NEW GAS BYPASS SYSTEM
FOR UNCONVENTIONAL WELLS ON ESP

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Sponsored by PetroLegacy

ABSTRACT

New unconventional wells in the Permian Basin have been very challenging to produce using electric submersible pumps (ESPs) due to high gas-to-liquid ratio's experienced early in the life of the well. ESP's by nature are designed to pump only liquids and have difficulty handling a large amount of free gas. Gas entering the ESP not only decreases volumetric efficiencies, but also causes high temperature issues and erratic run behavior. This decreases production and degrades the mechanical integrity of the ESP, leading to higher maintenance costs and ESP failures. Since ESP failures are a major expense incurred by the operator, the most effective method to reduce operating expense is to increase runtime, decreasing ESP failures by reducing the amount of free gas that enters the pump.

Operating conditions can be significantly improved by utilizing the new innovative technology of the ESP Gas ByPass when paired with proper ESP design and operational practices. The ESP Gas ByPass utilizes a cup-type packer to isolate all flow before reaching the pump intake and creates an isolation chamber below the ESP. Pressure is then created so as fluid moves upward, gas is released naturally. The primary focus of the tool is to utilize the casing to create a natural downhole gas separator and allow free gas trapped below the packer to be discharged well above the intake of the ESP.

This paper presents the technology behind the ESP Gas ByPass and offers case study results that prove the positive impact of this tool on overall operating expense.

INTRODUCTION

Unconventional wells in the Permian Basin have high initial rates with steep declines, cf. [3], which creates a major challenge for ESP's. Steep decline rates result in a high gas-to-liquid ratio (GLRs) very early in the life of the well. As the reservoir pressure draws down below bubble point pressure, increasing volumes of free gas begin to break out of solution, see [1].

These high GLRs create a major hurdle for ESP operations. ESP's are designed to pump only fluid and have difficulty handling a large amount of free gas, as described in [4, 5]. When ESP's encounter this condition, they typically gas lock, resulting in shutdowns due to insufficient cooling of the motor. This is costly for the operator in terms of lost production and time spent troubleshooting the issues.

Studies performed by Baker Hughes, cf. [6], were conducted to determine the severity of the impact of gas locking in an ESP. It was determined that for every two hours of ESP operations during a gas locking event, the temperature rises to an average of 430°F. High temperatures result in multiple failures throughout the ESP equipment including, but not limited to: unseated carbide bushings cutting the shaft, thermal shock and degraded carbide parts, and damaged motor lead extension (MLE).

Not only does gas locking decrease overall production, but it also degrades the mechanical integrity of the pump. This leads to higher maintenance costs and eventually a costly ESP failure.

The primary goal of the initial ESP is to achieve peak production rates and draw a high volume of fluid from the reservoir as quickly as possible, cf. [2]. Standard operating practices are to pump wells hard and fast using large equipment to achieve high initial rates. It is a normal practice for an operator to design the initial ESP with the expectation that it will have a short run life. There are many factors that contribute to this short run time, including gas interference and solids abrasion. Many attempts at mitigating these issues have been made over the years, however these challenging conditions have yet to be completely overcome. Some of the standard practices across the industry include running gas handler pumps and shrouded systems. Both methods can be beneficial, however they do not significantly reduce the amount of free gas entering the pump, which is key in extending the life of the ESP.

To overcome these operational challenges, the amount of free gas entering the pump must be minimized. This improves runtime, decreases operating expense and increases overall production.

PRE-ESP GAS BYPASS INDUSTRY STANDARD

In attempts to mitigate solids, much of the industry has settled on running ESP Desanders below the pump. Due to the functionality of ESP's, this requires a packer to be run below the ESP to control the flow path through the desander prior to pump intake.

During testing, it was determined that a combined gas and liquid interface accumulates beneath the packer. As gas is released out of solution, a column of gas builds up and eventually is pulled into the desander intake. The solution is then discharged above the packer and all of the free gas is forced to travel past the pump intake. Some of the gas naturally bypasses the ESP, however a large majority gets pulled into the pump, as shown in Figure 1.

