TESTING GAS LIFT EQUIPMENT FOR OFFSHORE APPLICATIONS PROVES SYNERGISTIC TO LAND BASED APPLICATIONS

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ABSTRACT

In many industries, technology improvements in high-end devices eventually improves performance in similar lower cost devices. The same is true in that gas lift equipment development for deepwater gas lift applications can help improve gas lift equipment designs used in land-based gas lift wells. Today's standards and client specifications for deepwater gas lift equipment requires extraordinary demands on equipment. The cost of intervention in deepwater installations due to an equipment failure is extremely high, so the cost is justified. One would think that deepwater gas lift applications are a separate technology pool from standard land applications, but this is not necessarily the case. One example is that high-injection pressure gas lift applications are becoming more popular in United States land gas lift applications. Booster compressors are being used for higher gas lift injection pressures to produce higher fluid rates. The injection pressures and injection volumes applied are like deepwater offshore high-pressure gas lift applications. Extensive testing to determine the actual pressure ratings and cycle life of a gas lift valve are also of paramount importance in deepwater applications. The testing and learnings of equipment required for deepwater, high-pressure gas lift applications can be of tremendous value to the development of standard-injection, pressure-operated gas lift equipment designs, materials selection, and supplier selection. This paper is the result of approximately 10 years of research and development for deepwater gas lift applications which has helped an equipment supplier improve equipment offerings for land-based gas lift applications.

INTRODUCTION

The major testing methods of gas lift equipment for deepwater certified equipment listed in API 19G2 include interface testing, insertion testing, probe and travel testing, load-rate testing, flow testing, back-check testing, open-and-close testing, actuation-lifecycle testing, erosion testing, shelf testing, and port/seat leakage-rate testing. This paper will focus on actuation lifecycle testing, open-and-close testing, dynamic-chatter testing, check-valve testing, and a new gas lift valve concept developed for high-pressure gas lift applications.

ACTUATION LIFE CYCLE TESTING

Actuation lifecycle testing is a procedure in which seven gas lift valves are pressurized to a specific dome pressure, put in a cycle tester, and fully opened and closed repeatably until the bellows in each test gas lift valve fails. The mean time before failure is determined from the overall testing results of the batch of seven gas lift valves. The purpose of this test is to measure the longevity of the gas lift valve operation over a time. The mechanical features affecting the cycle life are the quality of the bellows and how the bellows are packaged in the gas lift valve. The findings on the quality of the bellows range from each supplier and even vary based on the specific size from each supplier. By qualifying each supplier’s specific size of bellows based on cycle test data, a gas lift valve manufacturer can ensure the best quality of bellows is being utilized and the gas lift valve design is adequate to provide ample cycles to unload and produce a well over time.

Figure 1 - Actuation Life Cycle Tester

ACTUATION LIFE CYCLE GENERALIZED RESULTS

Test #	Test Objective	Result
1	API V1 validation	OK
2	failure investigation	Inferior
3	API V1 validation	Great
4	Qualification at max pressure rating	OK
5	API V1 validation	Good
6	Special Applications Test	Good
7	Special Applications Test	Good
8	API test Alternate Material	OK
9	API test	Questionable
10	Special Applications Test	Great
11	Special Applications Test	Great
12	API test	OK
13	Customer Specific Test	Questionable
14	API test	Great
15	Special Applications Test	Questionable
16		Questionable
17	API Validation Test	Great

SUBMERGENCE DIFFERENTIAL TESTING

The submergence-differential rating is the maximum pressure that can be exerted on the outside of the gas lift valve and still maintain a reasonable cycle life thereafter. For example, in many cases an operator will complete a well in a manner which requires pressure to be applied to the casing or the tubing to verify the completion integrity. Pressure applied to the surface plus the hydrostatic pressure is exerted on the outside of the gas lift valve compressing the bellows to the maximum opening position and causing high-differential pressure from the outside to the inside of the bellows. An injection-pressure operated (IPO) gas lift valve has in internal dome charge with nitrogen which regulates the injection pressure once the completion fluid is evacuated. There are different mechanical features and designs on an IPO gas lift valve that allow higher differential-submergence pressures such as internal bellows protection. Cost is the contributing factor which differentiates deepwater and land-based gas lift operations. A typical standard gas lift valve used on land-based gas lift applications has a submergence-differential rating of approximately 5,000 psi to 6,000 psi. Technology exists to allow exceptionally high differential submergence and differential pressure of approximately 10,000 psi, but the cost for this type of equipment is a multiple of approximately twenty times the standard IPO gas lift valves used in land-based gas lift applications. However, the testing done to qualify distinct technologies for specific economic criteria has gained awareness for the issue and driven better technology for land-based gas lift applications.

