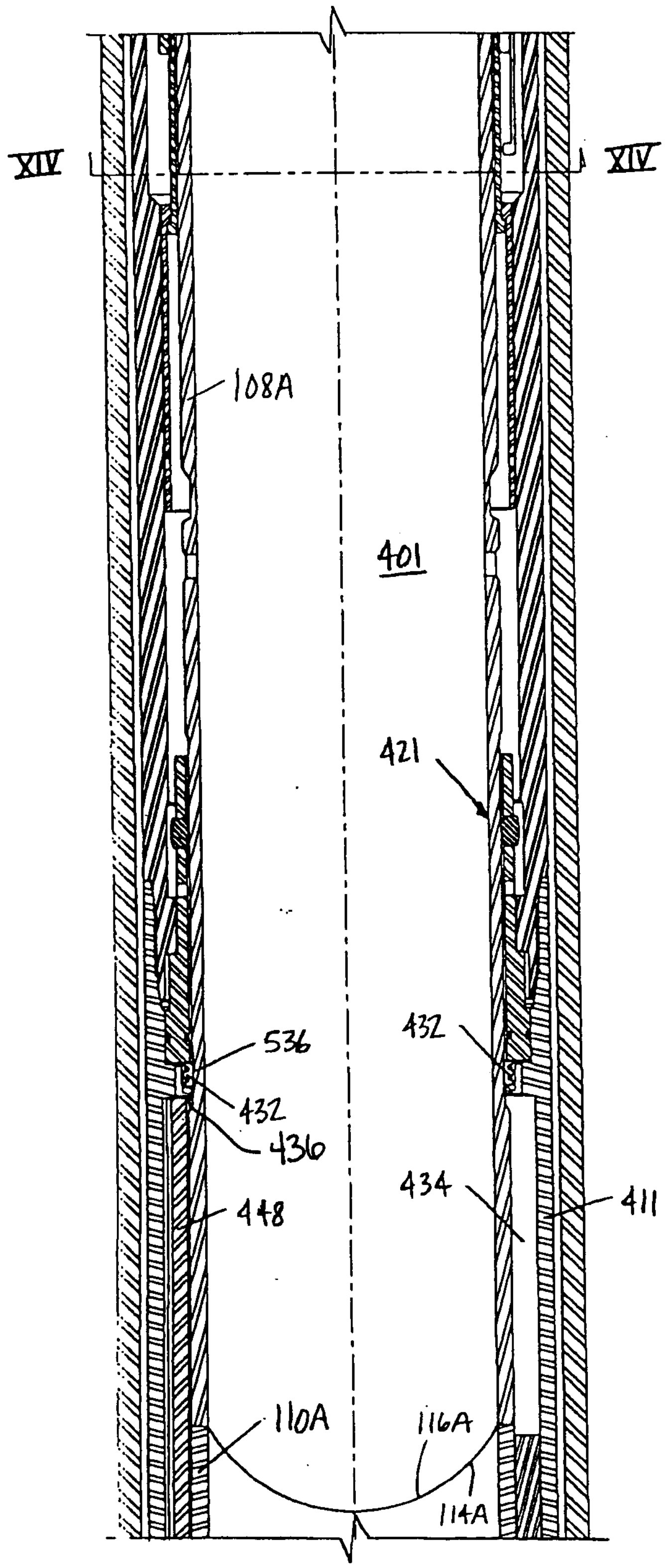
