PERFORMANCE CASE STUDY OF A STATIC - CENTRIFUGAL DOWNHOLE GAS SEPARATOR IN GASSY WELLS

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ABSTRACT
Poor performance in rod pumping wells using downhole gas separation tools is common. This stems from little to no evaluation of well conditions before inserting a “template” gas separation tool, to handle liquid production and free gas in the system. Evaluating well conditions before designing the downhole gas separation tool, while applying static and centrifugal principals, has led to increased success in recent installations. Designers must evaluate the correct factors when deciding which downhole gas separator to install.

INTRODUCTION

Gassy wells have been a big challenge for rod lift system, especially in wells converted from Gas Lift to a Sucker Rod Pump. In horizontal wells with high-formation GORs, 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 well behavior. 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 survey, perforation depths, pump depth, pump type, pressure, 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.

There are different methods to deal with gas in sucker rod pump system. One method will be discussed in this paper which involves using a static-centrifugal gas separation system below the pump to prevent large portion of free gas from entering the pump, which may cause gas interference and/or gas lock. Four Permian Basin case studies will be discussed in this paper, each of which is known to have a severe problem with gas and are in the Wolfcamp formation in West Texas. The methods for gas separation provided by the service company will be shown to have been successfully applied in each well.

WELL CONDITIONS

All wells (A, B, C, and D) have a 25-175-RHBC-24-5-1-1 pump installed, Wells A, B, and C have larger percentages of free gas, while Well D has a larger percentage of solution gas. Wells A, C, and D used a packer type gas separator in the previous BHA, and were replaced for OSI Static-Centrifugal Gas Separators. Well B previously had a Poor Boy or Mother Hubbard Style gas separator and it was replaced with an OSI Static Gas Separator. These designs were made to decrease the gas problem in the pump and increase fluid production. This information is illustrated in Table1.

Well A is a horizontal well that has a KOP at 5565 ft. and a landing point of 6131 ft. TVD / 6521 ft. MD. The seating nipple was landed in the 5-1/2 in. casing section at 5547 ft., gas flow 99 Mscf/D, water cut 64%, and 145 BFPD, GOR 2000 Scf/Stb, and GLR 683 Scf/Stb.

Well B is a horizontal well with a KOP at 5584 ft. and a landing point of 6126 ft. TVD / 6461 ft. MD. The seating nipple was landed in the 5-1/2 in. casing section at 5530 ft., gas flow 103 Mscf/D, water cut 67%, and 134 BFPD, GOR 2340 Scf/Stb, and GLR 769 Scf/Stb.

Well C is a horizontal well with a KOP at 5620 ft. and a landing point of 6156 ft. TVD / 6474 ft. MD. The seating nipple was landed in the 5-1/2 in. casing section at 5351 ft., gas flow 215 Mscf/D, water cut 44%, and 108 BFPD, GOR 3525 Scf/Stb, and GLR 1991 Scf/Stb.

Well D is a horizontal well with a KOP at 5584 ft. and a landing point of 6126 ft. TVD / 6461 ft. MD. The seating nipple was landed in the 5-1/2 in. casing section at 5530 ft., gas flow 173 Mscf/D, water cut 38%, and 110 BFPD, GOR 2507 Scf/Stb, and GLR 1573 Scf/Stb.

DESIGN OF DOWNHOLE GAS SEPARATOR

The OSI Static-Centrifugal Gas Separators for Wells A, B, and C were designed to separate gas through two stages, Well D was designed with one stage to separate gas; the reason for this was the amount of solution gas that this well produces. The first stage uses the Venturi principle utilizing gravity separation; the second stage uses a Centrifugal force, in this case a Vortex Gas Separator causes this force.

Stage 1

The design consisted of one 2-7/8in. x 24ft. x 15 slot Tubing Screen, functioning as an inlet for the well fluid and a filter for sand (>400 microns). The fluid enters through the 304-stainless steel screen, which provides 285.5 in² of open area where the first stage of separation of the free gas occurs. Fluid then travels down inside the base pipe of the tubing screens. The coalescing phenomenon makes the gas bubbles larger, which rise due to their lower density within the "downstream" of fluid and exits through the mesh of the Tubing Screen into the casing annulus. This action is illustrated in figure 1.

The next separation section is composed of three 2-7/8 in. x 3-1/2 in. x 24ft. Gas Separator Bodies, connected in series under the Tubing Screen. The gas separator body has a design which creates a Venturi effect on the "descending torrent" of the fluid flow through the 2-7/8 in. neck section into the 3-1/2 in. chamber. The separator body allows the separation of free gas in the fluid due to the change of pressure and velocity resulting from the changing diameter at the OSI Reduction Ring. This gas ascends by buoyant forces and exits the gas body through the mesh of the Tubing Screen using gravity separation (Figure 3). Inside the Tubing Screen and Gas Separator Bodies an internal pipe with a 1,656 in. O.D, called a Dip Tube is placed, in Wells A, B, and C the dip tube ends with a Helix 2.2. In Well D, the Dip Tube ends with a Pump Guard Screen (Strainer), which adds an extra step of filtration before entering to the Dip Tube.

Stage 2

In Wells A, B, and C the fluid, which now has less free gas, is received by a Vortex Gas Separator which forces the fluid to descend in a spiral creating a centrifugal force, which finishes separating the gas and sand (Figure 2). The fluid now rises through the center of the Vortex, then enters the Dip Tube, then finally enters the pump.

The Design of the Selected Equipment in Critical to the Project’s Success

- 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.
- 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.
- 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.
- The helix creating the vortex effect, must be selected to match the expected production through the system.
- 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.
- It is important to calculate the right amount of mud joints or tail pipes according to the sand production.

OPERATION OF STATIC-CENTRIFUGAL DOWNHOLE GAS SEPARATOR

When the fluid will flow up from the bottom until inlet of the Tubing Screen, the V-wire will act as coalescing plates forcing the gas bubbles to collide/baffle, making them larger and helping it to rise in the annulus. This is the first separation of the free gas. After the fluid passes through the Tubing Screen, it flows down and enters the first gas separator body. When the fluid passes from the smaller 2-7/8 in. diameter neck through the reduction ring the fluid velocity will decrease in the 3-1/2 in. oversized body tending to separate more free gas (Venturi effect). which will exit the system through the mesh of the Tubing Screen. The fluid now with less free gas flows down to the second (well D) and third gas separator bodies where the Venturi mechanism will repeat for separate more free gas (wells A, B, and C). After this, the fluid will reach the bottom of the dip tube and set inside the Vortex sleeve. The helix 2.2 is installed at the end of the dip tube and creates the centrifugal force to separate any remaining free gas and solids present. The fluid then enters the dip tube and flows up until reaching the pump. In the case of only using a static gas separator the theory will remain the same up to, but excluding the centrifugal gas separation step, it will have at the end of the dip tube a Pump Guard Screen or 45-degree inner section.

