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Downhole valve with rotational position sensor

Abstract

A flow control system for a well may include a valve body sized to fit in a wellbore and defining a valve body through bore. A valve closure is movably coupled to the valve body and moveable about a rotational axis between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore. A rotational sensor generates a signal responsive to a rotational position of the valve closure relative to the valve body.

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Background/Summary

BACKGROUND

(1) The present disclosure relates generally to downhole valve position sensing systems, downhole valves, and methods to determine a position of a downhole valve.

(2) Wellbores are sometimes drilled into subterranean formations to allow for the extraction of hydrocarbons and other materials. Valves are sometimes disposed in a wellbore and are utilized during one or more well operations to restrict fluid flow through the wellbore.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) These drawings illustrate certain aspects of some of the embodiments of the present disclosure and should not be used to limit or define the method.

(2) FIG. **1** is an elevation view of a well system as an example of a well environment for implementing a valve position sensing system according to aspects of this disclosure.

(3) FIG. **2** is an enlarged side view of a flapper valve and valve position sensing system according to an example configuration.

(4) FIG. **3** is a further enlarged view of the system of FIG. **2** according to an example configuration that employs a magnetic rotational sensor.

(5) FIG. **4** is a diagram of a first example profile defined by the knuckle of a hinge used to mount the flapper to the valve body.

(6) FIG. **5** is a diagram of a second example profile comprising a plurality of circumferentially spaced protrusions.

(7) FIG. **6** is a diagram of a third example profile whose radius varies gradually in a circumferential direction over a portion of the profile.

(8) FIG. **7** is diagram of a fourth example profile having a sensed feature at a fixed location along the profile.

(9) FIG. **8** is a sectional side view of the downhole valve with another example of a valve position sensing system.

(10) FIG. **9** is a sectional side view of the downhole valve of FIG. **8** with the flapper moved to an open position.

(11) FIG. **10** is a sectional side views of a ball valve in an open position.

(12) FIG. **11** is a sectional side view of the ball valve of FIG. **10** with the ball rotated to a closed position.

DETAILED DESCRIPTION

(13) A flow control system for a well is disclosed that may allow for precise determination of a valve position. The flow control system may include a downhole valve, such as a flapper valve or ball valve, having a closure that is rotatable to open and close flow through a valve body. The flow control system may also include a valve position sensing system that can sense the rotational position of the closure (e.g., flapper or ball), such as open, fully open, closed, and fully closed, and/or by measuring and outputting the angle of the closure. The valve position sensing system may include a rotational sensor that senses one or more feature (i.e., sensed features) of rotating components. In one example, a position sensor on one of the valve body and valve closure is positioned to detect movement of a sensed feature on the other of the valve body and the valve closure. For example, an electromagnetic sensor on the valve body may detect the rotational position (e.g., angle and/or distance) of a magnet on the valve closure with respect to the position of the sensor. In some examples, a profile may be defined that revolves about a rotational axis, and

a variation along that profile is detectable.

(14) Knowing the position of subsurface safety valves, barrier valves, and the like will help ensure that these valves are completely open or completely closed. Being fully open helps to ensure, for example, that there is no restriction to production flow, as well as to ensure that there are no valve lips that could catch a tool string. Being completely closed likewise helps to ensure that the valve is sealing properly without appreciable leakage.

(15) FIG. **1** is an elevation view of a well system **10** as an example of a well environment for implementing a valve position sensing system **60** according to aspects of this disclosure. The operating environment of the well system **10** includes a rig **14** positioned on the earth's surface **11** and extending over and around a wellbore **16**. The rig **14** may represent any type of rig for supporting operations in a wellbore during drilling, completion, production, and/or maintenance, e.g., workovers. The well system **10** and rig **14** are depicted as being land-based, but may alternatively represent other types of environments such as an offshore well system, in which case the rig **14** may represent an offshore platform or floating vessel in a body of water (e.g., the ocean, not shown) and the earth's surface **11** may represent a seabed below which the wellbore **16** has been formed. The wellbore **16** extends into a subterranean formation **112** that has been formed by drilling for recovering hydrocarbons, or for injecting fluids into a spent formation **112**. The wellbore **16** may follow any wellbore trajectory including sections that deviate from vertical, as formed by any suitable techniques such a directional drilling or multilateral techniques. By way of example, FIG. **1** includes a vertical portion **17** directly extending from the surface **11** and a deviated portion **19** branching off the vertical portion **17**. The vertical portion **17** is partially cased by a casing **15**, which could also be extended through the horizontal portion **19**.

