THE CASE STUDY OF APPLYING FIELD DATA BY UTILIZING PRESSURE AND TEMPERATURE SURVEY RESULTS AND WINKLER'S VALVE PERFORMANCE ANALYSIS TO OPTIMIZE PRODUCTION IN GAS ASSISTED PLUNGER LIFT (GAPL)

Haseeb Ahmed Janjua
PROLIFTCO

ABSTRACT

This case study has a completion with 2-7/8" tubing in 5-1/2" casing without a packer, with 8 IPO gas lift valves in conventional mandrels with an orifice as the last valve and a chemical screen below that. A grooved plunger was used in this well in combination with gas lift to reduce liquid fall back losses and provides a solid sealing interface between the liquid slug and the gas below it. The liquid rate declined drastically after operating the well on the gas lift at 800 MCFD rate and 900 psig injection pressure for eight months. The well did not recover after trying several combinations of lift gas volume and plunger speed.

As the lift depth in gas lift system depends upon the intersection point between surface injection pressure and multiphase flowing gradient. The pressure and temperature survey with resistance temperature detector (RTD) sensor has been run till the heal of the well at a stabilized injection gas flow rate along with wellhead recorders, recording casing and tubing pressures and temperatures for the entire duration of the survey. This process will help determine the lift point by identifying the Joules-Thompson cooling effect on the temperature curve. And it will also help sense the maximum and minimum pressures if the well is heading (surging or slugging) by keeping the wireline gauges at each depth for sufficient time.

The methodical approach of creating a bridge between gas lift design and pressure-temperature survey interpretation gives operational insights into what was wrong with the gas lift operating envelope. The injection pressure endpoints are generated after performing a well-delivery analysis simulation with lower bottom hole pressure (revealed from the survey). And by utilizing Winkler's gas passage analysis, the gas rate through designed port sizes in gas lift valves can be simulated, which is required for the existing deliverability of the well.

Recent changes in operating conditions were proposed after performing several simulations on downhole flowing pressure and temperature at changing injection rates to measure the decrease in production. And applying these new conditions backed by the well's data brought the well's production back on the curve. This case history shows the complete scheme of creating an effective lift gas troubleshooting matrix in gas lift systems from concept initiation to execution and field installation.

INTRODUCTION

Horizontal drilling is utilized to address the need to increase the contact area between the well and the reservoir in unconventional shale plays.

The viable commercial exploitation of these low permeability reservoirs requires stimulating methods such as hydraulic fracturing to increase the pathways or the permeability of the drainage area in the reservoir. Hence, the selection of artificial lift programs in unconventional reservoirs is peculiar due to many reasons, including:

1. The deliverability of multistage fractured horizontal well is controlled by many factors, including the scale of stage-fracturing and the number of stages.
2. The possible occurrence of multiple complex flow regimes that could occur sequentially during production.

However, a steady water cut and linear increases in the gas-to-liquids ratio in Permian Basin reservoirs have led more producers to choose gas lift to produce mature reservoirs. A good gas lift design is not enough to deal with the critical phase of lifting matured and depleted reservoirs. As transient flow takes place during most of the early life of the well where reservoir boundaries have not been established yet. Production instabilities may give birth to possible failure in downhole gas lift equipment and completion jewelry of the gas lift well. Also, several events are going-on in a gas lift well which makes troubleshooting of a gas lift well very complex. For example, evaluating the representative IPR curve is complicated because of the reservoir complexities or lack of characteristic information such as static reservoir pressure, skin, and wellbore formation damage parameters. Therefore, successfully handling and troubleshooting gas lift systems are crucial to saving producers from high well intervention costs and production loss. There are many field optimization techniques for troubleshooting a gas lift well. Some of them include:

1. CO_2 (Carbon dioxide) tracers.
2. Downhole temperature measurement using fiber optic surveys (distributed temperature sensing).
3. Fluid levels.
4. Use of Sonic devices.
5. Down hole pressure and temperature surveys.

This study explains how pressure-temperature survey interpretation can be used to re-evaluate current gas lift design and propose operational insights which will improve the production of the unconventional horizontally fractured gas lift well in the Upper Trend area.

EVALUATION

Comprehensive testing data regarding gas passage through ports of various sizes in a gas lift system is increasingly the norm. The availability of this data makes gas lift survey interpretation the perfect tool for well evaluations. A gas lift designer familiar with how gas passes through the 16 ports in a gas lift valve can interpret downhole temperature and pressure surveys to evaluate well conditions, both current and future.

A case study in the WOLFCAMP formation shows how a survey can improve the gas lift operating envelope design, study multiphase flow correlations, and obtain valuable operational references for future problems in the well.

