NEXT STEP: INCREASING PRODUCTION BY USING A 2-STAGES FILTRATION SYSTEM WITH A GAS SEPARATOR IN ROD PUMP

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ABSTRACT

To deal with gas and sand problems in their conversion and rod pump wells an operator company in south Texas started introducing a combined technology of two-stages filtration with a modified poor boy gas separator obtaining excellent results. This paper explains the technology used and share the information used to design the tools and the results achieved in the first wells completed.

The screening process to choose the best technology started trying different technologies for gas and sand control below the rod pump. Different technologies were revised sharing data like sand particle size, pump design, fluid production expected and wellbore configuration to get the best design from different companies. The technical and economic evaluation determined the combined system with two-stages filtration and gas separation was the best technology among all the installations. The results were spread to other wells changing the configuration based on the well conditions but maintaining the same principle of operation.

After the installation of this technology in each well, it was clear a substantial increase in production among the wells that was caused for the improvement in the pump cards after the installation. The downhole equipment has been able to handle better gas production and no sand problems have been reported so far. The success of this technology has extended the operational capabilities of the pumps allowing the engineers to operate better their wells. Pump cards before and after the installations are summarized in the presentation to show evidence of the good results obtained.

After the wells are converted from ESP to rod pump or when the gas represents an issue in the rod pumped wells, the production engineers are limited in the drawdown and the production they can get out of the wells. We are presenting an alternative for the operators to optimize the production's BHA and overcome sand and gas problems that limit the ability to increase the income of the oil fields.

INTRODUCTION

Gassy wells have been a big challenge for rod lift system, especially in horizontal wells with high-formation GORs where the fluid pumped creates additional issues, such as gas interference, gas locking, short run life, low productions, poor energy efficiency, increased failure rates, and other surface and downhole problems. The most effective solution is to reduce the amount of gas entering the pump. To have a good performance and achieve this ideal condition it is necessary to understand downhole conditions and analyze the well behavior. The separation efficiency is dependent on many factors including the Gas -Oil Ratio (GOR), Gas-Liquid Ratio (GLR), oil properties, water cut, Pump Intake Pressure (PIP), well deviation, perforation depths, pump depth, pump type, stroke length, and strokes per minute. Based on those conditions one can select the type and configuration best for each application. A general recipe or “template” tool does not exist which will overcome gas problems in all situations, thus it is important to do a full well analysis and so have as complete an understanding as possible to install the right gas separator according to the well’s needs.

Regarding the sand presence, Due to the mobile parts, small paths and the fluid circulating at high-speed transporting sand, the artificial lift systems need frequent maintenance to replace damaged equipment or the complete assembly. In sucker rod pumps the problem occurs when the sand is pumped with fluid to surface, which means thousands of feet from the pump. Because the sand is heavier, it will fall back to the top of the plunger causing premature wear and low run life. On top of this, because of the length and fit of the plunger (annular space between the outer diameter of the plunger and the internal diameter of the barrel), a hydrodynamic seal is formed, however, a small part of the production fluid can pass through this annular space. Furthermore, this runoff helps to lubricate the hydrodynamic seal generated. It is emphasized that the amount of fluid passing between the plunger and barrel is inversely proportional to the efficiency of the pump. During the pump operation, the sand suspended in the production fluid can migrate into the annulus between the plunger and barrel causing assisted channels by abrasion on the surface of these two elements (Sand cutting). These channels normally become sufficiently deep in the plunger, allowing for greater runoff sand passage. It generates a decline in the efficiency of the pump to the point that the production rate is unprofitable. There are not many methods to deal effectively with gas and sand in sucker rod pump system, but we will discuss the approach use on these applications using two-stages of filtration with a statis/centrifugal gas separator.

TWO-STAGES FILTRATION WITH GAS SEPARATION

A technical design of two stages filtration and gas control starts with the collection of a sand sample, the scope is to determine the size of sand particles with a sand sieve analysis. The procedure involves subjecting a sand sample of known weight to continuous vibration, using the sieve (Figure 1). It is passed through a series of sieves organized according to the size of the holes, larger at the top. The grains descend until the smaller particles are retained on a tray. A graphic of granulometric distribution is then generated and will help us to choose the best slot size of the screen to filtrate the adequate volume of sand.