WHAT IS THE ESP GAS BYPASS

The ESP Gas ByPass is a new innovative system that utilizes dual HNBR cup technology to isolate all flow before reaching the pump intake, creating an isolation chamber below the ESP. Beneath the packer, a two-phase system naturally develops as the gas rises out of the fluid. The gas column is then channeled through the ESP Gas ByPass system, discharged above the pump intake and encouraged to flow freely up the annulus. The fluid column travels through a desander where the solids are separated and discharged below the point of fluid intake. Clean fluid moves up through the desander through the ID of the packer and is discharged below the ESP, allowing for efficient cooling the motor.

In testing this tool, separation efficiencies were increased by 45 percent compared to other technologies on the market, resulting in improved pump performance in ESP wells. This system effectively reduces the amount of free gas entering the pump, which ultimately extends the life of the ESP system. The ESP Gas ByPass assembly is shown in Figure 2.

OBJECTIVES OF THE ESP GAS BYPASS

The best method for gas handling is to leverage natural gas separation as much as possible within every design. During testing, the fluid intake was set at various inclinations throughout the curve to determine the degree of inclination that would best utilize natural separation. It was determined that setting the fluid intake point at 45 degrees is the optimal set point. As gas accumulates beneath the packer, a column of gas will begin to form, creating a gas/liquid interface.

The primary function of the ESP Gas ByPass is to create a path for the gas accumulation to travel and discharge above the ESP intake. After the gas is discharged, it will naturally rise up the casing annulus to the surface. Utilizing the ESP Gas ByPass to reduce the amount of free gas entering the pump will accomplish two main objectives: It will help to stabilize pump performance and will in turn extend the runtime of the ESP. Longer ESP run times result in lower expenses for the operator.

DESIGN OF THE ESP GAS BYPASS

The standard design for the patented ESP Gas ByPass system is primarily based off two reference points: ESP sensor set depth and the desander or fluid intake point, which is recommended to be at 45-degree inclination. Working up from the bottom of the assembly, a typical design starts with a bull plug and mud joints. A bull plug is set at the very bottom of the assembly to create a closed system for separated solids to be stored. The recommended size and number of mud joints varies depending on severity of solids within each well. A very important factor to remember is that ESP's have maximum recommended hang off weights, which must be considered during the design process.

Above the top mud joint, a desander is set at 45-degree inclination. If solids are not a major concern, the desander can be replaced with a slotted sub for a fluid intake point. It is crucial to have this point of intake in the assembly to prevent fluid restriction. Above the desander, tail pipe is used to assist in reaching the recommended set point of the desander. A directional survey will be used to assist in determining the amount of tail pipe needed in order to achieve the 45-degree inclination set point.

Above the tail pipe, is the Gas ByPass port. This is a short sub with a built-in bypass channel that is ran between the tail pipe and the dual cup packer. The purpose of the Gas ByPass port is to create a flow path, allowing the gas accumulation below the packer to be moved through the assembly.

Above the Gas ByPass port is the dual cup packer. This dual cup packer has no setting elements and acts only to create a seal, minimizing the risk of a stuck packer. Moving up the assembly, a ported sub is ran to allow the clean fluid to be discharged above the packer and below the motor. A Gas ByPass Connection sub is then ran. This sub acts as the bottom connection point for the Gas ByPass tube that will be banded to the OD of the ESP assembly alongside of the ESP cable. The ESP assembly sits directly above the Gas ByPass Connection sub, followed by the Gas ByPass Discharge port. This discharge port is made with a ball and seat to mitigate any possible debris passing by the channel. The discharge port is the top connection for the Gas ByPass tubing and is machined to be an offset of the ESP assembly to protect the top of the Gas ByPass tubing. Production tubing is then ran to surface. Schematics for the ESP Gas ByPass can be seen in Figure 3.

CASE STUDY RESULTS

Case studies have been conducted on multiple wells that have resulted in stabilized ESP operations and production along with improved pump intake pressure drawdowns. Sensor data, production data and service data has been collected and analyzed for the case studies. These studies have shown actualized lease operating expense savings and increased overall production early on and are expected to result in extended ESP life based off stabilized ESP operations observed. PetroLegacy has sponsored the case studies for the purposes of this paper.