In general, the maximum capacity of the separation tool, is determined by the volume of the chamber, in the gas separator bodies. This is the volume between the ID of the oversize body and the OD of the dip tube (gas anchor).

RESULTS

On April 25, 2016, Well A was converted from a packer type gas separator to a static-centrifugal style of gas separator which consisted of a wire wrapped Tubing Screen, three OSI Gas Separator Bodies, and a Vortex Gas Separator (centrifugal separator). This change helped increase the amount of oil produced from 51 BOPD to 64 BOPD while increasing the fluid production from 145 BFPD to 155 BFPD (Figure 4). This type of increase in overall production can be attributed to increasing the pump efficiency (Figures 5) and a slight decrease in the pumping speed (Figure 6). The GOR increased from 1800-2000 SCF/STB to 2200 SCF/STB this occurs proportional to the increase in oil production. If the value of a barrel of oil is taken to be 50 USD that would entail that the increase would yield an extra 650 USD per day for this well.

On April 26, 2016, Well B was converted from a Mother Hubbard style of gas separator to a static-centrifugal style of gas separator which consisted of a wire wrapped tubing screen, three oversized static gas separators, and a vortex gas shield (centrifugal separator). This change helped increase the amount of oil produced from 44 BOPD to 57 BOPD while only increasing the fluid production from 134 BFPD to 145 BFPD (Figure 7). This type of increase in overall production can be attributed to increasing the pump efficiency (Figures 8) and a slight decrease in the pumping speed (Figure 9). The GOR rose from 2000-2500 SCF/STB to 2900 SCF/STB this occurs proportional to the increase in oil production, within the fluid. If the value of a barrel of oil is taken to be 50 USD that would entail that the increase would yield an extra 650 USD per day for this well.

On May 9, 2016, Well C was converted from a packer type gas separator to a static-centrifugal style of gas separator which consisted of a wire wrapped tubing screen, three oversized static gas separators, and a vortex gas shield (centrifugal separator). This change helped increase the amount of oil produced from 61 BOPD to 82 BOPD while increasing the fluid production from 108 BFPD to 136 BFPD (Figure 10). This type of increase in overall production is slightly uncommon but it can be attributed to increasing the pump efficiency (Figures 11) and a slight decrease in the pumping speed (Figure 12). The GOR decreased from 3500-4000 SCF/STB to 1638 SCF/STB this occurs because of the in two factor, first the gas separation and second the increase of the total production. If the value of a barrel of oil is taken to be 50 USD that would entail that the increase would yield an extra 1050 USD per day for this well.

On February 23, 2016, Well D was converted from a packer type gas separator to a static type gas separator, which consisted of a wire wrapped tubing screen and two oversized static gas separators. This change helped increase the amount of oil produced from 69 BOPD to 113 BOPD while increasing the fluid production from 109 BFPD to 186 BFPD (Figure 13). This type of increase in overall production is what is expected and it can be attributed to increasing the pump efficiency (Figures 14) and a slight increase in the pumping speed (Figure 15). The GOR decreased from 3000-4000 SCF/STB to <2000 SCF/STB this occurs because of the in two factor, first the gas separation and second the increase of the total production. If the value of a barrel of oil is taken to be 50 USD that would entail that the increase would yield an extra 2,200 USD per day for this well.

CONCLUSION

- The use of Tubing Screens combined with Gas Separator Bodies and a Vortex Gas Separator demonstrated to be an effective tool to separate the free gas when compared to the more traditional gas separators whose intakes are composed of slotted holes. The efficacy of OSI Gas separator has been successful in this high GOR wells.
- It is of utmost importance to design the first stage of free gas separation to the well conditions and fluid properties. In general, the fluid production, gas volume, API gravity, pump speed, stroke length, and pump size are the minimum data needed to design the correct tool.
- When the artificial lift system is a rod pump, the pumping speed (SPM) also affects the amount of free gas entering the system (This can be noted from figures 6, 9, 12, 15 and comparing them with their corresponding productions graphs 4,7,10,13). NOTE: Increasing pumping speed does not always increase production it has a chance to lower the pump efficiency and cause a decrease in production, because the drawdown is higher and more gas could be pushing into the pump.

REFERENCES

- 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.
- J. Diaz Sierra, Chevron; O. Moreno Mendoza, PDVSA; S. Rivas Johnson, Chevron; M. Arredondo, PDVSA. “A New Engineering Approach for Gas Anchor Applications for Extra Heavy Crude Oil – Study Case at PetroPiar In the Orinoco Belt.” SPE-169336-MS.
- James N. McCoy & Lynn Rowlan, “Downhole Gas Separator Selection”. SWPSC & ALDRC Gas Well Deliquification Workshop, February 17 – 20, 2013.
- A.L. Podio (U. of Texas at Austin) | Jaime Gomez (U. of Texas at Austin) | A.J. Mansure (Sandia Natl. Laboratories) | Benny Williams (Harbison-Fischer) | Mark Mahoney (Harbison-Fischer, “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. http:// 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.