(16) A tubular conveyance **18** is suspended from the rig **14** into the subterranean formation **112**. Any suitable conveyance could be used that supports the flow of well fluids, including but not limited to drill pipe, casing, coiled tubing, and so forth. A downhole valve **40** is disposed within the tubular conveyance **18** to control flow up through the tubular conveyance **18**. The downhole valve **40** is depicted, by way of example, as a flapper valve. However, other suitable valve types may alternatively be used, such as a ball valve, J-slot valve, or L-slot valve. The downhole valve **40** may be a subsurface safety valve (SSSV), or more specifically, a tubing-retrievable subsurface safety valve (TRSV) or wireline-retrievable subsurface safety valve (WRSV) for controlling the flow of production fluids up through the conveyance **18**. The rig **14** includes a derrick **22** with a rig floor **24** through which the conveyance **18** extends into wellbore **16**. In some embodiments, the rig **14** has a motor-driven winch and other associated equipment for extending tubular conveyance **18** into wellbore **16** to a selected depth. While FIG. **1** depicts a stationary rig **14** for land-based operations, alternative embodiments may include mobile workover rigs, wellbore servicing units (such as coiled tubing units), and the like used to lower tubular conveyance **18** into the wellbore **16**.

(17) The downhole valve **40** is sized to fit in the wellbore **16**, with its through bore **44** aligned with the wellbore **16** to control the flow of formation fluids. For example, an SSSV can open flow to a large volumetric flow rate of production fluids, and still shut down that flow in the event of an emergency. The flapper **42** is an example of a valve closure that may pivot between an open position as shown for allowing flow through the downhole valve **40** and a closed position for closing flow. The flapper **42** may be normally propped open with an actuation member **28**, e.g., a piston to directly or indirectly engage the flapper **42**. The flapper **42** may be biased to a closed position for automatically closing when the actuation member **28** is not engaging the flapper **42**.

(18) The valve position sensing system **60** includes a rotational sensor, with any of a variety of example configurations discussed below, to sense a rotational position of the flapper **42** or other valve closure type depending on the valve configuration. For example, the valve position sensing system **60** may at least determine whether the downhole valve **40** is open or closed based on the rotational position of the flapper **42**. The valve position sensing system **60** may be used to confirm, more particularly, whether the downhole valve **40** is fully open or fully closed, and to alert the

operator or take some other action when it is not. Being fully open helps to ensure, for example, that there is no restriction to production flow, as well as to ensure that there are no valve lips that could catch a tool string. Being fully closed likewise helps to ensure that the valve is sealing properly without appreciable leakage.

(19) Generally, the valve position sensing system **60** may include sensor hardware responsive to rotational position and a change in rotational position (movement) of the flapper or other valve closure. The valve position sensing system **60** may include a processor and control logic to interpret a sensor signal, such as to ascertain a rotational position of the valve closure as it correlates with the sensor signal and to output a representation of the rotational position of the valve closure in relation to the signal.

(20) A variety of example sensor configurations are given below, which in most cases may comprise an electromagnetic sensor. In some examples the sensor is an electromagnetic sensor used to sense the angle of a directional magnetic field. In other examples, a proximity sensor is used to determine how far away a reference point on a valve closure is from a valve body to infer its rotational position. The processor may be located in a downhole housing, or at surface **11**. For example, an information handling system **25** is optionally provided at the well site or at a remote location in communication with the valve position sensing system **60**. The information handling system **25** may include user input/output (I/O) peripherals, a process, control logic such as hardware, software, or firmware for processing and outputting information from the valve position sensing system **60**, such as to determine and display when the downhole valve **40** is open or closed or its precise rotational position. The information handling system **25** may be configured to control other system components based on its analysis of the rotational position.

(21) FIG. **2** is an enlarged side view of the downhole valve **40** and valve position sensing system **60** according to an example configuration. The downhole valve **40** includes a tubular valve body **46** defining a valve body through bore **44** and a flapper **42** pivotably coupled to the valve body **46** by a hinge **48**. The flapper **42** thus functions as a valve closure disposed within the valve body **46** that is pivotable between the open position of FIG. **1** and a closed position as shown in FIG. **2**. The flapper **42** may be in a fully closed position in FIG. **2**, forming a reliable seal with a valve seat **43**.