Case Study #1

Figure 4 shows ESP well diagnosis data including motor current, motor frequency, motor temperature, fluid temperature as well as number of faults and ESP tech callouts before and after ESP Gas ByPass installation for Case Study #1.

Looking at the first example in the case study, well #1, since the ESP Gas ByPass install, stabilized ESP operations along with improved pump intake pressure drawdown is observed. The ESP sensor data graph, displayed in Figure 4, shows motor temperature, motor frequency, along with ESP faults and tech callouts. Prior to the ESP Gas ByPass installation, the motor temperature is very sporadic, which signifies gas interference. Pump intake pressure, shown in Figure 5, draws down to around 1400 psi, at which point the ESP is unable to draw the well down further, and many ESP faults are observed. ESP faults and shutdowns play a huge factor in decreasing the life of the ESP and also decrease the overall production performance of the well. Since the Gas ByPass installation, the number of ESP faults have been reduced to zero, which means there has been no ESP downtime. ESP faults can be observed in Figure 4, notated by the thin red vertical lines. Stabilized motor temperatures shown post ESP Gas ByPass install, paired with improved PIP drawdown shows that gas interference has effectively been decreased and the motor is able to cool more efficiently.

Figure 5 shows production data including oil, water, gas production, pump intake pressure and tubing and casing pressure for Case Study #1.

Although more data needs to be collected to quantify the drop in ESP failures and downtime, a decrease in operating expense is already apparent. In this case, the operator spent an average of $10,000 in ESP tech callouts over the course of a six-month period prior to the Gas ByPass installation. Since installation about eight months ago, the operator has not needed a single ESP technician callout.

Production rates on this well prior to installation had dropped significantly, down to a rate of oil 250 BOPD, water 190 BWPD, gas 340 MCFD. This loss in production can be primarily attributed to inefficient ESP operations. When correlating the dates of the reduced production to the ESP faults shown in Figure 4, the data aligns. After the ESP Gas ByPass installation, production rates increased to more than 400 BOPD/375 BWPD/500 MCFD. This sustained production and reduced decline rate has been extremely profitable for the operator. Figure 5 shows the production trends before and after the installation of the ESP Gas ByPass.

Case Study #2

Figure 6 shows ESP well diagnosis data, including motor current, motor frequency, motor temperature, fluid temperature as well as number of faults and ESP tech callouts before and after ESP Gas ByPass installation for Case Study #2.

In the case of well #2, ESP operations have stabilized and PIP is steadily drawing down since the ESP Gas ByPass install. The ESP in this case was set at a slower speed initially, causing the well to draw down at a slower pace. Prior to install, the average life of the installed ESP was about six months before failure. Over the course of each ESP run, many ESP faults are observed, as shown in Figure 6. There has been one noted fault since the ESP Gas ByPass was installed during an ESP speed up. The frequency was sped up from 50 to 62Hz. Since this fault, ESP operations have stabilized and PIP has drawn down about 80 psi over the course of about 10 days. While it is still too early to quantify improved ESP life, stabilized conditions should allow for extended ESP life.

Figure 7 shows production data including oil, water, gas production, pump intake pressure and tubing and casing pressure for Case Study #2.

As seen in Figure 6 and 7, results show a much lower motor temperature as well as a lower PIP. Since install, a slight increase in production was observed. However, as can be seen in Figure 7, due to slowed ESP set points, a significant increase was not expected. Now that the ESP speed has been increased, improved production rates should be observed. Prior to the ESP Gas ByPass being installed, the ESP was operating around 60Hz.

CONCLUSION

The average initial ESP runs less than one year before failure due to challenging operating conditions. These conditions can be significantly improved by utilizing the ESP Gas ByPass, an innovative technology, when paired with proper ESP design and operational practices.

This technology can play a key part in substantially reducing ESP failures, decreasing operating expense, increasing runtimes and production. Case studies have shown improved ESP efficiencies, optimized production and stabilized runtimes utilizing the ESP Gas ByPass system.

Without the utilization of the ESP Gas ByPass system, all free gas that does not naturally bypass the ESP has to be produced through the pump, causing operational issues and ultimately decreases the life of the ESP.

