CONVERSION OF ESP TO ROD PUMPING SYSTEM WITH AN IMPROVED GAS SEPARATOR SYSTEM IN DEPLETED WELLS

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ABSTRACT
The conversion from ESP to rod pump is needed when well-inflow is insufficient to supply enough fluid to the ESP. However, achieving good pump performance in rod pump systems operating in depleted wells with high gas/oil ratio can be limited as well. Creating a multi-stage gas separator system which removes free gas before fluid entered the pump intake increases volumetric efficiency in depleted wells. The first stage is a slotted intake where gas can coalesce. The second stage utilizes three large gas separator bodies for increased expansion of free gas which travels with the fluid by action of an extended dip tube. Finally, a vortex tool which creates a centrifugal force increases free gas separation efficiency.

INTRODUCTION
The Electric Submersible Pump (ESP) has been used in the oil and gas industry to handle wells when there are large productions of fluid and gas, also there are many applications where the ESP can get a good performance in gassy wells, but when the flow rate of gas exceeds the gas separation capacity, the pump efficiency declines. The recommendation was made to evaluate alternatives to producing the well fluids, which would entail re-evaluating operational parameters, pump design, or possibly a new artificial lift method to optimize the system and maintain the production with minimal cost.

Based on the impact of the oil price in 2016, this case study was forced to make economic choices of whether to continue using an ESP, switch to a different artificial lift system or to shut down the well. Choosing which option is best depends on the well conditions, economic factors, such as the initial cost, recurring expenses, and the availability of electricity. This well was already set up with an ESP so there was already an available power source to keep the motor running. ESP systems tend to be expensive to install and maintain, so they are justified to be used when it can produce large amounts of fluid; but the amount of gas, in this case, was affecting the pump performance creating gas locking, an economic problem in the lifting cost, and premature failures. The operator company decided to consider a different ALS, that would be more economically viable and technically appropriate, to produce based on the well conditions. After all the simulations, a positive displacement pump was the most appropriate system for this well, and the Sucker Rod Pump was the best ALS that fit with the well conditions, in this situation, the ESP was chosen to be removed and replaced with a 912-365-168 beam pumping unit set to run with stroke length of 145in. and a 25-200-RHBC-24-5 insert pump.

But this decision was debated because this well had a severe gas problem and was believed that an SRP would not be able to handle the gas. To solve the gas issue the operator and Odessa Separator Inc (OSI) designed a gas separation tool to be installed below the pump, so it could handle the gas and protect the pump from gas locking, as well as offering a good pump performance which helps to optimize the system.

WELL CONDITIONS
To provide clarity in this paper, the well will be referred as Well #1 and it is in the Lower Clear Fork formation in Goldsmith, TX. Well #1 is a horizontal well that has a KOP of 5781 (MD) and a landing point of 6728 ft. (MD) / 6424 ft. (TVD). The casing size used in this section of the well is 5-1/2 in. (OD) and tubing is 2-7/8 in. (OD). The perforations are located from 6697 ft. to 10785 ft. (MD). The well was predicted to produce between 180 to 380 BFPD and have a gas flow of 1 MMSCF/D. The oil in this well has an API gravity of 38° and the water cut is 58%. The pump intake is going to be set at 5650 ft., at this location it will be submerged under 300 ft. of fluid. Apart from the gas problem this well suffers from a problem with corrosion.

These factors and more will help to decide the proper BHA that needs to be used. Since this well is a horizontal well caution must be taken when designing a BHA to ensure that it will function properly if the BHA is not placed in the vertical section of the well. The top of the BHA will be placed approximately 131 ft. before the KOP so there should not be a problem with the inclination of the surrounding well. This information is illustrated in Table 1, Table 2 and figure 1.

DESIGN OF DOWNHOLE GAS SEPARATOR

The design consists of an arrangement of equipment located below the pump, this set of equipment was the entry point for the fluid to the pump and separates the gas from the fluid using the Venturi principle in stage 1 and centrifugal force in stage 2.

