HIGH-RATE ROD LIFT CONVERSIONS WITH LONG-STROKE UNITS AND CONTINUOUS ROD

Brian Wagner and LJ Guillotte
Lightning Production Services

ABSTRACT

Operators have been challenged in designing rod pumping solutions for the life of the well, specifically in high-rate producers converting earlier from electric submersible pumps (ESP) to rod pumping in deviated wells. This paper examines the conversion of these wells, focusing on the use of long-stroke units and continuous rods. Continuous rods, with their reduced weight and improved flow characteristics, offer significant advantages in enhancing production efficiency and extending the operational lifespan of rod pump systems. This case study evaluates various well design scenarios in the Delaware Basin, demonstrating that early conversion to rod pumps can achieve targeted production volumes and reduce future artificial lift conversion costs. The findings underscore the potential of continuous rods to improve lifting capacity and operational efficiency in diverse well conditions when converting between these two artificial lift types.

INTRODUCTION

The conversion of liquid-producing wells to rod pump systems is a significant process in the lifecycle of a well. This paper discusses the benefits and considerations of using rod pumps, particularly focusing on high-rate rod lift conversions with long-stroke units and continuous rods. Rod pumps are an efficient method for producing liquids, utilizing positive displacement to maximize drawdown. They offer relatively low workover costs and customizable systems, making them suitable for various well conditions, including gassy wells with limited infrastructure. Installing rod pumps earlier in the well's life can reduce long-term expenses by minimizing future artificial lift conversion costs. By adopting this method sooner, operators may eliminate the need for additional conversions down the line.

Rod Pump Design Considerations

Several factors must be evaluated when considering rod pump conversion, including pump depth, fluid properties, and well deviation. Each factor impacts the ability to use a rod pump system to maximize production without overloading any component. There are several styles of pumping units that can be used, including conventional, enhanced geometry, or long stroke. Depending on the production target, some might be better suited for the application. The varying mechanics of these units will not be explored in this paper, but they were used in the evaluation to determine lift potential ahead of well installation. Similarly, there are three main rod types, conventional sucker rods with pin end connections, fiberglass rods with a similar connection, and continuous rod that is one long string of steel welded together. Each of these options will also be used in the design evaluation to derive the limiting component when maximizing production potential.

The timing of high-rate conversion from one artificial lift method to rod pump depends on fluid properties, well deviation, economic considerations, and available infrastructure. When installing rod pump earlier in the life cycle of the well, the goal is to maximize the lifespan of the system and optimize production volume while minimizing costs and associated failures. The pumping unit and rod type implemented are key components that must be carefully evaluated to achieve a successful return.

Continuous Rod Characteristics

Continuous rods are manufactured from raw steel coils and are custom-processed to offer varying mechanical properties. The two primary base steels are comprised of chromium-molybdenum alloyed steel (41 series) or nickel-chromium-molybdenum alloyed steel (43 series). With the addition of nickel, 43 series steel offers greater protection when corrosive elements are present in the wellbore. Dependent upon the heat treatment process during manufacturing, different tensile strengths are achieved to offer a standard or high strength finished product in either steel grade. Once produced, this rod is commonly coiled onto a six-meter reel where it can be used in reciprocating or progressive cavity pumping. Various rod sizes are available, with the most common ranging between 1-1/8” and 3/4". A pin end can be installed on either end of the rod or various rod sizes can be combined to create a rod taper similar to that of conventional sucker rods. Continuous rod practically eliminates coupled connections in the rod string, which provides several advantages not only when designing for increased production volumes. Reduced string weight, improved flow area, reduced friction, and load distribution are all benefits of continuous rod.

Increased Production with Continuous Rod

One of the main advantages of continuous rods is their reduced string weight, which is commonly ten percent lighter than a conventional rod string of similar sizes. This translates directly to the additional production potential of any given system because more of the gearbox load can be allocated to the fluid load instead of the rod string. Not only does the reduction in couplings improve the overall rod string weight, but it also provides a greater flow annulus that is now more uniform with less interference. The flow path is improved by reducing the pressure drops that occur traditionally every twenty-five feet around a connection. As shown in Figure 1, there is significant improvement when comparing the cross-sectional area of conventional rod couplings to continuous rods of equivalent size.