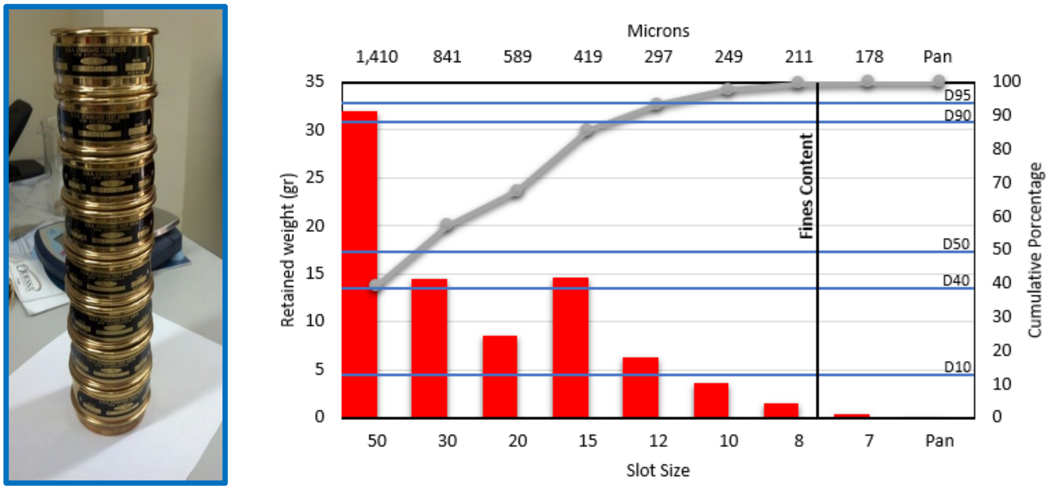


Figure 1 sieve set up and granulometric distribution.

The first stage of the tool is the Tubing Screen, which is responsible for filtering solids of a larger size than the aperture while functioning as an intake for the fluid. The opening size of the Tubing Screen will be determined by the sieve analysis and the length of the screened section is designed according to the fluid production expected and the amount of sand produced with the fluid. The second stage of separation is the Vortex Desander installed underneath the gas bogy and the tubing Screen. Its function is separate the finest particles flowing through the slots of the Tubing Screen and optimize the gas separation efficiency. The helix size is designed based on the production ranges and the sand size flowing inside the first stage of filtration.

Other considerations while designing the sand control system are:

1. Fluid production viscosity
2. Well deviation
3. Casing size configuration-mechanical well conditions
4. Chemical conditions (corrosion, scale, paraffin issues)

For the gas separator design is important to mention that exist three main mechanisms of free gas separation:

Gravitational: If the well stream is led into a space of sufficient capacity, then liquids, being denser than gas, flow downward due to gravity, but gas bubbles tend to rise. If the downward liquid velocity is lower than the terminal velocity of the gas bubbles, the resultant gas velocity is directed upward, and the gas phase continuously rises compared to the liquid phase. High liquid velocities, on the other hand, result in the gas bubbles being taken along with the liquid and no separation of the phases takes place. For an effective gas separation, therefore, the flow velocity of the liquid must be kept below the typical bubble rise velocity of 0.5 ft/s. This requirement can only be met if the cross-sectional area available for liquid flow is properly selected by considering the liquid production rate of the well. Downhole gas separators work according to this principle: they force the liquid phase to have a velocity lower than 0.5 ft/s by properly selecting the space available for liquid flow.

For high performance, the basic criteria considered is the velocity of the fluid in the system must be less than 0.5 ft/s. These conditions apply for water, however, through the experience, we have found that for crudes with a density greater than 30º the gas velocity must be considered as 0.44 ft/s. In heavy and extra heavy crude oil the gas problem can be even more complicated and for these cases, because the fluid properties, the gas bubbles need more time to release from the fluid so the velocity of the fluid in the system must be less than 0.3 ft/s. The information on the gas velocity depending on the API gravity of the oil is shown in Table 1.

Table 1. Fluid velocity recommended for gas separation

°API	GAS VELOCITY (FT/S)
>30	0.44
20-30	0.3
<15	0.22

Pressure Change: The effect to pass from a small diameter to a bigger one cause a Venturi effect to the "downstream" which produces the expansion of free gas that travels with the fluid due to the pressure change, and then the gas by density difference ascends again, to be out the system thru the venting area.

Agitation: The turbulence combined with the gravitational process promotes the coalescence of the gas bubbles doing easier the migration of the gas bubble to the outlet points. This mechanism is achieved through different techniques like screen surfaces, centrifugal processes, or changing paths.