The ESP Gas ByPass is a new innovative technology that will allow operators to produce these new unconventional wells more efficiently and economically, improving rate of return on investments.

ACKNOWLEDGMENTS

The WellWorx team would like to thank PetroLegacy for their sponsorship.

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FIGURES

FIGURE 1: Picture of gas overtaking ESP pump.

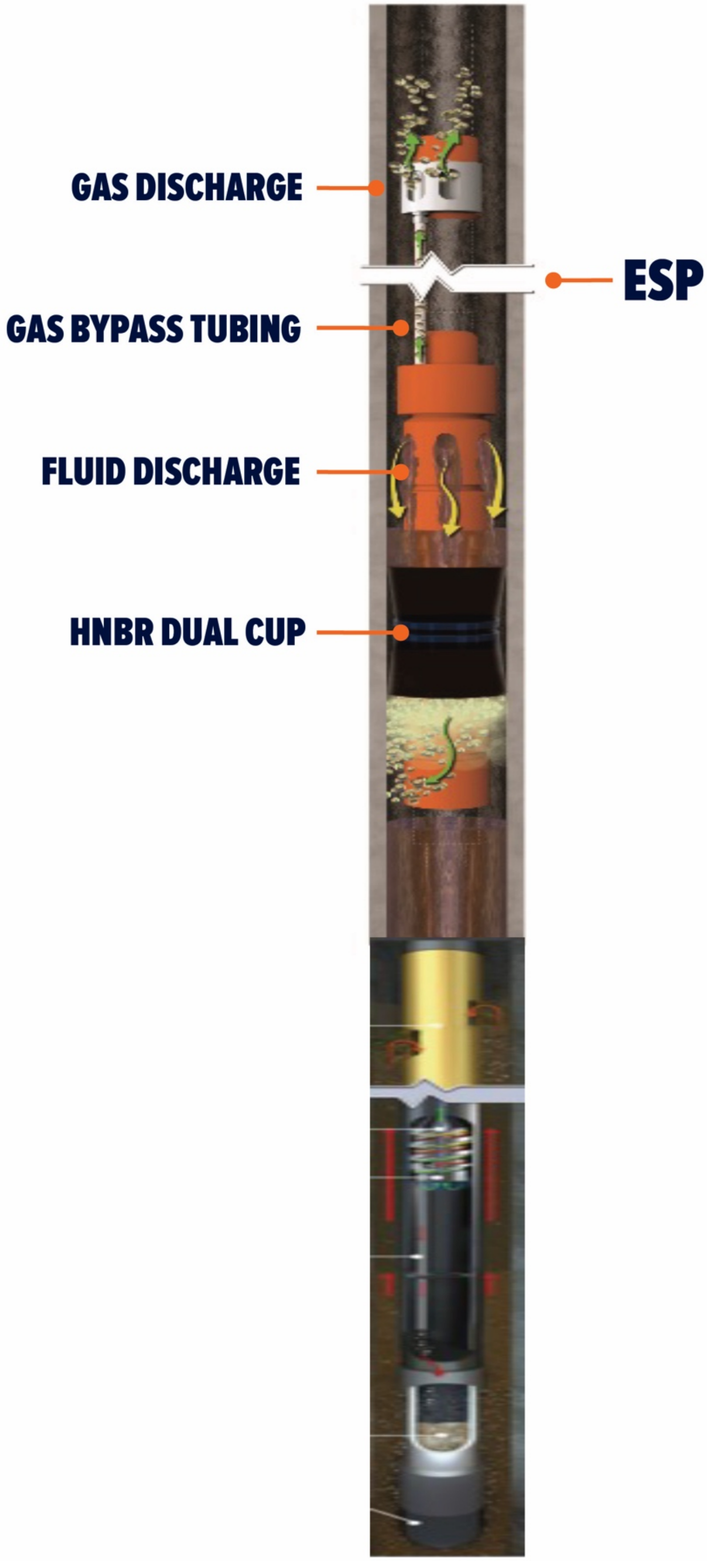

FIGURE 2: Picture of ESP Gas ByPass.