The following information can be interpreted from a gas lift optimization survey:

- Interpretation of pressure and temperature measurements at each valve can determine the new nitrogen bellows closing pressure, which can provide the rationale to adjust the test rack pressure of each valve.
- The downhole flowing pressure, along with liquid production measurement on a particular day, helps evaluate essential data, which can be used as well test to find the current IPR curve (type curve) of the well.
- The characteristic multiphase flow correlation can be deduced by having per foot actual temperature and pressure measurements for the entire tubing string along with water cut, gas flow rate, and liquid production.
- The explanation about Joules-Thompson cooling effect is the key factor in identifying the bellows' opening and closing in each gas lift valve.
- New pressure profile of the well at a particular stabilized injection flow rate can serve as a well test (while recording the surface tubing and casing pressures) to evaluate dynamic parameters of the reservoir. i.e., formation damage and instantaneous productivity index of the well.

METHODOLOGY

After operating the well on gas lift for 10 months, production had declined to around 35 barrels per day, much less than the gas lift lower-side design rate of 150 barrels per day. The significantly lower rate is usually the consequence of suspicious downhole gas lift system problems such as:

1. Flow cut gas lift valve.
2. Gas lift valve hung open.
3. Valve out of pocket.
4. Leaking packing in a gas lift valve.
5. Plugged gas lift valve.
6. Packer leak.
7. Hanger leak.
8. A hole in the tubing.

To find the actual cause of decreased production, a trained team decided to run resistance temperature detector (RTD) pressure-temperature sensors on a wire line. This obtains downhole temperature and pressure data while the well flows. The procedure involves two separate trips of wireline downhole. The wellbore completion of this well consists of a 13-3/8“ surface casing and a 9- 5/8” 40 pounds intermediate casing, then 2-7/8” tubing in 5-1/2” production casing. The gas lift system contains 8 IPO (injection-pressure operated) gas lift valves in conventional mandrels with 5000 psi (pounds per square inch) back check valves as a part of the valve assembly.

The back check valves are an essential part of the gas lift valve manufacturing and performance as they prevent any kind of flow from tubing to the casing.

Wellbore Trajectory defines the pace in wireline operations in gas-lifted wells.

This wellbore is deviated slightly toe down. The kick-off point is at 8538 ft, and the curve section of the well is created at the rate of about 11° DLS (Dogleg Severity) per 100 ft. Wireline logging can be possible in highly deviated wells with an inclination up to 85°. But if it gets stuck, It will become time-consuming and costly. Therefore a very cautious approach is required to log deviated segments of the well. The type of wireline used in executing pressure and temperature survey is slickline with the thickness of 0.125”. As there is no slip over the tool string is required so no wheeled carriages is used in this wireline procedure.

Limiting the process to two wireline trips.

The Wireline tool string, which cleans the 2-7/8” tubing, consists of spang jars with a circular metallic knife whose diameter is 2.175 inches. After rigging up the wireline BOP (Blow out preventer) on the well's Christmas tree, the entire tool string of the wireline is lowered to the packer depth and tripped out of the hole successfully. This ensures that there are no restrictions such as paraffin, wax, or scale. The run also ensures that the temperature and pressure gauges that follow can run clean without encountering wellbore debris entering and leaving the hole. An essential diagnostic method to identify any tight spots is to check the knife and the entire tool string to determine whether they have any scale deposits, parrafin and scratches on the tool string. Figure 1 shows 2.175” knife before tripping in the hole, and Figure 2 shows the knife after completing the entire trip from the surface to 9150 ft TVD (Total Vertical Depth). After checking the knife carefully and the whole tool string, it looks like the tool string encountered small amount of paraffin formation, and there are no severe tight spots present in the tubing.

Calibration and integrity of LMS (Line Management system) in wireline operations.

The wireline run with the knife will also serve as a calibration run for the LMS (Line Management System) Box, which will be connected with the counter head of the wheel through a depth encoder cable. Once the LMS box is calibrated and the depth on the LMS box and the mechanical counter of the wireline truck is the same, two RTD (4.50 milliAmpere sample and 0.10 milliAmpere sleep) Saphire memory gauges are connected to the weight bar, then connected to the slickline tool string. Figure 3 shows that two pressure-temperature gauges have been connected to the weight bars and the reason for going with an extra gauge is to have a backup gauge in case of any anomaly or pipe stuck down-hole.

Sampling and recording the data through wireline.

As the current operating conditions show the decline in liquid production, therefore capturing actual problematic well conditions without adding any other problem is required. Thus a safe approach has to be acquired in which well should not be choked (up or down) recently, and the gas injection rate must remain at a constant rate at a set pressure before and on the survey day. This will help maintain the survey's integrity and help monitor the actual temperature and pressure in the latter times of the unloading process. Also, the preferred line speed of the wireline job for recording and sampling is required to be around 75 ft/min consistent during down-pass and in up-pass.

Data from the survey obtains the analysis, which is shown in Figure 4. In Figure 4 downpass pressure is erratic at 1500 feet and deeper, giving the impression that the gauges encounter surging behavior going against the flow. It also shows that there is no hole in the tubing. The well has just slowed down while the well-flowing pressure is decreased to 1600 psi. The new bottom hole pressure will be the foundation for simulations.

