



US 20240344423A1

(19) **United States**

(12) **Patent Application Publication**
VOLL et al.

(10) **Pub. No.: US 2024/0344423 A1**

(43) **Pub. Date: Oct. 17, 2024**

(54) **FLOW CONTROL DEVICE**

Publication Classification

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(51) **Int. Cl.**
E21B 34/08 (2006.01)

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(52) **U.S. Cl.**
CPC **E21B 34/08** (2013.01)

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(57) **ABSTRACT**

A flow control device and associated method are provided, the flow control device comprising: a body locatable within a wall of a tubular and defining a primary inlet and a primary outlet, wherein a primary flow path is defined between the primary inlet and primary outlet; a valve member is disposed within the body, the valve member being moveable in reverse first and second directions to selectively vary a flow area of the primary flow path; and, a sealed pilot pressure chamber defining a pilot pressure inlet for receiving a pilot pressure, the valve member being in pressure communication with the sealed pilot pressure chamber such that pilot pressure may act to bias the valve member in one of the first and second directions, wherein the pilot pressure is provided as a function of a property of fluid flowing through the primary flow path.

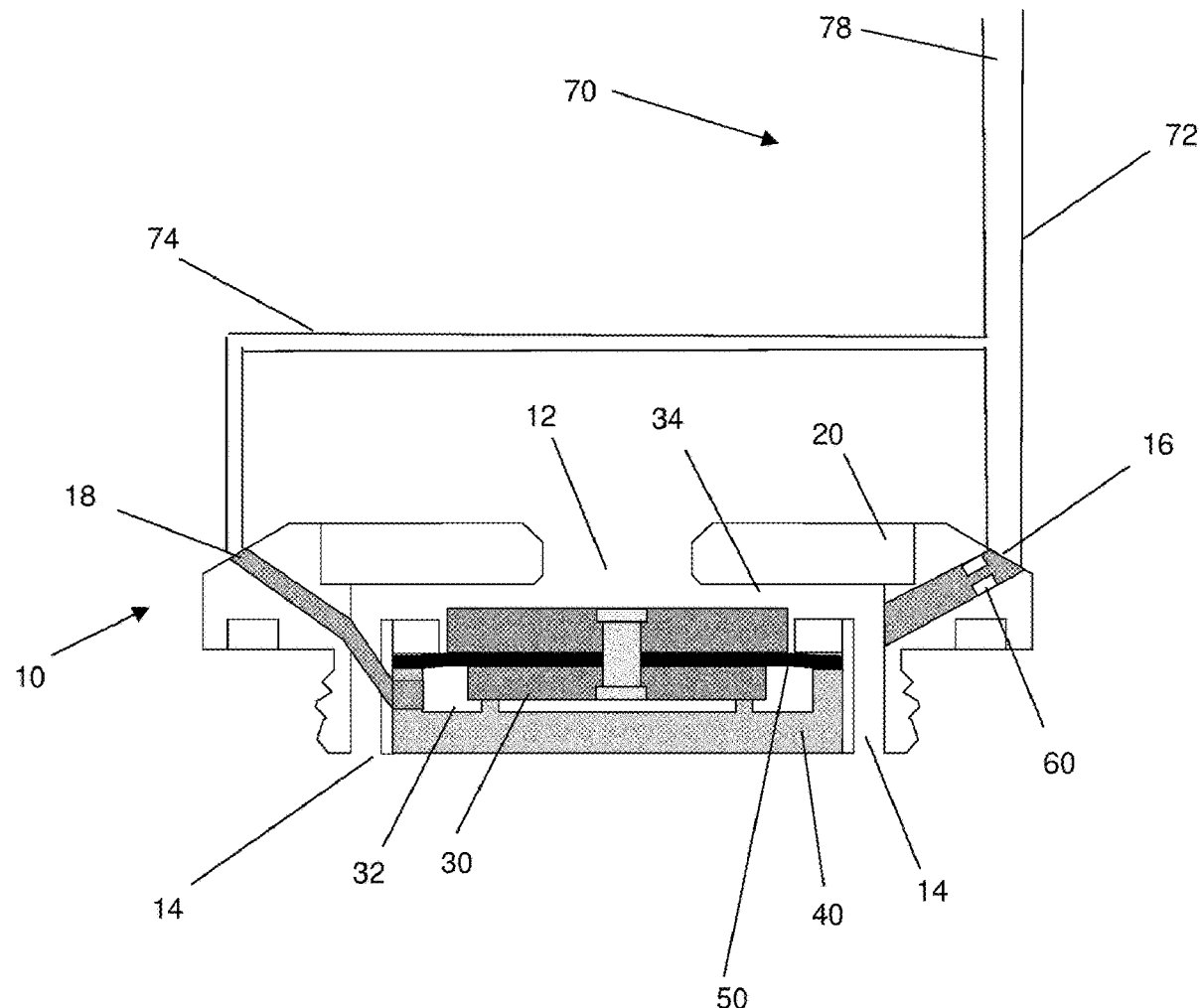
(21) Appl. No.: **18/682,828**

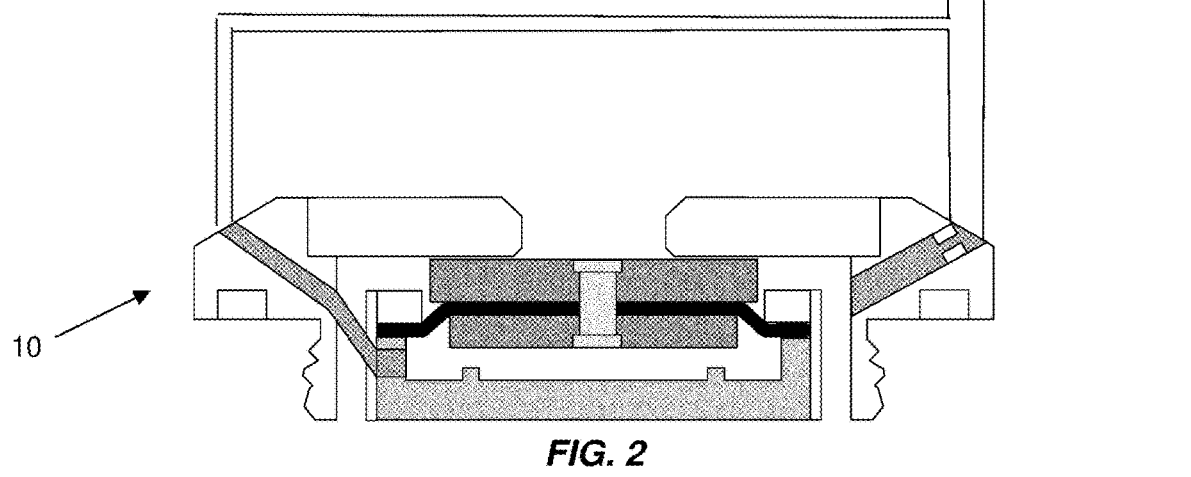
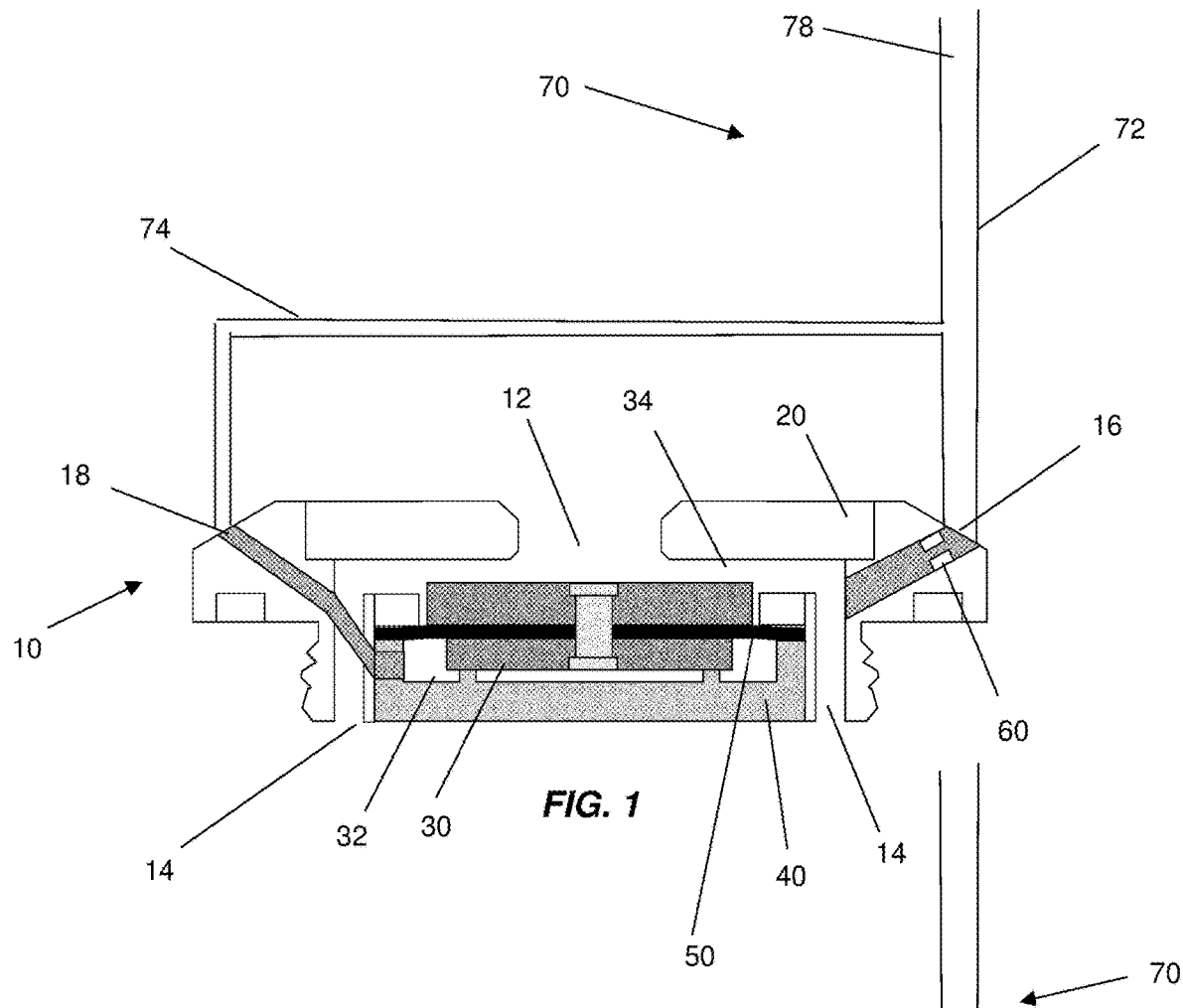
(22) PCT Filed: **Aug. 11, 2021**

