A REVOLUTIONARY PACKER TYPE GAS SEPARATOR THAT INVOLVES G-FORCE TO EXCEED TRADITIONAL GAS SEPARATION EFFICIENCY IN OIL AND GAS WELLS

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ABSTRACT

A revolutionary packer-type gas separator was designed to improve gas separation efficiency downhole. A deep analysis of gas separation methods was done to understand deeply the nature of the process and to design a tool that could generate enhanced conditions for the gas separation phenomenon. During the research stages where data from Permian fields were analyzed to develop this new design of gas separator, the engineering team found three main challenges in downhole gas separation. 1st. the wells were being converted from ESP to Rod Pump earlier, forcing the downhole gas separators to handle more production than before. 2nd the small production casing size that usually is 5.5" casing, which significantly reduces the annulus area that is vital to get an effective gas separation efficiency, and finally, 3rd the gas slugging behavior, which in high proportion can lead to a gas lock-in sucker rod pump system. Following the requirements and limitations, a packer-type gas separator was designed, built, and tested in oil wells. This gas separator has an outlet section of 1.89" OD, which means the design maximizes the gas separation area where it really matters at the fluid outlet point. The revolutionary fluid exit slots design creates a linear flow path allowing gas to separate and flow upward the casing annulus in a natural way. Additionally, a valve below the cup packer was included to eliminate surging in wells. This valve prevents surging by holding the fluid in the vertical section, thus avoiding backflow when the gas slug leaves liquids behind. To evaluate the new design, a calculator was developed to estimate the gas separation efficiency downhole and compare the gas separation efficiency among different gas separators. After the implementation of this design in 5 wells, the results confirmed the high gas separation efficiency obtained with this new gas separator configuration. The novelty of this gas separator design is the outlet section that takes advantage of the gravity force to increase the gas separation efficiency without limiting the tensile strength of the BHA. Also, the fact of including a valve to address the surging condition in the well before the fluids go through the gas separation is a new approach in a gas separation tool.

INTRODUCTION

Unconventional resources not only present multiple challenges in the drilling and completion stages due to thousands of feet vertically and horizontally that must be made, but also in the developing life of the well. The geometry of the well and the amount of gas that unconventional wells produce generate multiple difficulties when using Artificial Lift systems such as Rod lift and ESP (most common in the Permian besides Gas lift).

Some areas in the Permian basin produce large amount of gas and this represents a specific challenge for rod pump systems. The rod pumping system works by moving fluid from the intake (bottom of the BHA) into the pump and then compressing this fluid flow it up to surface. The pump (barrel of the pump) can only store a limited volume of fluid (gas, liquid, etc) if a % of this volume is occupied by gas then the system is losing efficiency by each stroke meaning losing money by the minute.

Sucker Rod Pump is one of the most reliable, with most history and deeply researched artificial lift mechanism in the Oil & Gas industry today, as many other basins in the world, the Permian basin has thousands of sucker rod pumps lifting fluid every day. Therefore, is crucial to make sure to reach the maximum potential of each downhole pump, which involves several factors that can affect the volumetric displacement of this system such as: gas production, Rod lift systems efficiency are specially affected by gas production (free and in solution). There are different consequences of pumping a well with a high GLR without any additional measurements such as: low pump fillage (Figure 1), failure due to “Buckling” which can be for gas accumulation inside the pump barrel, among others, which in time it will have an impact on the ROI of each well or field. To solve this problem, multiple gas separator designs have been created and modified throughout the years looking for the most precise and efficient design. Currently there are two families of gas separators known worldwide: Packer Type Gas separators and Packer-Less Gas Separator, as their names indicate the first one requires a packer to seal perforations and create an specific flow path to separate gas and the second does not require any type or seal, this difference makes these two types of separators totally different tools that aim for the same goal, separate the maximum amount of gas before this reaches the pump.

PROBLEM DESCRIPTION

Better Gas Separator designs are defiantly necessary in unconventional wells, these are extremely necessary due to the complexity of managing gas rates, fast declination curves meaning pressure declining below bubble point in a short time, horizontal section producing slugs of gas due to its geometry gas accumulates on the upper side of the casing and more, all aspects mentioned before making unconventional wells more challenging from the Gas managing standpoint.

Multiple companies deal with gas issues in conventional wells with the use of POC, to maintain a stable fluid level so under producing conditions the pump fillage maintains high percentages, however, POC could not have the same results in unconventional wells. Even though the POC will react as soon as the pump fillage is going down there is no certainty that when the system starts pumping back again there will be no gas flowing into the pump. Regardless of the fluid level above the pump when we have fluid moving from the perforations at the bottom of the horizontal section the gas will start to accumulate on the top section of the casing generating a slug regime (flow regime), it can be describe as “waves” of liquid pushed by slugs of gas, once these slugs reach the toe of the well the flow regime might change generating small bubbles and also big slugs of gas to rise and enters the pump. Slugs of gas can be intermittent which make it more difficult to control, they can be monitored by analyzing tubing pressure changes, pump cycles, etc. Other solutions such as back pressure valves are also implemented to maintain a certain pressure downhole to prevent solution gas to become free gas, however, backpressure only influences the pressure in the tubing above the traveling valve, after the fluid has been compressed and discharges out of the pump which does not solve the issue of free gas coming out of the formation either.

The loss of efficiency combined with high failure rates is the worst combination on a field economic evaluation, comparing oil production vs OPEX scenario, if the field has gas issues and these are not address properly oil production will decrease and OPEX will increase due to multiple failures (associate with Gas). In this study we are going to focus on what is the most efficient gas separator type in the market as a solution for free gas in Sucker rod pump systems: the Packer Type Gas Separator.

SOLUTION DESCRIPTION

A regular packer type separator (figure 2) works by creating a special flow path, which maximizes the conditions for natural gas separation (gravity and density involved), this type of gas separator uses the annular area between the casing ID and the separator OD to reduce the velocity of the liquid (down to 6 in/sec or lower) so the gas can rise and does not flow into the pump intake.