CONNECTION BETWEEN GAS LIFT DESIGN AND CURRENT PRESSURE-TEMPERATURE PROFILE.

Characteristic Inflow performance relationship.

The new temperature pressure profile to the heel of the well is available now. As the reservoir pressure drops from its initial condition, a significant amount of solution gas becomes free gas in the reservoir, making solution-gas drive a dominating factor in fluid production. Thus Nodal analysis analysis will be performed by incorporating actual flowing bottom hole pressure as a delivery node condition. Due to the variation in fluid properties such as relative permeability and gas liquid ratio, the productivity of the well will change and will not follow the trend stated in the gas lift design. Figure 5a presents the Vogel's inflow performance relationship (IPR) calculations at the time of the gas lift installation, and Figure 5b at current survey measured pressure-temperature conditions.

Port size selection for the gaslift system.

A simulation is performed to ensure that the proper port size gas lift valve that can pass the characteristic amount of injection rate through the valve at the calculated depth is utilized. Thornhill Craver calculated the gas passage considering a laminar flow through a square inch orifice plate in a meter run. And Winkler estimated gas passage based on the ball's position above the seat along with upstream and downstream pressure the valve is sensing. Figure 6 shows how we can create a simulation criteria using Winkler's gas passage analysis which will give us gas rate passing through unloading valve (8850 ft TVD) at a particular upstream, downstream, and transfer pressure. As we can see from Figure 6, In our gas lift setup, If the downstream pressure changes when more gas is injected while keeping the upstream pressure constant, the amount of gas passed through the well is upto 900 mscfd. But if the downstream pressure is reduced, the amount of gas passed through the valve would be decreased, and the valve will tend to close. This demonstration shows that the valve will be completely set to close if the downstream pressure is around 200 psi. Figure 7 shows the spread of gas injection rates through all the gas lift valves in our case study. Hence the above-discussed simulation endorses that 16 port size gas lift valves are the right choice for our gas lift setup and can handle 800 mscfd of injection gas.

Gas infrastructure simulation incorporating maturing reservoir conditions.

The calculations for gas pressure at depth are based on the static gas column. The pressure loss will be insignificant as the friction due to the flow of compressor gas through a conduit (casing-tubing annulus is negligible. Equation 1 is used widely to evaluate static injection pressure at depth.

$$P_{ioD} = P_{io} e^{\left\{\frac{\gamma g^{D}}{53.34(T)z}\right\}} \ldots\ldots\ldots\ldots\ldots Eq\ 1$$

P_{ioD} = injection pressure at depth in psia.

P_{io} = injection pressure at Surface in psia.

γ_g = Gas specific gravity.

D = true vertical depth of gas column, ft.

T = Average Temperature of gas column in R.

Z = compressibility factor as a function of temperature and pressure.

A simulation analysis using SNAP(System Nodal Analysis Program) is created for injection rate in which design-based operating conditions and current flowing conditions are plotted. Figure 8 shows that bottom hole pressure is 1330 psi at the start, and after injecting the gas through the gas lift valve from the backside of the tubing, bottom hole pressure is decreasing (which is the purpose of gas lift), creating a differential for reservoir pressure. Figure 8 also shows that, after injecting at 800 mscf/ day, increased injection would not lower the bottom hole pressure significantly. Thus, for 1330 PSI bottom hole pressure, the target injection rate for 16/64" port size gas lift valves should be 800 MSCF per day.

With gas lift survey results, a new lower bottom hole pressure of 600psi can be deduced from Figure 9. The results in the simulation shown in Figure 9 for 1600 psi indicate there is no decline in bottom hole pressure after injecting 600 mscf/ day. Hence, the new injection rate should be 600 mscf/day instead of 800 mscf/ day to create a better gas lift operating envelope.

Conclusion.

In a time when producers are looking to manage cash flow both by increasing production and reducing costs, it is ever more important to evaluate and update every well's performance.

A vital aspect in this case study is the marginal increase in oil production per unit from changing the injection rate of gas. The under injection of the gas rate will cause a decline in fluid rate due to inadequate reduction in the gravitational head in the tubing. Whereas over injection will create frictional head and high wellhead pressure, resulting in the back pressure on the formation halting the fluid production. Therefore gas lift optimization and troubleshooting is an elegant balance. In this case study, logistics were arranged to spend resources repairing a hole in the tubing, which would have been costly and would not have improved production, since there was no hole.

Instead, the survey revealed that downhole flowing pressure had naturally declined due to the age of the well, and a simple reduction in the injection rate could increase production. The wide availability of sensor data and the speed of evaluating a flowing well (shutting in production for testing is not only not necessary, but it also is not helpful) means a complete evaluation is a tool too valuable to ignore.

Figure 1: Knife before tripping in the hole throuhg slickline.

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Figure 2: Knife showing small paraffin traces after tripping in to the hole through slickline.

Figure 3: Temperature-pressure gauges with RTD sensors being deployed at the wellsite.

