USING CHOKES IN UNLOADING GAS-LIFT VALVES

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ABSTRACT

This paper presents the practice of using downstream chokes in unloading injection pressure operated (IPO) gas-lift valves. The practice helps to assure effective unloading and may provide protection against erosion damage during the unloading process. It has several other benefits that are discussed in the paper.

A gas-lift valve/choke model has been developed. It provides accurate predictions of the gas passage through the choked valve during the unloading process. And, it can help to analyze existing gas-lift performance, where the objective is to determine which valve(s) are open and how much gas is being injected through them. This model is described in the paper.

INTRODUCTION

For many years, Shell Operating Companies have used chokes in unloading IPO gas-lift valves. Other companies have questioned this practice. This paper explains the logic and presents new evidence that shows the significant advantages that come from it.

The choke limits the rate of gas injection through each unloading gas-lift valve to that amount required for the unloading process. The injection rate is prevented from becoming excessive when the valve is fully open.

The choke, which is installed downstream of the valve port, helps to maintain a higher pressure upstream of the choke and beneath the seat of the valve. This helps to keep the valve fully open during the unloading process, until it is time for the valve to close, and prevents throttling. Thus, the injection rate is prevented from becoming too low due to partial closing and throttling. See Figure 1 for a schematic representation of an unchoked valve and Figure 2 for a schematic representation of a choked valve.

In essence, with the proper use of chokes in unloading valves, the valves inject just the right amount of gas - not too much and not too little - to make the unloading process proceed with maximum effectiveness.

And, chokes may provide one other significant advantage. When a valve is choked, a significant portion of the pressure drop occurs across the choke; it does not all occur across the portlseat of the valve. And, as stated above, the valve does not throttle (partially close) during its operation. Thus, the potential for erosion damage to the valve during the unloading process is significantly reduced.

THE REASON FOR A GAS-LIFT VALVE/CHOKE MODEL

For many years, until 1998, Shell “knew” that using chokes in unloading gas-lift valves was a prudent thing to do. However, the “science” behind this practice was limited to using the “Thomhill-Craver” model’ to predict the amount of gas that would flow through the valves, without taking into consideration the dual effects of the gas-lift valve portlseat and the choke acting in series.

By 1998, a new tool was available - the gas-lift valve Performance models that are based on the API RP 11V2 gas-lift valve test procedures[2]. Shell asked Decker Technology if a model could be developed for choked gas-lift valves that would use the API model for the gas-lift valve performance and the Thornhill-Craver model for the choke, and would mathematically “add them together” to provide the overall performance of the valve.

The objectives of this model development exercise were to:

1. Develop a rigorous tool for designing choked, unloading IPO gas-lift valves - that is, for selecting the best combination of port size and choke size.

2. Develop an equally rigorous tool for analysing existing gas-lift wells where the objective is to understand which gas-lift valve(s) are open and how much gas is being injected through each open valve.

3. Have a way to develop accurate performance models for choked IPO gas-lift valves without having to conduct a full suite of API performance tests on each valve port/choke combination.

DEVELOPMENT OF THE MODEL

Tests were conducted at Southwest Research using the API RP 11V2 procedures to determine the flow response of a Macco R-1D gas-lift valve with downstream chokes. The valve was tested with three port sizes and a variety of choke sizes for each port. In addition, each choke was tested for a flow coefficient independent of the port size.

The dynamic tests were then analyzed to determine the flow coefficient of the valve as a function of the pressures acting on the valve. Knowing flow coefficients for the combined port and choke, it was then a simple matter to determine the flow coefficient of the port alone. With this information, it was then possible to determine the actual stem position of the valve during the test. This stem position was then compared to the stem position predicted by the static force balance equation.

The static stem travel and the dynamic stem travel will not be the same due to the dynamic pressure field that occurs at the port. In cases where there is no downstream choke, the dynamic stem position is usually less than the static stem position. In this case, with downstream chokes, the dynamic stem position was actually greater than the static stem position. This would indicate that the pressures acting on the bellows and valve stem are greater than would be predicted using the static force balance equation.

A correlation was developed for each combination of port and choke size that related the dynamic stem position to the static stem position as a function of the pressures acting on the valve. With this correlation, it then became possible to predict the actual valve stem position using the static force balance equation. A program was written to calculate the stem travel using the static force balance equation; the correlation was applied to determine the actual stem travel. Knowing the actual stem position, the flow coefficient for the port could be determined. A flow rate was calculated for the port alone and also for the choke alone. If the flow rate through the choke was less than the flow rate through the port, the flow rate of the choke was used.

