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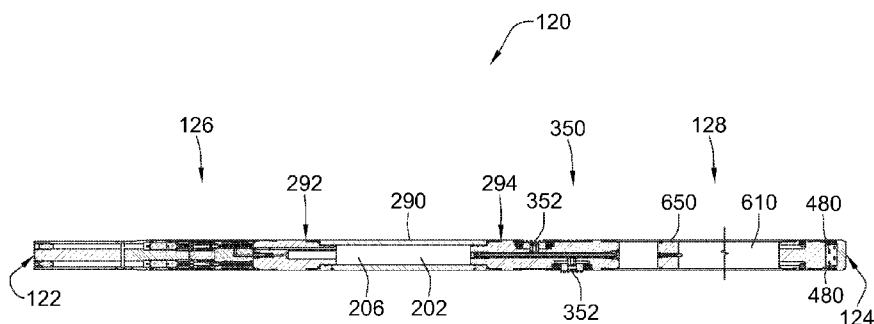


Figure 10

(57) Abstract: An apparatus and method for preparing a casing of a subterranean well and injecting a sealing mixture therein. The apparatus comprises an elongate body extending between top and bottom ends connectable to a wireline at the top and having a plurality of nozzles extending therethrough proximate to the bottom. A plurality of scrapers within the body each have a first retracted position and a second radially extended position engageable with the casing. A cavity is operable to contain the sealing mixture and a piston is movable therein so to eject the sealing mixture through the nozzles. The method comprises positioning the body in the well at a location to be sealed, extending the scrapers to engage with the casing, displacing the body so to scrape against the casing and retracting the scrapers. The piston is displaced so to eject the sealing mixture through the nozzles.



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SUBTERRANEAN WELL SEALING INJECTOR

BACKGROUND OF THE INVENTION

1. Field of Invention

5 The present invention relates generally to containment and sealing of subterranean wells and more specifically to an apparatus and method for preparing a well casing and injecting an abrasive sealing mixture into a subterranean well on top of a mechanical plug barrier inside the tubulars.

10 2. Description of Related Art

In hydrocarbon production, when a hydrocarbon well has reached the end of its functional life, it is common to seal the wellbore with a series of plugs, as is commonly known, in preparation for abandonment. The purpose of the plugs is to create an impermeable barrier to prevent hydrocarbons or other fluids from
15 migrating up the well and into the natural environment, such as into drinking water or to the surface.

In general, a minimum of three plugs are placed into a well to prepare for well abandonment. The most common material used to form the plugs is cement,
20 which is pumped into the well as a slurry and allowed to harden in place. Additives may be used to enhance properties of the cement. Once set, the cement is durable and has a low permeability.

Typically, the cement slurry is pumped into the well through coil or jointed tubing from a rig on the surface. This method can result in the use of an excess volume
25 of cement and there is a risk that the cement may cure prior to removal of the tubing, resulting in the tubing becoming stuck in the hole.

Another method to form the cement plug is with the use of a wireline deployed gravity displaced dump bailer. Disadvantageously, dump bailers may be
30 activated with a ballistic or mechanical impact glass or ceramic bottom release system which can result in premature release of the cement if the bailer is dropped or bumped before reaching the desired plug location. Additionally, the

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cement may not be fully discharged from the bailer within the well, resulting in the possibility that the cement may harden within the bailer and limit its reuse. There is also a contamination problem caused by moving or shaking the bailer to have product release from the bailer.

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Additionally, the above methods to seal a wellbore do not properly condition the casing for proper bonding of the cement or resin to the casing.

SUMMARY OF THE INVENTION

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According to a first embodiment of the present invention there is disclosed an apparatus for preparing a casing of a subterranean well and injecting a sealing mixture into the subterranean well comprising an elongate body extending between top and bottom ends, the body connectable to a wireline at the top end thereof and having a plurality of nozzles extending through the body proximate to the bottom end thereof and a plurality of scrapers positioned within the body, each having a first position retracted within the body and a second position radially extended from the body engageable with the casing. The apparatus further comprises a cavity within the body operable to contain the sealing mixture therein and a piston slideably movable within the cavity so as to eject the sealing mixture through the plurality of nozzles.

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The piston may divide the cavity into first and second chambers. The cavity may include a retention means selectably fluidically connected with the plurality of nozzles. The retention means may be selected from a group consisting of a check valve, a flap valve and a breakable seal.

The apparatus may further comprise a compressed gas tank within the body. The compressed gas tank may be fluidically connected to a valve assembly.

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The plurality of scrapers may include a plurality of radial pistons selectably fluidically connected to the compressed gas tank through the valve assembly. The plurality of radial pistons may be operable to extend the plurality of scrapers between the first position and the second position.

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5 The compressed gas tank may be selectably fluidically connected through the valve assembly to the first chamber. The apparatus may further comprise at least one motor within the body, the at least one motor operable to selectably move the valve assembly. Each of the at least one motor may comprise a step motor. The apparatus may further comprise a control circuit connected to the wireline and to the at least one motor. The control system may comprise a processor.

10 The piston may include a bypass passage therethrough operable to selectively connect the first chamber with the second chamber.

15 According to a further embodiment of the present invention there is disclosed a method for preparing a casing of a subterranean well and sealing the subterranean well comprising positioning a body having a cavity therein in the subterranean well at a location to be sealed, extending a plurality of scraper assemblies from the body thereby engaging the plurality of scraper assemblies with the casing, displacing the body within the well so as to engage the plurality of scraper assemblies against a length of the casing and retracting the plurality of scraper assemblies. The method further comprises positioning the body in the subterranean well at the location to be sealed and slideably displacing a piston within the cavity of the body so as to eject a sealing mixture contained within the cavity through a plurality of nozzles fluidically connected to the cavity and located through the body.

25 The method may further comprise, prior to ejecting the sealing mixture, slideably displacing the piston within the cavity of the body so as to eject a cleaning fluid contained within the cavity through the plurality of nozzles, removing the body from the subterranean well and filling the cavity of the body with the sealing mixture and positioning the body in the subterranean well at the location to be sealed.

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The piston may be displaced by introducing a compressed gas to the cavity on an opposite side of the piston from the plurality of nozzles. The compressed gas may be contained within a gas tank in the body with a valve assembly operable to selectably connect the gas tank with the scraper assemblies and with the cavity on the opposite side of the piston from the plurality of nozzles.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention wherein similar characters of reference denote corresponding parts in each view,

Figure 1 is a cross-sectional schematic view of a sealing injector apparatus in a run-in position according to a first embodiment of the present direction.

Figure 2 is a detailed cross-sectional schematic view of the sealing injector apparatus of Figure 1 at the second end in the run-in position.

Figure 3 is a detailed cross-sectional schematic view of the piston activation section in the run-in position.

Figure 4 is a cross-sectional schematic view of the sealing injector apparatus of Figure 1 in an injecting position.

Figure 5 is a detailed cross-sectional schematic view of the piston activation section in the injecting position.

Figure 6 is a detailed cross-sectional schematic view of the sealing injection section in the injecting position.

Figure 7 is a detailed cross-sectional schematic view of the sealing injection section in the compressed gas bypass position.

Figure 8 is a perspective view of a sealing injector apparatus according to a further embodiment of the present invention.

Figure 9 is an end view of the apparatus of Figure 8.

Figure 10 is a side plane cross-sectional view of the apparatus of Figure 8 taken along the line 10-10 of Figure 9.

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- Figure **11** is a detailed side plane cross-sectional view of the control and activation section of the apparatus of Figure **8** taken along the line **10-10** of Figure **9**.
- 5 Figure **12** is a detailed side plane cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **10-10** of Figure **9**.
- Figure **13** is a detailed top plane cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **13-13** of Figure **9**.
- Figure **14** is a radial cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **14-14** of Figure **13**.
- 10 Figure **15** is a radial cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **15-15** of Figure **13**.
- Figure **16** is a detailed angled plane cross-sectional view of the motor housing and valve manifold of the apparatus of Figure **8** taken along the line **16-16** of Figure **9**.
- 15 Figure **17** is a radial cross-sectional view of the throttle valve housing of the apparatus of Figure **8** taken along the line **17-17** of Figure **16**.
- Figure **18** is a radial cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **18-18** of Figure **16**.
- Figure **19** is a radial cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **19-19** of Figure **13**.
- 20 Figure **20** is a radial cross-sectional view of the valve manifold of the apparatus of Figure **8** taken along the line **20-20** of Figure **13**.
- Figure **21** is a schematic diagram of the valve manifold of the apparatus of Figure **8** in a first position.
- 25 Figure **22** is a schematic diagram of the valve manifold of the apparatus of Figure **8** in a second position.
- Figure **23** is a schematic diagram of the valve manifold of the apparatus of Figure **8** in a third position.
- Figure **24** is a schematic diagram of the valve manifold of the apparatus of Figure **8** in a fourth position.
- 30 Figure **25** is a detailed angled plane cross-sectional view of the throttle valve housing of the apparatus of Figure **8** taken along the line **25-25** of Figure **9**.

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- Figure 26 is a detailed angled plane cross-sectional view of the first stage throttle valve of the apparatus of Figure 8 taken along the line 25-25 of Figure 9.
- 5 Figure 27 is a detailed angled plane cross-sectional view of the second stage throttle valve of the apparatus of Figure 8 taken along the line 25-25 of Figure 9.
- Figure 28 is a detailed angled plane cross-sectional view of the scraper section of the apparatus of Figure 8 taken along the line 16-16 of Figure 9.
- 10 Figure 29 is a radial cross-sectional view of the scraper housing of the apparatus of Figure 8 with the scrapers in a retracted position, as taken along the line 29-29 of Figure 28.
- Figure 30 is a radial cross-sectional view of the scraper housing of the apparatus of Figure 8 with the scrapers in an extended position, as taken along the line 29-29 of Figure 28.
- 15 Figure 31 is a perspective view of a scraper of the apparatus of Figure 8.
- Figure 32 is a radial cross-sectional view of the scraper housing of the apparatus of Figure 8 with two scrapers in an extended position and one scraper in a retracted position, as taken along the line 32-32 of Figure 28.
- 20 Figure 33 is a detailed top plane cross-sectional view of the scraper housing of the apparatus of Figure 8 taken along the line 13-13 of Figure 9.
- Figure 34 is a detailed top plane cross-sectional view of the injection section of the apparatus of Figure 8 in an injecting position taken along the line 13-13 of Figure 9.
- 25 Figure 35 is a detailed top plane cross-sectional view of the injection section of the apparatus of Figure 8 with the piston in a flushing position taken along the line 13-13 of Figure 9.
- Figure 36 is a detailed side plane cross-sectional view of the injection assembly of the apparatus of Figure 8 taken along the line 10-10 of Figure 9.
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DETAILED DESCRIPTION

Referring to Figure 1, an apparatus for injecting an abrasive sealing mixture **200** into a subterranean well **6** having a casing **8** above a bridge plug **2** according to a first embodiment of the invention is shown generally at **10**. The apparatus **10** comprises a substantially elongate cylindrical body extending between first and second ends, **12** and **14**, respectively, along a central axis **500** and includes a control section **16** proximate to the first end **12** with a sealing injection section **56** proximate to the second end **14** and a piston activation section **80** therebetween. The sealing injection section **56** includes a cavity **40** adapted to retain the sealing mixture **200** therein. A piston **50** within the cavity **40** may be selectively moved to inject the sealing mixture **200** into the well **6** through a plurality of nozzles **72**, as will be more fully described below.

The control section **16** includes a first end connector **18** proximate to the first end **12** and a control system housing **20**, extending to a second end **28**, attached thereto, by means as are commonly known. The first end connector **18** is attached to a wireline **4** at the first end **12** by means as are commonly known, such as threading or the like. The wireline **4** connects to an internal electric line **22** which passes through the first end connector **18** and provides electrical signals from the wireline **4** to a control system **24** within the control system housing **20**. The control system **24** is comprised of such as, by way of non-limiting example, a solid-state board with control software and electrical connections **310** and **312** to a pressure transducer **26** and a step motor **94**, respectively, the purpose of which will be set out below.

The sealing injection section **56** is comprised of a tubular piston housing **30** extending between first and second ends, **32** and **34**, respectively, with an injection assembly housing **60** connected thereto at the second end **34**. The injection assembly housing **60** extends between a first end **62** and the second end **14** and includes the nozzles **72** extending therethrough, as will be set out below.

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The piston housing **30** includes outer and inner surfaces, **36** and **38**, respectively, and forms the cavity **40** therein. The piston housing **30** includes a plurality of axial grooves **46** in the inner surface **38** proximate to the second end **34**, the purpose of which will be set out below. The piston **50** is sealably retained in the piston housing **30** with piston seals **300** therebetween. The piston housing **30** may be comprised of two or more joined cylindrical portions, allowing for volume capacity adjustment of the cavity **40**. The piston **50** includes first and second surfaces **52** and **54**, respectively, and separates the cavity **40** into first and second cavities **42** and **44**, respectively.

Turning now to Figure **2**, the injection assembly housing **60**, having an outer surface **64**, is joined at the first end **62** to the second end **34** of the piston housing **30**, as outlined above. The injection assembly housing **60** includes a central cavity **66** therein, fluidically connected to the nozzles **72**. A cavity check valve **68** within the central cavity **66** is adapted to selectably fluidically connect the second cavity **44** with the nozzles **72**. The cavity check valve **68** may include an optional filter **302** thereon. Although a check valve **68** is illustrated in the present embodiment of the invention, it will be appreciated that other selectable retention means may be used, as well, such as, by way of non-limiting example, a flap valve or breakable seal.

The injection assembly housing **60** includes a fill port passage **70** extending therethrough from the outer surface **64** to the first end **62**, providing a fluidic connection from the outside of the apparatus **10** to the cavity **40**. The fill port passage **70** includes an ORB fill port/check valve, as is commonly known, such that the sealing mixture **200** may pass in one direction only, generally indicated at **502**, through the sealing fill port passage **70** into the cavity **40**.

The plurality of nozzles **72** extend through the injection assembly housing **60** in an oblique radial direction between the central cavity **66** and the outer surface **64** such that the nozzles **72** are oriented in a direction generally towards the first end **62**. The nozzles **72** may be oriented upwards at any angle. It will also be appreciated that angling the nozzles upwards may assist in lifting

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contaminants and debris off and away from the plug to provide a better seal thereover as well as to create a vacuum below the apparatus **10** thereby drawing the apparatus into closer contact with the bridge plug **2**.

5 Referring now to Figure **3**, the piston activation section **80** extends between first and second ends, **82** and **84**, respectively, and includes a compressed gas chamber **86** within a cylindrical housing **88** extending from the first end **82**, and a control valve assembly housing **90** extending between a first end **100** and the second end **84** and having an outer surface **92**. The compressed gas chamber
10 contains a compressed gas **202** such as, by way of non-limiting example, Nitrogen, although other compressed gases may be useful, as well. The pressure transducer **26** is positioned such that it is in fluidic communication with the compressed gas chamber **86** and thus provides a pressure measurement of the compressed gas **202** to the control system **24**. The control valve
15 assembly housing **90** includes the step motor **94** therein, joined by the electrical connection **312** to the control section **16**, as outlined above.

The control valve assembly housing **90** includes a plurality of passages therethrough, selectively fluidically connecting the compressed gas chamber
20 **86** with the first cavity **42**, as will be described herein. A valve **96** is sealably retained within a valve passage **98** extending between first and second ends, **110** and **112**, respectively, with first, second and third valve seals **304**, **306** and **308**, respectively, thereon. A compressed gas passage **102** extends through the control valve assembly housing **90** at the first end **100** and connects to the
25 valve passage **98**. In the run-in position, as illustrated in Figures **1** through **3**, the valve **96** is positioned within the valve passage **98** such that the compressed gas passage **102** is sealed between the first and second valve seals, **304** and **306**, thereby retaining the compressed gas **202** within the compressed gas chamber **86**. A compressed gas fill port passage **104** extends through the outer
30 surface **92** and fluidically connects to the compressed gas passage **102**. The compressed gas fill port passage **104** includes an ORB fill port/check valve, as is commonly known, such that the compressed gas **202** may pass in one

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direction only, generally indicated at **504**, through the compressed gas fill port passage **104** into the compressed gas chamber **86**.

5 A piston path passage **114** extends through the control valve assembly housing **90** at the second end **84**, fluidically connecting to the first cavity **42**, and connects to the valve passage **98**. In the run-in position, as illustrated in Figures **1** through **3**, the valve **96** is positioned within the valve passage **98** such that the piston path passage **114** is sealed between the second and third valve seals, **306** and **308**. First and second hydrostatic valve passages, **106** and **108**,
10 respectively, extend through the outer surface **92** and fluidically connect to the valve passage **98**, allowing well fluid at a hydrostatic pressure therethrough and balancing the valve **96**, as is commonly known. The first hydrostatic valve passage **106** fluidically connects to the valve passage **98** at the first end **110**. The second hydrostatic valve passage **108** is positioned proximate to the third
15 valve seal **308** and in the run-in position, as illustrated in Figures **1** through **3**, the valve **96** is positioned within the valve passage **98** such that the second hydrostatic valve passage **108** is sealed between the second and third valve seals, **306** and **308**. In this position, the piston path passage **114** and the second hydrostatic valve passage **108** are fluidically connected through the
20 valve **96**, thus maintaining the first cavity **42** at a hydrostatic pressure, equivalent to the pressure within the well **6**.

Referring now to Figures **4** and **5**, to inject the sealing mixture **200** into the well **6**, the apparatus **10** is positioned within the well **6** at a desired location and a
25 signal is sent through the wireline **4**, as is commonly known. The control section **16** sends a signal to the step motor **94**, activating the step motor **94** and shifting the valve **96** within the valve passage **98**. As best seen on Figure **5**, the valve **96** is shifted axially along the central axis **500** towards the first end **110** of the valve passage **98**, to the injecting position. In the injecting position, as illustrated
30 in Figures **4** and **5**, the valve **96** is positioned within the valve passage **98** such that the compressed gas passage **102** and the piston path passage **114** are sealed between the second and third valve seals, **306** and **308**, with the second hydrostatic valve passage **108** sealed on an opposite side of the third valve seal

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308. In this position, the compressed gas passage **102** and the piston path passage **114** are fluidically connected through the valve **96**, thus fluidically connecting the compressed gas chamber **86** and the first cavity **42**.

5 The pressure of the compressed gas **202** is pressurized to an activation pressure, such as, by way of non-limiting example, **10,000** PSI by way of non-limiting example, although it will be appreciated that other pressures may be useful as well when filled, whereas the pressure of the sealing mixture **200** within the second cavity **44** is essentially atmospheric. As the compressed gas
10 **202** enters the first cavity **42** it applies a force to the first surface **52** of the piston **50** which in turn transfers the force to the sealing mixture **200** on the second surface **54** of the piston **50**. As illustrated in Figure **6**, the force is sufficient to open the check valve **68**, therefore fluidically connecting the second cavity **44** with the nozzles **72**. The piston **50** moves in the direction generally indicated at
15 **506** in Figure **5**, forcing the sealing mixture **200** through the check valve **68** into the central cavity **66** and out of the apparatus **10** through the nozzles **72**. The abrasive sealing mixture **200** impacts the casing **8** at a high speed, clearing contaminants from the casing wall and promoting adhesion thereto.

20 The pressure of the compressed gas **202** is continuously measured by the pressure transducer **26**, as outlined above. As the piston **50** moves towards the first end **62** of the injection assembly housing **60**, the pressure within the compressed gas chamber **86** decreases, as is commonly known. Upon a decrease in pressure within the compressed gas chamber **86**, the apparatus **10**
25 is hoisted, therefore leaving the sealing mixture **200** over the bridge plug **2** to a depth required to form a permanent seal thereover such as, by way of non-limiting example, **3** meters for a resin-based, low-permeability gypsum cement or **8** meters for class "G" cement, although other interval distances for other sealants may be useful, as well. The sealing mixture **200** may be selected to
30 be of any known or suitable sealing type such a cement and resin-based epoxies. Additionally, the sealing mixture **200** may include a quantity of inert particles therein such as, by way of non-limiting example, silicate or ceramic

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which will be appreciated may assist in removing contaminants and debris from the wellbore wall.

5 The piston **50** continues to move within the piston housing **30** until the second surface **54** engages upon the first end **62** of the injection assembly housing **60**, as illustrated in Figure **7**. In this position the piston **50** is aligned with the axial grooves **46** within the inner surface **38** of the piston housing **30**. The piston seals **300** no longer sealably separate the first cavity **42** from the second cavity **44** and thus the compressed gas **202** passes around the piston **50** through the
10 axial grooves **46** in the direction indicated at **508** into the second cavity **44**. The compressed gas **202** thus passes into the central cavity **66** and out through the nozzles **72**, eliminating the sealing mixture **200** therefrom.

15 The apparatus **10** is removed from the well **6** upon discharge of the compressed gas and may be returned to the run-in position and reloaded with the sealing mixture **200** and compressed gas **202** to seal the well **6** at another location, as desired.

20 Turning now to Figures **8** and **10**, an apparatus for injecting an abrasive sealing mixture **200** into a subterranean well **6** having a casing **8** above a bridge plug **2** according to a further embodiment of the invention is shown generally at **120**. The apparatus **120** comprises a substantially elongate cylindrical body extending between first and second ends, **122** and **124**, respectively, along a central axis **510** and includes a control and activation section **126** proximate to
25 the first end **122** with an injection section **128** proximate to the second end **124** and a scraper section **350** therebetween. The scraper section **350** includes a plurality of extendable scrapers **352** operable to engage upon and mechanically scrape the casing **8** prior to injection, as will be set out further below. The injection section **128** includes a cavity **610** adapted to retain the sealing mixture
30 **200** or a cleaning fluid **204** therein. As set out above, the sealing mixture **200** may include a quantity of particles therein to add abrasive properties and to aid in cleaning and bonding to the wellbore wall. It will be appreciated that the cleaning fluid **204** may also include a quantity of inert abrasive particles therein,

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such as, by way of non-limiting example, silicate or ceramic particles. A piston **650** within the cavity **610** may be selectively moved to inject the contents of the cavity **610**, either the cleaning fluid **204** or the sealing mixture **200**, into the well **6** through a plurality of nozzles **480**, as will be more fully described below.

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Referring to Figures **10** and **11**, the control and activation section **126** utilizes signals from the wireline **4** to extend the scrapers **352** in the scraper section **350** and to control fluid flow through the nozzles **480** in the injection section **128** by controlling the positions of first and second valves, **150** and **152**, respectively, with first and second electric motors, **154** and **156**, respectively, such that compressed gas **202** contained in a compressed gas chamber **206** is selectively directed through a plurality of passages, as will be set out in further detail below.

