FIBERGLASS RODS IN THE EAGLE FORD

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ABSTRACT

This paper will highlight the overall effectiveness of fiberglass (FG) rods used in a portion of the Eagle Ford oil shale play. Data captured from real time SCADA software as well as from the POC, will be utilized to construct a clear picture of how FG rods perform. The benchmarks used to determine the efficiency of FG rods will be capital cost and LOE, power usage and fluid production.

INTRODUCTION

Engineers are never happy until they have been given an opportunity to turn a few knobs and tweak a few buttons. FG rods have the ability to give the engineer another batch of buttons and knobs to attempt to find a new method of saving money or increasing production. Though the concept of FG rods is not new, it is still going through the normal learning curves as if it were a new product here in the Eagle Ford.

The first well in our portion of the Eagle Ford to be rodded up with fiberglass was done in October of 2011. This paper will highlight some beginner mistakes (main reason for first failures) and give a better understanding of what to expect when running FG rods, as well as show the engineer what to look for to better optimize the entire unit.

There are a total of 21 wells that will be used as the guide for overall FG rod performance. These wells vary in depth, production rates and rod design. The goal was to find the best and worst candidates for FG rod application, try to find where the rods perform the best and where they perform the worst. Overall cost was also evaluated while testing the various set ups. The initial costs for the new install as well as LOE cost for fuel, power and any failures that would require rig work were tabulated for overall cost of the well.

BASIC WELL SET UP

Tubing BHA

Depending on the intent of the production engineer and the make-up of the reservoir, there are various, yet equally effective methods for rod pumping. No two oil plays are the same, and, for that matter, no two wells are the same either. For the purpose of this paper, the focus will be of one type of tubing BHA assembly. Each well observed was run with a packer style gas separator and seating nipple depths varying from 9,100' to 10,000' deep.

Rod & Pump BHA

All of the pumps used were heavy walled, standard cup type seating nipple, bottom hold down insert pumps that varied from (-) 0.004" to (-) 0.008" clearance between the plunger and the barrel. Pump diameters ranged from 1.75" to 1.25". Shear off tools were run with the FG rods just above the pump pull tube, in case sand or other debris managed to stick the pump in the tubing. A left or right hand on/off tool is not suggested, as the FG rods do not handle torsional loads well.

Rod String Configurations

The wells studied all had a rod design including fiberglass and steel rods. There were multiple rod configurations that will be described for each case study as needed. Generally, FG rods used were either 0.98" (1.00" diameter) or 1.225" (1.25" diameter) along with 1.00", 0.875" or 0.75" KD rods. There was also an average length of 280' of 1.50" sinker bars on every well.

Pumping Unit

Due to the lighter weight FG rods, the size of the pumping units and motors needed to lift the well are greatly decreased. All units used had either conventional or reverse mark geometry. Pumping units with FG rods were 456-305-144 or the 320-305-100 along with 30, 40 or 50-horsepower motors. Pumping units for the steel rod comparisons were 640-365-168 or 912-427-168 along with 50, 60 or 75-horsepower motors.

DESIGNING FOR THE NEW INSTALL

SROD was the designing program used to determine rod string design as well as pumping unit and motor recommended sizes. There are a few considerations to make while running the analysis and determining the final set up of the fiberglass well. 1) The program does not take into account difference in length of FG rods (37.5') versus steel rods (25') when determining rod guide placement, 2) check final gross pump stroke length to help determine overall length of the pump barrel 3) side loads over 150 lbs/rod should be reconsidered for a complete steel rod string.

It's important to note the weight difference between steel and FG rods. A 1.00" diameter steel rod is 2.904 lb/ft while a FG rod is 0.8188 lb/ft. The 1.00" FG rod weighs less per pound than even 0.75" diameter steel rods (1.634 lb/ft). It is this drastic weight difference that allows the engineer to spend less on capital for the size pumping unit needed. Depending on the production output, depths and lifting requirements are for a particular well, the use of FG rods could downsize the needed 912-365-168 pumping unit to possibly a 456-305-144 or even a 320-305-100, creating a cost savings on the well.

IDEAL SCENARIO

FG Well #1 was set at 9,600' with no major dog legs or side loads and had a production requirement of 250 bfpd. Normally at this depth with an 8-7-6 rod string, a 640 or 912 pumping unit would be required. With the use of a 40/60 FG to steel rod string and a 1.25" pump, a 320-305-100 pumping unit was utilized. Not only did the smaller pumping unit meet the production needs, but it also allowed for major cost savings. Depending on pricing from manufacturers, one could expect to see a savings of up to 14% (savings seen for this specific well) on the capital cost for the new FG rod install. All of this is subjective of course to the area and well specifics, as stated previously; no two wells are alike.