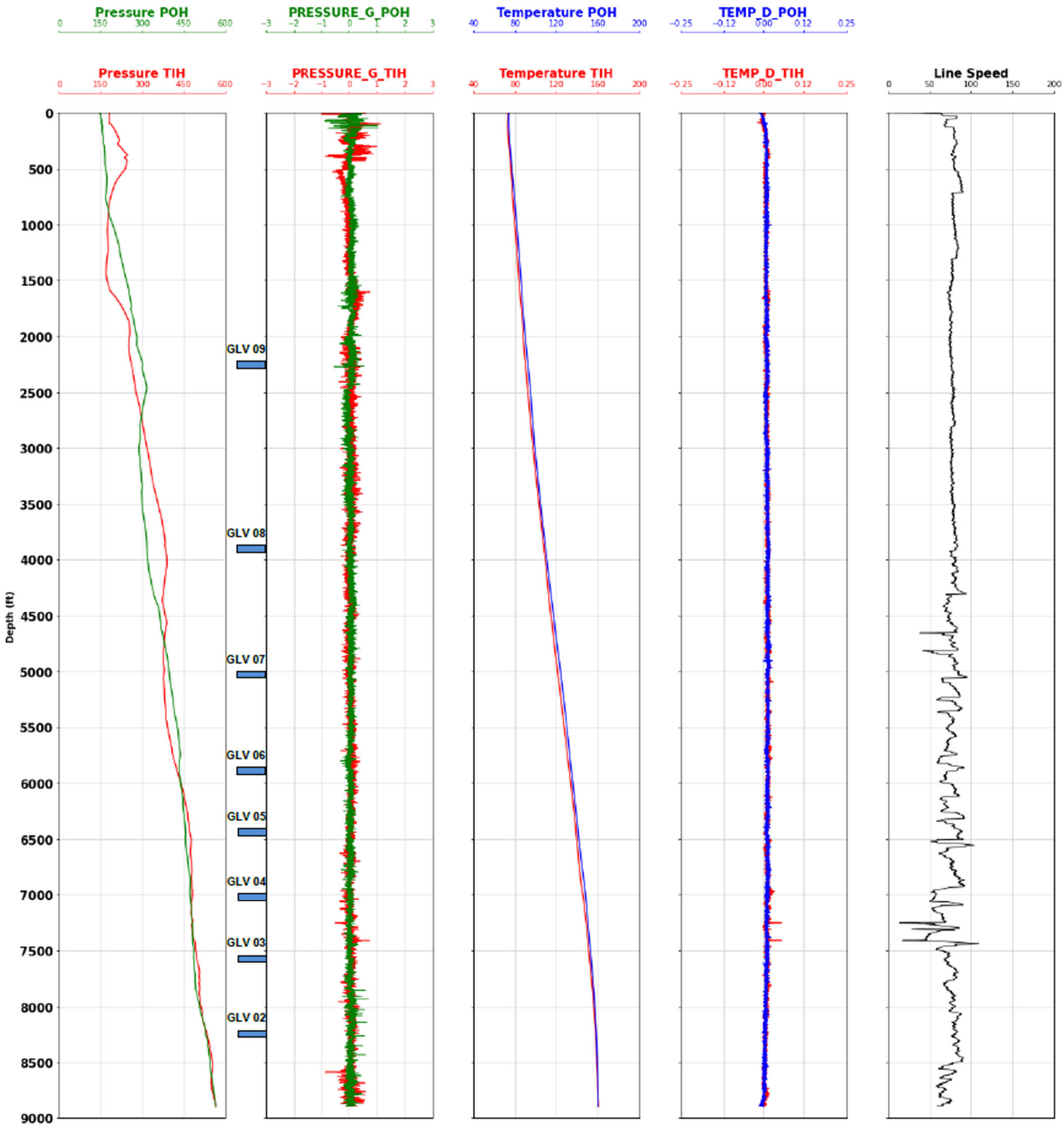

Figure 4: Continuous Pressure-Temperature Survey of the flowing well.