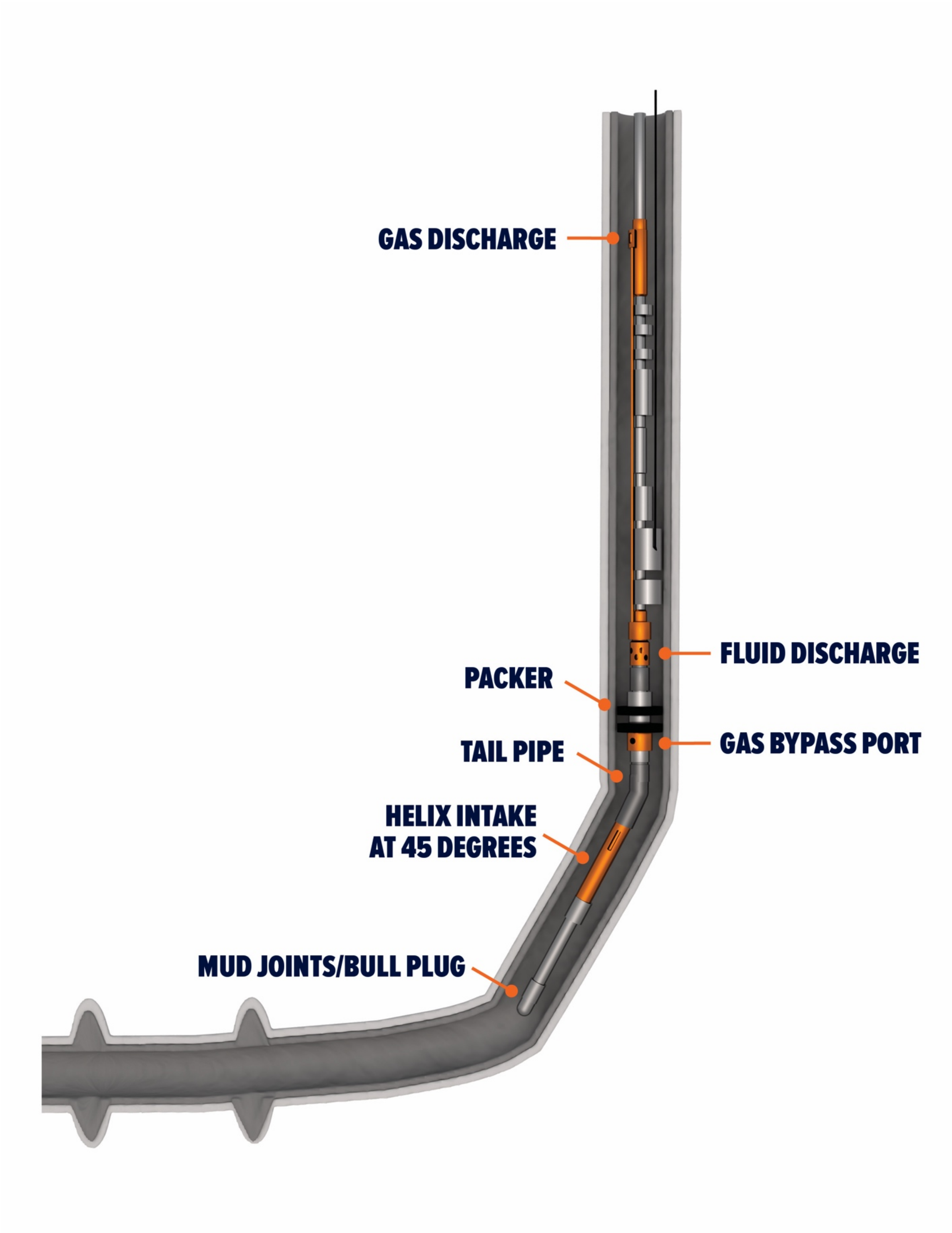

FIGURE 3: Schematics of ESP Gas ByPass installation.