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Turning now to Figure **11**, the control and activation section **126** includes a first end connector **118** extending from the first end **122** to a second end **130**. The first end connector **118** is attached to the wireline **4** at the first end **122** by means as are commonly known, such as threading or the like. A control system housing **132** is contained within the first end connector **118** and extends between the first end **122** and a second end **134** with a seal **320** therebetween proximate to the second end **134**. The first and second electric motors, **154** and **156**, are contained within a motor housing **136** which extends between first and second ends, **138** and **140**, respectively, and is connected to the second end **134** of the control system housing **132** within the first end connector **118** at the first end **138** with a seal **322** therebetween. The first and second valves, **150** and **152**, are contained within a valve manifold housing **142**, which extends between first and second ends, **144** and **146**, respectively. A valve outer housing **160** extends between first and second ends, **162** and **164**, respectively. The valve outer housing **160** is secured to the motor housing **136** at the first end **162** with threading or the like and with a seal **324** therebetween. The valve manifold housing **142** is contained within the valve outer housing **160** with a plurality of valve manifold seals **326** therebetween. The second end **164** of the valve outer housing **160** is secured to a throttle valve housing **166** with a seal

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326 therebetween. The throttle valve housing **166** extends between first and second ends, **168** and **170**, respectively, and contains a **2**-stage throttle valve **172** within a central throttle valve passage **174** therein, as will be set out below.

5 The wireline **4** provides electrical signals to a control system within the control system housing **132**. The control system is comprised of such as, by way of non-limiting example, a solid-state board with control software and electrical connections through sealed first and second feedthrough electrical connectors **180** and **182**, respectively, and through first and second valve electronics passages **184** and **186**, respectively, to first and second electric motors, **154** and **156**, respectively, connected by means as are commonly known. The first and second electric motors **154** and **156** are contained within first and second valve control cavities, **188** and **190**, respectively, within the motor housing **136**.

15 Turning now to Figure **12**, first and second valve manifold rods, **192** and **194**, respectively, are contained within first and second valve cavities, **196** and **198**, respectively, within the valve manifold housing **142**. The valve manifold housing **142** is aligned such that the first end **144** engages upon the second end **146** of the motor housing **136** and the first and second valve cavities **196** and **198** are aligned with the first and second electric motors **154** and **156** within the first and second valve control cavities **188** and **190**. The first and second electric motors **154** and **156** control the positions of the first and second valve manifold rods **192** and **194** with valve trains, as is commonly known.

25 The valve manifold housing **142** includes first, second, third, fourth and fifth annular passages, **210**, **212**, **214**, **216** and **218**, respectively, therearound proximate to the second end **146**, and include the valve manifold seals **330** therebetween to sealably separate the annular valve passages. The first valve cavity **196** includes first, second, third, fourth and fifth first-valve ports **230**, **232**, **234**, **236** and **238** respectively, and the second valve cavity **198** includes first, second, third, fourth and fifth second-valve ports **240**, **242**, **244**, **246** and **248**, respectively, with a plurality of seals **328** therebetween to sealably separate the valve ports, as is commonly known. A plurality of fluid passages are connected

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to the first and second valve cavities **196** and **198** at the valve ports, as will be set out further below. The first and second electric motors **154** and **156** control the positions of the first and second valve manifold rods **192** and **194** to adjust the fluidic connections between the plurality of fluid passages, as will be set out below and described more fully with schematics.

As illustrated in Figure **12**, a throttled compressed gas supply passage **220** is fluidically connected with the central throttle valve passage **174** within the throttle valve housing **166**, as will be set out further below. The throttled compressed gas supply passage **220** is fluidically connected to the first valve manifold cavity **196** through the throttle compressed gas connection passage **221** and the third first-valve port **234**.

As illustrated in Figure **12**, the fifth annular passage **218** is fluidically connected to the first valve cavity **196** at the fifth first-valve port **238** through a connection passage **268**. Turning now to Figure **13**, the fifth annular passage **218** is also fluidically connected to a bleed passage **222** through a connection passage **270**. Figure **19** further illustrates the connections at the fifth annular passage **218**. Turning back to Figure **13**, the bleed passage **222** is fluidically connected to the hydrostatic fluid in the production casing **8** through a check valve **224**, allowing for the contents of the bleed passage **222** to pass out of the apparatus **120** and into the surrounding hydrostatic fluid. The bleed passage **222** is also fluidically connected to first and second bleed connection passages, **226** and **228**. As illustrated in Figures **12**, **13** and **14**, the first bleed connection passage **226** is fluidically connected to the first valve manifold cavity **196** at the first first-valve port **230**. As illustrated in Figures **12**, **13** and **15**, the second bleed connection passage **228** is fluidically connected to the second valve manifold cavity **198** at the second second-valve port **242**.

As illustrated in Figure **13**, an injection supply passage **250** extends from the valve manifold housing **142** and through the throttle valve housing **166**, as will be set out further below. The injection supply passage is fluidically connected to first and second injection connection passages, **252** and **254**, respectively,

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within the valve manifold housing **142**. As illustrated in Figures **12**, **13** and **14**, the first injection connection passage **252** is fluidically connected to the second valve manifold cavity **198** at the first second-valve port **240**. As illustrated in Figures **12**, **13** and **15**, the second injection connection passage **254** is fluidically connected to the first valve manifold cavity **196** at the second first-valve port **232**.

Turning now to Figure **16**, a first compressed gas passage **256** extends from the first end **138** of the motor housing **136**, through the valve manifold housing **142** and into the throttle valve housing **166**. The first compressed gas passage **256** includes pressure transducer **208**, as is commonly known, proximate to the first end **138** of the motor housing **136**. As illustrated in Figures **16** and **17**, a compressed gas connection passage **258** extends from the first compressed gas passage **256** within the throttle valve housing **166** and joins a second compressed gas passage **260** which is fluidically connected to the compressed gas chamber **206** within a compressed gas housing **290**, as illustrated in Figure **11**. Referring to Figure **17**, the compressed gas connection passage **258** is also fluidically connected to a first stage throttle valve chamber **262**, thus providing full pressure compressed gas **202** to the first stage throttle valve chamber **262**, as will be set out further below.

As illustrated on Figure **16**, a scraper supply passage **264** extends from the valve manifold housing **142** and through the throttle valve housing **166**, as will be set out further below. The scraper supply passage **264** is fluidically connected to the scraper supply connection passage **266**. As illustrated in Figures **12**, **16** and **18**, the scraper supply connection passage **266** is fluidically connected to the second valve manifold cavity **198** at the third second-valve port **244**.

Referring now to Figures **12** and **20**, the fourth annular passage **216** fluidically connects the first valve manifold cavity **196** at the fourth first-valve port **236** to the second valve manifold cavity **198** at the fourth second-valve port **246** with connection passages **272** and **274**.

Figures **21** through **24** schematically illustrate the first and second valves **150** and **152** and the plurality of fluid passages as set out above in a first through a fourth operating position.

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As illustrated in Figure **21**, compressed gas **202** from the throttled compressed gas supply passage **220** enters the first valve **150** through the first compressed gas passage **256** into the third first-valve port **234**. In the first operating position, as illustrated, the position of the first valve manifold rod **192** is set for a fluidic connection between the third first-valve port **234** and the fourth first-valve port **236**. The fourth first-valve port **236** is connected to the fourth second-valve port **246**, which is sealed by the second valve manifold rod **194** in the first operating position. Thus, the compressed gas is blocked in the first operating position, and is retained within the compressed gas chamber **206**.

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Still referring to Figure **21**, the scraper supply passage **264** is fluidically connected to the third second-valve port **244** of the second valve **152** through the scraper supply connection passage **266**. In the first operating position, as illustrated, the position of the second valve manifold rod **194** is set for a fluidic connection between the first, second and third second-valve ports, **240**, **242** and **244**, respectively. The second second-valve port **242** is connected to the bleed passage **222**, therefore the scraper supply passage **264** is fluidically connected to the bleed passage, thus maintaining the scraper supply passage **264** at hydrostatic pressure in the first operating position.

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The injection supply passage **250** is fluidically connected to the first second-valve port **240** of the second valve **152** through the first injection connection passage **252** and to the second first-valve port **232** through the second injection connection passage **254**. In the first operating position, as illustrated, the position of the second valve manifold rod **194** is set for a fluidic connection between the first, second and third second-valve ports, **240**, **242** and **244**, respectively. The position of the first valve manifold rod **192** is set for a fluidic connection between the first and second first-valve ports, **230** and **232**,

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respectively. The second second-valve port **242** is connected to the bleed passage **222**, and the first first-valve port **230** is also connected to the bleed passage **222**, therefore the injection supply passage **250** is fluidically connected to the bleed passage, thus maintaining the injection supply passage **250** at hydrostatic pressure in the first operating position.

Turning now to Figure **22**, compressed gas **202** from the throttled compressed gas supply passage **220** enters the first valve **150** through the first compressed gas passage **256** into the third first-valve port **234**. In the second operating position, as illustrated, the position of the first valve manifold rod **192** is set for a fluidic connection between the third first-valve port **234** and the fourth first-valve port **236**. The fourth first-valve port **236** is connected to the fourth second-valve port **246**. The position of the second valve manifold rod **194** is set such that the fourth second-valve port **246** is connected to the third second-valve port **244**. The third second-valve port **244** is fluidically connected to the scraper supply passage **264** through the scraper supply connection passage **266**. Thus, in the second operating position, the compressed gas is directed to the scraper supply passage **264**.

Still referring to Figure **22**, the injection supply passage **250** is fluidically connected to the first second-valve port **240** of the second valve **152** through the first injection connection passage **252** and to the second first-valve port **232** through the second injection connection passage **254**. In the second operating position, as illustrated, the position of the second valve manifold rod **194** is set such that the first second-valve ports **240** is sealed. The position of the first valve manifold rod **192** is set for a fluidic connection between the first and second first-valve ports, **230** and **232**, respectively. The first first-valve port **230** is connected to the bleed passage **222**, therefore the injection supply passage **250** is fluidically connected to the bleed passage **222**, thus maintaining the injection supply passage **250** at hydrostatic pressure in the second operating position.

Turning now to Figure **23**, compressed gas **202** from the throttled compressed gas supply passage **220** enters the first valve **150** through the first compressed gas passage **256** into the third first-valve port **234**, as set out above. In the third operating position, as illustrated, the position of the first valve manifold rod **192** is set for a fluidic connection between the third first-valve port **234** and the second first-valve port **232**. The second first-valve port **232** is connected to the injection supply passage **250** through the second injection connection passage **254**. The second first-valve port **232** is also connected to the first second-valve port **240**, which is sealed by the second valve manifold rod **194**. Thus, the compressed gas is directed to the injection supply passage **250** in the third operating position.

Still referring to Figure **23**, the scraper supply passage **264** is fluidically connected to the third second-valve port **244** of the second valve **152** through the scraper supply connection passage **266**. In the third operating position, as illustrated, the position of the second valve manifold rod **194** is set for a fluidic connection between the third and fourth second-valve ports, **244** and **246**, respectively. The fourth second-valve port **246** is connected to fourth first-valve port **236**. The position of the first valve manifold rod **192** is set for fluidic connection between the fourth first-valve port **236** and the fifth first-valve port **238**. The fifth first-valve port **238** is fluidically connected to the bleed passage **222**. Therefore, in the third operating position, the scraper supply passage **264** is fluidically connected to the bleed passage **222** thus maintaining the scraper supply passage **264** at hydrostatic pressure.

Turning now to Figure **24**, compressed gas **202** from the throttled compressed gas supply passage **220** enters the first valve **150** through the first compressed gas passage **256** into the third first-valve port **234**. In the fourth operating position, as illustrated, the position of the first valve manifold rod **192** is set for a fluidic connection between the third first-valve port **234** and the second first-valve port **232**. The second first-valve port **232** is fluidically connected to the injection supply passage **250** as well as to the first second-valve port **240**. The second valve manifold rod **194** is set for fluidic connection between the first,

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second and third second-valve ports, **240**, **242**, and **244**, respectively, in the fourth operating position. The second second-valve port **242** is fluidically connected to the bleed passage **222**, while the third second-valve port **244** is fluidically connected to the scraper supply passage **264**. Thus, in the fourth operating condition, the throttled compressed gas supply passage **220** and the injection supply passage **250** and the scraper supply passage **264** are all fluidically connected to the bleed passage **222**. In this position, the compressed gas **202** within the compressed gas chamber **206** is bled into the surrounding hydrostatic fluid, resulting in a hydrostatic pressure throughout the apparatus **120**.

Referring now to Figures **11** and **25**, as set out above, the 2- stage throttle valve **172** is located within the throttle valve housing **166** proximate to the first end **168**. The 2-stage throttle valve **172** is comprised of a first stage throttle valve **400** and a second stage throttle valve **402**. The compressed gas **202** is received from the compressed gas chamber **206** through the compressed gas connection passage **258**, as set out above, into the first stage throttle valve **400**, where the pressure of the compressed gas **202** is regulated to a first stage pressure. The compressed gas **202** continues to the second stage throttle valve **402** through a connection passage **286** where the pressure is regulated to a second stage pressure before it is directed to the valves **150** and **152**, as set out above. The compressed gas **202** is stored within the compressed gas chamber **206** at a pressure such as, by way of non-limiting example, **5000** psig. The first stage throttle valve **400** regulates the pressure of the compressed gas **202** to such as, by way of non-limiting example, **2500** psig and the second stage throttle valve **402** further regulates the pressure of the compressed gas **202** to such as, by way of non-limiting example, **200** psig, as well be set out further below.

Referring now to Figure **26**, the first stage throttle valve **400** includes a first stage throttle valve plunger **404** having an outer surface **410** and extending between first and second ends, **406** and **408**, respectively. The second end **408** of the first stage throttle valve plunger **404** is contained within the first stage

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throttle valve chamber **262** and the first end **406** is contained within a first stage throttle valve sleeve **420**. A first stage throttle valve spring **422** is also contained within the first stage throttle valve chamber **262** and extends between the second end **408** of the first stage throttle valve plunger **404** and an inner annular shoulder **276** within the first stage throttle valve chamber **262**. The first stage throttle valve plunger **404** includes a widened portion **412** at the first end **406** with a downwardly oriented annular ridge **414** separating the widened portion **412** from a narrow portion **416**. The narrow portion **416** extends to an upright annular wall **418** defining a sealing portion **424** which extends to the second end **408** of the first stage throttle valve plunger **404**. A seal **332** within the sealing portion **424** sealably separates the first stage throttle valve chamber **262** into pressurized and hydrostatic chambers, **278** and **280**, respectively. The hydrostatic chamber **280** is fluidically connected to the surrounding hydrostatic fluid through a bleed passage **282** and filter **284**. The pressurized chamber **278** is fluidically connected to the compressed gas chamber **206** through the compressed gas connection passage **258**.

The first stage throttle valve sleeve **420** has an inner surface **426** forming a first stage throttling chamber **428** therein. The widened portion **412** of the first stage throttle valve plunger **404** extends into the first stage throttling chamber **428** through a throttle orifice **430**. The throttle orifice **430** is sized to form an annular gap **432** between the outer surface **410** at the narrow portion **416** of the first stage throttle valve plunger **404** and the inner surface **426** at the throttle orifice **430**. An inner annular shoulder **434** proximate to the throttle orifice **430** within the first stage throttling chamber **428** is sized such that the annular ridge **414** may engage thereupon, while providing a gap **436** between the widened portion **412** and the inner surface **426** of the first stage throttling chamber **428**, allowing compressed gas to pass therethrough. The gap **436** is sized to meter the flow of compressed gas therethrough, as is commonly known. The first stage throttle valve **400** is connected to the second stage throttle valve **402** through the connection passage **286** which extends from the first stage throttling chamber **428**.

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As illustrated in Figure **26**, the compressed gas **202** flows through the first stage throttle valve **400** in a direction indicated generally at **508**. The compressed gas **202** enters the first stage throttle valve **400** through the compressed gas connection passage **258** into the pressurized chamber **278** of the first stage throttle valve chamber **262**. The compressed gas **202** flows through the gap **432** and through a variable gap between the annular ridge **414** and the annular shoulder **434**, then through the gap **436** into the first stage throttling chamber **428**. As is commonly known, a reduction in pressure is achieved by forcing gas flow through a resistance point, such as an orifice. The pressurized compressed gas **202** shifts the location of the first stage throttle plunger **404** by applying force to the upright annular wall **418** which is counteracted upon by the spring force of the first stage throttle valve spring **422**. The first stage throttle valve spring **422** is selected to have a spring force which results in a pressure reduction such that the pressure of the compressed gas **202** in the first stage throttling chamber **428** is **2500** psig, as set out above.

Turning now to Figure **27**, the second stage throttle valve **402** includes a second stage throttle valve plunger **440** having an outer surface **446** and extending between first and second ends, **442** and **444**, respectively. The second end **444** of the second stage throttle valve plunger **440** is contained within the central throttle valve passage **174** and the first end **442** is contained within a second stage throttle valve sleeve **460**. The first end **442** of the second stage throttle valve plunger **440** includes a plurality of axial notches **474**. A second stage throttle valve spring **462** is also contained within the central throttle valve passage **174** and extends between the second end **444** of the second stage throttle valve plunger **440** and an inner annular shoulder **176** within the central throttle valve passage **174**. The second stage throttle valve plunger **440** includes a widened portion **450** at the first end **442** with a downwardly oriented annular ridge **452** separating the widened portion **450** from a narrow portion **454**. The narrow portion **454** extends to an upright annular wall **456** defining a sealing portion **464** which extends to the second end **444** of the second stage throttle valve plunger **440**. A seal **334** within the sealing portion **464** sealably separates the central throttle valve passage **174** into pressurized and

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hydrostatic chambers, **448** and **458**, respectively. The hydrostatic chamber **458** is fluidically connected to the surrounding hydrostatic fluid through the bleed passage **282** and filter **284**, as set out above. The pressurized chamber **448** is fluidically connected to the first stage throttle valve **400** through the connection passage **286**.

The second stage throttle valve sleeve **460** has an inner surface **466** forming a second stage throttling chamber **468** therein. The second stage throttling chamber **468** is fluidically connected with the notches **474** at the first end **442** of the second stage throttle valve plunger **440** and with the throttled compressed gas supply passage **220**. The widened portion **450** of the second stage throttle valve plunger **440** extends into the second stage throttling chamber **468** and is retained therein with an inner annular shoulder **470**. An annular gap **472** is formed between the outer surface **446** at the widened portion **450** of the second stage throttle valve plunger **440** and the inner surface **466** of the second stage throttle valve sleeve **460**. The annular shoulder **470** is sized such that the annular ridge **452** may engage thereupon, forming a variable gap therebetween allowing compressed gas to pass therethrough. The annular gap **472** is sized to meter the flow of compressed gas therethrough, as is commonly known. The first stage throttle valve **400** is connected to the second stage throttle valve **402** through the connection passage **286** which extends from the first stage throttling chamber **428**.

As illustrated in Figure **27**, the compressed gas **202** flows through the second stage throttle valve **402** in a direction indicated generally at **512**. The compressed gas **202** enters the second stage throttle valve **402** through the connection passage **286** into the pressurized chamber **448** of the central throttle valve passage **174**. The compressed gas **202** flows through the variable gap between the annular ridge **452** and the annular shoulder **470**, then through the gap **472** and through the notches **474** into the second stage throttling chamber **468** and into the throttled compressed gas supply passage **220**. As is commonly known, and as set out above, a reduction in pressure is achieved by forcing gas flow through a resistance point, such as an orifice. The pressurized compressed

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gas **202** shifts the location of the second stage throttle valve plunger **440** by applying force to the upright annular wall **456** which is counteracted upon by the spring force of the second stage throttle valve spring **462**. The second stage throttle valve spring **462** is selected to have a spring force which results in a pressure reduction such that the pressure of the compressed gas **202** in the second stage throttling chamber **468** is **200** psig, as set out above.

As illustrated in Figure **10**, the compressed gas housing **290** extends between first and second ends **292** and **294**, respectively. As illustrated in Figure **11**, the first end **292** of the compressed gas housing **290** is sealably secured to the second end **170** of the throttle valve housing **166** with a plurality of seals **336** therebetween. The compressed gas housing **290** is secured to the throttle valve housing **166** by means as are commonly known, such as, by way of non-limiting example, threading or the like. As illustrated in Figure **28**, the scraper section **350** includes a scraper housing **354** which extends between first and second ends **356** and **358**, respectively. The second end **294** of the compressed gas housing **290** is sealably secured to the first end **356** of the scraper housing **354** by means as are commonly known, such as, by way of non-limiting example, threading or the like, with a plurality of seals **338** therebetween.

Referring to Figures **16** and **28**, the scraper supply passage **264** passes from the valve manifold housing **142**, through the throttle valve housing **166** and through the compressed gas housing **290** into the scraper housing **354**.

Referring to Figures **28** through **32**, a plurality of scrapers **352** are supported on the scraper housing **354** at first and second scraper assemblies, **360** and **362**, respectively. A central mandrel **580** extends between first and second ends **582** and **584**, respectively, along the central axis **510** within a central axial bore **368** which extends between the first and second ends, **356** and **358**, respectively, of the scraper housing **354**. As best illustrated in Figure **29**, the central mandrel **580** is sized such that the axial bore **368** and the central mandrel **580** form an annular passage **378** therebetween, the purpose of which will be set out further below.

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Each scraper assembly, **360** and **362**, includes three scrapers **352** rotationally separated by **120** degrees about the central axis **510**. The scraper assemblies **360** and **362** are formed in a similar manner with an offset from each other of **60** degrees such that the first and second scraper assemblies **360** and **362** together include scrapers **352** covering the full **360** degrees around the central axis **510** of the apparatus **120**. A radial scraper piston **364** is secured within a radial bore **366** in the scraper housing **354** corresponding to each scraper **352**, as best illustrated in Figure **29**. Each radial bore **366** is fluidically connected to the annular passage **378**, the purpose of which will be set out further below. Each radial scraper piston **364** extends between first and second ends, **370** and **372**, respectively, with the first end **370** sealably secured within the radial bore **366** by means as are commonly known, such as, by way of non-limiting example, threading or the like, and a seal **338** therebetween. The second end **372** of each radial scraper piston **364** is slideably retained within a scraper extension bore **374** within the corresponding extendable scraper **352** with a seal **340** therebetween. Each radial scraper piston **364** includes a central passage **376** therethrough.

