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ELECTRIC GAS LIFT VALVE

BACKGROUND

Field

[0001] The present disclosure generally relates to electric gas lift valves.

Description of the Related Art

[0002] Oil and gas wells utilize a borehole drilled into the earth and subsequently completed with equipment to facilitate production of desired fluids from a reservoir. Subterranean fluids, such as oil, gas, and water, are produced from the wellbore. In some cases, the fluid is produced to the surface naturally by downhole formation pressures. However, the fluid must often be artificially lifted from wellbores by the introduction of downhole equipment. Various types of artificial lift are available. In a gas lift system, a compressor is located on the surface. The compressor pumps gas down the casing tubing annulus. The gas is then released into the production tubing via gas valves that are strategically placed throughout the production tubing. The gas that is introduced lightens the hydrostatic weight of the fluid in the production tubing, allowing the reservoir pressure to lift the fluid to surface.

SUMMARY

[0003] In some configurations, an electric gas lift valve includes an electric actuator, a back check assembly comprising a flow tube and a flapper, and an electro-magnet fail-close mechanism.

[0004] The electric gas lift valve can include a variable choke orifice. The electric gas lift valve can include a first pressure sensor configured to read tubing pressure and a second pressure sensor configured to read annulus pressure. The valve can be configured to open or close automatically based on a pressure differential between the first and second pressure sensors.

[0005] In some configurations, an electric gas lift valve includes an electric actuator and a variable choke.

[0006] The electric gas lift valve can further include a mechanism configured to open and close the valve. The mechanism can be a quarter turn mechanism. The electric actuator can be configured to actuate both opening and closing of the valve, and adjustment of the variable choke.

The variable choke can include a nozzle and a venturi, wherein the nozzle is adjustable relative to the venturi to choke flow of gas through the venturi.

BRIEF DESCRIPTION OF THE FIGURES

[0007] Certain embodiments, features, aspects, and advantages of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein.

[0008] Figure 1 illustrates a portion of an example of a gas lift system.

[0009] Figure 2 illustrates example existing gas lift valves.

[0010] Figures 3-8 illustrate an example electric gas lift valve according to the present disclosure.

[0011] Figures 9-10 illustrate an example electric gas lift valve according to the present disclosure.

[0012] Figure 11 illustrates the electric gas lift valve of Figures 9-10 including a U-turn loop for the gas flow.

DETAILED DESCRIPTION

[0013] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments are possible. This description is not to be taken in a limiting sense, but rather made merely for the purpose of describing general principles of the implementations. The scope of the described implementations should be ascertained with reference to the issued claims.

[0014] As used herein, the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple”, “coupling”, “coupled”, “coupled together”, and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms "up" and "down"; "upper" and "lower"; "top" and "bottom"; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point at the surface from which drilling operations are initiated as being the top point and the total depth being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface.

[0015] Figure 1 illustrates a downhole portion of an example gas lift system 140. The gas lift system 140 includes a compressor located at the well surface. In use, the compressor pumps gas down the annulus between the casing 102 and the tubing 104, as indicated by arrow 142. The gas is then released into the tubing 104 via one or more gas valves 144 that are strategically placed throughout the tubing 104. The gas lessens the hydrostatic weight of the fluid in the tubing 104, allowing the reservoir pressure to lift the fluid to the surface, as indicated by arrow 146.

[0016] Figure 2 illustrates examples of currently available valves 144 that may be used in a gas lift system 140. As shown, the valve 144 includes a check bushing 152, a check dart 154, and a spring (positioned at location 156) disposed in an outer housing 150. The check dart 154 has a hemispherical head 158 and a stem 160 extending away from the head 158. The spring can be disposed about the stem 160. In a closed position, the hemispherical head 158 of the check dart 154 seals against the check bushing 152. The spring can bias the check dart 154 toward the closed position when no pressure is applied to the valve 144. When pressure is applied, e.g., by gas flow along direction 142, the spring is compressed and the check dart 154 moves away from the check bushing 152, thereby opening the valve 144. Flow is allowed in only one direction – from the annulus into the production tubing 104.

