INSIGHTS AND RESULTS FROM NEW APPLICATIONS OF AN ENHANCED GAS SEPARATION METHOD FOR HIGH-FLUID, HIGH-GLR HORIZONTAL ROD PUMP WELLS

Alexander Davis, Adam Davidson, Michael Snider, Matthew Wilson, ConocoPhillips
Talor Nunez, Diamondback Energy
Luis Guanacas, Shivani Vyas, Gustavo Gonzalez – Odessa Separator Inc. (OSI)

ABSTRACT

This paper builds on last year's paper, which detailed the development of a new gas separation method for rod pump wells operating under gassy conditions, without limiting the liquid production rate. In this second part, the focus shifts to results from new applications in a different field within the Midland Basin, highlighting lessons learned from various BHA configurations, performance outcomes, and new challenges encountered during the evaluation process.

Six case studies with two different operators will be presented. The first case involves a conversion from a struggling ESP to rod pump, resulting in a 49% increase in total liquid rate and a 55% uplift in oil production compared to ESP's performance. The current pump fillage, after 5 months, has stabilized between 96% and 100%.

The second case focuses on a rod pump repair, where the legacy gas separator was not operating effectively and replaced with new technology while using the same type of pump. This allows a direct comparison of performance when replacing a legacy gas separator in an existing rod-pumped well. After the replacement, fluid production increased by 220%, with a 200% uplift in oil production. The average pump fillage before the replacement was 70%, whereas the current average stabilized at 96%.

The third case study presents another conversion from a low-rate ESP to rod pump. Here, the results not only show an uplift but also consistent pump fillage and 100% runtime, thus reducing wear on equipment from gas interference.

The fourth case involves a conversion from a low-rate ESP to a rod pump, resulting in a 41% increase in total oil production and a 42.7% decrease in gas production compared to ESP's performance. The current pump fillage, after 3 months, has stabilized between 98% and 100%.

The fifth case involves a conversion on a rod pump from a legacy gas separator to GRS, resulting in a 50% increase in total liquid rate and a 61% uplift in oil production compared to Legacy Gas Sep performance. The current pump fillage, after 3 months, has stabilized between 90% and 96%.

The sixth case study is a Midland basin well with a high GLR and an ideal application for gas lift that had to be converted from Gas Lift to rod pump due to pressure restrictions. The production after the conversion was higher and the pump fillage has remained high through the evaluation period.

These case studies were selected to illustrate the benefits of optimizing the gas separator to achieve the desired liquid production rate in both existing rod pump wells and ESP to rod pump conversions. Production losses after ESP-to-beam pump conversions are common, and this study has shown that this technology is an effective way to maintain or improve production targets and effectively rod pump horizontal wells.

Throughout this paper, we will cover the challenges faced, as well as the well selection criteria, and engineering solutions implemented or planned to achieve optimal outcomes for each installation. Based on the analyzed cases, a new design was developed, considering not only production rate and pump fillage but also velocity profiles, pressure drop, and tool geometry. Simulations and designs will be shared to explain the analyses conducted.

INTRODUCTION

One of the main challenges in the Permian Basin is high gas production, which presents specific difficulties for rod pumps, especially in wells that have been converted from electric submersible pump (ESP) and gas lift with higher fluid rates.

Given the previous criteria, the primary goal was to convert high GLR wells to rod pumps in areas constrained by gas lift infrastructure, enabling better efficiency and enhanced production capabilities. By leveraging the available pumping units, the objective was to achieve higher liquid rates while maintaining or surpassing pre-conversion production rates and drawdown targets. Furthermore, our efforts focused on optimizing the performance of existing rod pumps, addressing issues such as inconsistent pump fillage and high fluid levels to ensure reliable and efficient operations.

The initial method proposed was setting the gas separator intake inside the curve as shown in figure 1. The sketch below highlights the presence of free gas (red circles) and liquid (green areas), showing how gas enters the separator in the wellbore curve. The absence of a Gas Release System (GRS) above the separator can affect gas separation efficiency, which can lead to changes in production. Optimizing gas separation and pump intake placement in curved sections is critical to improve rod pump performance and ensure efficient fluid recovery in high GLR wells.

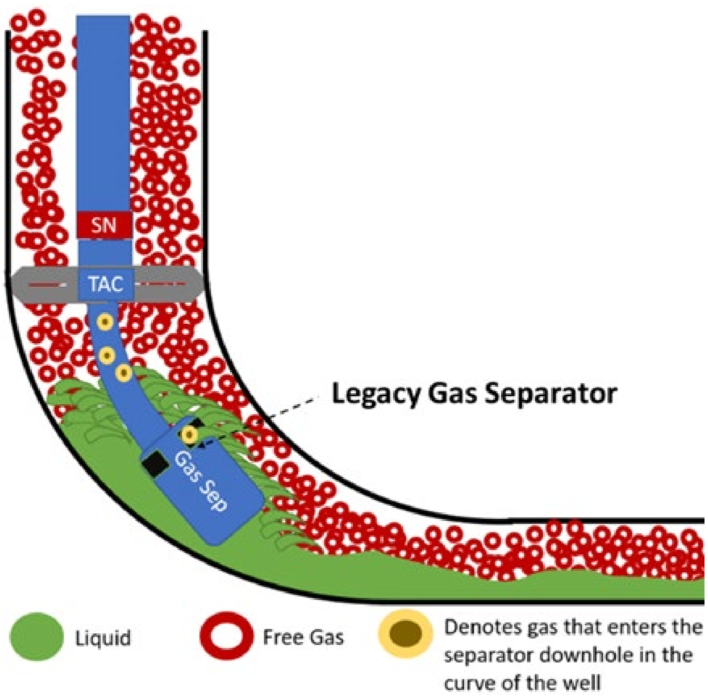

Figure 1 Intake in the Curve without Gas Release System

PROBLEM DESCRIPTION

After deploying the configuration shown in figure 1, we identified challenges related to inconsistent performance. Figure 2 shows the trends of the daily average pump fillage (gray line), pump fillage (light orange line) after attempting multiple troubleshooting techniques by changing the pumping speed and the tubing pressure. The problems encountered after this first installation are listed below:

- Low and inconsistent pump fillage: One of the problems encountered is low and inconsistent pump fill due to poor separation of gas and liquid, resulting in an excess of free gas reaching the pump. When the pump receives a mixture of gas and liquid instead of a constant flow of liquid, its efficiency is compromised, thus showing a reduction in production rates and an increased wear of the equipment. To provide an early solution to these limitations, design changes were required to optimize gas/liquid separation and ensure consistent pump performance.

- Fluid Intake Below the Kickoff Point (KOP): A serious consideration is the KOP. In the case of a legacy gas separator set above KOP, fluid levels below this point will effectively be pumped off. In other words, the pump performance will be suboptimal, as it does not have sufficient fluid levels to enter the pump and surface the fluid effectively.

- Gas Cannot Escape Before Entering Downhole Rod Pump: In the legacy gas separator system, gas cannot escape before entering the downhole rod pump. A major consequence may be gas becoming trapped in the fluid being pump, resulting in gas lock and preventing the opening of the standing and traveling valves.

- Unresponsive to Surface Optimization and Set-Point Changes: Surface enhancements and set-point changes are techniques used to adjust pump operation to improve pump performance. Attempts to optimize pump performance from the surface are ineffective, resulting in operational problems and persistent inefficiencies.

The Gas Release System (GRS) was designed to solve various well problems listed above, as it helps to optimize the separation of gas from liquid and ensures that only the gas-free liquid enters the downhole pump. The system uses dip tubes with strategic design features, such as a 45-degree bevel and inlet orifices, to effectively direct fluid through the separation process. Free gas is diverted upward and released through an orifice in the housing.