Table 1 Wells Information

	Well A	Well B	Well C	Well D
Pump	25-175-RHBC-24-5-1-1	25-175-RHBC-24-5-1-1	25-175-RHBC-24-5-1-1	25-175-RHBC-24-5-1-1
Predominately Free Gas	Yes	Yes	Yes	No
Predominately Solution Gas	No	No	No	Yes
Previous Gas Separator	Packer type	Poor boy/Mother Hubbard	Packer type	Packer type
New Gas Separator	OSI Static/Centrifugal Gas Separator	OSI Static/Centrifugal Gas Separator	OSI Static/Centrifugal Gas Separator	OSI Static Gas Separator
Well Type	Horizontal	Horizontal	Horizontal	Horizontal
Kick-Off Point	5565ft	5584ft	5620ft	5584ft
Landing Point	6131ft TVD / 6521ft MD	6126ft TVD / 6461ft MD	6126ft TVD / 6461ft MD	6126ft TVD / 6461ft MD
Casing Size	5-1/2in	5-1/2in	5-1/2in	5-1/2in
Seating Nipple Depth	5547ft	5530ft	5351ft	5530ft
Gas Flow	99Mscf/D	103Mscf/D	215Mscf/D	173Mscf/D
Water Cut	64%	67%	44%	38%
Fluid Production	145 BF/D	134 BF/D	108 BF/D	110 BF/D
GOR	2000 Scf/Stb	2340 Scf/Stb	3525 Scf/Stb	2507 Scf/Stb
GLR	683 Sct/Stb	769 Sct/Stb	1991 Sct/Stb	1573 Sct/Stb