[0017] Injection pressure-operated gas lift valves are designed to open in response to a specific gas pressure in the annulus. Traditional backcheck valves use applied pressure and springs to operate. When the pressure in the annulus is high enough to compress the spring, the valve

opens. When the pressure is not high enough, the valve closes to prevent flow from the tubing to the annulus.

[0018] The present disclosure provides electric gas lift valves, assemblies, systems, and methods. As shown in Figure 9, the gas lift valve can be disposed in a side or external pocket of a mandrel coupled to the tubing. Electricity is supplied to the gas lift valve. This electric power can be used to actuate the valve to open and/or close. The electric power can also be used by sensors, such as pressure, temperature, vibration, and/or flow sensors. Information provided by the sensors can be valuable data for the well operator. The use of electric power to operate the gas lift valve can advantageously allow for increased reliability and extra functionality.

[0019] In some valves, assemblies, systems, and methods according to the present disclosure, the gas lift valve can be opened and/or closed based on data from sensors, such as pressure sensors, instead of a calibrated spring. An electric actuator can move the valve to the open or closed position. In some configurations, the gas lift valve includes a variable choke that allows for fine tuning of the amount of flow through the valve. The gas lift valve can include a flapper with flow tube back check valve. In some configurations, the valve includes an electro-magnet fail-safe mechanism that defaults to closing the valve when the operator does not intentionally want the valve open.

[0020] In some configurations, two pressure sensors are used – one sensor measures tubing pressure, and the other measures annulus pressure. The differential pressure measured between the tubing and annulus sensors is used to govern when the valve is opened or closed. The operator can advantageously change the differential pressure settings triggering opening or closing when required or desired. In some configurations, if the sensors read the differential pressure defined to cause closing of the valve, the system automatically closes the valve. In some configurations, a close command is sent to a fail-close mechanism to seal the tubing/annulus instantly or nearly instantly. Various fail-close scenarios are possible. For example, the valve can be designed to be default or biased closed unless and until the operator wants it open. In some scenarios, the operator may want the valve closed even with high annulus pressure. In systems and methods according to the present disclosure, the fail-close mechanism is based on the command of the operator rather than the environment in the well (such as pressure, temperature, and/or flow).

[0021] Figures 3-8 illustrate an example electric gas lift valve according to the present disclosure. Figure 6 shows the actuation string of the valve when the valve is in the closed position.

Figure 7 shows the actuation string of the valve when the valve is in the open position. Figure 8 shows the flow path of gas through the valve from the annulus to the tubing.

[0022] The fail-closed mechanism includes an electro-magnet + collet + spring assembly that creates a coupling with the actuator. When engaged, the electro-magnet holds the collet in a locked position, compressing a spring. When the electro-magnet releases, the spring pushes the collet to the unlocked position, and the coupling is released. The fail-closed mechanism is used to close the valve.

[0023] The gas lift valve includes an electric actuator configured to open the valve with desired or required. The actuator can be any type of mechanism that converts electric power to mechanical motion. In the illustrated configuration, the actuator is an electro-mechanical actuator (EMA). The EMA includes an electric motor, gearbox, and ball screw. In use, the actuator engaged the electro-magnet coupling to move the valve to an open position. The actuator opens the flapper mechanism (which seals backpressure). The actuator can then adjust the variable choke to allow more or less flow through the valve.

[0024] The orifice size of gas lift valve(s) controls the gas injection rate. In traditional operating valves, orifice size is fixed during installation and cannot be changed during operation. To change the orifice size, for example if needed due to new well conditions, the operating valve must be replaced through intervention. The present disclosure provides a variable choke gas lift valve.

[0025] In some configurations, gas lift valves, systems, and methods according to the present disclosure can include a nozzle having an adjustable stroke, a mechanism, e.g., a venturi, that cooperates with the nozzle to choke the passage of gas, and/or a mechanism to open and close the valve to completely interrupt the passage of gas when needed. In some configurations, the mechanism for opening and closing the valve is or includes a quarter turn mechanism. The electric motor can actuate either or both of the open/close mechanism and variable choke. Methods according to the present disclosure can combine both the open/close and variable choke functions to be accomplished by a single electric motor.