During the first few weeks the pumping unit was brought online, there were recordings of down hole stroke lengths up to 130", as seen in Figure 1, while the surface stroke capability of the pumping unit was only 100". Pump over travel allowed by the elasticity of the FG rods permitted the longer stroke lengths and thereby the required production rates not typical of a 320-305-100 pumping unit producing from these depths.

FG Well #1 is still producing with the original set up for the past 300 days with no obvious signs of problems. A current down-hole card can be seen from this well in Figure 2. The initial production on the well is the easiest to get with FG rods, and the wellbore conditions at this phase are easy to handle with high pump intake pressures and higher reservoir pressures allowing the pump to thrive. The next phase of pumping begins as the production rates decrease due to natural decline and more gas is able to infiltrate the pump. This starts the "pumped off" phase of rod pumping. Insight for this phase is described in the next well scenario below.

PUMPED OFF SCENARIO

FG Well #2 was an older well that was considerably pumped off. The well started as gas lift from March 2010 and was converted to rod pump with FG rods in September 2011. The FG rods made up half the string and were 1.25" diameter with high temp resin (the glue used to hold the coupling to the rod body).

> **Note:** It was later determined through a temperature gradient analysis, there was no need to run the high temp resin, and the less expensive resin could be used. This particular manufacturer recommended high temp resin for wellbores over 150 degrees Fahrenheit. Since only the upper half of the rod string would be FG, by the time the fluid reached the rods it would be cooler and would therefore not be a problem. There have been no problems with temperature thus far with the normal temp rated FG rods currently in the well.

The FG rods were in service for approximately 318 days before they were removed and a full steel string was put in place. There was no noticeable change in production after going from gas lift to rod pump; however, this could be a factor of the depleted reservoir and the IPR curve for this well.

The main problem found during this operation was the inability to effectively pump without gas locking the pump due to shortened net down-hole stroke to the pump. Due to the naturally low production of the well there was never an efficient inflow of fluid to keep the pump full, because of the low pump fillage the variable speed drive (VSD) was hitting the limit parameters and slowing down to the suggested 3 strokes per minute (SPM). The beauty and curse of the FG rod is the elasticity. At the slower speed, the rod stretch was displacing a majority of the surface stroke. There was no transfer of work from the surface to the pump down-hole, and this led to the shorter down-hole stroke lengths. The upside to this event is that it gives the reservoir time to inflow and allows the pump intake pressure to rise. The downside is that during this phase there is less production and a higher risk at this time for gas locking, fluid pound as well as poor pump spacing. The importance of proper pump spacing was learned during these cyclical phases. If the pump was spaced too high, during a slug phase of lower fluids and more gas, the VSD would slow the SPM's down, which caused the net down-hole stroke length to shorten. This increases the possibility of tagging on the up-stroke and the danger of gas locking the pump; all because the plunger was operating higher in the barrel. If the pump was spaced too low, then there was the risk of tagging on the down-stroke which causes a lot of stress on the pump and rods.

A happy medium was never found for this well, and the FG rods were eventually pulled and replaced with steel. The FG rods were sent in for inspection and were then used on another well. The ultimate decision made for this well was to keep a stiffer rod string design. This allowed for a more direct current to the plunger because of its cyclic nature, and low production volumes made for a poor environment for FG rods.

HEAVY DEVIATION SCENARIO

FG Well #3 was a new install well that had multiple severe degree dog legs high in the wellbore. The first dog leg severity (DLS) was 1.09 degree/100' in the first 50' of the wellbore, which equated to a side load of 160 lbs/rod. The second DLS was only a 0.7 degree/100' but, because it was in the first 1,000' of the wellbore, it created a side load of 100 lbs/rod. The rods were in the well a total of 81 days before they catastrophically failed just 12 joints below the surface at roughly 450'. DLS creates side loading problems of different magnitudes at different depths, a DLS of 1 deg/100' has much greater consequences (higher side loads) in the first 3000' of the well than it does in the lower 3000' of the well.

The learning curve surrounding this case cost more than a usual failure. Once the heavy deviation was noted along with the overall depth of 10,200', it was determined that not only would the rods need to be replaced with steel, but that a larger pumping unit would need to be swapped in to lift the rods. Deviation and depth are vital parameters to consider when choosing the proper FG rod string and pumping unit requirements.

FIELD APPLICATION

Due to the elasticity of the FG rods, the harmonics are a more important issue than with steel rods. Going from 4 SPM to 8 SPM can change the overall pump stroke length by 7' (depending on well characteristics) as seen in Figures 2 & 3. This makes pump space out a very crucial moment when first installing the rods. Follow the suggestions of the rod manufacturer and compare that with any historical data in the field to properly space out the pump.

Rod handling is another major issue when dealing with FG rods. The standard steel rod is 25.0' long; the standard FG rod is 37.5'. A longer spreader bar for the forklift operator will also be needed when transporting the FG rods from the truck to the racks.