(22) Over time, various downhole factors may result in the flapper **42** not fully closing, such as due to general wear and tear, corrosion, or debris accumulated on the valve seat **43** or about the hinge **48**. The valve position sensing system **60** includes a rotational sensor **62** to generate a signal **61** responsive to a rotational position of the flapper **42** relative to the valve body **46**. The valve position sensing system **60** includes a controller schematically depicted at **65** in communication with the rotational sensor **62**. The controller **65** includes a processor and control logic to process and interpret the signal **61** from the rotational sensor **62**. The valve position sensing system **60** is thereby able to determine, for example, when the flapper **42** is open or closed, including to confirm when it is in a fully open or fully closed position, and may optionally be able to determine and output an accurate angle reading. The processor is configured to output a representation of a rotational position of the flapper **42** or other valve closure in relation to the signal **61**.

(23) A range of possible configurations are possible using a magnetic rotational sensor. The magnetic rotational sensor may comprise a magnet on one of the valve closure and the valve body and a magnetic sensor on the other of the valve closure and the valve body. Thus, movement of the valve closure relative to the valve body results in a corresponding movement of the magnet with respect to the magnetic sensor. The magnetic sensor may sense this movement of the magnet and generate a signal responsive thereto. The magnetic sensor may sense the position and the movement of the magnet by noting the magnitude of the magnetic signal, the direction of the magnetic signal, or the combination of two or more magnetic sensors. The magnetic sensor may be used to thereby obtain (e.g., by inference or correlation) the rotational position of the valve closure based on the signal.

(24) FIG. **3** is a further enlarged view of the valve position sensing system **60** of FIG. **2** according

to an example configuration that employs a magnetic rotational sensor. The valve closure (in this case, the flapper **42**) is pivotably coupled to the valve body with a hinge **70**. The hinge **70** includes a knuckle **72** and a pin **74** received within the knuckle **72**. The hinge **70** allows the flapper **42** to pivot about a rotational axis **45**, which is approximately aligned with the pin **74** and/or center of the knuckle **72**. The knuckle **72** is incorporated with or otherwise secured to the flapper **42** and the pin **74** is secured to the valve body **46**, or vice-versa, such that the knuckle **72** revolves about the pin **74** as the flapper **42** correspondingly rotates with respect to the valve body **46**. In this example, the magnet **64** is coupled to the flapper **42** via the magnet **64** being located on the knuckle **72**. The rotational sensor **62** thereby determines the rotational position of the flapper **42** about the rotational axis **45** based on a position of the magnet **64** with respect to the magnetic sensor **66**. In an alternative configuration, a magnet could be incorporated into the pin **74** and a magnetic sensor incorporated into the knuckle **72**, again so that the rotational sensor determines the rotational position of the flapper **42** about the rotational axis **45** based on a position of the magnet with respect to the magnetic sensor.
(25) Depending on the configuration, a magnetic sensor may detect movement of a magnet based on an angle of the magnet and/or a distance of the magnet with respect to the magnetic sensor. In the example of FIG. **3**, the magnet **64** generates a directional magnetic field schematically drawn at **68**. The magnetic sensor **66** is responsive to a change in an angle of the directional magnetic field **68**. As the flapper **42** pivots at the hinge **70**, the knuckle **72** rotates about the pin **74** in conjunction with the pivoting of the flapper **42** with respect to the valve body **46**. Thus, by detecting the angle or change in angle of the magnetic field **68**, the magnetic sensor **66** may be used to determine the precise angle of the flapper **42**. By determining the angle of the magnetic field **68**, and thereby the flapper **42**, the valve position sensing system **60** is able to determine if the flapper **42** is fully open, fully closed, or even determine a measurement of the angle of the flapper **42**.
(26) In some examples, a proximity sensor has a sensor location on the valve body or the valve closure. A feature being sensed by the proximity sensor as a sensed location on the other of the valve body or the valve closure. The proximity sensor thereby senses a changing proximity between the sensor location and the sensed location.
(27) In some of these examples, the sensor location may be a fixed location on the valve body or the valve closure. The sensed location may be a fixed location on the other of the valve body or the valve closure. A distance between the two fixed location varies in relation to movement of the closure. Thus, the rotational sensor may infer the rotational position of the valve closure from that distance between fixed positions.
(28) For example, in FIG. **3**, instead of the magnetic sensor **66** being responsive to the angle of the magnetic field **68**, the magnetic sensor **66** may alternatively be a proximity sensor responsive to a distance of the magnet **64** from the magnetic sensor **66**. The magnetic sensor **66** is at a fixed position on the knuckle **72**, and therefore at a fixed position with respect to the flapper **42**. Since the strength of a magnetic field may vary with distance, a magnetic proximity sensor may be used to infer the distance between the fixed locations based on a strength of the detected magnetic field. Thus, as the flapper **42** pivots, the distance between the magnet **64** and the magnetic sensor **66** and the corresponding strength of the magnetic field **68** vary, so that the strength of the magnetic field **68** detected by the magnetic sensor **66** could be used to determine the angle of the flapper **42**.
(29) In other examples, a proximity sensor may be used to detect proximity of a sensor element to a profile defined by one of the valve components about the rotational axis, but not necessarily to a fixed location on that profile. As the valve closure moves, the profile rotates around the rotational axis and moves past the sensor element. The sensor element may detect variations along the profile as the profile moves past the sensor element. That information may be analyzed to ascertain the rotational position of the valve closure.
(30) In the above example, the proximity sensor is based on a magnetic field, which is one example of a variable electrical parameter. A proximity sensor may alternatively sense other electrical