Stage 1

The first stage consisted of one 2-7/8" x 3-1/2" x 24' Slotted Gas Shield and three 2-7/8" x 3-1/2" x 24' Gas Separator Bodies. The Slotted Gas Shield has slotted ports which functioned as an intake which provides 158 in^2 of open area, where the first stage of separation of the free gas occurs. Fluid then travels down inside the base pipe. The coalescing phenomenon makes the gas bubbles larger, which rise due to their lower density within the "downstream" of the fluid and exit through the ports of the Slotted Gas Shield into the casing annulus

The section is created by three 2-7/8" x 3-1/2" x 24' Gas Separator Bodies, connected in series under the Slotted Gas Shield. The gas separator body has a design which creates a Venturi effect on the "descending torrent", the fluid flows 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 within the OSI Reduction Ring. This gas ascends by buoyant forces and exits the gas body through the slots of the slotted gas body by "gravity separation". Inside the Slotted Gas Shield and Gas Separator Bodies is an internal pipe that has an external diameter of 1.669 in. and is 96 ft. long, called Dip Tube is, which has a Helix 2.3 connected on the end, that induces centrifugal force onto the fluid.

Stage 2

Now the fluid which 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 correct design of the selected equipment in this case is very important:

- Knowledge of chemical issues in a well helps to determine what intake to use in the system, evaluating the presence of paraffin, scale, corrosion or asphaltenes. In this case slots were chosen because of the presence of high corrosion and scale tendency.
- 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. Figure 3 shows the simulation of the fluid velocity inside the gas separator bodies.
- 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.
- It is important to calculate the right amount of mud joints or tail pipes according to the sand production.
- The helix will create a centrifugal force to increase separation, with the curvature designed based on the production expected through the system.
- The inclination of the well must be taken into consideration because of the functionality of the tool would be more efficient if the tool is landed concentrically.

OPERATION OF THE BHA

In this installation, OSI gas separators are located above the perforations (+/- 830 ft.). So, the fluid will flow up from the bottom until it reaches the slotted intake of the Slotted Gas shield. After the fluid passes through the slots, it flows down to the first gas separation chamber, which is the slotted gas shields' oversized body.

When the fluid passes from the smaller 2-7/8 in. diameter neck through the reduction ring where the fluid velocity will decrease in the 3-1/2 in. oversized body tending to separate more free gas (Venturi effect). The gas will then exit the system through the slots (gravity separation). The fluid with less free gas will flow down to the three consecutive Gas Separator Bodies where the same mechanism will be repeat it to separate more free gas.
After this, the fluid will reach the bottom of the dip tube, which will be set inside the vortex sleeve. The dip tube will have a helix installed on its end to create the vortex and separate the remaining free gas and any solids that are present. It is the combination of these principles, where the fluid is subjected to different paths, agitating in each section increasing the size of the gas particles, that ensures that the most free gas will be separated and kept from entering the pump. This allows the pump to have a better volumetric efficiency and a better pump fillage. This process is illustrated in Figure 5 and 6.

RESULTS

Well #1 was converted to a Rod Lift on February 27, 2016 and the OSI Static/Centrifugal Gas Separator was installed on the same day. There was not any information that could be provided about the new pump's performance without the gas separators installed because the artificial lift system was converted at the same time the tool was installed. The only references that could be used were done using the information gathered while the ESP was in operation. In the last month before the ESP was converted the well was producing approximately 280 BFPD and 984 MSCFD. After the beam pump conversion, the production was approximately 250 BFPD with the gas flow reduced to 335 MSCFD (Figure 5). The pump efficiency, with the use of the OSI gas separation system, remains almost constant around 85%. Pump fillage is almost constant and the operational and lifting cost are low when compared to the ESP's cost. The pump parameter is illustrated in Figure 7 and 8.

CONCLUSION

- Conversion from an ESP to a SRP can be an economical choice even when there are gas and chemical issues with the well, if the system is combine with the right downhole gas separator tool.
- Gas issues can be tamed and pump efficiency can be raised with the use of properly sized gas separation system (diameters, length, and intake),
- It is of utmost importance to design the 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 required to design the correct tool.
- The ALS conversion of this well improved the well performance.
- The economic choice was very beneficial because of the large difference in the operating cost of an ESP compared to an SRP with relatively little change in the production.
- The lifting cost was reduced with the new ALS, generating almost the same production with less operational cost.
- The synergistic relationship between the operator and the service company (Odessa Separator Inc) was a key asset to creating excellent communication and optimizing the entire system.