> **Note:** When designing a rod string that calls for rod guides, make sure that the design model is using the proper rod length for guide placement. SROD for example, generates a rod guide design in increments of 25.0' and requires further math to convert to the 37.5' FG rods for correct guide placement. If the design shows side loads over 170 lbs/rod, then either steel rods should be considered or refer to the FG rod manufacturer for more advice on how to proceed.

Just like steel rods, the FG rods are extremely sensitive to external stress damage. If the rods need to be carried around the location for whatever reason, then there should be at least three people to do the task, two on the end and one in the middle. The excessive sag when carrying the rods horizontally will cause undue stress and cause the rod to fail prematurely.

When running the 1.25" diameter FG rods, make note that the pulling rigs are generally only capable of hanging 1.00" diameter rods and smaller in the derrick. While thinking about the fingers in the derrick and its capability of handling larger OD rods, also take into account the elevators used to lift the rods. The standard elevators used to run 1.00", 0.875" or 0.75" will not pick up the 1.25" diameter FG rods.

POWER USAGE

Comparing only horse power usage being measured from the surface controller, there is a notable difference with wells running FG rods vs. steel. Figures 4 & 5 are actual horse power output graphs from two neighboring wells with similar production rates. The well in Figure 4 has FG rods and therefore needed only the 1.25" pump along with the smaller 320-305-100 pumping unit. One of the thoughts behind the use of the FG rods was that there would be fewer cyclic loads occurring on the motor due to the elasticity of the rods absorbing some of the load. By comparing the standard deviation across the data points in Figure 4 & 5, it can be seen that the FG rods do provide a more consistent power pull on the motor. Figure 6 & 7 is another set of neighboring wells, both set with 456-305-144 pumping units and still shows a much more consistent power draw from the FG rod well. The FG rods are also picking up a 1.75" pump while the steel rods are lifting a 1.50" pump.

ECONOMICS & PRODUCTION

The overall life economics of the well comes into account when determining what equipment to run. There is a constant balancing act between production volumes, initial costs and operating costs. Trying to design for the first month's production rates on a well that will be pumping for ten years is not practical; nor is setting equipment with the tenth year in mind and missing the larger production rates up front. Knowing where to draw the line between new production and long-term costs can only be done after the engineer has put in the due diligence needed to understand that particular field.

Tables 1 – 3 show pumping unit costs for multiple sizes of pumping units as well as total rod string costs for three different types of string configurations. Table 1 has the cost for several types of pumping units as well as complete rod string packages derived from Table 2. Table 2 is a break-down of pricing for rods both steel and FG on a per joint basis for both the rod and the coupling while assuming a pump depth of 9700'. The dollar amounts for everything were obtained through vendors who gave their industry standard pricing with no discounts. Obviously some vendors offer more or less for products, and the prices in this paper should not be manipulated or taken out of context. They are intended for the use of this paper in cost comparisons between FG rod string and complete steel strings.

> **Note:** The guidelines used when establishing the cost estimates in Table 1 – 3, were for a well making 150 bfpd, pumping from a depth of 9,700' with a pump intake pressure of 100 psi. The only items accounted for in the cost estimates were for the pumping unit and the rods, nothing more. These shouldn't be taken as real world prices to install a new pumping unit.

Table 4 & 5 shows SROD scenarios that high-light CASE-S1and CASE-FG4 from Table 3. In these scenarios pump depth, pump intake pressure and needed production rates were kept constant across the steel rods and FG rods. The only items changed were the pumping units, make-up of the rod string and pump diameters. The purpose for this comparison was to show a real example of an Eagle Ford well and when FG rods can be beneficial to the engineer.

Maximum production needed in Table 4, was 200 bfpd, CASE-S1 used a 912-427-168 pumping unit that was more than capable of handling the loads but was at a higher initial install cost of $203,333 (price includes only pumping unit and rods). The same needed production rate at the same pump depth of 9700' can also be produced with FG rods and a 320-305-100 pumping unit as seen with CASE-FG4, with a much lower initial install cost of $95,797 (price includes only pumping unit and rods). The production rates used in Table 4 are representative of a well for only a short period of time when looking at the entire life of the well. Table 5 shows a longer term example with production rates of 80 bfpd. CASE-S1 is now more than what the well needs to be efficiently pumped whereas CASE-FG4 is still well within the efficient operating limits. The criteria in these scenarios used to determine efficiencies were size of pumping unit compared to calculated horse power needed.

CASE S1 was the most expensive set up combining steel rods (8-7-6 design) with a large 912-427-168 pumping unit. This is an accepted application used in the Eagle Ford; deep wells producing lots of fluids require more horse-power up front to move the fluids. The problem is, as the well pumps down and is no longer making hundreds of barrels of fluid but only 30 – 80 bfpd, there is no longer a need for the large pumping unit. The first step to optimize the well and bring overall operating costs down is to either shorten the surface stroke length or downsize the down-hole pump. The next step would be to remove the 912, send it to another well and place a smaller more cost efficient pumping unit in its place. Of course, with the downsized pumping unit, the rod string will have to be reevaluated to ensure the new pumping unit will be able to lift the load. The majority of the time, this only pays out when downsizing pumping units from a 912 to a 320.

