# gas lift valve with open shear mechanism for pressure testing

## Abstract

translated from Portuguese

For gas lift, gas lift valves are installed at a completion in a well. The gas lift valve has a pressure sensitive valve and a check valve configured to control communication at the valve. A piston is held closed with a first connection relative to the valve outlet exposed to piping pressure, while the check valve is held open on the valve with a second connection. Pressure testing can be performed on the integrity of the piping and casing, increasing piping and annular space pressures while the piston remains closed. The gas lift valve is then actuated into operation by increasing the piping or annular space pressure beyond a predetermined limit of the first connection to release the piston to move open relative to the outlet. The movement of the piston releases the retention of the second connection in the check valve so that the check valve can function normally as a one-way valve.

## Classifications

E21B43/123 Gas lift valves

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**Inventor:** Zlatko Salihbegovic, Stephen Long, Lance RACCA, Brian Sternaman

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## Claims (20)

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1. Apparatus for a gas lift valve in the pipeline in a well, the gas lift valve having a pressure sensitive valve and a check valve, the pressure sensitive valve configured to control communication from an inlet towards the one outlet, the inlet exposed to one of the well annular space pressure and piping pressure, the outlet exposed to the other of the annular space pressure and the piping pressure, the check valve configured to prevent communication of the outlet in towards the inlet, the apparatus characterized by the fact that it comprises: a piston disposed between the check valve and the outlet and exposed to a pressure differential between the annular space pressure and the pipeline pressure, the movable piston in a closed condition for an open condition with respect to the output; a first connection holding the piston in the closed condition and configured to release the piston hold in response to a predetermined level of pressure differential; and a second connection connecting the piston to the check valve, the second connection with the piston in the first position holding the check valve open, the second connection with the piston in the second position releasing the check valve check to close. 2. Apparatus according to claim 1, characterized in that the piston comprises: a piston body sealed in the valve, the piston body exposed to the pressure differential between the annular space pressure in the valve and the piping pressure through a valve piping port; and a sleeve body sealed to the valve and movable from the closed condition to the open condition with respect to the outlet port, wherein the first connection connects the piston body to the sleeve body, and wherein the second connection connects the sleeve body to the check valve. 3. Apparatus according to claim 2, characterized in that the first connection comprises a rod having a first end coupled to the piston body and having a second end coupled to the sleeve body, the rod breakable in response to a load between the first and second ends caused by annular space pressure greater than the piping pressure. 4. Apparatus according to claim 2 or 3, characterized in that the second connection comprises a cable having a first end affixed to the check valve and a second end affixed to the glove body, the glove body in the closed condition holding the check valve open with the rope tension, the sleeve body in the open condition releasing the rope tension on the check valve to close. 5. Apparatus according to any one of claims 1 to 4, characterized in that the piston comprises: a glove body sealed in the valve and exposed to the pressure differential, the glove body movable from the closed condition to the open condition in relation to the output; and wherein the first connection connects the glove body to a fixed portion of the valve, and wherein the second connection connects the glove body to the check valve. 6. Apparatus according to claim 5, characterized in that the first connection comprises a stem having a first end coupled to the glove body and having a second end coupled to the fixed part of the valve, the stem breakable in response to a predetermined load between the first and second ends caused by piping pressure greater than the annular space pressure. 7. Apparatus according to claim 5 or 6, characterized in that the second connection comprises a cable having a first end affixed to the check valve and a second end affixed to the glove body, the glove body in closed condition holding the check valve open with the rope tension, the sleeve body in the open condition releasing the rope tension on the check valve to close. 8. Apparatus according to any one of claims 1 to 7, characterized in that the first connection comprises a rod having a first end coupled to the piston and having a second end coupled separately, the rod breakable in response to a predetermined load between the first and second ends caused by the pressure differential. 9. Apparatus according to any one of claims 1 to 8, characterized in that the second connection comprises a cable having a first end affixed to the check valve and a second end affixed to the piston, the piston in the closed condition maintaining the check valve open with rope tension, the piston in open condition releasing rope tension in the check valve to close. 10. Apparatus according to any one of claims 1 to 9, characterized in that the check valve comprises a dart body tensioned with a tensioning element towards a seat in the valve. 11. Apparatus according to any one of claims 1 to 10, characterized in that the piston comprises a lock that locks the piston in the open condition, once moved. 12. Apparatus according to claim 11, characterized in that the lock comprises a clamp arranged on the piston engageable with a shoulder defined on the valve. 13. Apparatus according to any one of claims 1 to 12, characterized in that the piston comprises seals that seal the outlet with the piston in the closed condition. 14. Apparatus according to any one of claims 1 to 13, characterized in that the piston comprises an opening that communicates an interior of the piston outside the piston, the misaligned opening of the output with the piston in the closed condition, the aligned opening with the output with the piston in open condition. 15. Apparatus according to any one of claims 1 to 14, characterized in that the piston comprises a tensioning element that tensions the piston from the closed condition to the open condition. 16. Apparatus according to any one of claims 1 to 15, characterized in that it further comprises a housing having the piston, the first connection and the second connection, the