(86) PCT No.: **PCT/EP2021/072427**

§ 371 (c)(1),

(2) Date: **Feb. 9, 2024**





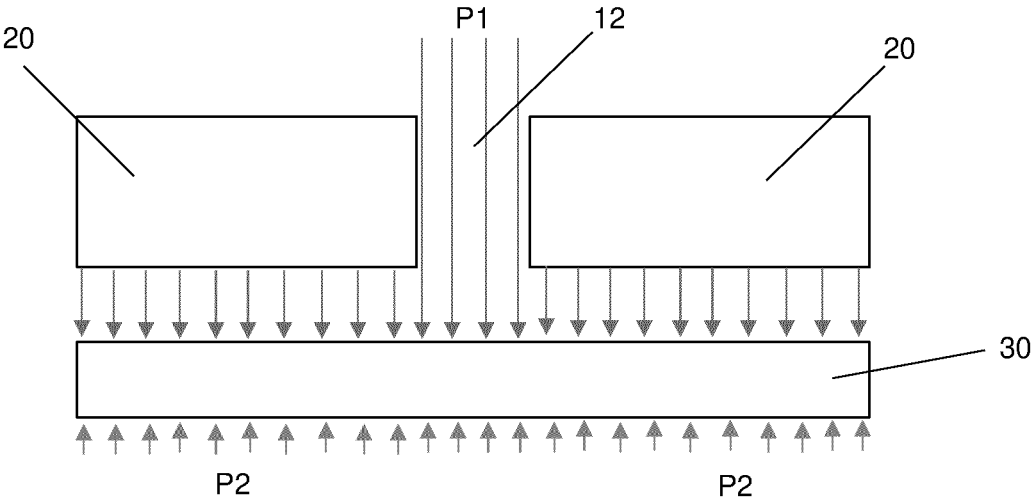


FIG.3A

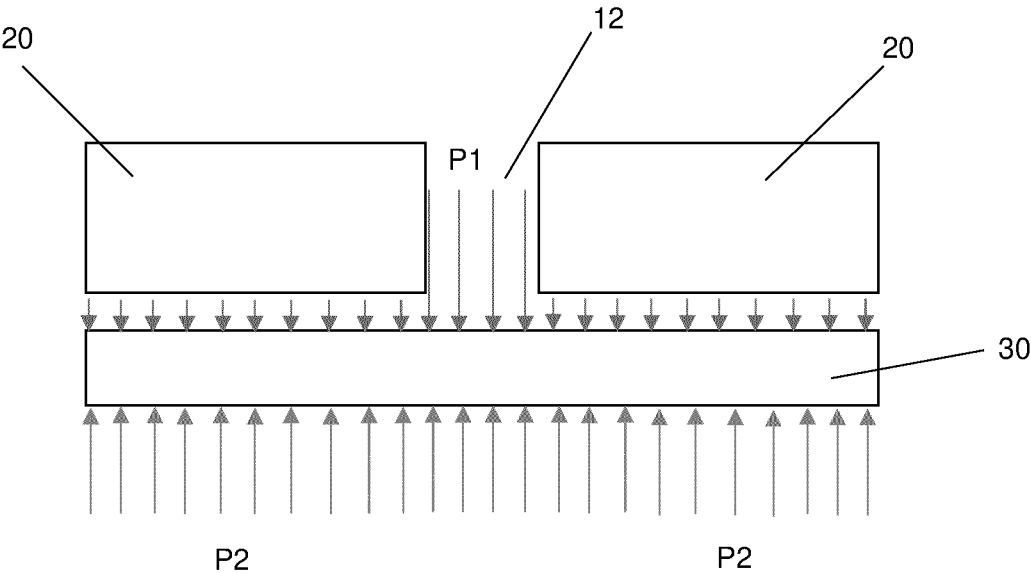


FIG.3B

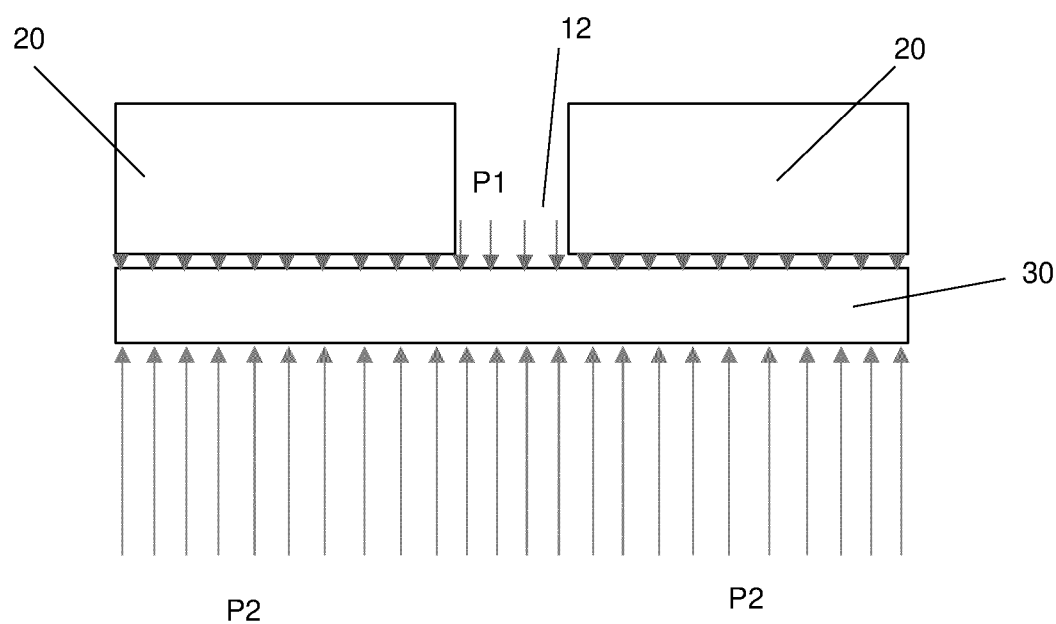


FIG.3C