[0026] As shown in Figures 9-10, in some configurations, the electric gas lift valve can include a venturi sleeve, a needle, a governor, a rotational bellow, a housing, a gearbox, an electrical motor, and an encoder. The rotational bellow can be metallic. A first end of the bellow can be coupled, e.g., welded, to the housing, and an opposite second end of the bellow can be

coupled, e.g., welded, to an output shaft of the gearbox. The bellow therefore allows the electrical motor, encoder, and gearbox to be hermetically sealed against the external environment.

[0027] In some configurations, the gearbox output shaft is configured to rotate ¼ turn in each direction relative to neutral. A first end of the gearbox output shaft is coupled to the gearbox. An opposite second end of the gearbox output shaft extends beyond the second end of the bellow and is coupled to the governor. The governor can therefore rotate quarter turns along with the gearbox output shaft.

[0028] An upper portion of the governor can be at least partially spherical or ball shaped as shown. A lower portion of the governor extending from the upper portion can be generally tube shaped. The upper portion includes a through hole. When the governor is rotated such that the through hole aligns with side ports of the mandrel, gas can flow from one side to the other through the side ports and through hole. Barrier seals are disposed between the upper portion ball and the side portions to prevent or inhibit the gas from spreading outwards. When the governor is rotated a quarter turn, the through hole is not aligned with the side ports, and the ball blocks the passage of gas. This quarter turn mechanism of the gearbox output shaft and governor opens and closes the valve. This can allow the valve to be kept closed in the early production years of the well, when gas is not needed to assist production. As bottom hole pressure is reduced after years of production and gas is required, the valve can be opened without intervention, rather than using a dummy valve in the early years that must be replaced by a gas lift valve via intervention.

[0029] The lower half of the governor partially houses the needle. A portion of the needle is disposed within the venturi sleeve. The needle has a longitudinal side slot. An anti-rotation key anchored to the mandrel extends into the side slot of the needle. The needle can therefore only move axially, as rotation of the needle is constrained by the engagement of the anti-rotation key in the side slot. The needle also include a taper slot that receives a pin anchored in the lower half of the governor. As the governor rotates, the pin drives the needle to move outward/downward or inward/upward relative to the governor. The needle therefore moves toward or away from the venturi throat, thereby decreasing or increasing the flow.

[0030] In use, if the gearbox output shaft and governor ball are rotated to the open position such that the through hole of the governor ball is aligned with the side ports, the gas can flow from the annulus, through a first side port, through the through hole, through the second side port, and into a U-turn loop or transfer cavity that directs the gas toward the flow control device, for example

as shown in Figure 11. A U-turn loop can be formed using pipes, elbows, and end flanges sealed with the mandrel body, as shown in Figure 11. In other configurations, a transfer cavity can be formed via a void space in the mandrel body. After flowing through the U-turn loop or transfer cavity, the gas reaches the venturi sleeve. As the needle moves closer to and into the venturi throat, the cross-sectional area is reduced, thereby reducing the flow rate of the gas for a given pressure. After the gas passes through the venturi throat, the gas reaches the tubing zone, where the gas can mix with production fluid to lighten the fluid density and hydrostatic pressure of the fluid, allowing in situ reservoir pressure to lift the lightened liquids.

[0031] Seals are disposed on the exterior of the venturi sleeve to contain the gas in different pressure zones for different purposes. A first pressure zone is formed between upper and central seals. The first pressure zone restricts gas coming from the U-turn loop or transfer cavity so that the gas passes through taper holes formed in the venturi sleeve. A second pressure zone is formed between the central and lower seals. The second pressure zone is configured for pressure probe.

[0032] A seal must also be disposed to seal between the venturi chamber and the annulus of the governor (outside the governor, between the governor and the mandrel pocket) to prevent gas from flowing through the governor annulus and through the annulus between the ball and the inner diameter of the external pocket to the exterior of the rotational bellow. In the case of reverse flow with the valve in the closed position, the pressure in the venturi chamber could be higher or lower than the annulus pressure. The inside of the bellow and housing is the same as the annulus pressure. Depending on the pressure delta, the bellow could be damaged. A seal is therefore included between the venturi chamber and the governor annulus. As the governor rotates relative to the pocket, a dynamic mechanic seal could be used.