The separation mechanisms described previously are the ones applied in the gas separator design and illustrated in figure 2. The whole tool assembly is then formed by the connection of the tubing screen as a primary intake with a gas separation body below. Both tools have an inner tube pre-assembled that connect that suction point (vortex desander) with the pump intake. At the end of the inner tube, the vortex desander is connected to centrifugate the production fluid and separate the finest sand particles. The separated solids will be stored in the tail joints installed underneath the vortex desander. As higher the sand production and the fine particle percentage, longer should be the tail joints assembly needed.

The step by step to design the gas and sand control system is described below.

1. The slot size of the tubing screen maximizes total open area available for the planned production rate. The velocity should be less than the critical non-erosive velocity for the open area and production rate.
2. The diameter of the static gas separator will provide the required fluid velocity

decrease to generate free gas separation and increase efficiency of gravity separation. In this case, because the density, a fluid velocity less than 0.5 ft./s was recommended.

3. The length of the static-centrifugal gas separator is critical when allowing for sufficient agitation to generate as much gas as possible before entering to the pump.
4. The helix creating the vortex effect, must be selected to match the expected production through the system.
5. The determining factor in choosing a static gas separator or a static-centrifugal gas separator is the amount of gas in solution and the amount of free gas in the well.
6. It is important to calculate the right amount of mud joints or tail pipes according to the sand production.

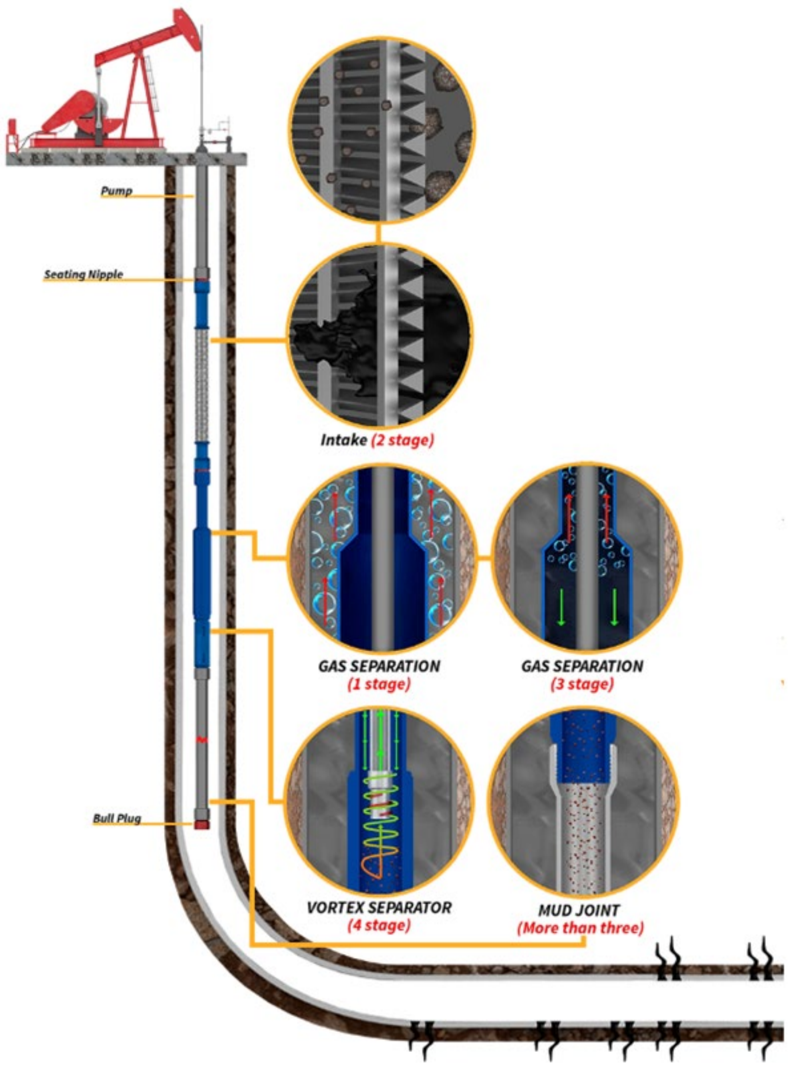


Figure 2 Combination Tool: 2-Stages Filtration with Gas Separation

CASE STUDY AND RESULTS

The sand control and gas separation systems were designed for 3 wells located in South Texas (CML-1, CML-2, and CML-3). The wells had a history of low volumetric efficiencies due to high gas production and sand related failures. The trajectory of the wells is horizontal with a maximum depth of around 5,400 ft TVD and 16,000 ft MD. the horizontal section was open hole, so the production of sand was high. Additionally, due to the shallow vertical depth of the wells, the pump was installed at a high inclination, making it more difficult to design the BHA for sand and gas control. The figure 3 shows an example of the inclination of one of the wells. The inclination was considered for the calculation of the total open area of the Tubing Screen and the selection of the size of the slot in the mesh.