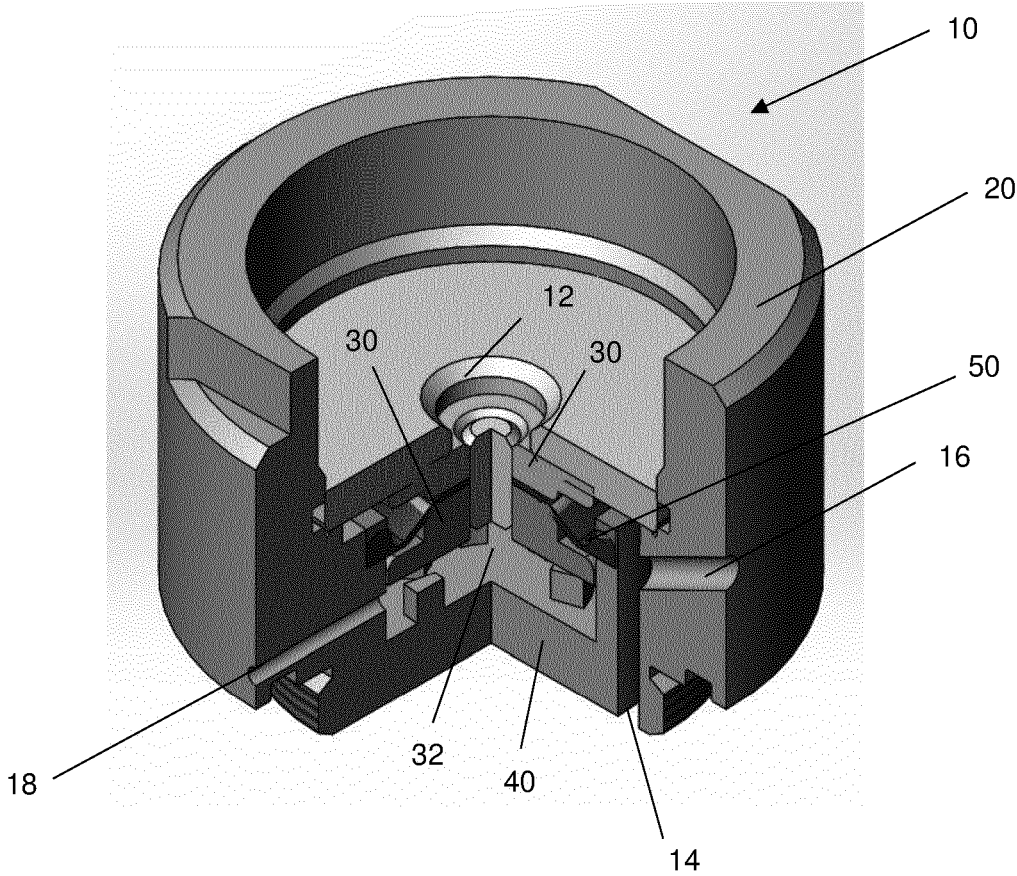
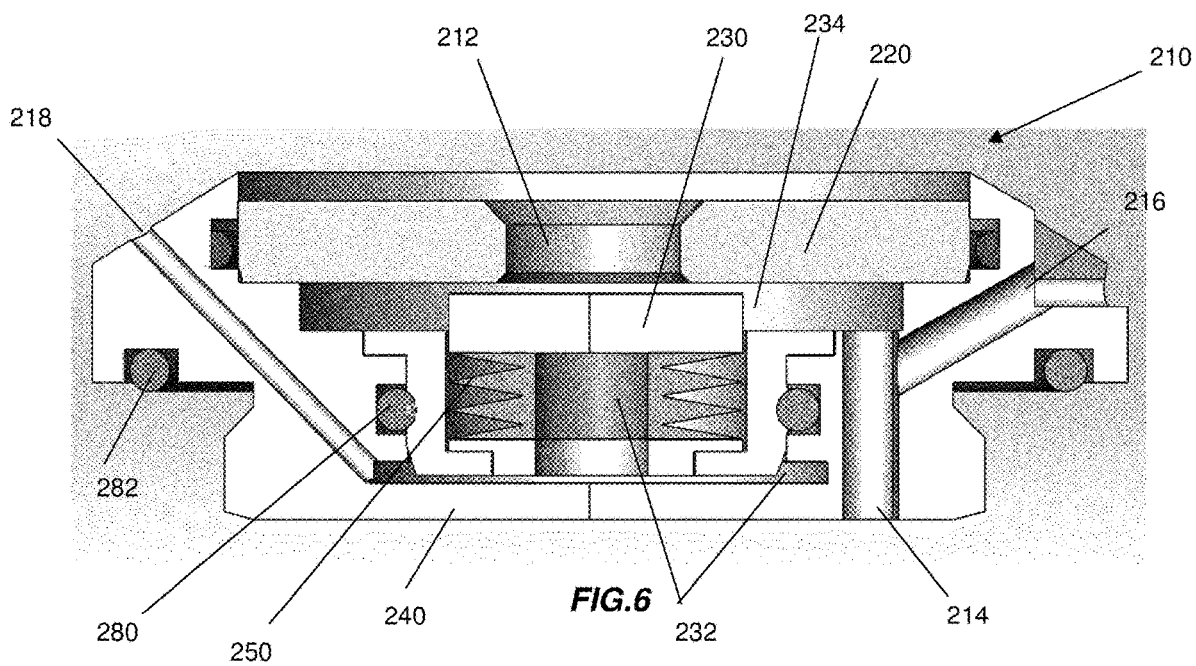
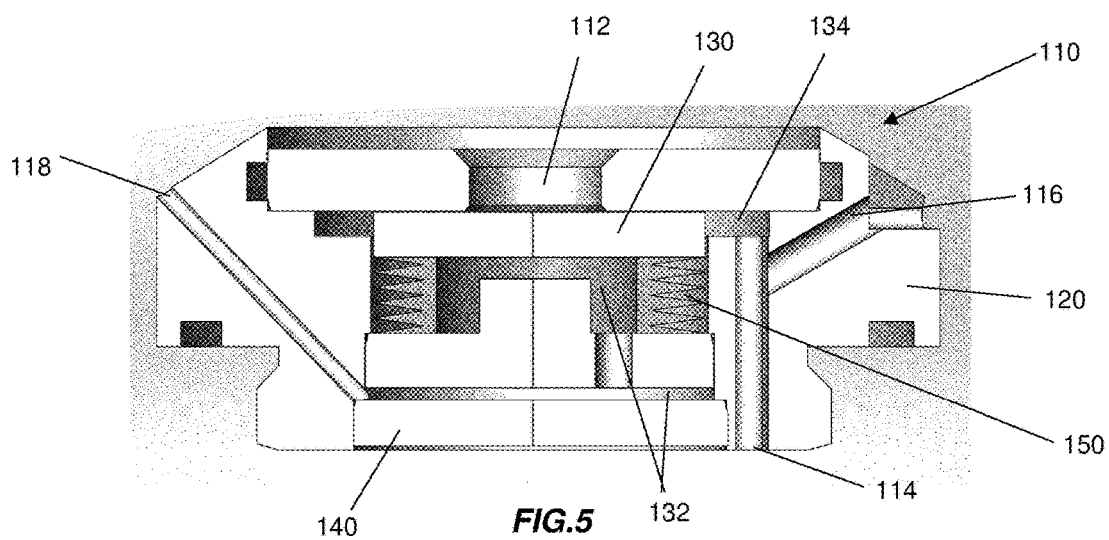
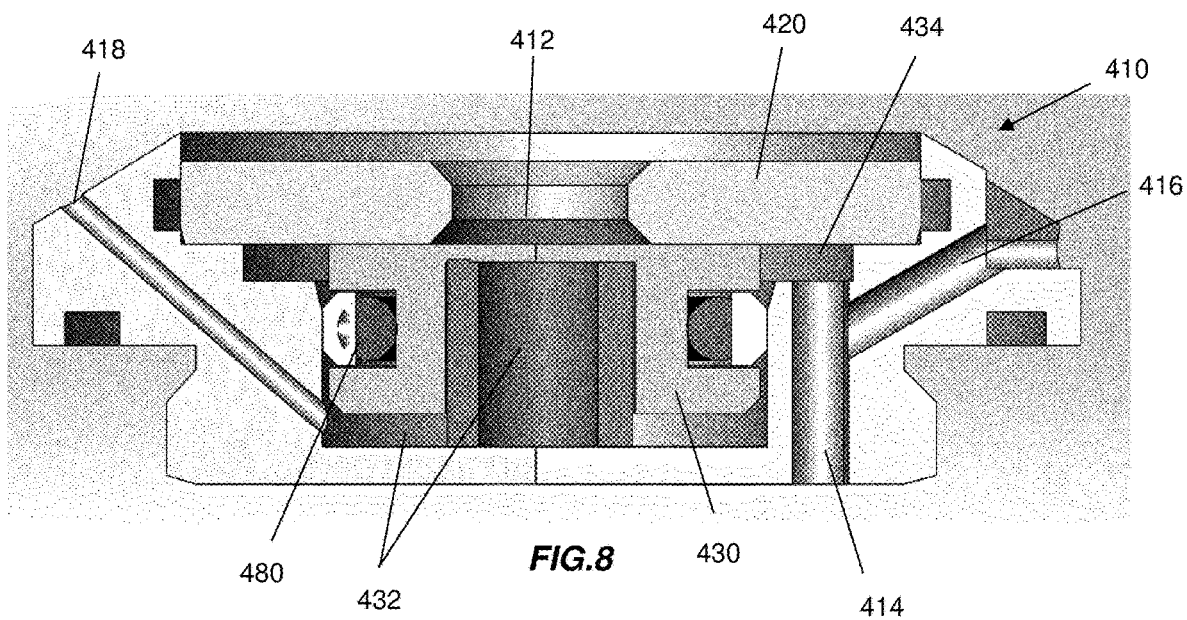
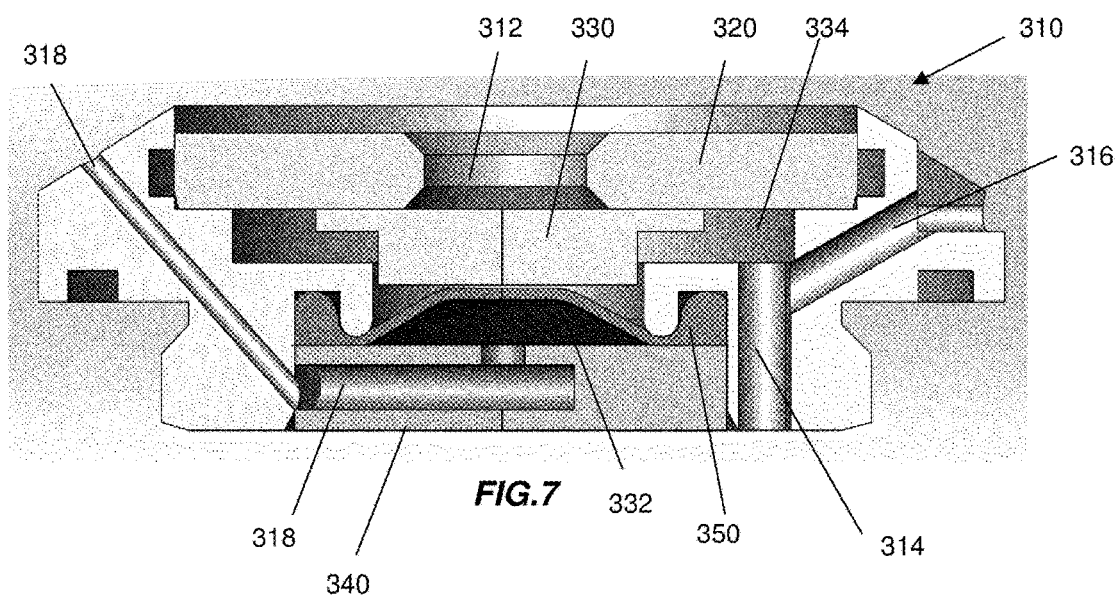
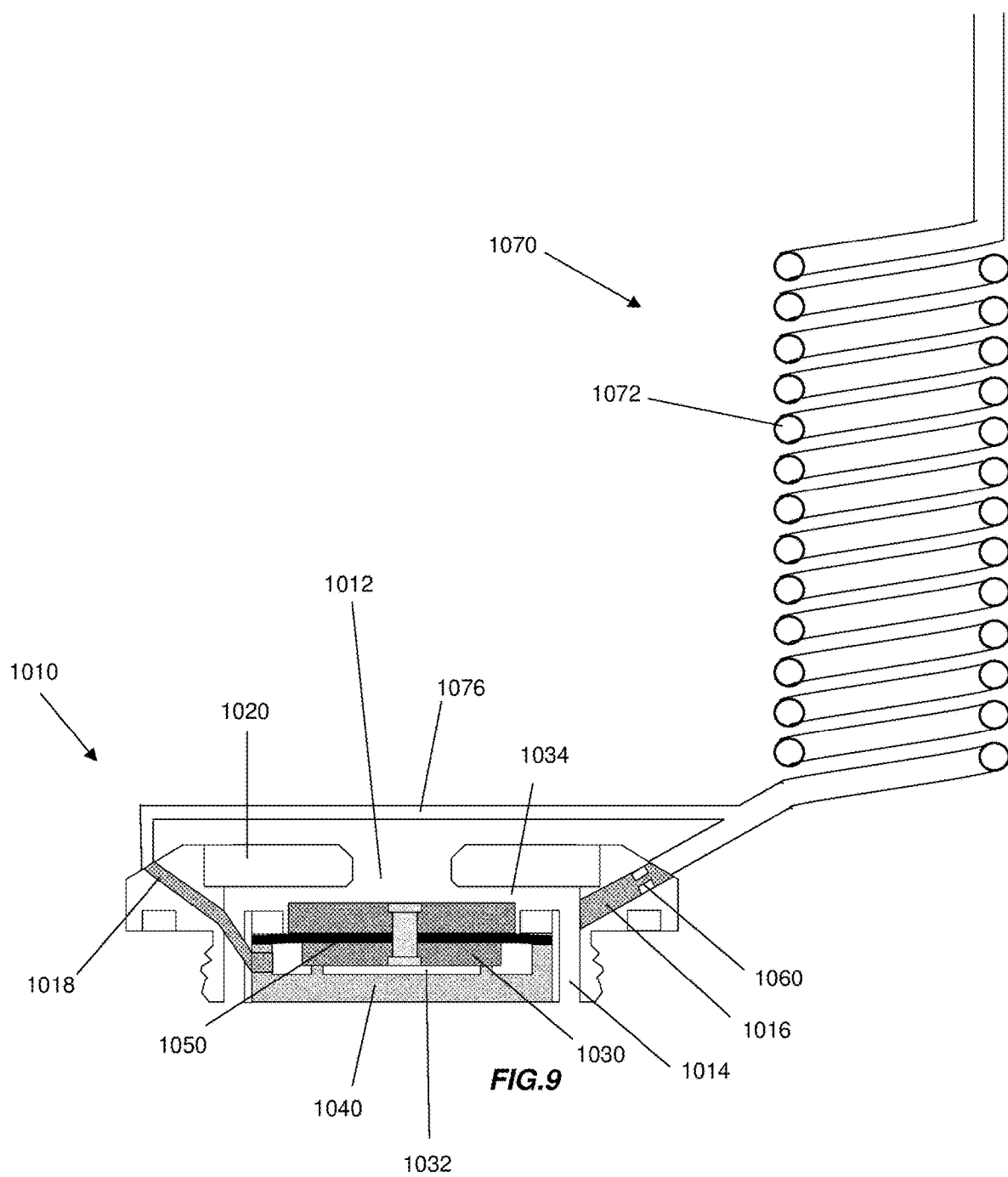