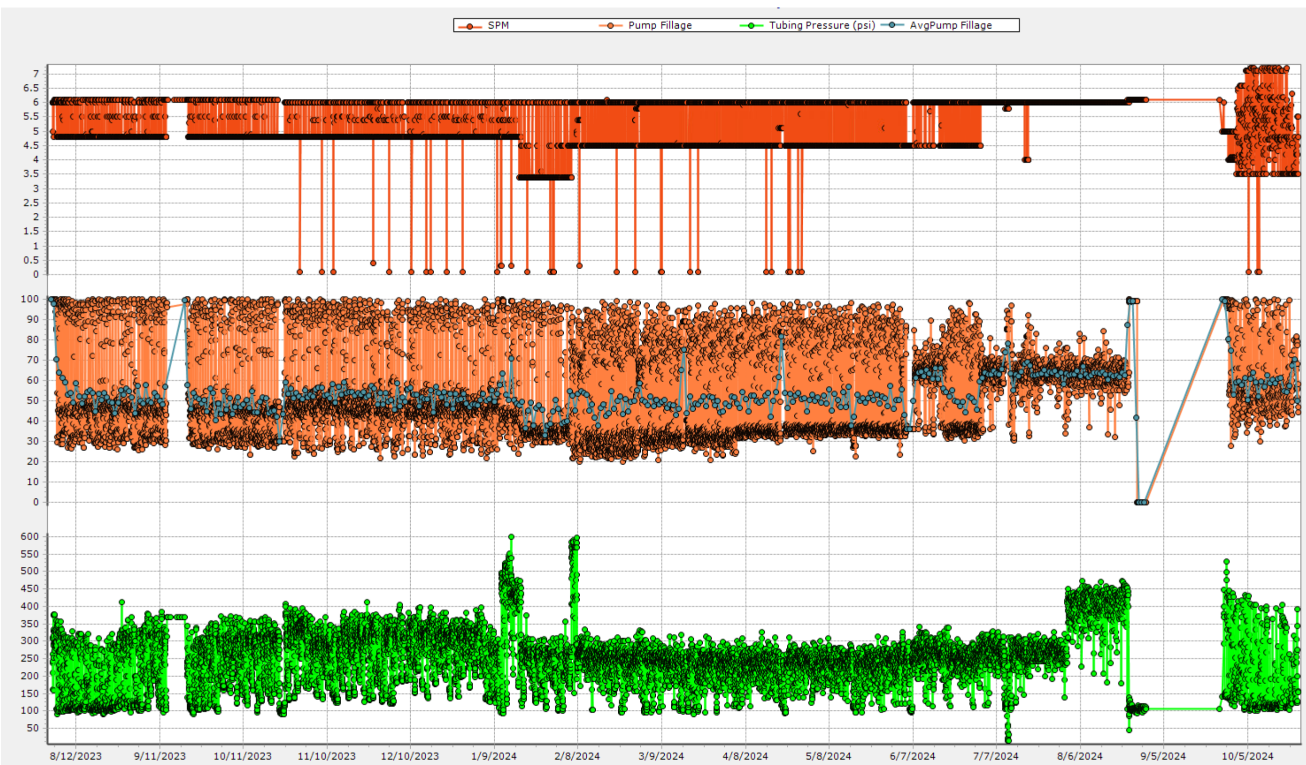

Figure 2 Results of Setting the Intake in the Curve Without Gas Release System

GAS RELEASE SYSTEM

There are two separate stages of gas separation in this design. The first is the "G-Force" gas separator installed inside the curve. In this stage, the gas enters the intake ports, separating the free gas from the liquid by gravity. By setting the gas separator at a high inclination, the intake will be at the lower section of the curve allowing the free gas to migrate upwards between the tubing and casing annulus. Once fluid enters the gas separator, the initial gas free liquid will flow through the dip tube and then will pass to the velocity string the connects the gas separator with the GRS.

The second stage is the GRS. It starts when the fluid rises internally from the gas separator system below and enters through the dip tube with a 45-degree bevel. This is a point of access to the GRS, where the separation of remaining free gas coming from stage 1 and liquid occurs. Additional gas may be present due to the differential pressure and breaking out from solution. The gas is directed upwards inside the GRS tool, ultimately exiting the GRS via a port venting to the tubing and casing annulus (red flow arrow). The gas-free liquid descends to the bottom of the GRS, entering the second dip tube with a 45-degree bevel, allowing the flow into the downhole rod pump.

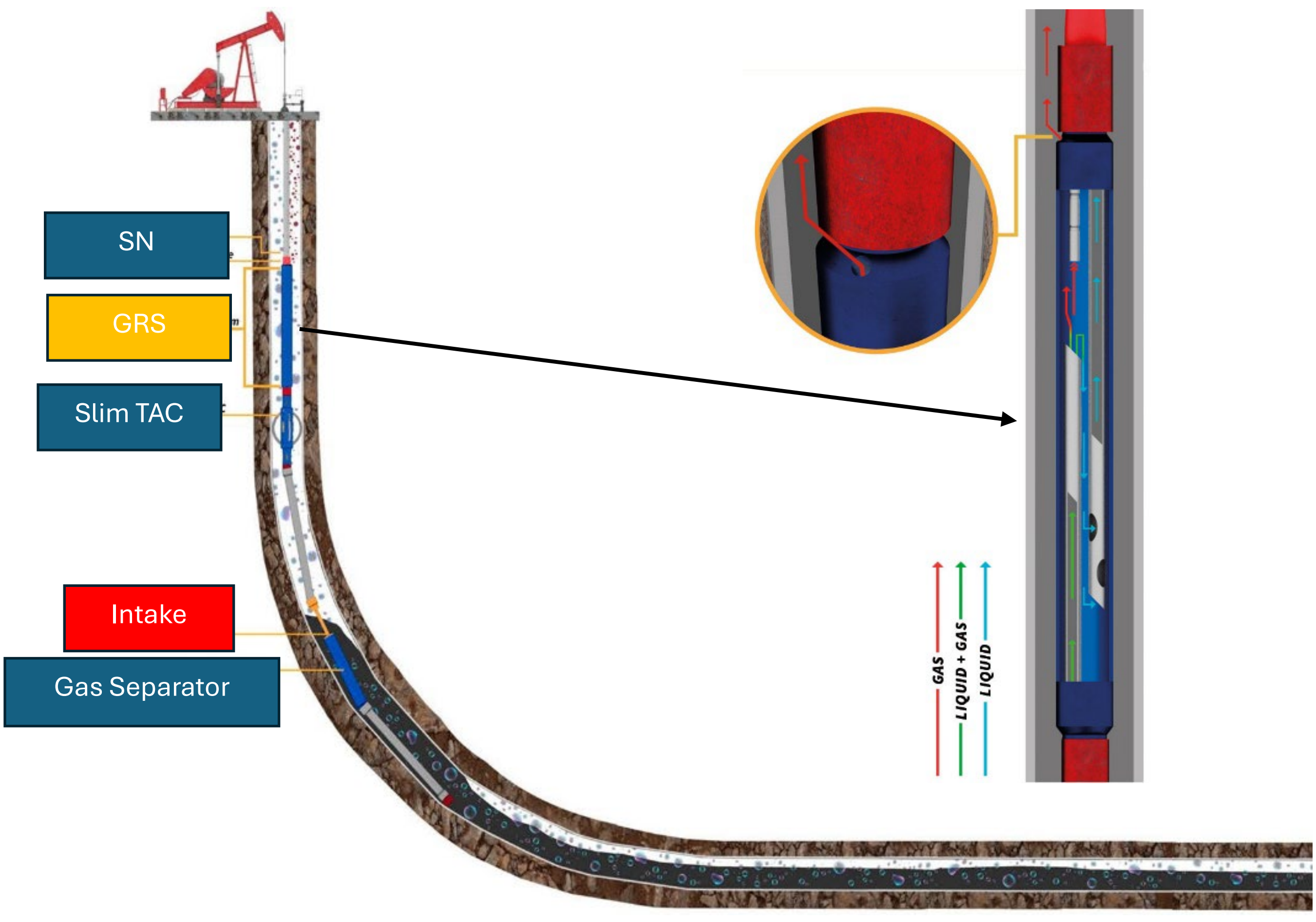

Figure 3 Gas Release System

CASE STUDIES:

Case Study #1: Legacy Gas Separator to GRS

The first case study analyzes the impact of replacing a legacy gas separator with a GRS BHA (Gas Release System Bottom Hole Assembly) in a rod pump (RP) well. The production performance before and after the modification was analyzed to evaluate the results. Before the replacement of the gas separator, the liquid production rate remained low, as well as the gas rates. Once the GRS BHA was implemented, there was a significant increase in oil (96%) and liquid (47%) production, demonstrating the effectiveness of the new system. (Figure 4).

