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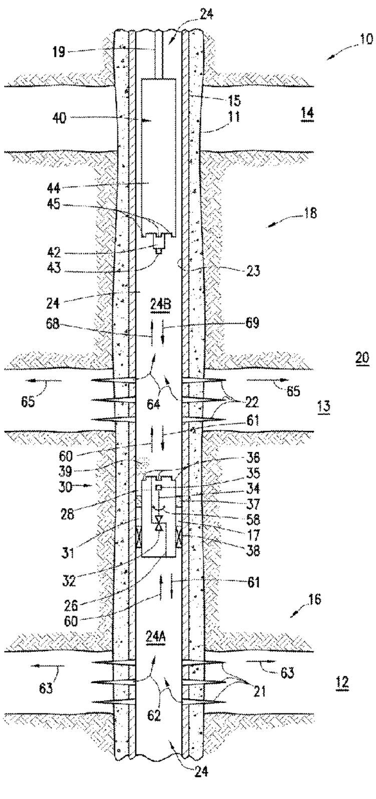
(54) Title: WELLBORE PLUG WITH A ROTARY ACTUATED VARIABLE CHOKE

FIG. 1



(57) Abstract: A method for controlling fluid flow through a wellbore by introducing a plug with a variable choke into the wellbore, setting the plug in the wellbore, and mechanically adjusting the variable choke in the wellbore, thereby controlling a flow rate of a fluid through the plug. A plug that can control fluid flow through a flow passage in a wellbore, where the plug can include a body, an annular seal element that prevents fluid flow through an annulus between the plug and the wellbore, and a variable choke, where a closure member of the choke is mechanically rotated downhole to adjust a fluid flow rate through the choke. A method that can include producing fluids from two zones and using a plug to control a ratio of the fluids in a produced mixture.

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WELLBORE PLUG WITH A ROTARY ACTUATED VARIABLE CHOKE

Technical Field

[0001] A wellbore plug with a rotary actuated variable choke and methods of controlling fluid flow through a flow passage in a wellbore. The plug can include profiles that engage mating profiles of a rotary actuator, thereby allowing mechanical actuation of the plug downhole to adjust a flow rate through the plug. According to certain embodiments, the plug is used in an oil or gas well operation.

Brief Description of the Figures

[0002] The features and advantages of certain embodiments will be more readily appreciated when considered in conjunction with the accompanying figures. The figures are not to be construed as limiting any of the preferred embodiments.

[0003] **Fig. 1** depicts a schematic diagram of a well system containing a plug with a rotary actuated variable choke that can be adjusted downhole by a rotary actuator to control fluid flow through a flow passage in a wellbore.

[0004] **Figs. 2-5** depict schematic representations of the plug with various rotary actuated variable chokes.

[0005] **Fig. 6** depicts a partial cross-sectional view of the plug with yet another rotary actuated variable choke.

[0006] **Fig. 7** depicts a detailed cross-sectional view of a plug similar to the plug shown in **Fig. 2.**

Detailed Description

[0007] Oil and gas hydrocarbons are naturally occurring in some subterranean formations. In the oil and gas industry, a subterranean formation containing oil or gas is referred to as a reservoir. A reservoir may be located under land or off shore. Reservoirs are typically located in the range of a few hundred feet (shallow reservoirs) to a few tens of thousands of feet (ultra-deep reservoirs). In order to produce oil or gas, a wellbore is drilled into a reservoir or adjacent to a reservoir. The oil, gas, or water produced from a reservoir is called a reservoir fluid. As used herein, a "fluid" is a substance having a continuous phase that tends to flow and to conform to the outline of its container when the substance is tested at a temperature of 71 °F (22 °C) and a pressure of one atmosphere "atm" (0.1 megapascals "MPa"). A fluid can be a liquid or gas. A homogenous fluid has only one phase; whereas a heterogeneous fluid has more than one distinct phase. A heterogeneous fluid can be: a slurry, which includes an external liquid phase and undissolved solid particles as the internal phase; an emulsion, which includes an external liquid phase and at least one internal phase of immiscible liquid droplets; a foam, which includes an external liquid phase and a gas as the internal phase; or a mist, which includes an external gas phase and liquid droplets as the internal phase.

[0008] A well can include, without limitation, an oil, gas, or water production well, or an injection well. As used herein, a "well" includes at least one wellbore. A wellbore can include vertical, inclined, and horizontal portions, and it can be straight, curved, or branched. As used herein, the term "wellbore" includes any cased, and any uncased, open-hole portion of the wellbore. The well can also include multiple wellbores, such as a main wellbore and lateral wellbores. As used herein, the term "wellbore" also includes a main wellbore as well as lateral wellbores that branch off from the main wellbore or from other lateral wellbores. A near-wellbore region is the subterranean material and rock of the subterranean formation surrounding the wellbore. As used herein, a "well" also includes the near-wellbore region. The near-wellbore region is generally considered to be the region within approximately 100 feet radially of the wellbore. As used herein, "into a well" means and includes into any portion of the well, including into the wellbore or into the near-wellbore region via the wellbore.

[0009] In an open-hole wellbore portion, a tubing string may be placed into the wellbore. The tubing string allows fluids to be introduced into or flowed from a remote portion of the wellbore. In a cased-hole wellbore portion, a casing is placed into the wellbore that can also contain a tubing string. A wellbore can contain an annulus. Examples of an annulus include, but are not limited to: the space between the wellbore and the outside of a tubing string in an open-hole wellbore; the space between the wellbore and the outside of a casing in a cased-hole wellbore; the space between the inside of a casing and the outside of a tubing string in a cased-hole wellbore; the space between a well tool and a casing in a cased-hole wellbore portion, and the space between a well tool and a wellbore wall in an open-hole wellbore portion.

[0010] It is not uncommon for a wellbore to extend several hundreds of feet or several thousands of feet into a subterranean formation. The subterranean formation can have different zones. A zone is an interval of rock differentiated from surrounding rocks on the basis of its fossil content or other features, such as faults or fractures. For example, one zone can have a higher permeability compared to another zone.

Each zone of the formation can be isolated within the wellbore via the use of packers, plugs, or other similar devices.