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Table 1 - Well Conditions

Well Information	
Artificial Lift System	SRP
Min Production (BFPD)	180
Max Production (BFPD)	380
Gas Flow [Mscf/D]	1000
Bottom Temperature [ºF]	130
Surface Temperature [ºF]	65
API Gravity [ºAPI]	38
Specific Gravity of Water	1.02
Specific Gravity of Gas	0.7
Water Cut [%]	58%
GOR (Gas-Oil Ratio) [SFC/STB]	8410
GLR (Gas-Liquid Ratio) [STB/STB]	**3565**
Total Wel Depth @ Float Collar (MD) [Ft]	10912
Top of Perforations (MD) [Ft]	6697
Bottom of Perforations (MD) [Ft]	10785
Fluid Level over Pump [Ft]	300
Pump Intake (MD) [Ft]	5650
ID Production Casing [in]	**5.5**
ID Production Tubing [in]	2.875
Packer	NO
Packer Depth (MD) [Ft]	No packer in wellbore
Max. Desviation Pased Through [Deg]	**2.42**
Bubble Pressure [Psi]	2200
Tubing Pressure (THP) [Psi]	80-200
Minimun PIP [Psi]	30-100
Scale/corrosion/parraffin problems	CORROSION

Table 2 – ESP Production Test

Production Tests

Date	Q Oil (bbl/day)	Q Water (bbl/day)	Q Gas (MCF/day)
12/12/2015	117.00	159.00	984.00
9/21/2015	153.00	218.90	883.40
9/10/2015	155.60	235.70	948.90
9/1/2015	146.90	202.90	777.90
8/20/2015	159.80	226.10	924.80
8/9/2015	132.50	180.40	385.00
6/28/2015	135.50	625.10	586.40
6/17/2015	129.70	634.70	665.00
6/15/2015	134.50	664.80	573.90
6/12/2015	130.50	623.60	514.80
6/9/2015	129.80	643.00	641.80
6/2/2015	133.30	687.70	668.90
5/19/2015	148.00	771.10	507.90
5/16/2015	152.60	769.70	418.00
5/14/2015	185.70	782.20	421.80
5/5/2015	187.30	810.90	686.80
5/2/2015	186.20	805.70	700.30
4/22/2015	186.80	832.80	549.70
4/16/2015	199.00	887.30	567.80
4/14/2015	161.40	868.30	636.30
4/8/2015	183.80	854.20	669.90
4/6/2015	142.70	825.30	537.80
3/28/2015	180.60	831.40	497.60
3/25/2015	238.20	928.90	674.70
3/21/2015	297.70	959.30	661.40
3/17/2015	133.90	932.00	653.70
3/13/2015	190.70	918.70	654.80
3/8/2015	174.70	974.70	628.10
2/21/2015	123.30	987.80	644.80
2/13/2015	122.00	865.00	564.00
2/8/2015	134.80	977.90	622.60
2/4/2015	191.40	1,049.70	613.50
1/27/2015	270.80	1,072.00	359.10
12/22/2014	208.90	1,010.60	615.90
12/21/2014	253.90	1,069.40	597.70
12/20/2014	297.80	1,036.40	378.10