An additional calculation was performed to determine if the choke was in critical flow. If this occurs, then the pressure acting on the valve stem will not be the same as the downstream tubing pressure. When the choke is in critical flow, the valve will close only with a reduction of casing pressure.

The Valve Performance Clearinghouse (VPC) program, which is used by Decker, and which is based on the API RP 11V2 procedures, takes into account all of the above considerations and then plots a performance curve of flow rate versus pressure. The correlation proved to be within +/-15% of the actual dynamic tests.

IMPLEMENTATION OF THE MODEL

Shell has taken two steps to implement the gas-lift valve/choke model.

1. The model has been incorporated into Shell's "WinGLUE" gas-lift design, analysis, and optimization program[3]. Every Shell gas-lift specialist who designs unloading IPO gas-lift valves can choose to use this model. Also, this model can be used any time the performance of an existing gas-lift completion that uses choked IPO valves is analysed.

2. Shell has donated this model to the Valve Performance Clearinghouse[4]. The VPC is a "joint industry project" that is operated for the testing and modelling of gas-lift valves. The VPC has the right to use this model to augment any of its modelling work. And, all member companies of the VPC have the right to use the model in their gas-lift design and analysis work.

IMPROVING PERFORMANCE OF UNLOADING GAS-LIFT VALVES USING CHOKES - CASE HISTORY

The Shell EP Operating Company in the USA typically installs chokes downstream of the port in IPO gas-lift valves. The historical documentation for this practice has been lost but it has probably been done to:

1. Finely control the rate of gas passage through the valves as the well unloads.

2. Allow the purchase and storage in inventory of batches of valves with a standard seat (typically 1" IPO valves with 3/16" ports).

Gas-lift vendors and other industry experts have challenged this practice, but it has largely remained in place because it has seemed to work very well and Shell has expected that there might be other benefits.

When we became familiar with the testing of gas-lift valves for performance[2,4], it was logical to test the effect of a choke on the gas-lift valve. This testing was done and it showed a significant change in the characteristics of the valve behavior. Models were developed from the resultant test data (by Decker Technology), were incorporated into WinGLUE (Shell's gas lift design software)[3], and are published for the first time here.

Using the model, we can simulate what happens to a particular valve as the injection pressure at the valve is increased. The following figures show model results for a Macco RD-1 valve with a 3/16" port and a 10/64" choke.

In Figure 3, the valve performance is shown at an injection pressure of 1000 psi. The injection rate is shown on the y-axis and the production (tubing) pressure on the x-axis. At this injection pressure (1000 psi), the valve cannot open, regardless of the tubing pressure. This is shown by the dashed red line at zero flow rate. (The tubing pressure in this case is at just over 300 psi.)

In Figure 4, the injection pressure is increased to 1100 psi. At this point, the gas-lift valve is open when the production pressure is above about 900 psi. Note the typical throttling action of the unchoked valve as the production pressure is reduced below the opening pressure. And, note that the choked valve actually transmits more gas and remains fully open until just before the closing pressure is reached. Essentially, the choked valve maintains the full, desired injection rate across the entire operating range and then snaps closed instead of throttling closed.

In Figure 5, the injection pressure is increased to about 1200 psi. Now the gas-lift valve is open at tubing pressures above about 400 psi. The same throttling performance is seen for the unchoked valve, and again the choked valve transmits much more gas over the full range of operation of the valve.

How is it possible for a valve that is choked to inject more? The answer appears to be that, with the downstream choke, the pressure beneath the valve stem is maintained much higher, since much of the pressure drop occurs across the choke. This higher pressure holds the valve fully open over its entire operating range and prevents it from throttling closed.

OUTSTANDING ISSUES

There are three outstanding issues that need to be pursued.

1. Originally, the gas-lift valve/choke model was tested and verified using a 1-inch IPO gas-lift valve. The model is designed to be generic, but originally it was not verified with 1.5-inch IPO valves, and it was not even considered for use with PPO valves. In 2001, the Shell Operating Unit in Oman, Petroleum Development Oman, authorized testing and validation of the model for 1.5-inch IPO valves. The model indicates similar advantages for the 1.5-inch valves as have been demonstrated for 1-inch IPO valves, especially with large ported valves. The subject of PPO valves has not been fully discussed. This may be addressed in the future, if there is interest from Shell Operating Companies or others.