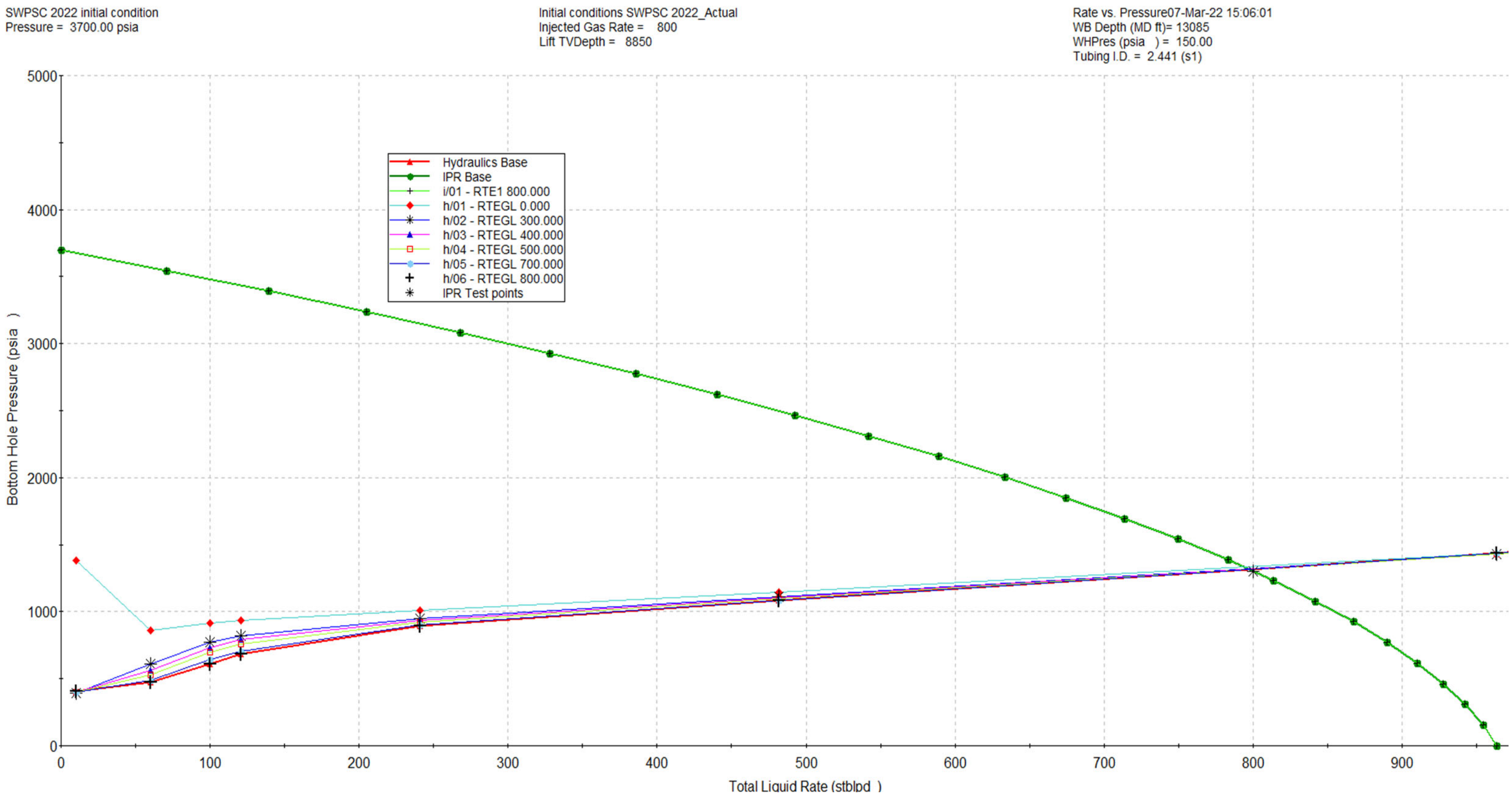

Figure 5a: Inflow performance relationship at the time of gas lift installation.