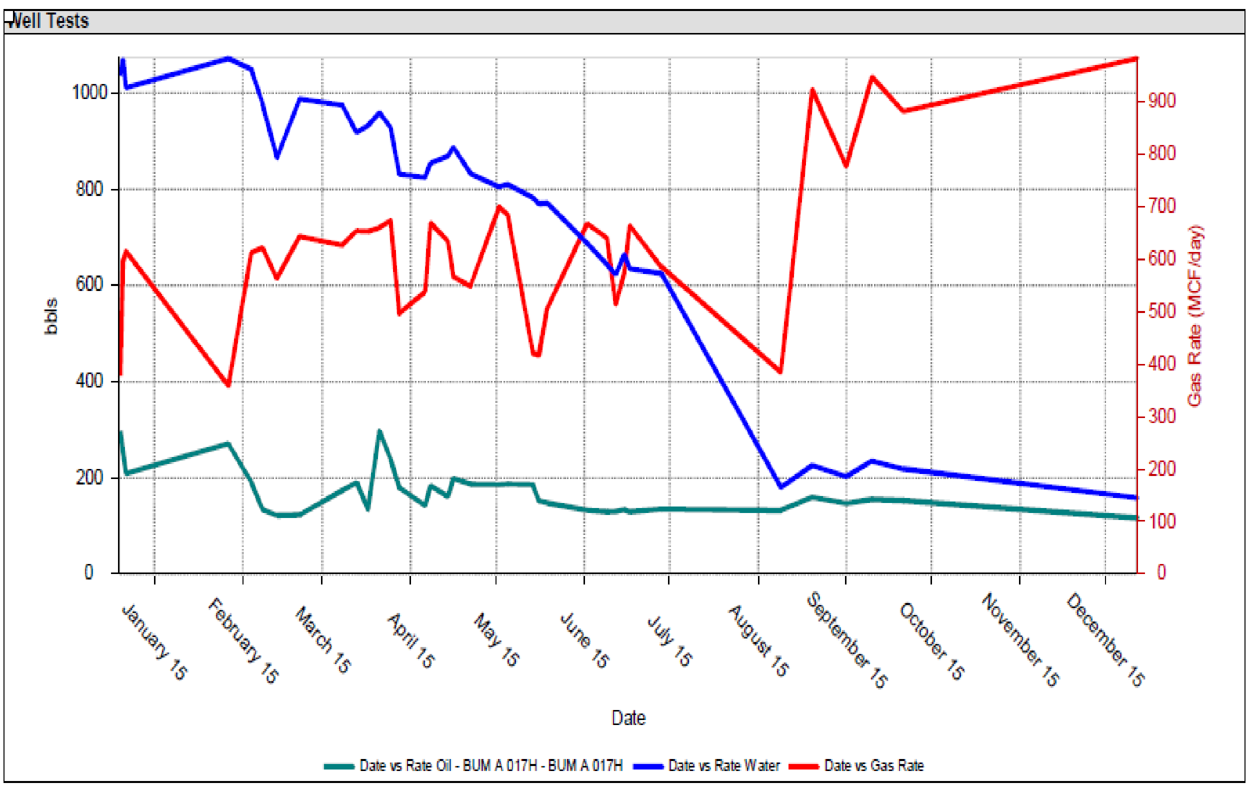


Figure 1. ESP Well Test

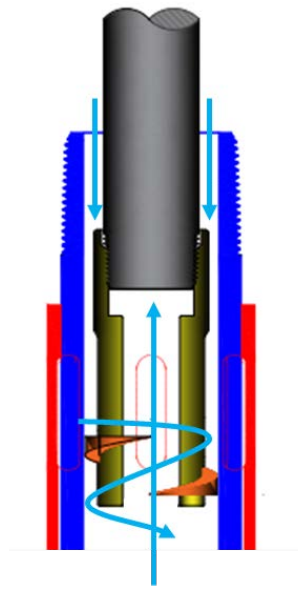


Figure 2 – Vortex gas separator

OSI GAS SEPARATOR			
INPUT DATA			
Production of total liquid barrel per day	280	BFPD	
Casing	5 1/2	in	
OSI SIZE	2-7/8"x3-1/2" OD	in	
GOR	8410	SFC/STB	
GLR	3565	SFC/STB	
Slot	Slotted		
Open area "Tubing Screen"	158.0	in^2	
ID Tubing MA:	3.00	in	2.441 NECK
OD dip tube:	1.656	in	
Percentage of Run time	100%	%	
CALCULATED RESULTS			
Area mud anchors	23.50	in^2	
Area dip tube	4.31	in^2	
AMA (Area of the downpassage)	19.19	in^2	
86400 sec per day *% of time	86400	sec/day	
9702 (cubic in of a barrel * total barrels)	2716560	bbl/sec	
Cubic inch per sec total cubic / by sec of run time	31.44	in^3/sec	
Fluid Velocity in the dead space	0.34	ft/sec	
	4.10	in/sec	

For an effective separation of gas, the rate of fluid loss should not exceed 0.5 ft/sec or 6 In/sec