FIG.4







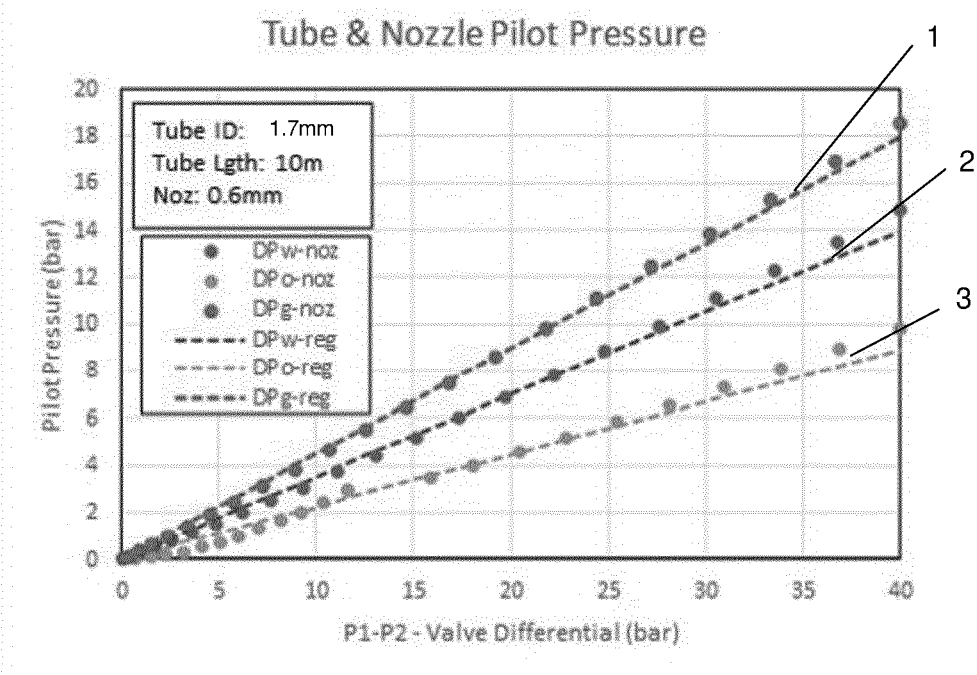


FIG.10

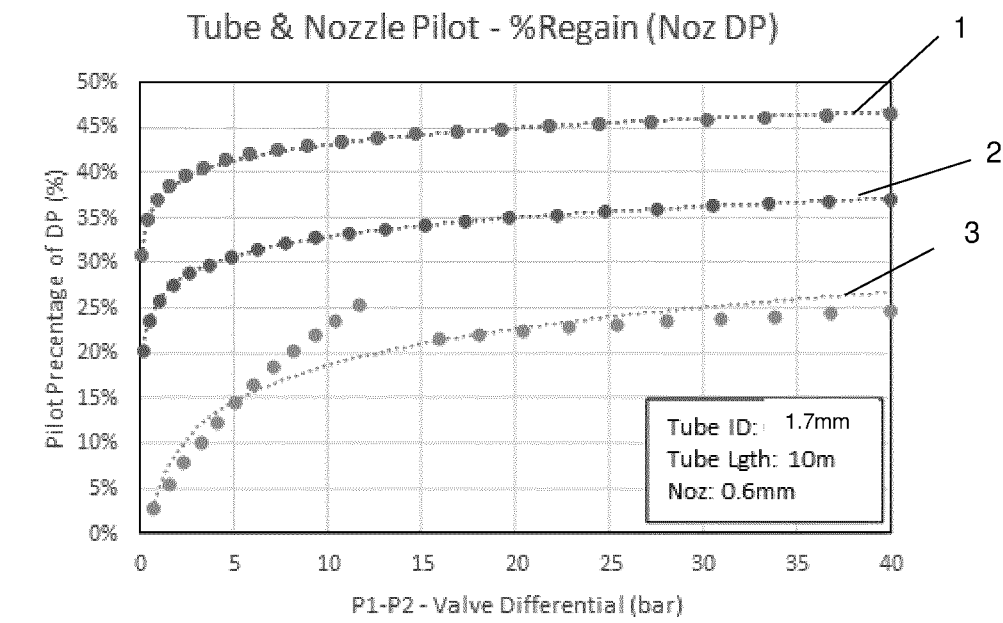


FIG.11

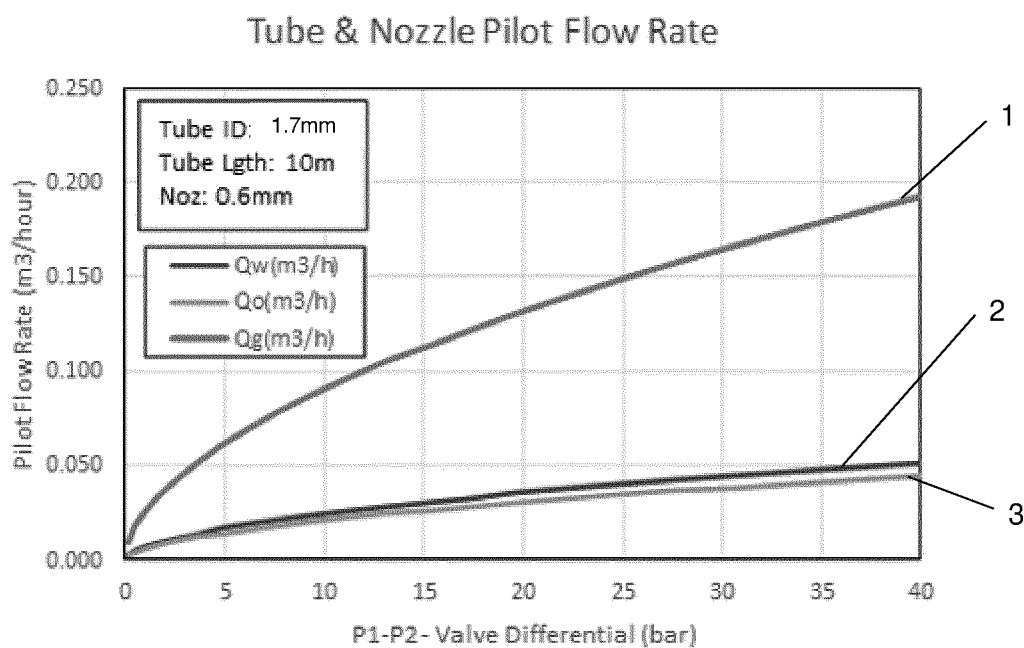


FIG.12

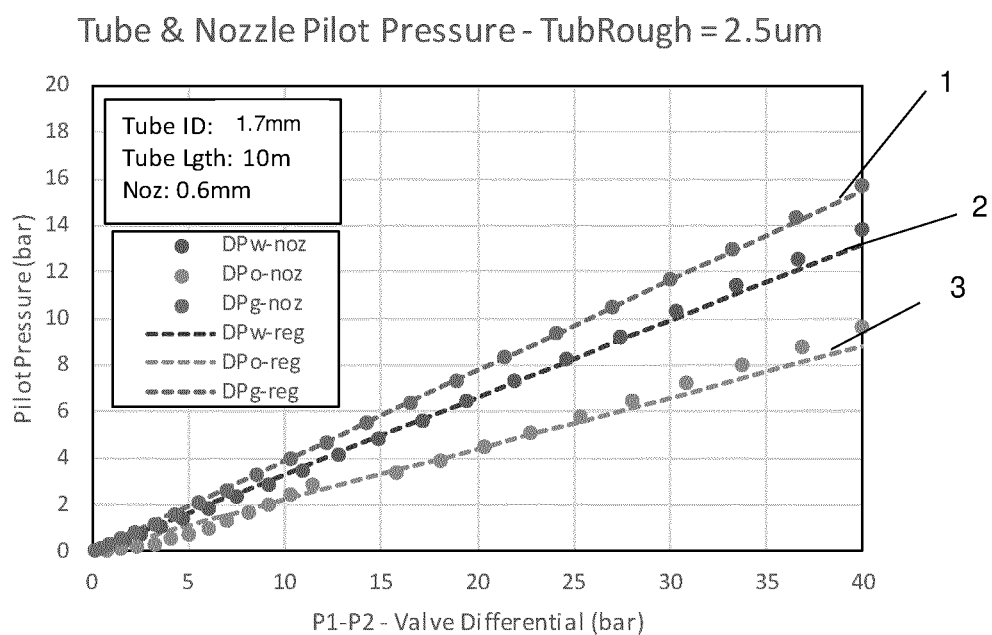


FIG.13

FLOW CONTROL DEVICE

FIELD

[0001] The present disclosure relates to a downhole flow control device and uses thereof, particularly downhole flow control devices for use in oil and gas operations.

BACKGROUND

[0002] Wellbore completions often include inflow control devices which assist with controlling the amount and/or type of wellbore fluid that is allowed to pass from a reservoir into a production flow path. A subterranean hydrocarbon reservoir typically produces both hydrocarbons (such as oil and natural gas) and water, with it being only the production of hydrocarbons that is desired. Further, it may also be the case that production of specifically only one kind of hydrocarbon, such as oil, is desired. In this instance, it may be desirable to implement a control system that optimises oil production from the reservoir, while limiting the production of water and natural gas. The concept of selectively producing fluids from a subterranean hydrocarbons reservoir is well known in the art, with the principles being utilised to optimise production of the desired fluid from the reservoir.

[0003] When selectively producing fluid from a reservoir, it is not always desirable to have a flow control device that switches instantaneously between a fully open to a fully closed position when an undesired fluid (or a desired fluid containing elements of an undesired fluid) begins to be produced, due to loss of sinkhole (or pressure drawdown) around the wellbore and possible loss or reduced production of desired wellbore fluid. Further, it is not desirable to have a device that switches from a fully closed position to a fully open position when the desired fluid begins to be produced, as rapid onset of an undesired fluid may occur.

SUMMARY

[0004] An aspect of the present disclosure relates to a downhole flow control device, comprising:

[0005] a body locatable within a wall of a tubular and defining a primary inlet and a primary outlet, wherein a primary flow path is defined between the primary inlet and primary outlet;

[0006] a valve member disposed within the body, the valve member being moveable in reverse first and second directions to selectively vary a flow area of the primary flow path; and,

[0007] a sealed pilot pressure chamber defining a pilot pressure inlet for receiving a pilot pressure, the valve member being in pressure communication with the sealed pilot pressure chamber such that pilot pressure may act to bias the valve member in one of the first and second directions, wherein the pilot pressure is provided as a function of a property of fluid flowing through the primary flow path.

[0008] Accordingly, flow rate through the flow control device may be varied based upon one or more properties of a fluid flowing along the primary flow path. Flow rate through the flow control device may be controlled via a pilot pressure system (further described below). The fluid supplied to the pilot pressure system may be the same as the fluid that is flowing through the primary flow path. Therefore, it may be said that the pilot pressure is provided as a function of fluid flowing through the primary flow path.

[0009] For example, when a fluid with a first fluid property (such as a first viscosity) is flowing along the primary flow path, the valve member may be positioned to allow a first flow rate through the flow control device. When a fluid with the second fluid property (such as a second viscosity, wherein the second viscosity differs from the first viscosity), begins to flow along the primary flow path, the position of the valve member may be altered to allow a second flow rate through the flow control device, wherein the second flow rate differs from the first flow rate. This effect may be advantageous in that an autonomous valve may be provided, wherein the flow rate through the valve may be autonomously varied reactive to changes in properties of the fluid flowing through the device; without the need for user input. This may allow for an increased flow rate through the device when a desired product is flowing from a reservoir and into the primary flow path (or vice versa), with flow being restricted when an undesired product flows from the reservoir and into the primary flow path (or vice versa). Therefore, a flow control device is provided that may vary the primary flow path based upon a property of the fluid, described below in further detail.

[0010] Further, by virtue of controlling movement of the valve member via a sealed pilot pressure chamber the device may therefore not need to be configured to manipulate the flow of fluid via the Bernoulli effect, as is known in the art with devices of this nature. That is, many known inflow control devices seek to operate based on the principle of lift applied on a valve disc as a result of the Bernoulli hydrodynamic principle, wherein such lift is varied in accordance with variations on fluid viscosity.

[0011] Further, a device that utilises the Bernoulli effect to vary the flow rate through a flow control device may require some form of restrictions to be provided in order to manipulate the fluid to provide a desired effect (e.g. a change in pressure of the fluid). It is an advantage of the present disclosure to autonomously control a flow control device using fluid pressure without the need for restrictions, and manipulation of fluid properties using the Bernoulli effect may not be required.

[0012] The valve member may be moveable between a fully open position, wherein there is minimal restriction to flow within the primary flow path, and a fully closed position wherein maximum restriction to flow is provided. In some examples some flow may still be permitted when the valve member is in its fully closed position. That is, although the term “closed” is used this should not be understood to also mean fully sealed, unless explicitly indicated otherwise. However, in other examples zero flow may be permitted when the valve member is in its fully closed position.

[0013] In use, the position of the valve member, and therefore the size of the flow area, may be determined by a pressure differential acting upon the valve member. For example, fluid flowing through the primary inlet of the device may be in pressure communication with the valve member. The pressure acting upon the valve member may act to bias the valve member in the first direction. Biasing the valve member in the first direction may act to increase the flow area of the device, for example, moving the valve member towards a fully open position. When the pressure at the primary inlet is greater than the pressure at the primary outlet, the valve member may be moved in the first direction (e.g. towards the fully open position). Therefore, it is estab-

lished that the movement of the valve member in the first direction may be actuated by a pressure differential acting across the valve member.