There are multiple aspects when designing a packer type gas separator that have to be considered, on one hand not all packer type GS in the market can be modified based on GOR, GLR values, total fluid production and WC, so their efficiency is limited by the one design available, on the other hand there are some other gas separators such as the one presented in this paper, that can be modified depending on specific well conditions. It is crucial to mention that: outlet open area, OD of the gas separator, inlet section (Intake) open area, ID of the dip tube connecting the intake section to the pump, will have a huge impact on separation efficiency.

Small open areas create fluid acceleration which can make liquid to drag gas bubbles into the pump intake, the best approach is trying to avoid the flow regime to become turbulent. The dip tube inside the gas separator will carry the “clean fluid directly into the pump, so the gas in solution must not turn into free gas, the technology can avoid these by calculating the pressure drop during the designing process, at this point an evaluation of pressure drop vs efficiency must be done to determine the most suitable length that allows maximum separation efficiency without causing free gas inside the dip tube.

Despite multiple efforts and different designs some wells present extremely difficult conditions, GLR’s above 1,000 SCF/STB combined with slugging wells challenges regular packer type gas separators efficiency, on wells with these downhole conditions Gas separators are reaching 70 – 80% maximum, so the necessity of further improvements was necessary to achieve pump fillage values above 85% at the minimum.

The Revolutionary Packer Type Gas Separator presented in this study proved that applying G-Force to the outlet section and increasing the annular area is possible to exceed traditional gas separation efficiency and reach pump fillage above 85%.

This specific design of packer type is divided into 4 sections which will be explained as: (1) Outlet, (2) Gas separation section and (3) Intake and finally (4) the triple seal level cup packer, these different sections have their own specific function but all work as one in terms of gas separation.

(4). Sealing section. For the wells analyzed and monitored during this technical evaluation the technology was used in conjunction with a triple seal level cup packer, this type of packer seals with 3 cups, 2 of them in the opposite side of the packer mandrel top cup facing up (sealing with fluid above) and bottom facing down (sealing with fluid coming from perforations), both cups been pressurized squeeze the middle packer generating expansion and creasing the 3rd seal, figure 3 shows the extract geometry of the packer used on the 5 applications, however, this is not a limitation, this g-force packer type gas separator can be installed with mechanical packer or rotational packer, this GS is designed to withstand the tension as a regular 2-3/8” tubing.

(3) Intake section. this section has two isolated intakes (Figure 4): Slots located at the bottom of the tool are used to allow flow into the gas separator, and the slots on the side are the intake of the system for the fluid after the gas separation, “clean fluid flows to those ports connecting to an inner dip tube and directly t the pump.

(2) Separation section. The length of this section can be modified, based length on this section is 24 ft long but if the well expects extremely high GLRs the separation section can increase to 48 ft or 72’ if need it making sure the system does not generate high pressure drops through the dip tube. This section is called separation section because once the fluid exists the GS the fluid must travel down to reach the pump intake located at the bottom of the assembly, the space between the ID of the casing and OD of this section defines the capacity of free gas that can be separated.

(1) Outlet section. This is the 1st section of the revolutionary packer type gas separator from top to bottom of the technology, it consists of a regular 2-3/8” connection to match any EUE tubing connection follow to a 1.89” neck that connects to the outlet port which has its slots geometry facing upwards, by applying this modification to the packer type gas separator the kinetic energy boosting the gas towards surface, by doing these this action reduces the amount of gas that is dragged by the liquid into the annular area of the separation section, by having less gas to separate on this section the efficiency can increase even though the well produces high GLRs

FIELD EVALUATION: DIAGNOSTIC

The 5 wells mentioned in this paper are in the Midland basing (Spraberry trend area), all wells are unconventional wells that initially produced 2500 – 4000 BPD through ESP systems, vertical sections between 9,560 – 10,000 ft and a lateral up to 9,500 ft, after depletion excepted all 5 wells were planned to be converted into Rod Pump with the concern that gas production will be an issue. Once bottom hole pressure has dropped below bubble point the pump will have to handle free gas coming out of the formation plus gas coming out of solution. The last months the wells were producing with ESPs experienced gas affectation, producing GLRs above 1,000 SCF/STB, based on this information it was crucial to run a gas separator on the next stage expecting to handle a large amount of gas and keeping a constant separation efficiency.

All these wells have a history of middle to high sand production levels, another advantage of this revolutionary packer type gas separator is that can be combined with a desander below the packer separating the sand before it reached the intake section of the packer type gas separator. In the field application section, a WBD is shown to explain the process of the combination of sand and gas and the flow path of it.

An additional measure had to be considered in these applications based on corrosion rates on this field, all BHA was plastic coated. Previous water analysis showed some corrosion trends, this additional modification does not affect the functioning of the tool, it only provides an extra layer of protection against corrosion due to H_2S and CO_2.

FIELD APPLICATION

Table 2 summarizes the general information for the 2 wells (information available) with the G-force application packer type gas separator and table 3 specify some of the information considered when designing each well gas separator. It is important to consider these conditions alongside deviation survey, casing pressure, tubing pressure and PIP to simulate and design the most accurate design.

Based on all information analyzed two designs were proposed and installed downhole: well B has a 62' long packer type gas separator with the g-force outlet design, indicators showed that this well had high trend for gas production, therefore a longer technology was chosen, the rest of the wells were evaluated and a 38' packer type gas separator was selected to deal with the respective GLR values expected.

Figure 7 represents the order and how the revolutionary packer type gas separator looks like and how it was complemented with the sand control device below the triple seal packer. In this application and as it was mentioned before 62' gas separator provides more space (Volume) to combat higher GLRs, a longer gas separation means also longer retention time or time before liquid reaches the intake, this gives the opportunity to provide higher fluid velocity reduction.

RESULTS

- Table 4 shows all results in all installations of the packer type gas separator, all reached an excellent result in terms of pump fillage.
- Well A achieved a pump fillage average greater than 90% and Well B showed an 88% average pump fillage, considering the high GLR (4,572 SCF/STB) on this specific well it is considered as a success application.
- It was possible to maintain high pump fillages despite producing GLR levels above 1,000 SCF/STB.

- Well B had a failure due to an offset frac, it had to be pulled, the gas separator was inspected and re-run in the same well no modifications required. As figure 13 shows there is a stable tendency until the frac hit, then there is fluctuation of pump fillage and production.