housing being an integral part of the gas lift valve or being attachable separately to the gas lift valve. 17. Apparatus in the pipeline in a well, the apparatus characterized in that it comprises: a gas lift valve disposed in the pipeline and having an inlet and an outlet, the inlet exposed to an annular space pressure of the well and a pressure of piping piping, the outlet exposed to other annular space pressure and piping pressure; a pressure sensitive valve disposed on the gas lift valve and configured to control communication from the inlet towards the outlet; a check valve disposed on the gas lift valve and configured to prevent communication from the outlet towards the inlet; a piston disposed in the gas lift valve between the check valve and the outlet and exposed to a pressure differential between the annular space pressure and the piping pressure, the piston moving from a closed condition to an open condition relative to the exit door; a first connection holding the piston in the closed condition and configured to release the piston hold in response to a first predetermined level of pressure differential; and a second connection connecting the piston to the check valve, the second connection with the piston in the first position holding the check valve open, the second connection with the piston in the second position releasing the check valve check to close. 18. Apparatus according to claim 17, characterized in that the first connection is configured to release the piston retention in response to the first predetermined level of the annular space pressure greater than the piping pressure, or in which the first connection is configured to release the piston hold in response to the first predetermined level of piping pressure greater than the annular space pressure. 19. Apparatus according to claim 17 or 18, characterized in that it further comprises: a plurality of gas lift valve disposed in the pipeline; and a shearable orifice disposed in the downhole piping of the gas lift valves, the shearable orifice being configured to open in response to a second predetermined level greater than the first predetermined level. 20. Method for lifting gas in a completion column arranged in a well, the method characterized in that it comprises: configuring a gas lift valve having an inlet and an outlet retaining a piston in the gas lift valve with a first detent in a first closed condition relative to the outlet, and retaining a non-return valve on the gas lift valve with a second detent in a second open condition between the inlet and the outlet; install the gas lift valve in the completion column arranged in the well, whereby the inlet is exposed to an annular space pressure of the well and piping piping pressure, whereby the outlet is exposed to another annular space pressure and pressure of piping; test the completion pressure integrity by alternately increasing a pressure differential (i) between piping pressure versus annular space pressure and (ii) between annular space pressure versus piping pressure; and actuate the gas lift valve for operation after testing the pressure integrity by: releasing the first hold on the piston to move from the first closed condition towards a first open condition relative to the outlet, increasing the pressure differential beyond a predetermined limit of the first retention; and releasing, in response to movement of the piston, the second check valve detent to move from the second open condition towards a second closed position between the inlet and the outlet.

## Description

translated from Portuguese

GAS LIFTING VALVE WITH OPEN MECHANISM
SHEAR FOR PRESSURE TEST

### BACKGROUND OF THE DISCLOSURE

[0001] To obtain hydrocarbon fluids from a terrestrial formation, a well is drilled in an area of interest within a formation. The well can then be "completed" by inserting casing into the well and laying the casing using cement. Alternatively, the well can remain unlined as an "open hole", or it can be only partially lined. Regardless of the shape of the well, production piping runs in the well to transport production fluid (eg, hydrocarbon fluid, which can also include water) to the surface.

[0002] Often, the pressure inside the well is insufficient to cause the production fluid to naturally rise through the production pipeline to the surface. In these cases, an artificial lift system can be used to transport the production fluid to the surface. One type of artificial lift system is a gas lift system, of which there are two main types of systems: pipe recoverable gas lift systems and cable recoverable gas lift systems. Each type of gas lift system uses multiple gas lift valves spaced along the production pipeline. Gas lift valves allow gas to flow from the annular space into the production pipeline so that the gas can lift the production fluid in the production pipeline. However, gas lift valves prevent fluid from flowing in the opposite direction from the production piping to the annular space.

[0003] A typical cable recoverable gas lifting system 10 is shown in Figure 1. Operators inject compressed gas G into the annular space 22 between a column of production piping 20 and casing 24 within a sheathed well 26. valve system 12 delivers injection gas G from the surface and allows the fluid produced to exit the gas lift system 10.

[0004] Side pocket chucks 30 spaced along production column 20 maintain gas lift valves 40 within side pockets 32. As noted earlier, gas lift valves 40 are one-sided valves that allow gas flow from the annular space 22 to production column 20 and prevent reverse flow from production column 20 to annular space 22.

[0005] A production packer 14 located in the production column 20 forces the flow of production fluid P from a formation upward through the production column 20 instead of upward through the annular space 22. In addition, production filling 14 forces gas flow from annular space 22 to production column 20 through gas lift valves 40.

[0006] In operation, the production fluid P flows from the formation to the well 26 through the casing bores 28 and then flows into the production pipe column 20. When it is desired to raise the production fluid P, the compressed gas G is introduced into annular space 22, and gas G enters from annular space 22 through ports 34 in side pockets of mandrel 32. Disposed within side pockets 32, gas lift valves 40 control the flow of inject gas I in production column 20. As inject gas I rises to the surface, it helps to lift production fluid P through production column 20 to the surface.

[0007] Gas lift valves 40 have been used for many years to aid in the production of fluid to the surface. Valve 40 uses a pressure sensitive valve mechanism with a metal bellows and piston to convert pressure into motion. The injected gas acts on the bellows to open the pressure-sensitive valve mechanism, and the gas passes through valve 40 to the piping column. As the differential pressure in the bellows is reduced, the valve mechanism in valve 40 may close.

[0008] Depending on completion, other types of downhole devices can be installed in the side pocket chucks 30. For example, "dummy" valves can be installed in the side pockets 32 of the chucks 30 to allow certain pressure tests to be performed. These dummy valves are not really valves because they merely sit on the mandrels 30 to seal the mandrel ports 34, acting as isolation devices.

[0009] With dummy valves installed, for example, the integrity of the piping and casing of the completion can be tested at high pressures. After testing, the dummy valves are removed and replaced with live gas lift valves 40. Typically, cable intervention is used to remove the dummy valves from the chucks 30 and then install the live gas lift valves 40 in chucks 30. Cable intervention can be time-consuming, technically challenging and expensive, particularly in offshore applications.