CASE FG1-4 makes it is possible to use a 320-305-100 pumping unit accompanied with FG rods and move 220 – 250 bfpd. This will capture the necessary up front production but will also allow for easier optimization later in the life of the well. Instead of needing to remove the pumping unit and reconstructing the pad for a new unit; we simply reconfigure the rod string and/or pump when needed. Currently in the Eagle Ford, when a well gets to the gassy, “pumped off” realm, it becomes difficult pumping with FG rods. As the VSD continuously alters the speed of the pumping unit based on the pump fillage percentage, it causes the down-hole stroke length to vary greatly from 100% of the surface stroke to only 30%. This drastic change in down-hole stroke length wreaks havoc for the technician in the field. Once the well reaches the pumped off state, as part of the total well optimization process, the FG rods are removed and replaced with a steel 7-6 rod string. This string was not capable of handling the larger fluid loads at the beginning, but is more than capable of handling the smaller production rates later in the well life. The changing out of a rod string is much more cost effective than changing out an entire pumping unit. Assuming the FG rods are still in good condition, they can be utilized on another well; giving a savings to the new well along with sending a credit back to the original well the rods were pulled from.

Unless future observations along with trial & error shed light on more efficient ways of pumping the “pumped off” well with FG rods, this long-term optimization option (replacing the FG with steel 7-6) will be less expensive than changing out the entire pumping unit.

CONCLUSIONS

As stated previously, no two wells are the same, and for this reason the engineer should always allow the well to tell its story before installing any form of artificial lift. In some scenarios the FG rods will save costs over the life of the well and other times the rods are just not practical to run. Further testing is still needed to better understand how to utilize the FG rods in a “pumped off” well scenario; this understanding will result in the largest well savings because there will no longer be the need to replace the FG rods with steel as done in the past. FG rods will continue to be run and tested in the Eagle Ford but will be done so on a well by well basis, taking caution not to get carried away with the great upfront cost savings.

Table 1 – Costs for pumping units and 9700' of various rod strings

PUMPING UNIT	COST
912-427-168 RM	$ 154,000.00
640-365-168 RM	$ 137,000.00
456-305-144 RM	$ 116,700.00
320-305-100 C	$ 60,000.00

RODS (AVG 9700' STRING)	COST
STEEL RODS (1.00"SR - 7/8"SR - 3/4"SR)	$ 49,333.23
FG/SR (1-1/4"FG - 7/8"SR - 3/4"SR)	$ 43,624.65
FG/SR (1.00"FG - 7/8"SR - 3/4"SR)	$ 35,797.14

Table 2 – Cost breakdown for rods & couplings of both steel and FG

ROD STRING LENGTH: 9700 FT

FIBERGLASS ROD & COUPLING PRICING:

ITEMS	DIAMETER	PRICE/ROD/COUPLING	TOTAL PRICE	# OF JTS	TOTAL FOOTAGE
ROD & COUPLING	1.25" FG	$ 202.33	$ 26,168.53	129.3333333	4850
ROD & COUPLING	1.00" FG	$ 141.81	$ 18,341.02	129.3333333	4850
ROD & COUPLING	7/8" KD	$ 100.36	$ 9,735.31	97	2425
ROD & COUPLING	3/4" KD	$ 79.60	$ 7,720.81	97	2425

STEEL ROD & COUPLING PRICING (HIGH STRENGTH RODS):

ITEMS	DIAMETER	PRICE/ROD/COUPLING	TOTAL PRICE	# OF JTS	TOTAL FOOTAGE
ROD & COUPLING	1.00"	$ 168.78	$ 16,371.66	97	2425
ROD & COUPLING	7/8"	$ 126.52	$ 18,408.66	145.5	3637.5
ROD & COUPLING	3/4"	$ 100.02	$ 14,552.91	145.5	3637.5

Table 3 – Total cost scenario comparison

COST SCENARIOS	
CASE S1 - STEEL RODS (912 PU)	$ 203,333.23
CASE S2 - STEEL RODS (640 PU)	$ 186,333.23
CASE S3 - STEEL RODS (456 PU)	$ 166,033.23
CASE FG1 (1.25") - 456 PU	$ 160,324.65
CASE FG2 (1.25") - 320 PU	$ 103,624.65
CASE FG3 (1.00") - 456 PU	$ 152,497.14
CASE FG4 (1.00") - 320 PU	$ 95,797.14