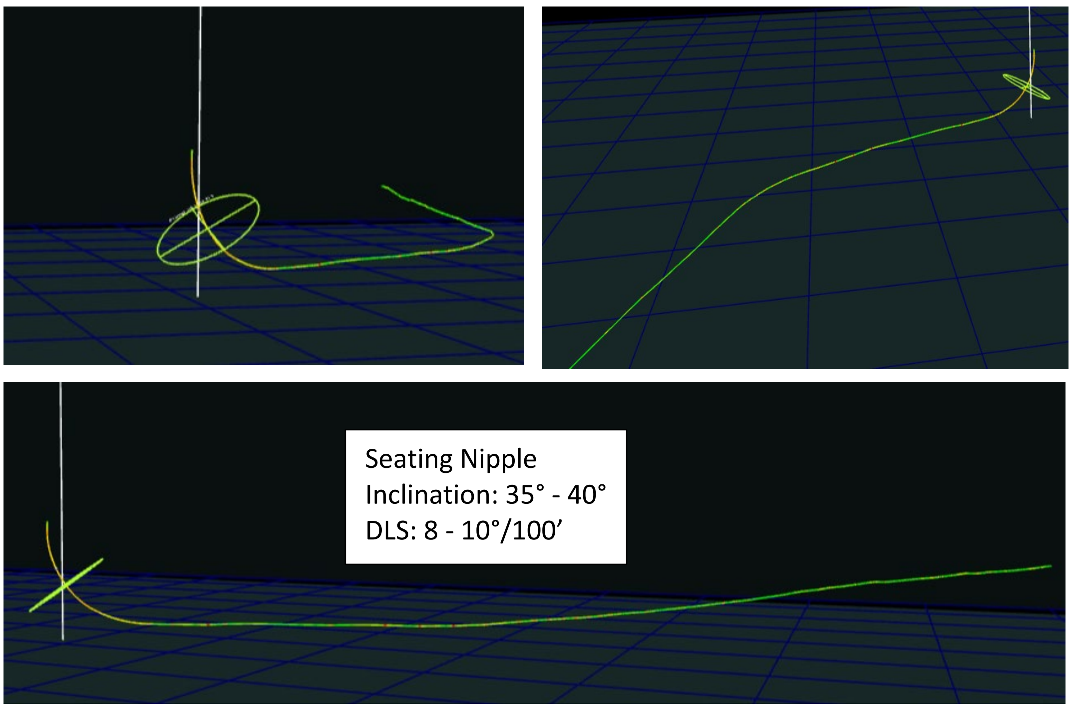


Figure 3 Deviation sketch of the wells designed.

Regarding liquid and gas production, the wells produced between 20 and 60 BPD with a GLR between 6700 and 20,000 SCF/STB, which created volumetric efficiencies of less than 10%.

To determine the total length of the intake it was considered the total fluid production and the chemical conditions of the wells. Figure 4 shows the main solid issues in the wells were calcium carbonate, sand and organic precipitations (Paraffin, wax). Because of the size distribution and the chemical problems found, it was decided that the Tubing Screen couldn’t have a slot size smaller than 0.012 in, so the intake was sized to filter out particles bigger than 305 microns.

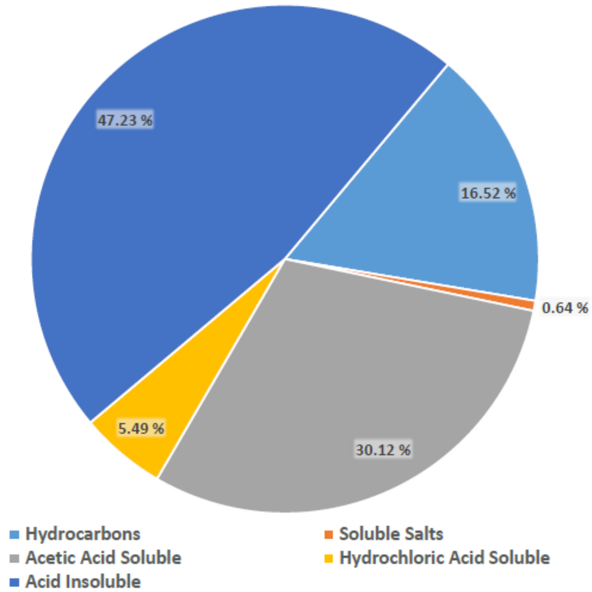


Figure 4 Solid Analysis

Regarding the gas separation design, the previous conditions were simulated, and it was estimated the separation efficiency between 80% and 90%. The results are showed in figure 5. The simulator uses the downhole conditions of the wells and the fluid production downhole to estimate the liquid velocity and the separation efficiency based on the type and dimensions of the gas separator.