parameters that changes in response to the changing proximity. For instance, the electrical parameter may alternatively comprise an inductance, a capacitance, a resistance, and/or a voltage, which change with the rotational position of the valve closure with respect to the valve body. By sensing the changed electrical parameter, the rotational sensor may determine the rotational position of the valve closure.

(31) FIGS. **4-7** provide examples of profiles about a rotational axis that have detectable features along the profile. These profiles may be defined, for example, by the knuckle of a hinge (i.e., a knuckle profile) where the hinge rotatably couples the valve closure to the valve body. The flapper or other valve closure may be rigidly coupled to the knuckle, with the proximity sensor on the valve body so that rotating the valve closure moves the knuckle profile with respect to the proximity sensor. Although a hinge knuckle provides a useful structure for defining a profile about a rotational axis, these profiles may be alternatively defined by some structure of the valve closure or body other than by a hinge. In any of these examples, the profiles may be generally arcuate, e.g., circular or partially circular about the rotational axis, but with some detectable variation.

(32) FIG. **4** is a diagram of a first example profile **100** defined, by way of example, by the knuckle **72** of a hinge **70** used to mount a valve closure **142** to a valve body **146**. The valve closure may be the flapper of a flapper valve or the ball of a ball valve, for example. A proximity sensor comprises a sensor element **110** in proximity to the profile **100**. The sensor element **110** may be coupled to a fixed location on the valve body **40**. The knuckle **72** may be incorporated on or otherwise secured to the valve closure **142**. The knuckle **72** may rotate about the pin **74** as the valve closure **142** is moved about the corresponding rotational axis **45**. The sensor element **110** is responsive to a variation along the knuckle profile **100** as the knuckle **72** rotates relative to the sensor element **110**. The knuckle profile **100** comprises a radius “r” that varies along the profile from a radius “r.sub.1” at a first knuckle portion **102** to a radius “r.sub.2” at a second knuckle portion **104** circumferentially spaced from the first knuckle portion **102**.

(33) In this example, the first knuckle portion **102** comprises a recess and the second knuckle portion **104** comprises a protrusion. The sensor element **110** is responsive to the recess or protrusion based on proximity of the profile **100** to the sensor element **110**. The two knuckle portions **102**, **104** are associated with different positions of the flapper or other valve closure **142**. For example, the first knuckle portion **102** may be proximate to the sensor element **110** when the closure element **142** is in the closed position and the second knuckle portion **104** may be proximate to the proximity sensor element when the closure element is in the open position, or vice-versa. Thus, the controller **65** may determine whether the valve is open or closed based on whether the recess at the first location **102** or protrusion at the second location **104** are adjacent to the sensor element **110**.

(34) FIG. **5** is a diagram of a second example profile **200** comprising a plurality of circumferentially spaced protrusions **204**A, **204**B, **204**C, etc. Each protrusion **204** corresponds to a different angular position of a valve closure. For example, one of these protrusions may correspond to a fully open position, another of these protrusions may correspond to a fully closed position, and other protrusions in between may correspond to open positions, such as positions of reduced flow that is less than in the fully open position. As the profile **200** rotates about the rotational axis **45**, the protrusions **204** successively pass under the sensor element **110**. The sensor element **110** may be configured to sense the proximity each protrusion **204**. The protrusions **204** may all have an equal radius r, in which case the sensor element **110** can be configured to detect a rotational direction as the protrusions **204** pass by the sensor element **110**, to keep track of the rotational position. Alternatively, the protrusions **204** may all be given a unique radius so the sensor element **110** may ascertain based on radius which protrusion **204** is adjacent to the sensor element **110**, and the corresponding rotational position. The sensor element **110** could alternatively be configured to detect the circumferentially-spaced recesses (reduced radius) between adjacent protrusions.