[0014] Moving the valve member in the first direction via flow through the primary inlet may oppose any biasing force provided by a pilot pressure acting in the sealed pilot pressure chamber. For example, pilot pressure within the pilot pressure chamber may act to bias the valve member in the second direction, for example, towards a fully closed position, wherein maximum flow restriction (e.g., minimum flow or zero flow) is established. Therefore, when the flow through the primary inlet provides a biasing force on the valve member that is greater than the biasing force provided on the valve member by the pilot pressure within the sealed pilot pressure chamber, the pressure differential acting across the valve member may be such that the valve member may be moved to increase the flow area of the primary flow path (e.g. the valve member may be moved by some increment in the first direction towards the fully open position). The rate at which the valve member may be moved towards the fully open position, and the increment by which it is moved, may be dependent on the magnitude of the pressure differential across the valve member.

[0015] Further, any fluid that may be in pressure communication with the valve member via the primary outlet of the primary flow path may act to bias the valve member in the second direction. As outlined above, biasing the valve member in the second direction may move the valve member towards a fully closed position, wherein maximum flow restriction (e.g., minimum flow or zero flow) is established. Therefore, when the pressure at the primary inlet provides a biasing force on the valve member that is greater than the biasing force provided by pressure at the inlet, the pressure differential across the valve member may be such that the valve member may be moved to decrease the flow area of the primary flow path (e.g. the valve member will be moved by some increment towards in second direction towards the fully closed position). As outlined above, the rate at which the valve member may be moved towards the fully closed position, and the increment by which it is moved, may be dependent on the magnitude of the pressure differential across the valve member.

[0016] Alternatively, when the biasing force acting on the valve member provided by the pilot pressure exceeds the force acting upon the valve member provided by flow through the primary inlet of the device, the valve member may be moved in the second reverse direction to decrease the flow area of the primary flow path (e.g. towards the fully closed position).

[0017] Alternatively, fluid pressure at the outlet of the primary flow path may be combined with the biasing force provided by the pressure within the sealed pilot pressure chamber to create a pressure differential across the valve member to move the valve member incrementally towards the fully closed position.

[0018] Therefore, an autonomous valve may be provided wherein the flow area of the primary flow path, and therefore the flow rate through the device, is controlled by a pressure differential across the valve member created by one or more properties of the fluid flowing along the primary flow path, e.g. a fluid flowing from a reservoir.

[0019] In use, the sealed pilot pressure chamber may be pressurised by a pilot pressure system, wherein the pilot pressure system supplies fluid to the sealed pilot pressure

chamber. The fluid supplied by the pilot pressure system may be wellbore fluid. The fluid supplied by the pilot pressure system may be the same fluid which is controllably flowed through the primary flow path. The pilot pressure system may be configured to control the pressure within the sealed pilot chamber based upon a property of the fluid within the pilot pressure system. The pressure within the sealed pilot chamber may be determined by the viscosity and/or the density of the fluid in the pilot pressure system. The pressure within the sealed pilot pressure chamber may be determined by a characteristic of the pilot pressure system. The pressure within the sealed pilot pressure system may be determined by a combination of one or more properties of the fluid within the pilot pressure system and one or more characteristics of the pilot pressure system. That is, fluid dynamic interaction or interplay may be achieved between one or more properties of the fluid and one or more characteristics of the pilot pressure system. Such interaction or interplay may function to provide a desired fluid pressure to the sealed pilot pressure chamber.

[0020] The pilot pressure system may be formed integrally with the flow control device, with the flow control device and pilot pressure system forming a single unit or system. In other examples, the pilot pressure system may be provided as a separate unit or system that can be coupled to the flow control device.

[0021] The pilot pressure system may comprise a secondary flow path. The secondary flow path may comprise an inlet and an outlet. The inlet of the secondary flow path may be in communication with an inflow region (e.g., a wellbore annulus region). The primary inlet of the device may be in communication with the same inflow region. In this example the primary inlet of the device and the inlet of the secondary flow path may receive fluid from a common source and/or be exposed to a common pressure, for example fluid pressure from an annulus formed between a tubular and a subterranean reservoir. In this example, the outlet of the secondary flow path may be exposed to the interior flow path of a tubular within which the flow control device is disposed. Conversely, the inlet of the secondary flow path may be in pressure communication with the interior flow path of the tubular within which the flow control device is disposed. In this example, the outlet may be exposed to annulus formed between the tubular and a subterranean reservoir.

[0022] In use, flow along the primary and secondary flow paths may be in same direction (i.e., both into the tubular or out of the tubular). The outlet of the secondary flow path may be in fluid communication with the primary flow path of the flow control device. Flow leaving the secondary flow path may enter the primary flow path and exit the flow control device via the primary outlet. The outlet of the secondary flow path may be distinct from the primary flow path of the flow control device. In an example, fluid may exit the secondary flow path in a region near the outlet of the primary flow path.

[0023] The pressure at the inlet of the primary flow path and the secondary flow path may be the same. The fluid supplied to the primary and secondary flow paths may be provided from the same source. The fluid source may be an annulus formed between a subterranean reservoir and a downhole tubular. The fluid source may be the interior flow path within the tubular within which the flow control device is disposed.

[0024] The secondary flow path may be formed partially through the body of the flow control device. The secondary flow path may be formed partially through the wall of a tubular within which one or more flow control devices are disposed. The secondary flow path may be formed partially through the body of a flow control device and through the wall of the tubular within which one or more flow control devices are disposed.

[0025] Fluid flow along the secondary flow path may provide a dynamic pressure within the secondary flow path. The dynamic pressure may vary along the length of the secondary flow path (e.g. between the inlet and the outlet). The dynamic pressure may stay constant along the length of the secondary flow path (e.g. between the inlet and the outlet).

[0026] The sealed pilot pressure chamber may be in pressure communication with the secondary flow path. The dynamic pressure created by flow along the secondary flow path may cause a change in the static pressure within the sealed pilot pressure chamber.

[0027] In use, deviations in the dynamic pressure along the secondary flow path may be used to provide a desired static pressure within the sealed pilot pressure chamber. For example, if a specific pilot pressure (e.g. static pressure) may be required within the sealed pilot pressure chamber, pressure communication between the secondary flow path and the sealed pilot pressure chamber may be established at the point along the secondary flow path at which said specific pressure required is provided.

[0028] In one example, fluid from the secondary flow path may be communicated to the sealed pilot pressure chamber, providing a pilot pressure (e.g., a static pressure). Alternatively, the fluid supplied to the sealed pilot pressure chamber may be isolated from the fluid in the secondary flow path, so that only the pressure from the secondary flow path is communicated to the pilot pressure chamber. For example, the fluid within the secondary flow path may be in pressure communication with a piston or other equivalent pressure transfer arrangement, such as a bellows, diaphragm etc. Said piston may also be in pressure communication with fluid contained between the piston and the sealed pilot pressure chamber. When pressure from the secondary flow path is communicated to the piston, said piston acts to impart pressure on the fluid contained between piston and the sealed pilot pressure chamber, thereby raising the pressure in the sealed pilot pressure chamber.

[0029] In one example, a pressure drop may be established along the length of the secondary flow path (e.g. wherein the pressure at the inlet of the secondary flow path is greater than the pressure at the outlet of the secondary flow path). This pressure drop may be established by one or more factors within the understanding of the skilled person. For example, the pressure drop may be caused by the internal diameter of the secondary flow path. The pressure drop may be caused by the internal surface roughness of the secondary flow path. The pressure drop may be caused by the relative roughness of the secondary flow path, the relative roughness being the relationship between the internal diameter of the secondary flow path and the surface roughness of the internal surface of the secondary flow path. These factors, either alone or in combination, may cause different pressure drop effects within fluids with different fluid properties flowing along the secondary flow path. For example, a fluid with a first viscosity may experience a larger pressure drop

along the secondary flow path than a fluid with a second, lesser viscosity. In another example, a fluid with a first density may experience a larger pressure drop along the secondary flow path than a fluid with a second, greater density. The pressure drop along the secondary flow path may be dependent on both the viscosity and density of a fluid. The pressure drop along the secondary flow path may be determined by the velocity of the fluid along the secondary flow path. The density of a fluid, the viscosity of a fluid, the inner diameter of the secondary flow path and the velocity of the fluid may all influence the Reynold's number of a fluid. Therefore, changes in any of these factors may result in a change of Reynold's number of the fluid.

[0030] Changes in the Reynold's number of a fluid may influence changes in the friction factor within the secondary flow path, in accordance with the known Moody Diagram (wherein the Moody Diagram shows the relationship between the relative roughness of the internal surface of a flow path and the Reynold's number of the fluid flowing within said flow path, with the Moody Diagram providing an overall coefficient of friction within said flow path based on these factors). When considering the friction factor of the secondary flow path, the ratio between the surface roughness of the secondary flow path and the inner diameter of the secondary flow path, wherein this ratio is named the relative pipe roughness, may also be considered.

[0031] Therefore, a suitable point along the length of the secondary flow path may be selected at which to establish pressure communication between the secondary flow path and the sealed pilot pressure chamber, based upon the pressure drop along the length of the secondary flow path and the static pressure required within the sealed pilot pressure chamber.

[0032] The point along the secondary flow path that provides the required pressure (e.g., static pressure) within the sealed pilot pressure chamber may be established using the Darcy-Weisbach equation for pressure loss in a pipe/tubular;

$$\Delta p = \frac{fL\rho V}{2D}$$

[0033] Wherein Δp is the pressure loss along the length of the secondary flow path, f is the friction factor, L is the length of the length of the secondary flow path, V is the velocity of the fluid within the secondary flow path and D is the internal diameter of the secondary flow path. The point along the secondary flow path at which pressure communication may be established between the secondary flow path and the sealed pilot pressure chamber (L_1) may be selected by rearranging the Darcy-Weisbach equation (wherein the required static pressure within the sealed static pressure chamber and the inlet pressure of the secondary flow path, wherein the inlet pressure of the primary and secondary flow paths are equal, are known-providing the required pressure differential, Δp);

$$L_1 = \frac{\Delta p 2D}{f\rho V}$$

[0034] In another example, the secondary flow path may be provided with a restriction disposed therein. The restriction may be disposed upstream of the point at which the

pressure communication is established between the secondary flow path and the sealed pilot pressure chamber. The restriction may provide a drop in pressure of the fluid flowing along the secondary flow path. The restriction may be configured to provide a desired pressure (e.g., static pressure) within the sealed pilot pressure chamber.

[0035] One or more restrictions may be present within the secondary flow path. The one or more restrictions may be of any suitable form within the understanding of the skilled person, for example, a nozzle.

[0036] One or more restrictions may be used in combination with one or more features of the secondary flow path to provide a desired pressure drop within the secondary flow path. For example, one or more restrictions may be used in combination one or more of; the surface roughness of the internal surface of the secondary flow path, the internal diameter of the secondary flow path, and the length of the secondary flow path, to provide a desired pressure drop within the secondary flow path.

[0037] The secondary may be in the formed of a tubular member, such as hydraulic tubing. The secondary flow path may define a straight path between its inlet and its outlet. The secondary flow path may have one or more deviations between its inlet and its outlet. The secondary flow path may define a coiled or helical (“pig-tail” like) path between its inlet and its outlet. The secondary flow path may be of any suitable form within the knowledge of the skilled person that allows the device to function as intended. Providing the secondary flow path with deviations or in “pig-tail” like form may act to increase the overall length of the secondary flow path without increasing the “point-to-point” length between the inlet and the outlet of the secondary flow path. as outlined above, an increase in length of the secondary flow path may be used to influence a pressure drop within the fluid flowing within the secondary flow path.

[0038] As outlined above, using a system that does not utilise the Bernoulli effect to provide a required pressure drop may be advantageous for many reasons. Firstly, no variations (e.g. restrictions, choke points, expansions, etc.) may be required within any primary flow paths to manipulate the fluid flow to achieve the desired effect (i.e., while restrictions may help achieve a desired effect, as outlined above, they are not essential).