[0011] It is often desirable to produce a reservoir fluid from one or more zones of a formation. However, there are problems associated with producing from or injecting into multiple formation zones. A zone with higher permeability can produce fluid at a higher rate when compared to another zone with reduced permeability. Higher flow rate from one zone may cause accelerated degradation of the wellbore components related to that zone due to the higher fluid velocities. Therefore, it may be desirable to reduce flow velocity from the high permeability zone by increasing flow restrictions to the fluid flow from that zone through the tubing string. It may also be desirable to isolate one zone from another to permanently seal off a lower zone from production, temporarily isolate a lower zone from an upper zone during treatment of the upper zone, or control fluid flow from the lower zone as it mixes with a fluid from the upper zone where the mixture is then flowed to the surface.

[0012] Selective production can be accomplished by installing a plug, such as a bridge plug, into the wellbore. The plug can define an upper and lower fluid passage through the wellbore. The plug can variably restrict fluid flow between the upper and lower passages during production or injection operations. A plug can be beneficial to production wells since limited support equipment may be needed to manage the installation, operation, and possible retrieval of the plug. The plug can be located and set within the wellbore. The plug can be permanent or retrievable, thereby enabling a lower zone to be permanently sealed from production and/or temporarily isolated from a treatment operation conducted on an upper zone. As used herein, "setting" and all grammatical variations thereof refers to longitudinally fixing a well tool in a wellbore. The setting can be performed by engaging an anchoring device with an inside of a component in the wellbore and/or sealingly engaging an annular seal element with the inside of the component, where the inside of the component can be an inner diameter of a casing in a cased wellbore, an inner diameter of the wall of the wellbore in an uncased wellbore, or an inner diameter of a tubing string in the wellbore.

[0013] Some plugs include a flow control device that provides a selectable restriction to fluid flow through the plug. This selectable restriction can be provided by selecting an orifice from a set of interchangeable orifices and screwing the selected orifice into the plug before installing the plug in the wellbore. Each of the interchangeable orifices has a fixed opening size that is different from the other orifices in the set. Therefore, selecting the orifice also selects the opening size for fluid flow through the plug.

[0014] Unfortunately, if the selected orifice does not produce a desired flow rate through the plug when the plug is set at a predetermined location in the wellbore, then the plug must be retrieved (or otherwise removed) to allow a plug with a different orifice to be set in the wellbore at the predetermined location. The undesired flow rate can be due to changing conditions in the wellbore, erroneous data used to make orifice size selection, selecting a wrong orifice size, *etc.* This iterative process of changing out plugs with different orifice sizes to achieve a desired flow rate requires multiple trips into the wellbore for each iteration. At least one trip to set the plug and another trip to retrieve the plug if the orifice needs to be changed. Due to the expense of tripping in and out of the wellbore, it is desirable to minimize the trips necessary to achieve a desired flow rate through the plug.

[0015] Additionally, setting the new plug with the new orifice back at the predetermined location from which the previous plug was retrieved (or otherwise removed) can also be problematic. It can take a significant amount of time to locate and set the new plug at substantially the same location as the previous plug. This can cause a sealing element of the plug to set prior to locating the plug at the predetermined location, if the sealing element is a swellable sealing element. Also, the setting tool used to set the plug at the predetermined location can have a time limitation that requires that the plug be set before a certain amount of time has elapsed. This problem can be more of an issue with deeper wellbores. Therefore, there is a need to provide a downhole controllable plug that allows for flow rate adjustments without having to retrieve the plug from the wellbore.

[0016] As used herein, the term "swell" and all grammatical variations thereof means an increase in volume of a material. Typically, this increase in volume is due to the swellable material imbibing a fluid within the material's structure. Note that swelling is not the same as expanding, although a material may expand as a result of swelling. For example, in some conventional packers, a seal element may be expanded radially outward by longitudinally compressing the seal element, or by inflating the seal element. In each of these cases, the seal element is expanded without any increase in volume of the material of which the seal element is made. Thus, in these conventional packers the seal element expands, but does not swell.

[0017] It has been discovered that a plug used to provide zonal isolation via the creation of one or more wellbore intervals can include a variable choke for adjusting the flow rate through the plug without retrieving or otherwise removing the plug from the wellbore. A rotary actuator can be used to adjust the variable choke by mechanically rotating a closure member of the variable choke while the plug remains set in the wellbore. The plug of the current disclosure does not require any directly connected control lines to adjust the variable choke, thereby maintaining the simplicity of a plug compared to more conventional inflow control devices, which usually require directly connected control lines for actuation.

[0018] As used herein, "variable choke" refers to a fluid flow control device that can be adjusted through open, partially open, and closed configurations, where the open configuration allows a maximum fluid flow rate through the device, the partially open configuration allows a fluid flow rate that is reduced from the maximum fluid flow rate through the device, and where the closed configuration prevents fluid flow through the device. It should be understood that there can be a minor amount of fluid flow through a plug in a closed configuration, but such amount should be only trivial or negligible.

[0019] According to a certain embodiment, a method for controlling fluid flow through a wellbore is provided, where the method can include introducing a plug, with a variable choke, into the wellbore, setting the plug in the wellbore, and mechanically adjusting the variable choke, thereby controlling a flow rate of a fluid through the plug.

[0020] According to another certain embodiment, a plug is provided that can control fluid flow through a flow passage in a wellbore, where the plug can include a body, an annular seal element that prevents fluid flow through an annulus between the body and an inside of a wellbore component when the annular seal element is set downhole, and a variable choke that can include a closure member, which is mechanically rotated downhole to adjust a fluid flow rate through the variable choke.

[0021] According to yet another certain embodiment, a method of mixing production fluids in a wellbore is provided, the method can include running a plug to a predetermined location in the wellbore, where the plug can include a variable choke. Setting the plug at the predetermined location, where the predetermined location is between first and second production zones. Producing a first fluid from the first production zone which is upstream from the plug, flowing the first fluid through the plug at a first flow rate, producing a second fluid from the second production zone which is downstream from the plug, mixing the first fluid with the second fluid in a portion of the flow passage that is downstream from the plug, mechanically rotating a closure member of the variable choke, and operating the variable choke to any one of closed, open and partially open configurations, thereby adjusting the flow of the first fluid through the plug. As used herein, the relative term "downstream" or "upper" means at a location closer to a wellhead, and "upstream" or "lower" means at a location further away from the wellhead.

[0022] Any discussion of the embodiments regarding the plug or any component of the plug is intended to apply to all of the apparatus and method embodiments.