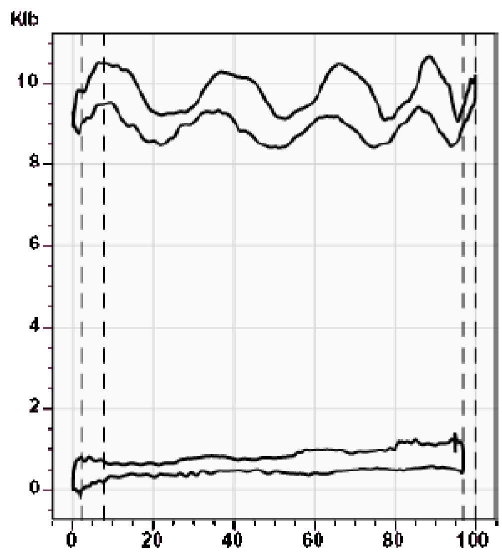
GAS SEPARATION EFFICIENCY		
INPUT DATA		
Percentage of Run time	100%	%
Pump Capacity	60	BFPD
Pump Capacity / Stroke	1.89	Gal/Stroke
Production of total liquid barrel per day	60	BFPD
Water Cut	0%	%
Oil Rate	60.0	BOPD
Water Rate	0.0	BWPD
Gas Rate	400	MSCFD
GLR	6666.67	scf/stb
Produced WOR	0.00	BWPD/STBPD
Produced GOR	6666.67	scf/STB
Temp.	160	F
PIP	400	psi
Casing I.D.	6.184	In
Tubing O.D.	2.875	in
Gas Separator O.D.	3.5	In
Gas Separator I.D.	3	In
OD Dip Tube:	1.6	in
Water SPGr	1.05	
Gas SPGr	0.8654	
Oil API	35	
Oil SpGr	0.85	
Interfacial Tension	0.04	lb/sec^2
Gravtitational Force	32	ft/sec^2
CALCULATED RESULTS		
Free Gas Entering Pump wo/Separator, q'g	**14207**	scf/d
Gas Bubble Terminal Velocity, Vb	**0.563**	ft/s
Cross Sectional Area in Annulus, A	**0.035**	ft^2
In-Situ Superficial Liquid Velocity Inside Casing Annular, Vsl	**0.1**	ft/s
Natural Separatation Effeciency, ηn	**82.52**	%
Free Gas Entering Pump w/Separator, q'g2	**2482.90**	scf/d

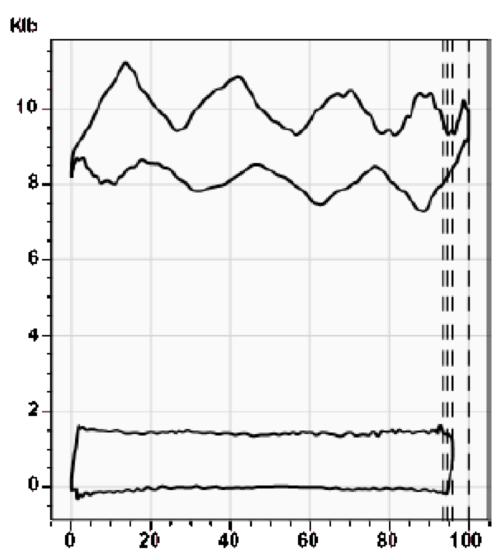
Figure 5 Gas Separation Simulation

Another important point to consider was the number of tail joints below the Vortex Desander. Because there was a lot of uncertainty on the volume of sand being produced. Of course, this criterion needed to be re-validated by a sieve analysis from each well and the right estimation of the sand rate.

The wells were installed in May 2022 and after the installations the impact in production was immediate and the increase in the volumetric efficiency of the pump was outstanding. Table 2 through 4 summarizes the results for CML-2, CML-3, and CML-1.