- As we can see in figure 12 and 13 after the installation the pump cards on both wells show excellent pump fillage, values on table 4 are average values calculated during current runtime.

- It is possible to successfully to convert ESP to SRP without compromising its efficiency due to high gas flow.

- 3 more wells installed in the same area are pending to evaluate and determine the success of each gas separator. Well conditions on additional 3 wells are like Well A, GLR<2,500 STC/STB

CONCLUSIONS

- The revolutionary Packer Type Gas Separator increased the pump efficiency eliminating most of the free gas before reaches the pump.

- New technologies such as the g-force applied to a Packer Type Gas Separator in this paper has proved to be an efficient gas separator using multiple gas separation stages and customizable designs that are build based on the well conditions.

- Running a Packer Type Gas separator downhole helps to separate a high amount of free gas reducing shutdowns caused by gas lock due to the high chamber of separation created between the tools and the casing ID.

- The inverted triple cup packer presents a great performance when it comes to isolating the system and directing the fluid through the New Packer Type Gas Separator. It is recommend run the rotational packer with a slim TAC

- After the installation of this enhance Packer Type Gas Separator, the lifting cost is affected positively because the system reduced energy consumption and prevented possible future shutdowns due to a good gas downhole management.

- Low pump efficiencies were avoided by separating the gas and sending it to the annular area so it will not cause pump efficiency affectation.

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Table 1. G-force Packer Type gas separator - Annular area

Packer Type G -force Neck OD (in)	1.89				
Casing ID (in)	7" (29#)	7" (32#)	5.5" (17#)	5.5" (20#)	5.5" (23#)
Casing ID (in)	6.184	6.094	4.892	4.778	4.67
Annular Space (in^2)	27.2	26.4	16.0	15.1	14.3

Table 2. Wells General information

	Installation date	Pump Size (in)	Casing	Tubing	Expected GLRs (SCF/STB)
WELL A	8/04/2021	1.75	5.5" 20#	2-7/8"	1,500
WELL B	12/17/2022	1.75	5.5" 20#	2-7/8"	>6,000

Table 3. Well conditions Well B

WELL CONDITIONS - WELL B		
CASING 20#	5-1/2	IN
DRIFT CASING	4.653	IN
CASIND ID	4.778	IN
TUBING	2-7/8	IN
MAX FLUID PRODUCTION	364	BFPD
AVERAGE FLUID PRODUCTION	300	BFPD
WC	65	%
OIL PRODUCTION	100	BOPD
WATER PRODUCTION	200	BWPD
GAS FLOW	837	MCFPD
GOR	2,299.45	SCF/STB
GLR	6,569.9	SCF/STB
PUMP DEPTH	8,525	MD FT

Table 4. Gas Separator BHA and op parameters after parameters

	PUMP SIZE (in)	G-force GS length (ft)	SL (in)	SPM	Pmp Depth (ft)	Pump Efficiency
WELL A	1.75	38	141	4.4	7,950	93.5%
WELL B	1.75	62	166	6.7	8,525	88.7%

Table 5. Results after installation

	BFPD	BOPD	WC	GAS RATE (MCPD)	GLR (AVE)	GLR (MAX)	GOR	Runtime (Days)
WELL A	158	140	5%	167	1,080	1,405	1,560	230
WELL B	209	73	65%	948	4,572	6,030	13,868	94