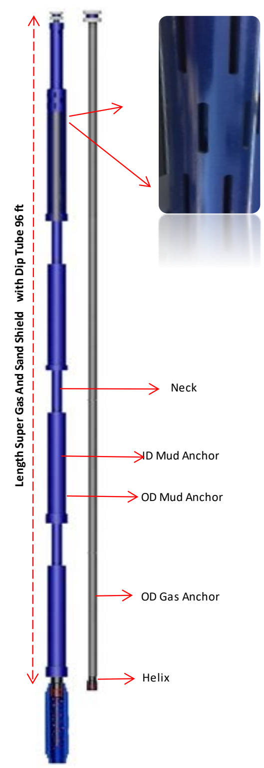


Figure 3 - Gas separation simulation

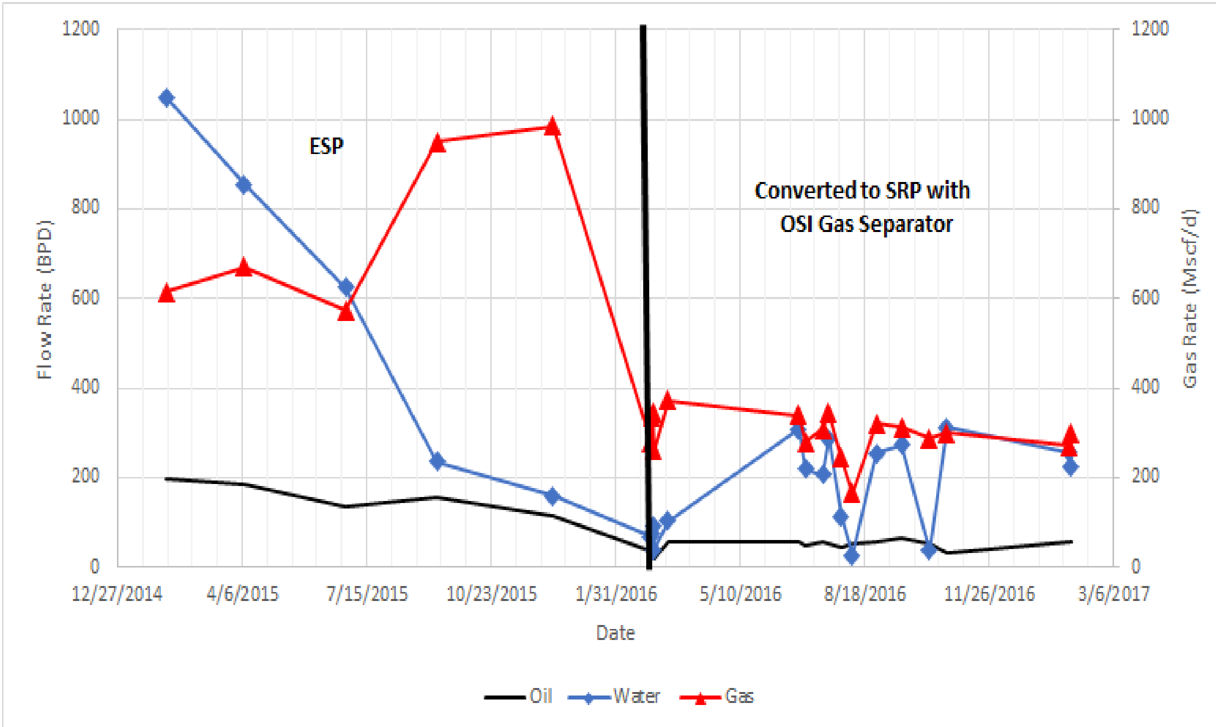


Figure 4 - Production report

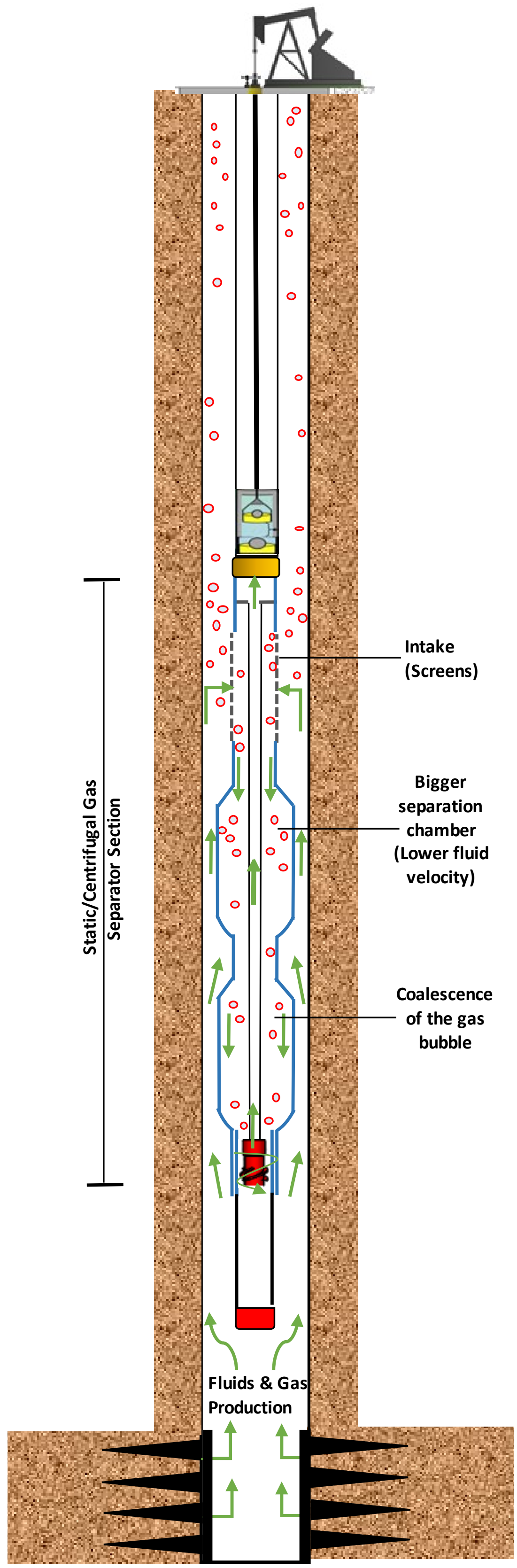


Figure 5 – Bernoulli effect in the gas separator body