Table 2 Well Performance CML-2

<table>
<tr><th>Date</th><th>Pump Card</th><th>Parameters</th></tr>
<tr><td colspan="3">Before Installation</td></tr>
<tr><td>01/17/2022</td><td>
</td><td>25-125 RHBC 20-6

Oil: 18 BPD
Water: 0 BPD
Gas: 0 MCFD
Volumetric Eff.: 8.2%
SL: 100 in
SPM: 4.563 spm
Pump Depth: 5,316 MD ft
Liquid Level: 5,093 ft
THP: 105 psig
CHP: 284.4 psig</td></tr>
<tr><td colspan="3">After Installation</td></tr>
<tr><td>05/18/2022</td><td>
</td><td>25-125 RHBC 16-6

Oil: 37 BPD
Water: 80 BPD
Gas: 0 MCFD
Volumetric Eff.: 98.4%
SL: 100 in
SPM: 4.461 spm
Pump Depth: 5,156 MD ft
Liquid Level: 1,608 ft
THP: 75 psig
CHP: 141.7 psig</td></tr>
</table>

Table 3 Well Performance CML-3

<table>
<tr><th>Date</th><th>Pump Card</th><th>Parameters</th></tr>
<tr><td colspan="3">Before Installation</td></tr>
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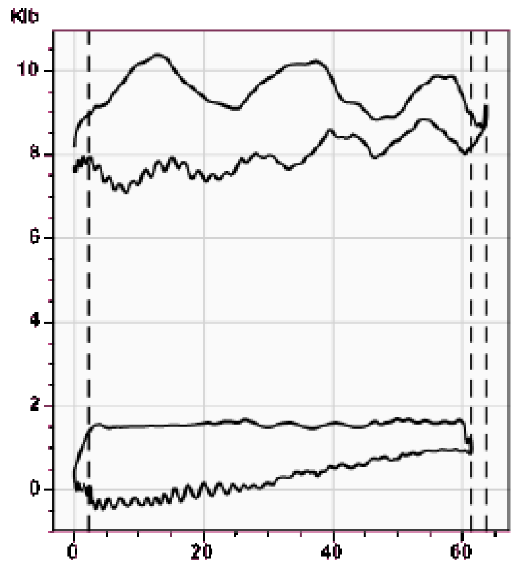
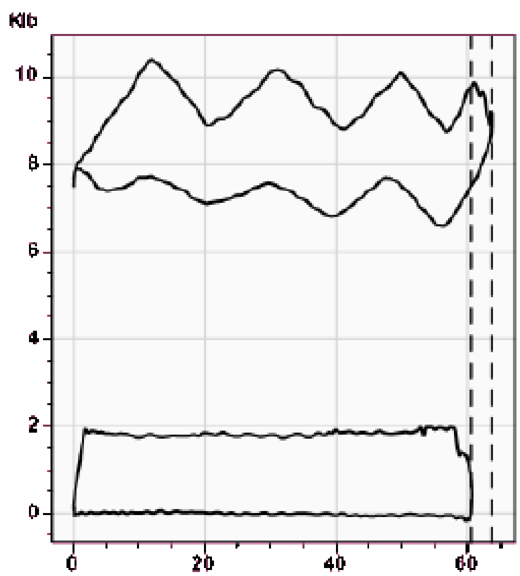


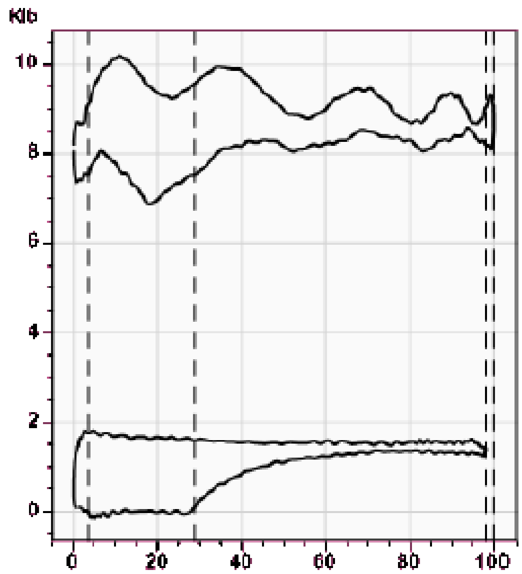
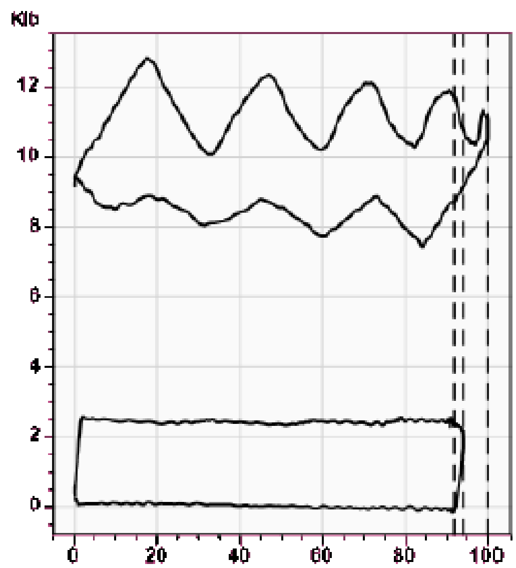
</td><td>25-125 RHBC 16-6-4-0