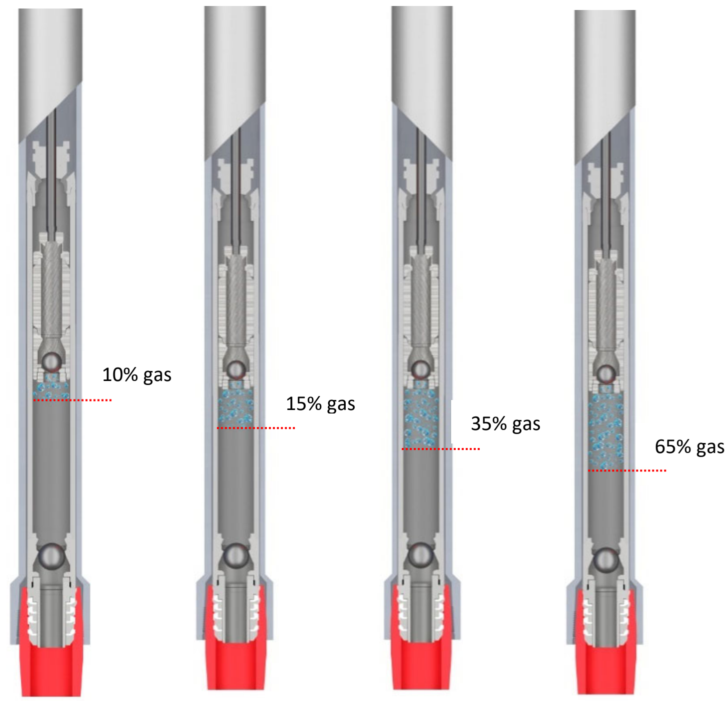

Figure 1. Gas interference - Volume distribution

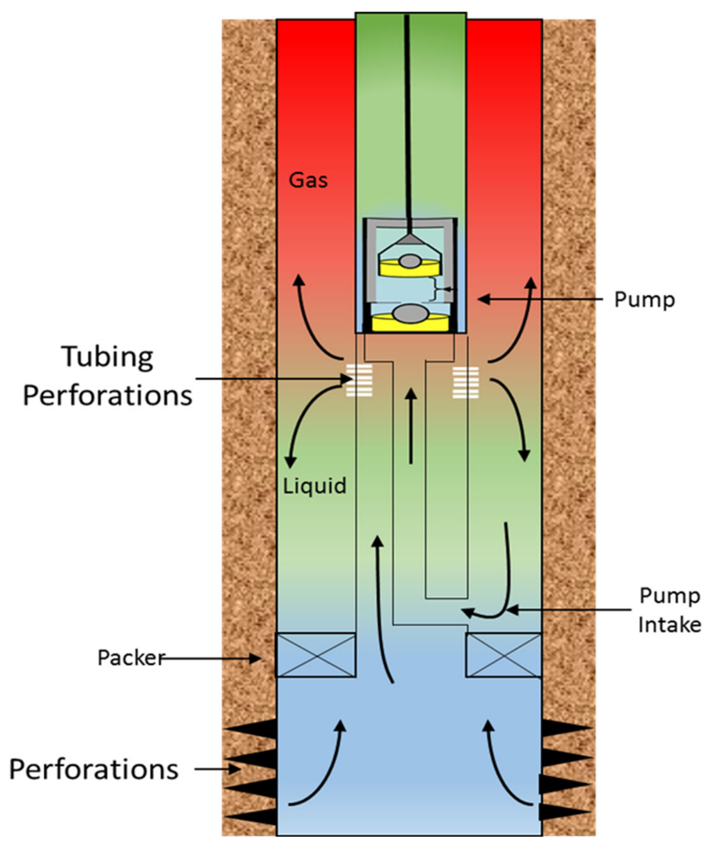

Figure 2. Packer Type Gas Separator - schematic

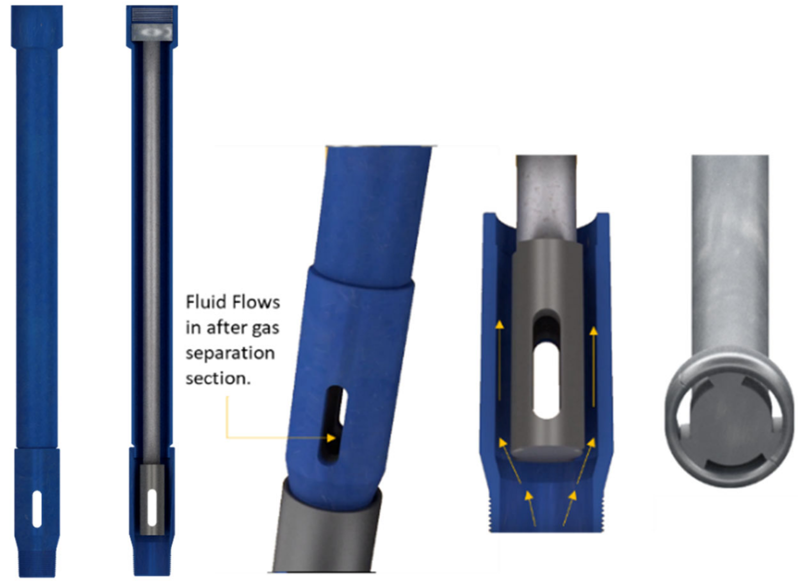