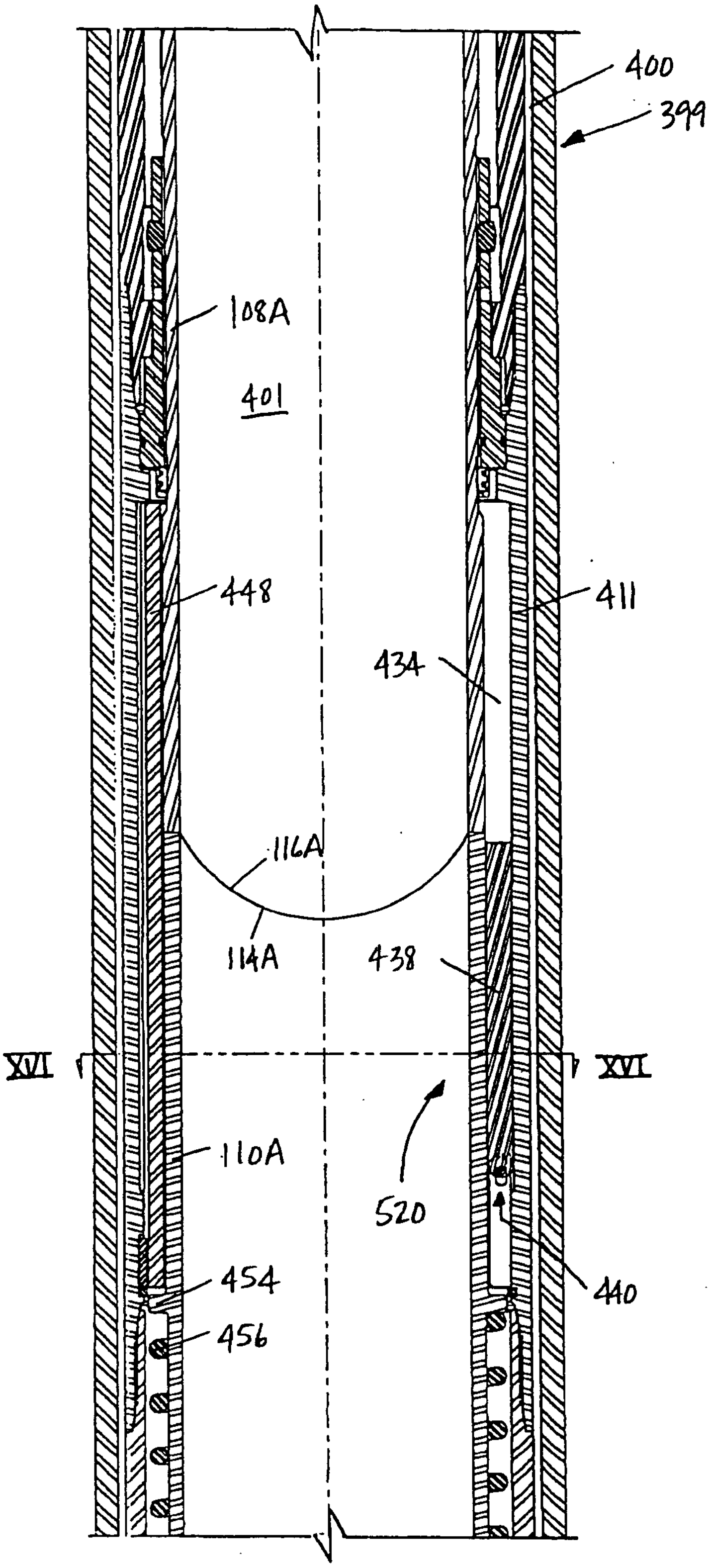