2. The presence of the choke may help to limit the risk of erosion damage to the gas-lift valve port/seat during unloading. This has not been confirmed. However, if this were the case, it could be a significant additional advantage of using chokes. This will be pursued in tests being performed by the VPC in 2003[5]. Previous testing has indicated that typical unloading rates of 1 - 2 bbl/min with fresh water through monel ports result in very minor erosion of the port. The use of downstream chokes and other unloading rate(s) and fluid(s) will be tested in 2003.

3. The original intent was that the gas-lift valve/choke model could be used to simplify the process of testing and modelling any new gas-lift valve. This speculation still needs to be investigated. Prior testing has shown that two critical factors affect valve performance. They are: valve load rate, and valve flow coefficient. Both of these factors must be determined to develop an accurate performance model. However, the valve/choke model may be of significant value when multiple combinations of valve port size/choke size must be evaluated.

SUMMARY OF BENEFITS OF USING CHOKES IN UNLOADING GAS-LIFT VALVES

There are several known or suspected benefits of using chokes in unloading gas-lift valves.

1. The gas injection rate through each unloading valve can be limited to the desired amount. The risk of "over injection" during the unloading process is eliminated.

2. The problem of throttling in unloading gas-lift valves can be significantly reduced. The risk of "under injection" during the unloading process is greatly reduced.

3. The ability to design the unloading process for a known injection rate, and to be able to count on this rate being realized at each unloading valve, can help assure that the unloading process is successful in its objective of reaching the desired operating depth.

4. Because the injection rate can be 'fine tuned" with the use of chokes, one standard port size can be chosen for all unloading gas-lift valves in a string, and often in a field. This minimizes gas-lift valve purchasing and inventory problems.

5. There is a strong likelihood that the presence of a choke reduces the risk of erosion damage of the gas-lift valve port/seat during the unloading process.

6. There is the possibility that the gas-lift valve/choke model can be used to simplify the process of testing gas-lift valves with the API process. This could potentially reduce the cost of this process and thus allow more valves to be tested.

CONCLUSIONS

The unloading process is perhaps the most critical time in the life of a gas-lift well. If the well is not unloaded successfully to "bottom," or if an unloading gas-lift valve is damaged during the unloading process, the well may suffer significant inefficiency and deferred production for months or years to come.

The practice of using judiciously designed chokes in unloading valves has been proven to help in the unloading process, and may also help to protect the valves from potential erosion damage.

The practice is recommended for consideration by all gas-lift operating companies.

ACKNOWLEDGEMENTS

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REFERENCES

1. Thornhill-Craver is a standard, published method for calculating the gas flow rate through a "square edge" orifice.

2. API Recommended Practice 11V2 ,"Gas Lift Valve Performance Testing," 1st Edition, January 1995. This document covers the test procedures for flow performance testing of wireline-retrievable and tubing-retrievable IPO (injection pressure operated), and PPO (production pressure operated) gas lift valves. Pages: 36.

3. For more on the Shell WinGLUE Gas-Lift Design, Analysis, and Optimization program, see the WinGLUE web site at http://www.appsmiths.com.

4. The Valve Performance Clearinghouse (VPC) is a joint industry project for the purpose of testing and modelling gas-lift valves. For more information, see the VPC web site htm:!iww-w.deckertecli.com. Currently, the member companies of the VPC are: ChevronTexaco, Shell International, Weatherford, and ExxonMobil. Any gas-lift related Operating or Service company is eligible to join.

5. The VPC conducts an annual testing and modelling program on behalf of its member companies. The results of the testing are proprietary to member companies; however, the VPC conducts an annual meeting at which "visitors and guests" are invited to attend. Contact Decker Technology, Inc. (770-496-9680) for more information.