[0010] The subject matter of the present disclosure is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

### DISCLOSURE SUMMARY

[0011] According to the present disclosure, an apparatus is used for a gas lift valve in the pipeline in a well. The gas lift valve has a pressure sensitive valve and a check valve. The pressure sensitive valve is configured to control communication from an input to an output. The inlet can be exposed to one annular space pressure and one well piping pressure, and the outlet can be exposed to another annular space pressure and piping pressure.

[0012] For example, the gas lift valve can be configured for a pipe flow application. As such, the inlet would be exposed to annular space pressure, and the outlet would be exposed to piping piping pressure. In turn, the check valve is configured to prevent communication from the output to the input. Alternatively, the gas lift valve can be configured for an annular space flow application. As such, the inlet would be exposed to piping pressure, and the outlet would be exposed to annular space pressure.

[0013] The apparatus comprises a piston, a first connection, and a second connection. The piston is disposed between the check valve and the outlet and is exposed to a pressure differential between the annular space pressure and the piping pressure. The piston is movable from a closed condition to an open condition with respect to the output.

[0014] The first connection holds the piston in the closed condition and is configured to release the piston hold in response to a predetermined level of pressure differential. The second connection connects the piston to the check valve. The second connection with the piston in the first position holds the check valve open, while the second connection with the piston in the second position releases the check valve check to close.

[0015] In one configuration, the piston comprises a piston body and a sleeve body. The piston body is sealed to the valve and exposed to the pressure differential between the annular space pressure in the valve and the piping pressure through a valve piping port. The sleeve body is sealed to the valve and is movable from closed to open condition with respect to the outlet port. The first connection connects the piston body to the sleeve body, and the second connection connects the sleeve body to the check valve.

[0016] The first connection may include a rod having a first end coupled to the piston body and having a second end coupled to the sleeve body. The rod may be breakable in response to a predetermined load between the first and second ends caused by annular space pressure greater than the piping pressure. The second connection may include a cable having a first end affixed to the check valve and a second end affixed to the glove body. The sleeve body in the closed condition holds the check valve open with cable tension, while the sleeve body in the open condition releases the cable tension on the check valve to close.

[0017] In another configuration, the piston comprises a sleeve body sealed to the valve and exposed to the pressure differential. The glove body is movable from the closed condition to the open condition in relation to the output. The first connection connects the sleeve body to a fixed portion of the valve, and the second connection connects the sleeve body to the check valve.

[0018] Again, the first connection may include a stem having a first end coupled to the glove body and having a second end coupled to the fixed portion of the valve. The rod may be breakable in response to a predetermined load between the first and second ends caused by piping pressure greater than the annular space pressure. Additionally, the second connection may include a cable having a first end affixed to the check valve and a second end affixed to the glove body. The sleeve body in the closed condition holds the check valve open with cable tension, while the sleeve body in the open condition releases the cable tension on the check valve to close.

[0019] In a number of variations, the check valve may include a dart body tensioned with a tensioning element towards a seat in the valve. The piston may include a lock locking the piston in the open condition once moved. For example, the latch may include a caliper disposed on the piston that is engageable with a shoulder defined on the valve.

[0020] In additional variations, the piston may include seals sealing the outlet with the piston in the closed condition. The piston may include an opening which communicates an interior of the piston outside the piston, the opening being offset from the outlet with the piston in the closed condition and being aligned with the outlet with the piston in the open condition. The piston may include a tensioning element directing the piston from the closed condition to the open condition.

[0021] The apparatus may further comprise a housing having the piston, the first connection, and the second connection. The housing can be integrated with the gas lift valve or can be attached separately to the gas lift valve.

[0022] According to the present disclosure, an apparatus is used in piping in a well. The apparatus comprises a gas lift valve disposed in the pipeline and having an inlet and an outlet. The inlet can be exposed to one annular space pressure and one well piping pressure, and the outlet can be exposed to another annular space pressure and piping pressure. For example, the gas lift valve can be configured for a pipe flow application. As such, the inlet would be exposed to annular space pressure, and the outlet would be exposed to piping piping pressure.

[0023] A pressure sensitive valve arranged on the gas lift valve is configured to control communication from the inlet towards the outlet, and a check valve disposed on the gas lift valve is configured to prevent communication from the outlet towards the outlet. The entrance.

[0024] A piston is disposed in the gas lift valve between the check valve and the outlet and is exposed to a pressure differential between the annular space pressure and the piping pressure. The piston is movable from a closed condition to an open condition with respect to the output port.

[0025] The first connection holds the piston in the closed condition and is configured to release the piston hold in response to a first predetermined level of pressure differential. The second connection connects the piston to the check valve. The second connection with the piston in the first position holds the check valve open, while the second connection with the piston in the second position releases the check valve check to close.

[0026] The piston, the first connection, and the second connection may have any of the features described above. Again, the first connection may be configured to release the piston hold in response to the first predetermined level of annular space pressure greater than the piping pressure, or the first connection may be configured to release the piston hold in response to the first predetermined level of piping pressure greater than the annular space pressure.

[0027] The apparatus may further include a plurality of gas lift valve disposed in the pipeline. Indeed, the apparatus may further include a shearable orifice disposed in the downhole piping of the gas lift valves. The shearable hole is configured to open in response to a second predetermined level greater than the first predetermined level.