Figure 3. Intake Section

Figure 4. Sealing Mechanism

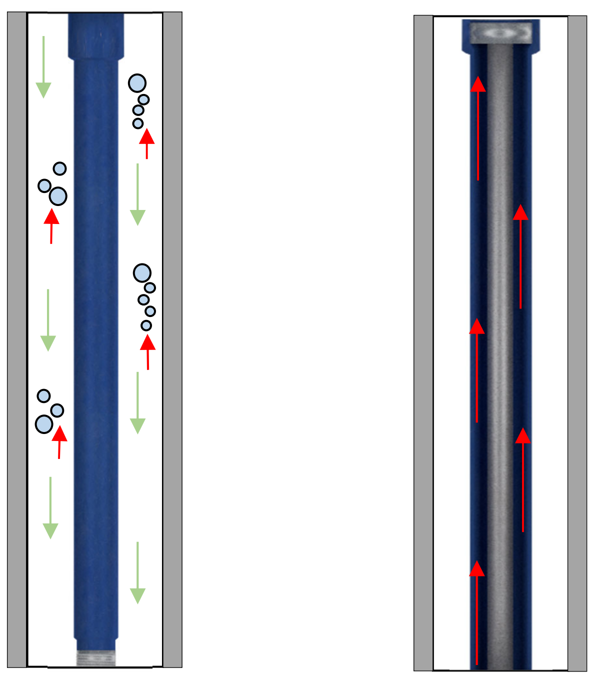

Figure 5. Separation Section

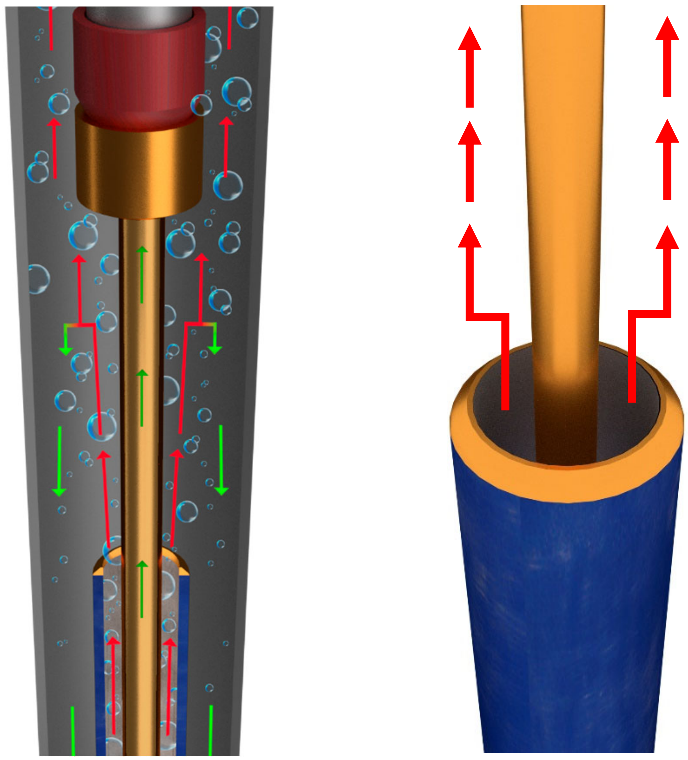

Figure 6. Outlet section

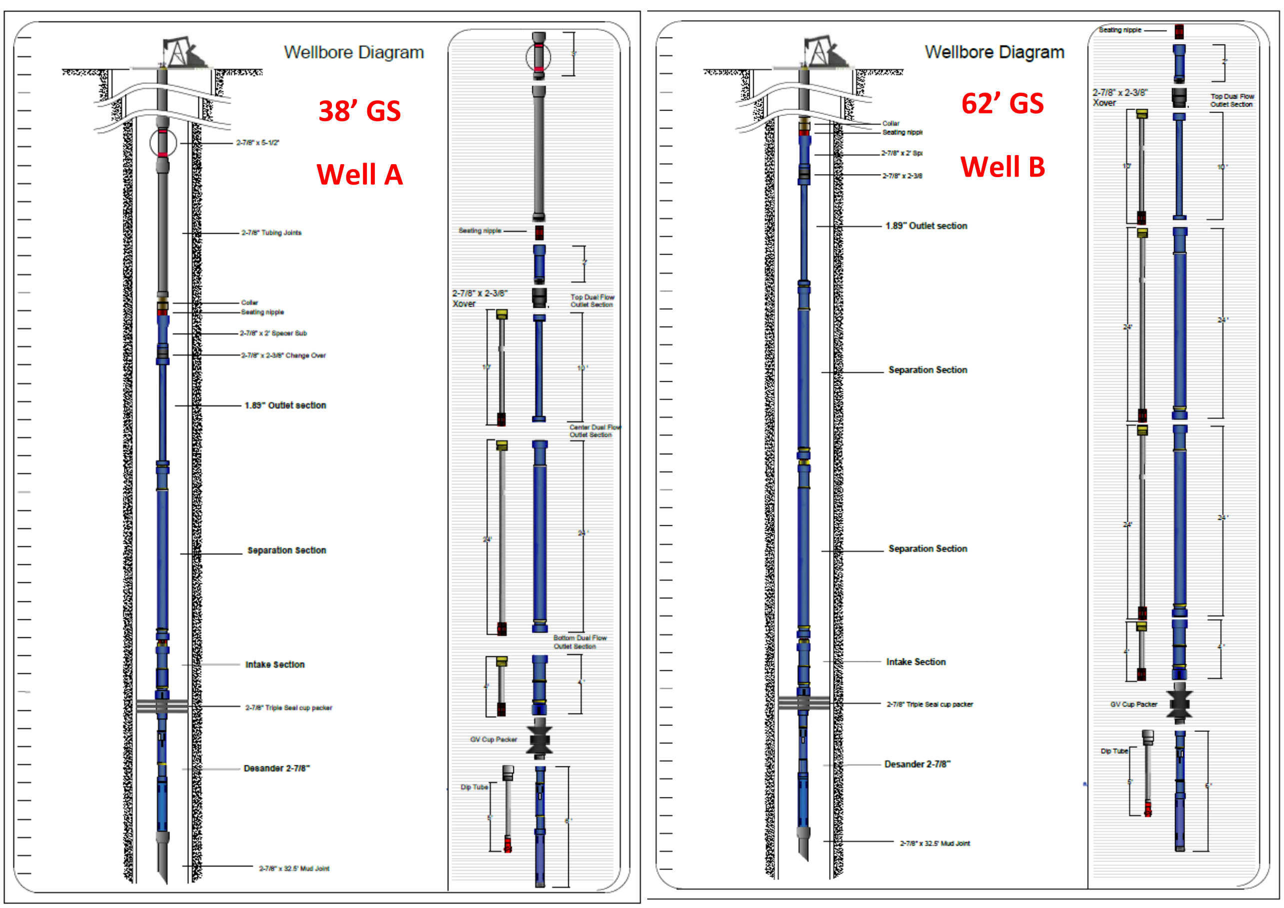