(35) FIG. **6** is a diagram of a third example profile **300** whose radius “r” varies gradually over a

portion of the profile **300**. The varying radius r correlates with an angular position (θ) of the valve closure so that the radius increases in one circumferential direction and decreases in an opposing circumferential direction. The profile **300** may be generally circular and fully encircle the rotational axis **45**, such as might be the case with the knuckle of a hinge about a pin as discussed above. However, the profile **300** is not required to fully encircle the rotational axis **45**. Rather, the profile **300** could instead extend only partially around the rotational axis **45**. For example, a flapper-type closure or ball-type closure may travel on the order of about ninety degrees between a fully open position and a fully closed position, in which case the profile or at least a detectable portion of the profile **300** may only span a like amount. In FIG. **6** the profile **300** extends three-hundred-and-sixty degrees about the rotational axis **45**, but only about ninety degrees of that profile **300** passes adjacent to the sensor element **110** from a first location **302** corresponding to fully open to a second location **304** corresponding to fully closed. The sensor element **110** senses its proximity to the profile **300** and is used to obtain the angular position (θ) therefrom. In one variation, the profile **300** may contact the electromagnetic sensor **110** so that it can create a low resistance electrical connection.

(36) FIG. **7** is diagram of a fourth example profile **400** having a sensed feature at a fixed location along the profile **400**. The sensed feature in this example may be a magnet **410** (e.g., the magnet **64** in FIG. **3**). A surrounding portion of the profile **400** may be non-magnetic or otherwise have diminished magnetic properties, such that the sensor element **110** may detect the magnet **410** but not the non-magnetic portion of the profile **400**. The sensor element **110** is at a fixed location, e.g., on a valve body. Thus, the sensor element **110** is responsive to a changing proximity between the sensor element **110** at its fixed location and the magnet **410** at its fixed location as the profile **400** rotates about the rotational axis **45**.

(37) In FIG. **7**, the magnet **410** is aligned with the sensor element **110**, at a minimum distance “d.sub.1” between the sensor element **110** and the magnet **410**. This may correspond to a maximum or minimum travel, e.g., with a fully open or fully closed position of a valve closure. As the valve closure moves, so too the profile **400** will rotate, carrying the magnet progressively further from the sensor element **110**. Although the magnet **410** moves along a circular path about the rotational axis **45**, the signal strength may vary with the linear distance (straight-line path) “d” from the sensor element **110**, which distances increases from d.sub.1 to d.sub.2 to d.sub.3. The magnetic signal may vary with position, such as by correspondingly decreasing as the distance increases from d.sub.1 to d.sub.2 to d.sub.3. Thus, the distance and corresponding signal strength may be correlated with angular position, so that the rotational position of the flapper, ball, or other valve closure element may be determined based on the signal.

(38) FIG. **8** is a sectional side view of the downhole valve **40** with another example of a valve position sensing system **160**. The downhole valve **40** is again depicted as a flapper valve by way of example. The valve position sensing system **160** senses the rotational position of the flapper **42** at least to the extent that it may detect whether the flapper **42** is open or closed, which the valve position sensing system **160** detects by virtue of whether an electrical circuit is open or closed. When open, little current flows. An electrical pathway **162** is routed along and insulated from the valve body. The electrical pathway **162** may comprise, for example, an insulated wire or a circuit trace routed along a non-conductive substrate pathway. A voltage source **164** is applied to the electrical pathway **162**. One can apply voltage for a short time to avoid corrosion of the electrode. Voltage can be alternating current (AC) or direct current (DC).

(39) The flapper **42** is metallic and electrically conductive, so the flapper **42** and the valve body **46** provide an electrical ground. Alternatively, an electrically conductive pathway may be incorporated into an otherwise electrically non-conductive portion of the flapper **42**. In either case, an electrically conductive portion of the flapper **42**, i.e., an electrical contact on the flapper **42**, electrically contacts the electrical pathway **162** when the flapper **42** is closed. The valve position sensing system detects the completed circuit as indicative of the downhole valve **40** being closed.