[0023] Turning to the Figures, **Fig. 1** depicts a well system **10**. The well system **10** can include at least one wellbore **11**. The wellbore **11** can include a casing **15**. The wellbore **11** can penetrate a subterranean formation **20**. The subterranean formation **20** can be a portion of a reservoir or adjacent to a reservoir. The subterranean formation **20** can have one or more zones, as seen in **Fig. 1** with a first zone **12**, a second zone **13**, and a third zone **14**.

[0024] The well system **10** can include multiple wellbore intervals, such as a first wellbore interval **16** and a second wellbore interval **18.** The well system **10** can also include more than two wellbore intervals, for example, the well system **10** can further include a third wellbore interval, a fourth wellbore interval, and so on. At least one wellbore interval can correspond to a zone of the subterranean formation **20.** By way of example, the first wellbore interval **16** can correspond to the first zone **12** and/or the second wellbore interval **18** can correspond to the second zone **13.**

[0025] The wellbore **11** can include a longitudinally extending flow passage **24** that can carry production fluid from the zones **12, 13, 14** during production operations and can carry injection and/or treatment fluid from the surface to any of the zones **12, 13, 14.** The flow passage **24** can be separated into upper and lower flow passages **24B, 24A** by installing a plug **30** between zones **12** and **13**, for example. The plug can isolate the upper and lower flow passages **24B, 24A** from each other, so that pressure and/or fluid flow in one zone **12, 13, 14** does not affect the other zones **12, 13, 14.**

[0026] It should be noted that the well system **10** illustrated in the drawings and described herein is merely one example of a wide variety of well systems in which the principles of this disclosure can be utilized. It should be clearly understood that the principles of this disclosure are not limited to any of the details of the well system **10,** or components thereof, depicted in the drawings or described herein. Furthermore, the well system **10** can include other components not depicted in the drawing. For example, the well system **10** can further include a perforating gun assembly. By way of another example, **Fig. 1** shows the wellbore **11** with a casing **15** and with cement filing an annulus between the wellbore and an outer diameter of the casing **15.** However, the wellbore **11** can be an open-hole wellbore **11** without casing **15** or the cement.

[0027] Additionally, perforations may be included in the wellbore **11** at each of the zones **12, 13, 14** to assist in fluid flow between the zones and the flow passage **24**; however, perforations are not required. As seen in **Fig. 1**, perforations **21** are formed at the first zone **12**, and perforations **22** are formed at the second zone **13**, but no perforations are formed at the third zone **14.** Fractures (not shown) may also be formed at each of the zones **12, 13, 14** to further stimulate the zone.

[0028] In injection operations, fluid flow **69** into the wellbore can cause fluid flow **63** into the zone **12** through perforations **21**, and fluid flow **65** into the zone **13** through perforations **22.** Without plug **30** set in the wellbore **11**, then the fluid flows **63, 65** into zones **12, 13**, respectively, will largely depend upon the relative permeability of the zones **12, 13.** The zone with a higher permeability can receive a larger portion of the fluid flow **69**, with the lower permeability zone receiving a smaller portion of the fluid flow **69.** Installing the plug **30** can provide variable fluid flow control between upper and lower flow passages **24B, 24A** to control the portion of the fluid flow **69** that enters zone **13** (*i.e.*, fluid flow **65**), and the portion of the fluid flow **69** that enters zone **12** (*i.e.*, fluid flow **63**). This can allow the injection operation to treat both zones more equally without significant fluid loss into the higher permeability zone.

[0029] In production operations, fluid flow **68** can be produced to the surface via a flow passage in the wellbore **11.** Fluid flow **68** can be a mixture or combination of the fluid flow **62** from zone **12** and the fluid flow **64** from zone **13.** Without a plug **30**, the amount of contributions of fluid flows **62, 64** to the fluid flow **68** is generally determined by fluid characteristics in each zone **12, 13** (*e.g.*, fluid pressure, fluid type, fluid viscosity, *etc.*). However, installing the plug **30** can provide variable fluid flow control between upper and lower flow passages **24B, 24A** to control the portion of the fluid flow **62** from zone **12** (indicated as fluid flow **60** that flows through the plug **30**) that is mixed with the fluid flow **64** in the upper flow passage **24B** to produce the fluid flow **68**, which can flow to the surface.

[0030] This variable fluid flow control can be used advantageously for economically controlling mixtures of fluids from various formation zones to produce various fluid compositions. For example, a high quality fluid can be mixed with a lower quality fluid to produce a desired fluid composition that can increase the profitability of the well system **10**. Additionally, a gas producing zone can be used to gas lift a fluid produced from another zone. By way of example, zone **12** can produce the fluid flow **62** that contains a pressurized gas, while zone **13** can produce the fluid flow **64** that contains a pressurized liquid hydrocarbon, where zone **13** may not produce sufficient fluid pressure to force a desired amount of the liquid hydrocarbons to the surface. Without the plug **30** installed in the wellbore **11**, the gas production from zone **12** can overcome the liquid hydrocarbons being produced from zone **13**, thereby reducing, if not eliminating, production of the liquid hydrocarbons. With the plug **30** installed in the wellbore **11**, the amount of gas produced to the surface can be controlled, thereby enabling more of the liquid hydrocarbons to be produced. Controlling the amount of gas (*e.g.*, fluid flow **60**) that is mixed with the liquid hydrocarbons (*e.g.*, fluid flow **64**) in the upper flow passage **24B** to produce the fluid flow **68** can be used to “gas lift” the liquid hydrocarbons to the surface. This can result in a desired amount of liquid hydrocarbons being produced at the surface without requiring the additional expense of injecting gas into the wellbore to provide the necessary "gas lift" for the liquid hydrocarbons.

[0031] The plug **30** can be installed in the wellbore at a predetermined location by conventional running tools. The running tool (not shown) can carry the plug **30** to the predetermined location. The running tool can also include a setting tool that sets the plug **30** at the predetermined location by engaging an anchoring device **37** with an inside surface of a wellbore component **23**, such as the wall of the wellbore **11**, or the inner surface of a casing **15** or tubing string. The setting tool can also set the plug **30** by expanding a seal element **38** into sealing contact with the inside of the wellbore component **23**. It should also be understood that the plug **30** can be set in the wellbore **11** without using an anchoring device **37**. In this configuration, the seal element **38** can be used to anchor the plug at the predetermined location in the wellbore as well as sealingly engage the wellbore component **23**.