As illustrated in Figures **28** and **31**, Each scraper **352** extends between first and second ends, **380** and **382**, respectively with upper and lower surfaces, **384** and **386**, respectively. Each scraper **352** includes a retention portion **388** with a spring seat **390** formed in the upper surface **384** at each of the first and second ends, **380** and **382**, as shown in Figures **31** and **32**. A plurality of circumferential scraper ridges **392** extend from the upper surface **384** between the two retention portions **388**. The scraper ridges **392** are formed to correspond with the interior surface of the casing **8** such that when the scrapers **352** are extended, as will be set out below, they will contact the casing **8** such that any debris collected thereon may be engaged upon by the scraper ridges **392**. The scraper extension bore **374** is formed in the lower surface **386** of each scraper **352**, centered between the first and second ends, **380** and **382**, to correspond with the radial scraper piston **364**, and forms an extension cavity **396** therein.

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Turning now to Figure **28**, a first scraper retention collar **550** extends between first and second ends, **552** and **554**, respectively, with outer and inner surfaces, **556** and **558**, respectively. The first scraper retention collar **550** engages upon the scraper housing **354** at the first end and the second end **554** extends over the retention portion **388** at the first end **380** of the three scrapers **352** in the first scraper assembly **360**. A retraction spring **394** extends radially from within each spring seat **390** at the first end **380** of each scraper **352** in the first scraper assembly **360** to the inner surface **558** of the first scraper retention collar **550** proximate to the second end **554**.

A second scraper retention collar **560** extends between first and second ends, **562** and **564**, respectively, with outer and inner surfaces, **566** and **568**, respectively. The first end **562** of the second scraper retention collar **560** extends over the retention portion **388** at the second end **382** of the scrapers **352** in the first scraper assembly **360**, while the second end **564** extends over the retention portion **388** at the first end **380** of the scrapers **352** in the second scraper assembly **362**, and the second scraper retention collar **560** engages upon the scraper housing **354** at a middle portion therebetween. Retraction springs **394** extend radially from within the spring seats **390** at the second end **382** of each scraper **352** in the first scraper assembly **360** to the inner surface **568** of the second scraper retention collar **560** proximate to the first end **562**, and retraction springs **394** extend radially from within the spring seats **390** at the first end **380** of each scraper **352** in the second scraper assembly **362** to the inner surface **568** of the second scraper retention collar **560** proximate to the second end **564**.

A third scraper retention collar **570** extends between first and second ends, **572** and **574**, respectively, with outer and inner surfaces, **576** and **578**, respectively. The first end **572** of the third scraper retention collar **570** extends over the retention portion **388** at the second end **382** of the scrapers **352** in the second scraper assembly **362**, while the second end **574** engages upon the scraper housing **354**. Retraction springs **394** extend radially from within the spring seats

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390 at the second end **382** of each scraper **352** in the second scraper assembly **362** to the inner surface **578** of the third scraper retention collar **570** proximate to the first end **572**.

5 The third scraper retention collar **570** and second scraper assembly **362** are illustrated in cross section in Figure **32** through the retention portion **388** at the second end **382** of the scrapers **352**. It will be appreciated that for illustration purposes only, the top two scrapers **352** are illustrated in an extended position, while the bottom scraper **352** is illustrated in a retracted position. In operation,
10 all scrapers **352** would be in either the extended or retracted position. The retraction springs **394** are compression springs, as are commonly known, and offer resistance to compressive forces. When the scrapers **352** are in an extended position, the retraction springs **394** are compressed, as illustrated on the top two scrapers **352** in Figure **32**, providing a spring force between the
15 inner surface **578** of the third scraper retention collar **570** and the upper surface **384** of the scrapers **352** within the spring seats **390**.

Referring to Figures **13** and **33**, the injection supply passage **250** passes from the valve manifold housing **142**, through the throttle valve housing **166** and
20 through the compressed gas housing **290** into the scraper housing **354**. As illustrated in Figures **28** and **33**, a first end plug **586** is sealably retained within the central axial bore **368** proximate to the first end **356** with seals **342** between the first end plug **586** and the scraper housing **354**. The first end **582** of the central mandrel **580** is sealably retrained within the first end plug **586** with a seal **344** therebetween. As best illustrated in Figure **33**, the injection supply passage **250** continues from the scraper housing **354** through the first end plug **586** and through the center of the central mandrel **580**. Referring to Figure **28**, a second end plug is sealably retained within the central axial bore **368**
25 proximate to the second end **358** with a seal **346** between the second end plug **588** and the scraper housing **354**. The second end **584** of the central mandrel **580** is sealably retrained within the second end plug **588** with a seal **348** therebetween. The injection supply passage **250** is thus sealably separated from the annular passage **378**.
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Referring now to Figure **28**, as set out above, the scraper supply passage **264** extends into the scraper housing **354**. The scraper housing **354** includes a check valve **590** fluidically connecting the scraper supply passage **264** with the surrounding hydrostatic fluid. The check valve **590** is selected to allow flow in one direction only, from the scraper supply passage **264** into the surrounding hydrostatic fluid, when the pressure within the scraper supply passage **264** reaches a threshold pressure, such as, by way of non-limiting example, 300 psig. The scraper supply passage **264** is fluidically connected to the annular passage **378**. As set out above, and as illustrated in Figures **29** and **30**, the annular passage **378** is fluidically connected to the central passage **376** within each radial scraper piston **364**.

As set out above, throttled compressed gas **202** may be selectively directed to the scraper supply passage **264** by setting the first and second valves **150** and **152** to the second position, as illustrated in Figure **22**. When pressurized compressed gas **202** is directed through the scraper supply passage **264**, the compressed gas **202** passes through the annular passage **378** and through the central passages **376** to the extension cavities **396** within the scrapers **352**. When the pressure of the compressed gas **202** exceeds the spring force of the two retraction springs **394** on each scraper **352**, the compressed gas **202** shifts the scrapers **352** from the retracted position, as illustrated in Figure **29**, to the extended position, as illustrated in Figure **30**, thereby filling the extension cavities **396**.

Turning now to Figure **34**, the injection section **128** is comprised of a tubular piston housing **600** extending between first and second ends, **602** and **604**, respectively, with an injection assembly **630** connected thereto at the second end **604**. The first end **602** is sealably secured to the second end **358** of the scraper housing **354** by means as are commonly known, such as, by way of non-limiting example, threading or the like, with a seal **314** therebetween. The injection assembly **630** extends between a first end **632** and the second end

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124 and includes the nozzles **480** extending therethrough, as will be set out below.

5 The piston housing **600** includes outer and inner surfaces, **606** and **608**, respectively, and forms the cavity **610** therein. The piston **650** is sealably retained in the piston housing **600** with a piston seal **316** therebetween. The piston housing **600** may be comprised of two or more joined cylindrical portions, allowing for volume capacity adjustment of the cavity **610**. It will be appreciated that for illustration purposes, only a portion of the piston housing **600** is shown
10 in Figure **34**. The piston **650** includes first and second surfaces **652** and **654**, respectively, and separates the cavity **610** into first and second cavities **612** and **614**, respectively.

Referring to Figures **13**, **28**, **33** and **34**, the injection supply passage **250** passes
15 from the valve manifold housing **142**, through the throttle valve housing **166**, through the compressed gas housing **290**, through the scraper housing **354** and through the central mandrel **580** and second end plug **588**. The injection supply passage **250** is fluidically connected to the first cavity **612** through the second end plug **588**.

20 The piston **650** includes a central bore **656** therethrough containing a bypass pin **660** therein. The central bore **656** is fluidically connected with a bypass passage **658** within the piston **650**, which is fluidically connected with the second cavity **614**. As best shown on Figure **35**, the bypass pin **660** extends between first and second ends, **662** and **664**, respectively, and includes an annular wall **670** separating a wide portion **672** extending from the first end **662** from a narrow sealing portion **674** extending to the second end **664**. The sealing portion **674** includes a plurality of seals **318** thereon. The bypass pin **660**
25 includes an axial bypass passage **666** therein, extending from the first end **662** to a radial bypass passage **668** extending radially through the bypass pin **660** at a location on the sealing portion **674** between two seals **318**.
30

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A first end spring seat **676** with a central passage **678** therethrough is secured within the central bore **656** proximate to the first surface **652** of the piston **650**. The central passage **678** fluidically connects the first cavity **612** with the axial bypass passage **666** within the bypass pin **660**. A pin spring **680** extends between the first end spring seat **676** and the first end **662** of the bypass pin **660**. As illustrated in Figure **34**, the pin spring **680** provides a spring force, as is commonly known, to position the bypass pin **660** such that the annular wall **670** engages upon an inner annular wall **682** within the central bore **656**. In this position the radial bypass passage **668** is sealably separated from the bypass passage **658**, thus the first and second cavities, **612** and **614**, respectively, are sealably separated.

The injection assembly **630** includes a valve housing **634** extending from the first end **632** to a second end **636** with a nozzle housing **686** sealably secured thereto with a seal **482** therebetween. The first end **632** of the injection assembly **630** is sealably secured to the second end **604** of the piston housing **600** with a seal **484** therebetween. The valve housing **634** includes an axial bore **640** therethrough with a check valve **642** sealably retained therein with a seal **484** therebetween. The check valve **642** is formed as is commonly known, and includes a plurality of passages **644** therethrough. It will be appreciated that, for illustration purposes, the check valve **642** is illustrated in an open position in Figures **34** and **35**, indicating that pressure is applied to the check valve **642** to force it open and to fluidically connect the second cavity **614** with the nozzles **480**. Although a check valve **642** is illustrated in the present embodiment of the invention, it will be appreciated that other selectable retention means may be used, as well, such as, by way of non-limiting example, a flap valve or breakable seal.

The nozzle housing **638** includes a central cavity **486** therein, fluidically connected to the nozzles **480**. The check valve **642** within the valve housing **634** is adapted to selectably fluidically connect the second cavity **614** with the nozzles **480**. The check valve **642** may include an optional filter thereon.

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As illustrated in Figure **36**, the valve housing **634** includes at least one fill port passage **616** extending therethrough from an outer surface **618** to the first end **632**, providing a fluidic connection from the outside of the apparatus **120** to the second cavity **614**. The fill port passage **616** may include an ORB fill port/check valve, as is commonly known, such that the contents of the second cavity **614** may pass in one direction only, generally indicated at **514**, through the fill port passage **616** into the second cavity **614**.

The plurality of nozzles **480** extend through the nozzle housing **638** between the central cavity **486** and an outer surface **488** such that the nozzles **480** are oriented in a direction generally towards the casing **8**. The nozzles **72** may be oriented at any angle.

As set out above, throttled compressed gas **202** may be selectively directed to the injection supply passage **250** by setting the first and second valves **150** and **152** to the third operating position, as illustrated in Figure **23**.

When compressed gas **202** is directed into the injection supply passage **250**, it enters the first cavity **612** and the pressure of the compressed gas **202** acts upon the first surface **652** of the piston **650**, thereby shifting the piston within the cavity **610** in a direction generally indicated at **516** in Figure **34**. As the piston **650** shifts within the cavity **610**, the second surface **654** applies force to the contents of the second cavity **614**, thereby opening the check valve **642** and pushing the contents of the second cavity **614** through the check valve **642**, through the passages **644**, into the central cavity **486** and out through the nozzles **480** such that the contents of the second cavity **614** impact the casing **8**. It will be appreciated that the nozzles **480** are oriented such that the wellbore fluid is displaced upward within the wellbore, thereby reducing contamination and further improving bonding to the casing **8**.

The piston **650** continues to shift in the direction indicated at **516** until the second end **664** of the bypass pin **660** engages upon the first end **632** of the

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injection assembly **630**, as illustrated in Figure **35**. With continued applied pressure, the piston **650** continues to move in the direction indicated at **516** until the second surface **654** engages upon the first end **632** of the injection assembly **630**. The pin spring **680** compresses and the bypass pin **660** shifts within the central bore **656** until the radial bypass passage **668** is aligned with the bypass passage **658** such that the compressed gas **202** may pass therethrough.

As illustrated in Figure **35**, the bypass passage **658** is aligned with the check valve **642**. Continued supply of compressed gas **202** passes through the axial bypass passage **666** and the radial bypass passage **668** and through the bypass passage **658** into and through the check valve **642** such that the compressed gas **202** fills the central chamber **486** and passes out of the apparatus **120** through the nozzles **480**. This flushes the nozzles **480**. As the compressed gas **202** is depleted, the pressure decreases and the spring force of the pin spring **680** eventually overcomes the pressure of the compressed gas **202** and shifts the bypass pin **660** within the central bore **656**, moving the piston **650** away from the injection assembly **630**. As the pin spring **680** shifts within the central bore **656**, the radial bypass passage **668** is moved away from the bypass passage **658** such that they are sealably separated and no longer in fluidic communication.

To prepare the apparatus **120** for operation, the first and second valves **150** and **152** are set to the first operating position, as illustrated in Figure **21**, such that the compressed gas **202** is blocked, with the scraper supply passage **264** and injection supply passage **250** open to the bleed passage **222**. In this position, the compressed gas chamber **206** may be filled.

The compressed gas chamber **206** is filled with compressed gas **202** through the first compressed gas passage **256**, which is fluidically connected to the second compressed gas passage **260** through the compressed gas connection passage **258**, as illustrated in Figure **17**, with the second compressed gas

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passage **260** fluidically connected to the compressed gas chamber **206**, as illustrated in Figure **11**.

5 The second cavity **614** is initially filled with the cleaning fluid **204** through the fill port passages **616** illustrated in Figure **36**. As the second cavity **614** is filled, the piston **650** is shifted towards the first end **602** of the piston housing **600**.

10 The apparatus **120** is then positioned within the well **6** at a desired location and a signal is sent through the wireline **4**, as is commonly known. The control and activation section **126** sends a signal to the first and second electric motors **154** and **156**, activating the motors **154** and **156** and shifting the first and second first and second valve manifold rods **192** and **194** of the valves **150** and **152** within the first and second valve manifold cavities **196** and **198**, as set out above.

15 Once in position, the first and second valves **150** and **152** are set to the second position, as illustrated in Figure **22**, with the compressed gas **202** directed to the scraper supply passage **264** such that the scrapers **352** are extended, as set out above. With the scrapers **352** extended, the apparatus **120** may be
20 mechanically moved within the well **6** by raising and lowering the wireline **4** such that the scrapers **352** engage upon the casing **8** and scraper off any debris accumulated there.

25 After scraping debris from the casing **8**, the first and second valves **150** and **152** are set to the third operating position, with the compressed gas **202** directed to the injection supply passage **250**, as set out above. In this position, the cleaning fluid **204** is jetted out of the nozzles **480** at a high pressure and velocity to further clean the casing **8** and to prepare it for cement bonding. The apparatus **120** may be mechanically moved within the well **6** by raising and
30 lowering the wireline **4** while the cleaning fluid **204** is jetted out of the nozzles **480**.

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After the cleaning fluid **204** is depleted from the cavity **610**, the first and second valves **150** and **152** are set to the fourth position, with the compressed gas **202**, scraper passage **264** and injection supply passage **250** all connected to the bleed passage **222**, as set out above. In this position, the compressed gas **202** within the apparatus **120** is bled out until it reaches hydrostatic pressure, for safety purposes. The apparatus **120** may then be returned to the surface to prepare for the sealing procedure.

As set out above, the first and second valves **150** and **152** are set to the first operating position, as illustrated in Figure **21**, and the compressed gas chamber **206** is filled with compressed gas **202** through the first compressed gas passage **256**.

The second cavity **614** is then filled with the sealing mixture **200** through the fill port passages **616** illustrated in Figure **36**. As the second cavity **614** is filled, the piston **650** is shifted towards the first end **602** of the piston housing **600**.

The apparatus **120** is then positioned within the well **6** at a desired location and a signal is sent through the wireline **4**, as set out above. The first and second valves **150** and **152** are set to the third operating position, with the compressed gas **202** directed to the injection supply passage **250**, as set out above. In this position, the sealing mixture **200** is jetted out of the nozzles **480** at a high pressure and velocity such that it impacts the casing **8** at a high speed, clearing remaining contaminants from the casing wall and promoting adhesion thereto.

When the sealing mixture **200** is depleted from the cavity **610** and the nozzles **480** have been flushed, as set out above, the first and second valves **150** and **152** are set to the fourth position, with the compressed gas **202**, scraper passage **264** and injection supply passage **250** all connected to the bleed passage **222**, as set out above. In this position, the compressed gas **202** within the apparatus **120** is bled out until it reaches hydrostatic pressure, for safety purposes. The apparatus **120** may then be returned to the surface.

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While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

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What is claimed is:

1. An apparatus for preparing a casing of a subterranean well and injecting a sealing mixture into the subterranean well comprising:
 - 5 an elongate body extending between top and bottom ends, said body connectable to a wireline at said top end thereof and having a plurality of nozzles extending through said body proximate to said bottom end thereof;
 - 10 a plurality of scrapers positioned within said body, each having a first position retracted within said body and a second position radially extended from said body engageable with the casing;
 - a cavity within said body operable to contain the sealing mixture therein;
 - 15 and
 - a piston slideably movable within said cavity so as to eject the sealing mixture through said plurality of nozzles.
- 20 2. The apparatus of claim 1 wherein said piston divides said cavity into first and second chambers.
3. The apparatus of claim 1 wherein said cavity includes a retention means selectably fluidically connected with said plurality of nozzles.
- 25 4. The apparatus of claim 3 wherein said retention means is selected from a group consisting of a check valve, a flap valve and a breakable seal.
5. The apparatus of claim 2 further comprising a compressed gas tank
- 30 within said body.
6. The apparatus of claim 5 wherein said compressed gas tank is fluidically connected to a valve assembly.

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7. The apparatus of claim **6** wherein said plurality of scrapers include a plurality of radial pistons selectably fluidically connected to said compressed gas tank through said valve assembly.

5

8. The apparatus of claim **7** wherein said plurality of radial pistons are operable to extend said plurality of scrapers between said first position and said second position.

10

9. The apparatus of claim **6** wherein said compressed gas tank is selectably fluidically connected through said valve assembly to said first chamber.

15

10. The apparatus of claim **6** further comprises at least one motor within said body, said at least one motor operable to selectably move said valve assembly.

11. The apparatus of claim **10** wherein each said at least one motor comprises a step motor.

20

12. The apparatus of claim **10** further comprises a control circuit connected to said wireline and to said at least one motor.

13. The apparatus of claim **12** wherein said control system comprises a processor.

25

14. The apparatus of claim **9** wherein said piston includes a bypass passage therethrough operable to selectively connect said first chamber with said second chamber.

30

15. A method for preparing a casing of a subterranean well and sealing the subterranean well comprising:

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positioning a body having a cavity therein in the subterranean well at a location to be sealed;

5 extending a plurality of scraper assemblies from said body thereby engaging said plurality of scraper assemblies with the casing;

displacing said body within the well so as to engage said plurality of scraper assemblies against a length of the casing;

10 retracting said plurality of scraper assemblies;

positioning said body in the subterranean well at said location to be sealed; and

15 slideably displacing a piston within said cavity of said body so as to eject a sealing mixture contained within said cavity through a plurality of nozzles fluidically connected to said cavity and located through said body.

20 **16.** The method of claim **15** further comprising:

prior to ejecting said sealing mixture, slideably displacing said piston within said cavity of said body so as to eject a cleaning fluid contained within said cavity through said plurality of nozzles;

25 removing said body from the subterranean well and filling said cavity of said body with said sealing mixture; and

30 positioning said body in the subterranean well at said location to be sealed.

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17. The method of claim **15** wherein said piston is displaced by introducing a compressed gas to said cavity on an opposite side of said piston from said plurality of nozzles.

5 **18.** The method of claim **17** wherein said compressed gas is contained within a gas tank in said body with a valve assembly operable to selectably connect said gas tank with said scraper assemblies and with said cavity on said opposite side of said piston from said plurality of nozzles.