Figure 10C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XVI
XVI
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456

Figure 10D

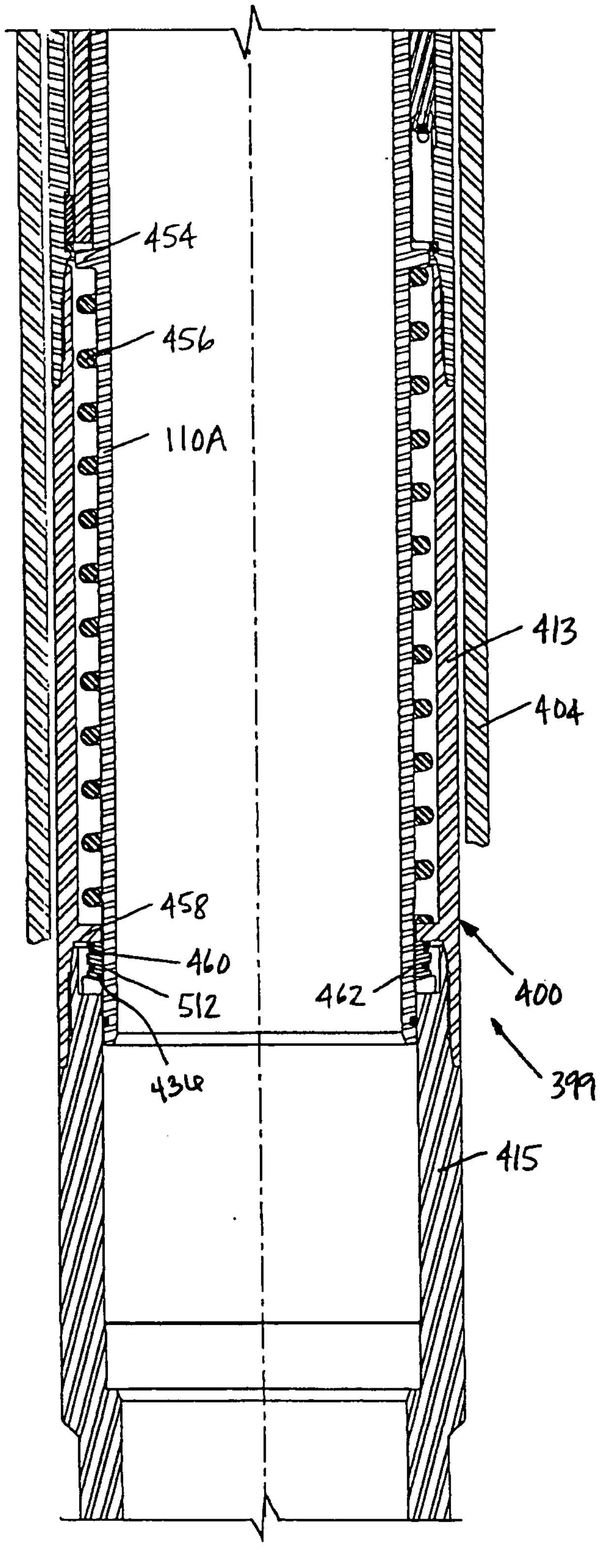


Figure 10E

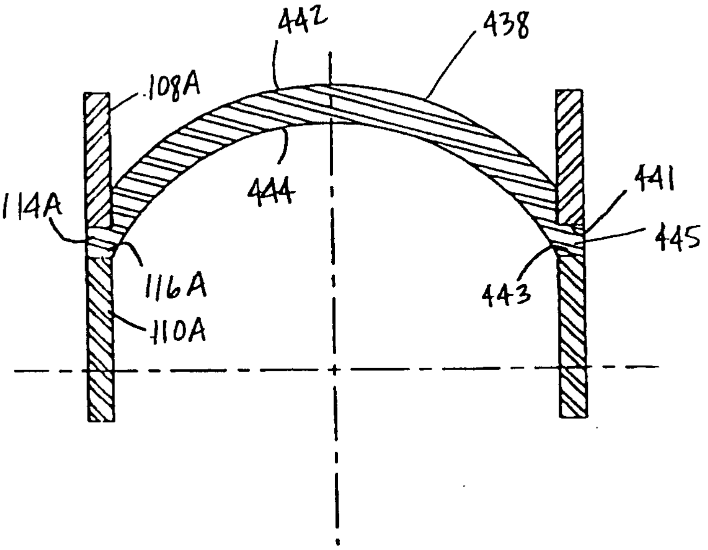