[0032] The anchoring device **37** can be any anchoring device that securely grips the wellbore component **23**, thereby preventing further longitudinal movement of the plug **30** in the wellbore **11** while the anchoring device **37** is set. For example, the anchoring device **37** can be extendable slips, extendable dogs, an extendable gripping device, a lock mandrel or other lock mechanisms, expandable seal elements, *etc.* The seal element **38** can be any seal element (or group of seal elements) that expands (or extends) into sealing engagement with the wellbore component **23**, thereby preventing fluid flow through the annulus **17** between the plug **30** and the wellbore component **23**. For example, the seal element **38** can be an inflatable bladder that is inflated into sealing contact with the wellbore component **23.** Alternatively, or in addition to, the seal element can be one or more swellable seal elements that surround the plug **30.** When the swellable seal elements are contacted by an activating agent **39**, the elements swell into sealing contact with the wellbore component **23.** The activating agent **39** can be 1) flowed from the surface to the plug through the upper flow passage **24B**, 2) contained in the setting tool and released when it is desired to swell the swellable seal elements, 3) already present in the wellbore, and/or 4) otherwise delivered to the plug to contact the swellable seal elements.

[0033] The plug **30** can include a body **31**, a variable choke **32** with a closure member **34**, upper and lower flow paths **26**, **28**, the anchoring device **37**, and the seal element **38.** The body **31** can include a stationary profile **36** that is rotationally fixed to the wellbore component **23** by the anchoring device **37** and/or the seal element **38.** As used herein, the phrase "rotationally fixed" means that one item is substantially prevented from rotating relative to another item. As used herein, the phrase "substantially prevented" means that a slight relative rotation from approximately 0 to 10 degrees between the two items can occur while still being rotationally fixed. The closure member **34** can include a drive profile **35** that can rotate the closure member **34** (indicated by arrows **58**) relative to the body **31** and selectively adjust the variable choke between closed, open, and partially open configurations. It should be understood that the variable choke can be any flow control device that can provide a variable restriction to flow through the device, such as a needle valve, a plug valve, a gate valve, a ball valve, a sleeve valve, and a flapper valve. It should also be understood that the variable flow restriction can include a valve that has only open and closed positions. As used herein, the term "selectively" (*e.g.*, *selectively* moved between open and closed positions) and all grammatical variations thereof means that the different conditions being selected are not necessarily selected at the same time. Usually only one of these conditions is selected, but any of the different conditions can be selected.

[0034] The flow paths **26, 28** and the variable choke **32** can provide a continuous flow path through the plug to establish fluid communication between the upper flow passage **24B** and the lower flow passage **24A.** The lower flow path **26** can provide fluid communication between the lower flow passage **24A** and the variable choke **32.** The upper flow path **28** can provide fluid communication between the variable choke **32** and the upper flow passage **24B.** The variable choke **32** can provide a variable restriction to flow through the plug's **30** continuous flow path. Therefore, with the variable choke **32** in the closed configuration, fluid flow **60, 61** through the plug **30** is prevented and the upper and lower flow passages **24B, 24A** can be isolated from each other. The fluid flow **60, 61** through the plug **30** can be incrementally increased by incrementally opening the variable choke **32.** With the variable choke **32** in the open configuration, the fluid flow **60, 61** through the plug **30** can be maximized. The fluid flow **60** is indicated as being fluid flow from the lower flow passage **24A,** through the plug **30** and into the upper flow passage **24B** for production operations. The fluid flow **61** is indicated as being fluid flow from the upper flow passage **24B,** through the plug **30** and into the lower flow passage **24A** for injection operations.

[0035] A rotary actuator **40** can travel through the longitudinal flow passage **24** on a conveyance **19** to engage the plug **30** and mechanically actuate the variable choke **32.** As used herein, "conveyance" refers to a means of transporting a well tool through a tubing string. For example, the conveyance can be a coiled tubing, a wireline, a tractor system, a segmented tubing string, *etc*. As used herein, "mechanically" actuated, rotated, or adjusted refers to a device being actuated by the application of a mechanical force that acts on a component of the device without electrical energy, optical energy, magnetic coupling, or an increased fluid pressure being applied to the device. When the rotary actuator **40** engages the plug **30**, a drive profile **43** engages the mating drive profile **35** on the closure member **34**, thereby rotationally fixing the drive profile **43** to the drive profile **35**, and a stationary profile **45** engages a stationary profile **36**, thereby rotationally fixing the stationary profile **45** to the stationary profile **36**. The rotary actuator **40** can rotate the drive member **42** and drive profile **43** relative to the stationary member **44** and stationary profile **45**. Therefore, the rotary actuator **40** can rotate the closure member **34** (indicated by arrows **58**) relative to the body **31**.

[0036] The rotation **58** can cause the closure member **34** to vary the flow restriction through the variable choke **32**, thereby actuating the variable choke **32** to at least one of a closed, an open and a partially open configuration. The rotation **58** can cause the closure member **34** to move rotationally and/or longitudinally to actuate the variable choke **32**. For example, if the closure member **34** is threaded into the variable choke **32**, then the rotation **58** can cause the closure member **34** to move both longitudinally and rotationally. However, if the closure member **34** mates to longitudinal splines in the variable choke **32**, then the closure member **34** can be restricted to only longitudinal movement. Additionally, if the variable choke is a ball valve, then the closure member **34** can be restricted to only rotational movement.

[0037] Referring now to **Figs. 2-6**, these figures show a variety of configurations for the variable choke **32** that can be used with the plug **30**. **Fig. 2** depicts a plug **30** with a needle valve as the variable choke **32.** As the conical shaped closure member **34** is threaded up and down in the body **31**, the closure member **34** moves both rotationally and longitudinally as shown by arrows **58** and **33**, respectively. The longitudinal movement **33** of the closure member **34** can vary the flow restriction through the variable choke **32.** **Fig. 3** depicts a plug **30** that is very similar to the plug **30** in **Fig. 2.** However, **Fig. 3** illustrates that fluid can enter or exit the lower flow path **26** through a side of the body **31** as opposed to the bottom of the body **31**, as in **Fig. 2.** It should be understood that both the upper and lower flow paths **26, 28** may provide fluid communication through an end and/or side of the body **31**, as long as one flow path **26, 28** is in fluid communication with the lower flow passage **24A**, and the other one of the flow paths **26, 28** is in fluid communication with the upper flow passage **24B.**