10

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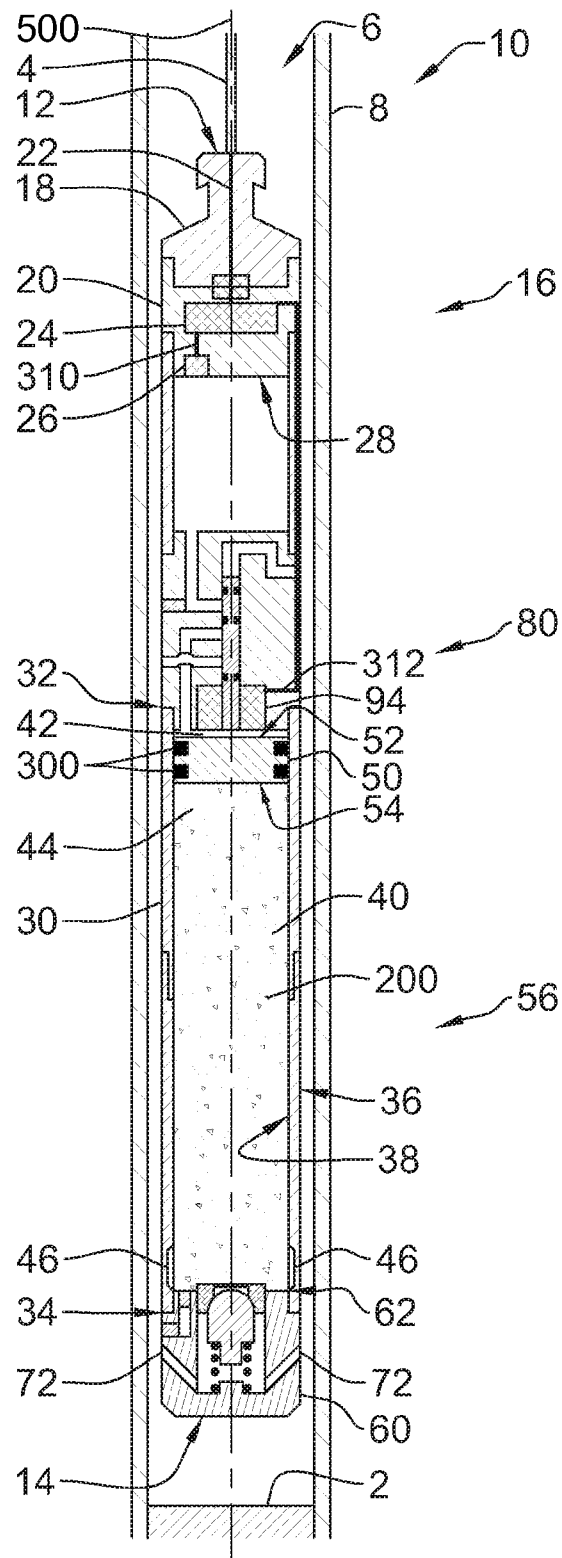


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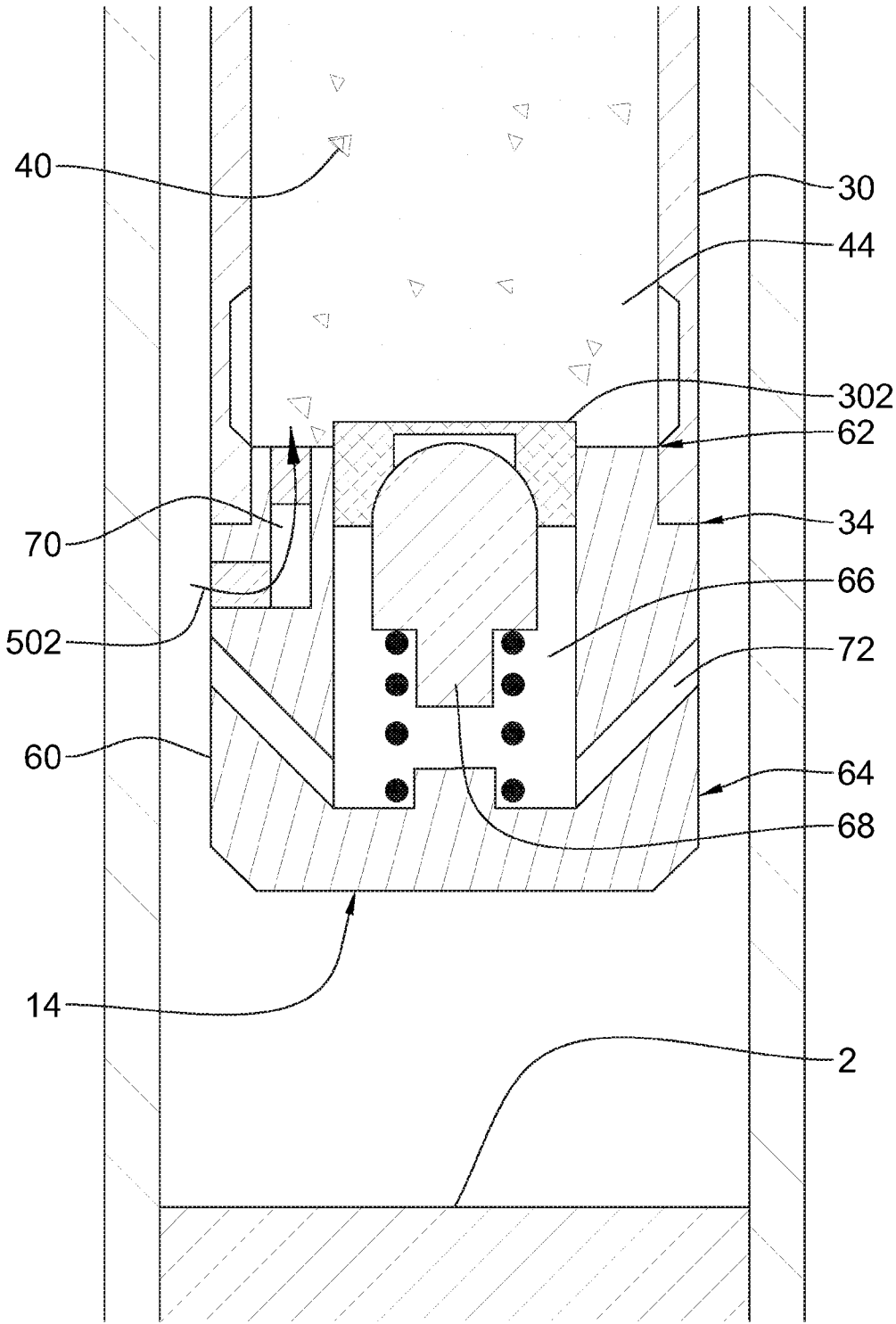