[0028] The present disclosure discloses a method for lifting gas in a completion column disposed in a well. A gas lift valve having an inlet and an outlet is configured by retaining a piston in the gas lift valve with a first check in a first closed condition relative to the outlet, and retaining a check valve in the gas lift valve with a second hold in a second open condition between input and output. The gas lift valve is installed in the completion column arranged in the well. The inlet can be exposed to one annular space pressure and one well piping pressure, and the outlet can be exposed to another annular space pressure and piping pressure. For example, the gas lift valve can be configured for a pipe flow application. As such, the inlet would be exposed to annular space pressure, and the outlet would be exposed to piping piping pressure.

[0029] The method comprises testing the completion pressure integrity by alternately increasing a pressure differential (i) between the piping pressure relative to the annular space pressure and (ii) between the annular space pressure relative to the pipeline pressure . The gas lift valve is actuated for operation after testing the pressure integrity by: releasing the first hold on the piston to move from the first closed condition towards a first open condition relative to the outlet by increasing the pressure differential beyond a limit predetermined of the first retention; and releasing, in response to movement of the piston, the second check valve detent to move from the second open condition towards a second closed position between the inlet and the outlet.

[0030] Installing the gas lift valve in the completion column arranged in the well may comprise the implantation of the gas lift valve with cable or implanting the gas lift valve in the pipeline.

[0031] Testing the completion pressure integrity may comprise first increasing the piping pressure relative to the annular space pressure followed by increasing the annular space pressure relative to the piping pressure. Therefore, actuating the gas lift valve may comprise releasing a temporary connection to the piston, increasing the pressure differential of the annular space pressure with respect to the piping pressure beyond the predetermined limit to release the temporary connection.

[0032] Testing the completion pressure integrity may comprise first increasing the annular space pressure relative to the pipeline pressure followed by increasing the pipeline pressure relative to the annular space pressure. Therefore, actuating the gas lift valve may comprise releasing a temporary connection to the piston, increasing the pressure differential of the piping pressure with respect to the annular space pressure beyond the predetermined limit to release the temporary connection.

[0033] The foregoing summary is not intended to summarize each potential modality or all aspects of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Figure 1 illustrates a conventional gas lift system.

[0035] Figures 2A-2B illustrate a gas lift chuck without and with a gas lift valve of the present disclosure installed.

[0036] Figure 2C illustrates a completion having gas lift valves in accordance with the present disclosure.

[0037] Figure 3 illustrates a gas lift valve having a first activation assembly in accordance with the present disclosure.

[0038] Figures 4A-4B illustrate details of the first activation set during the stages of operation.

[0039] Figure 5 illustrates a gas lift valve having a second activation assembly in accordance with the present disclosure.

[0040] Figures 6A-6B illustrate details of the second set of activation during the stages of operation.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0041] Referring to Figures 2A-2B, a gas lifting chuck 60 is installed in a completion column 20 of a well completion. Mandrel 60 is shown without and with a gas lift valve 100 of the present disclosure installed. As shown here, the gas lift valve 100 is cable retrievable, but the teachings of the present disclosure may apply to other types of valves, such as retrievable piping valves when used with an appropriate mandrel and piping operating procedures. Gas lift valve 100 includes an activation assembly 200 in accordance with the present disclosure. Activation set 200 is initially in a closed condition, but is configured to open once activated, as discussed below.

[0042] While the activation assembly 200 is in the closed condition, the valve 100 can be passed to the tubing needle 20 by cable and can be inserted into the side pocket 64 of the mandrel 60. A latch 101 of the valve 100 engages a profile 65 in the side pocket 64 to retain the valve 100 in it. Gasket seals 114a-b on valve 100 isolate fluid communication between a port 66 on mandrel 60 and a valve port 116 on valve 100.

[0043] Valve 100 with activation set 200 may be a discharge type of gas lift valve used for a typical pipeline flow application. In this case, as will be described throughout the present disclosure, the gas is injected below the annular space 22 in order to enter the pipe 20 through the mandrel 60 and the gas lift valve 100, so that the injected gas can then , raise the production fluid onto line 20. Alternatively, valve 100 with activation set 200 can be used in the annular space flow configuration in which gas is instead injected into line 20 in order to enter the annular space 22 through the gas lift valve 100 and the mandrel 60 so that the injected gas can then lift the production fluid into the annular space 22. Although the annular space flow configuration is less common, it is applied in certain circumstances. To achieve the annular space flow configuration, the features and operation of the disclosed valve 100 and activation assembly 200 are essentially reversed, and a different form of gas lift chuck can be used. In general, the inlet of gas lift valve 100 is exposed to tubing 20 instead of annular space 22, while the output of gas lift valve 100 is exposed to annular space 22 instead of tubing 20. The Activation Assembly 200 operates with the pressure differential between inlet and outlet to set the active opening of valve 100.

[0044] Rather than being conventional, the gas lift valve 100 is configured to remain closed during installation and during initial completion testing. Therefore, once valve 100 is installed, activation assembly 200 keeps valve 100 closed so that pressure testing can be performed. For example, piping pressure TP can be increased in piping string 20 to test piping integrity, and annular space pressure TP can be increased to test liner integrity.

[0045] Upon completion of the test, valve 100 can be opened when ready to inject gas through the side pocket chuck 60 and valve 100 for inlet to tubing 20 of the completion column. In particular, the gas lift valve 100 is configured to open to a predetermined pressure so that the valve 100 can be used for gas injection. Therefore, cable intervention to remove a dummy valve and replace it with a live gas lift valve is not necessary to test completion integrity as required in conventional practice. To achieve the configured opening of valve 100, valve 100 includes activation set 200 to control the initial activation of gas lift valve 100. Details of activation set 200 are discussed later.