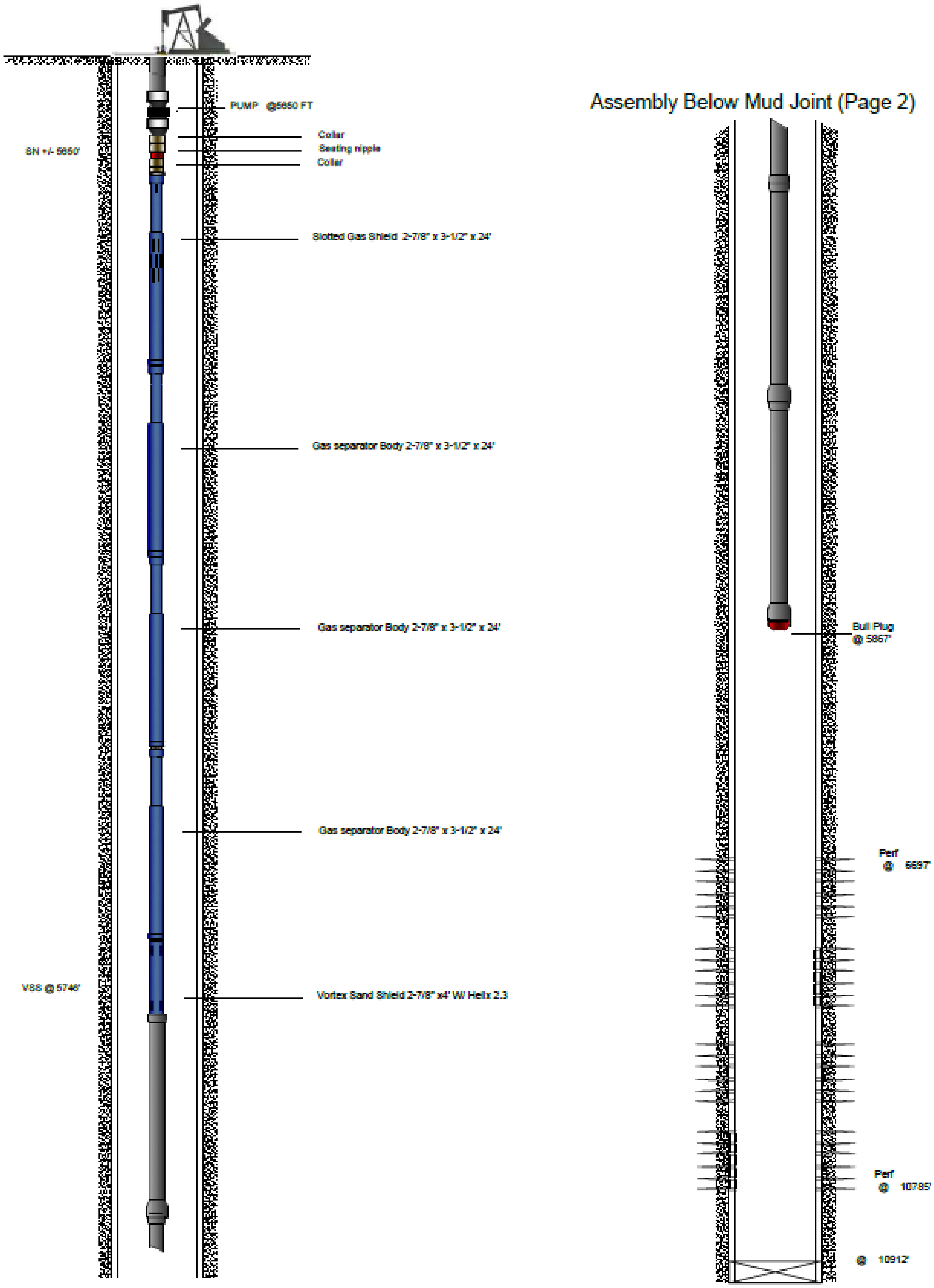


Figure 6 – Wellbore Diagram

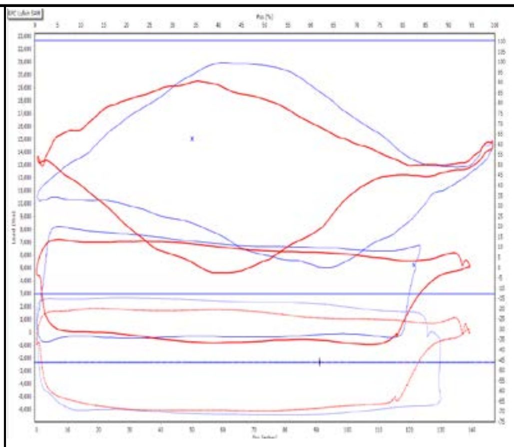
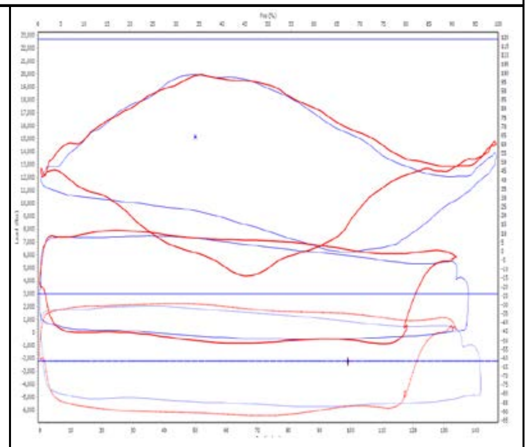
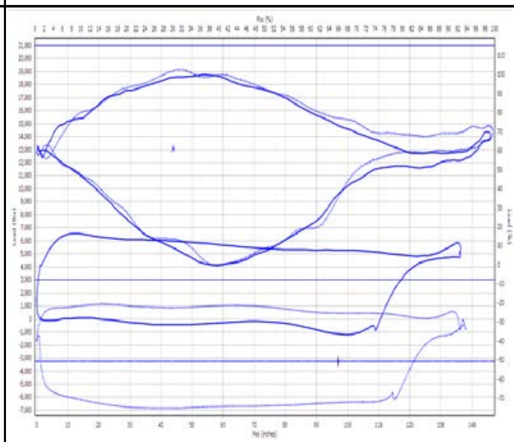
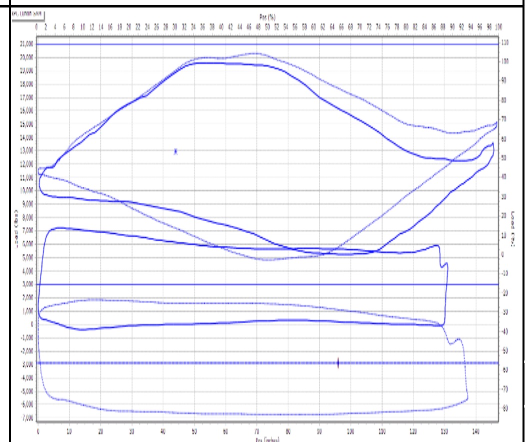