Figure 2

3/36

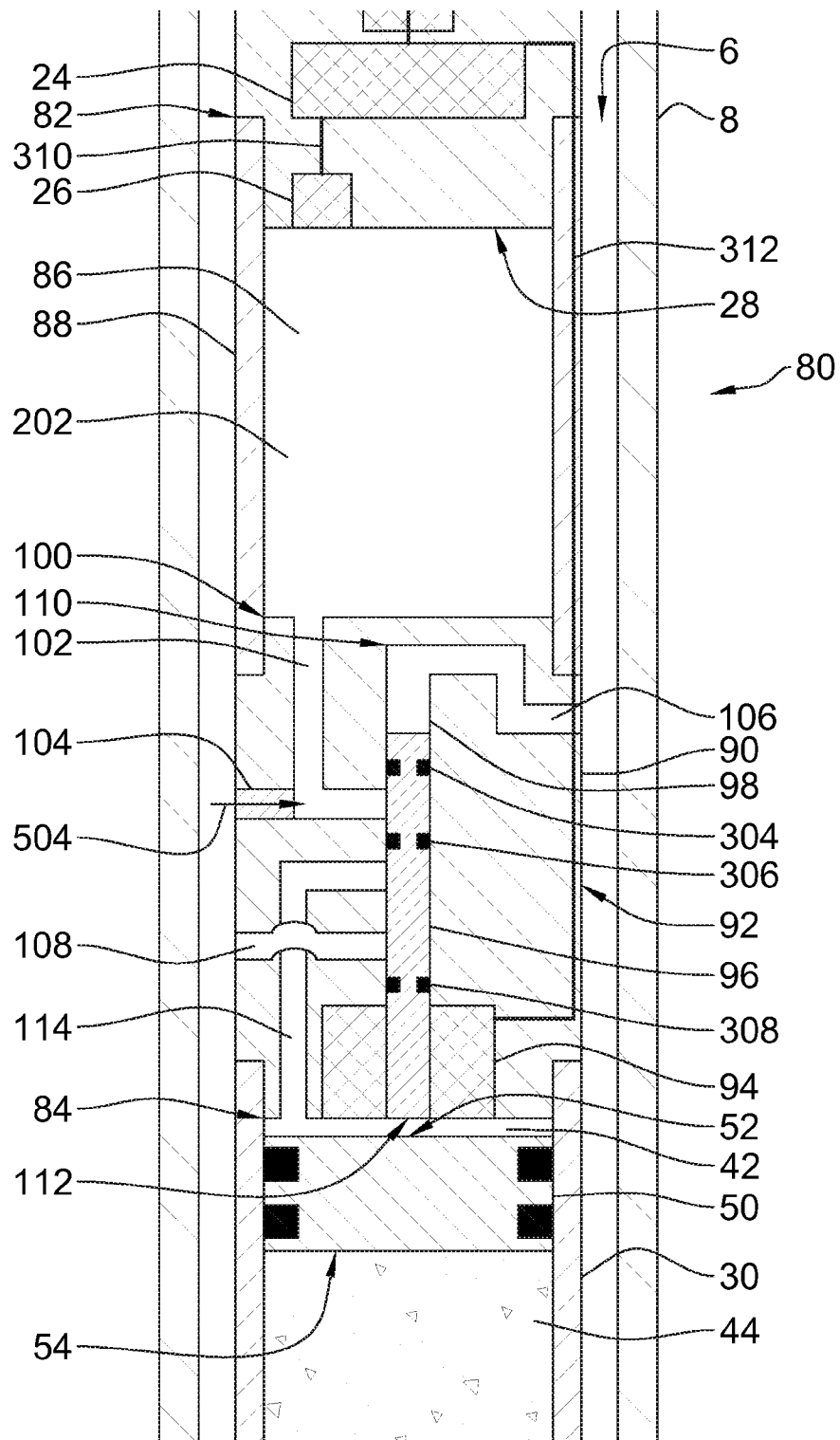


Figure 3

4/36

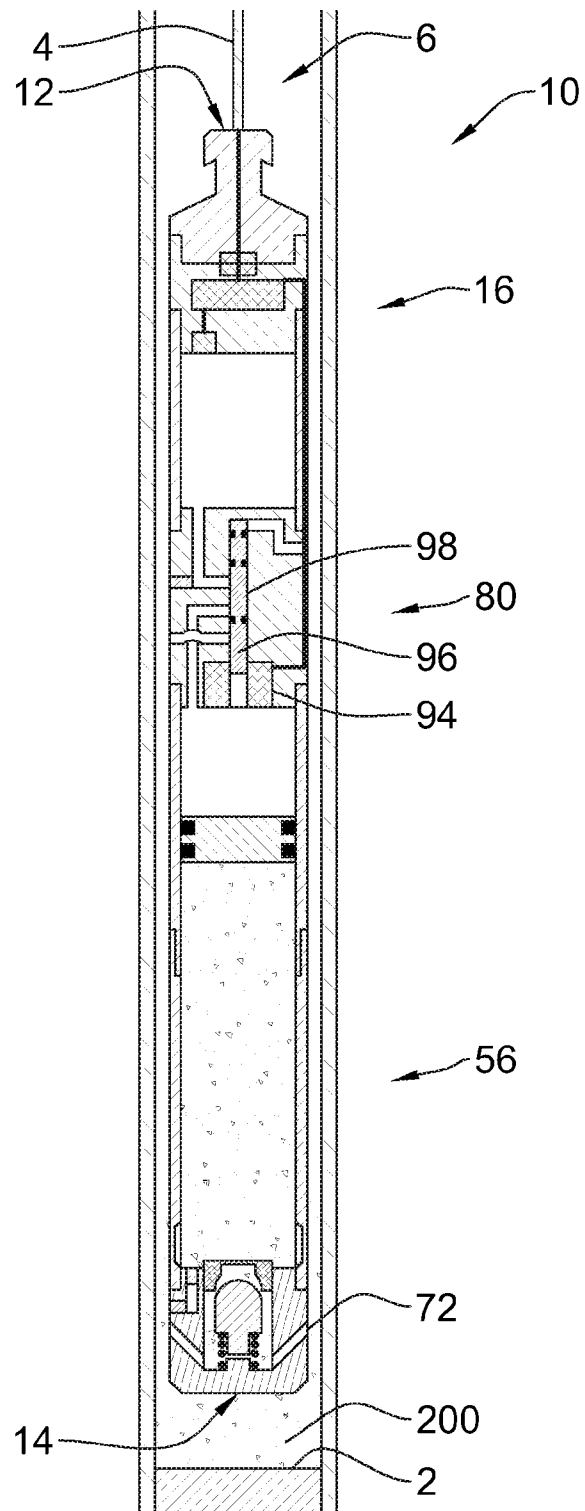


Figure 4

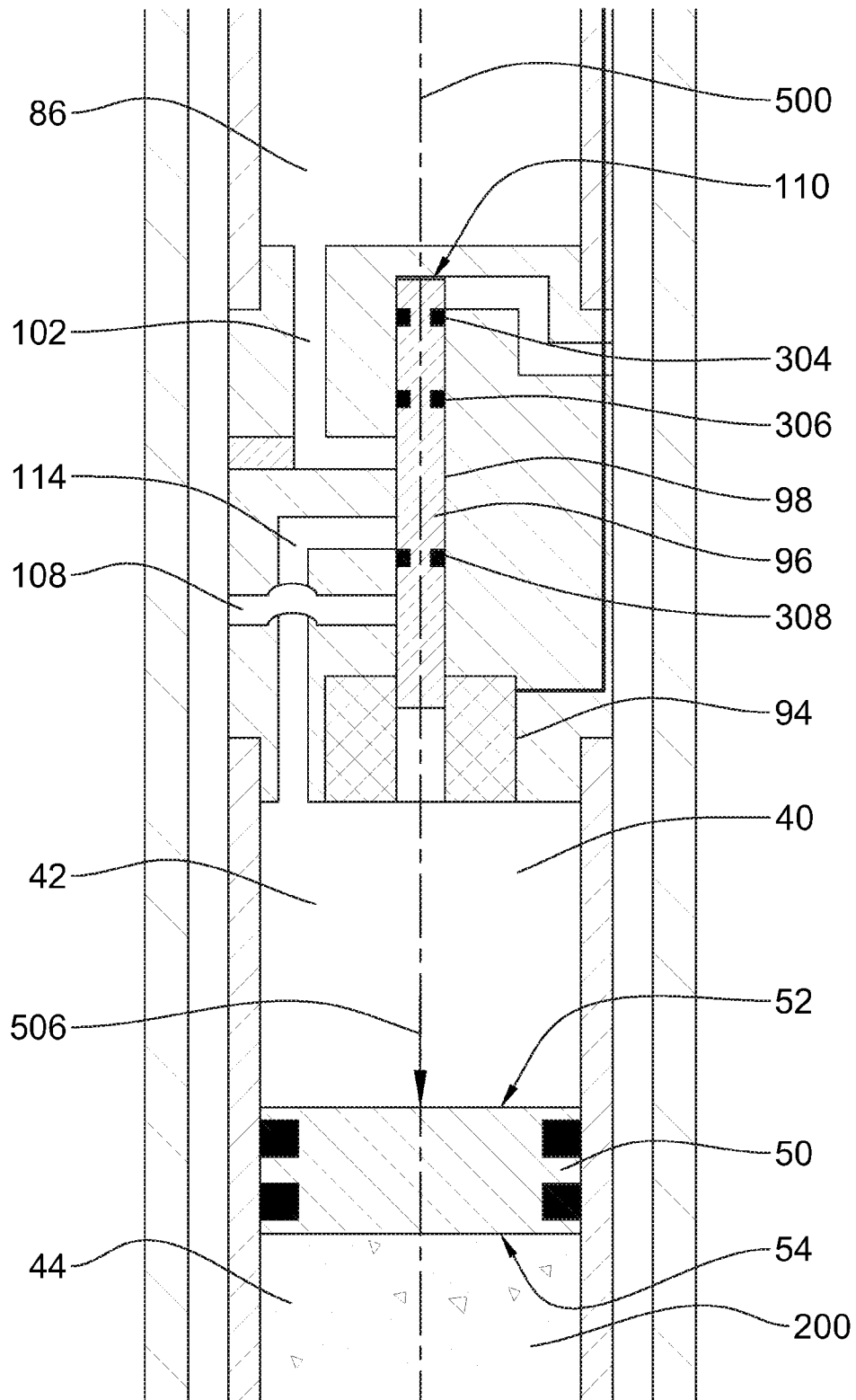


Figure 5

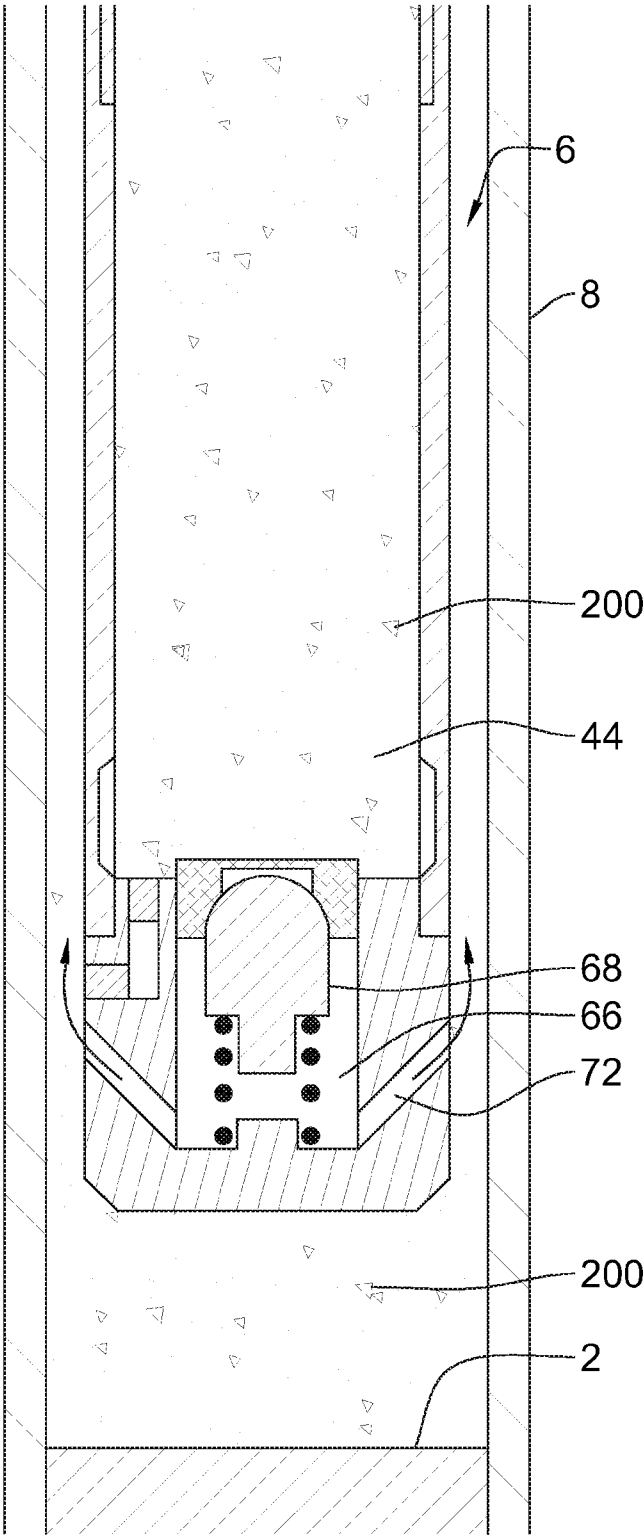


Figure 6

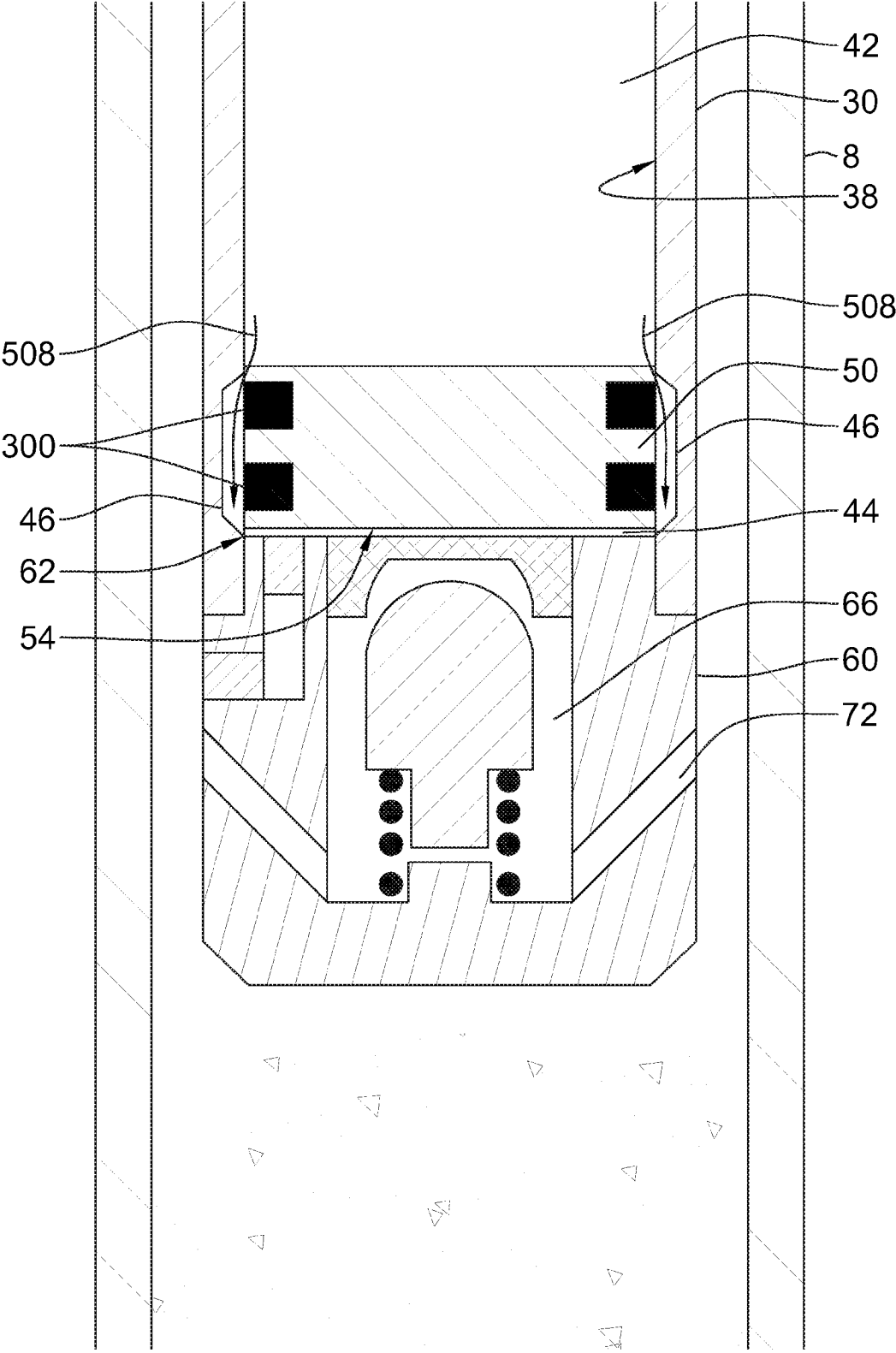


Figure 7

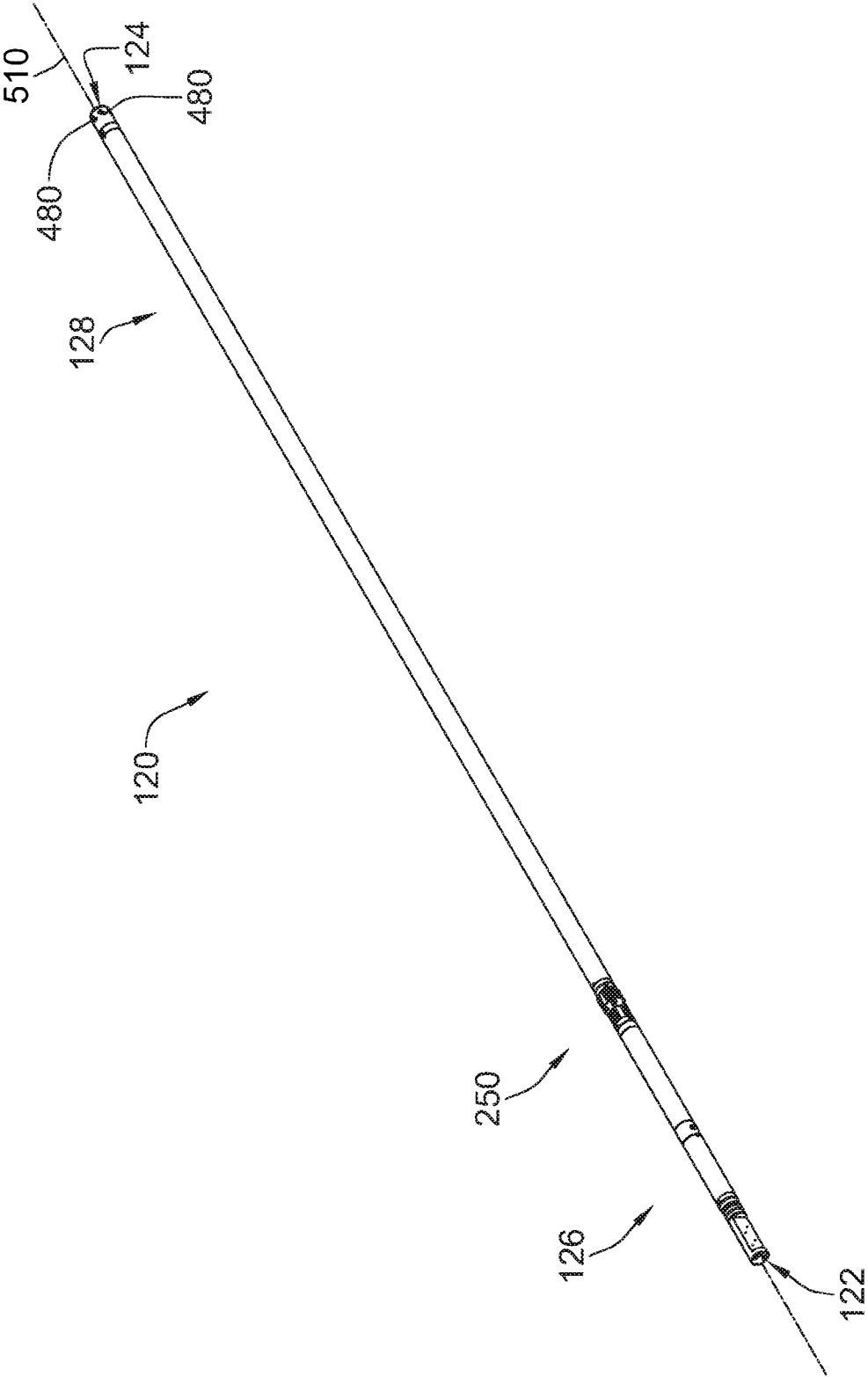


Figure 8

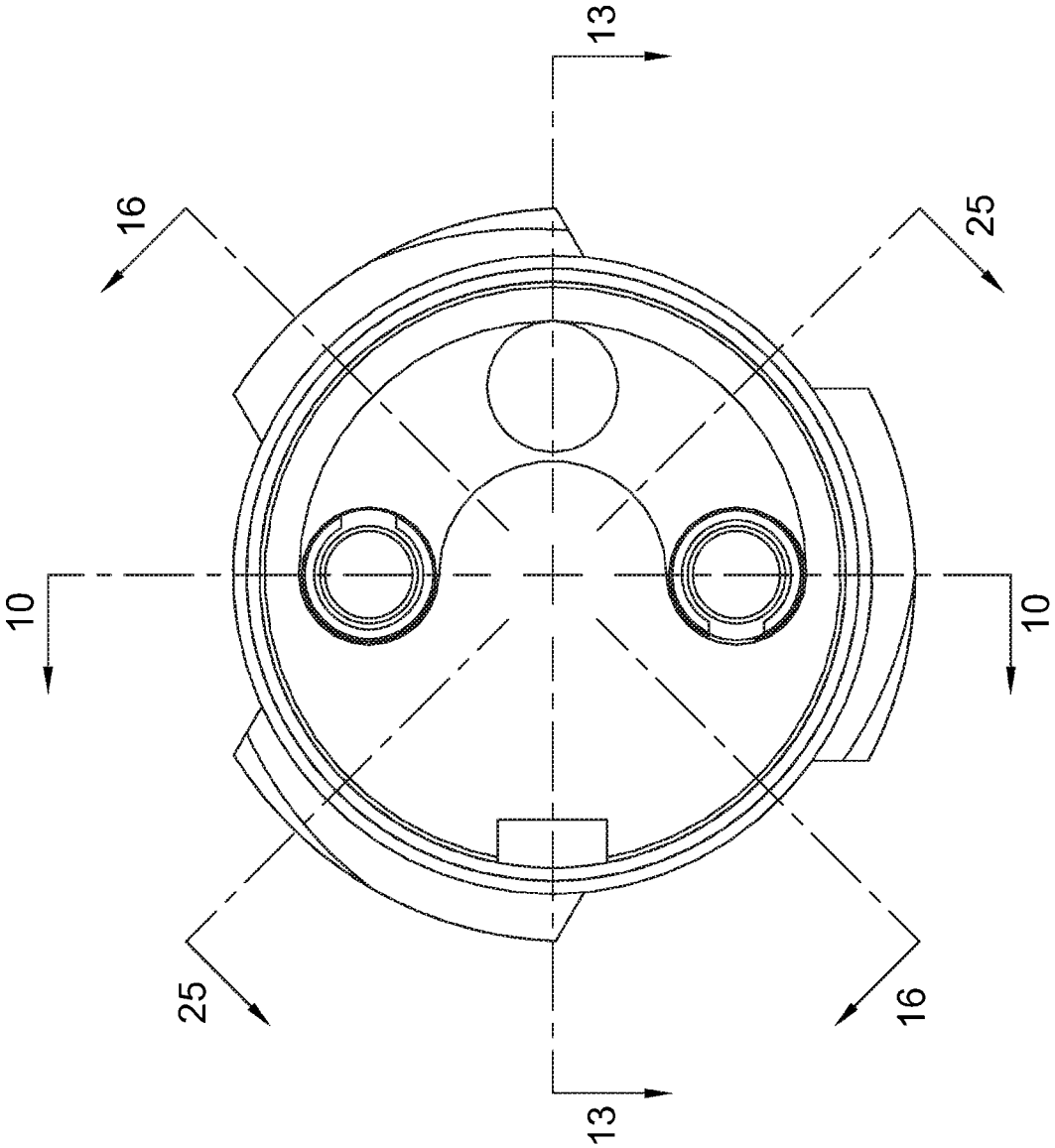


Figure 9

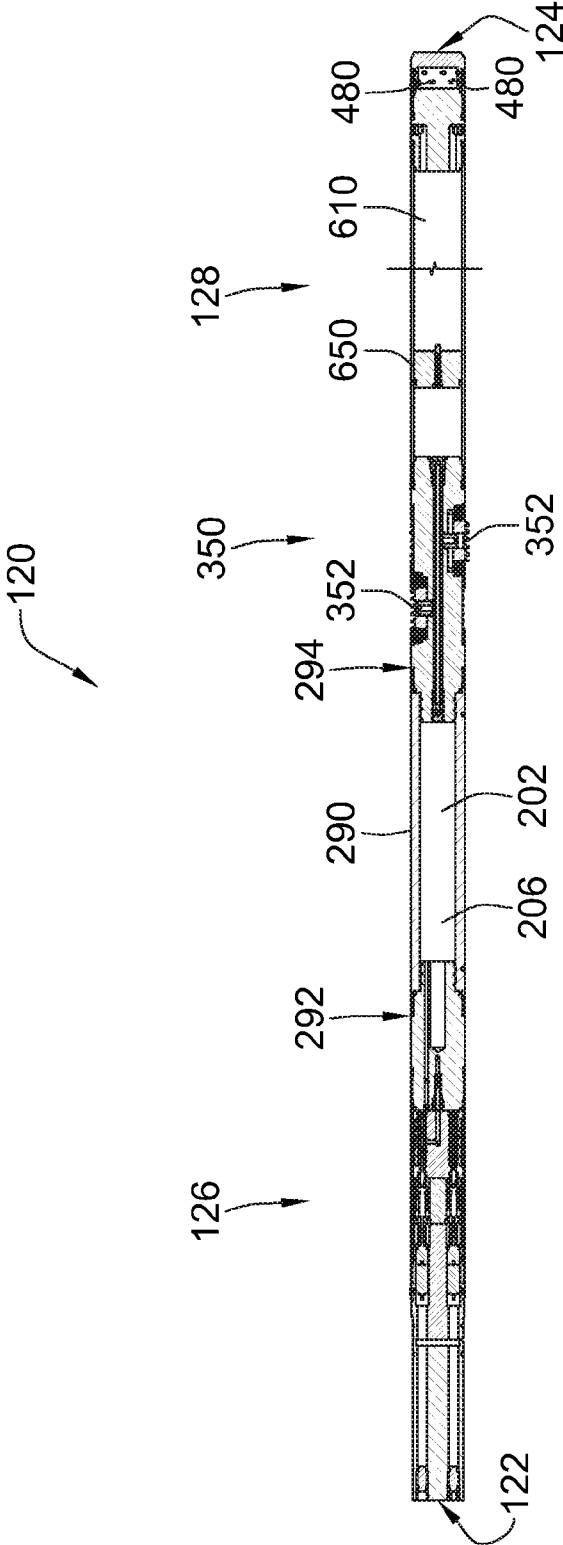


Figure 10

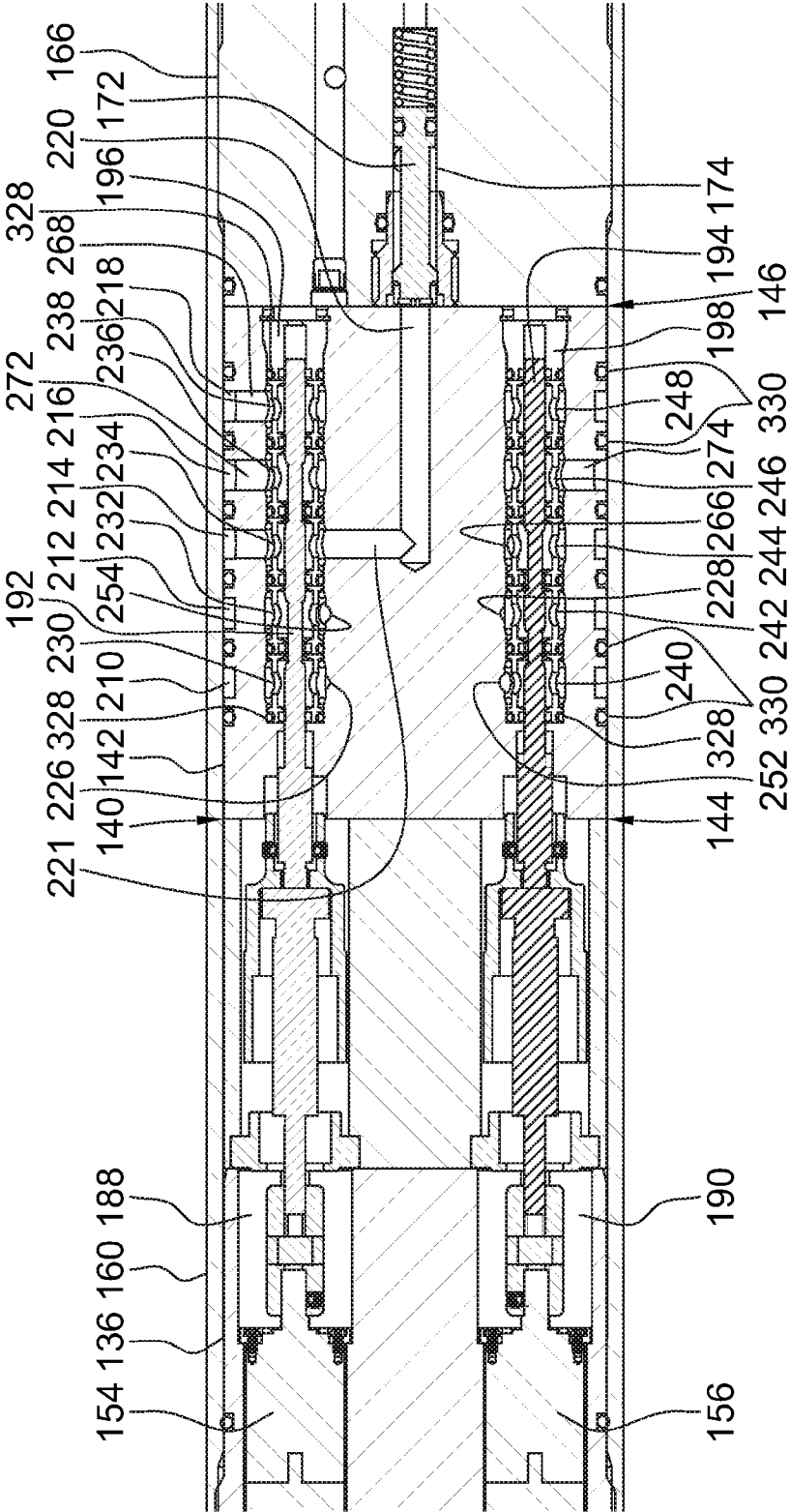