OPEN-AND-CLOSE TESTING

Open-and-close testing is conducted by charging an IPO gas lift valve to a specific dome pressure and then open and closing the valve in a systematic manner such that the mechanical performance (opening-and-closing) of the valve can be verified. A gas lift design defines the port size, dome pressure, and placement of a gas lift valve in a well. The gas lift design assumes the valve will open at a specified opening pressure then close at a specified closing pressure. If the valve doesn't operate as intended, the well may not produce optimally. By testing the different bellows types and designs, the threshold of dome pressure can be determined for a specific gas lift valve to operate as intended. For example, based on testing, when a gas lift valve with a formed type bellows is pressurized above ~2,200 psi, the open-and-close values will start becoming distorted. The further above this open-and-close pressure rating threshold, the more the open-and-close values become distorted. This testing has exposed the real limitations of gas lift valves manufactured with a formed bellows when the user specifies a gas lift valve to be rated to API 19G2 standards.

CHATTER TESTING

Gas lift valve chatter occurs when the valve stem isolates at a very high frequency in a resonate state. If a valve begins to chatter, it will usually fail within a relatively short period of time. Classic signs of failure due to chatter are beat-out seat along with a bellows failure. The bellows fail due to cyclical fatigue. Testing for chatter is not an API requirement but is critical in proving gas lift valve designs. The only practical way to perform chatter testing is from actual usage of the valve in a well or testing in a flow loop at various rates with upstream and downstream pressures. Deepwater applications often utilize high-pressure compression and therefore a faulty gas lift design will go into a chattering state and quickly fail. Again, this testing and development of deepwater applications expose which specific gas lift valve designs will withstand high-injection and high-differential pressure scenarios.

CHECK-VALVE TESTING

Check-valve testing requirements in API 19G2 consist of flowing freshwater through check valve at a specific rate then checking the sealing integrity of the valve. The most rigorous testing required in API 19G2 is injecting 1-1/2 barrels per minute for a total cumulative volume of 600 BFPD. Periodic stops and checks are made to ensure the check valve is maintaining sealing integrity. This is a good start to provide proof of gas lift valve, check-valve designs. However, with the prevalence of sand in so many unconventional land applications, new designs and concepts are being tested for greater sand-tolerance.

ALTERNATE CONCEPTS

High-pressure and stringent operational requirements have driven the need to develop gas lift equipment-regulating devices for high pressure. These findings and concepts are also applicable in land-based applications. Two such developments are the high-pressure injection-pressure operated (IPO) gas lift valve and the new differential operated gas lift valve design.

To achieve exceptionally high dome pressure, high-submergence differential pressures, and reliable operational characteristics, a method that utilizes two bellows filled with incompressible fluid and a timed internal-sealing device, illustrated in figure 2 below, must be used. When the valve travels to full-closed position, the sealing device between to two bellows isolates the fluid in the upper bellows and provides protection from high differential pressure in the dome. Similarly, when this valve travels to the fully-open position, the sealing device between the bellows isolates the fluid in the lower bellows and prevents excessive differential-pressure exposure from outside the gas lift valve. This design an IPO gas lift valve design and the methods of application engineering gas lift designs is remarkably similar to current standard IPO gas lift valves.