Figure 11

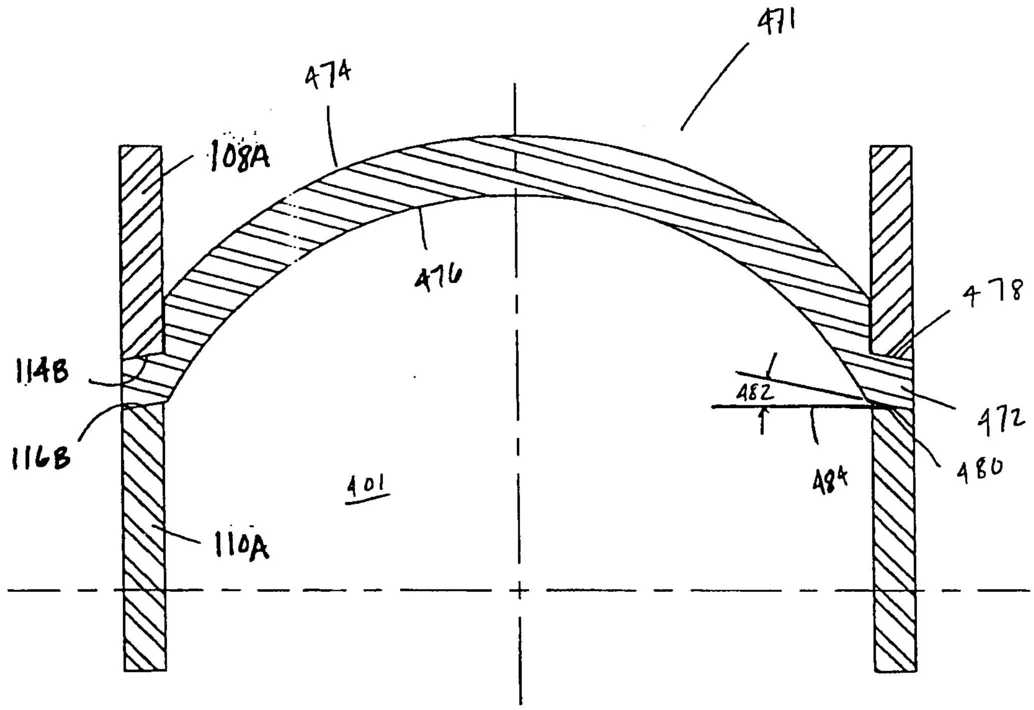
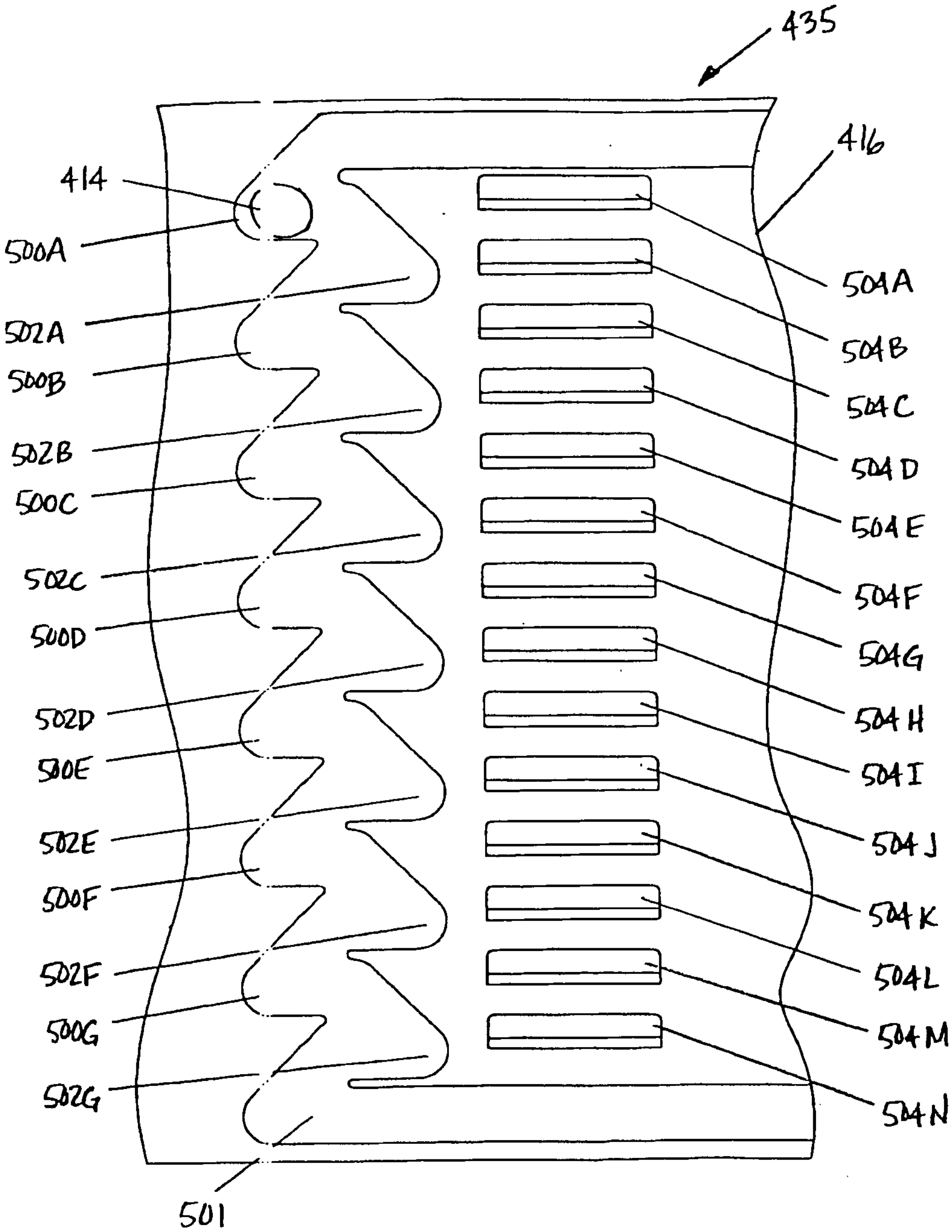