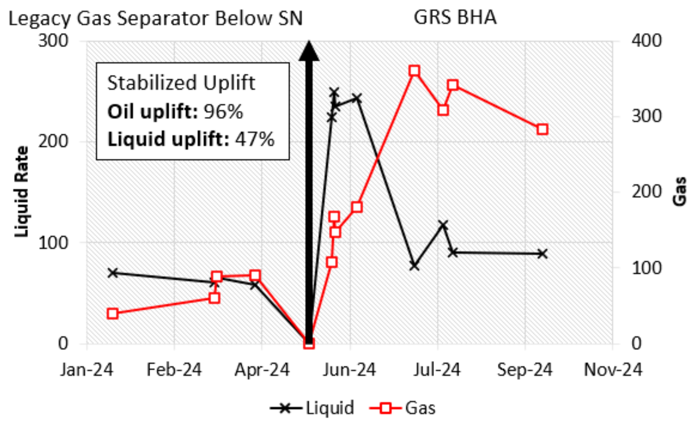

Figure 4 First Case Study Production Rates

In terms of pump performance, it is evident that before the replacement, the pump fillage fluctuated significantly at an average of 65%, indicating inefficient gas separation (Figure 5). Once the replacement was made, the pump fillage stabilized around 90-100% which aligns with the increased liquid production rate obtained after the installation. Analysis of the SPM graph (Figure 6) showed that the variable frequency drive (VFD) was continually adjusting the speed to match the desired fillage before the separator replacement. After the installation, the SPM stabilized. The replacement of the legacy gas separator with the GRS BHA significantly improved, as evidenced by the figures 4, 5 and 6, showing the production increase. Pump fillage increased from 69% daily average to 92% after the GRS installation. It should be noted that no other simulation, such as acid or other chemical squeezes were made upon conversion.

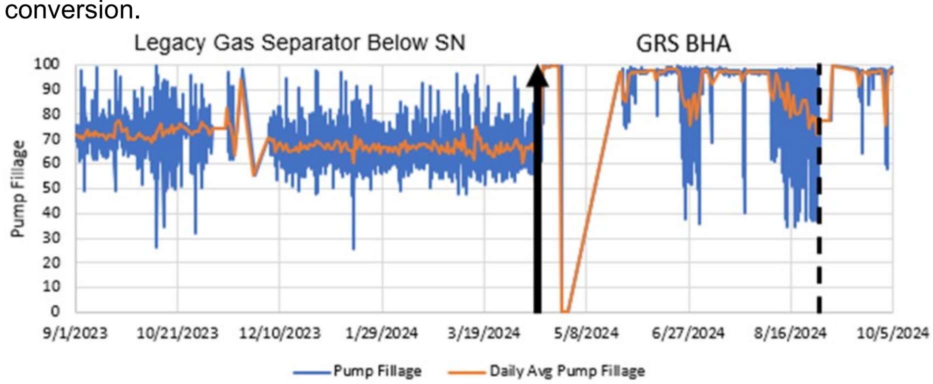

Figure 5 First Case Study Pump Fillage

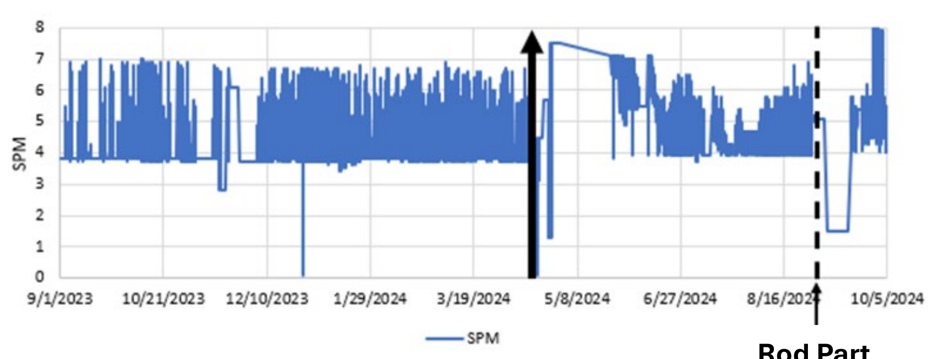

Figure 6 First Case Study SPM Graph

Case Study #2: ESP to RP Conversion

The second case study analyzed the conversion from an ESP to Rod Pump and evaluated the effectiveness of the conversion by monitoring liquid and gas production, pump fillage and pump speed.

Under the ESP system, liquids and gas production experienced a steep decline from October 2023 until the conversion to RP. After the transition to rod pump, both liquids and gas production recovered, with an increase of 11% for oil and 8% for liquids, but most important, with a less aggressive decline. (Figure 7). Again, no acid or chemical stimulation treatments were made during the intervention.

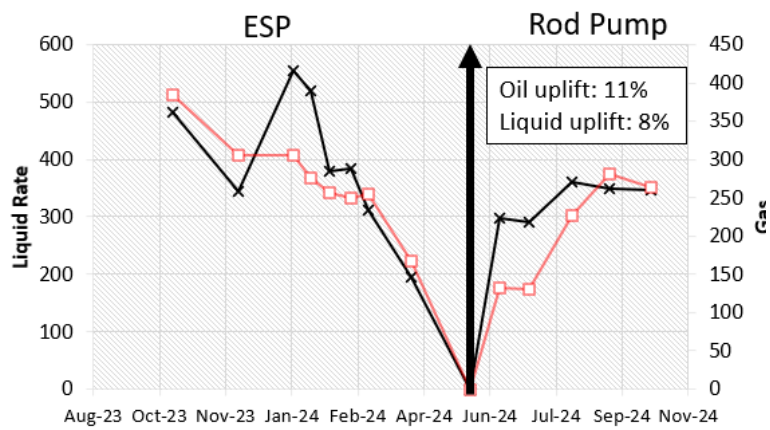

Figure 7 Second Case Study Production Rates

When analyzing the post-conversion rod pump performance, pump fillage (Figure 8) remained between 80-100%, on average, indicating efficient operation. The pump was also operating at a fixed speed which contributed to a smooth operation and fewer downhole failures (Figure 9).

The conversion from ESP to rod pump had a net positive impact on production, as an increase in liquid and oil rates was evident. Historically, conversions from ESP to RP typically result in lower production and this case study indicates a smooth conversion without production losses.