[0046] An example completion assembly 50 is shown in Figure 2C having multiple gas lift valves 100 installed in a completion column 20 disposed in casing 24 of a well. Each of the gas lift valves 100 is installed on a gas lift mandrel 60 in the completion column 20, and each of the valves 100 has an activation assembly 200 to control the initial activation of the gas lift valve 100.

[0047] Multiple gas lift valves 100 can be used in conjunction with a shear orifice valve 70 installed at the deepest point in completion assembly 50. The shear orifice valve 70 has an open shear mechanism for opening a pressure higher than the activation pressure for activation set 200 on gas lift valves 100. An example of such a shearable orifice valve 70 is the "RDDK-2A Shearable Orifice Gas Lift Valve" available from Weatherford International, Inc.

[0048] Activation sets 200 allow casing 24, pipe column 20 and other components (eg, packings) at well completion 50 to be tested. Then, once activated open, the open sets 200 allow gas lift operations to continue without cable intervention. Different settings can be used for activation.

[0049] In one configuration, the activation sets 200 of valves 100 are configured to open after testing in response to the increase of annular space pressure AP in annular space 22. As used in this document, "annulus space pressure" AP se refers to the pressure in the annular space 22 between the piping 20 and the well casing 24. In contrast, "pipe pressure" TP refers to the pressure in the piping of the completion string 20 in the well.

[0050] During testing in this configuration, for example, piping 20 and annular space 22 are filled with completion fluid, which creates hydrostatic pressure on each inlet and outlet side of valves 100. Operators first perform a test of piping increasing the TP piping pressure to a defined test pressure. This tests the integrity of the 20 completion column piping. Operators then purge the TP piping pressure.

[0051] At this point, operators increase the annular space pressure AP to apply a test pressure fit to the annular space 22 of the surface. This increase in AP annular space pressure tests fillings (not shown) and casing 24 of completion 50 creating a pressure differential between casing 24 and tubing 20.

[0052] With the integrity of the coating tested, the annular space pressure AP is then increased to a predetermined first level above the established test pressure to open the activation assemblies 200 of the gas lift valves 100. The annular space pressure AP is then further increased to a second, higher predetermined level to open the shearable orifice valve 70.

[0053] Once the annular space pressure AP reaches the opening pressure differential of the shearable orifice valve 70, the annular space and piping pressures AP, TP throughout the well will equalize. With the pressures AP, TP then equalized, the gas lift valves 100 are now in an open condition and ready for gas injection operations.

[0054] In another configuration, the activation sets 200 of the gas lift valves 100 are configured to open after the test in response to the increase in piping pressure TP. (This installation cannot use the shear orifice valve 70 at completion 50.) During testing, for example, tubing 20 and annular space 22 are filled with completion fluid, which creates hydrostatic pressure on each side of valves 100 Operators first perform a coating integrity test by increasing the annular gap pressure AP of the surface to a defined test pressure. This increase in annular space pressure AP tests any fillings and tests casing 24 of completion 50 creating a pressure differential in annular space 22 relative to tubing 20. Annular space pressure AP is then purged.

[0055] Operators then increase the TP piping pressure to a predetermined level that opens the activation sets 200 of the gas lift valves

100. Although valves 100 are now open, certain check valves (eg, check valve 160 in Figures 3 and 4A-4B) in gas lift valves 100 will close and prevent the reverse flow of pressure from line 20 to the annular space 22. Operators now test piping integrity by increasing the TP piping pressure to a certain test level. The TP piping pressure is then purged, and the activating devices for the gas lift valves 200 are now in an open condition and ready for gas injection.

[0056] Having an understanding of how an activation set 200 of the present disclosure is used in a gas lift valve 100 in a completion set 50, the discussion now turns to particular details of the different configurations of the activation set 200.

[0057] Referring to Figure 3, a gas lift valve 100 having an activation assembly 200 according to a first configuration is shown in cross section. As shown, valve 100 is a discharge type of gas lift valve, and activation assembly 200 is configured to open valve 100 in response to increased annular space pressure (i.e., the pressure that can enter the valve 100 through its injection ports 116).

[0058] The valve 100 includes a housing 110 having stacks of gaskets 114a-b disposed around and having the activation assembly 200 disposed toward the outlet side of the valve. Gasket stacks 114a-b provide a seal that isolates annular space and piping pressures when installed in a typical side pocket gas lift chuck such as chuck 60 of Figures 2A-2C. In this way, the valve 100 of Figure 3 executed on the mandrel (60) is exposed to the annular pressure through the injection ports 116. Thus, when the term "annulus pressure" is used in reference to the valve 100, it means the pressure communicated within of valve 100. Reference to piping pressure, however, refers to the pressure in the completion column to which the outlet of valve 100 is exposed.

[0059] Internally, valve 100 uses a pressure sensitive valve mechanism to control gas injection. In particular, valve 100 has a dome chamber 120 and a bellows 135 which tensions a valve piston 130 in valve 100 to control the flow of injected gas entering from valve port 116 to an injection passage 115 within valve 100 The dome chamber 120 contains a compressed gas, typically nitrogen, which is filled through a port 113 on an upper member 112. This port 113 usually has a center valve (not shown) to fill the chamber 120 and usually has a plug. additional tail (not shown) installed during assembly. (Various other components of the valve 100, such as a latch connected to the top end, are not shown but would be present, as one skilled in the art would appreciate.)