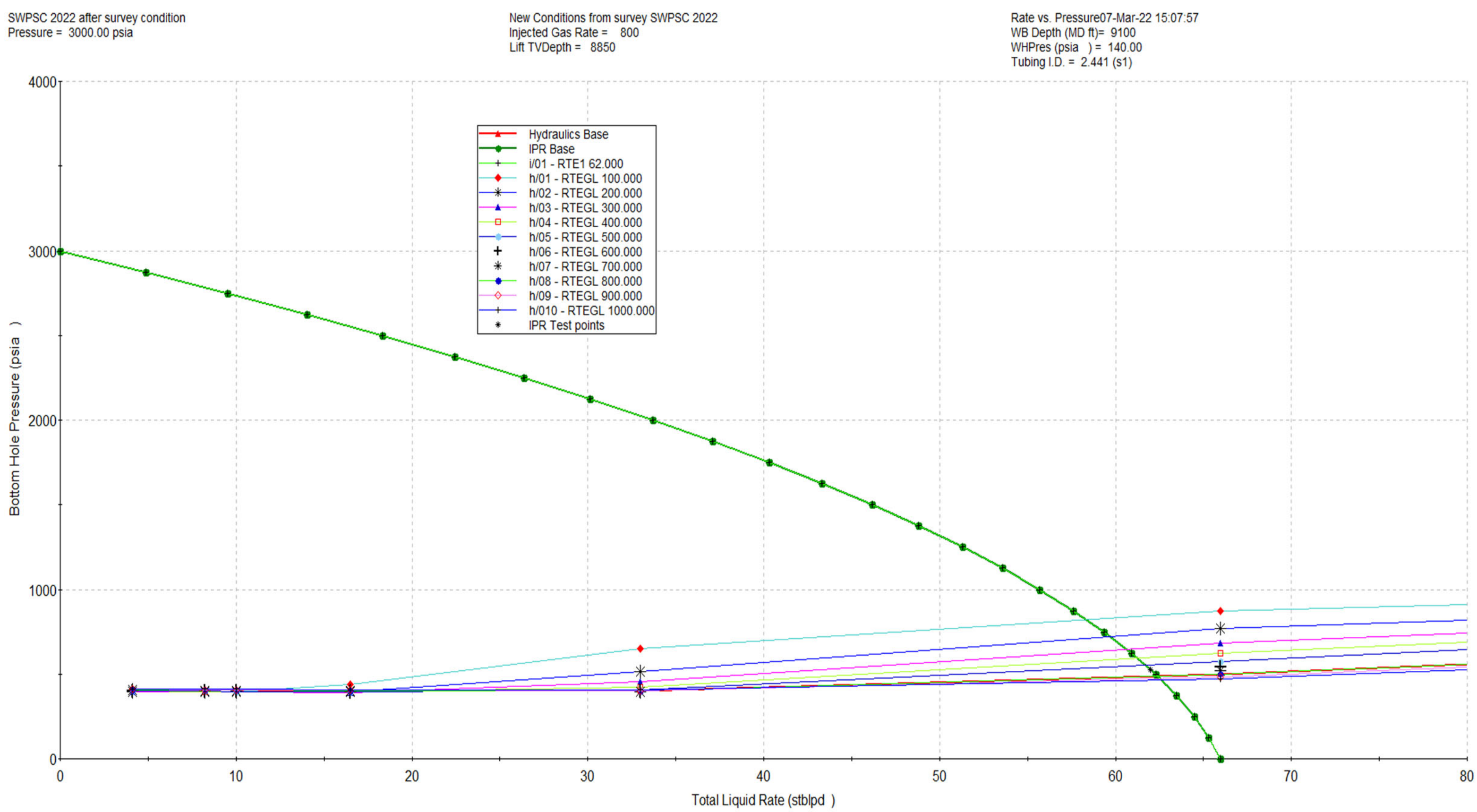

Figure 5b: Inflow performance relationship at current condition.

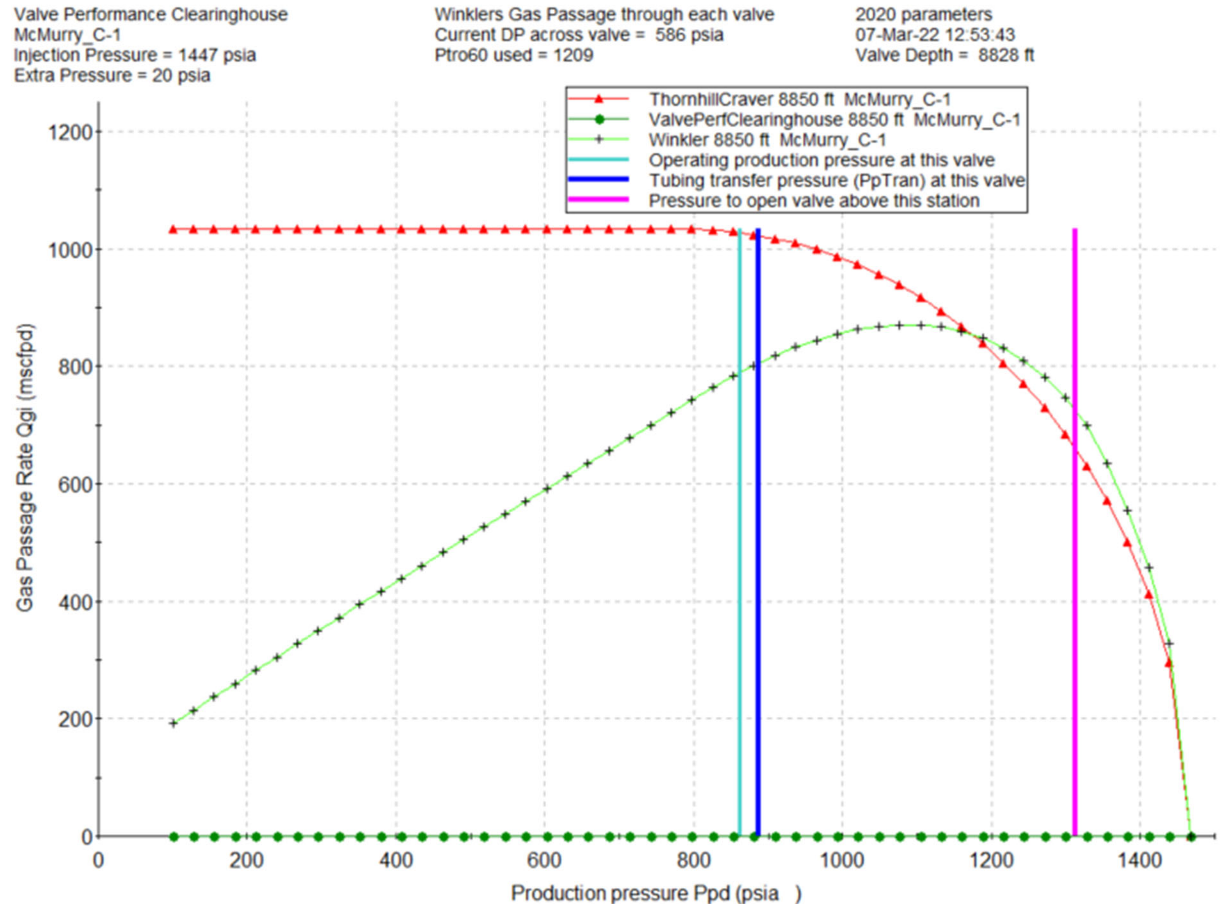

Figure 6: Valve performance relationship of the unloading valve.