[0038] **Fig. 4** depicts a plug **30** with a gate valve as the variable choke **32.** As the closure member **34** is rotated, the rotation **58** causes the closure member **34** to also move longitudinally as indicated by the arrow **33.** This longitudinal movement **33** of the closure member **34** can vary the flow restriction through the variable choke **32.** **Fig. 5** depicts a plug **30** with a ball valve as the variable choke **32.** As the closure member **34** is rotated, a ball in the variable choke **32** is also rotated, as indicated by arrows **48.** The rotation **48** of the ball can vary the flow restriction through the variable choke **32.**

[0039] **Fig. 6** depicts a plug **30** with a sleeve valve as the variable choke **32.** When the plug **30** is engaged with the rotary actuator **40** (or any other actuator **40** capable of imparting mechanical rotation to the closure member **34**), drive profiles **35** are engaged with mating drive profiles **43** of the rotary actuator **40** (see **Fig. 1**), and the stationary profiles **36** are engaged with the stationary profiles **45** of the rotary actuator **40.** When the drive profiles **35, 43** are rotated relative to the stationary profiles **36, 45,** the closure member **34** is rotated relative to the body **31.** **Fig. 6** shows a variation of the drive profile **35** when compared to the drive profile **35** in **Fig. 7.** However, these profiles are not mutually exclusive. The recess-type profile **35** in **Fig. 7** can also be used with the closure member **34** in **Fig. 6**, and the ring-type profile **35** in **Fig. 6** can also be used with the closure member **34** in **Fig. 7.** Many other modifications to the drive and stationary profiles are also possible.

[0040] Referring again to **Fig. 6**, threads **52** on an outer wall of the closure member **34** can be threaded into threads **50** on an inner wall of the body **31.** Rotation **58** of the closure member causes the threaded interface between threads **50** and **52** to move longitudinally (movement **33**) up or down within the body **31.** The flow path **28** is indicated as being an internal bore of the closure member **34.** The flow path **26** includes multiple openings in the side wall of the body **31.** As the closure member **34** is moved down, the openings of flow path **26** are incrementally blocked, thereby increasing flow restriction through the variable choke **32.** If the closure member **34** moves down enough to engage an annular seal **49** (such as an O-ring), then the variable choke **32** would be in a fully closed configuration, thereby preventing fluid flow through the flow passage **26** into or out of the variable choke **32.** Any of the plugs **30** shown in **Figs. 2-6** can be used as the plug **30** in the well system **10** shown in **Fig. 1.**

[0041] **Fig. 7** depicts a more detailed partial cross-sectional view of a plug **30.** The plug **30** is very similar to the plug **30** shown in **Fig. 2.** The plug **30** has already been set at the predetermined location by engaging the anchoring device **37** with the wellbore component **23** and expanding the seal element **38** into sealing contact with the wellbore component **23.** Fluid flow through the annulus **17** is prevented by the expanded seal element **38** and fluid communication between the lower flow passage **24A** and the upper passage **24B** is established through the flow paths **26, 28** and the flow chamber **29.** The variable choke **32** was preset to at least a partially open configuration prior to being installed in the wellbore **11.** The variable choke **32** may have been set to the particular partially open configuration to provide a flow rate through the plug **30** that is estimated to provide a desired flow rate. After the plug is set, an actual flow rate of the fluid flowing through the plug **30** (fluid flow **60** for production, and fluid flow **61** for injection) can be determined.

[0042] If the actual flow rate is substantially equal to the desired flow rate (where "substantially equal" means that the actual flow rate is within an acceptable range when compared to the desired flow rate), then no further adjustment of the variable choke **32** is necessary. The actual flow rate may change over time as the conditions downhole change, but as long as the actual flow rate remains substantially equal to the desired flow rate, then adjustments of the variable choke **32** may not be necessary. However, if the actual flow rate does not substantially equal the desired flow rate, then adjustments to the variable choke **32** can be performed to change the flow rate through the variable choke **32** to be substantially equal the desired flow rate.

[0043] These adjustments can be made downhole while the plug **30** remains set in the wellbore **11.** A rotary actuator **40** can be run into the well on the conveyance **19** (**Fig. 1**) into engagement with the plug **30.** **Fig. 7** depicts the rotary actuator

40 separated from the plug **30** for clarity, but, when engaged, the actuator **40** and plug **30** can be in contact with each other. The drive profile **43** on the drive member **42** engages the drive profile **35** on the closure member **34.** The stationary profiles **45** on the stationary member **44** engage the profiles **36** on the body **31** of the plug **30.** Inclined surfaces **46** can be used to help axially align the rotary actuator **40** with the plug **30.** Once the rotary actuator **40** is engaged with the plug **30**, the drive member can rotate the closure member **34** about the center axis **56** via the engaged drive profiles **35, 43.** The center axis **56** of the plug is shown aligned with the center axis **54** of the flow passage **24.** However, it is not necessary for the axis **56** to be aligned with the axis **54.** For example, an eccentric seal element can offset the axis **56** from the axis **54.** The rotation **58** of the closure member **34** relative to the body **31** can cause the threaded connection between threads **50, 52** to move the closure member **34** longitudinally, as indicated by arrows **33.** The longitudinal movement **33** of the closure member **34** can actuate the variable choke to one of closed, open and partially open configurations.

[0044] Therefore, the present system is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is, therefore, evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. As used herein, the words "comprise," "have," "include," and all grammatical variations thereof are each intended to have an open, non-limiting meaning that does not exclude additional elements or steps. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods also can "consist essentially of" or "consist of" the various components and steps.

[0045] Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent(s) or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

WHAT IS CLAIMED IS:

1. A method for controlling fluid flow through a wellbore, the method comprising:

introducing a plug into the wellbore, wherein the plug comprises a variable choke and a closure member; and

setting the plug in the wellbore,

wherein a flow rate of a fluid flowing through the plug is controlled by mechanically adjusting the variable choke, and

wherein the choke is adjusted within the wellbore via rotation of the closure member.

2. The method according to Claim 1, wherein the closure member selectively moves between closed, open and partially open configurations in response to the rotation.

3. The method according to Claim 1, wherein the closure member moves longitudinally in response to the rotation.

4. The method according to Claim 1, wherein a first drive profile on the closure member engages a second drive profile on a drive member of a rotary actuator, thereby rotationally fixing the closure device to the drive member, wherein a first stationary profile on a body of the plug engages a second stationary profile on a stationary member of the rotary actuator, thereby rotationally fixing the body to the stationary member, and wherein rotation of the drive member by the rotary actuator rotates the closure member relative to the body, thereby adjusting the variable choke.