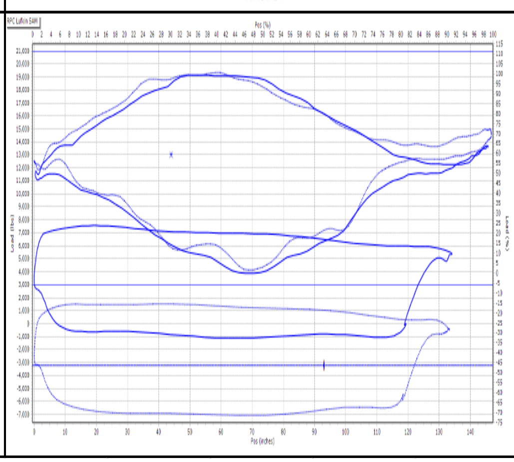
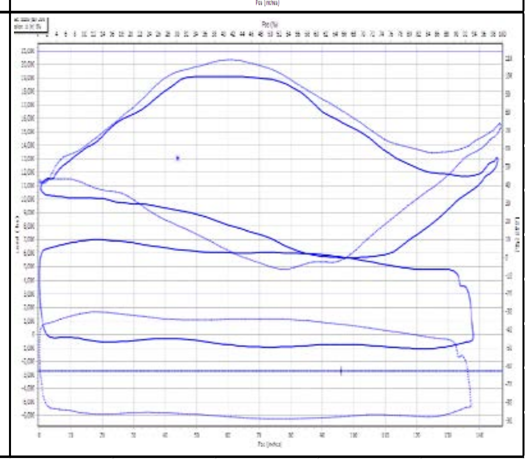
PUMP CARDS			
2/13/17 2:18 A.M.		1/3/17 3:18 A.M.	
11/1/2016 3:17 A.M		7/25/2016 6:36 P.M.	
5/19/2016 1:41 A.M.		3/13/2016 12:06 A.M.	