[0039] The pilot pressure system may be provided as a system that is separate from the flow control device. The outlet of the pilot control line may be configured to be connected to inlet of the sealed pilot pressure chamber, allowing for pressure communication between the pilot pressure system and sealed pilot pressure chamber. The outlet of the secondary flow path of the pilot pressure system may be configured to be connected to the body of the valve member, creating a flow path through the body of the flow control device. The outlet of the secondary flow path may be configured to be connected to the tubular within which the flow control device is disposed, creating a flow path through the wall of the tubular.

[0040] The flow control device and flow control device may be provided as a single unit.

[0041] The pilot pressure system may comprise a pilot control line. The inlet of the pilot control line may be in pressure communication with the secondary flow path. The outlet of the pilot control line may be in pressure communication with the sealed pilot pressure chamber.

[0042] The pilot control line may tap into the secondary flow path at a specific point along the secondary flow path, the point at which the tap is provided being selected in the manner as outlined above. Alternatively, a restriction may be placed upstream of the point at which the pilot control line taps into the secondary flow path to provide the desired pressure drop prior to the fluid reaching the pilot control line. A restriction may be used in combination with selection of a specific “tap” point along the secondary flow path to provide the desired pressure drop prior within the fluid prior to it reaching the pilot pressure line.

[0043] The source of the fluid flowing along the primary flow path may be the same as the source of the fluid flowing along the secondary flow path.

[0044] A sealing arrangement may be disposed between the valve member and the body of the flow control device. The sealing arrangement may isolate the sealed pilot pressure chamber from the primary flow path of the flow control device. The sealing arrangement may be any suitable sealing arrangement within the knowledge of the skilled person. For example, the sealing arrangement may be or comprise a diaphragm seal, bellows, metal-to-metal seal, an o-ring and/or the like.

[0045] The sealing arrangement may provide a biasing force, biasing the valve member in one of the first or second directions.

[0046] In use, the flow control device may be used to facilitate inflow between exterior and interior regions of a tubular (e.g., production tubular), thereby acting as an inflow control device. This may be used, for example, when producing fluid from a hydrocarbon reservoir. A tubular may be provided with a plurality of flow control devices axially disposed along the length of the tubular. Each of the plurality of flow control devices disposed along the length of the tubular may act as an inflow control device. A tubular may be provided with a plurality of flow control devices circumferentially disposed around the tubular. Each of the plurality of flow control device may act as an inflow control device. A tubular may have a plurality of inflow control devices, disposed both circumferentially around the tubular and axially along the tubular.

[0047] In use, the flow control device may be used to facilitate outflow between interior and exterior regions of a tubular, thereby acting as an outflow control device. For example, a tubular may be disposed within a wellbore, with the tubular being used to inject fluid into the wellbore via one or more flow control devices. A tubular may be provided with a plurality of flow control devices axially disposed along the length of the tubular. Each of the plurality of flow control devices disposed along the length of the tubular may act as an outflow control device. A tubular may be provided with a plurality of flow control devices disposed circumferentially around the tubular. Each of the plurality of flow control devices may act as an outflow control device. A tubular may have a plurality of outflow control devices, disposed both circumferentially around the tubular and axially along the length of the tubular.

[0048] In another example, a tubular may comprise a plurality of flow control devices disposed axially along its length and/or around the circumference, wherein a selection of both inflow and outflow control devices are used.

[0049] In another example, a tubular may comprise a plurality of flow control devices disposed axially along its length and/or around its circumference, wherein the flow

area of one or more flow control device is configured to vary differently from the other flow control devices. For example, the flow area of one or more of the flow control devices may increase by a greater magnitude than the other flow control devices in response to fluid from the same source. Conversely, the flow area of one or more devices may increase by a lesser magnitude than the other flow control devices in response to the same fluid from the same source.

[0050] The body of the flow control device may be of any suitable construction within the understanding of the skilled person that ensures the device still functions as intended. The body may be generally cylindrical.

[0051] The body of the flow control device may be connected to the tubular by any suitable means. For example, the body of the flow control device may define a threaded portion. The threaded portion of the body may be configured to mate with a threaded portion defined in the wall of a tubular.

[0052] The body may be sealingly engaged with the tubular.

[0053] The valve member may be of any suitable construction within the understanding of the skilled person that allows the device to function as intended. The shape of the valve member may be configured to be complementary with the internal configuration of the flow control device. The valve member may be generally disc shaped. In some examples the body, or an appropriate component disposed with or within the body may define a valve seat. The valve member may be configured to cooperate with the valve seat to permit variability of the flow area through the primary flow path. In some examples the valve member and valve seat may be intimately engagable.

[0054] An aspect of the present disclosure relates to a downhole flow control system, comprising;

[0055] a downhole flow control device, the downhole flow control device comprising:

[0056] a body locatable within a wall of a tubular and defining a primary inlet and a primary outlet, wherein a primary flow path is defined between the primary inlet and primary outlet;

[0057] a valve member disposed within the body, the valve member being moveable in reverse first and second directions to selectively vary a flow area of the primary flow path;

[0058] a sealed pilot pressure chamber defining a pilot pressure inlet for receiving a pilot pressure, the valve member being in pressure communication with the sealed pilot pressure chamber such that pilot pressure may act to bias the valve member in one of the first and second directions; and,

[0059] a pilot pressure system in pressure communication with the sealed pilot pressure chamber and configured to provide a pilot pressure as a function of a property of fluid flowing through the pilot pressure system.

[0060] The pilot pressure system may be configured to provide a secondary flow path. The pilot pressure system may accommodate a separate flow of the same fluid flowing through the primary flow path.

[0061] The secondary flow path may be partially formed through the body of a flow control device. The secondary flow path may be partially formed through the wall of a

tubular. The secondary flow path may be partially formed through both the body of a flow control device and the wall of a tubular.

[0062] The flow control device and pilot pressure system may be provided as a single unit for installation to a tubular. The flow control device and pilot pressure system may be provided as separate units, wherein the flow control device is connected to a tubular, and the pilot pressure system is then arranged to be in pressure communication with the flow control device.

[0063] An aspect of the present disclosure relates to a flow control system, comprising;

[0064] a tubular member; and,

[0065] one or more flow control devices axially disposed along the length of the tubular; wherein at least one flow control device comprises:

[0066] a body located within a wall of the tubular and defining a primary inlet and a primary outlet, wherein a primary flow path is defined between the primary inlet and primary outlet;

[0067] a valve member disposed within the body, the valve member being moveable in reverse first and second directions to selectively vary a flow area of the primary flow path; and

[0068] a sealed pilot pressure chamber defining a pilot pressure inlet for receiving a pilot pressure, the valve member being in pressure communication with the sealed pilot pressure chamber such that pilot pressure may act to bias the valve member in one of the first and second directions, wherein the pilot pressure is provided as a function of a property of fluid flowing through the primary flow path.

[0069] One or more of the flow control devices of the flow control system may be configured to function as an inflow control device. One or more of the flow control devices may be configured to act as an outflow control device. The flow control system may comprise both inflow and outflow control devices.

[0070] An aspect of the present disclosure relates to a pilot pressure system, comprising;

[0071] a flow path comprising a first inlet and a first outlet, wherein the flow path is configured to create a specific pressure drop between the first inlet and first outlet based upon one or more characteristics of a fluid flowing within the flow path; and,

[0072] a pilot pressure line, the pilot pressure line comprising a second inlet and a second outlet, wherein the second inlet is configured to allow the pilot control line to be in pressure communication with the secondary flow path, and the second outlet of the pilot control line is configured to be connected to a sealed pilot pressure chamber of a downhole flow control device.

[0073] The characteristics of the flowing fluid that may provide the pressure drop in the flow path of the pilot pressure system may be the viscosity and/or density of the fluid.

[0074] The pilot pressure system may in pressure communication with a plurality of flow control devices. The pilot pressure system may be in pressure communication with a single flow control device.

[0075] An aspect of the present disclosure relates to a downhole flow method, comprising:

[0076] flowing a fluid through a primary flow path of a flow control device disposed within the wall of a

tubular, wherein the flow control device comprises a valve member disposed within the primary flow path;

[0077] flowing a fluid through a secondary flow path, wherein the secondary flow path is configured to provide a pressure variation of the fluid flowing through the secondary flow path based upon a variation of at least one characteristic of said flowing fluid; and

[0078] communicating a pressure from the secondary flow path to a sealed pilot pressure chamber, said pressure providing a biasing force on the valve member to vary the flow area of the primary flow path.

[0079] The characteristic of the flowing fluid that may provide a pressure variation within the secondary flow path may be the viscosity of the fluid or the density of the fluid. The pressure variation in the secondary flow path may be based upon both the viscosity and the density of the fluid.

[0080] Features defined in relation to one aspect may be provided in combination with any other aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0081] These and other aspects of the present disclosure will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0082] FIG. 1 is a diagrammatic cross sectional view of a flow control device, with a valve member of the device in a fully open position;

[0083] FIG. 2 is the same cross sectional view of the flow control device of as FIG. 1, with the valve member in a fully closed position;

[0084] FIGS. 3A-C diagrammatically illustrate the forces acting upon the valve member of the device of FIG. 1 to move the valve member towards an open position, to maintain the valve member in an intermediate position and to move the valve member towards a closed position, respectively;

[0085] FIG. 4 is an isometric view of an example of a flow control device, wherein a section of the device has been cut away;

[0086] FIG. 5 is a further example of a flow control device of the present disclosure;

[0087] FIG. 6 is a further example of a flow control device of the present disclosure;

[0088] FIG. 7 is a further example of a flow control device of the present disclosure;

[0089] FIG. 8 is a further example of a flow control device of the present disclosure;

[0090] FIG. 9 is a cross sectional view of an example of a flow control device of the present disclosure;

[0091] FIG. 10 demonstrates computer simulated results verifying the principles of the present disclosure;

[0092] FIG. 11 demonstrates further computer simulated results verifying the principles of the present disclosure;

[0093] FIG. 12 demonstrates further computer simulated results verifying the principles of the present disclosure; and

[0094] FIG. 13 demonstrates further computer simulated results verifying the principles of the present disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

[0095] FIG. 1 is a diagrammatic cross section of a side elevation view of a downhole flow control device generally identified by reference numeral 10. As will be described in further detail below, the device 10 may be secured within the wall of a downhole tubular, such as a production tubular or

an injection tubular, for use in providing a degree of flow control during inflow and/or outflow relative to the tubular. In the present examples, the device 10 is autonomously controlled based upon one or more properties of the fluid flowing through the device 10, such as viscosity and/or density.

[0096] The flow control device 10 comprises a body 20, the body being locatable within the wall of a tubular, in this example secured via a threaded connection (80). The flow control device 10 also comprises a primary inlet 12 and a primary outlet 14 (a circumferential array of outlets 14 in this example), and a primary flow path 34 extending through the body 20 between the primary inlet and outlet 12, 14.

[0097] A valve member 30 is disposed within the body 20 of the device 10, specifically within the primary flow path 34. The valve member 30 is movable between a fully open position, wherein there is minimal restriction to flow within the primary flow path 34, and a fully closed position wherein maximum restriction to flow is provided. In some examples some flow may still be permitted when the valve member 30 is in its fully closed position. This arrangement might be achieved via features such as one or more stand-off ribs (not shown) preventing the valve member 30 from fully contacting the body 20. However, in other examples zero flow may be permitted when the valve member 30 is in its fully closed position. FIG. 1 demonstrates the valve member 30 in the fully open position, while FIG. 2 demonstrates the valve member 30 in the fully closed position. When the valve member 30 is moved towards the open position, the flow area of the primary flow path 34 is increased. When the valve member 30 is moved towards the closed position, the flow area of the primary flow path 34 is decreased.