(40) An optional configuration could incorporate a proximity sensor on the valve body and a magnet or other feature on the flapper, to sense the proximity of the flapper to the closed position. For example, a proximity sensor could measure the distance to the flapper as the flapper is approaching the seat. As in other examples, the proximity sensor can be a magnetic, capacitive, inductive, or resistive sensor.
(41) FIG. **9** is a sectional side view of the downhole valve **40** of FIG. **8** with the flapper **42** moved to an open position. This opens the electrical circuit, which the valve position sensing system **160** detects as indicative the downhole valve **40** is now open. By sensing the changed electrical parameter (in this case, a voltage), the valve position sensing system **160** detects the rotational position of the flapper **42**.
(42) The above examples are discussed primarily in the context of a flapper valve. However, the disclosed principles may be applied to any other type of valves that has a valve closure rotatable between open and closed positions. FIGS. **10** and **11** are sectional side views of a ball valve **540** as another example of a downhole valve for use with a valve position sensing system **560** according to another example configuration.
(43) FIG. **10** is a sectional side view of the ball valve **540** with a ball **542**. The ball **542** defines a ball through bore **534** rotatable about a rotational axis **545**, into and out of fluid communication with a valve body through bore **544**. FIG. **10** shows the ball **542** in an open position in fluid communication with the valve body through bore **534**, thus allowing any flow **536** through the valve body through bore **544**. The valve position sensing system **560** includes a sensor element **510**, which may be any of the types discussed above. For example, the sensor element **510** may comprise a magnetic sensor that detects a directional magnetic field, or a proximity sensor responsive to a changed electrical parameter (magnetic field, inductance, capacitance, and/or a voltage). By sensing proximity and/or the changed electrical parameter, the sensor element **510** serves as a rotational sensor to determine the rotational position of the ball **542**. In the fully open position of FIG. **10**, a sensed feature **520** (e.g., protrusion, recess, magnet, etc.) is in close proximity to the sensor element **510**.
(44) FIG. **11** shows the ball valve **540** of FIG. **10** with the ball **542** rotated out of fluid communication with the valve through bore **544** to a fully closed position, fully closing the flow **536** through the valve body through bore **544**. The sensed feature **520** has been shifted to a maximal distance from the sensor element **510**. The valve position sensing system **560** determines, at least by virtue of the sensed feature **520** moving away from the sensor element **510**, that the ball **542** is no longer in the fully open position. More particularly, the sensor element **510** may determine, based on signal strength, the relative distance of the sensed feature from the sensor element **510**, thereby inferring an angular position of the ball **542** in relation to that signal.
(45) In other configurations, a profile such as any of the examples of FIGS. **4-7** may be provided about the rotational axis **545**, such as defined by the valve body **546**. The sensor element **510** may sense variations in that profile as it moves relative to the sensor element **510** to infer a rotational position of the ball **542**.
(46) Accordingly, the present disclosure may provide a flow control system for a well and a downhole valve for controlling flow in a well. The methods, systems, tools, etc. according to this disclosure may include any of the various features disclosed herein, including one or more of the following examples.
(47) Example 1. A flow control system for a well, comprising: a valve body sized to fit in a wellbore and defining a valve body through bore; a valve closure coupled to the valve body and moveable about a rotational axis between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore; and a rotational sensor to generate a signal responsive to a rotational position of the valve closure relative to the valve body.
(48) Example 2. The flow control system of Example 1, wherein the valve closure comprise a