Figure 12

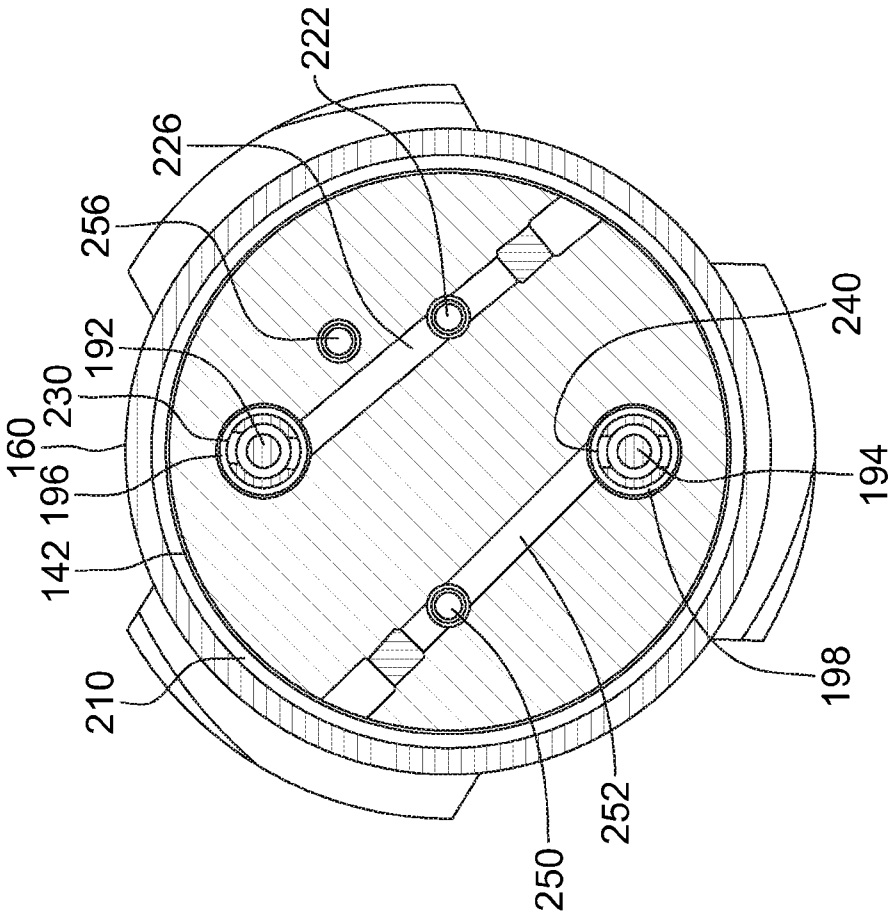


Figure 14

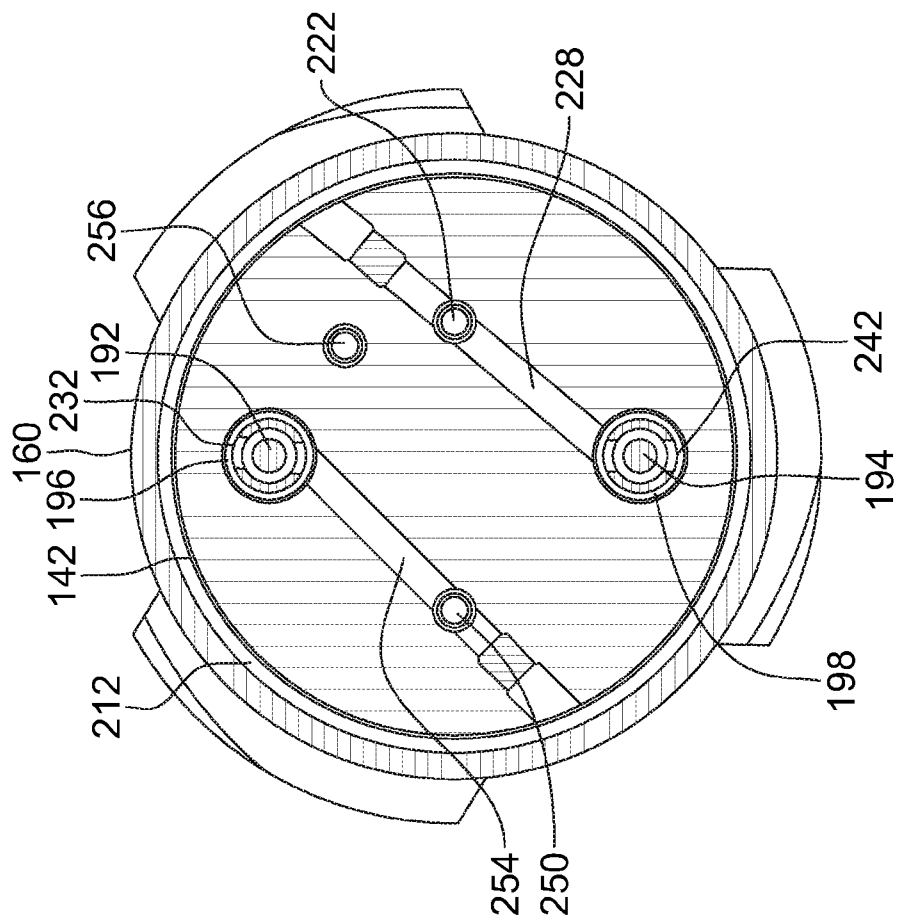


Figure 15

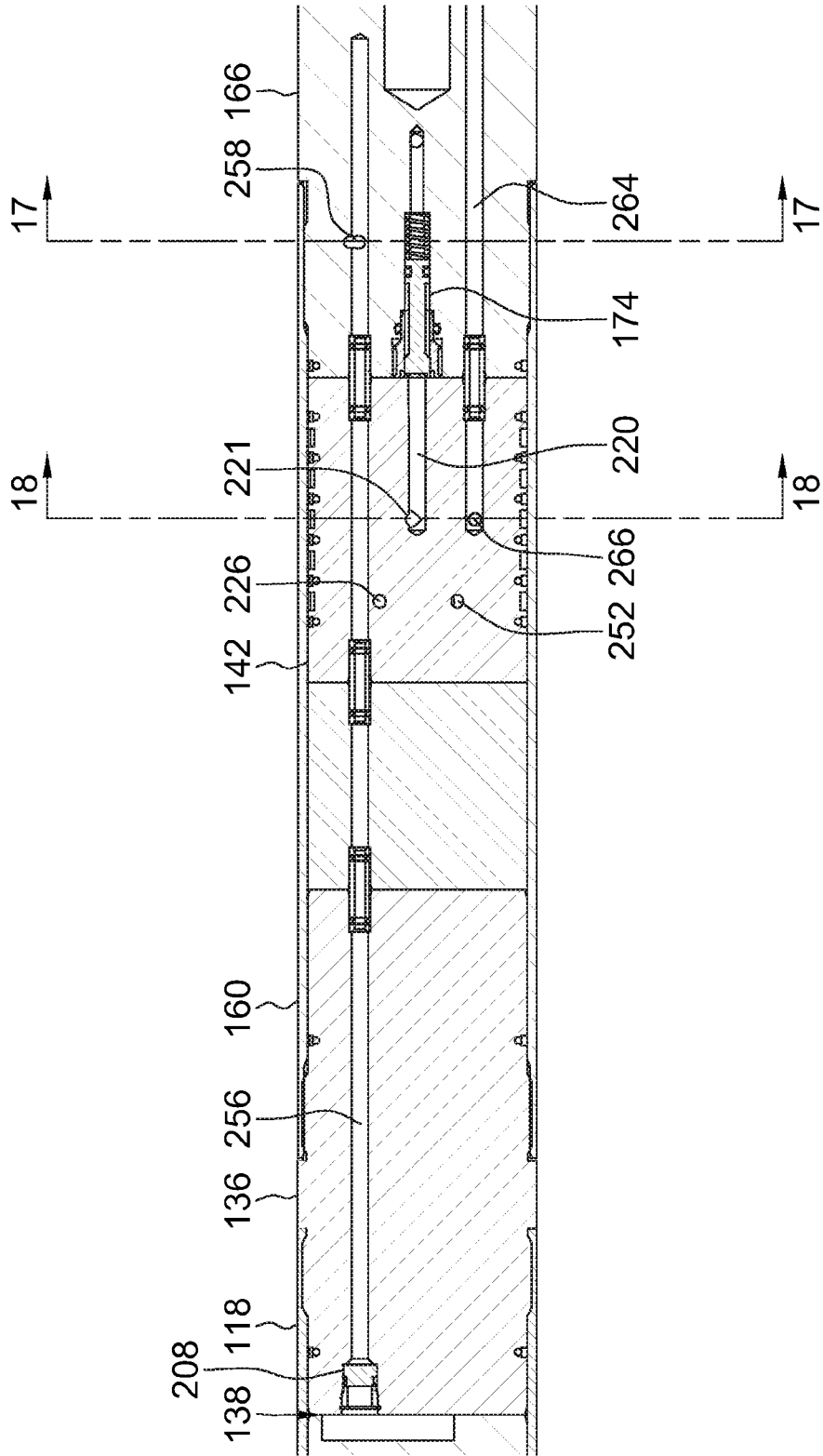


Figure 16

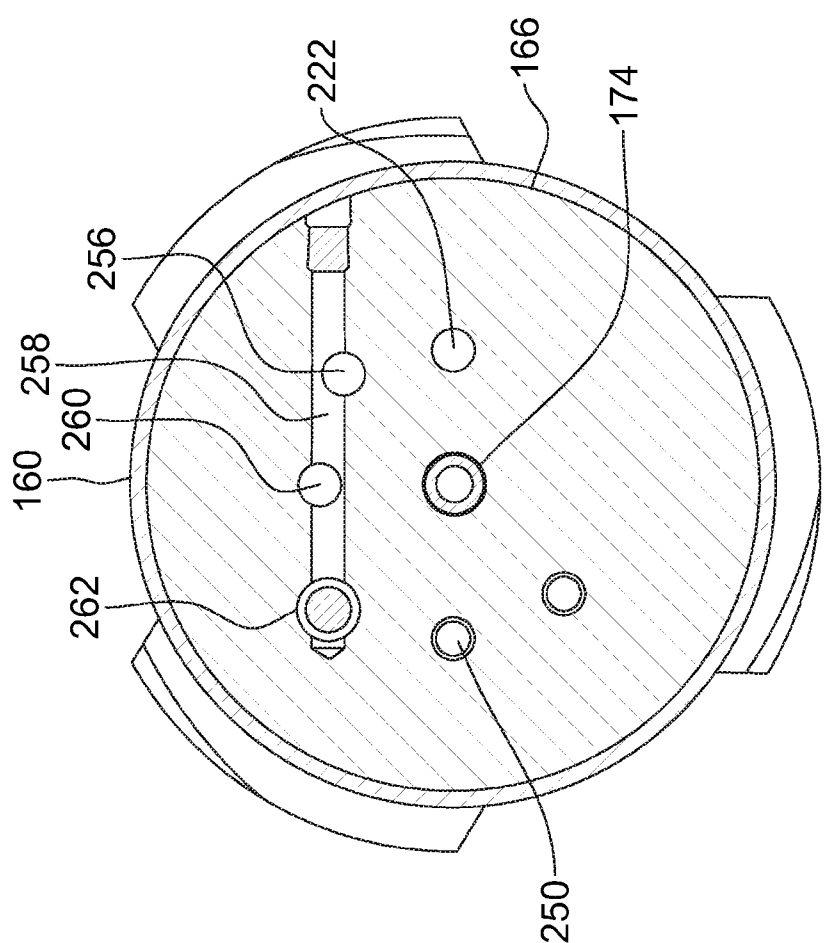


Figure 17

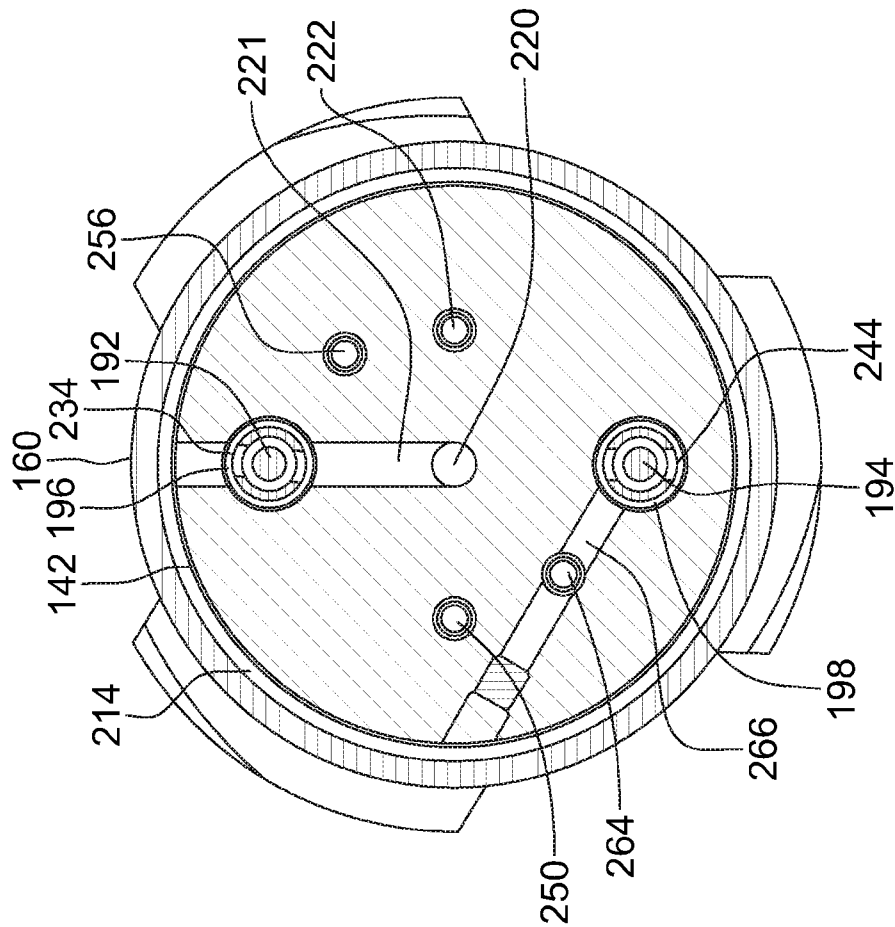


Figure 18

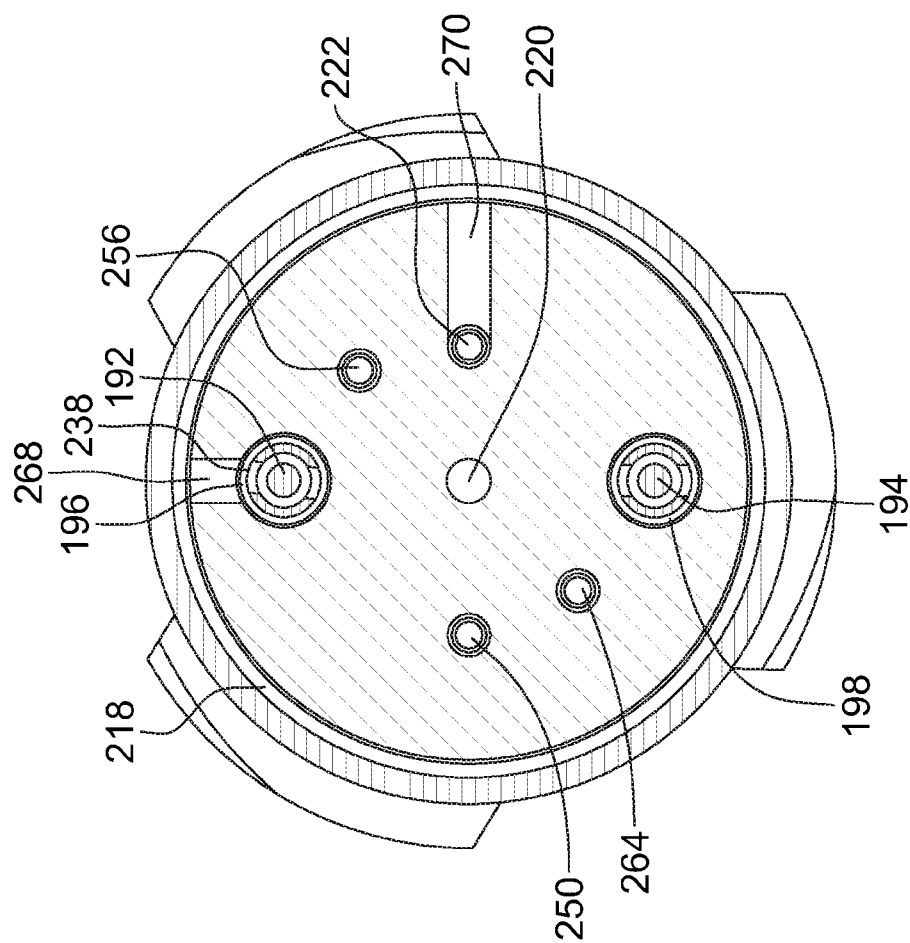


Figure 19

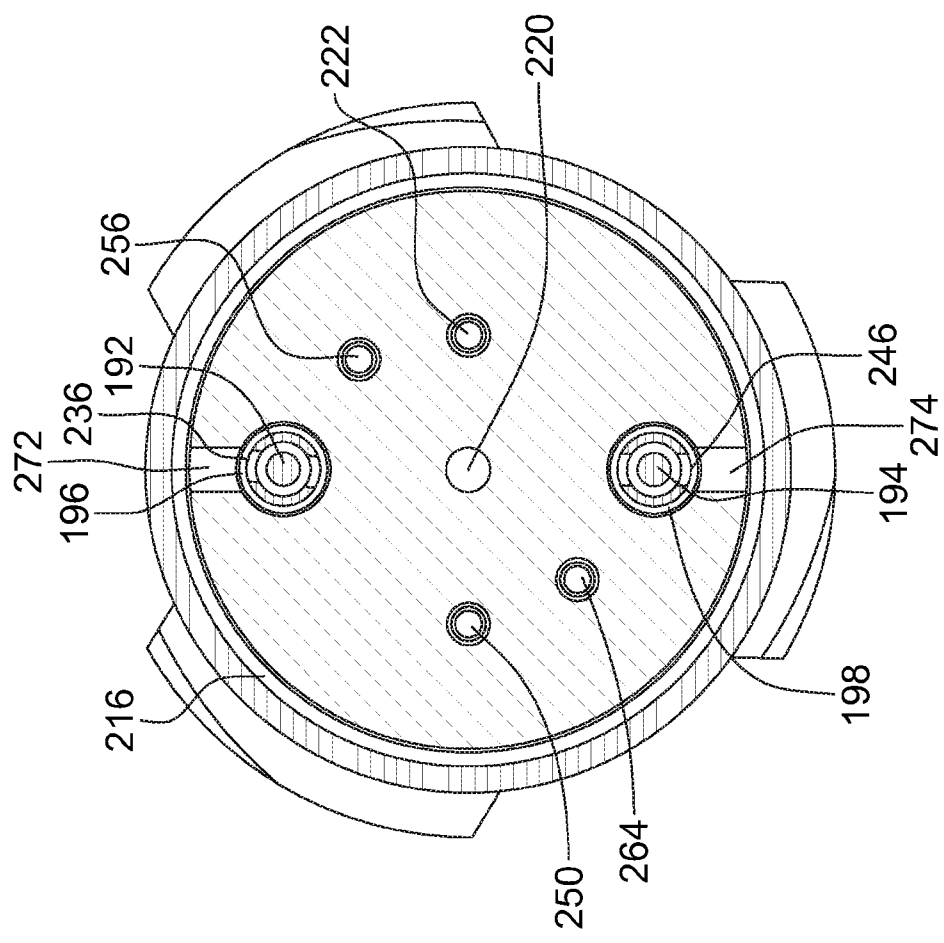


Figure 20

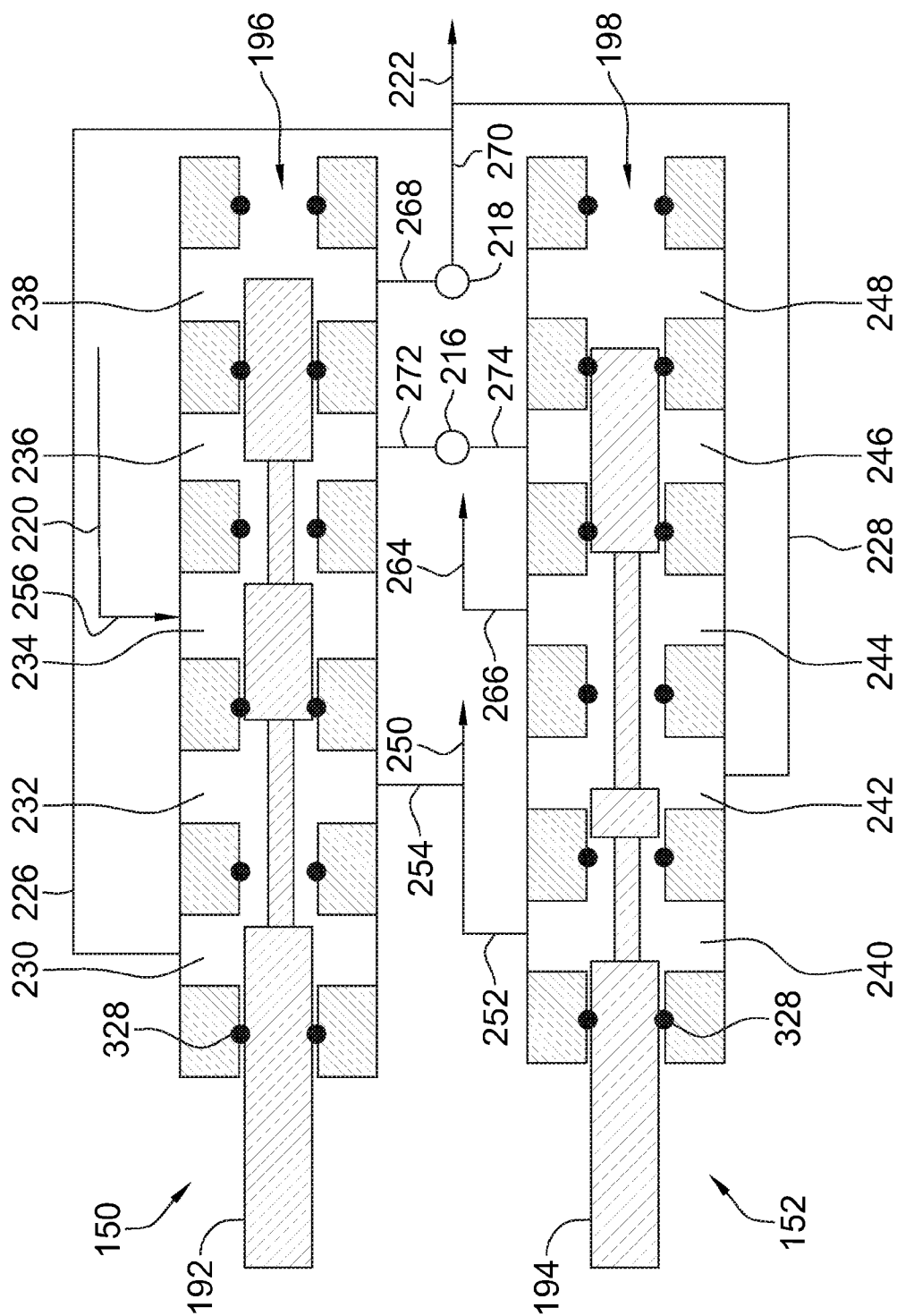


Figure 21

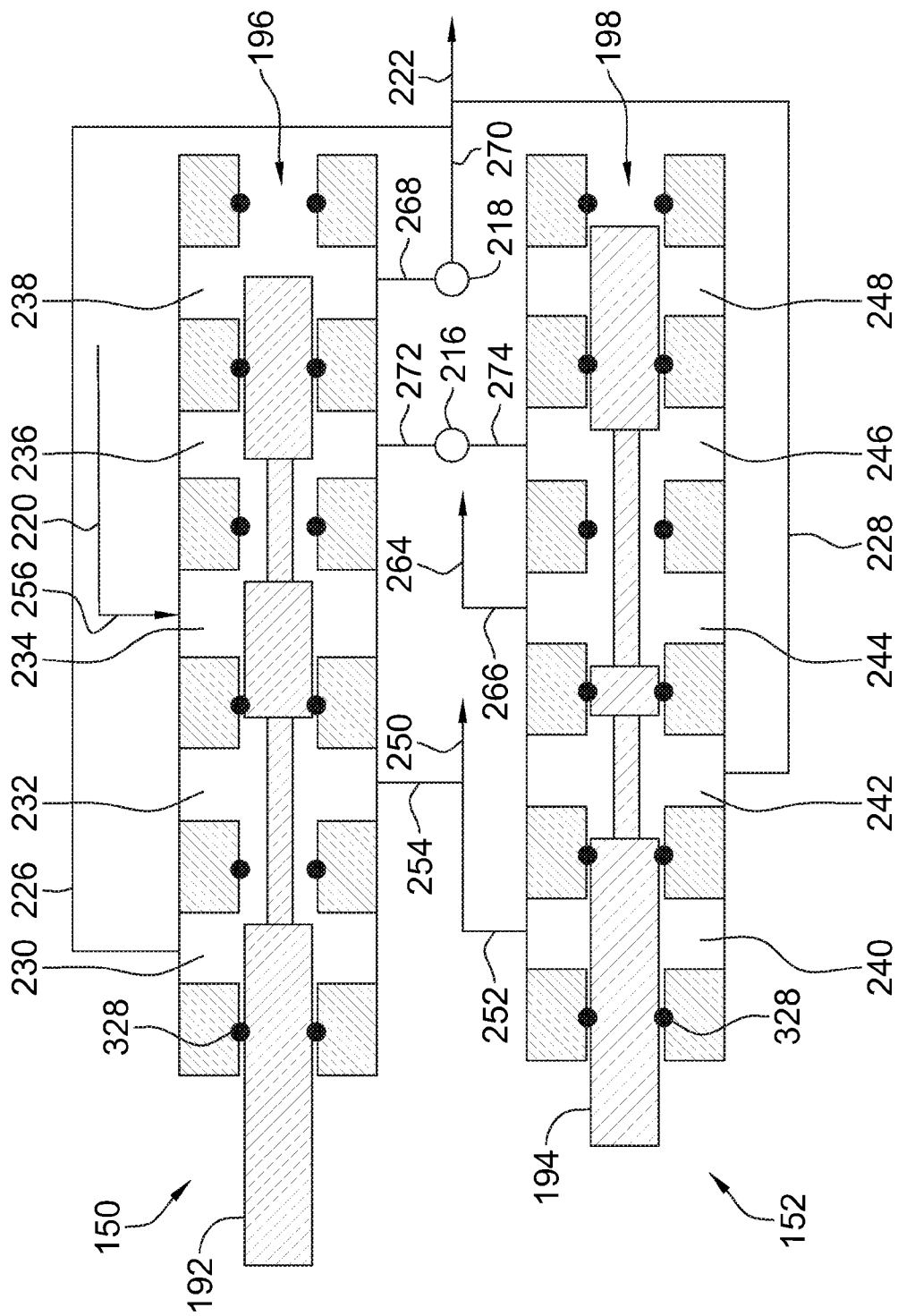