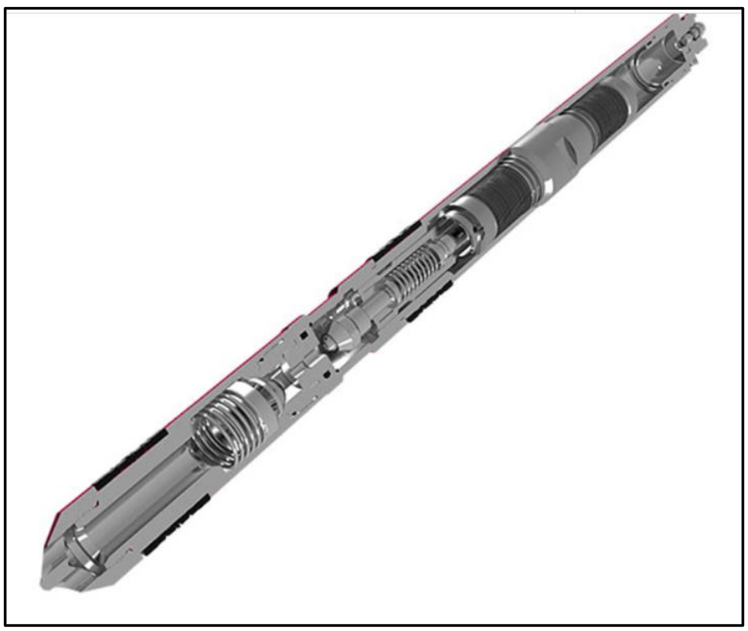

Figure 2 - Dual Bellows Gas Lift Valve

Operating Equations for Injection Pressure Operated (IPO) Gas Lift Valve

$$Pd(Ab) = Pt(Ap) + OP(Ab - Ap)$$

$$PVC = OP(1\text{-}R) + PT\ (R)$$

$$OP = PVC + PT\ (R)/1\text{-}R$$

OP = Opening Injection Pressure at Depth

PVC = Closing Injection Pressure at Depth

PT = Tubing or "Transfer Pressure" at Depth

Ab = Area of Bellows

Ap = Area of Port

R = Ap/Ab

Another design to achieve high-injection pressure capabilities is to utilize a gas lift valve designed to open, close, and reopen based upon differential pressure. The differential valve, shown below in figure 3, is designed to be a normally open valve, but when closed, the differential pressure caused by upstream injection pressure flowing across the choke compresses the spring and causes the sealing head to close. The valve reopens when the differential pressure from the injection stream to the production stream is within the differential pressure range of the opposing spring force. Since this valve doesn't operate by compressing a bellows, there are no relevant operating pressure limitations.

Another inherent advantage of the valve, relative to wells in unconventional shale wells utilizing booster compressors, is that this valve will operate at varying injection pressures. This is assuming a well is utilizing a high-pressure booster compressor capable of 2,500 psi to gas lift a well. If the booster compressor becomes temporarily inoperable, the well is shut in because the downhole gas lift configuration is designed for high-pressure gas lift. Since the differential valve operates on the difference between injection pressure and production pressure instead of an absolute injection pressure, as in the IPO gas lift valve, the operator could temporarily shift the well back to low pressure compression for gas lifting until the booster compressor becomes operational again. Further, when the well needs to be permanently shifted to intermediate or low-pressure compression, theoretically, the differential valves would unload and produce the well without having to change the downhole gas lift and completion configuration.

In summary, with a differential-operated gas lift valve, a well may be able to be produced with high-pressure compression then subsequently converted to low-pressure compression without a change to the gas lift valves. This can help an operator maintain production if a booster compressor were to go offline and conversely, the well can be permanently converted to low pressure at the most opportune phase of the well's life—all without changing the gas lift valves.

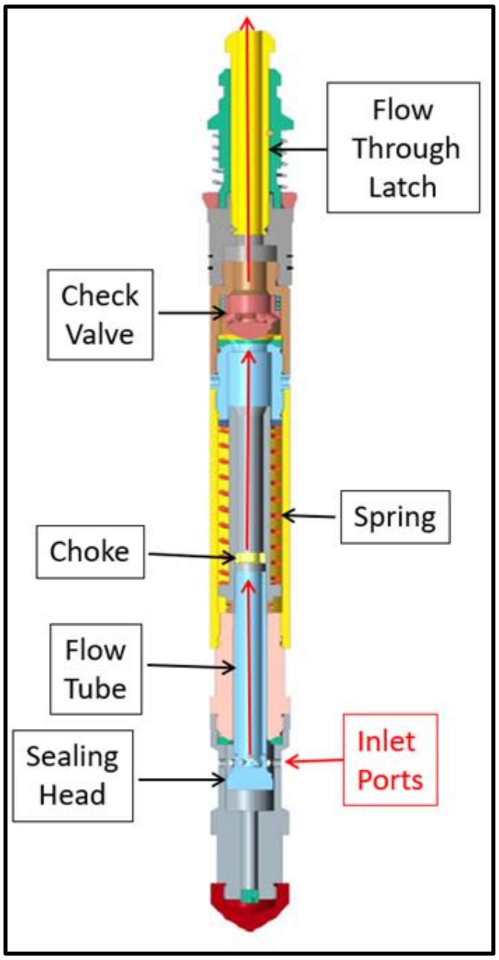

Figure 3 – 1 1/2-in. Differential Valve

Operating Equations for 1 1/2-in. Differential Operating Gas Lift Valve as Shown

$$\text{Differential Closing Pressure} = \left[\frac{\text{Spring Force}}{(\text{ID Area of flow-tube}) - (\text{ID area of choke})} \right] \left[\text{Friction Factor} \right]$$

Operational Parameters:

$$\text{Differential Closing Pressure} = (\text{Injection Pressure}) - (\text{Production Pressure})$$

$$\text{Differential Reopening Pressure} = \left[\frac{\text{Spring Force}}{\text{ID Area of Sealing Head}} \right]$$

Operational Parameters:

$$\text{Differential Reopening Pressure} = (\text{Injection Pressure}) - (\text{Production Pressure})$$

CONCLUSION

Testing and equipment development per the current standards listed in API 19G2, stated to be applicable for deepwater gas lift applications, have improved the equipment offerings for land-based equipment applications. Bellows lifecycle testing is a good indication of the integrity of the bellows design arrangement and quality. This testing helps qualify suppliers and determines the best of each size available in the market. Differential-submergence testing and open-and-close testing has helped determine the boundaries of pressure ratings for “formed” type bellows typically used in unconventional shale wells. Chatter testing proves up valve designs for different scenarios of multipoinding and valve unloading transfer. Finally, the quest of new designs in high-pressure gas lift valve concepts have prompted research and development projects in search of solutions.

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