Table 4 – SROD comparison at 200 bfpd

SROD ANALYSIS (200 BFPD)	CASE S1	CASE FG4
Motor	Nema D Motor30 hp (Recommended)	Nema D Motor30 hp (Recommended)
Power Required (hp)	22.06	25.04
Pumping Unit	**RM 912-427-168 PUMPING UNIT**	**C 320-305-100 PUMPING UNIT**
Average Pumping Speed (SPM)	3.98	10.62
Structure Load (% of Rating)	83	63.6
Existing Gearbox Load (% of Rating)	71.6	61.3
Pump Diameter (in)	2	1.25
Net bpd	**200**	**200**
1) Rod Type	HIGH STRENGTH STEEL	FG ROD
1) Diameter (in)	1	0.98
1) Rod Loading	74	65
2) Rod Type	HIGH STRENGTH STEEL	HIGH STRENGTH STEEL
2) Diameter (in)	0.875	0.875
2) Rod Loading	73	40
3) Rod Type	HIGH STRENGTH STEEL	HIGH STRENGTH STEEL
3) Diameter (in)	0.75	0.75
3) Rod Loading	74	52
4) Rod Type	API K	API K
4) Diameter (in)	1.5	1.5
4) Rod Loading	30	19

Table 5 – SROD comparison at 80 bfpd

SROD ANALYSIS (80 BFPD)	CASE S1	CASE FG4
Motor	Nema D Motor15 hp (Recommended)	Nema D Motor15 hp (Recommended)
Power Required (hp)	11.74	13.06
Pumping Unit	**RM 912-427-168 PUMPING UNIT**	**C 320-305-100 PUMPING UNIT**
Average Pumping Speed (SPM)	2.05	6.74
Structure Load (% of Rating)	80.9	62.2
Existing Gearbox Load (% of Rating)	73.1	44.8
Pump Diameter (in)	2	1.25
Net bpd	**80**	**80**
1) Rod Type	HIGH STRENGTH STEEL	FG ROD
1) Diameter (in)	1	0.98
1) Rod Loading	65	59
2) Rod Type	HIGH STRENGTH STEEL	HIGH STRENGTH STEEL
2) Diameter (in)	0.875	0.875
2) Rod Loading	65	36
3) Rod Type	HIGH STRENGTH STEEL	HIGH STRENGTH STEEL
3) Diameter (in)	0.75	0.75
3) Rod Loading	66	42
4) Rod Type	API K	API K
4) Diameter (in)	1.5	1.5
4) Rod Loading	30	16

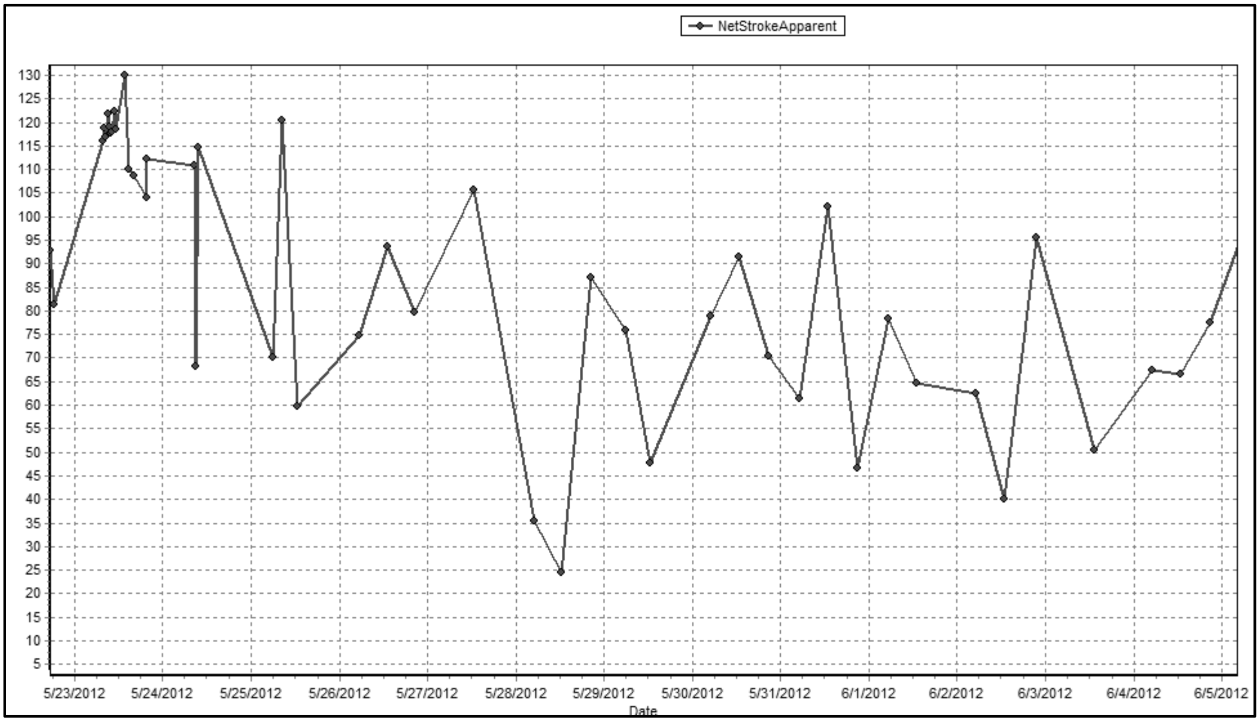

Figure 1 – Fiberglass rods at initial start-up – 130” down-hole stroke length on 100” surface stroke unit