Figure 22

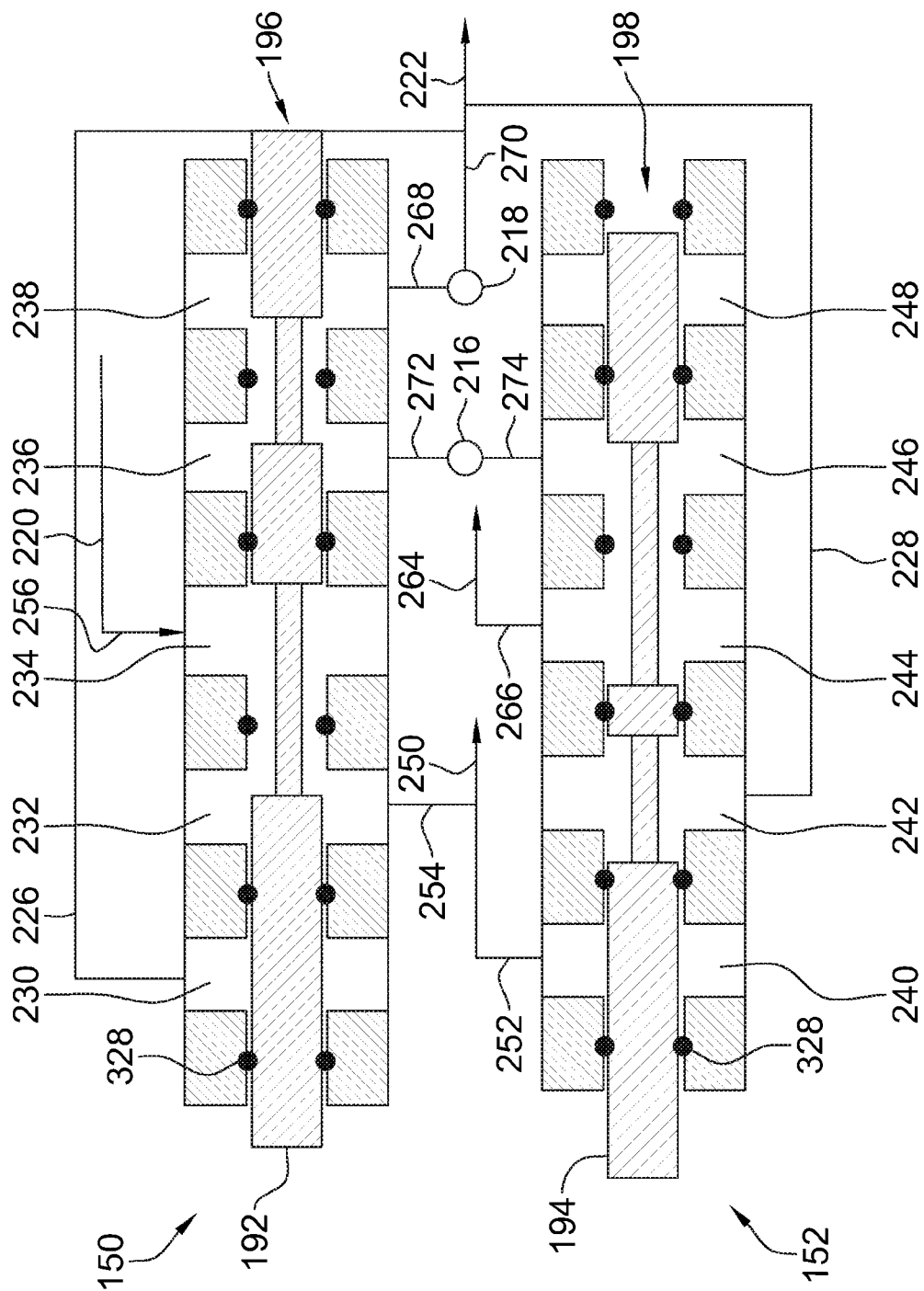


Figure 23

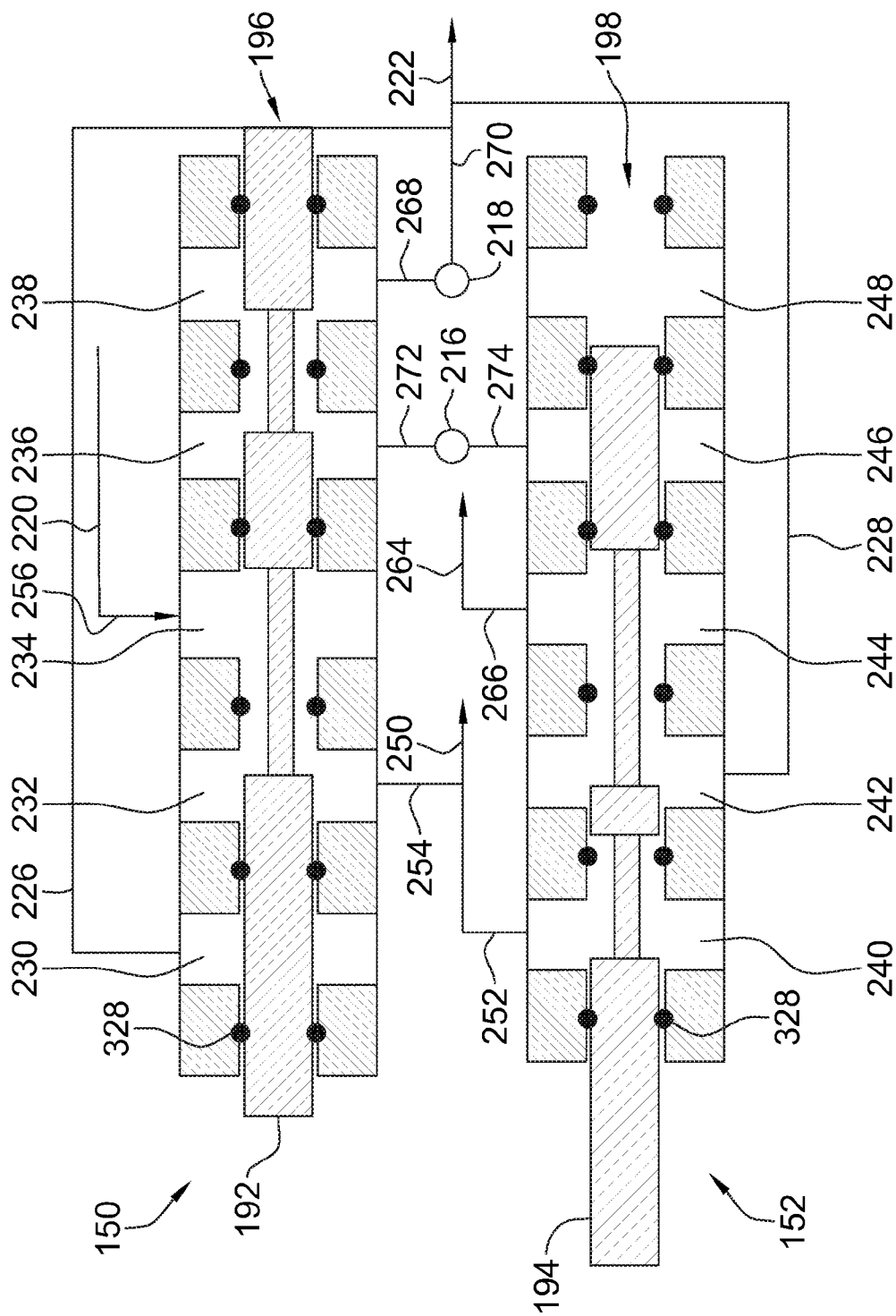


Figure 24

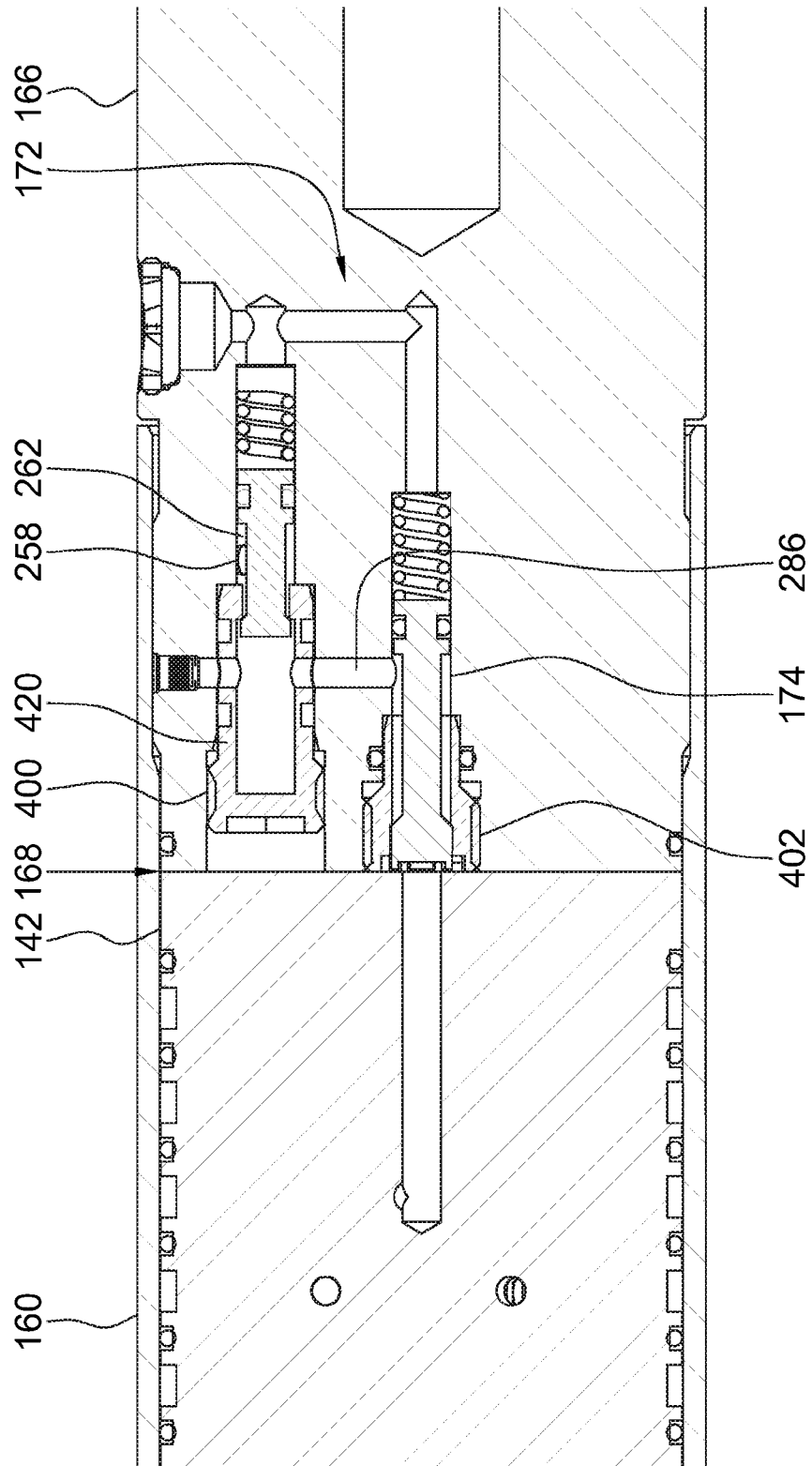


Figure 25

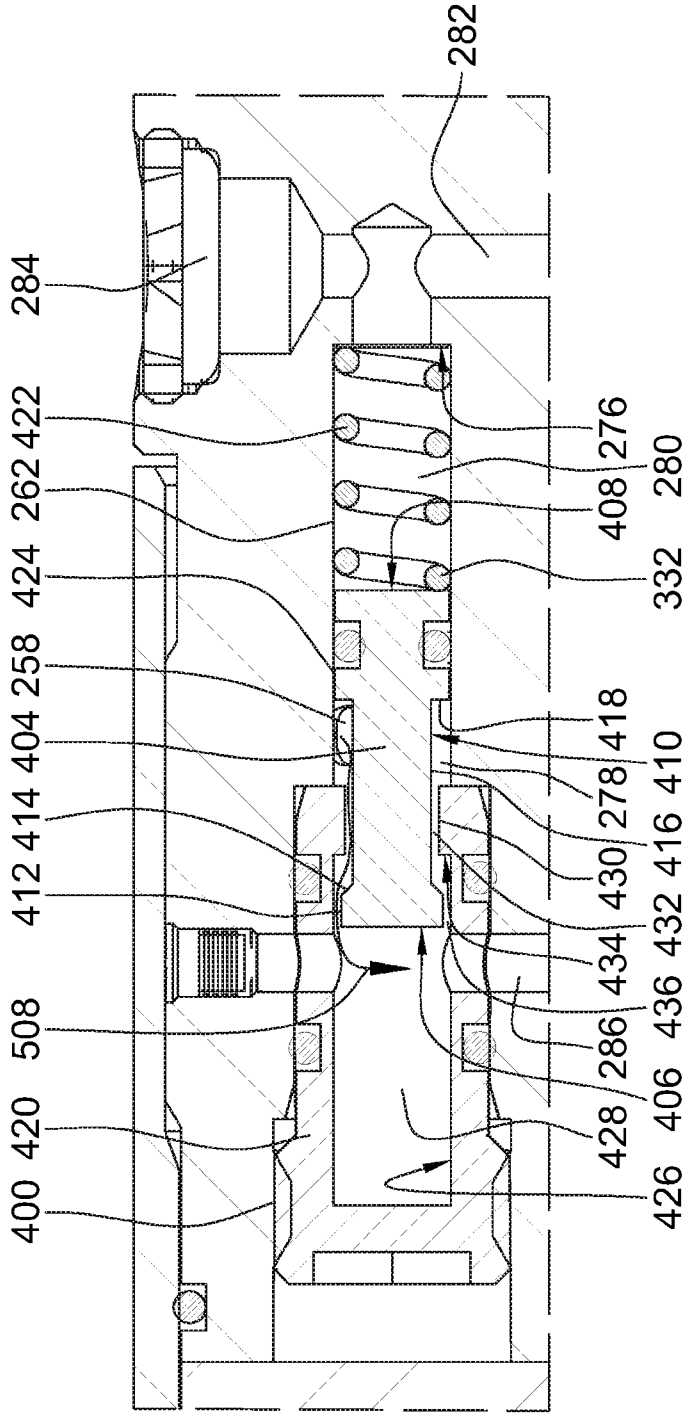


Figure 26

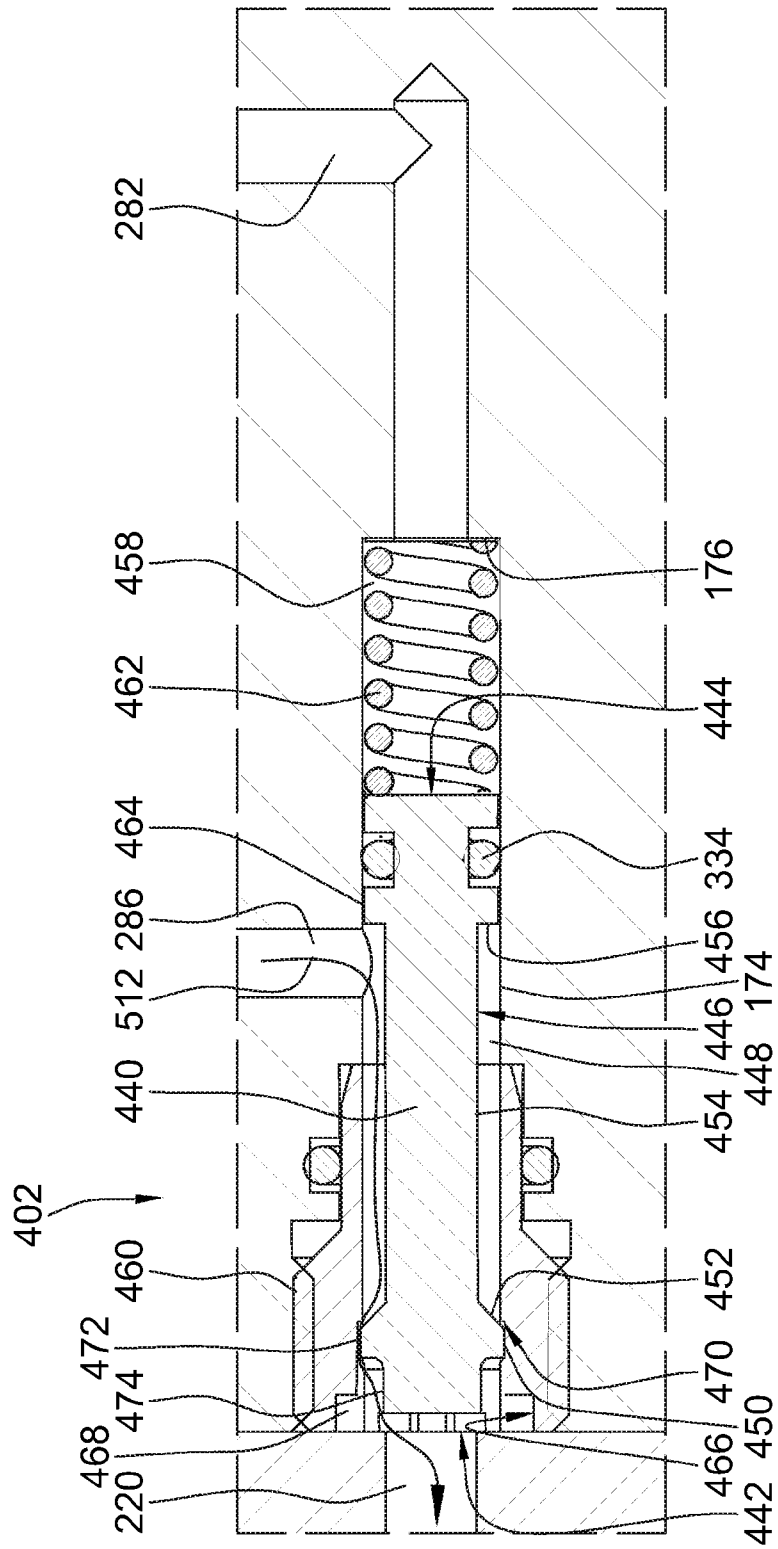


Figure 27

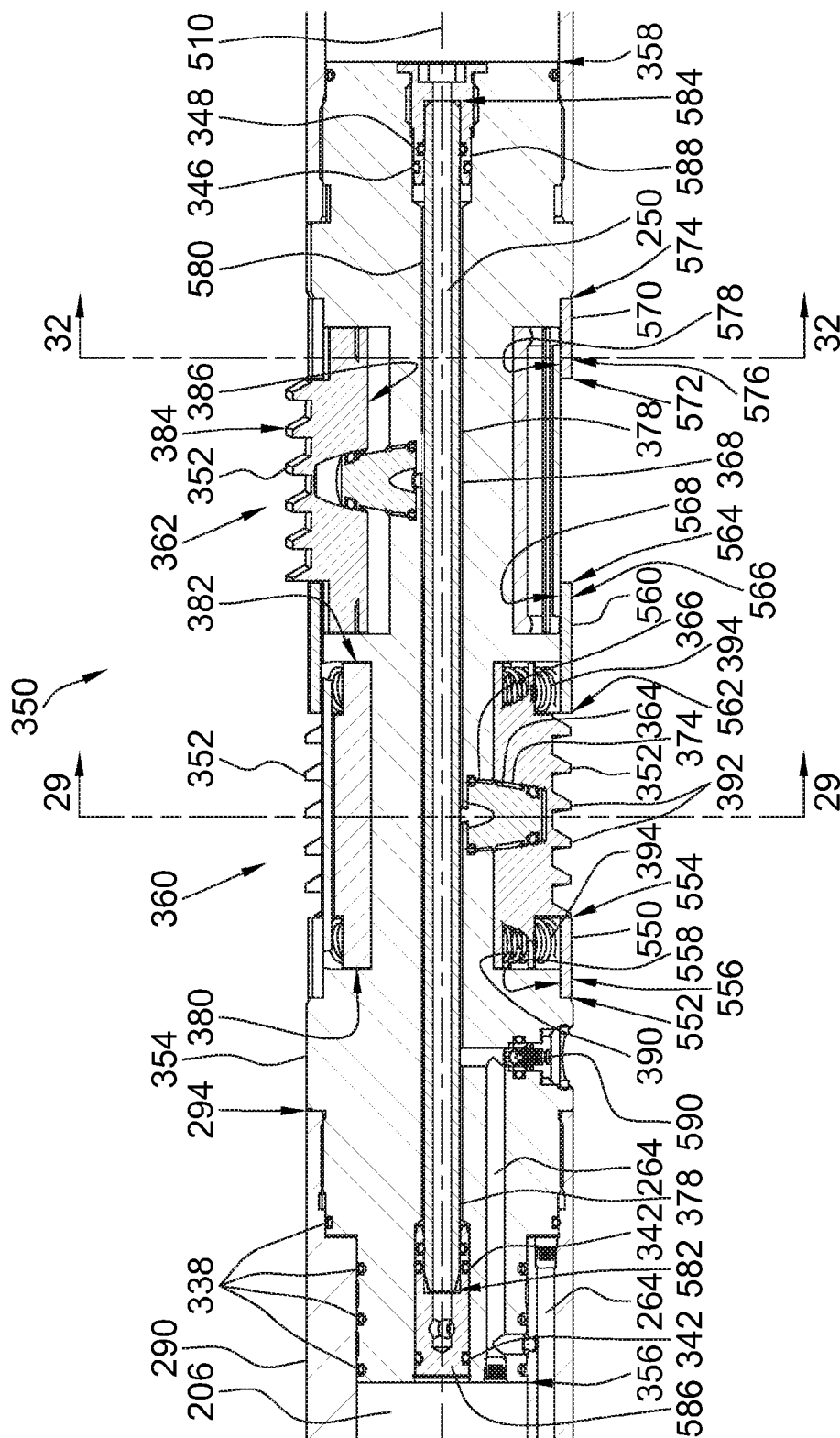


Figure 28

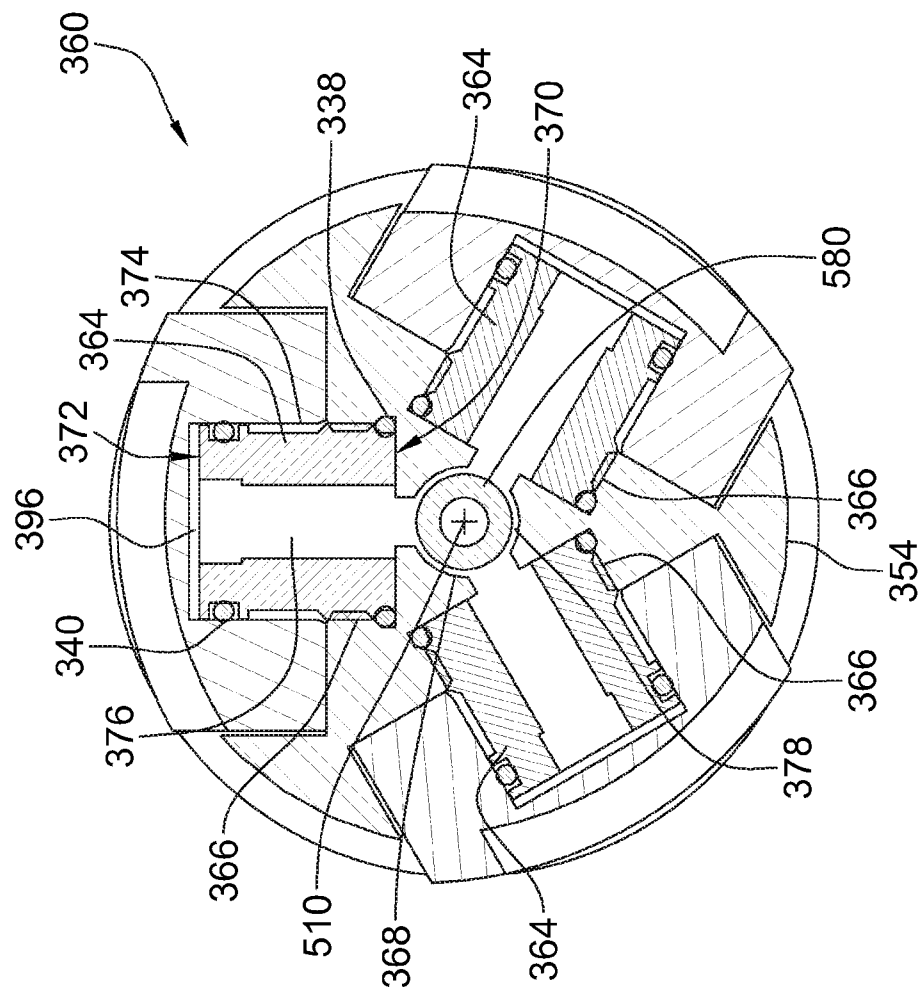


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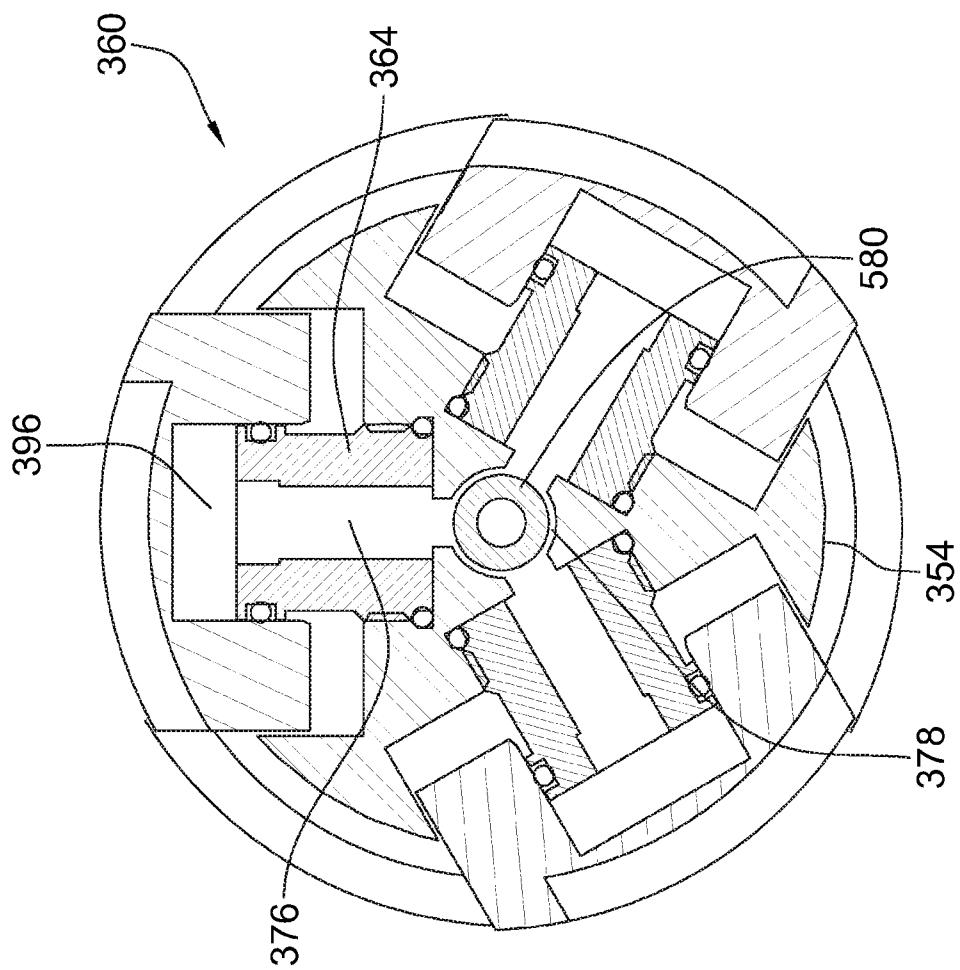