[0098] In this example, the valve member 30 comprises a sealing arrangement 50 disposed between the valve member 30 and the body 20 of the flow control device 10. The sealing arrangement isolates a sealed pilot pressure chamber 32 from the primary flow path 34. In this example, the sealing arrangement 50 is a diaphragm seal. In other examples, the sealing arrangement may comprise a bellows, one or more o-rings, and/or any other suitable sealing mechanism. In some examples, the sealing arrangement 50 may assist to bias the valve member 30 in either the first or second directions (e.g., the sealing arrangement 50 may be resiliently or elastically deformable). In examples where such biasing is necessary this could alternatively or additionally be achieved by a separate biasing mechanism, such as a spring or the like.

[0099] The sealed pilot pressure chamber 32 is defined between the valve member 30 and a base 40 of the body 20 of the flow control device 10. This sealed pilot pressure chamber 32 is supplied with fluid via a pilot pressure chamber inlet 18.

[0100] Fluid pressure applied within the sealed pilot pressure chamber 32 acts on the valve member 30, thus biasing the valve member 30 towards the closed position. As will be described below in further detail, the pressure differential created across the valve member by the opening force at the inlet 12, and the lift force within the sealed pilot pressure chamber 32 determines the flow area within the body 20 of the flow control device 10. In some examples the pressure at the outlet 14 may also provide some effect on the valve member 30.

[0101] The flow control device of FIGS. 1 and 2 also comprises a bore 16 defined through the body 20 of the

device 10. The function of this bore 16 will be described below in further detail. The bore 16 of this example comprises a restriction 60, the purpose of which will also be described below in further detail, although this restriction is optional.

[0102] FIGS. 1 and 2 also illustrate a pilot pressure system 70. In this example, the pilot pressure system 70 is provided integrally with the flow control device 10, with the flow control device 10 and the pilot pressure system 70 forming a single unit. In other examples, the pilot pressure system 70 may be provided as a separate unit that can be retrofitted or otherwise separately secured with the flow control device 10.

[0103] An inlet 78 of the pilot pressure system 70 and the primary inlet 12 of the flow control device 10 are supplied with fluid from the same source (e.g. a wellbore annulus). Therefore, the same fluid flows within the pilot pressure system 70 as flows through the primary flow path of the flow control device 10.

[0104] The pilot pressure system 70 comprises a secondary flow path 72, which, in the example shown in FIGS. 1 and 2, is defined by a fluid conduit. The secondary flow path 72 of the pilot pressure system 70 is connected to the bore 16 defined through the flow control device 10, which is in fluid communication with the outlet 14 of the primary flow path. In another example, the secondary flow path 72 defined by the pilot pressure system 70 may not provide flow through the body 20 of the flow control device 10, and may simply pass through the wall of the tubular within which the flow control device 10 is disposed.

[0105] In the example shown within FIGS. 1 and 2, a restriction 60 is provided within the bore 16 through the body 20 of the flow control device 10. In other examples there may be multiple restrictions 60 along the secondary flow path. In some examples there may be multiple restrictions disposed within the secondary flow path 72. In other examples there may be no restrictions provided within the secondary flow path 72. The restrictions within the secondary flow path 16, 72 may be provided to influence the pressure or velocity of the fluid flowing therein. The one or more restrictions 60 may be in the form of a nozzle.

[0106] The secondary flow path 72 is configured to influence characteristics of the fluid flowing therein. For example, the internal surface roughness of the secondary flow path 72 may be configured to interact with the viscosity of the fluid flowing therein, providing a pressure drop within the fluid flowing along the secondary flow path 72. Alternatively, the internal diameter of the secondary flow path 72 may be selected to influence the relative roughness of the secondary flow path 72. The relative roughness may be selected to interact with the viscosity of a fluid, also providing a pressure drop in the fluid flowing along the length of the secondary flow path 72. The internal diameter and the surface roughness may be used in combination to provide a desired pressure drop within a fluid flowing along the secondary flow path 72.

[0107] Another factor that may be selected or controlled to affect the pressure drop within the fluid flowing along the secondary flow path 72 is the length of the secondary flow path 72. Therefore, the length of the secondary flow path 72 may be configured to provide a desired pressure drop within the fluid flowing therein. For example, the pressure drop between the inlet and outlet of a secondary flow path 72 that is 10 m long will be greater than the pressure drop of a

secondary flow path that is 3 m long (assuming all other features of the secondary flow path 72 are the same in both instances).

[0108] The pilot pressure system 70 also comprises a pilot pressure line 74, the pilot pressure line extending from the secondary flow path and being in communication with the sealed pilot pressure chamber 32 of the flow control device 10. In this example, fluid is provided from the secondary flow path 72 to the sealed pilot pressure chamber 32 via the pilot pressure line 74, as the pilot pressure line 74 taps into the secondary flow path 72. Therefore, the pressure at the point at which the pilot pressure line 74 taps into the secondary flow path is communicated to the sealed pilot pressure chamber 32, providing what may be considered to be a static pressure within the sealed pilot pressure chamber.

[0109] In another example, the fluid supplied to the sealed pilot pressure chamber 32 may be isolated from the fluid in the secondary flow path 72, so that only the pressure from the secondary flow path 72 is communicated to the pilot pressure chamber 32. For example, the fluid within the secondary flow path 72 may be in pressure communication with a piston (not shown) or other equivalent pressure transfer device or system. Said piston may also be in pressure communication with fluid contained between the piston and the sealed pilot pressure chamber 32. When pressure from the secondary flow path 70 is communicated to the piston, said piston acts to impart pressure on the fluid contained between piston and the sealed pilot pressure chamber 32, thereby raising the pressure in the sealed pilot pressure chamber 32.

[0110] As outlined above, the secondary flow path 72 can be configured to provide a pressure drop with the fluid flowing therein along its length. Therefore, the static pressure within the sealed pilot pressure chamber can be determined by the point along the length of the secondary flow path 72 at which the pilot pressure line 74 taps into the secondary flow path 72. Therefore, if a greater pressure drop is required prior to fluid entering the sealed pilot pressure chamber 32, the pilot pressure line 74 may be fluidly connected to the secondary flow path 72 further away from the inlet 78 of the secondary flow path 72. This effect, potentially in combination with other factors concerning the configuration of the secondary flow path 72 (e.g. internal surface roughness, diameter, etc.) allows the lift force acting on the valve member 30 caused by the static pressure within the sealed pilot pressure chamber 32 to be provided and controlled by the same fluid that is flowing along the primary flow path of the flow control device 10.

[0111] In view of the above factors, it is understood that the higher the viscosity of a fluid flowing within the pilot pressure system 70, the lower the static pressure that will be provided within the sealed pilot pressure chamber 32. As a higher viscosity will cause greater friction forces within the secondary flow path 72, the greater the pressure losses along the length of the secondary flow path 72. For example, the viscosity of three typical reservoir fluids; water, oil and gas, are 0.42 cp, 3.07 cp and 0.02 cp respectively. Therefore, it is understood that the pressure losses within oil flowing along the secondary flow path 72 of a system will be greater than the pressure losses of water and gas flowing along the secondary flow path 72 of the same system. This means that when water and gas are flowing within the pilot pressure system 70, a greater static pressure is generated in the sealed pilot pressure chamber 32 than if oil is flowing within the

pilot pressure system 70. Therefore, water and gas are able to generate larger lift forces on the valve member 30 of the device 10 than if oil is flowing within the pilot pressure system 70. Therefore, when water and gas are flowing within the pilot pressure system 70, the biasing force acting on the valve member 30 towards the fully closed position is greater than when oil is flowing within the pilot pressure system 70. Therefore, within this system, the valve member 30 may be moved towards the closed position by a pressure (e.g., static pressure) within the sealed pilot pressure chamber 32, wherein the pressure is derived from fluid dynamic conditions or characteristics within the secondary flow path 72. Therefore, the system may not be dependent upon the Bernoulli effect to provide a lift force to move the valve member 30 towards the closed position, as the lift force is provided as a function of the fluid flowing along the secondary flow path 72.

[0112] In fact, in some examples it may be desirable to ensure the flow control device is configured such that any lift on the valve member by the Bernoulli effect does not exist across a range of fluid types or characteristics. This may be achieved by appropriate physical considerations, such as the flow area of the primary inlet 12, the diameter of the valve member 50, control of frictional losses and/or the like. Avoiding any influence via the Bernoulli effect across different fluid types or characteristics may permit control of the valve member to be primarily achieved via the pressure delivered from the pilot pressure system 70. This may permit a higher degree of incremental control of the flow control device 10.

[0113] The pressure drop along the length of the secondary flow path 72 may also be influenced by the density of the fluid flowing therein. For example, changes in density of a fluid may also bring about a change in the Reynold's number of said fluid. A change in the Reynold's number of a fluid will then bring about a change coefficient of friction within the secondary flow path 72. Therefore, if the coefficient of friction changes, the pressure losses within the secondary flow path 72 will also change, in accordance with the Darcy-Weisbach equation.

[0114] Therefore, different fluid densities may also be used to influence the pressure that is provided within the sealed pilot pressure chamber 32. For example, when gas, with a typical density of 109 kg/m^3 , is flowing along the secondary flow path 72, the pressure losses will typically be less than the pressure losses within oil, with a typical density of 832 kg/m^3 . Therefore, it can be said that when either of these fluids are flowing through the same system, the static pressure generated within the sealed pilot pressure chamber 32 will be greater when gas is flowing within the pilot pressure system 70 than when oil is flowing within the pilot pressure system 70. As outlined above, the greater the static pressure within the sealed pilot pressure system 32, the greater the lift force provided on the valve member 30, the lift force moving the valve member 30 towards the fully closed position.

[0115] FIGS. 3A to 3C demonstrate how the valve member 30 of the flow control device 10 can be moved incrementally between the fully open position and fully closed position based on the forces acting on the valve member 30.

[0116] FIG. 3A shows the valve member 30 in the fully open position. Wellbore fluid is flowing through the inlet 12 of the device and impinging on the valve member 30, with the inlet pressure P1 of the fluid providing a force on the

valve member to bias it towards the fully open position. The pilot pressure P2 within the sealed pilot pressure chamber is of a sufficiently low magnitude that the force applied by inlet pressure P1 dominates and the valve member 30 is located and held in the fully closed position. In this example, while pressures P1 and P2 are provided by the same fluid source, P1 is much greater than P2. Therefore, the valve member 30 is moved towards the fully open position. In this example, a biasing mechanism may also be present, biasing the valve member 30 either towards a fully open or fully closed position. In this example, the fluid flowing through the flow control device 10 and within the pilot pressure system 70 may be oil, wherein P2 is much smaller than P1 due to the pressure losses within the pilot pressure system 70 caused by a property of the oil (as described above).

[0117] FIG. 3B shows an example wherein P2 (i.e., pilot pressure) has increased in view of a change of one or more fluid properties, and the valve member 30 has been moved to an intermediate position, wherein the flow through the flow control device 10 is partially choked, and the flow area of the device 10 has been decreased. While the pressure P1 at the inlet 12 has stayed the same, the pressure P2 within the sealed pilot pressure 32 has increased, thereby generating a larger closing force on the valve member 30 of the device 30. This increase in pilot pressure P2 may be by virtue of change in fluid property of the fluid flowing along the primary flow path of the flow control device 10 and within the pilot control system 70. For example, if the fluid flowing along the primary flow path and within the pilot control system is now water (or oil with a greater water content), the changes in fluid properties may have brought about less significant pressure losses within the pilot pressure system 70. This, in turn, means that a greater pilot pressure is generated within the sealed pilot pressure chamber 32, changing the pressure differential across the valve member 30 of the flow control device.