[0060] The bellows 135 is disposed on the valve piston 130 in an auxiliary chamber 124 separated from the dome chamber 120 by a chamber seat 122. The bellows 135 separates the compressed gas in the dome chamber 120 from communication with the valve port 116 and the injection passage 115 so that pressure can be maintained in the chamber 120. Therefore, the valve 100 uses this bellows 135 as the membrane between the dome chamber 120 and the annular space injection pressure that opens the valve 100.

[0061] Looking at valve piston 130 in more detail, valve piston 130 can move between open and closed conditions in valve 100. Opposite bellows 135, valve piston 130 has a distal end 140 that moves in relation to an internal seat 150 of the accommodation

110. The distal end of the piston 140 has a valve head 142, which may be spherical in shape to engage the seat 150. By controlling the flow of injected gas, the valve head 142 at the distal end of the piston 140 engages or disengages the seat 150 for closing and opening communication from valve port 116 to injection passage 115.

[0062] To prevent reverse flow of piping to the annular space through valve 100, a check valve 160 is used in the injection port 115 of valve 100. As is typical, check valve 160 may be a dart valve with ports 162. A spring 166 tensions check valve 160 toward a seat 164, which may have an elastomeric component and a retainer, although other types of seals may be used.

[0063] Instead of having a conventional outlet for passing injected gas directly out of the valve 100 of the injection passage 115 to a completion column (not shown), the valve 100 of Figure 3 includes the activation set 200 installed in the outlet end of valve 100 to control initial fluid communication from injection passage 115 out of valve 100. Activation assembly 200 modifies initial operation of valve 100 in a manner described later.

[0064] In general, the activation assembly 200 can be attached/threaded to the end of the gas lift valve 100 in place of a conventional nose. As will be appreciated, activation assembly 200 can be adapted to fit standard gas lift valves and to be used on standard gas lift chucks. For example, activation assembly 200 may be a module threaded into a gas lift valve gasket housing component 170

100. As discussed in more detail later, activation assembly 200 is configured to initially remain closed for completion integrity testing and is configured to open to a predetermined pressure after integrity tests have been completed, so that valve 100 can be opened for gas injection.

[0065] In regular operation, however, injected gas passing to valve 100 through injection ports 116 above an injection pressure may overcome the tensioning of valve piston 130. Injected gas may pass to the injection passage. injection 115 when the valve head 142 is distanced open from the seat 150. The injected gas can then overcome the tension of the reverse check valve 160 and can exit the injection ports 204 to enter the completion piping for the lifting operation of gas.

[0066] Before such regular operation can be performed, however, the activation set 200 that modifies the initial operation of valve 100 must first be opened. Detailed views of the activation set 200 are shown in a closed condition in Figure 4A and an open condition in Figure 4B. (Piston rod end 140 is not shown with any particular operating position in Figures 4A-4B and is merely shown in a given position for illustrative purposes. As will be appreciated, piston rod end 140 will move open and closed depending on of the piston exposure to the annular pressure relative to the dome pressure in the piston chamber.)

The activation assembly 200 includes a piston housing 202 affixed to the gasket housing 170 of the valve 100. In fact, the piston housing 202 can retain the lower gasket stack 114b in the gasket housing

170. The piston housing 202 has outlet ports 204 communicating the interior of the housing 202 to the outside of the assembly 200 for gas injection from the valve 100 to the completion column. The piston housing 202 also has a nose 206 affixed to its end having a tubing pressure port 208.

[0068] Internally, housing 202 contains a piston sleeve or sleeve body 210 movable in housing 202 from a closed condition (with openings 214 misaligned with outlet ports 204 as shown in Figure 4A) to an open condition (with openings 214 aligned with the output ports 204 as shown in Figure 4B). The piston sleeve 210 includes seals 213 sealing the outlet ports 204 when the sleeve 210 is in the closed condition of Figure 4A. The piston sleeve 210 also includes a collet 216 or other form of lock for engaging a lock profile on the piston housing 202 or elsewhere, such as a lock profile 176 on the gasket housing 170, as shown in Figures 4A -4B.

[0069] A spring 218 tensions the piston sleeve 210 from the closed condition (Figure 4A) to the open condition (Figure 4B), but a temporary connection 230 affixed to an activating piston or piston body 230 in the assembly 200 prevents movement of piston sleeve tensioning 210. (Temporary connection 230 is shown here as a fracture or shear rod. As will be appreciated, temporary connection 230 may use other shearable or breakable connections.)

[0070] As shown, the piston sleeve 210 sealed in the housing 202 with the seals 213 is exposed to a pressure differential between the annular space pressure (through the piston housing 202) and piping pressure (through the outlet ports 204). As also shown, actuation piston 220 sealed in nose 206 with seals 223 is exposed to a pressure differential between annular space pressure (through piston housing 202) and piping pressure (through piping pressure port 208). Fracture rod 230 has a breakable split or portion 235 configured to break/fracture under a predetermined load caused by the pressure differential (and the added tension of spring 218).

[0071] Once valve 100 is installed and before regular operation can begin, pressure integrity tests can be performed as described above. With the assembly 200 in its initial condition, as in Figure 4A, for example, the piping integrity is tested first. The pressure in the completion piping is increased to a predetermined test pressure while the piston sleeve 210 remains held in its closed condition. The differential pressure between the piping and the annular space pressures (AP, TP) act in the effective area between the lower and upper seals 213 (eg O-rings) in the piston sleeve 210. The differential pressure also acts on the piston of activation 220, but set 200 does not open during this testing phase. After the piping test is done, the assembly 200 remains in the closed position.