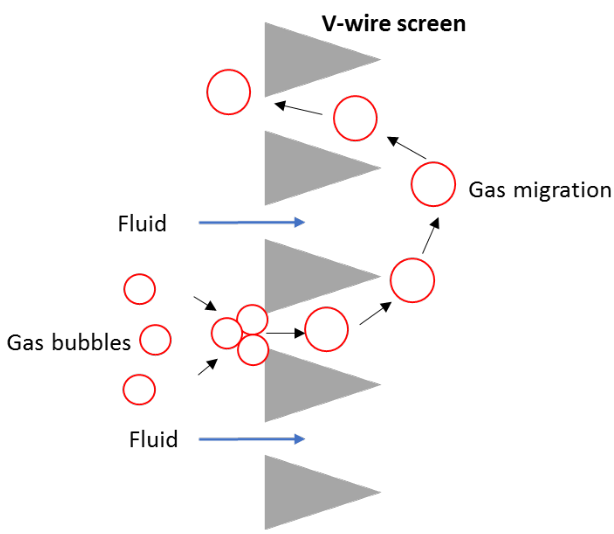

Figure 1 – Coalescence on the V-wire screen

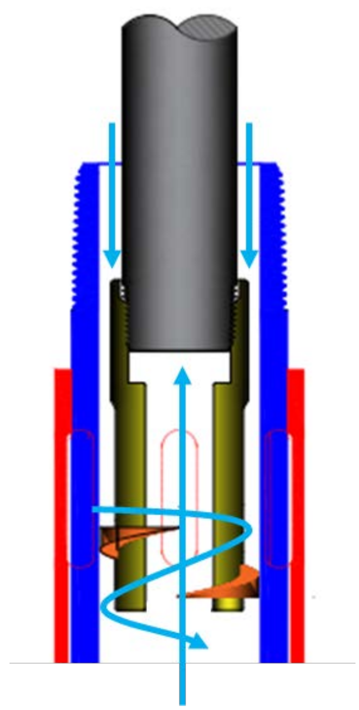

Figure 2 – Vortex gas separator

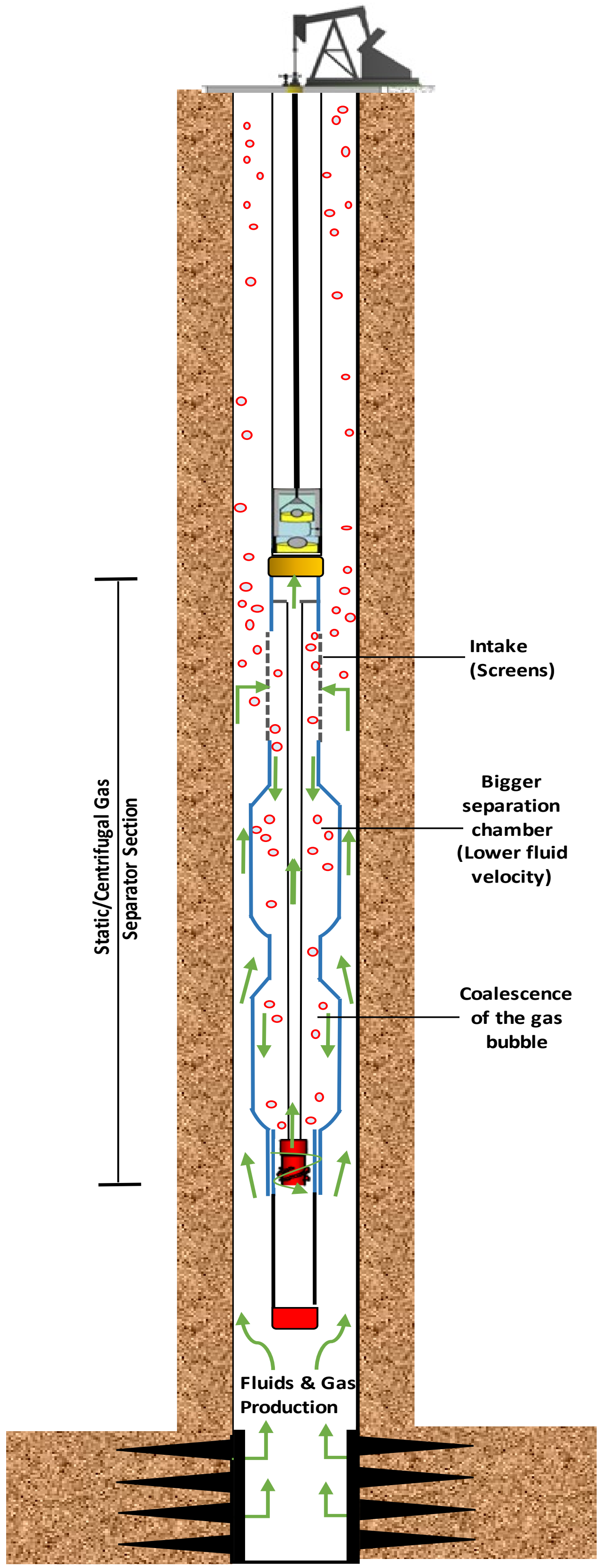

Figure 3 – Bernoulli effect in the gas separator body

Well A

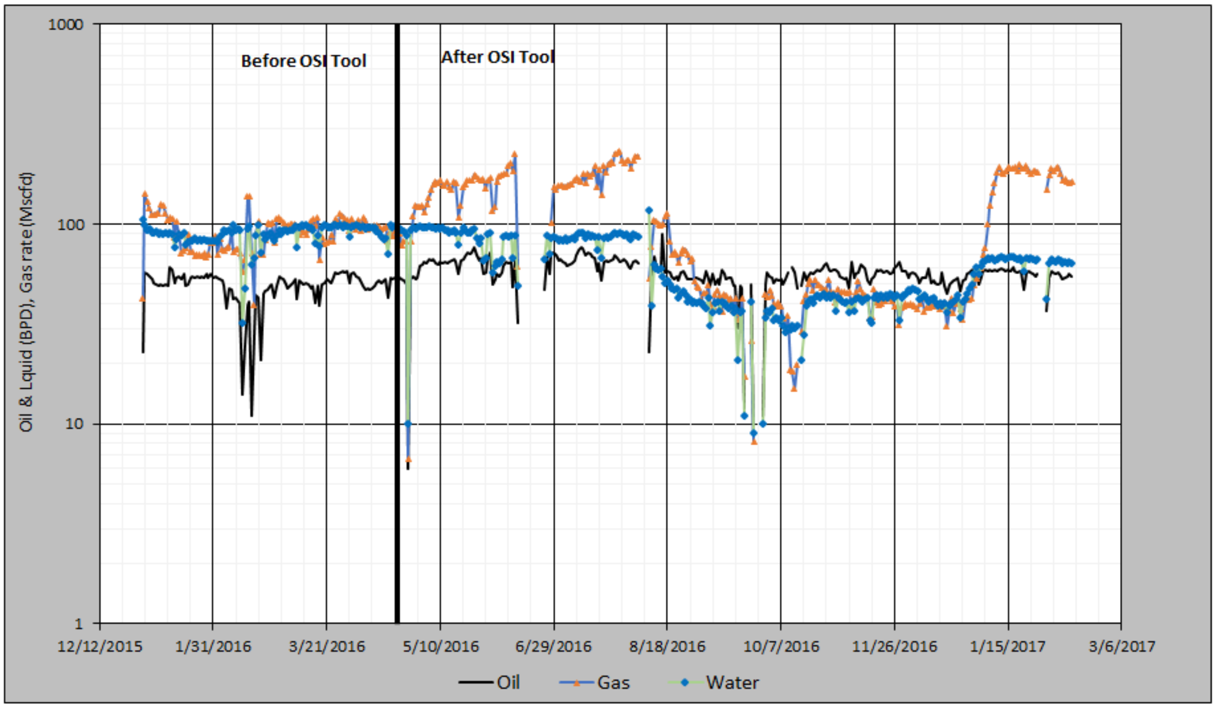

Figure 4 -Well A’s production curve before and after the installation of the OSI’s tools.

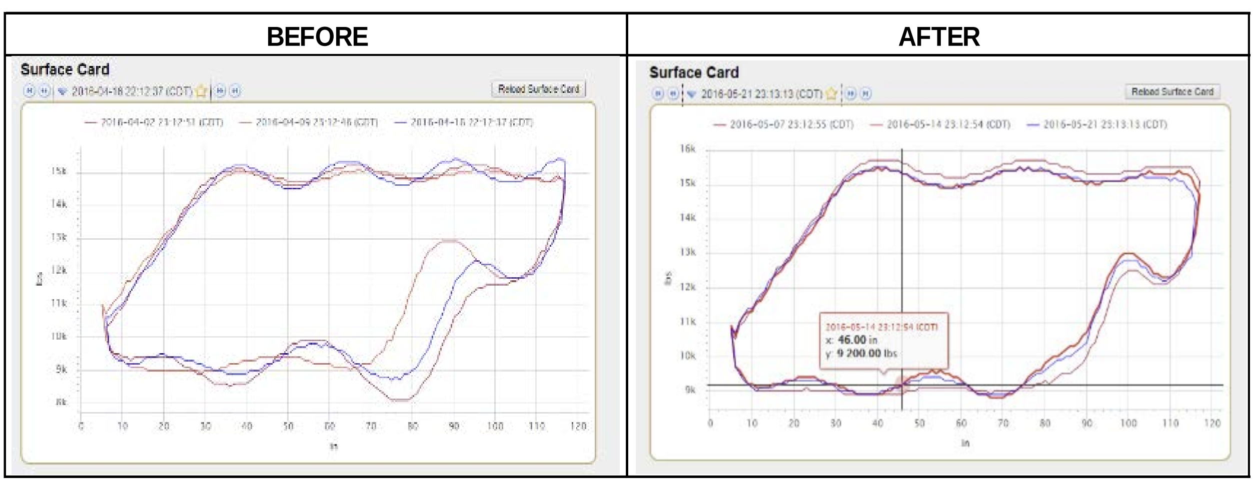

Figure 5 - Surface pump cards for (Well A) before/ after installation of OSI Gas Separator.