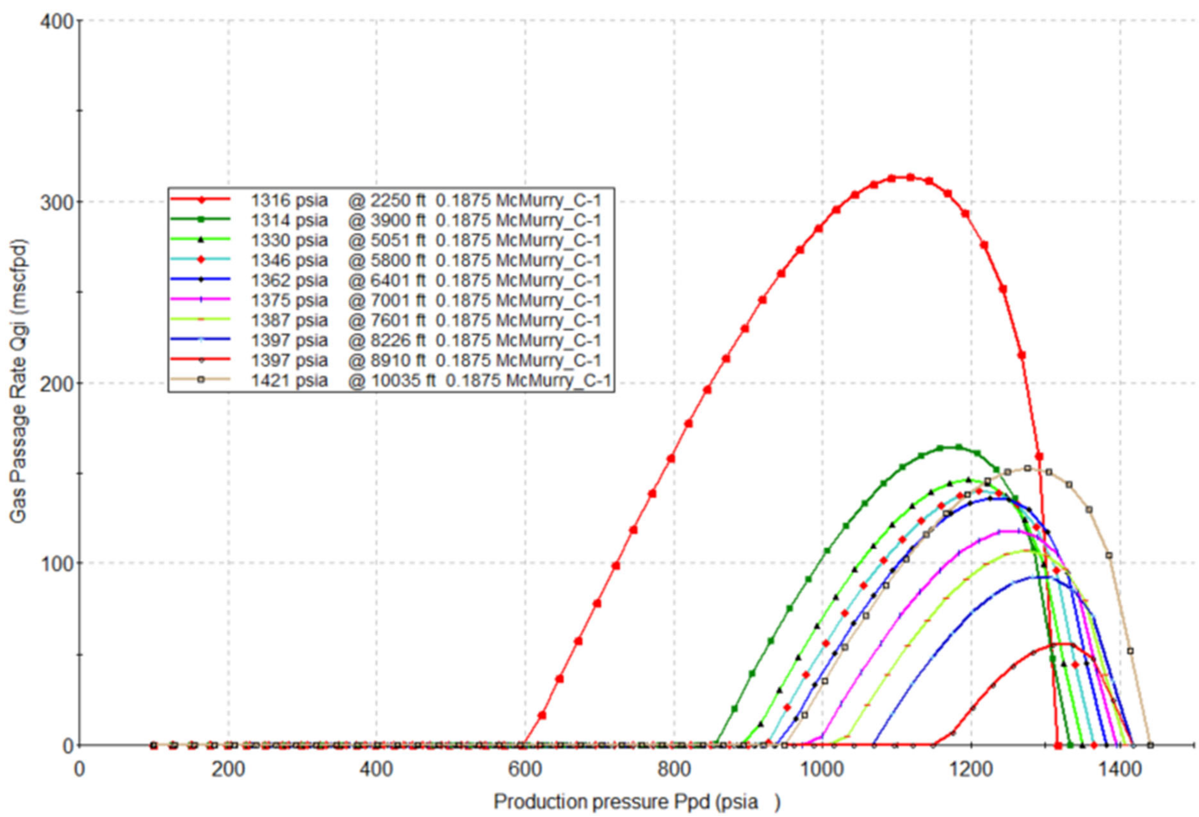

Figure 7: Spread of gas injection rate through all the 16 ports gas lift valve in this casestudy.