[0072] The next step is to test the casing annular space pressure to a first predetermined pressure. This allows the differential between the annular space and piping pressures (AP, TP) to act over the entire area of the lower piston 220. Once the liner is tested to the predetermined pressure, the assembly 200 is activated by increasing the pressure in the valve 100, which is the completion annular space pressure. On the surface, for example, an operator increases pressure in the annular space around the completion string, but not within the completion string. Annular space pressure (AP) is increased to a predetermined burst pressure of fracture rod 230.

[0073] In particular, the annular space pressure increase AP can pass through the injection ports 116, through the open piston 130, past the open check valve 160, and into the activation assembly 200. Meanwhile, the sleeve 210 in the piston housing of assembly 202 is held closed by fracture rod 230 coupled to activation piston 220. Activation piston 220 is in turn exposed on its upper bore side to increasing annular space pressure (AP) within of the piston housing 202 and is exposed on its downhole side through the piping port 208 to the lower piping pressure (TP) present in the completion string.

[0074] By increasing the annular pressure (AP) in relation to the piping pressure (TP), the activation piston 220 is pushed down in relation to the other parts of the valve

100. When the force pushing piston 220 is great enough, fracturing rod 230 is stretched until it fails at its breaking point 235, causing fracturing rod to fail

230. When liner pressure is vented, spring 218 within piston housing 202 is then able to push inner sleeve 210 so that openings 214 in sleeve 210 align with ports 204 in piston housing

210. At this point, valve 100 is in fluid communication, through the side pocket mandrel, with the interior of the completion column.

[0075] As the well equalizes, however, a column or cable 240 connected to the piston sleeve 210 and the check valve 160 keeps the check valve 160 momentarily in the open position, allowing the annular space pressure (AP ) evacuate the area between the check valve 160 and the lower piston sleeve 210. This function is desired because the pressure trapped in the area between the check valve 160 and the piston housing 170 can act on the greater net force of the sealing area of the piston and prevent the piston sleeve 210 from shifting to the open position.

[0076] Once the well equalizes, spring 218 forces piston sleeve 210 to the open condition as shown in Figure 4B, allowing tongs 216 to lock onto coupling shoulder 176 on gasket housing 170. piston sleeve 210 is displaced, clearance in cable 240 allows check valve 160 to function normally as a spring loaded one-way valve.

[0077] With the piston sleeve 210 in the locked and open condition, as shown in Figure 4B, the flow passages 214, 204 are aligned in the piston sleeve 210 and in the housing 202 allowing the passage of the injected gas. In this way, lift gas can enter liner valve 100 through ports 116 to the piping through ports 204, thus allowing the discharge and production process to begin without cable intervention.

[0078] Although a 230 shear or fracture rod is disclosed, it is possible to use other types of shear or breakable connections. For example, although rod 230 is configured to break in response to a longitudinal load, shear pins, screws or other temporary connections can be used and configured to break due to a lateral or shear load.

[0079] Interconnecting cable 240 may be intended to remain within valve 100 during operations, provided cable 240 does not interfere with operation of check valve 160 or the flow of injection gas out of valve 100. Alternatively , cable 240 can be composed of a material that is degradable, dissolvable, or disintegratable over time in response to certain environmental conditions. For example, cable 240 can be composed of a reactive metal alloy, such as an aluminum-based alloy or a magnesium-based alloy, or it can be composed of a degradable plastic material such as polyglycolic acid (PGA), polylactic acid ( PLA) or similar.

[0080] Although described above as a cable 240 using tension and clearance to temporarily hold the check valve 160 open, other forms of connection can connect the piston sleeve 210 to the check valve 160 to keep the check valve 160 open and, then release the check valve check 160. For example, the connection 240 may be a rigid rod of a certain length that holds the check valve 160 open, as long as the piston sleeve 210 is closed. Displacement of piston sleeve 210 open may allow check valve 160 to open, but the difference in displacement between the two may break rigid rod 240 in one or more places. Broken stem 240 may remain in valve 100 or may be composed of a material that is degradable, dissolvable, or disintegratable. These and other forms of connection 240 can be used between the piston sleeve 210 and the check valve.

160.

[0081] Referring to Figure 5, a gas lift valve 100 having an activation assembly 200 according to a second configuration is shown in cross section. Valve 100 is similar to that disclosed above with respect to Figures 3 and 4A-4B, so that like reference numerals are used for like components.

[0082] As before, valve 100 in Figure 5 is a discharge type gas lift valve. Valve 100 is installed on a typical gas lift chuck, and packing stacks 114a-b provide a seal that isolates annular space and piping pressures. The valve 100 includes a housing 110 having stacks of gaskets 114a-b disposed around it and having the activation assembly 200 disposed toward the outlet side of the valve. Gasket stacks 114a-b provide a seal that isolates annular space and piping pressures when installed in a typical side pocket gas lift chuck such as chuck 60 of Figures 2A-2C.

[0083] The activation assembly 200 is installed at the outlet end of the valve 100 to control initial fluid communication from the injection passage 115 to the outside of the valve 100. Rather than being configured to open in response to an annular space pressure increased

(i.e., the pressure that can enter valve 100 through its injection ports 116), activation assembly 200 of Figure 5 is configured to open valve 100 in response to increased piping pressure (i.e., pressure to which the output of valve 100 is exposed).