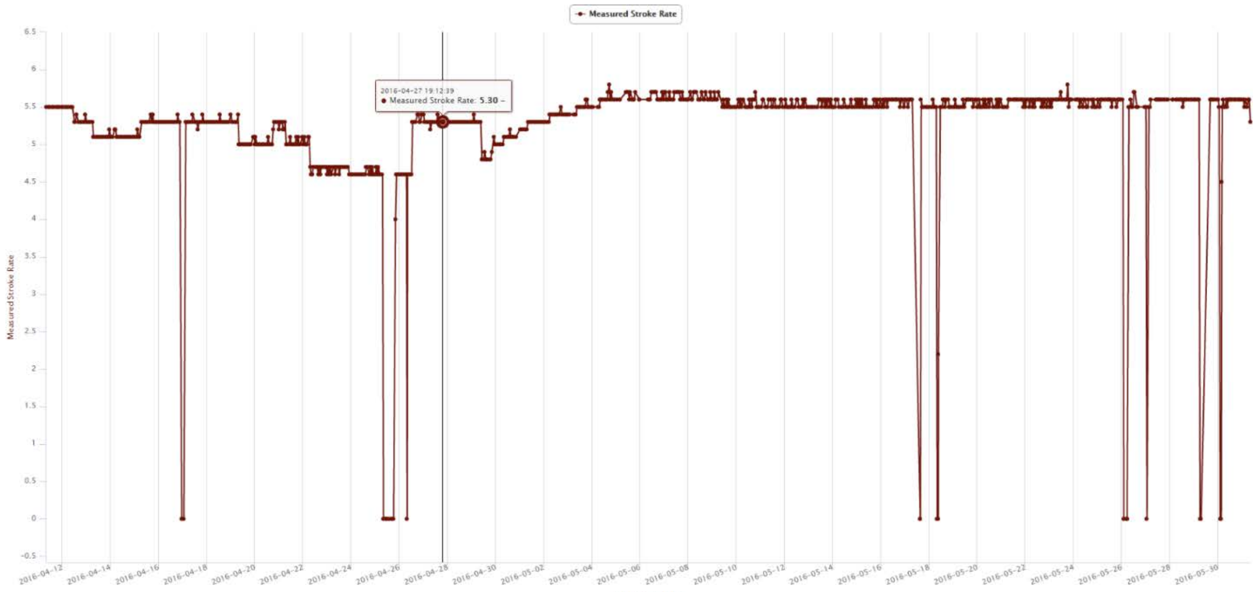

Figure 6 – Pumping speed for Well A before and after tool installation

Well B

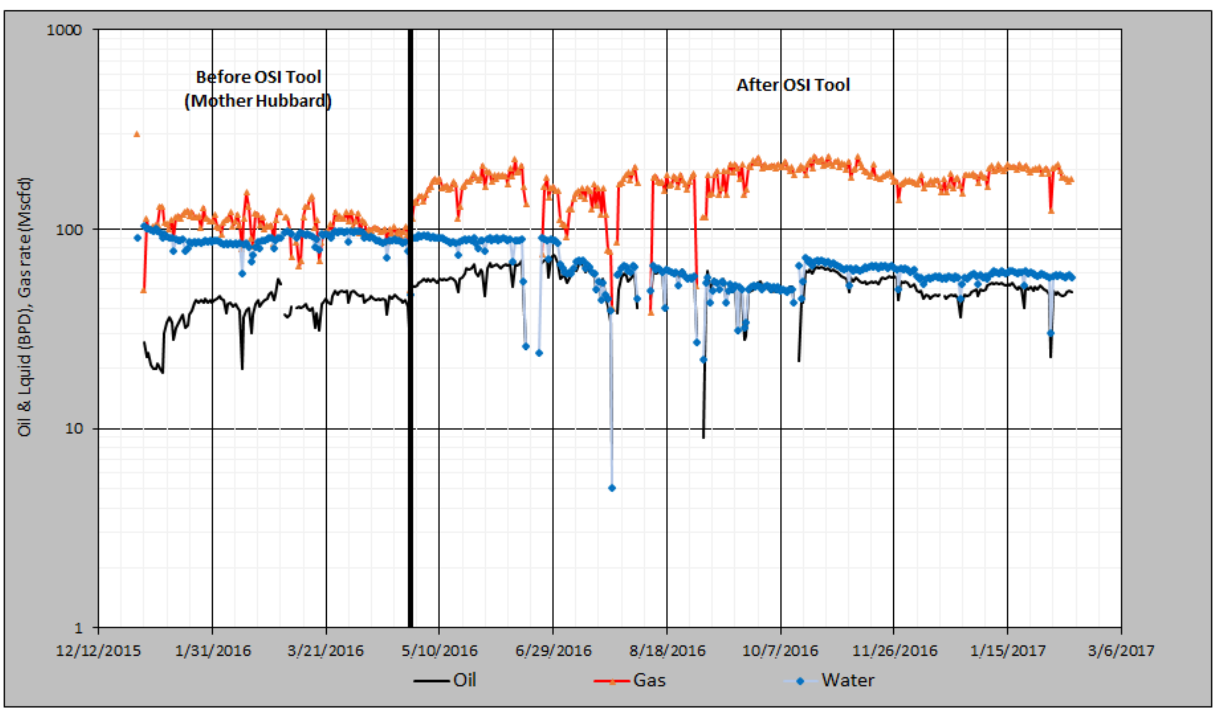

Figure 7 -Well B's production curve before and after the installation of the OSI tools

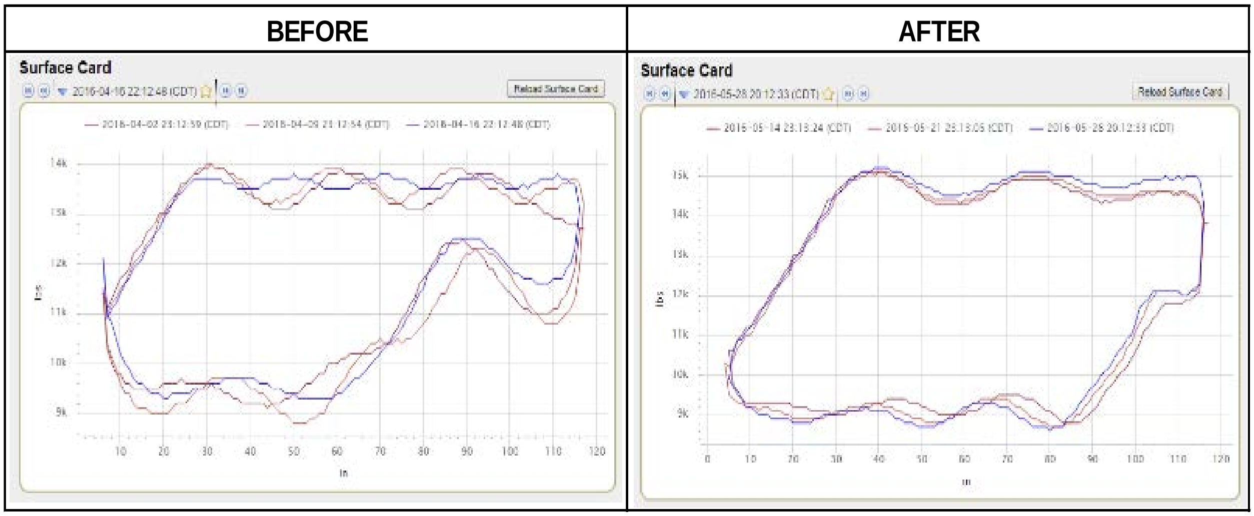

Figure 8 - Surface pump cards for (Well B) before/After installation of OSI Gas Separator