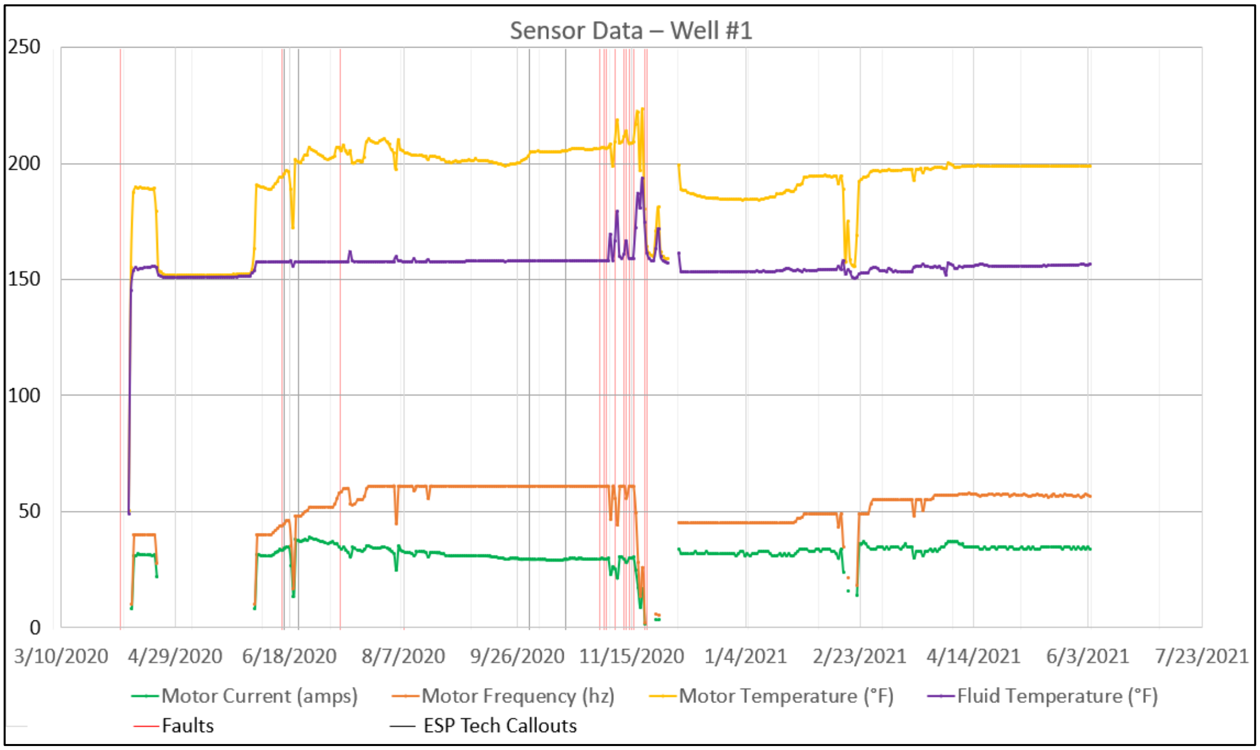

FIGURE 4: ESP well diagnosis data including motor current, motor frequency, motor temperature, fluid temperature as well as number of faults and ESP tech callouts before and after ESP Gas ByPass installation for case study #1.