5. The method according to Claim 1, further comprising:

causing or allowing a fluid to flow through the plug at a first flow rate;

determining the first flow rate;

mechanically adjusting the choke within the wellbore in response to the first flow rate, wherein the adjustment provides a second flow rate through the plug; and

causing or allowing the fluid to flow through the plug at the second flow rate.

6. The method according to Claim 5, wherein the step of mechanically adjusting is performed in response to the first flow rate being different than a desired flow rate.

7. The method according to Claim 1, wherein the step of setting further comprises anchoring the plug at a predetermined location in the wellbore with an anchoring device, and wherein the anchoring device is selected from the group consisting of a slip, a gripping device, and a lock mechanism.

8. The method according to Claim 1, wherein the step of setting further comprises expanding a sealing element to sealingly engage an inside of a wellbore component, thereby preventing flow through an annulus between the outside of the plug and the inside of the wellbore component.

9. The method according to Claim 1, wherein the step of setting further comprises swelling a swellable sealing element to sealingly engage an inside of a wellbore component, thereby preventing flow through an annulus between the outside of the plug and the inside of the wellbore component.

10. The method according to Claim 1, further comprising isolating an upper portion of a flow passage in the wellbore from a lower portion of the flow passage when the plug is set and the variable choke is in a closed configuration.

11. The method according to Claim 1, wherein the variable choke is selected from the group consisting of a needle valve, a plug valve, a gate valve, a ball valve, a sleeve valve and a flapper valve.

12. A plug that controls fluid flow through a flow passage in a wellbore, the plug comprising:

a body;

an annular seal element that prevents fluid flow through an annulus between the outside of the body and an inside of a wellbore component when the annular seal element is set in the wellbore; and

a variable choke comprising a closure member, wherein the closure member is mechanically rotated in the wellbore to adjust a flow rate of a fluid flowing through the variable choke.

13. The plug according to Claim 12, wherein the annular seal element expands into contact with the wellbore component and prevents flow through the annulus when the annular seal element is expanded.

14. The plug according to Claim 12, wherein the annular seal element includes a swellable seal element, which swells when contacted by a swelling fluid, and wherein the annular seal element prevents flow through the annulus when the swellable seal element has swelled.

15. The plug according to Claim 12, further comprising an anchoring device that anchors the plug at a predetermined location in the wellbore, and wherein the anchoring device is selected from the group consisting of a slip, a gripping device and a lock mechanism.

16. The plug according to Claim 12, wherein a first drive profile on the closure member engages a second drive profile on a drive member of a rotary actuator, thereby rotationally fixing the closure device to the drive member, wherein a first

stationary profile on the body of the plug engages a second stationary profile on a stationary member of the rotary actuator, thereby rotationally fixing the body to the stationary member, and wherein rotation of the drive member by the rotary actuator rotates the closure member relative to the body, thereby adjusting the variable choke.

17. The plug according to Claim 12, wherein the variable choke is selected from the group consisting of a needle valve, a plug valve, a gate valve, a ball valve, a sleeve valve and a flapper valve.

18. The plug according to Claim 12, wherein the fluid flows through the plug at a first flow rate, wherein the variable choke is adjusted downhole to produce a second flow rate through the plug, and wherein the second flow rate is different from the first flow rate.

19. The plug according to Claim 12, wherein the closure member selectively moves between closed, open, and partially open configurations in response to the mechanical rotation.

20. A method of mixing production fluids in a wellbore of a subterranean formation, the method comprising:

running a plug to a predetermined location in the wellbore, wherein the plug includes a variable choke;

setting the plug at the predetermined location, wherein the predetermined location is between first and second zones of the subterranean formation;

producing a first fluid from the first zone;

flowing the first fluid through the plug at a first flow rate;

producing a second fluid from the second zone;

mixing the first fluid with the second fluid to form a mixed fluid in a portion of the flow passage that is downstream from the plug;

mechanically rotating a closure member of the variable choke; and

operating the variable choke to any one of closed, open, and partially open configurations in response to the rotation, wherein the configuration adjusts the flow rate of the first fluid through the plug.

21. The method according to Claim 20, further comprising:

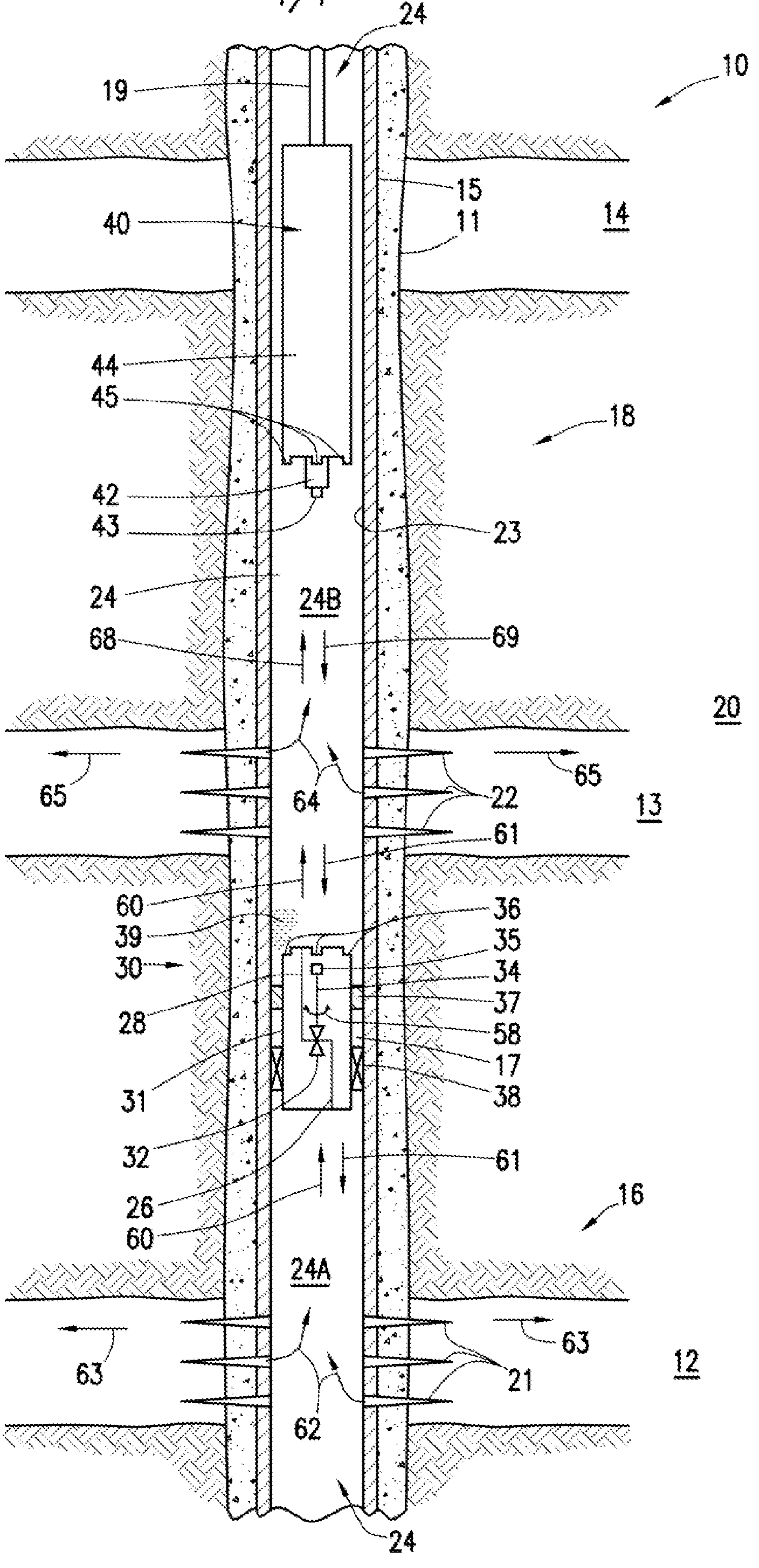
flowing the mixed fluid to the surface; and