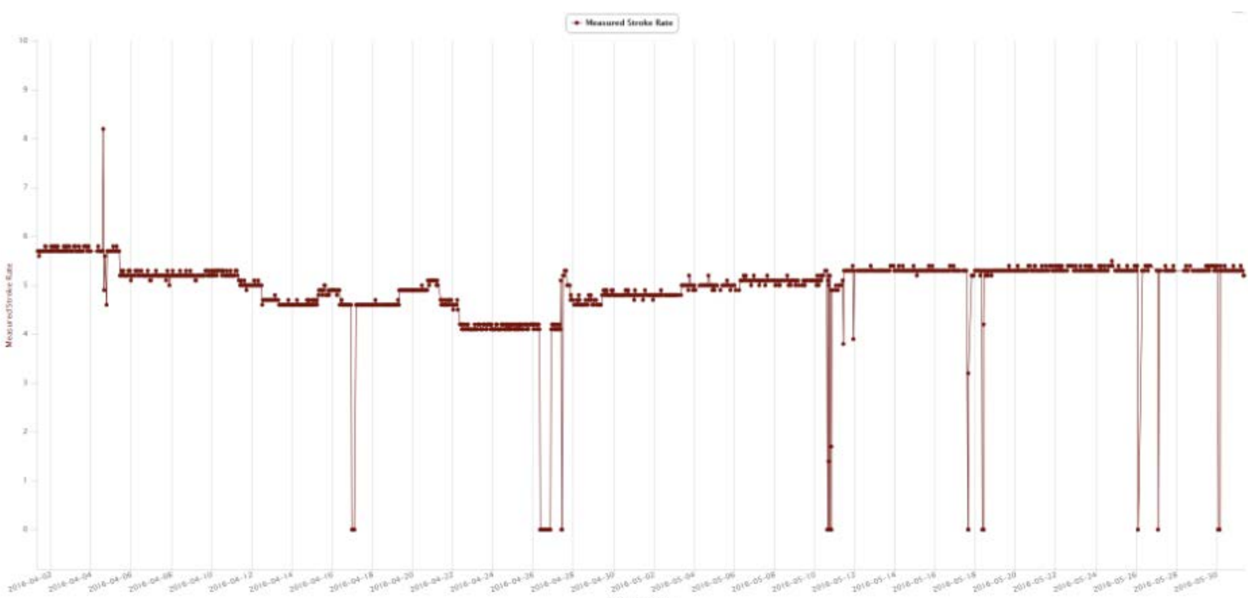

Figure 9 – Pumping speed for Well B before and after tool installation

Well C

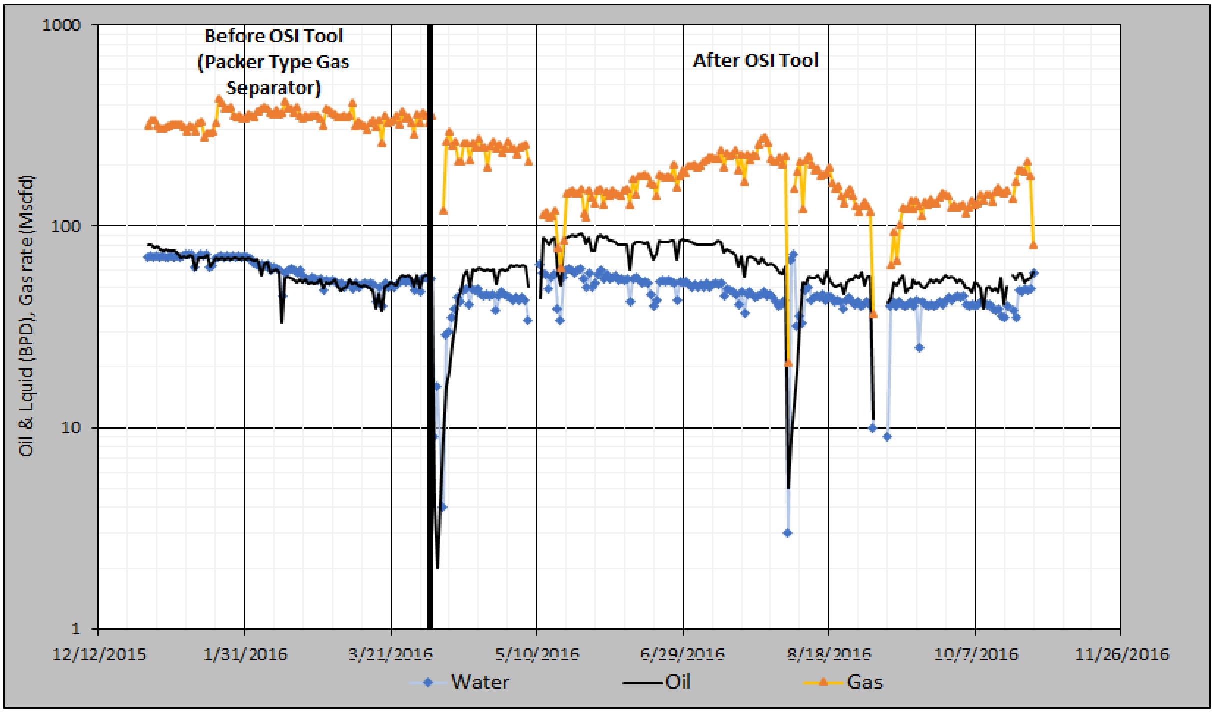

Figure 10 -Well C's production curve before and after the installation of the OSI tools.