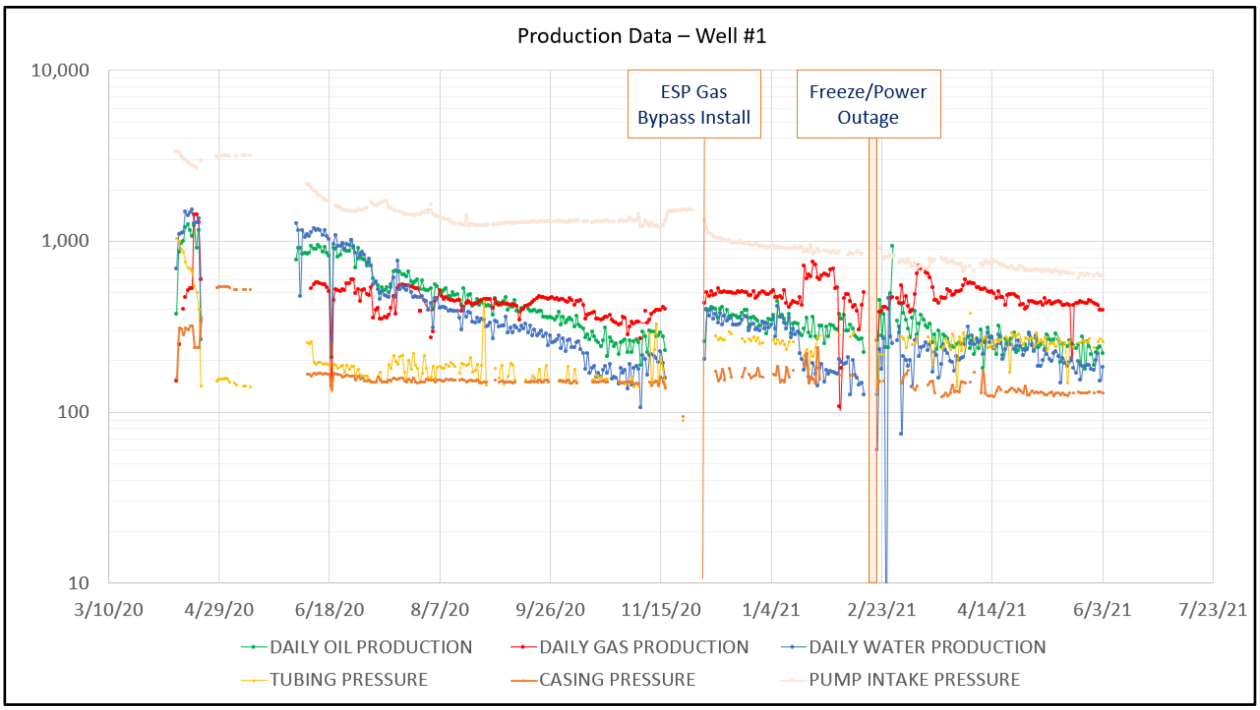

FIGURE 5: Production data including oil, water, gas production, pump intake pressure and tubing and casing pressure for Case Study #1.