Figure 7. Gas Separator options

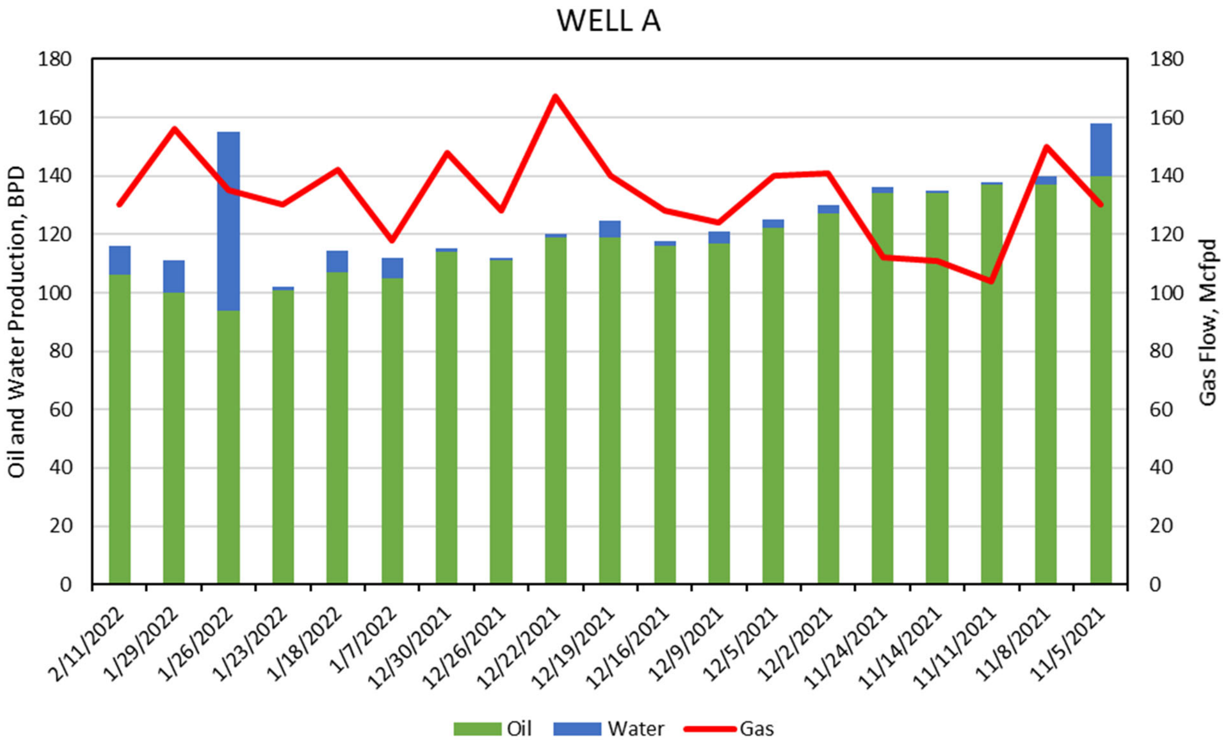

Figure 8. Well A Production profile after installation

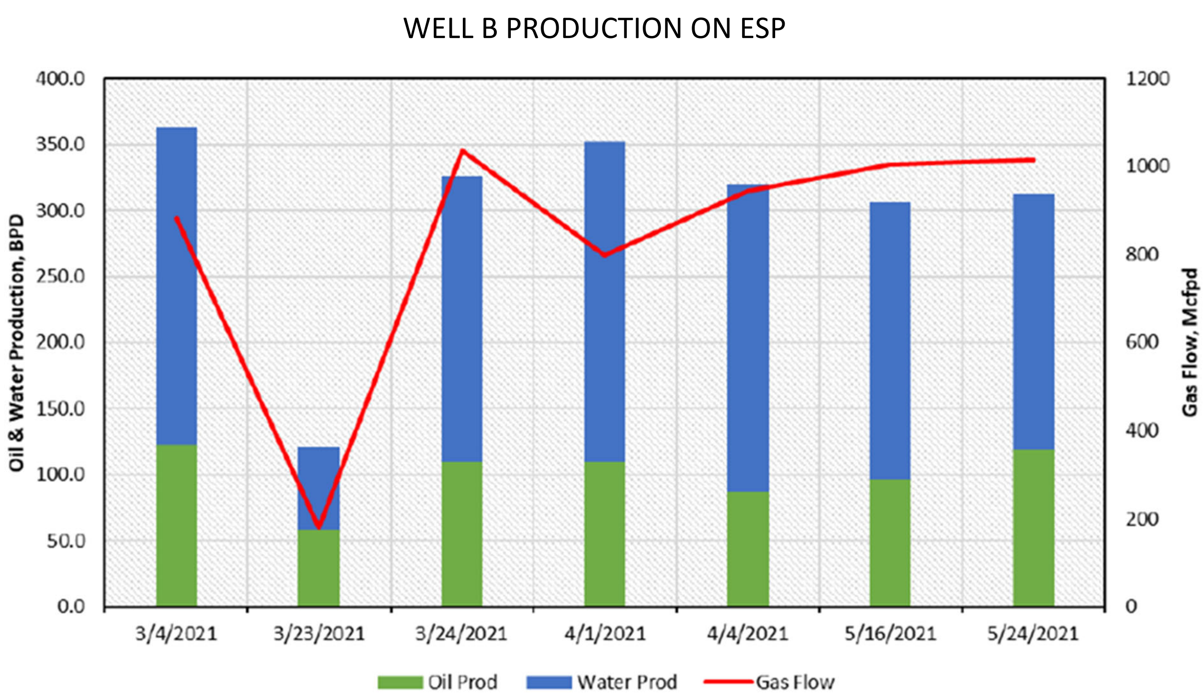

Figure 9. Well B Production profile before installation