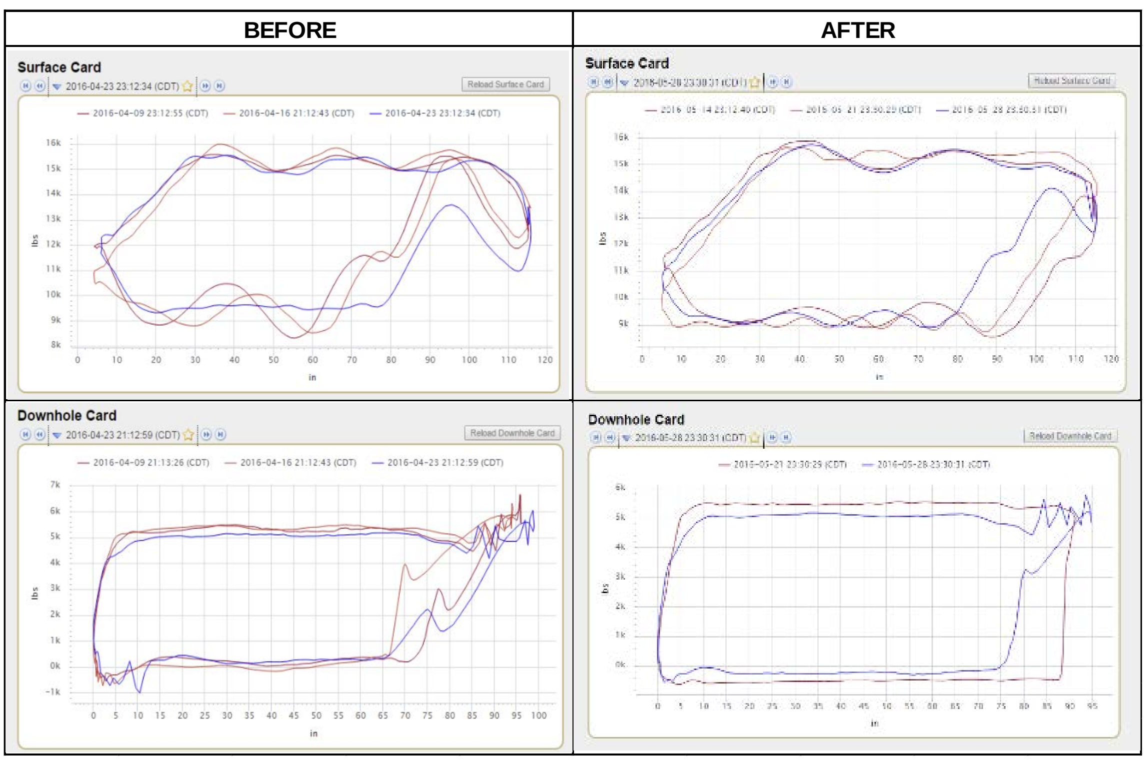

Figure 11 –Pump cards for Well C before and after installation of OSI Gas Separator

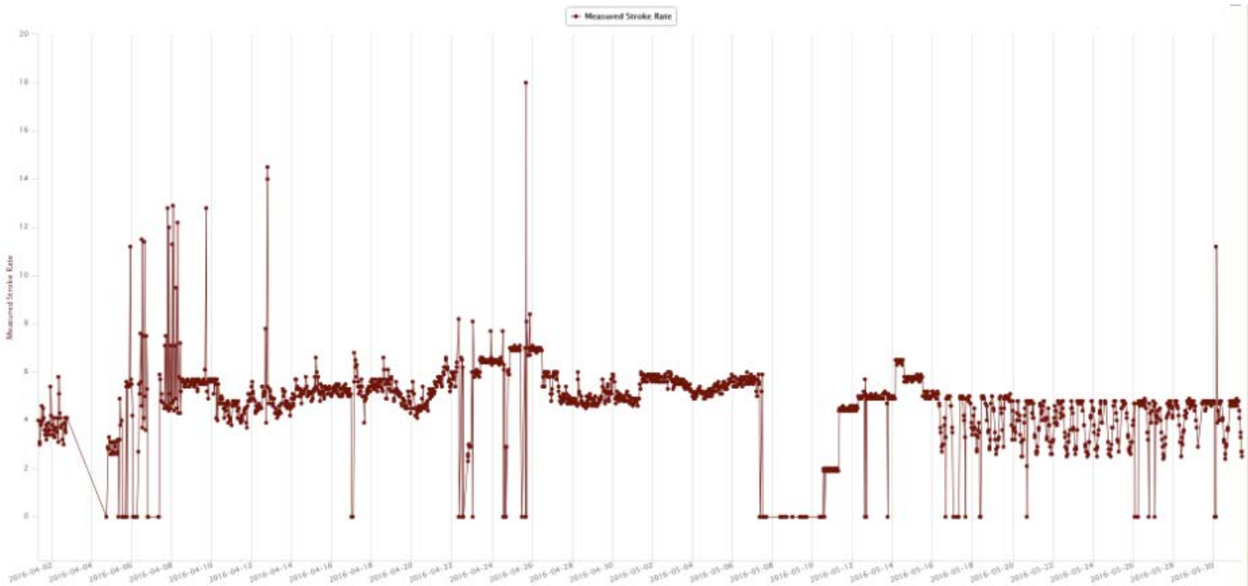

Figure 12 – Pumping speed for Well C before and after installation

Well D

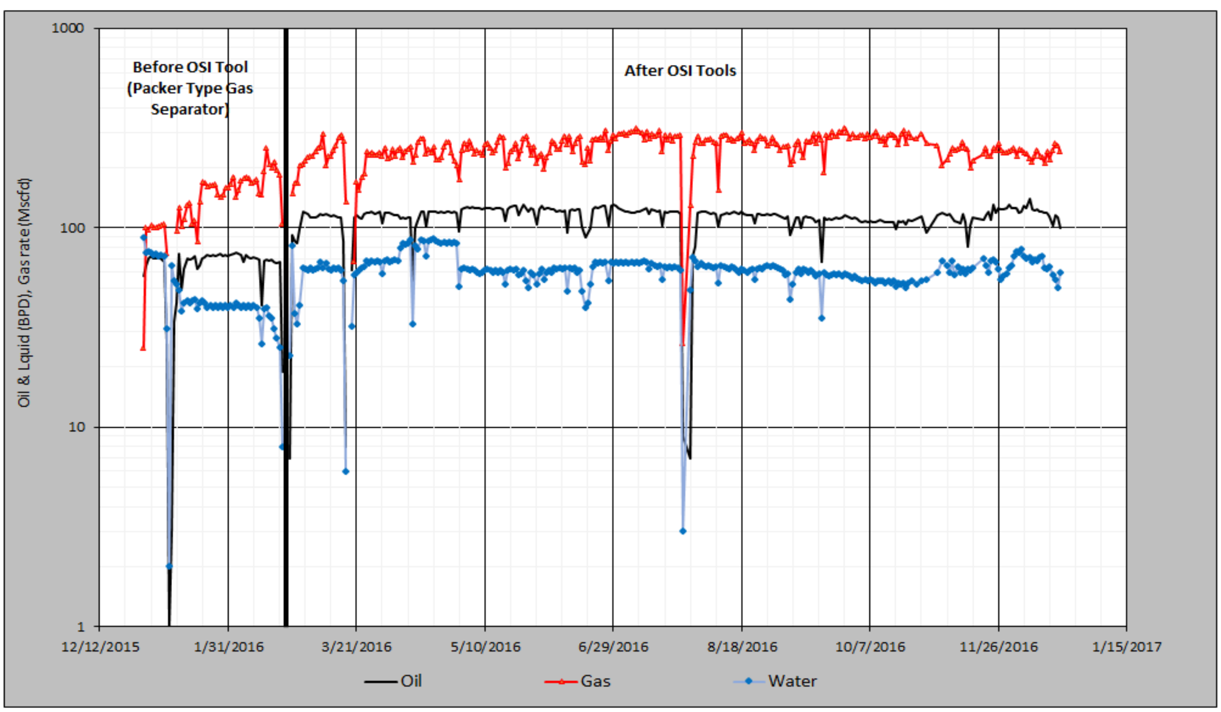

Figure 13 -Well D’s production curve before and after the installation of the OSI Tools.