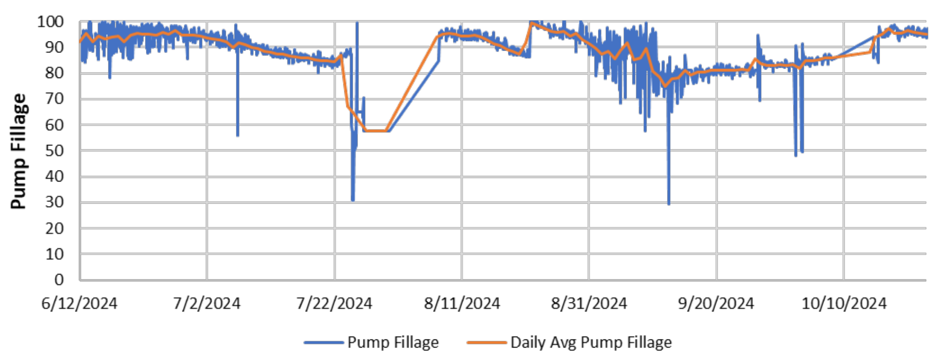

Figure 8 Second Case Study Pump Fillage

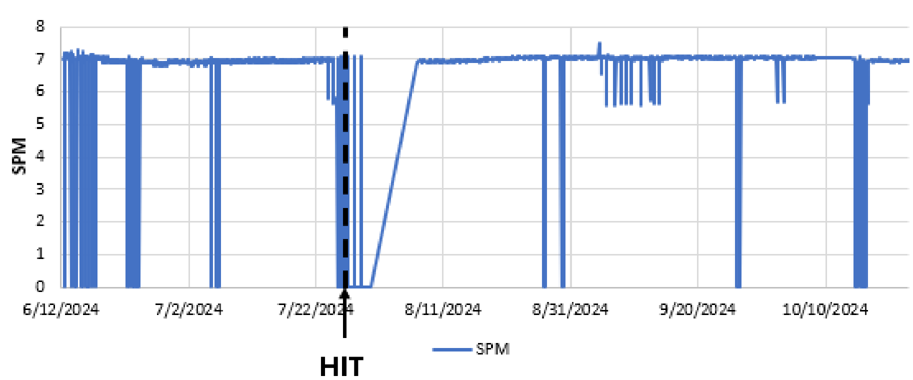

Figure 9 Second Case Study SPM Graph

Case Study #3: ESP to RP Conversion
The third case study reviews a second conversion from ESP to a Rod Pump and evaluates the production performance. The objective of the conversion was to enhance operational stability and production rates.

In the last month before conversion, it was observed that liquid and gas production rates were trending downward. When the well was converted to rod pump, there was a 54% increase in oil production and a 50% increase in total liquid production, demonstrating the effectiveness of the GRS BHA in improving production rates without stimulations during the intervention (Figure 10).

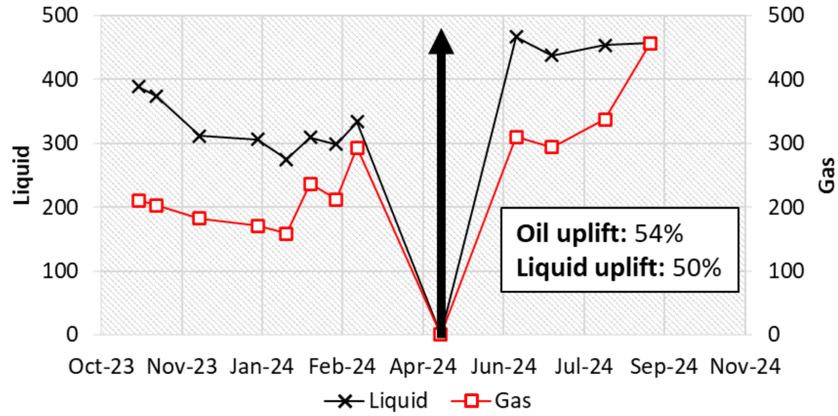

Figure 10 Third Case Study Production Rates

After the conversion, pump fillage stabilized close to 90-100% (Figure 11), indicating efficient performance. Figure 12 shows how the VFD held the strokes per minute (SPM) relatively constant and still maintained good production performance.

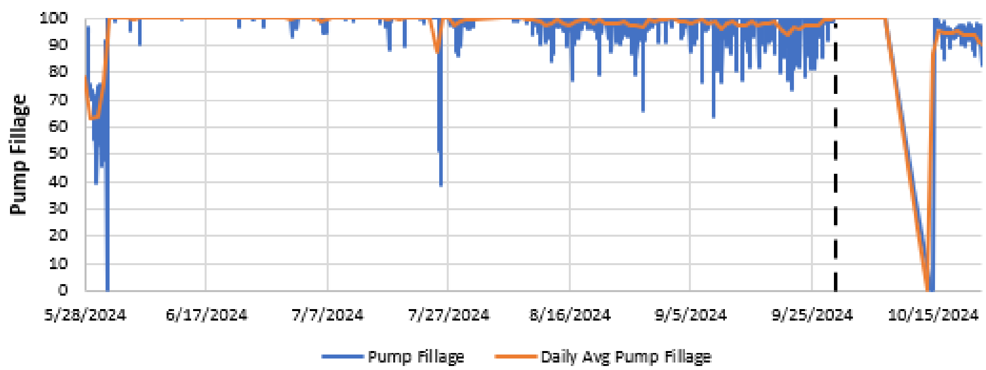

Figure 11 Third Case Study Pump Fillage

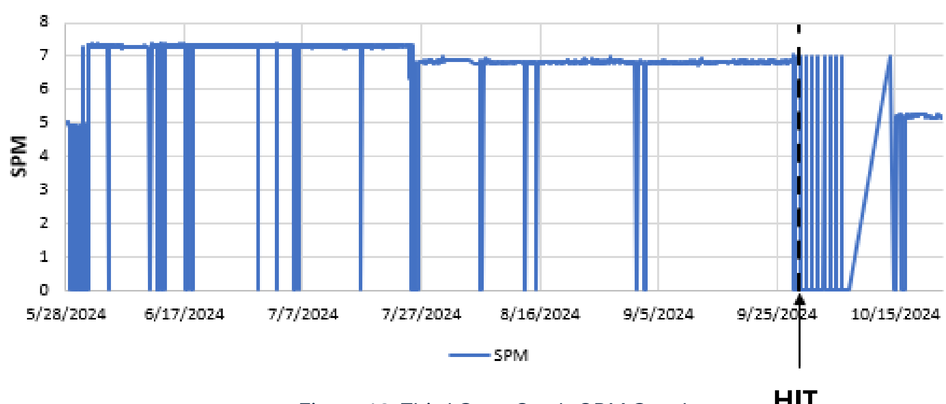

Figure 12 Third Case Study SPM Graph

Case Study #4: ESP to Rod Pump

Figure 13 illustrates liquid and gas production rates before and after the conversion to rod pump. A noticeable performance improvement is observed in the decline trend from ESP to rod pump. Prior to the GRS installation, production declined 2.33 bbls per day, on average, while producing significantly higher water cuts. After the installation, the liquid rate stabilized, with an average oil uplift of 41%. Similarly, gas production showed an upward trend, indicating enhanced efficiency in handling gas-liquid separation. These results suggest that the equipment upgrade positively impacted overall production, minimizing downtime and optimizing well performance.

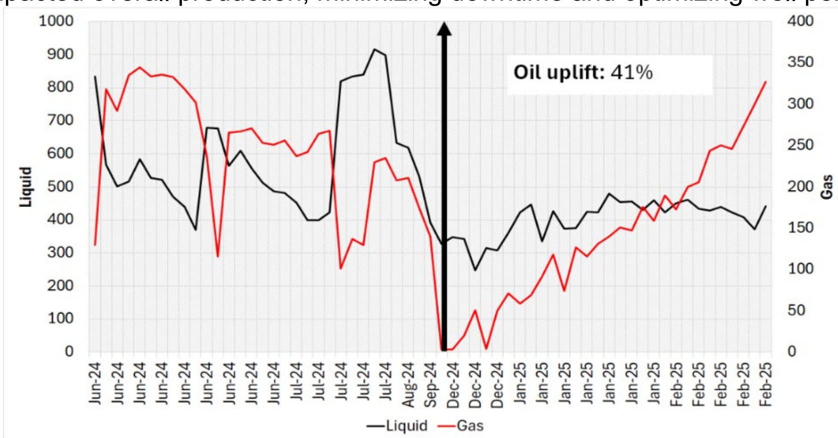

Figure 13 Fourth Case Study Production Data

Figure 14 illustrates the pump fillage over time, highlighting the consistent results obtained after the installation. Overall, an average pump fillage of nearly 100% has been achieved after the conversion.