Figure 12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504M
504N

Figure 13

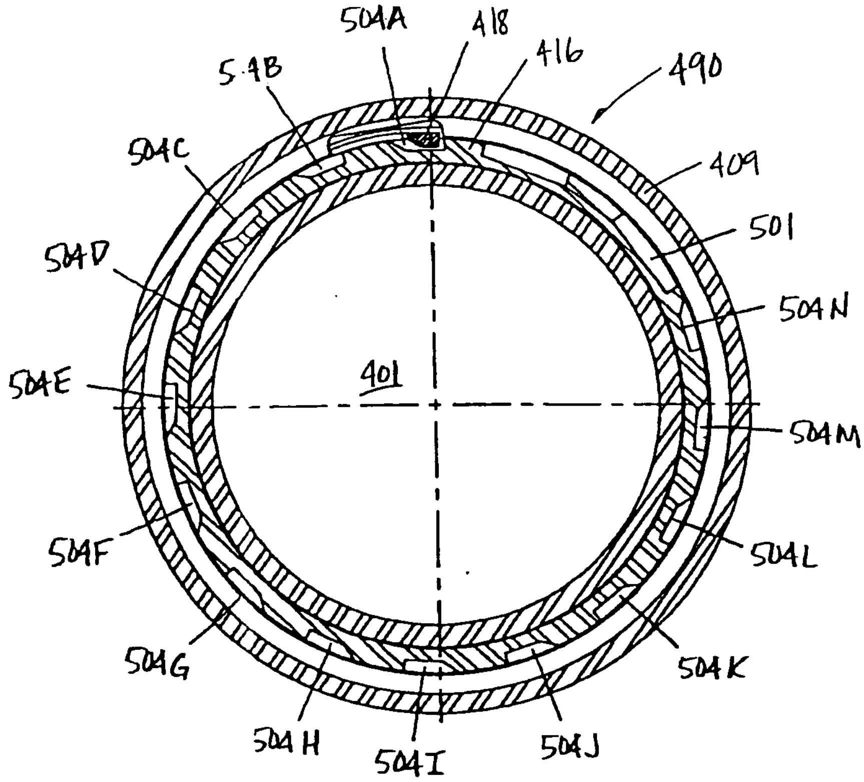

Figure 14

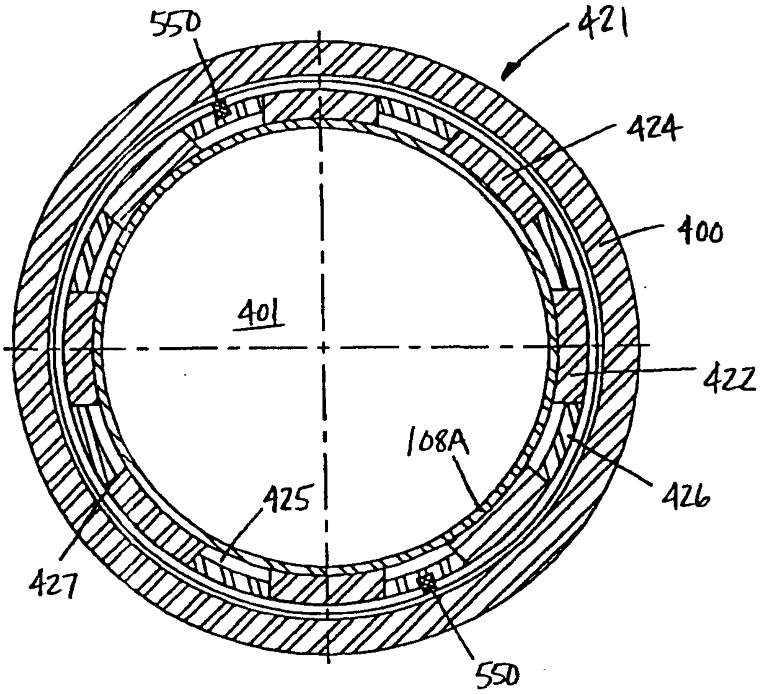

Figure 15

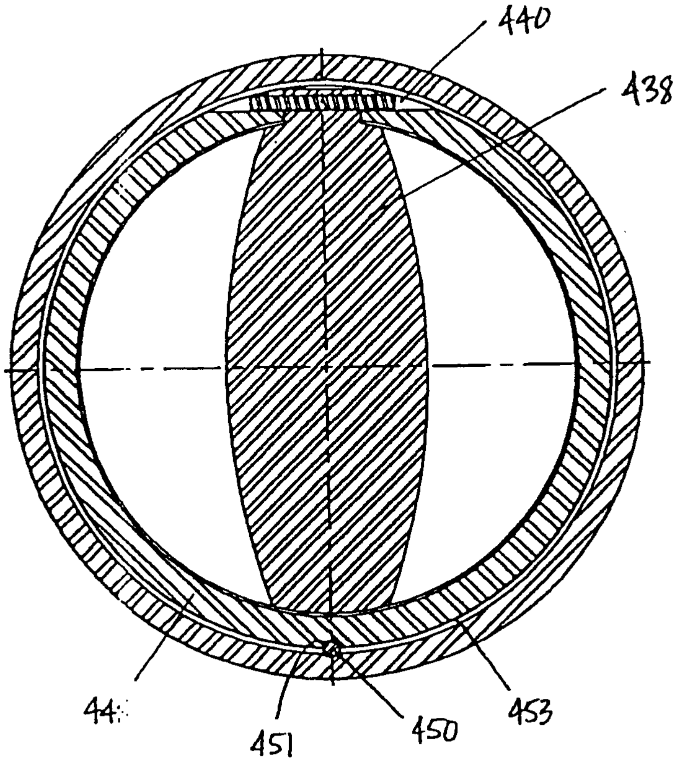

Figure 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/31452

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :E21B 34/06
US CL :166/373,332.8
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 166/373,332.8,374,321,323,331,332.2; 251/298,360,363

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

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2,849,207 A (CONRAD) 26 August 1958 (26/08/58), see entire document.	1-11,15-20,24-28,30,33,34,41,47,48,51,52

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 MARCH 2001	26 APR 2001

Name and mailing address of the ISA/US	Authorized officer
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