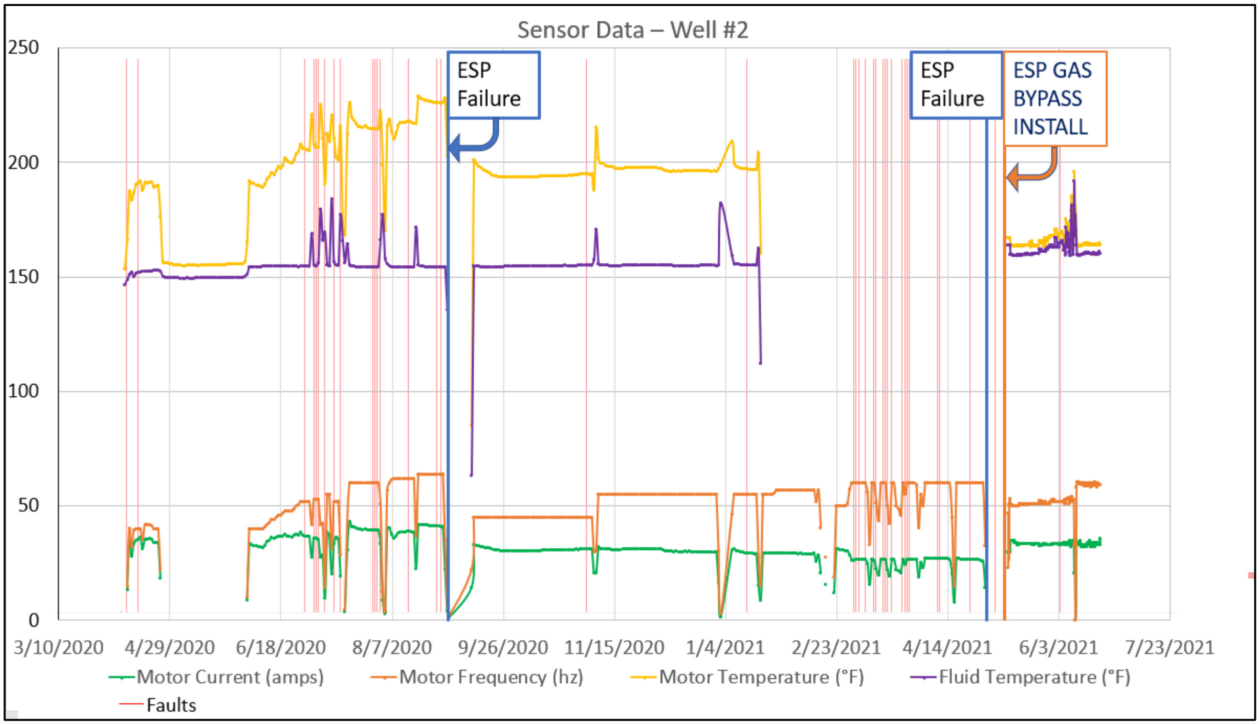

FIGURE 6: ESP well diagnosis data including motor current, motor frequency, motor temperature, fluid temperature as well as number of faults and ESP tech callouts before and after ESP Gas ByPass installation for case study #2.

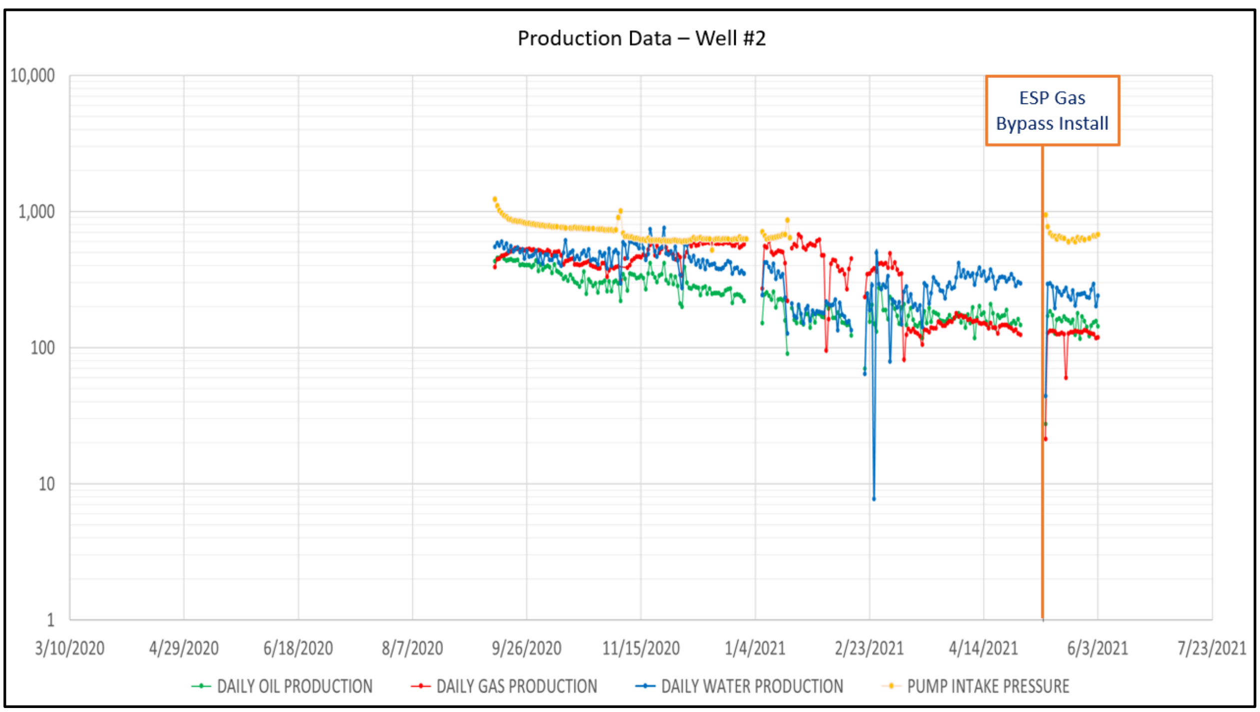

FIGURE 7: Production data including oil, water, gas production, pump intake pressure and tubing and casing pressure for Case Study #2.