Figure 7 - Pump cards

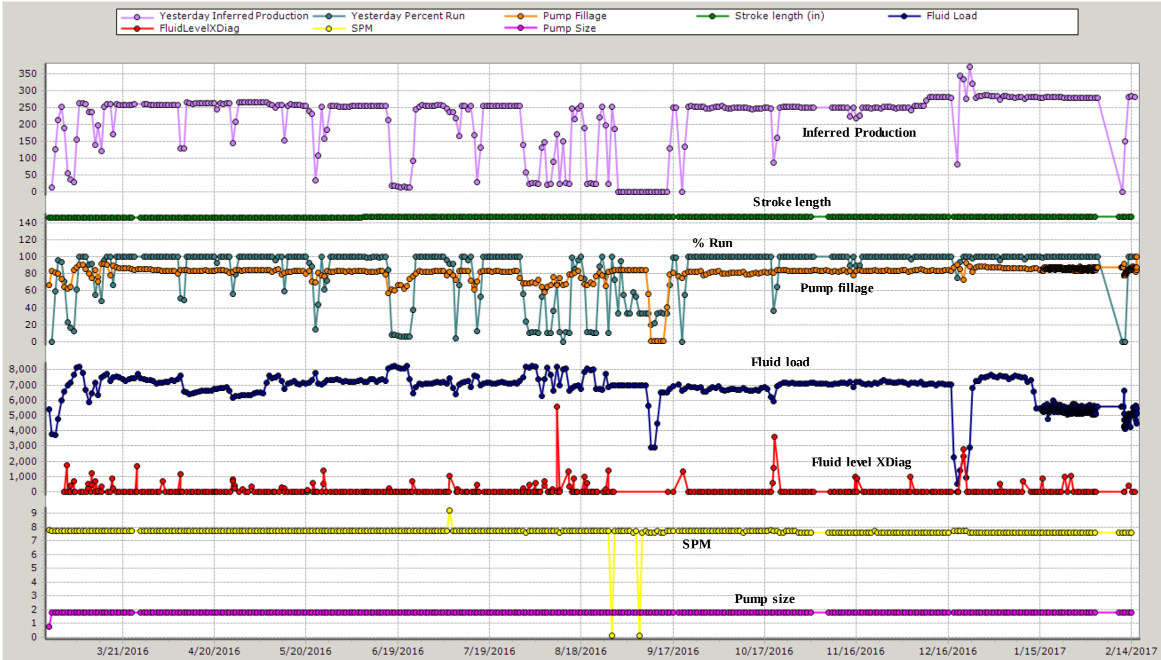


Figure 8 - Pump parameters