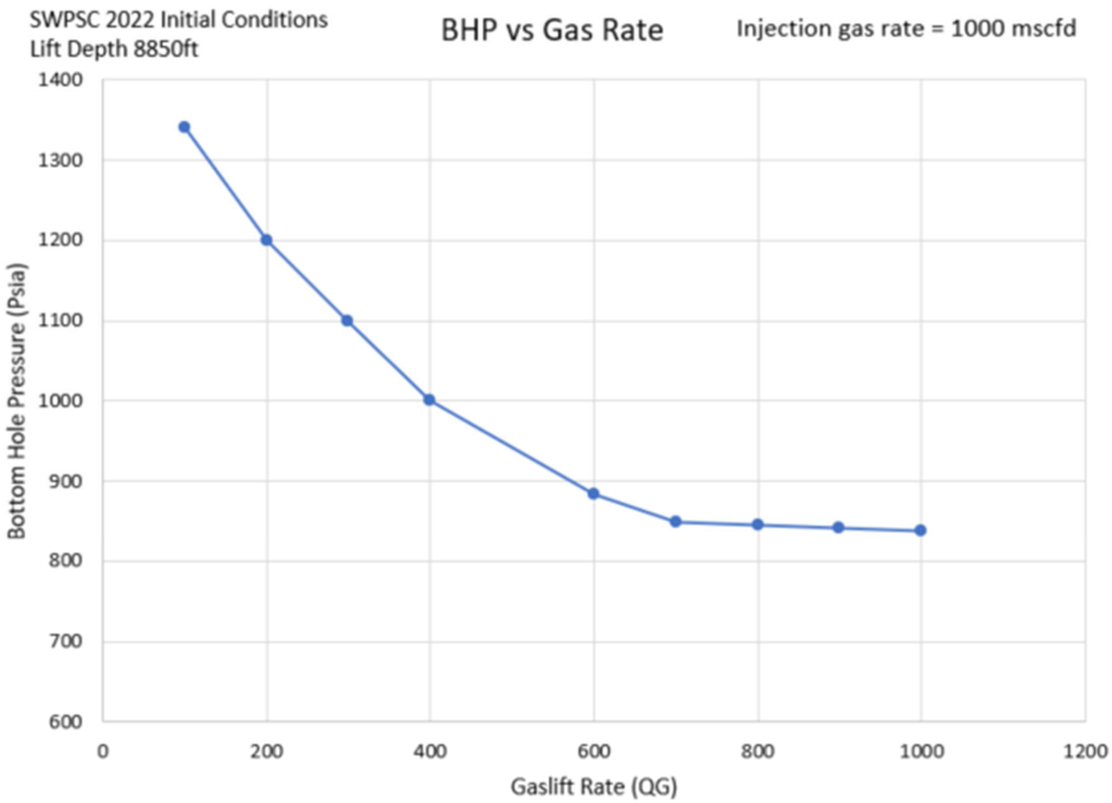

Figure 8: Gas injection sensitivity analysis on initial operating conditions.

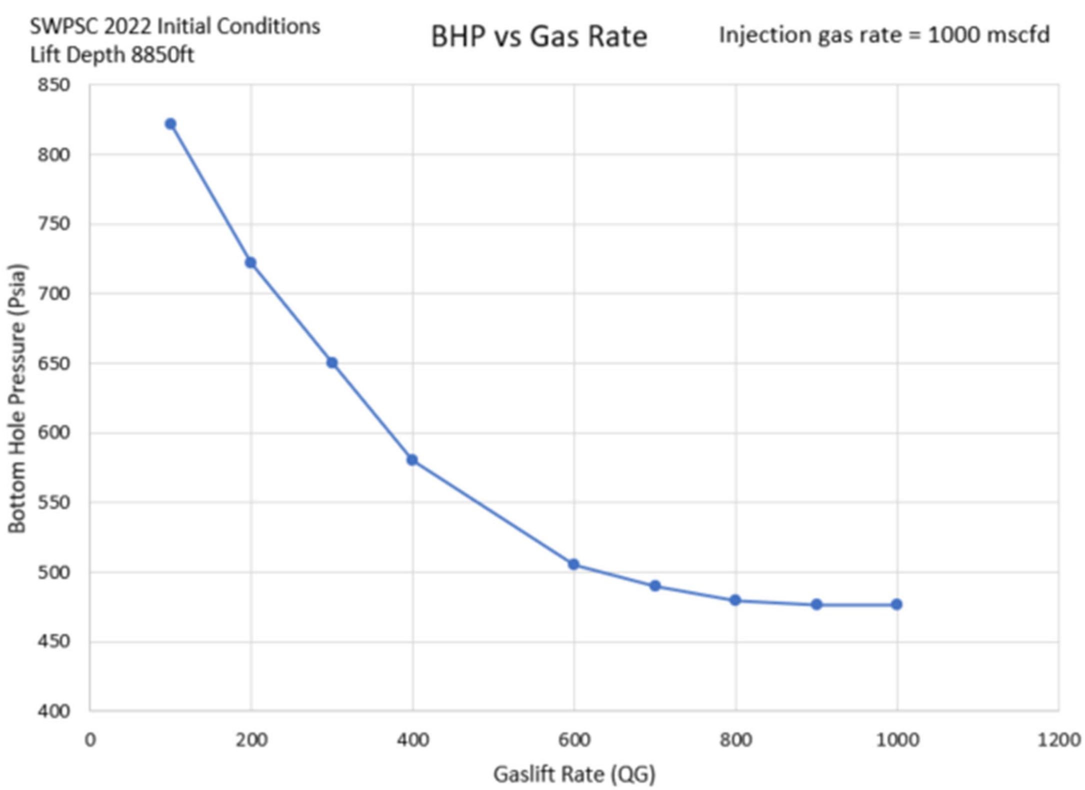

Figure 9: Gas injection sensitivity analysis on survey measured flowing conditions.

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