determining the amounts of first and second fluids contained in the mixed fluid, wherein the step of operating is performed in response to the amounts of the first and second fluids.

22. The method according to Claim 21, wherein the mixed fluid contains desired amounts of the first and second fluids after the adjustment of the flow rate of the first fluid.

23. The method according to Claim 20, wherein the first fluid is a gas and the second fluid is a liquid.

FIG. 1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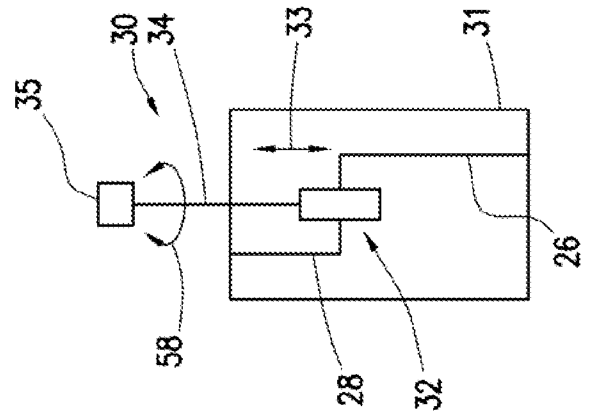

FIG. 4

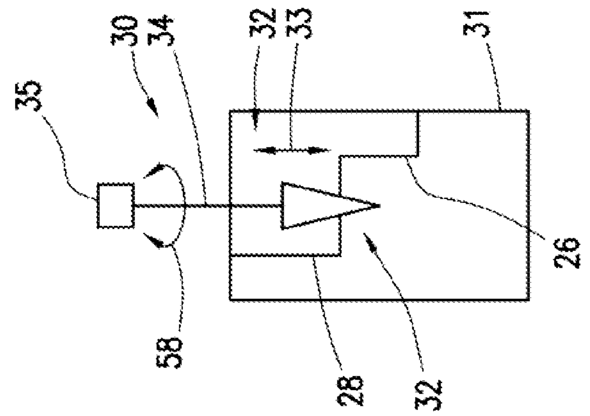

FIG. 3

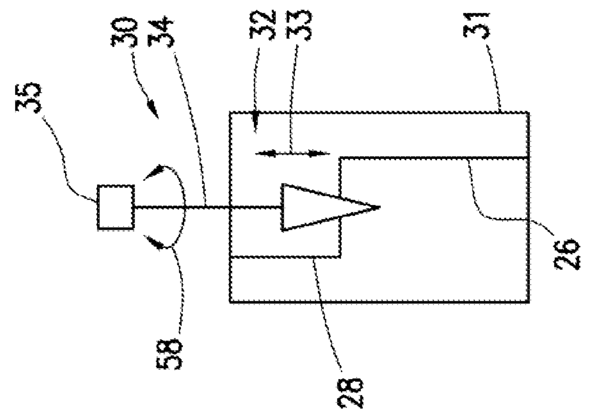

FIG. 2

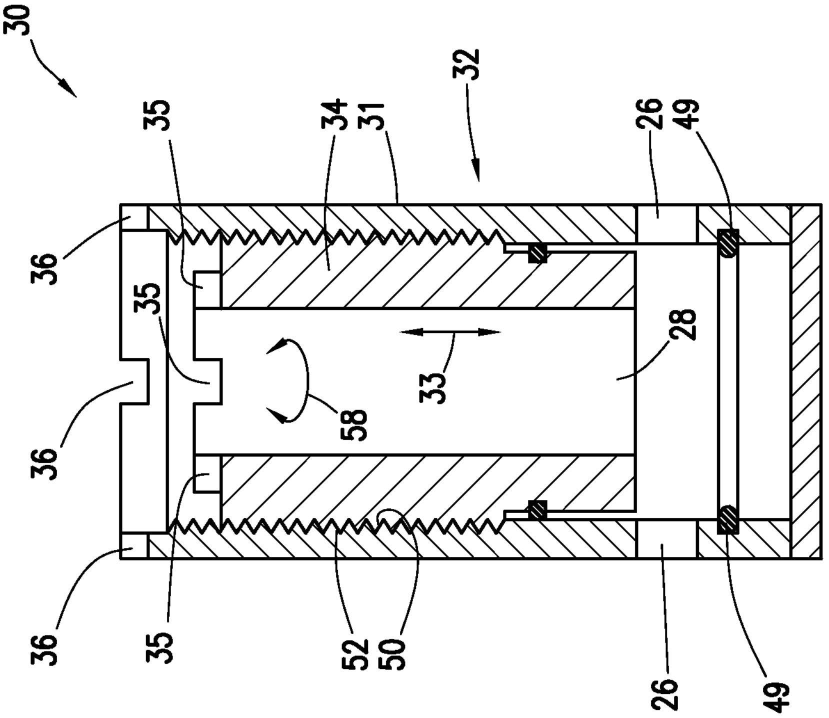
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FIG. 6