Oil: 10 BPD
Water: 0 BPD
Gas: 17.6 MCFD
Volumetric Eff.: 3.7%
SL: 63.77 in
SPM: 5.678 spm
Pump Depth: 4,579 MD ft
Liquid Level: 2,291 ft
THP: 30 psig
CHP: 169.3 psig</td></tr>
<tr><td colspan="3">After Installation</td></tr>
<tr><td>05/20/2022</td><td>


</td><td>25-125 RHBC 16-6-4-0

Oil: 93 BPD
Water: 30 BPD
Gas: 102.8 MCFD
Volumetric Eff.: 99.6%
SL: 63.77 in
SPM: 5.128 spm
Pump Depth: 4,457 MD ft
Liquid Level: 875 ft
THP: 45 psig
CHP: 204.5 psig</td></tr>
</table>

Table 4 Well Performance CML-1

Date	Pump Card	Parameters
Before Installation		
03/24/2022		25-125 RHBC 20-6-2-0 Oil: 0 BPD Water: 0 BPD Gas: 445.3 MCFD Volumetric Eff.: 29.3% SL: 100 in SPM: 5.333 spm Pump Depth: 4,678 MD ft Liquid Level: 2,201 ft THP: 35 psig CHP: 40.2 psig
After Installation		
05/19/2022		25-125 RHBC 20-6 Oil: 87 BPD Water: 0 BPD Gas: 325.3 MCFD Volumetric Eff.: 97.7% SL: 100 in SPM: 4.534 spm Pump Depth: 5,154 MD ft Liquid Level: 2,323 ft THP: 73 psig CHP: 77.4 psig

Regarding the production of fluids, the total volume of oil produced from the 3 wells had a significant increase after the installation of the gas separators. Figure 6 shows the accumulated monthly production of oil and gas, where an increase and later stabilization of the production volumes is evident. Currently, the wells continue a less drastic decline line than that seen just before the installation of downhole gas separators.