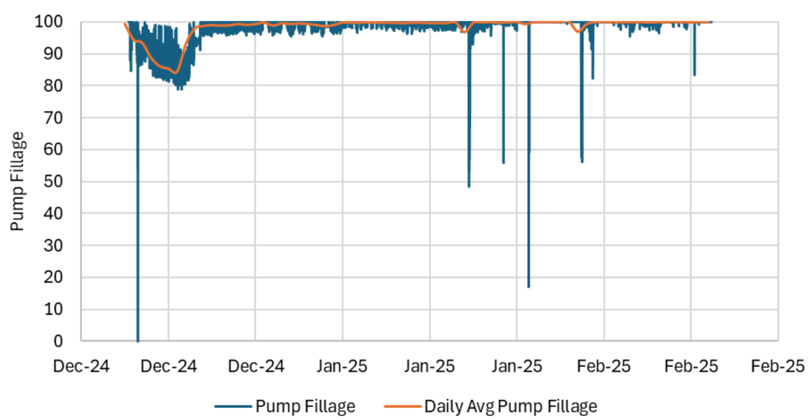

Figure 14 Fourth Case Study Pump Fillage

Figure 15 shows the pumping unit running at a fixed speed with minor fluctuations that have been responding properly in terms of performance and stability. Fewer changes in the pump speed will contribute to a longer durability of the rods and the mobile components of the rod pump system.

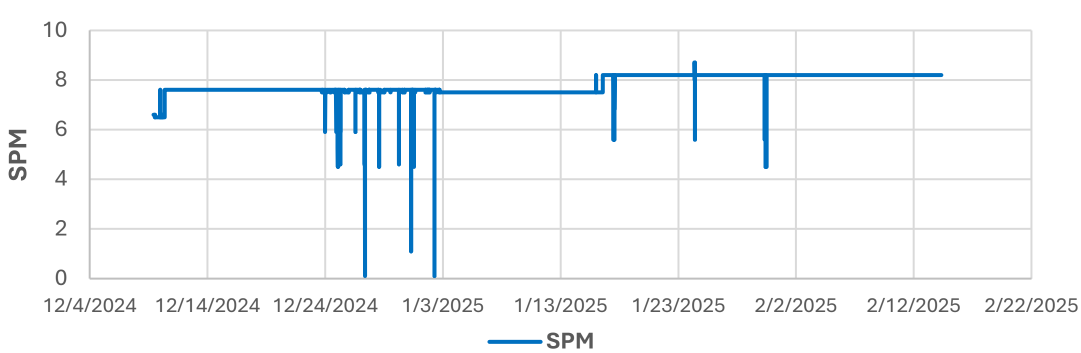

Figure 15 Fourth Case Study SPM Graph

Case Study #5: Legacy Gas Separator to GRS

Figure 16 illustrates the impact of a GRS since December, significantly improving the pump fillage. Before the installation, the pump fillage exhibited considerable fluctuations, with frequent dips indicating inefficiencies in gas handling. Before the installation, the daily average pump fillage (orange line) was around 55%, creating possible failure points due to gas interference. After the GRS was installed, the system stabilized, with pump fillage reaching and maintaining values at around 90% or above. This suggests that the GRS helped optimize gas-liquid separation, allowing for more efficient pump operation and stable production.

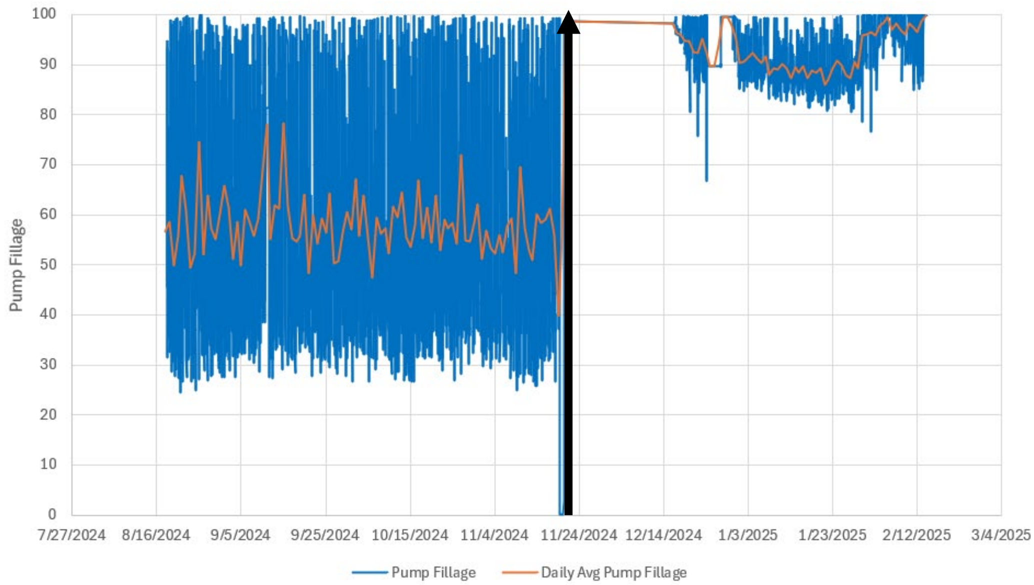

Figure 16 Fifth Case Study Pump Fillage

Figure 17 shows the effect of a GRS installation in December, which significantly improved operational stability. Before the installation, the instantaneous SPM fluctuated heavily, with the average SPM ranging between 4.5–6.5 SPM. Following the GRS implementation, there was a noticeable change reaching a more stable speed above 6 SPM. In the long term, this stable speed will prevent frequent failures in the downhole equipment.

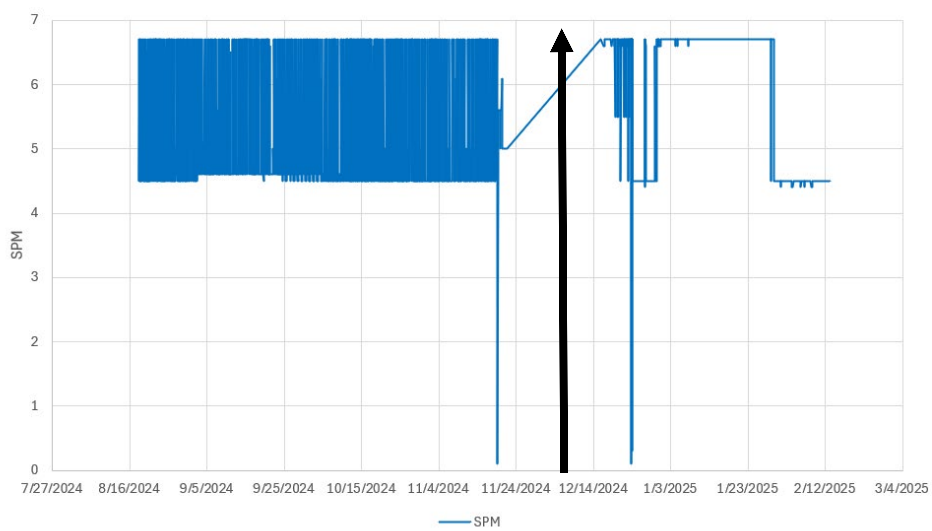

Figure 17 Fifth Case Study SPM Graph

Case Study #6: Conversion from Gas Lift to Rod Pump

Figure 18 shows the production trends and pressure behavior of the well overtime. Key parameters such as tubing pressure (yellow line), casing pressure (purple line), gas production (red line), oil production (green line), and water production (blue line) are tracked. The GRS was installed in July, leading to noticeable improvements in production stability and efficiency. Before the GRS installation, fluctuations in gas and oil production were more prevalent, with significant spikes and drops. Following the conversion gas production stabilized and oil and water production showed a consistent trend, suggesting improved gas separation efficiency and reduced interference in liquid flow. These improvements indicate that the GRS successfully optimized fluid handling and enhanced overall performance. The addition of the GRS resulted in an 83% increase in total liquid rate and a 165% uplift in oil production