Figure 30

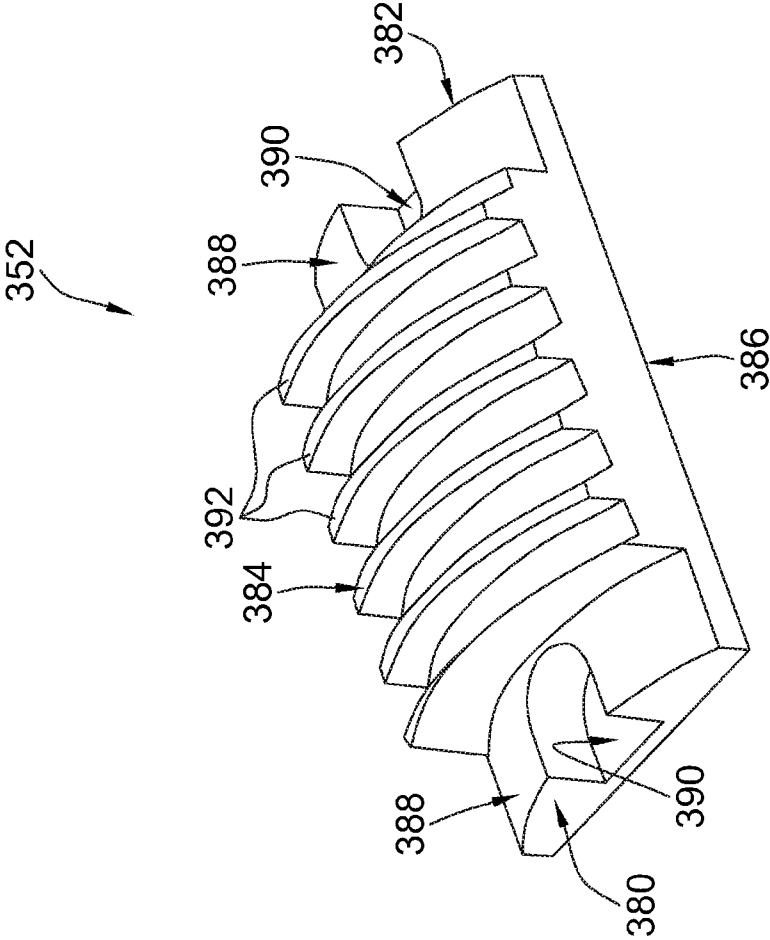


Figure 31

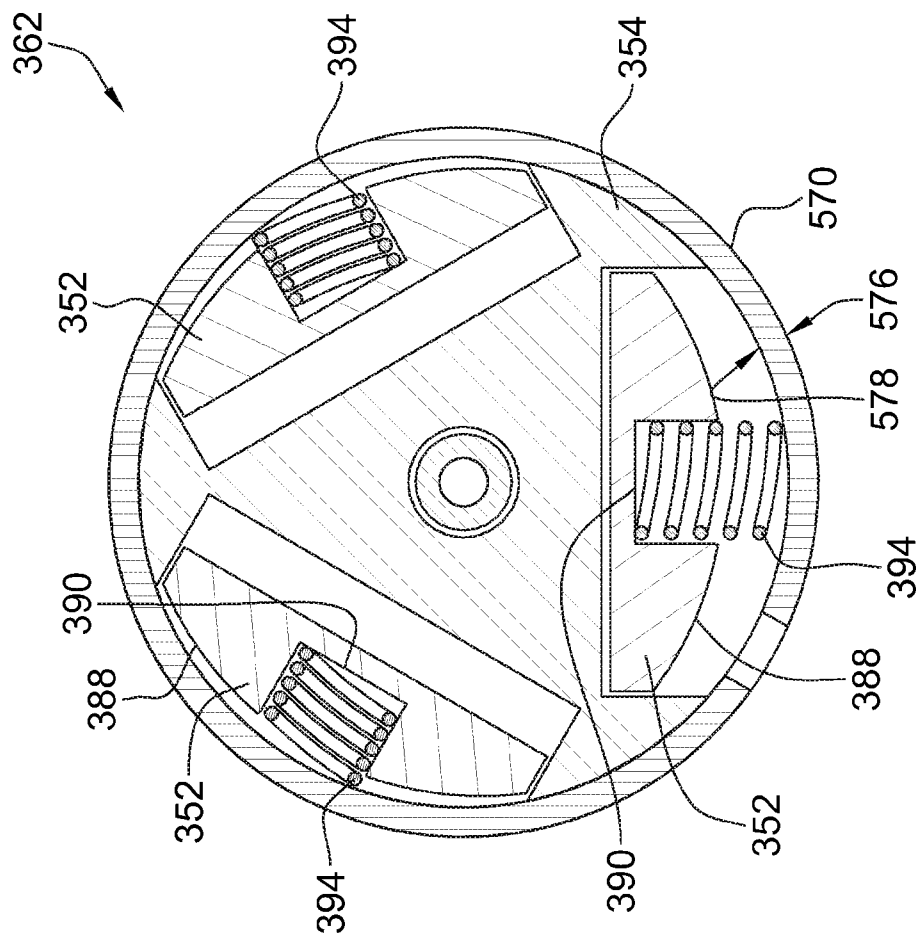


Figure 32

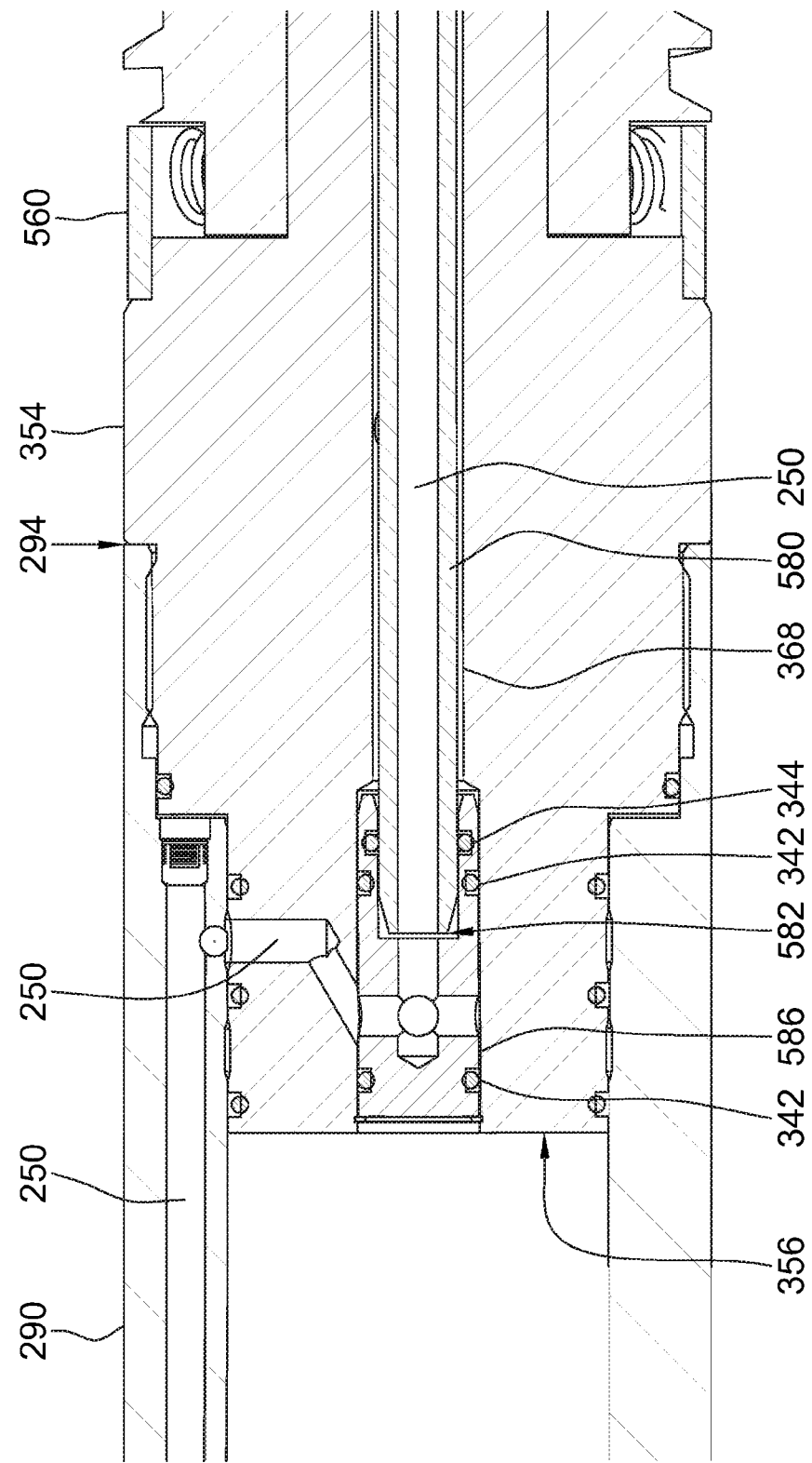


Figure 33

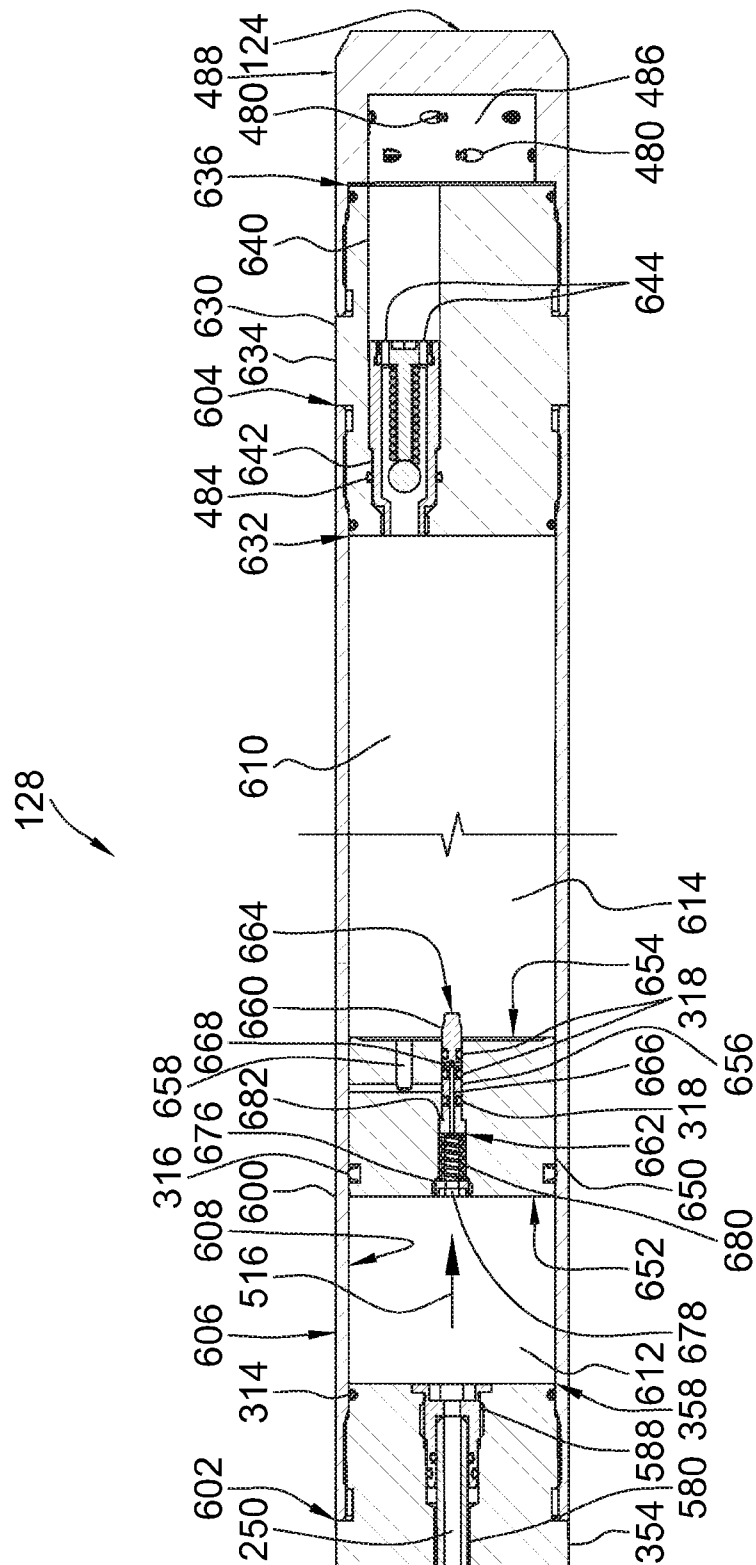


Figure 34

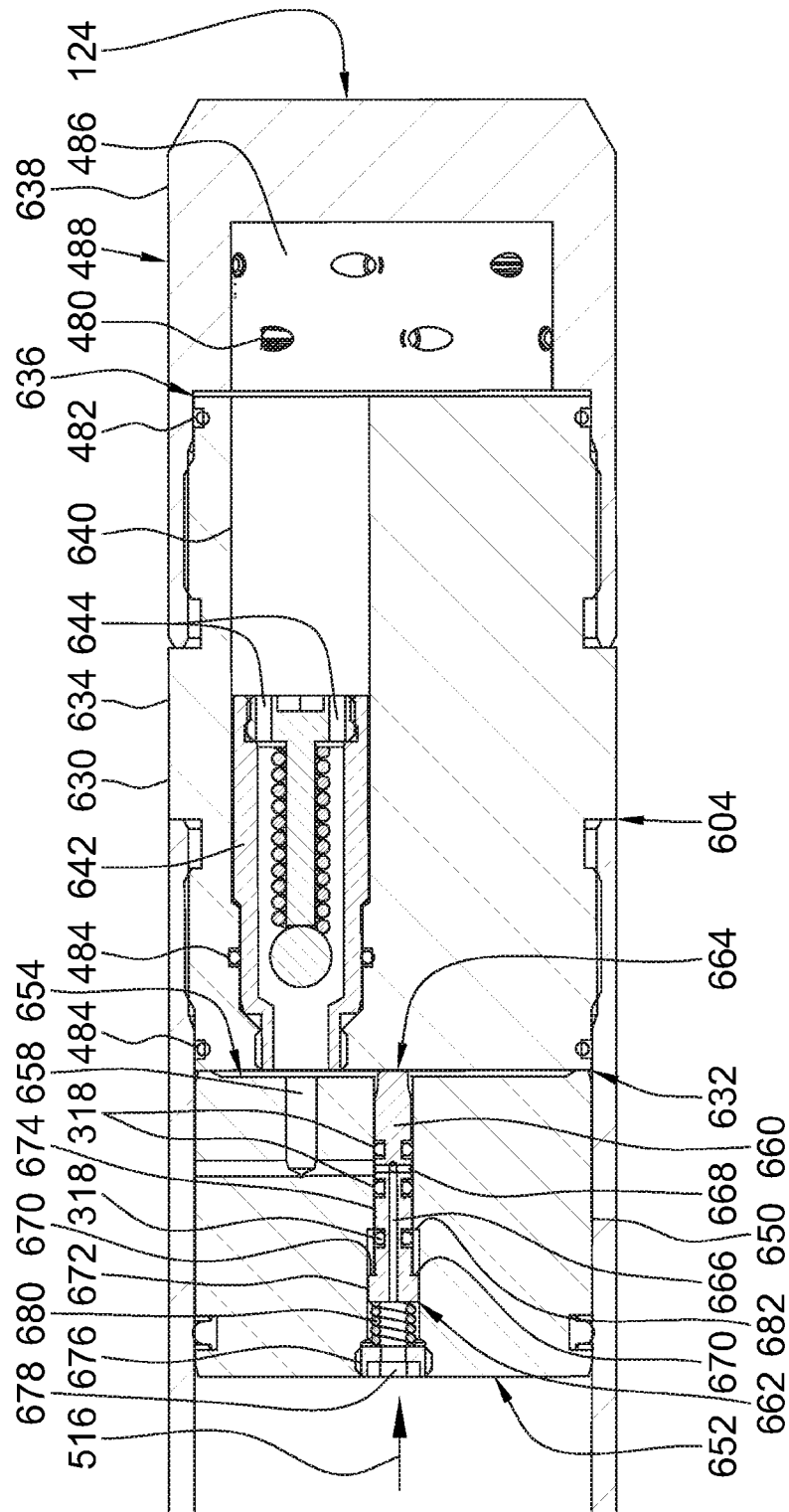


Figure 35

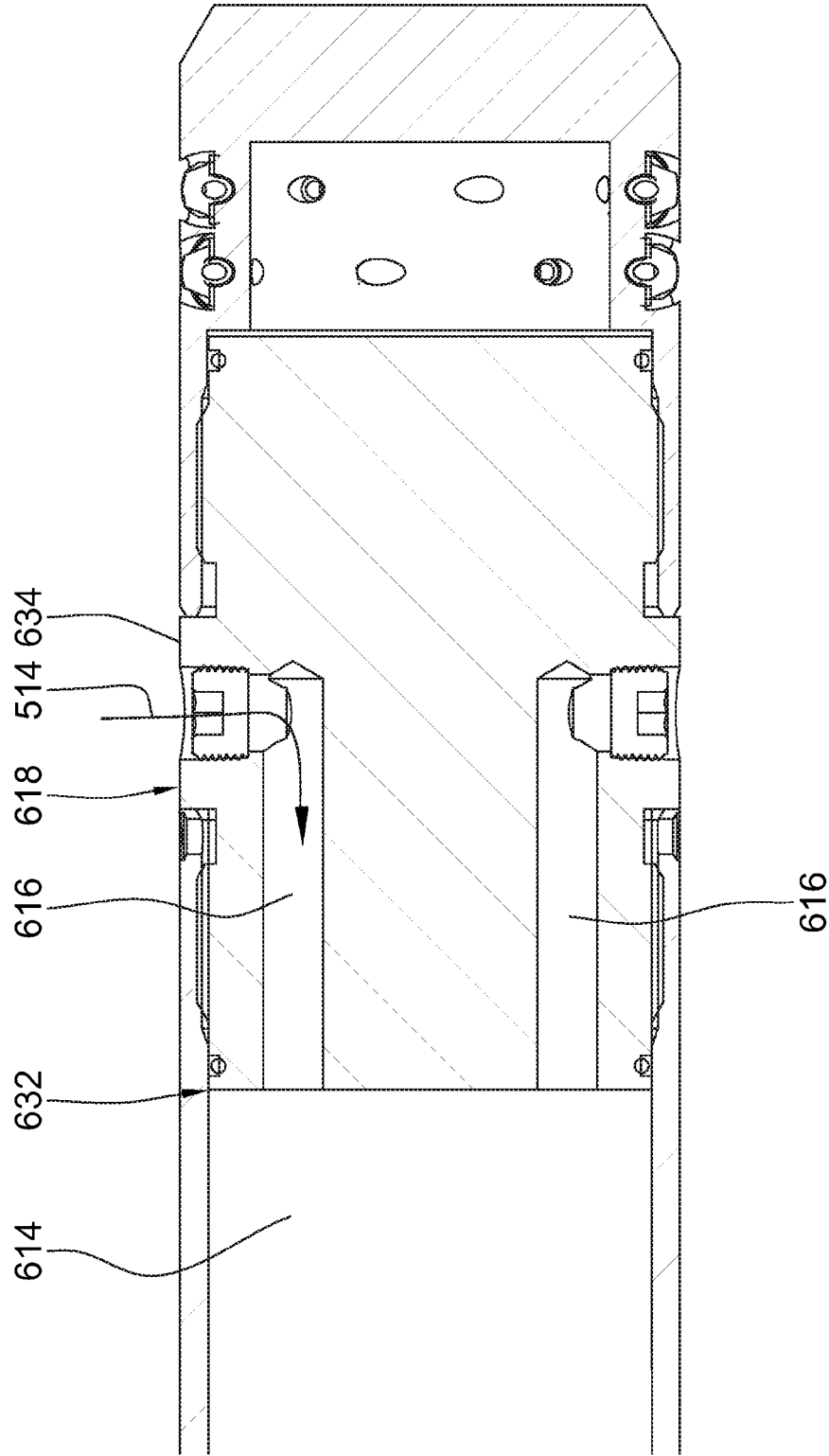


Figure 36

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2018/051481A. CLASSIFICATION OF SUBJECT MATTER
IPC: **E21B 33/138** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B-033/13, E21B-033/134, E21B-033/134, E21B-033/138

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
QUESTEL-ORBIT (FAMPAT database)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO0138691 A2 (HEIJNEN et al.) 31 May 2001 (31-05-2001) - refer to abstract; fig.1	1-8, 10-13, 15 & 16
Y	US4809779 A (LEDYASHOV et al.) 07 March 1989 (07-03-1989) - refer to abstract; figs. 1-3; col.1, lin.53-57	1-8, 10-13, 15 & 16
Y	WO2014083057 A1 (HANSEN et al.) 05 June 2014 (05-06-2014) - refer to figs. 1-8; pg. 27, lin.11-23; pg. 29, lin.1-6	5-8 and 10-13
A	WO2007003894 A2 (TELFER) 11 January 2007 (11-01-2007) - refer to entire document	1, 15
A	US6371207 B1 (REYNOLDS) 16 April 2002 (16-04-2002) - refer to entire document	1, 15

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

* "A" "E" "L" "O" "P"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance earlier application or patent but published on or after the international filing date 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) document referring to an oral disclosure, use, exhibition or other means document published prior to the international filing date but later than the priority date claimed	"T" "X" "Y" "&"	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 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 document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art document member of the same patent family
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Date of the actual completion of the international search
15 February 2019 (15-02-2019)Date of mailing of the international search report
21 February 2019 (21-02-2019)Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer

Ishtiaque Ibne Rashid (819) 639-7889

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2018/051481

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
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