[0033] The taper holes in the venturi sleeve help direct gas entering the pre-venturi chamber toward the venturi throat. This can help condition the gas to a smooth flow. A side through hole in the pocket connects to the second pressure zone and can allow for measuring with a first pressure probe. A second pressure probe can be located in the annulus. The first and second pressure probes allow for measuring the gas flow rate with further post-processing.

[0034] The use of an electric actuator to control a variable orifice advantageously allows a changeable and precise flow area opening. This gives the operator flexibility with respect to the flow rate and pressure drop through the completion. The flapper back check system advantageously increases reliability for the back check sealing mechanism. The flow tube is used

as a conduit for the flow. The flow tube can therefore prevent or inhibit flow from eroding or damaging the seals or seal surfaces. The flow tube flapper back check system is more robust than a poppet style back check valve. The open/close state of the valve does not depend on the well environment. Instead, the valve is opened or closed automatically or on command of the operator. Opening or closing can be triggered with a button. In other configurations, data from pressure sensors in the tubing and/or annulus can be used to automatically trigger closure or opening of the valve. Valves and systems according to the present disclosure can advantageously be low power as the motor uses a braking system to hold in place, and a low power electro-magnet coupling is used in the fail-close mechanism. The valve or system is more reliable than existing systems, which may allow for eliminating the complexity of including a retrieval system. This can advantageously reduce cost and reduce manufacturing difficulty.

[0035] In configurations in which a single motor actuates to provide both the open/close mechanism and variable orifice adjustment, use of a single motor can help increase reliability of the system. In some configurations, the open and close function of the valve is provided by the motor shaft rotating ¼ turn in one direction, and the flow control function of the valve is provided by the motor shaft moving ¼ turn in an opposite direction. As the needle moves axially in response to a rotation of the governor without the need for a linear actuator, the system may not require an axial bellow with a large compensation system. As the needle and needle actuating mechanism are disposed in a single pressure chamber, barrier seals are not required as would normally be needed outside the chamber for the actuation mechanism. The rotational system can advantageously provide increased system reliability and improved performance against scale and debris.

[0036] Language of degree used herein, such as the terms "approximately," "about," "generally," and "substantially" as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms "approximately," "about," "generally," and "substantially" may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and/or within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms "generally parallel" and "substantially parallel" or "generally perpendicular" and "substantially perpendicular" refer to a value, amount, or

characteristic that departs from exactly parallel or perpendicular, respectively, by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.

[0037] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments described may be made and still fall within the scope of the disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with, or substituted for, one another in order to form varying modes of the embodiments of the disclosure. Thus, it is intended that the scope of the disclosure herein should not be limited by the particular embodiments described above.

CLAIMS

What is claimed is:

1. An electric gas lift valve comprising:

an electric actuator;

a back check assembly comprising a flow tube and a flapper; and

an electro-magnet fail-close mechanism.

2. The electric gas lift valve of Claim 1, further comprising a variable choke orifice.

3. The electric gas lift valve of Claim 1, further comprising a first pressure sensor configured to read tubing pressure and a second pressure sensor configured to read annulus pressure.

4. The electric gas lift valve of Claim 1, wherein the valve is configured to open or close automatically based on a pressure differential between the first and second pressure sensors.

5. An electric gas lift valve comprising:

an electric actuator; and

a variable choke.

6. The electric gas lift valve of Claim 5, further comprising a mechanism configured to open and close the valve.

7. The electric gas lift valve of Claim 6, the mechanism comprising a quarter turn mechanism.

8. The electric gas lift valve of Claim 5, the electric actuator configured to actuate opening and closing of the valve, and adjustment of the variable choke.

9. The electric gas lift valve of Claim 5, wherein the variable choke comprises:

a nozzle; and

a venturi, wherein the nozzle is adjustable relative to the venturi to choke flow of gas through the venturi.