[0084] Detailed views of the activation set 200 are shown in a closed condition of Figure 6A and an open condition of Figure 6B. (Piston rod end 140 is not shown with any particular operating position in Figures 6A-6B and is merely shown in a given position for illustrative purposes. As will be appreciated, piston rod end 140 will move open and closed depending on of the piston's exposure to the pressure relative to the dome pressure in the piston chamber.)

The activation assembly 200 includes a piston housing 202 affixed to the gasket housing 170 of the valve 100. The piston housing 202 has outlet ports 204 communicating the interior of the housing 202 to the outside of the assembly 200 for gas injection from the valve for piping a completion. The piston housing 202 also has a closed nose 206 affixed to its end.

[0086] Internally, housing 202 contains a piston sleeve or sleeve body 210 movable in housing 202 from a closed condition (with openings 214 misaligned with outlet ports 204 as shown in Figure 6A) to an open condition (with openings 214 aligned with the output ports 204 as shown in Figure 6B). The piston sleeve 210 includes seals 213 sealing the outlet ports 204 when the sleeve 210 is in the closed position of Figure 6A. The piston sleeve 210 also includes a collet 216 or other form of lock for engaging a lock profile on the piston housing 202 or elsewhere, such as on the lock profile 176 on the gasket housing 170, as shown in Figures 6A- 6B.

[0087] A spring 218 tensions the piston sleeve 210 from the closed condition (Figure 6A) to the open condition (Figure 6B), but a temporary connection 230 (eg, a fracture rod) affixed to the housing 202 by means of a 250 anchor prevents piston sleeve tensioning movement

210. As shown, piston sleeve 210 sealed in housing 202 with seals 213 is exposed to a pressure differential between annular space pressure (through piston housing 202) and piping pressure (through outlet ports 204) . Fracture rod 230 has a breakable split or portion 235 configured to break/fracture under a predetermined load caused by the pressure differential (and the added tension of spring 218).

[0088] Once valve 100 is installed and before regular operation can begin, pressure integrity tests can be performed as described above. With the assembly 200 in its initial condition, as in Figure 6A, for example, the coating integrity is tested first. Pressure is applied to the annular lining space of the test wellbore. The force of the annular space pressure (AP) acts on piston sleeve 210, which will hold piston sleeve 210 in the closed position of Figure 6A.

[0089] Once the annular space pressure test is completed, the annular space pressure (AP) is released. As the annular space pressure (AP) is released, the column or connected cable 240 maintains the spring-loaded check valve 160 in the open position, thus allowing the pressure between the check valve 160 and the nose 206 of the assembly 200 to be evacuated. This function is desired because the pressure trapped in the area between the check valve 160 and the nose 206 can act on the greater net force of the piston seal area (upper and lower seals 213) and prevent the piston sleeve 210 from opening during piping shear operation discussed below.

[0090] After the casing pressure test, the next step is to test the integrity of the pipe. Piping pressure (TP) is increased to a test level to test the integrity of the completion piping. Fracture rod 230 can be configured to break at a pressure differential greater or less than the planned pipe test. Either way, the increase in piping pressure can reach the burst pressure of the fracture rod 230.

[0091] In a multiple gas lift valve completion, all activation sets 200 can be designed to open relative to the same differential pressure. However, as each fracture rod 230 breaks, piston sleeve 210 travels in the up position. As this occurs, tension on connecting cable 240 is released and allows check valve 160 to move to the closed position. As the check valves 160 change to the closed position after each individual set 200 shears, the piping pressure can be increased by some amount above the projected shear value. This can help ensure that all assemblies 200 of the multiple gas lift valves 100 are moved to the open position.

[0092] After the pipe shear operation is completed, the piston sleeve 210 changes to the up position allowing the piston ports 214 to be aligned with the output ports 204 in the housing 202 and thus allow the passage of the injected gas. The piston sleeve 210 is held in the open condition by tongs 216 which interlock at the coupling shoulder 176 on the gasket housing 170.

[0093] After the piston sleeve 210 is displaced, the slack in the cable 240 allows the check valve 160 to function normally as a spring loaded one-way valve. Therefore, the check valve 160 can prevent the increased piping pressure TP from communicating out of the gas lift valve 100 so that further piping integrity tests can be performed. After the above operations, the gas lift valve 100 is ready for regular operation in which the lift gas can enter valve 100 from the casing to the pipeline through port 116 to the pipeline through ports 204, thus allowing the process to unloading and production starts without cable intervention.

[0094] Although a 230 shear or fracture rod is disclosed, it is possible to use other types of shear or breakable connections. For example, although rod 230 is configured to break in response to a longitudinal load, shear pins, screws or other temporary connections can be used and configured to break due to a lateral or shear load.

[0095] Again, interconnect cable 240 may be intended to remain within valve 100 during operations, or may be composed of a material that is degradable, dissolvable, or disintegratable over time in response to certain environmental conditions. In addition, other forms of connection 240 may connect piston sleeve 210 to check valve 160 to hold check valve 160 open and then release the check valve check 160.

[0096] The foregoing description of preferred embodiments and other embodiments is not intended to limit or restrict the scope or applicability of the inventive concepts conceived by the Applicants. It will be appreciated with the benefit of the present disclosure that the resources described above in accordance with any modality or aspect of the disclosed subject may be used, alone or in combination, with any other resource described, in any other modality or aspect of the disclosed subject.

[0097] In exchange for the disclosure of the inventive concepts contained herein, the Applicants desire all the patent rights conferred by the appended claims. Therefore, the appended claims are intended to include all modifications and alterations to the fullest extent that fall within the scope of the following claims or their equivalents.

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## Concepts

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