flapper pivotably coupled to the valve body and pivotable about the rotational axis between the open position and the closed position.
(49) Example 3. The flow control system of any of Examples 1 to 2, wherein the valve closure comprise a ball rotatably disposed within the valve body through bore about the rotational axis, the ball defining a ball through bore rotatable into and out of fluid communication with the valve body through bore.
(50) Example 4. The flow control system of any of Examples 1 to 3, wherein the rotational sensor comprises a magnet on one of the valve closure and the valve body and a magnetic sensor on the other of the valve closure and the valve body such that the rotational sensor determines the rotational position of the valve closure about the rotational axis based on a position of the magnet with respect to the magnetic sensor.
(51) Example 5. The flow control system of Example 4, wherein the magnet generates a directional magnetic field and the magnetic sensor is responsive to a change in an angle of the directional magnetic field.
(52) Example 6. The flow control system of any of Examples 1 to 5, wherein the rotational sensor comprises a proximity sensor having a sensor location on the valve body or the valve closure to sense a changing proximity between the sensor location and a sensed location on the other of the valve body or the valve closure.
(53) Example 7. The flow control system of Example 6, wherein the proximity sensor senses an electrical parameter that changes in response to the changing proximity.
(54) Example 8. The flow control system of Example 7, wherein the electrical parameter comprises a magnetic field, an inductance, a capacitance, or a voltage.
(55) Example 9. The flow control system of Example 6 or 7, wherein the sensor location is a fixed location on the valve body or the valve closure and the sensed location is a fixed location on the other of the valve body or the valve closure, and wherein the rotational sensor determines the rotational position of the valve closure from a distance between the fixed location on the valve body and the fixed location on the valve closure.
(56) Example 10. The flow control system of any of Examples 1 to 9, wherein the valve body or valve closure define a profile about the rotational axis, wherein the rotational sensor is responsive to a variation along the profile as the valve closure moves between the open position and the closed position.
(57) Example 11. The flow control system of any of Examples 1 to 10, wherein the valve closure is pivotably coupled to the valve body with a hinge comprising a knuckle and a pin, wherein the knuckle defines a knuckle profile about the pin and wherein the rotational sensor is responsive to a variation along the knuckle profile as the knuckle rotates relative to a sensor location.
(58) Example 12. The flow control system of Example 11, wherein the variation along the knuckle profile comprises a radius that varies from a first knuckle portion to a second knuckle portion circumferentially spaced from the first knuckle portion.
(59) Example 13. The flow control system of Example 12, wherein the knuckle is oriented with the first knuckle portion proximate to a proximity sensor element when the valve closure is in the closed position and with the second knuckle portion proximate to the proximity sensor element when the valve closure is in the open position.
(60) Example 14. The flow control system of Example 12 or 13, wherein the first knuckle portion comprises a recess and the second knuckle portion comprises a protrusion.
(61) Example 15. The flow control system of any of Examples 11 to 14, wherein the variation along the knuckle profile comprises a plurality of circumferentially spaced recesses or protrusions each corresponding to a different angular measurement.
(62) Example 16. The flow control system of any of Examples 11 to 15, wherein the variation along the knuckle profile comprises a radius that gradually increases in one circumferential direction, such that the radius correlates with an angular position of the valve closure.

(63) Example 17. The flow control system of any of Examples 11 to 16, further comprising a magnet at a fixed location along the knuckle profile, wherein the rotational sensor is responsive to a changing proximity between the magnet and a sensor location as the knuckle rotates about the pin.
(64) Example 18. The flow control system of Example 1, wherein the rotational sensor comprises: an electrical pathway routed along and insulated from the valve body; a voltage source coupled to the electrical pathway; and an electrical contact on the valve closure that electrically contacts the electrical pathway to close an electrical circuit when the valve closure is closed and to open the electrical circuit when the valve closure is open.
(65) Example 19. The flow control system of any of Examples 1 to 18, further comprising: an information handling system in communication with the rotational sensor and configured to output a representation of the rotational position.
(66) Example 20. A downhole valve for controlling flow in a well, the downhole valve comprising: a valve body sized to fit in a wellbore and defining a valve body through bore; a valve closure pivotably coupled to the valve body with a hinge and moveable between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore; the hinge comprising a knuckle and a pin defining a rotational axis for the valve closure, wherein the knuckle defines a knuckle profile that revolves about the pin as the valve closure moves between the open position and the closed position; a rotational sensor adjacent to the knuckle profile to generate a signal responsive to a variation in the knuckle profile as the knuckle profile revolves about the pin; and a processor configured to output a representation of a rotational position of the valve closure in relation to the signal.
(67) Therefore, the present embodiments are 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 embodiments may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Although individual embodiments are discussed, all combinations of each embodiment are contemplated and covered by the disclosure. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. 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 disclosure.

Claims

1. A flow control system for a well, comprising: a valve body sized to fit in a wellbore and defining a valve body through bore; a valve closure coupled to the valve body and moveable about a rotational axis between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore, wherein the valve closure comprise a flapper pivotably coupled to the valve body and pivotable about the rotational axis between the open position and the closed position; a hinge configured to pivotably couple the flapper of the valve closure to the valve body, wherein the hinge comprises a knuckle and a pin. wherein the knuckle defines a knuckle profile about the pin; and a rotational sensor to generate a signal responsive to a rotational position of the valve closure relative to the valve body, wherein the rotational sensor comprises a magnet and a magnetic sensor, wherein the magnet is disposed within a portion of the valve body, and wherein the magnetic sensor is disposed on an outer surface of the valve body, and wherein the rotational sensor is responsive to a variation along the knuckle profile as the knockle rotates relative to a sensor location.
2. The flow control system of claim 1, wherein the valve body or valve closure define a profile about the rotational axis, wherein the rotational sensor is responsive to a variation along the profile