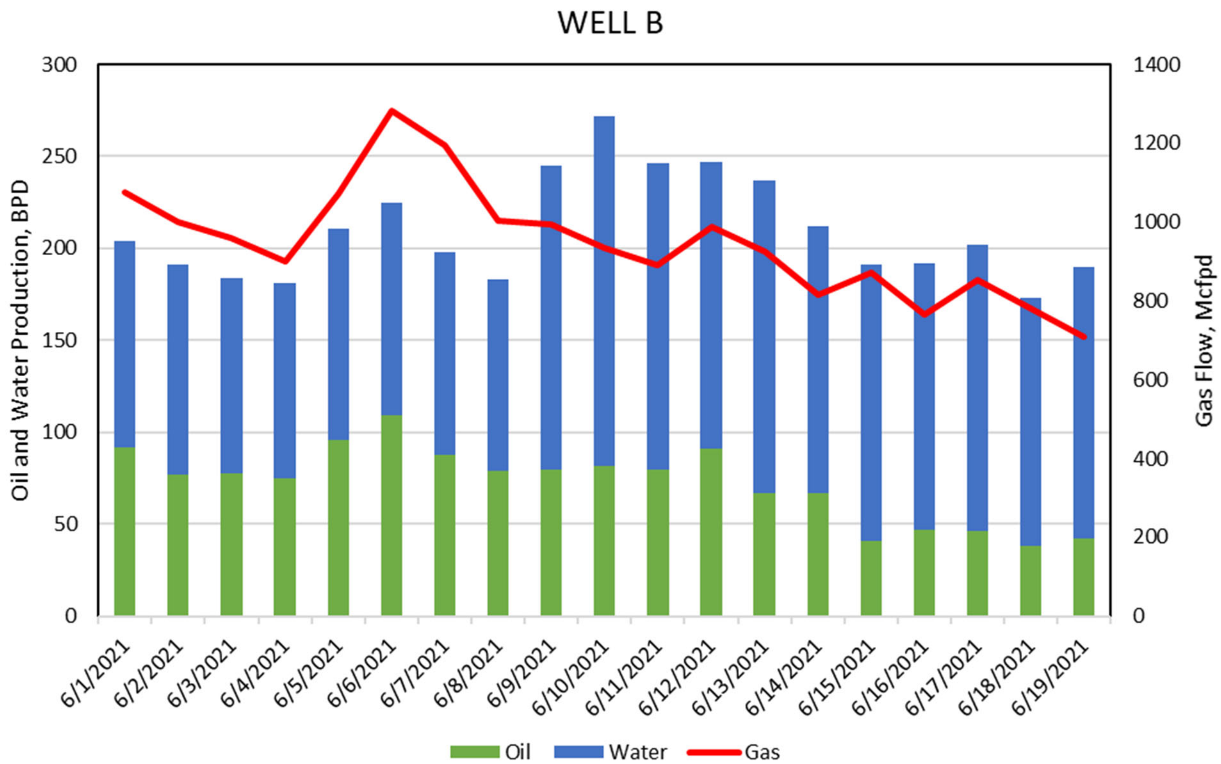

Figure 10. Well B production after installation

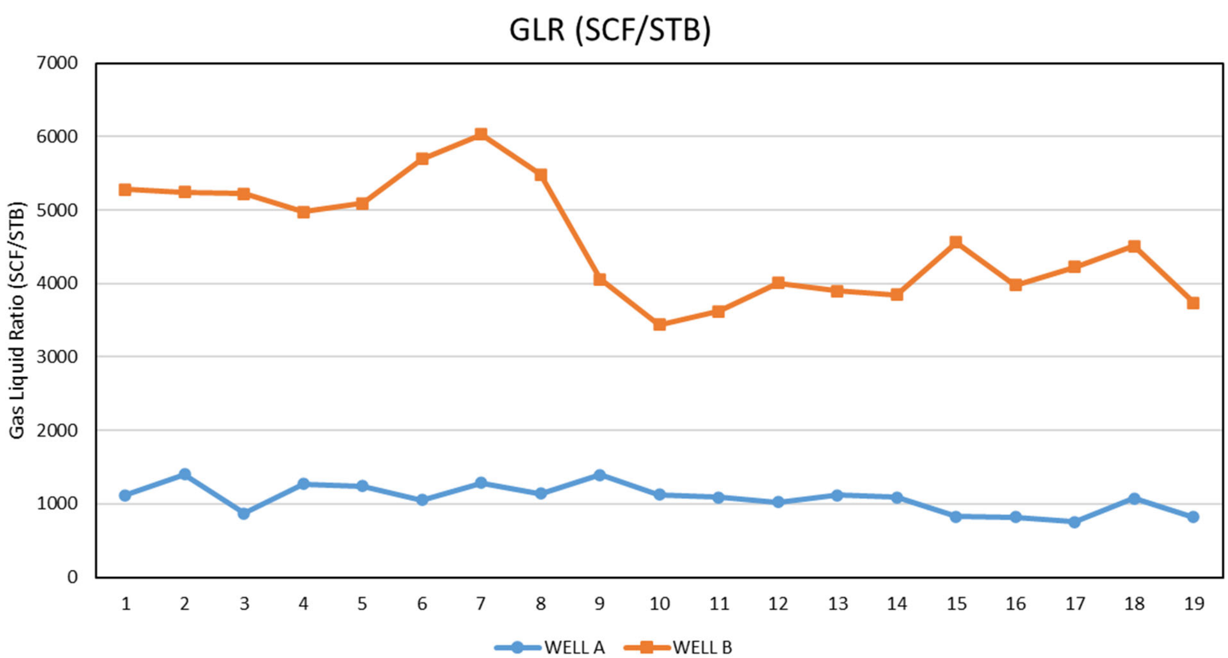

Figure 11. GLR after installation WELL A & B

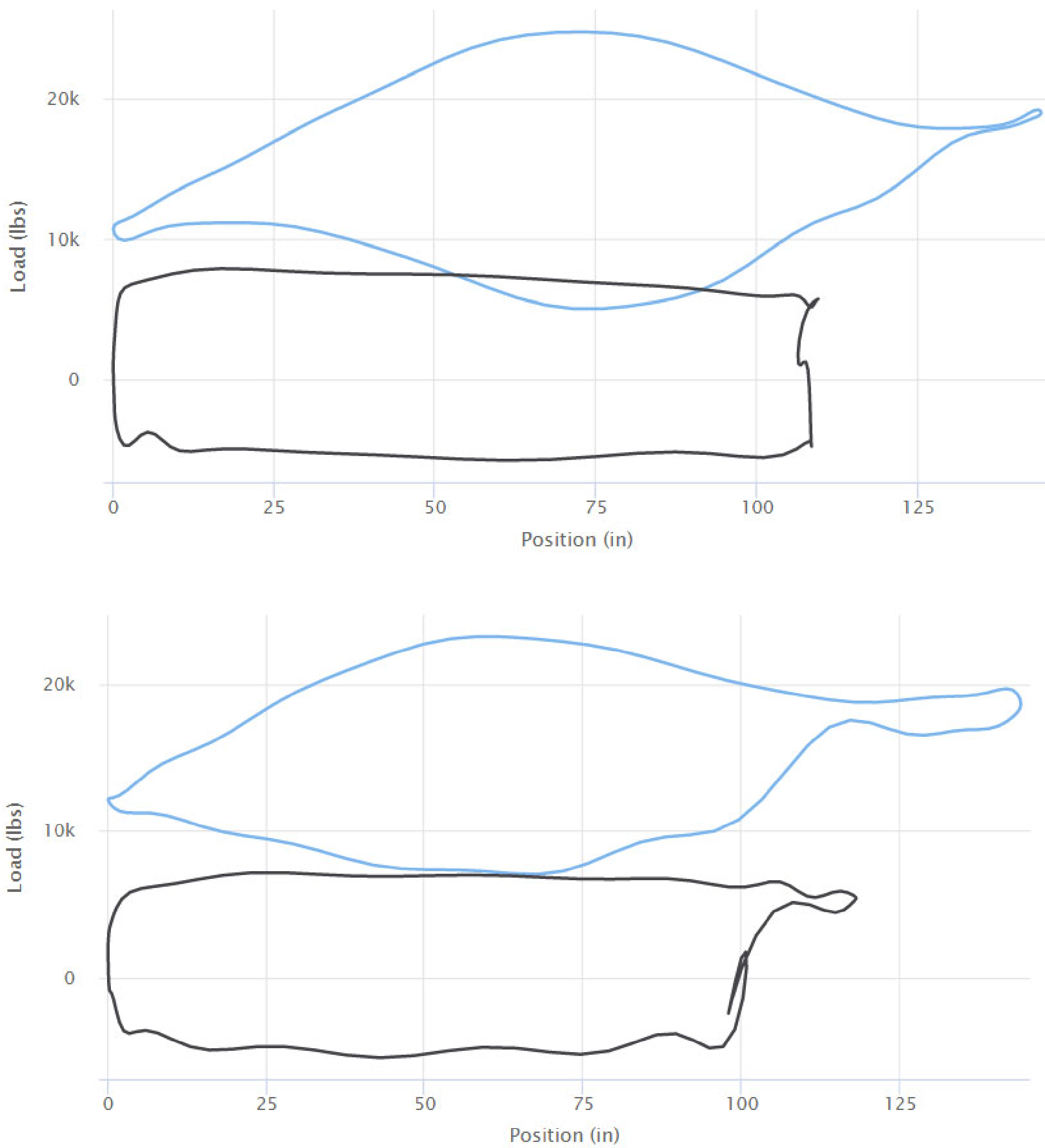