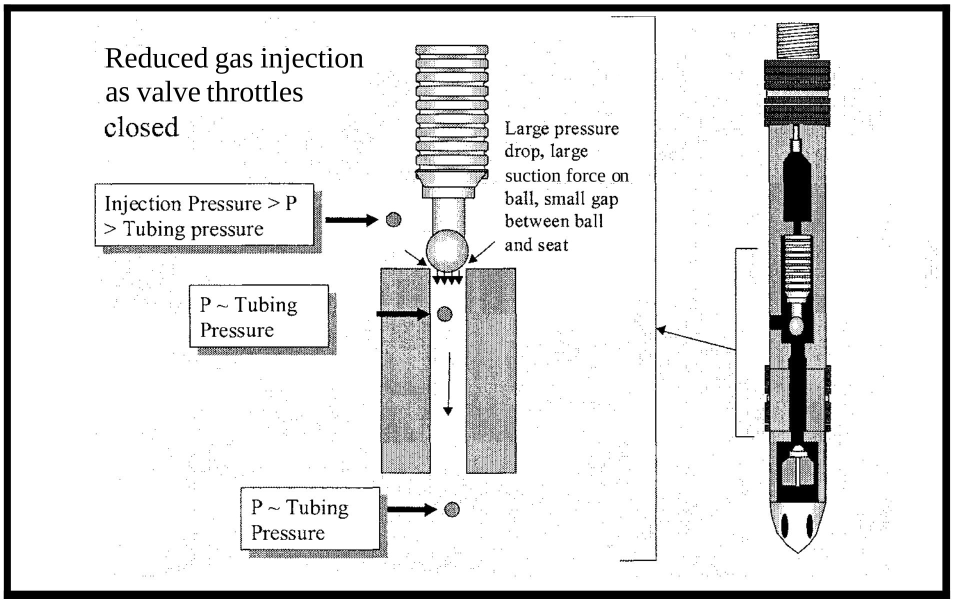

Figure 1- Unchoked Gas-Lift Valve

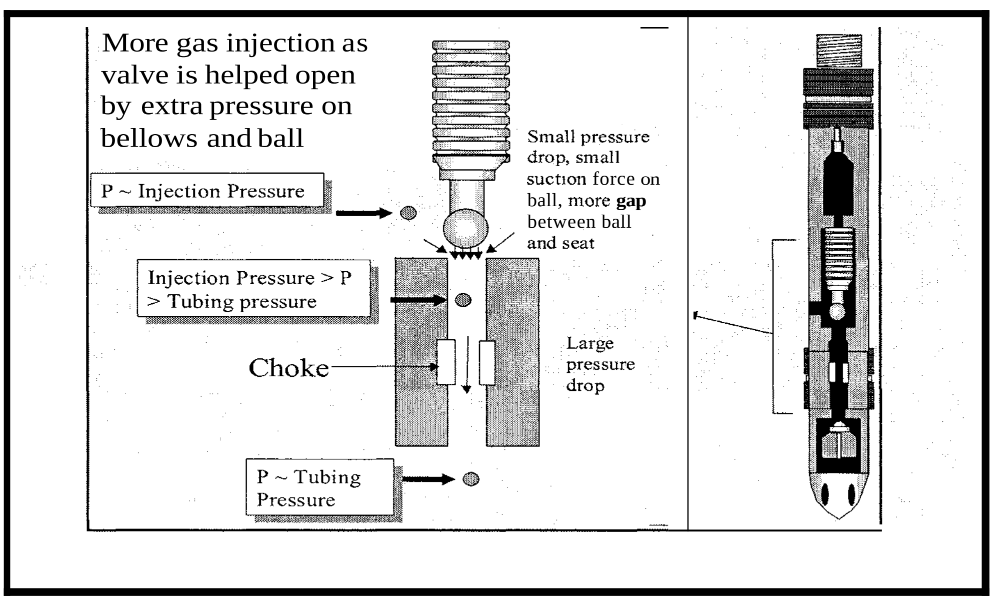

Figure 2 - Choked Gas-Lift Valve

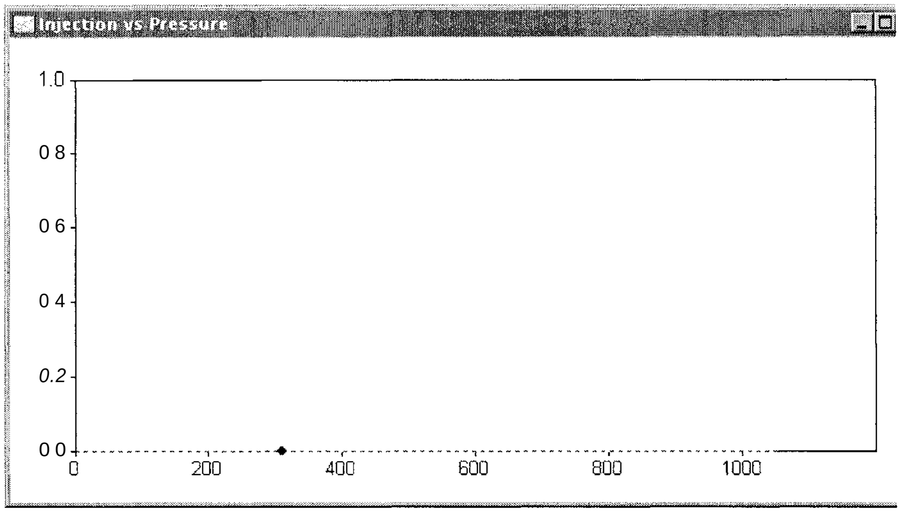

Figure 3 -Closed Gas-Lift Valve

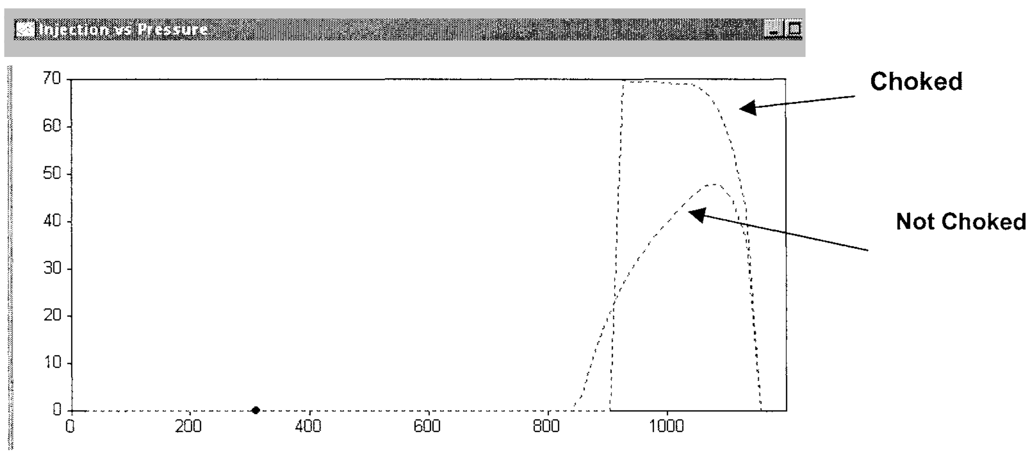