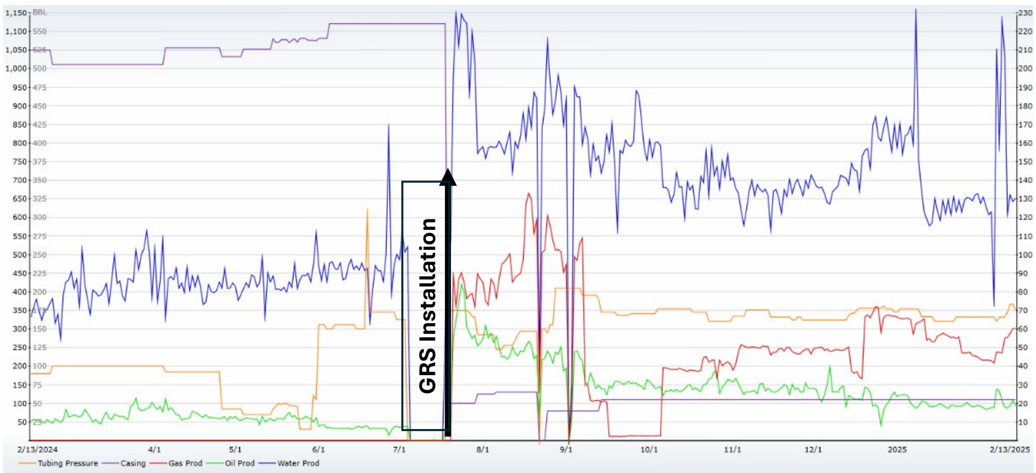

Figure 18 Sixth Case Study Production Data

Figure 19 shows the performance parameters, including pump fillage, tubing pressure, casing pressure, well test gross and oil, and inferred production. The pump fillage (upper-most dark blue line) remained high for most of the evaluation period, the inferred production (golden markers) shows fluctuations but remained relatively stable after an initial ramp-up phase. The well tests of oil and gross production indicate periods of increased and stabilized output, suggesting effective artificial lift operation. The pump fillage remains high for most of the period, with occasional drops keeping values between 90 and 100%. The observed trends highlight the impact of operational adjustments and possibly the implementation of a gas separation system, ensuring more stable production and improved performance showing the operational efficiency of GRS.

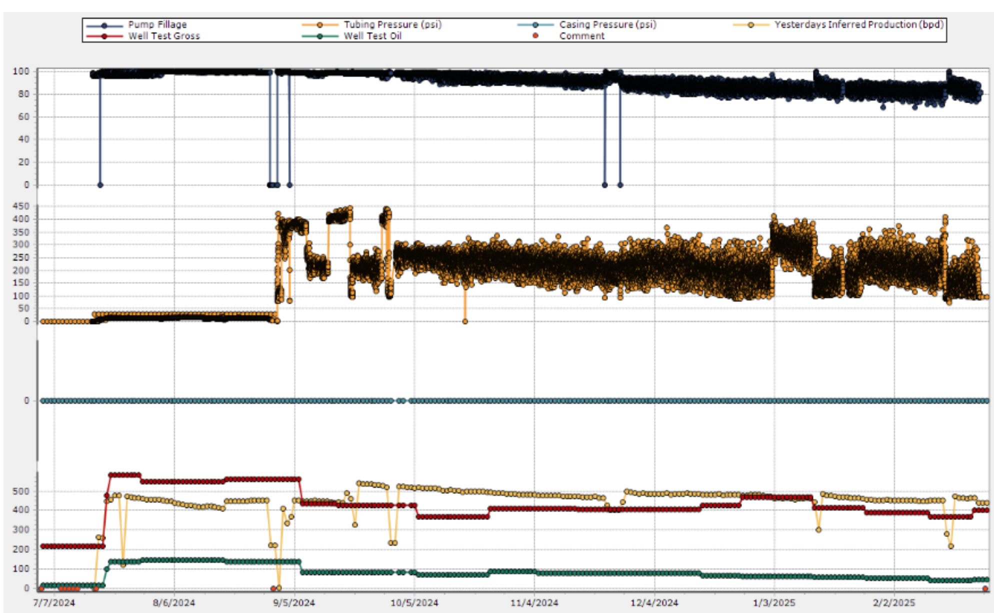

Figure 19 Sixth Case Study Well Performance Metrics

Figure 20 illustrates the relationship between pump fillage, runtime, and strokes per minute over time. The pump fillage stays consistently high. The runtime (blue markers) is mostly stable to yield a higher cumulative oil production compared to previous periods. The SPM (yellow markers) indicate stability, operating at a fixed speed, which is healthy for the overall pumping system. The well is continuing to operate efficiently with high pump fillage.

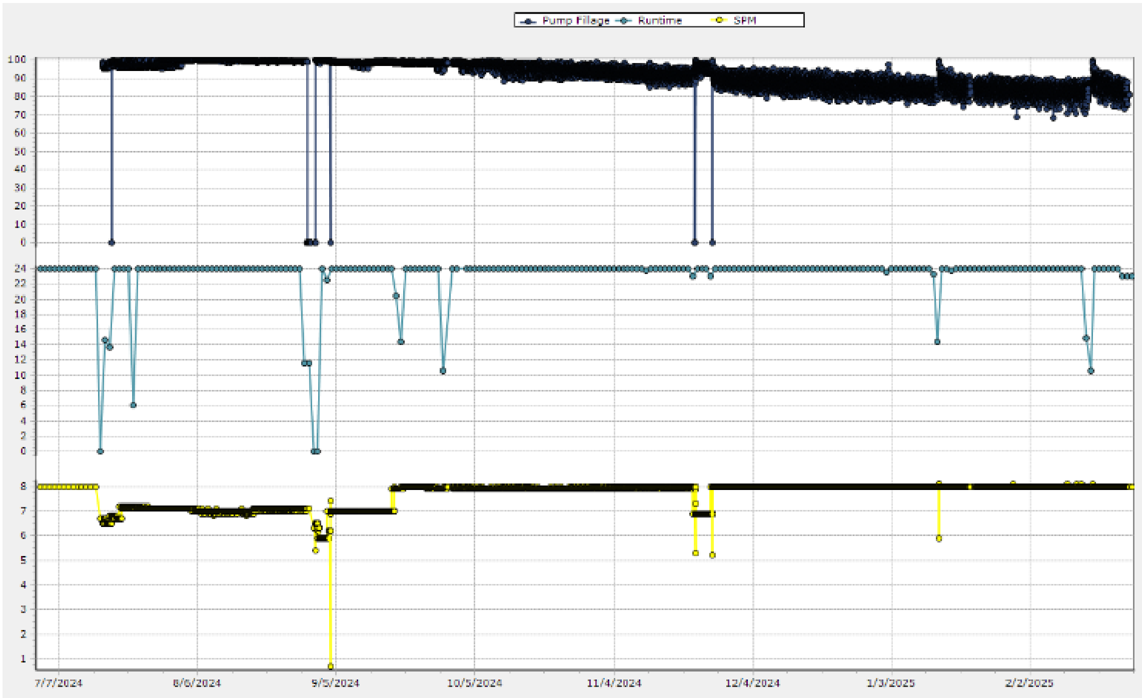

Figure 20 Sixth Case Study Pump Fillage, Run Time & SPM

Challenges Requiring Further Investigation

Challenge #1: Legacy Gas Separator to GRS

A legacy gas separator was replaced with the GRS BHA due to inconsistent pump fillage at an average of 60%. Figure 21 shows the pump fillage trend over time, with the installation of the GRS marked by a bold vertical arrow in August 2024. Prior to this installation, the pump fillage exhibited high variability, fluctuating significantly. After the GRS was implemented, the pump fillage initially remained stable at nearly 100%, indicating improved volumetric efficiency. After the conversion, fluid levels decreased from approximately 2,500' gas free above pump (GFAP) to 1500' GFAP with no change in rod design or stroke length. After the conversion, we noticed prolonged periods of low pump fillage. A preliminary analysis suggests severe gas interference and the plunger inside the downhole pump during a pump change in October 2024 showed signs of scoring, indicating the presence of solids.