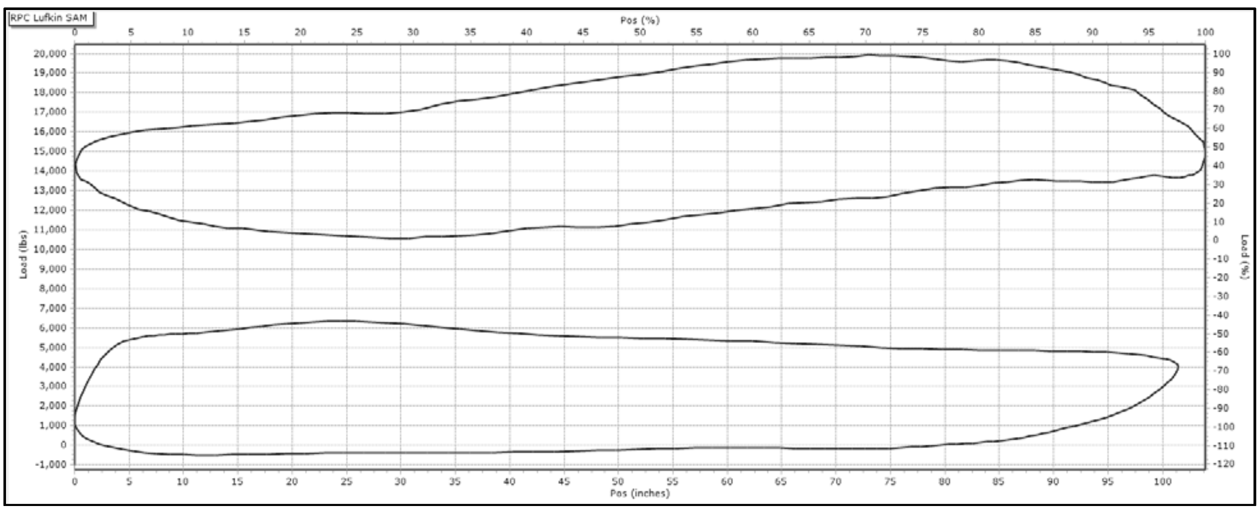

Figure 2 – Fiberglass rods running at 8.5 SPM (Net pump stroke of 105”)

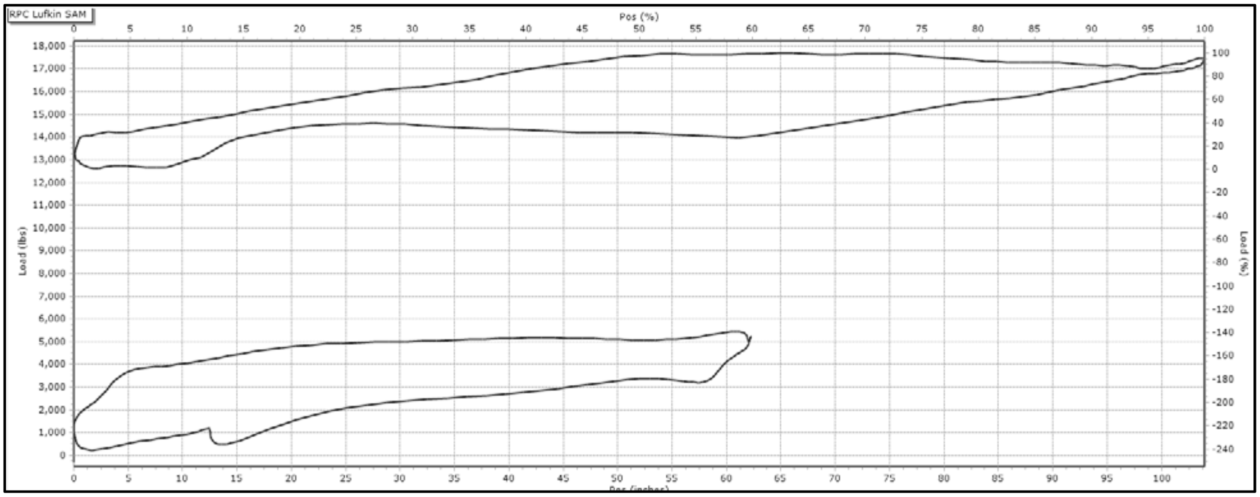

Figure 3 – Fiberglass rods running at 5.5 SPM (Net pump stroke of 60”)