Figure 4 - Unloading Gas-Lift Valve with Choke vs. Unloading Valve with No Choke

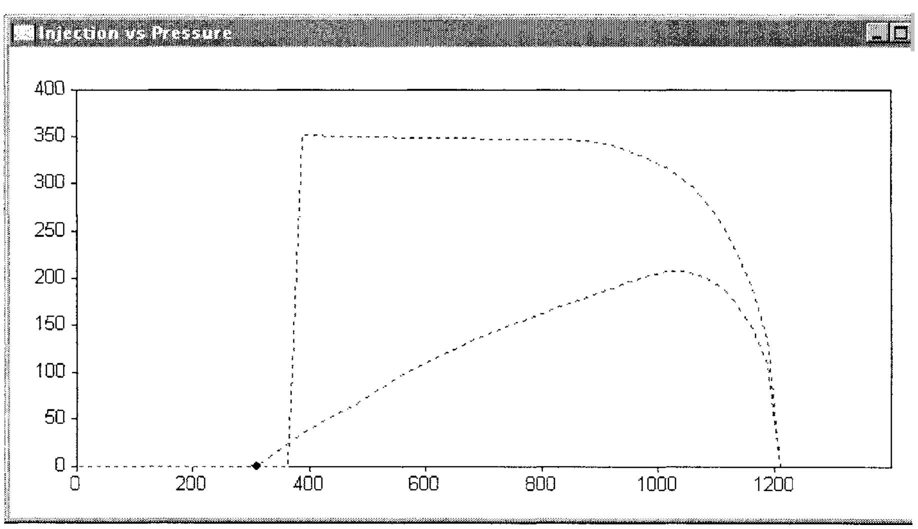

Figure 5 - Choked vs. Unchoked Unloading Valve with Higher Injection Pressure and thus Larger Operating Range