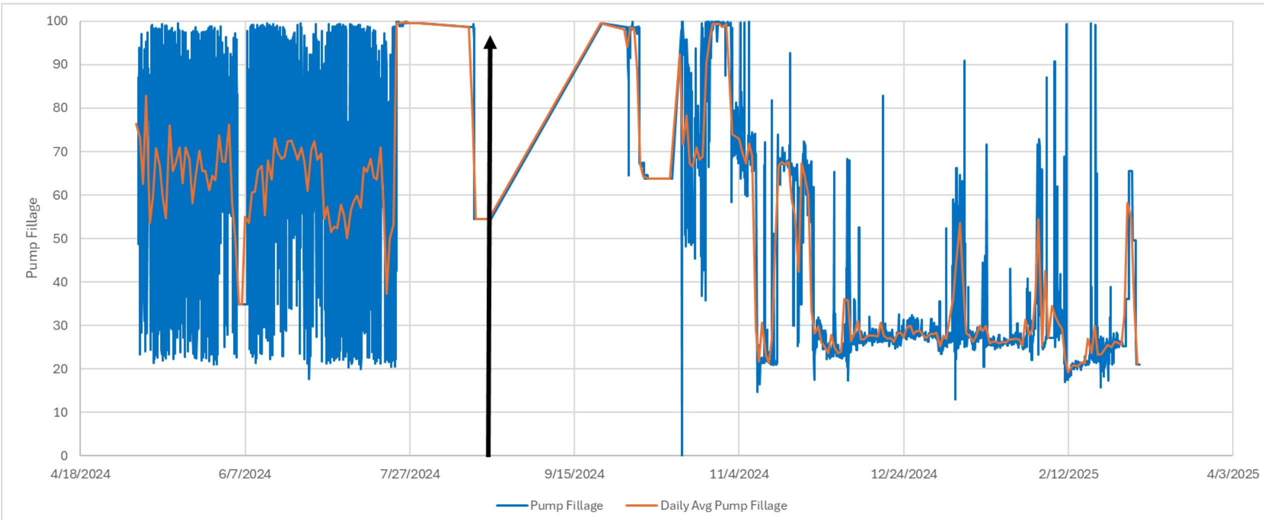

Figure 21 Challenge #1 Pump Fillage

Figure 22 shows the pump speed graph that indicates significant operational changes around the time of the GRS installation in August 2024, marked by a vertical arrow. Before the installation, the SPM remained inconsistent, suggesting a high number of cycles and intermittent production. A similar trend was seen post-installation, even after slowing the unit down.

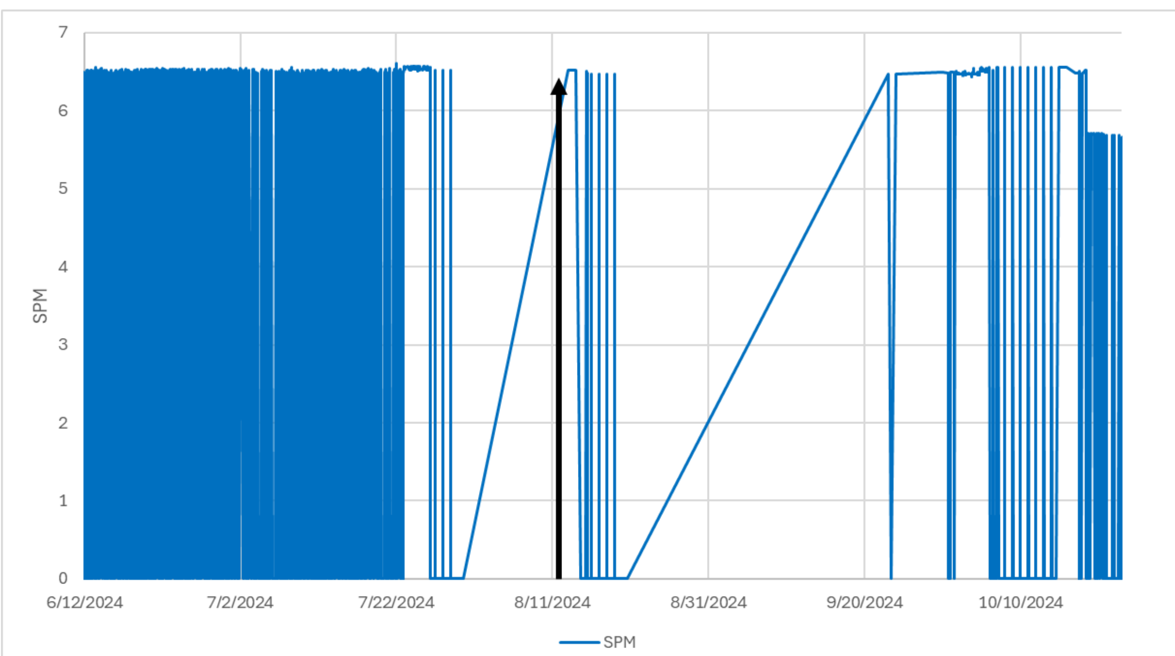

Figure 22 Challenge #1 SPM

Despite the unusual performance shown in the pump fillage and SPM plots, the production before and after the installation has been compromised, emphasizing the effect of low pump fillage. Figure 23 shows the production trends for liquid and gas over time. An installation of a GRS was made in August 2024, marked by a bold vertical arrow. In our previous case studies, it is interesting to see how a consistently low pump fillage using the same pump and similar production parameters is producing similar or higher rates than the period before the GRS installation. Considering the lower gas separator was installed at a high inclination (60 degrees) and had a history of solids with no cleanout upon conversion, a second possibility of the underperformance may be due to a plugged intake, thus restricting fluid flow and reducing pump efficiency. The well is still running awaiting further analysis to identify the root cause of the underperformance.