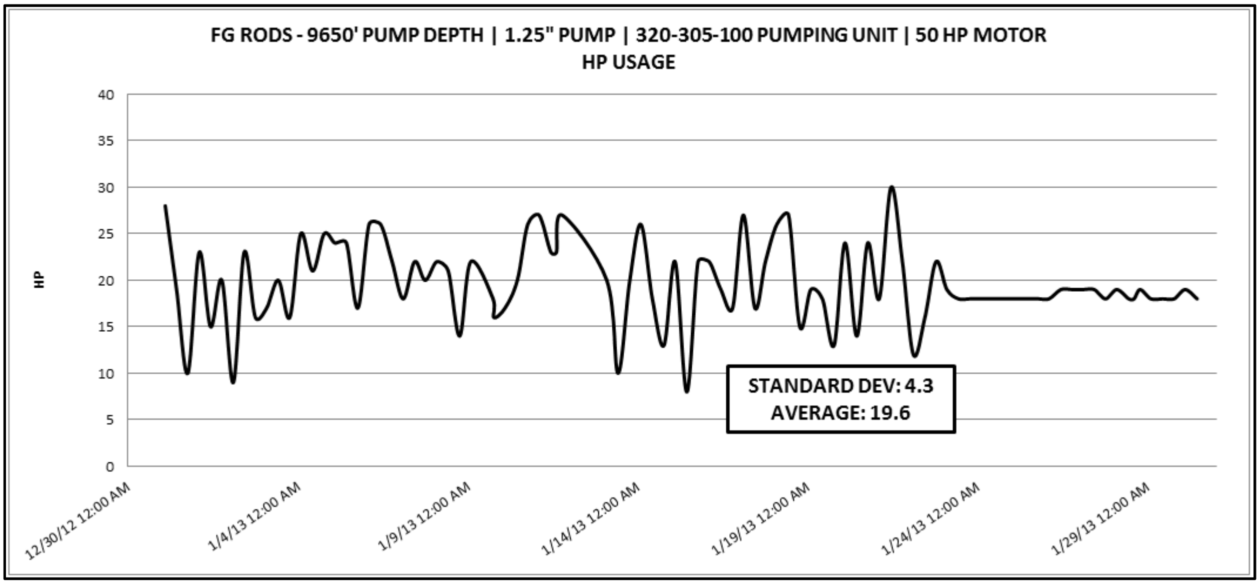

Figure 4 – FG rods and horse power usage

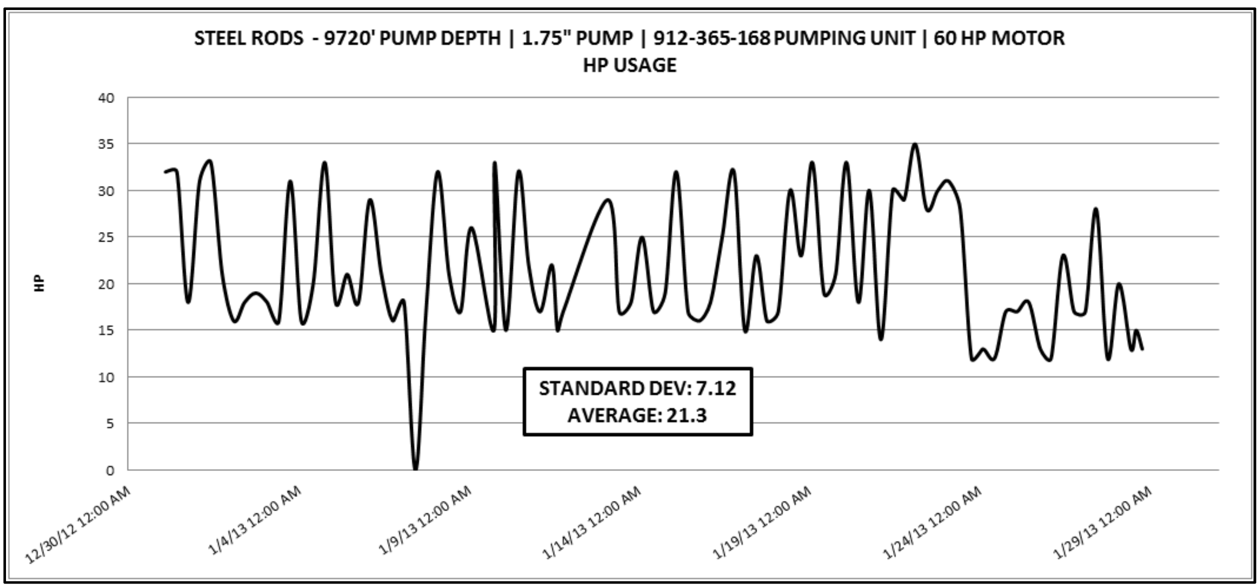

Figure 5 – Steel rods and horse power usage