as the valve closure moves between the open position and the closed position.
3. The flow control system of claim 1, wherein the variation along the knuckle profile comprises a plurality of circumferentially spaced recesses or protrusions each corresponding to a different angular measurement.
4. The flow control system of claim 1, wherein the variation along the knuckle profile comprises a radius that gradually increases in one circumferential direction, such that the radius correlates with an angular position of the valve closure.
5. The flow control system of claim 1, wherein the magnet is disposed at a fixed location along the knuckle profile, wherein the rotational sensor is responsive to a changing proximity between the magnet and a sensor location as the knuckle rotates about the pin.
6. The flow control system of claim 1, further comprising: an information handling system in communication with the rotational sensor and configured to output a representation of the rotational position.
7. The flow control system of claim 1, wherein the rotational sensor determines the rotational position of the valve closure about the rotational axis based on a position of the magnet with respect to the magnetic sensor.
8. The flow control system of claim 7, wherein the magnet generates a directional magnetic field and the magnetic sensor is responsive to a change in an angle of the directional magnetic field.
9. The flow control system of claim 1, wherein the variation along the knuckle profile comprises a radius that varies from a first knuckle portion to a second knuckle portion circumferentially spaced from the first knuckle portion.
10. The flow control system of claim 9, wherein the knuckle is oriented with the first knuckle portion proximate to a proximity sensor element when the valve closure is in the closed position and with the second knuckle portion proximate to the proximity sensor element when the valve closure is in the open position.
11. The flow control system of claim 9, wherein the first knuckle portion comprises a recess and the second knuckle portion comprises a protrusion.
12. The flow control system of claim 1, wherein the rotational sensor comprises a proximity sensor having a sensor location on the valve body or the valve closure to sense a changing proximity between the sensor location and a sensed location on the other of the valve body or the valve closure.
13. The flow control system of claim 12, wherein the sensor location is a fixed location on the valve body or the valve closure and the sensed location is a fixed location on the other of the valve body or the valve closure, and wherein the rotational sensor determines the rotational position of the valve closure from a distance between the fixed location on the valve body and the fixed location on the valve closure.
14. The flow control system of claim 12, wherein the proximity sensor senses an electrical parameter that changes in response to the changing proximity.
15. The flow control system of claim 14, wherein the electrical parameter comprises a magnetic field, an inductance, a capacitance, or a voltage.
16. A flow control system for a well, comprising; a valve body sized to fit in a wellbore and defining a valve body through bore; a valve closure coupled to the valve body and moveable about a rotational axis between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore, wherein the valve closure comprise a flapper pivotably coupled to the valve body and pivotable about the rotational axis between the open position and the closed position: a hinge configured to pivotably couple the flap der of the valve closure to the valve body; a rotational sensor to generate a signal responsive to a rotational position of the valve closure relative to the valve body, wherein the rotational sensor comprises a magnet and a magnetic sensor, wherein magnet is disposed within a portion of the valye body, and wherein the magnetic sensor is disposed on an outer surface of the valve body; an

electrical pathway routed along and insulated from the valve body; a voltage source coupled to the electrical pathway; and an electrical contact on the valve closure that electrically contacts the electrical pathway to close an electrical circuit when the valve closure is closed and to open the electrical circuit when the valve closure is open.
17. A downhole valve for controlling flow in a well, the downhole valve comprising: a valve body sized to fit in a wellbore and defining a valve body through bore; a valve closure pivotably coupled to the valve body with a hinge and moveable between an open position allowing flow through the valve body through bore and a closed position closing flow through the valve body through bore; the hinge comprising a knuckle and a pin defining a rotational axis for the valve closure, wherein the knuckle defines a knuckle profile that revolves about the pin as the valve closure moves between the open position and the closed position; a rotational sensor adjacent to the knuckle profile to generate a signal responsive to a variation in the knuckle profile as the knuckle profile revolves about the pin, and wherein the variation along the knuckle profile comprises a radius that gradually increases in one circumferential direction, such that the radius correlates with an angular position of the valve closure.
18. The flow control system of claim 1, wherein the magnet is secured to the hinge.
19. The flow control system of claim 1, wherein the magnet is secured to the flapper of the valve closure.