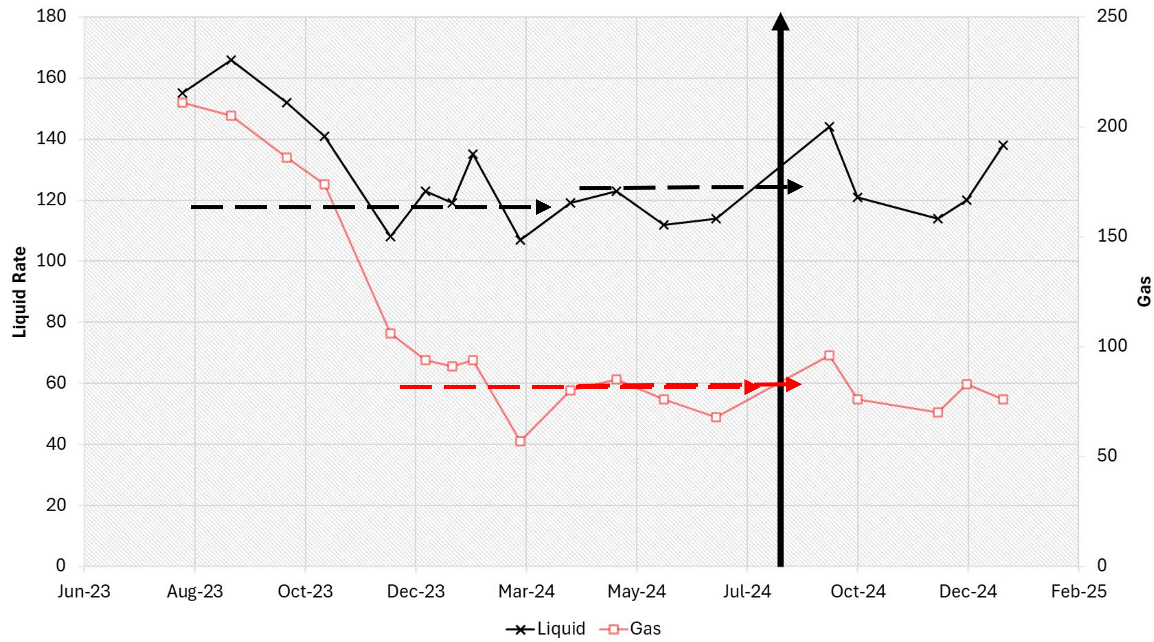

Figure 23 Challenge #1 Production Data

WELL APPLICATIONS SUMMARY

Figure 24 summarizes the results obtained from a sample of 17 wells. Wells 1-5 were ESP to RP conversions and wells 6-17 were legacy gas separators to GRS installations. The pump fillage before the GRS is represented with blue bars while the orange bars represent the pump fillage after the installation. The pre-conversion fillage (blue bars) are consistently lower than the post-conversion fillage (orange bars), demonstrating that the GRS has significantly enhanced the efficiency of the pumping system on most installations. Additionally, the wells that have only orange bars (other ALS to beam pump conversion) indicate consistently high pump fillage, suggesting that these wells started with optimal conditions and have benefited greatly from the GRS installation, ensuring efficient fluid production and minimizing gas interference. This overall trend highlights the positive impact of the GRS on pump performance across the wells. Furthermore, an average of 90% pump fillage among the 17 shows a great gas-separation efficiency of the GRS.

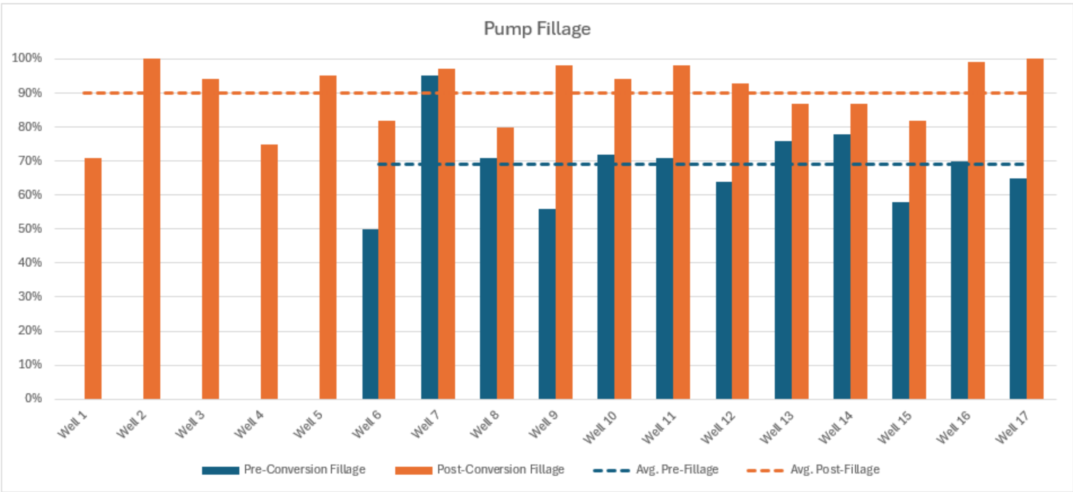

Figure 24 Pump Fillage on Various GRS Installations

Figure 25 shows how the installation of the GRS has significantly contributed to improving key production factors, as demonstrated in the charts. In terms of oil uplift, the GRS has shown enhanced efficiency, with 97% of the total oil production showing uplift and only 3% experiencing losses. Similarly, BOE (Barrels of Oil Equivalent) uplift reached 86%, with losses only of 14%. Fluid uplift also improved, with 89% uplift and only 11% losses. Additionally, when analyzing uplift by well count, most of the wells benefited from uplift, with 79% showing improvement in oil and 71% in BOE production, and 86% in fluid production, while only a small percentage experienced losses. These results indicate that the GRS has effectively optimized production by reducing gas interference, improving pump efficiency, and enhancing overall fluid handling, leading to a net positive impact across multiple production parameters.

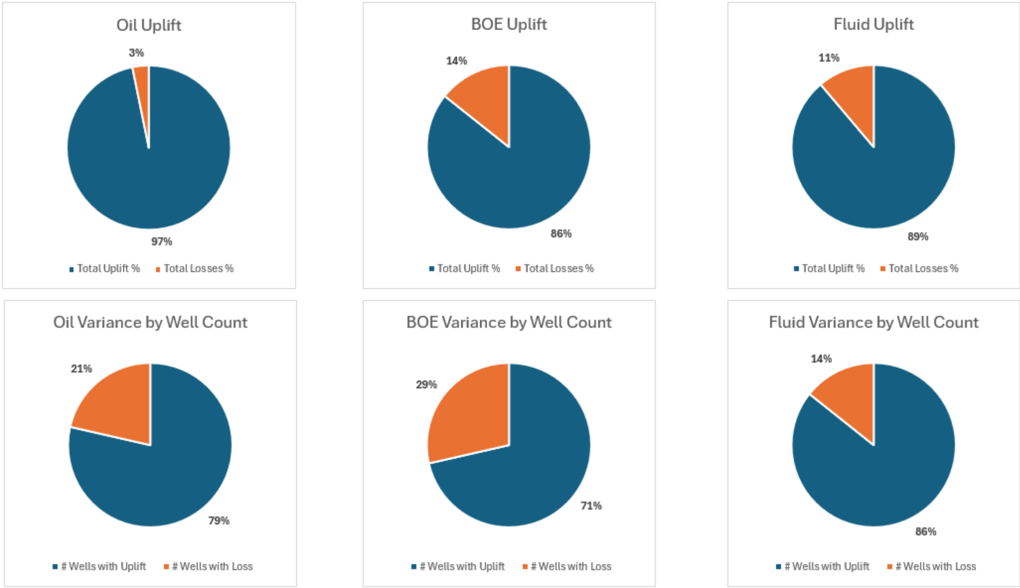

Figure 25 Production Uplift/Losses

CONCLUSIONS

The implementation of the Gas Release System (GRS) as an enhanced gas separation method for high-fluid, high-GLR horizontal rod pump wells has demonstrated significant improvements in well performance. Based on the data analyzed, several key conclusions can be drawn:

- Increased Pump Fillage Stability – Prior to the GRS installation, the pump fillage experienced frequent and severe drops, likely due to gas interference led by poor gas separation efficiency. After the installation, pump fillage stabilized at higher rates compared to previous rod pump installs or at high and consistent values in the conversion cases.
- Reduced Operational Instabilities – The pre-GRS period displayed erratic variations in both SPM and pump fillage, pointing to operational inefficiencies in handling high-GLR conditions. The GRS application successfully mitigated these issues by providing a more stable and controlled downhole environment.
- Out-performance in Gas Lift/ESP to Rod Pump conversions – four case studies were presented where high fluid rates and high GLR wells were converted to rod pump achieving outstanding results not only in the oil rate but in the operational stability of the pump. With oil uplifts ranging from 11 to 165%, this new method has proven versatility and capacity to handle different values of gas and liquid.
- As an optimization approach in developed areas with legacy gas separators, this strategy can add significant value, though it is important to consider the fluid level above pump.
- When sand production is suspected, strategies such as adjusting the inclination and performing curve clean-outs may be beneficial. However, sand-related issues remain a challenge that requires further attention from both design and operational perspectives.
- The evaluation of the well productivity plays an important role in this type of application. Wells with low productivity or suspected obstruction issues in the formation need to be analyzed to determine the possibility of performing an operation such as a clean out or acid job to obtain a significant benefit out of the GRS BHA.
- After pumped-off conditions, new strategies like setting the pump at a high inclination warrants further evaluation with the corresponding changes in the rod string to avoid downhole failures.

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