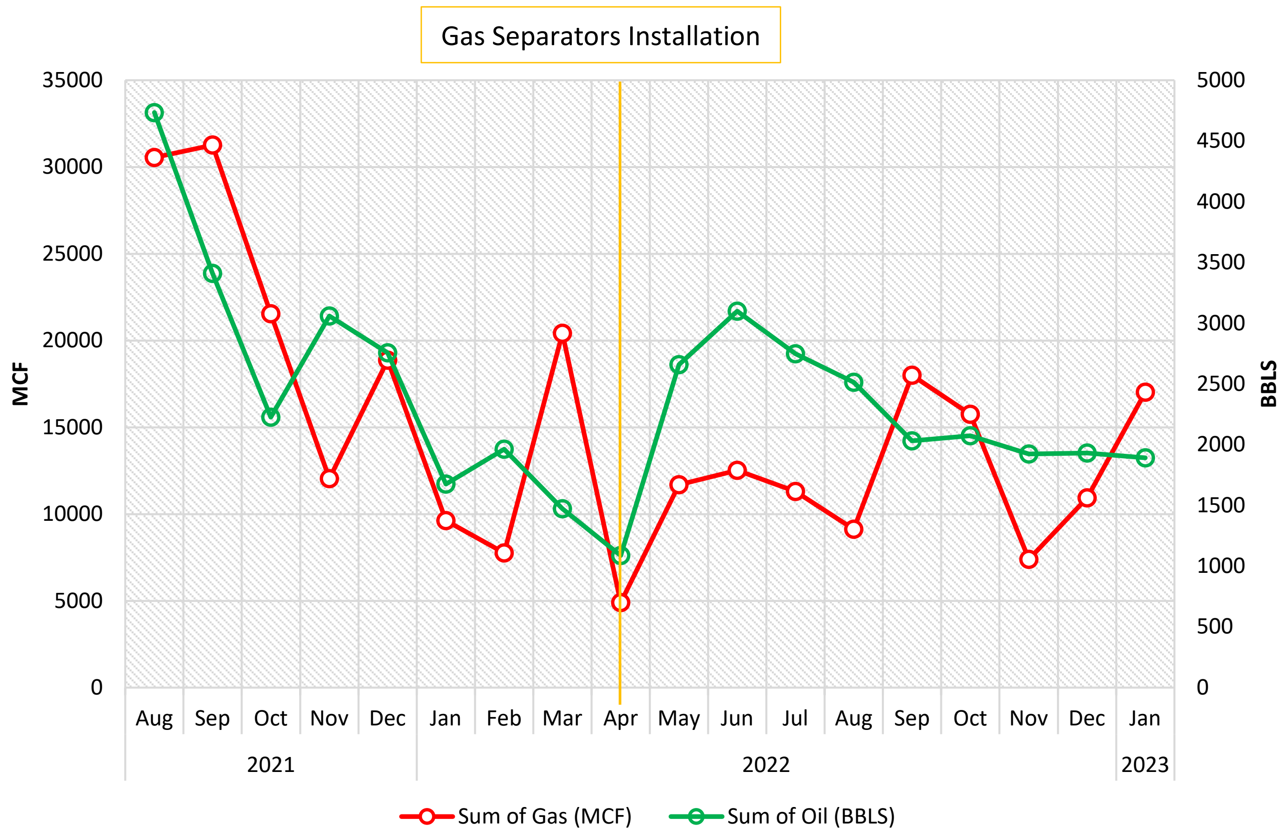


Figure 6 Cumulative fluid production

CONCLUSIONS

- The gas interference reduced the volumetric efficiency of the analyzed wells creating a more severe declination in the production profile. The rapid decline in production was stopped by installing a gas separator designed based on well conditions.

- The increase and stabilization in the production of the wells was due to the combined effect of the gas separator with the two-stage sand control system. This allowed for better pump performance while extending the run life of the equipment. To date the wells have been running for more than 9 months without any kind of failure.

- For the design of the gas separator, the correct analysis of the downhole conditions is important to determine the best method for gas separation. In general, for a more realistic modeling of gas separation, it is necessary to know the total fluid production, downhole pressure and temperature, fluid properties, casing size, and gas separator geometry. The type of intake of the separator also influences the modeling.

- The 2-stages filtration system is designed based on the particle size distribution, the sand production rate, and the fluid production rate. The chemical conditions in the well are important to size the slot size and the number of joints installed below the vortex desander.

REFERENCES

- John VanNatta, Phillip Logan, and Alyssa Stieg, Apache Corp.; Gustavo Gonzalez and Luis Guanacas, Odessa Separator Inc.. "Improved Rod-Pump Run Time in Sandy Wells Two Stages Filtration". SPE-195186-MS.
- A.F. Harun, SPE, M.G. Prado, SPE, S.A. Shirazi, SPE, and D.R. Doty, U. of Tulsa, "An Improved Model for Predicting Separation Efficiency of A Rotary Gas Separator in ESP Systems" SPE 63044.
- M. Ghareeb, B. Frost, C. Tarr, N. Sadek. Application of Beam Pumping System for High Gas/Oil Ratio Wells. 2008.
- Campbell, J.H. Meridian Oil Co., Brimhall, R.M. Texas A&M University, "An Engineering Approach to Gas Anchor Design", SPE-18826, 1989.
- E.J. Dottore (Boiland y Cia. S.A.), "How to Prevent Gas Lock in Sucker Rod Pumps", SPE 27010-MS.
- Gabor Takacs. Sucker-Rod Pumping Manual 1st Edition, 2002.
- X. Xu, Q. yang, C. Wang, H. Wang. "Impact of Bubble Coalescence On Separation Performance of A Degassing Hydrocyclone". 2015.
- James N. McCoy & Lynn Rowlan, "Downhole Gas Separator Selection". SWPSC & ALDRC Gas Well Deliquification Workshop, February 17 – 20, 2013.
- A.L. Podio, J. Gomez, A.J. Mansure, B. Williams, M. Mahoney, "Laboratory-Instrumented Sucker-Rod Pump" SPE-83674-PA.
- L. Suarez, F. Kenyery, and M. Asuaje, USB, and M. Peña, PDVSA-Intevep, "3D CFD Simulation of Rotary Gas Separator Performance Under Two-Phase Flow Condition". SPE 94959.
- Odessa Separator Inc (www.odessaseparator.com)
- R. Franklin, Odessa Separator Inc, "The Ultimate Filtration Tool, The Utilization of Tubing Screens and Pump Screens in Down Hole Pump Operations" SWPSC 56 Annual Meeting, 2009.