Figure 12. Highest and lowest pump cards Well A

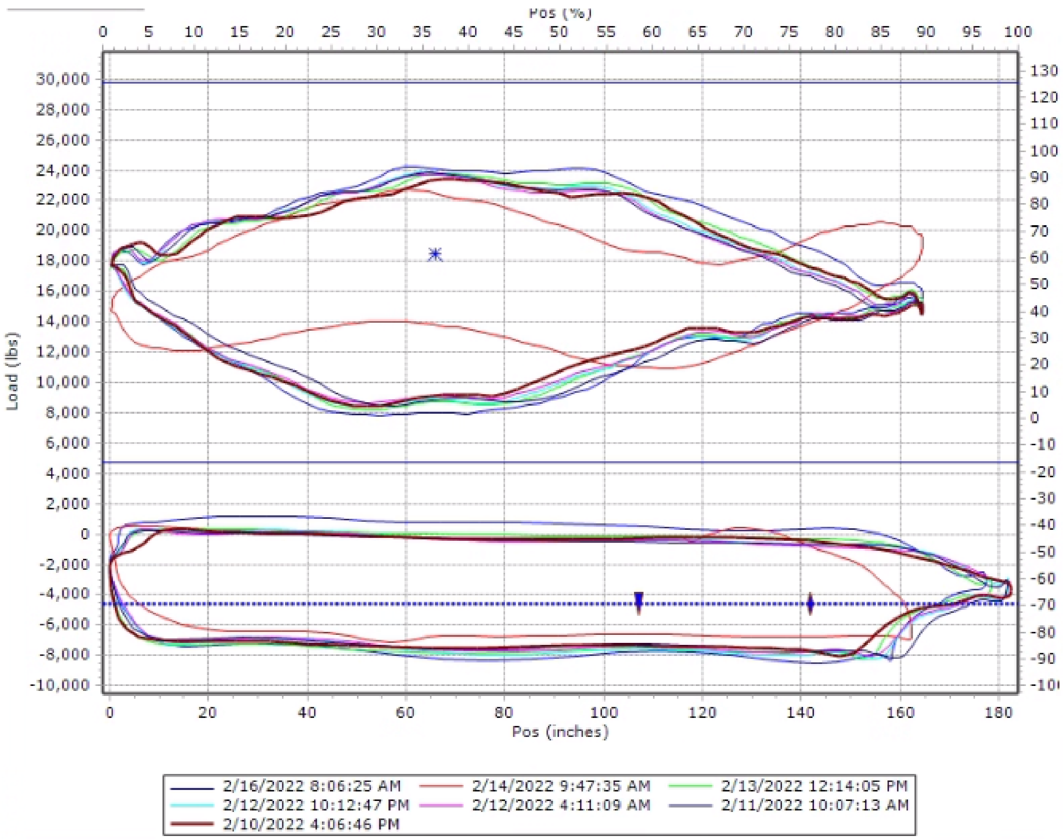

Figure 13. Pump Cards after installation WELL B

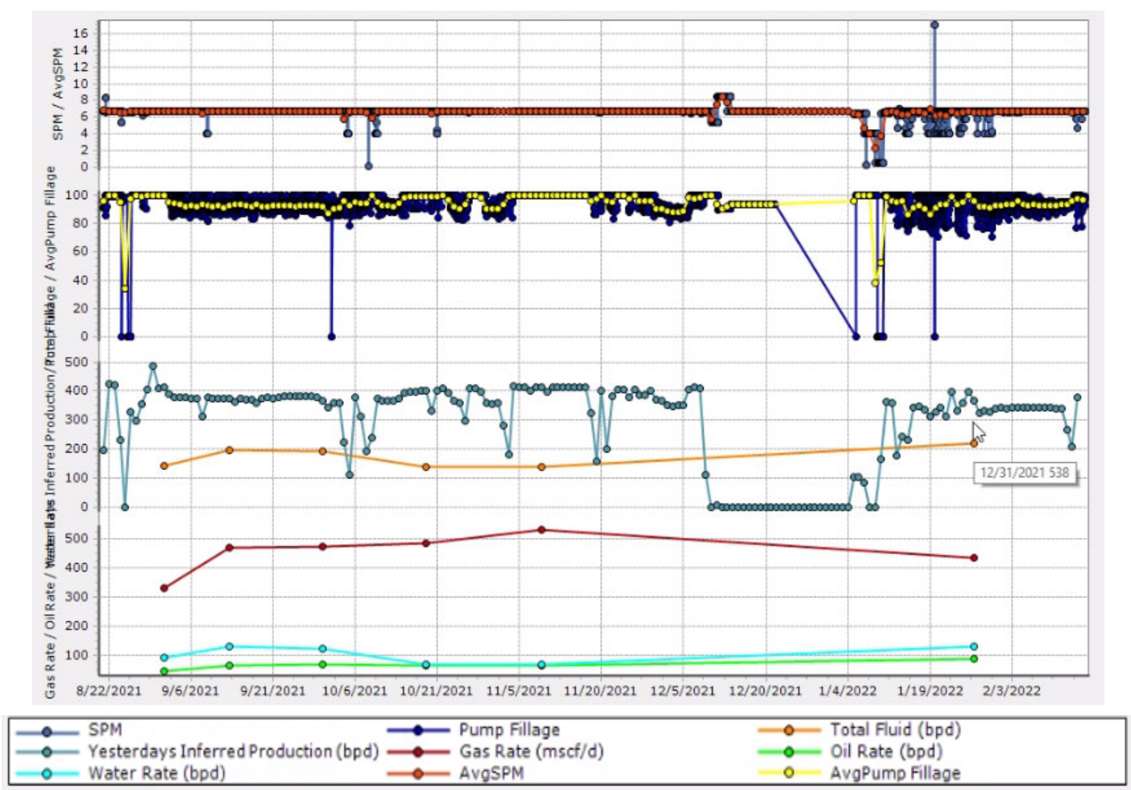

Figure 14. Pump parameters Well B