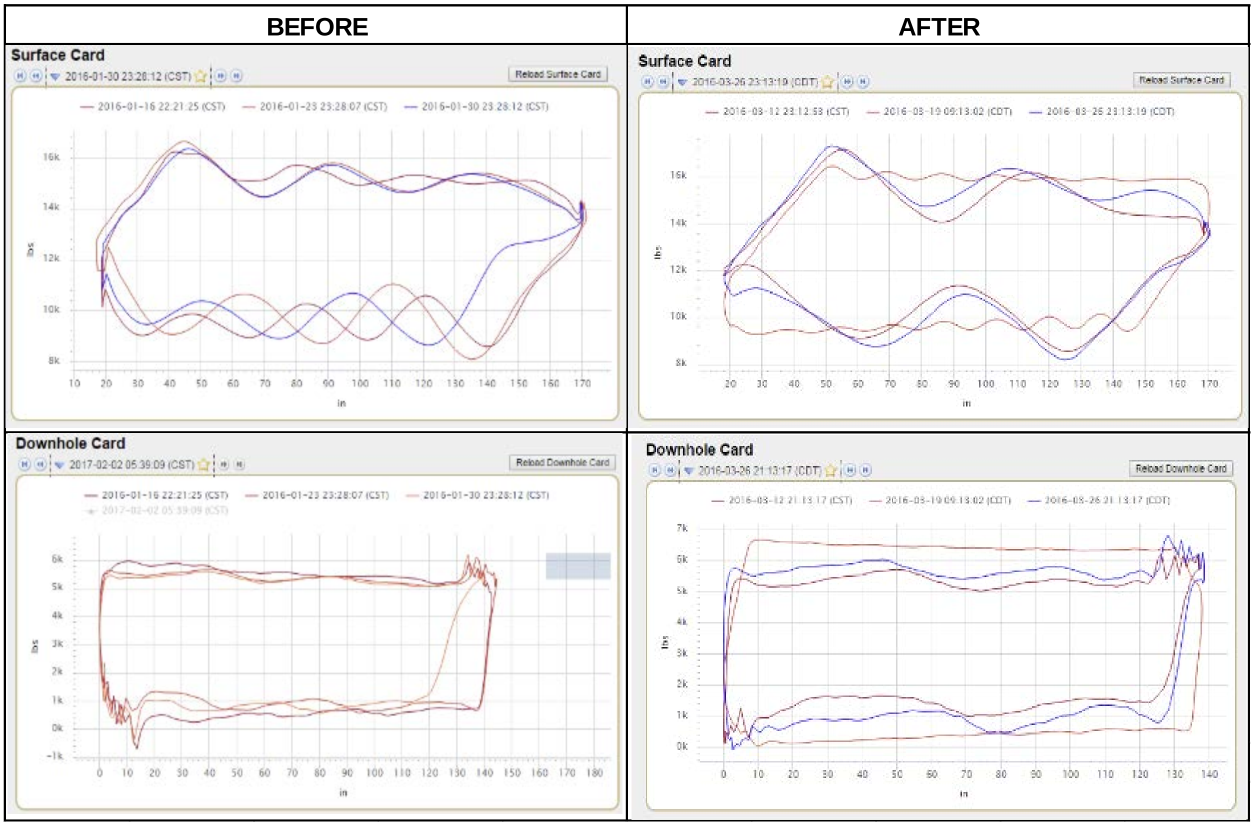

Figure 14 –Pump cards for Well D before and after installation of OSI Gas Separator

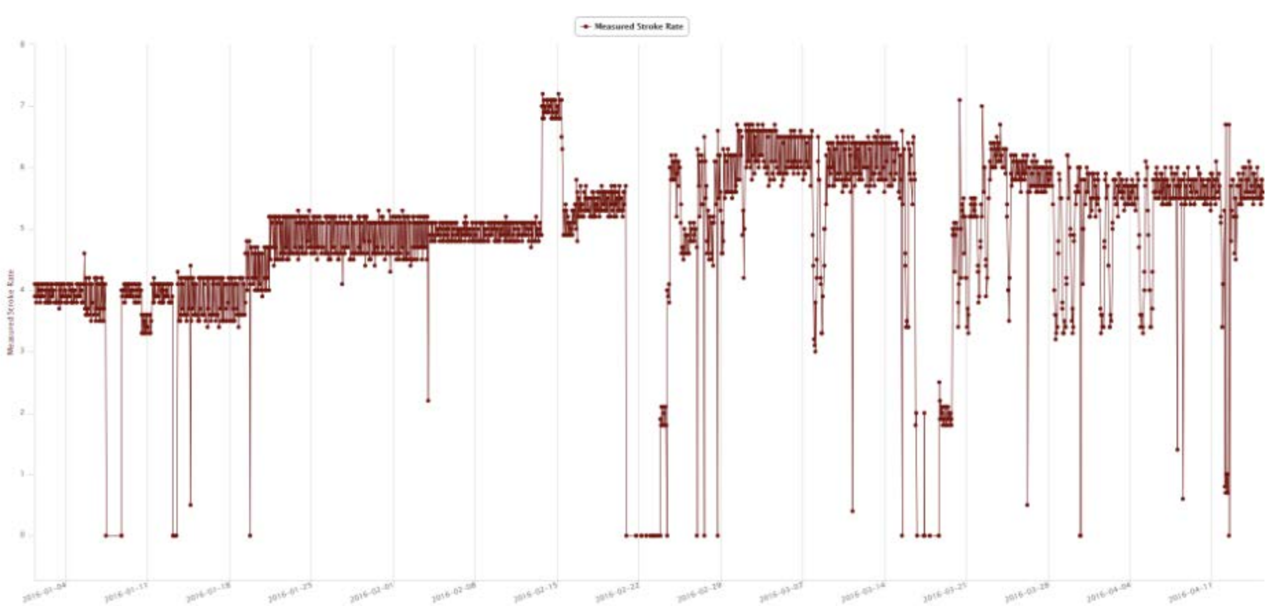

Figure 15 – Pumping speed for Well D before and after tool installation