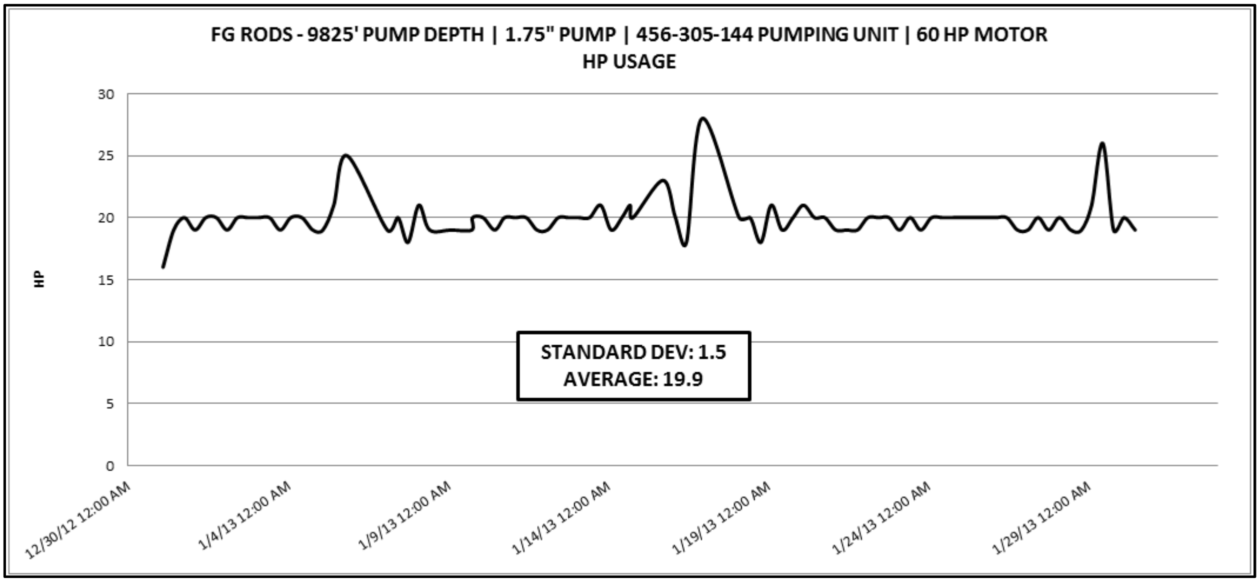

Figure 6 – FG rods and horse power usage

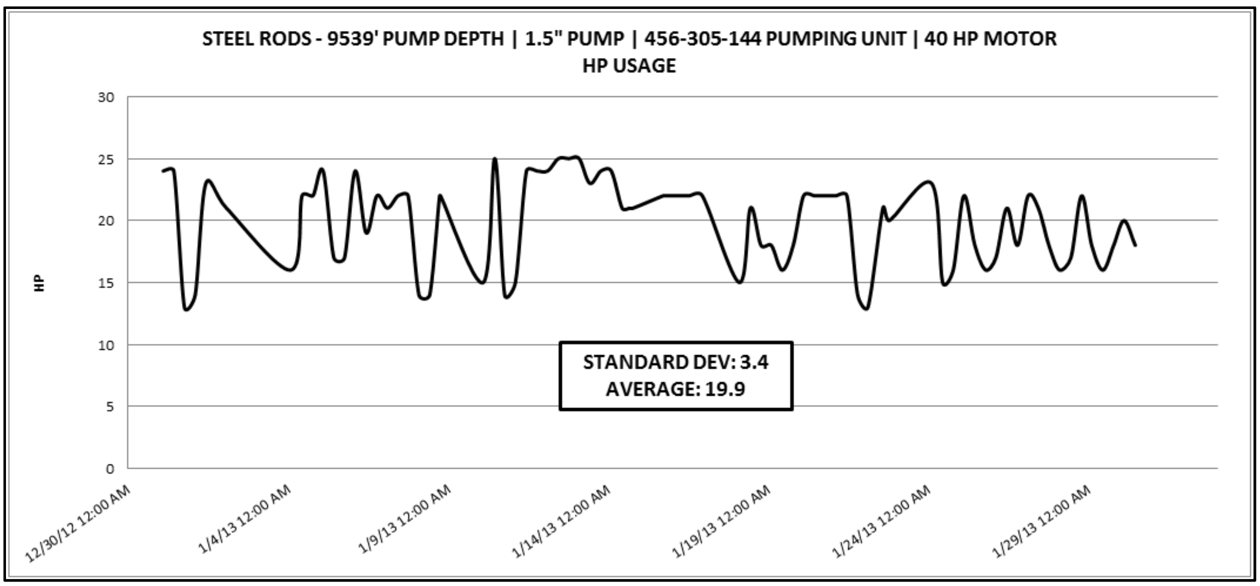

Figure 7 – Steel rods and horse power usage