[0118] FIG. 3C illustrates a scenario in which the flow control device 10 has been significantly choked. The pilot pressure P2 generated within the sealed pilot pressure chamber 32 is now of such a magnitude that the valve member 30 has been moved even closer to the fully closed position. In this example, the fluid flowing along the primary flow path of the flow control device 10, and within the pilot pressure system 70, may be water (or oil with a high water content) or natural gas. These fluids may not generate significant pressure losses (with respect to oil) within the pilot pressure system 70, therefore P2 has increased to a magnitude wherein the flow control device is significantly choked.

[0119] As outlined above, in this example the flow control device may also comprise a biasing mechanism to assist with moving the valve member 30 incrementally between the fully open and fully closed position based on the properties of the fluid flowing through the flow control device 10 and within the pilot pressure system 70.

[0120] FIG. 4 is an isometric view of an example of a flow control device of similar construction to that shown in FIGS. 1 and 2, wherein a section of the valve has been cut away. All of the like features shown in FIGS. 1 and 2 are shown with like reference numerals. In this example, the valve member 30 has been provided in two parts, with a biasing mechanism 50 provided between the two parts of the valve member 30. In this example, the sealing mechanism 50

disposed between the valve member **30** and the body **20** of the flow control device **10** has been provided as a diaphragm seal.

[0121] FIGS. **5** to **8** show alternative examples of the flow control device as described above.

[0122] FIG. **5** shows an example of a flow control device of similar construction to that described within the FIGS. **1** and **2**. All like features are denoted by the same reference numerals, increased by an increment of **100**.

[0123] Within FIG. **5**, the sealing mechanism provided is a bellows mechanism **150**, isolating the sealed pilot pressure chamber **132** from the primary flow path **134**. In this example, a bore **116** is also defined through the body **120** of the device **110**.

[0124] The example shown FIG. **6** is similar to that of FIG. **5**, with all like features denoted by the same reference numerals, increased by an increment of **100**. This example also uses a bellows mechanism **250** to provide sealing between the sealed pilot pressure chamber **232** and the primary flow path **234**. A first o-ring **280** provides sealing between the sealed pilot pressure chamber **232** and the primary flow path **234**. A second o-ring **282** is provided at the interface between the flow control device body **220** and the tubular wall within which the device is disposed **210**.

[0125] FIG. **7** is a further example of the present disclosure, of largely similar construction to the device shown in FIGS. **1** and **2** and as such all like features are denoted by like reference numerals, incremented by **300**. Within the example shown in FIG. **7**, a diaphragm **350** is used as the sealing mechanism **350**, isolating the sealed pilot pressure chamber **332** from primary flow path **334**.

[0126] FIG. **8** is a further example of the present disclosure, of largely similar construction to the device shown in FIGS. **1** and **2** and as such all like features are denoted by the same reference numerals, incremented by **400**. Within this example, the valve member is a simple piston **430**, with an o-ring **480** provided between the valve member **430** and the body **420** of the flow control device, wherein the o-ring isolates the sealed pilot pressure chamber **432** from the primary flow path **434**.

[0127] FIG. **9** shows a further example of the flow control device of FIGS. **1** to **4**, with an alternative form of pilot pressure system **1070**. All like features are provided with like reference numerals, increased by an increment of **1000**. In this example, the secondary flow path **1072** is provided in a helical arrangement, which permits the length of the secondary flow path **1072** to be maximised in areas where space may be limited. One skilled in the art will appreciate that the secondary flow path **1072** may be configured in any arrangement that achieves this effect while still allowing the device to function as intended. In a specific example, a flow control device with the following parameters was used;

Feature	Value
ID of secondary flow path	1.7 mm
ID of pilot control line	1.7 mm
Internal surface finish of secondary flow path	0.25 μm
Relative surface roughness of secondary flow path	8.1×10^{-5}
Wall thickness of secondary flow path	0.7 mm
Length of secondary flow path	10 m

-continued

Feature	Value
*ID of restriction within secondary flow path	0.6 mm

*Note that while a restriction is not required within the secondary flow path for proper functioning, one has been used in this example.

[0128] The reservoir conditions used in this example are;

Feature	Value
Downhole pressure	130 bar
ρ_{water}	1000 kg/m ³
μ_{water}	0.43 cp
ρ_{gas}	90 kg/m ³
μ_{gas}	0.02 cp
ρ_{oil}	895 kg/m ³
μ_{oil}	3 cp

[0129] Using the above data, a computer simulation was performed to verify the principles of the present disclosure, as outlined above, using software based on pressure drop calculations for both gases and liquids. The calculations use a combination of acceleration (inflow), retardation (outflow) and friction pressure drop (within a pipe) elements known within the industry. The results of this simulation are provided in the graphs of FIGS. **10** to **13**.

[0130] The graph of FIG. **10** demonstrates how the static pressure in the sealed pilot pressure chamber varies as the pressure differential between the primary inlet (P1) and the primary outlet (P2) of the flow control device varies. As outlined above, P2 is varied by a pressure drop within the secondary flow path. Therefore, the pressure differential may also be the difference in pressure between the inlet of the secondary flow path and the outlet of the secondary flow path.

[0131] As shown in FIG. **10**, the pilot pressure increases at a greater rate when gas (identified by line 1) and water (identified by line 2) are flowing within the system than if oil (identified by line 3) is flowing within the system; as the pressure differential across the valve member increases. Therefore, it is shown that while gas **1** and water **2** are flowing through the flow control device, a greater pressure will be delivered within the sealed pilot pressure chamber, biasing the valve member incrementally towards the fully closed position at a faster rate.

[0132] This is supported by the graph of FIG. **11**, which demonstrates the static pressure within the sealed pilot pressure chamber as a percentage of the pressure differential across the valve member. Again, it is oil **3** that is shown to have the smallest percentage of the pressure differential across the valve, meaning that the valve member will remain closer to the fully open position than if water **2** or gas **1** are flowing through the system.

[0133] The graph of FIG. **12** shows the changes in flow rate in the pilot control line as the differential pressure across the valve member changes; again for water **2**, gas **1** and oil **3**.

[0134] FIG. **12** indicates that oil **3** will always have the lowest flow rate along the pilot pressure line, especially as the pressure differential across the valve member changes. Therefore, when oil **3** is flowing through the system, a static pressure within the sealed pilot pressure chamber sufficient to move the valve member to the fully closed position cannot be provided-thus ensuring the valve member remains closer

to the fully open position when oil is flowing through the flow control device than if gas 1 or water 2 are flowing.

[0135] These results demonstrate the proper functioning of the flow control device as described above.

[0136] In another example, wherein all conditions are kept constant, and the surface roughness of the secondary flow path is changed to 2.5 μm , the results illustrated by the graph of FIG. 13 are provided;

[0137] As shown within FIG. 13, the results are again consistent with what is expected from this device, wherein the static pressure within the sealed pilot pressure chamber is increased at a faster rate when gas 1 and water 2 are flowing through the system, as opposed to when oil 3 is flowing through the system; ultimately moving the valve member closer to the fully closed position when gas 1 and water 2 are flowing through the device, as opposed to when oil 3 is flowing through the device.

[0138] It should be understood that the examples described herein are merely exemplary and that various modifications may be made thereto within the understanding of the skilled person, without departing from the scope of the present disclosure.

1. A flow control device, comprising;
 - a body locatable within a wall of a tubular and defining a primary inlet and a primary outlet, wherein a primary flow path is defined between the primary inlet and primary outlet;
 - a valve member disposed within the body, the valve member being moveable in reverse first and second directions to selectively vary a flow area of the primary flow path; and
 - a sealed pilot pressure chamber defining a pilot pressure inlet for receiving a pilot pressure, the valve member being in pressure communication with the sealed pilot pressure chamber such that pilot pressure may act to bias the valve member in one of the first and second directions, wherein the pilot pressure is provided as a function of a property of fluid flowing through the primary flow path.
2. The flow control device according to claim 1, wherein the flow rate through the flow control device is varied based upon one or more properties of a fluid flowing along the primary flow path.
3. The flow control device according to claim 1, wherein the position of the valve member and the size of the flow area provided is determined by a pressure differential between at least the inlet of the primary flow path and within the sealed pilot pressure chamber.
4. The flow control device according to claim 1, comprising a pilot pressure system, wherein the pilot pressure is provided from the pilot pressure system.
5. (canceled)
6. The flow control device according to claim 4, wherein the pilot pressure system comprises a secondary flow path.
7. The flow control device according to claim 6, wherein the secondary flow path comprises an inlet and an outlet.
8. The flow control device according to claim 6, wherein the secondary flow path is in pressure communication with the sealed pilot pressure chamber.
9. The flow control device according to claim 6, wherein the secondary flow path is partially formed through the body of the flow control device.

10. The flow control device according to claim 6, wherein the secondary flow path is partially formed through the wall of a tubular within which the flow control device is located.

11. The flow control device according to claim 6, wherein the secondary flow path is configured to create a pressure drop between the inlet and the outlet.

12. The flow control device according to claim 6, wherein pressure is communicated to the sealed pilot pressure chamber from a point between the inlet and the outlet of the secondary flow path.

13. The flow control device according to claim 12, wherein the secondary flow path provides a static pressure within the sealed pilot pressure chamber.

14. The flow control device according to claim 13, wherein the static pressure within the sealed pilot pressure chamber is determined by the inlet pressure of the secondary flow path and the pressure drop along the secondary flow path.

15. The flow control device according to claim 6, wherein the inlet pressure of the primary flow path and the secondary flow path are substantially the same.

16. The flow control device according to claim 6, wherein a fluid source provides fluid to both the primary and secondary flow paths, wherein the fluid source is the same for both the primary and secondary flow paths.

17. The flow control device according to claim 6, wherein the secondary flow path comprises one or more flow restrictions.

18. The flow control device according to claim 1, wherein biasing the valve member in the first direction moves the valve member towards a fully open position, increasing the flow area.

19. The flow control device according to claim 18, wherein the valve member is biased in the first direction by fluid pressure at the primary inlet.

20. The flow control device according to claim 1, wherein biasing the valve member in the second direction moves the valve member towards a fully closed position, decreasing the flow area.

21. The flow control device according to claim 20, wherein the valve member is biased in the second direction by fluid pressure within the sealed pilot pressure chamber.

22. The flow control device according to claim 1, wherein the pilot pressure is provided as a function of at least one of the viscosity and the density of the fluid flowing through the primary flow path.

23. The flow control device according to claim 1, comprising a sealing arrangement disposed between the valve member and the body of the flow control device, wherein the sealing arrangement provides a biasing force biasing the valve member in one of the first or second directions.

24. A downhole flow control method, the method comprising:

flowing a fluid through a primary flow path of a flow control device disposed within the wall of a tubular, wherein the flow control device comprises a valve member disposed within the primary flow path;

flowing a fluid through a secondary flow path, wherein the secondary flow path is configured to provide a pressure variation of the fluid flowing through the secondary flow path based upon a variation of at least one characteristic of said flowing fluid; and

communicating a pressure from the secondary flow path to a sealed pilot pressure chamber, said pressure pro-

viding a biasing force on the valve member to vary the flow area of the primary flow path.

25. The method according to claim **24**, wherein the at least one characteristic of the flowing fluid that provides the pressure variation within the secondary flow path comprises at least one of the viscosity and the density of the fluid.

* * * * *