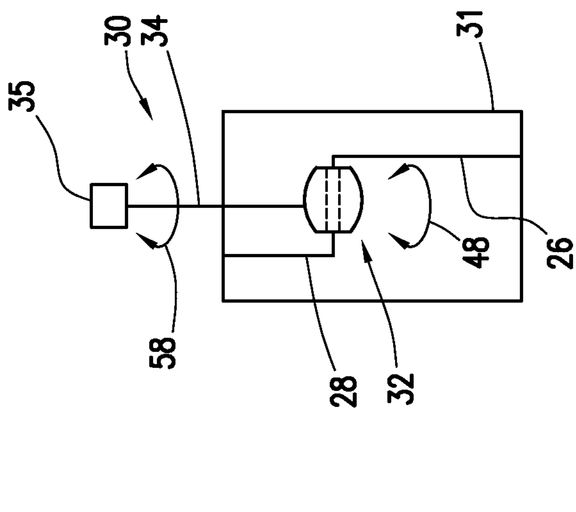
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FIG. 5

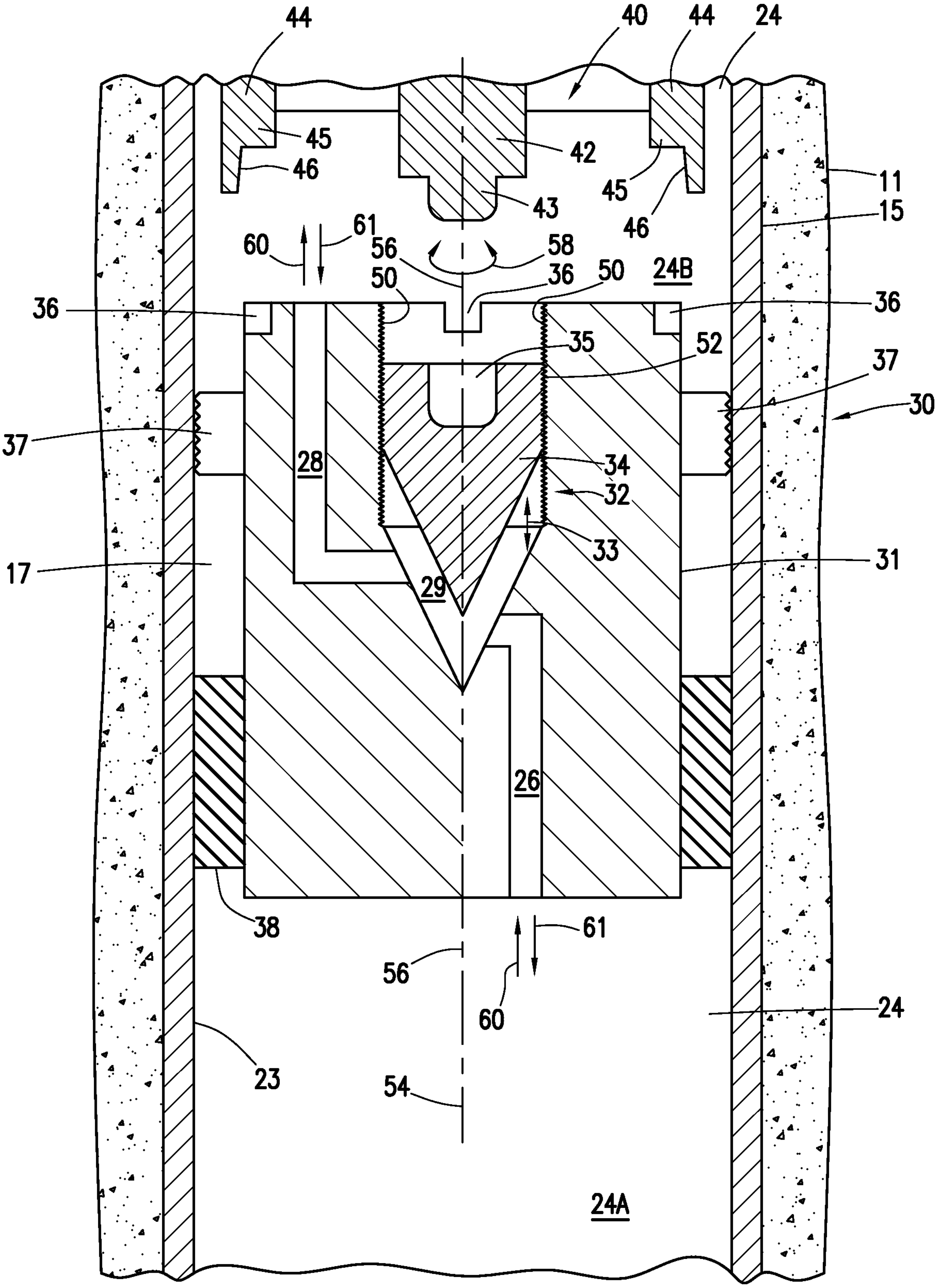
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FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/011871

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/12(2006.01)i

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 43/12; F16K 5/10; E21B 34/06; E21B 34/00; E21B 43/18; E21B 33/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: flow control, adjust, flow rate, plug valve, actuator

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009-0065199 A1 (PATEL et al.) 12 March 2009 See paragraphs [0029], [0031]-[0040]; and figures 1, 3-5.	1-23
Y	US 5273112 A (SCHULTZ, ROGER L.) 28 December 1993 See column 5, lines 4-48; and figures 4A-4B.	1-23
A	US 2009-0032244 A1 (ZUPANICK, JOSEPH A.) 5 February 2009 See paragraphs [0051]-[0052]; and figures 4-5.	1-23
A	US 2006-0284134 A1 (DWIVEDI, ALOK) 21 December 2006 See paragraphs [0022]-[0023]; and figure 1.	1-23
A	WO 2008-009955 A1 (HALLIBURTON ENERGY SERVICE, INC.) 24 January 2008 See paragraphs [0018]-[0020]; and figures 1-2.	1-23

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 October 2015 (07.10.2015)	**07 October 2015 (07.10.2015)**

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Telephone No. +82-42-481-8288

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