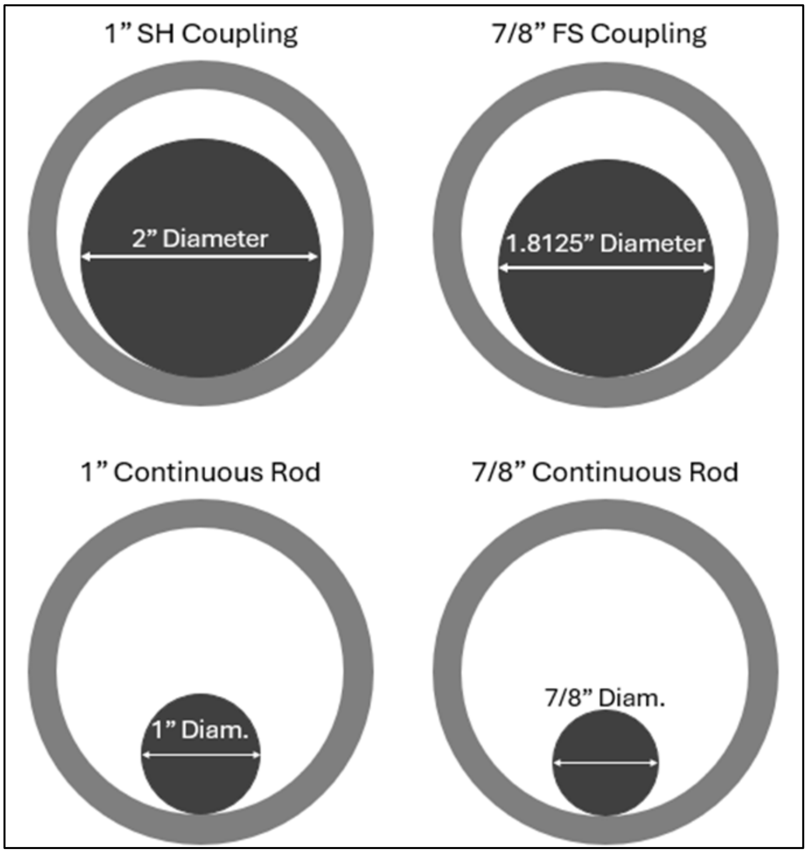

Figure 1. Cross-sectional flow comparison of sucker rod couplings to continuous rod inside 2-7/8" tubing.

Because the clearance is greater, there is even the ability to run 1-1/8" continuous rod in 2-7/8" tubing when necessary for higher rates and still have better flow characteristics than a 1" coupling. Overall, minimizing the disturbance in flow can also lead to greater production in the system or allow for more efficient operation to reach targeted volumes.

Continuous Rod Side Load Distribution

Wellbores will commonly have varying levels of deviation that ultimately will lead to some amount of wear between the rods and tubing. The reduction in overall string weight in continuous rod can lead to slightly lower side load forces, but this is not the main reason wear rates decline compared to conventional rods. Continuous rod naturally distributes the forces that lead to wear over a larger area because there are no couplings to focus the load. As seen in Figure 2, the side load concentrates on the 4” coupling on either side of the conventional rod every twenty-five feet compared to the distribution over that same length in continuous rod.

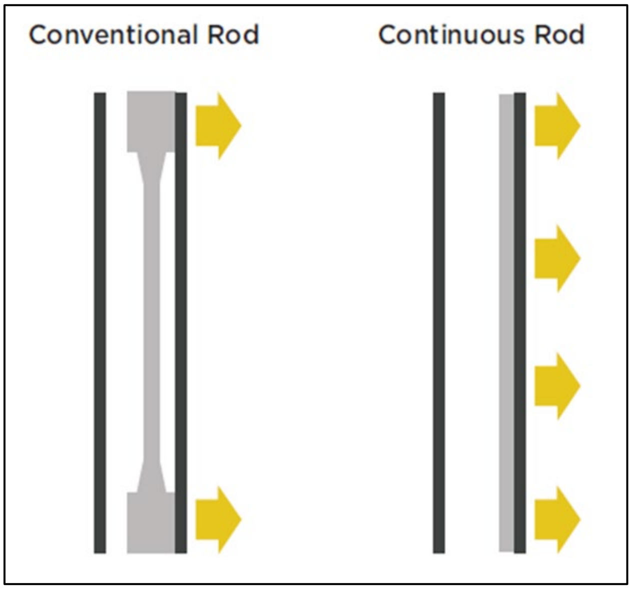

Figure 2. Side load distribution of conventional sucker rod compared to that of continuous rod.

Using the normal force and the equivalent contact areas for this common interval of twenty-five feet, a resulting effective pressure from contact can be calculated. Area of contact is found using Equation 1, shown with inputs for a 1” slim hole sucker rod coupling and 1” continuous rod.

Equation 1. The contact area between couplings and continuous rod is determined by the length of the contact area and contact angle.

$$A_C = L_C \cdot s = L_C \cdot 2\pi r \cdot \left(\frac{\theta}{360}\right)$$

A_C = area of contact
L_C = length of contact area (conventional rod – 0.333’; continuous rod – 25’)
s = arc length
r = radius (conventional rod – 0.083’; continuous rod – 0.042’)
θ = contact angle (conventional rod – 40°; continuous rod – 30°)

The normal force is solved using Equation 2, again shown with inputs for a 1” conventional and continuous rod.

Equation 2. Normal force of conventional and continuous rod over a 25’ interval with standardized inclination and fluid properties.

$$F_N = L_r \cdot W_r (1 - 0.127 \cdot \gamma_F) \sin \alpha$$

F_N = normal force
L_r = length rod string (25’)
W_r = weight rod string (conventional rod – 72.80 lbs; continuous rod – 66.75 lbs)
γ_F = fluid specific gravity
α = inclination angle (15°)

Having determined the contact area and normal force, Equation 3 can easily be used to determine the resulting equivalent pressure of the two rod configurations.

Equation 3. Effective pressure (σ) between coupling, rod, and tubing based on normal force and contact area.

$$\sigma = \frac{F_N}{A_C}$$

The results of these calculations can be seen in Table 1, displaying how the normal forces are similar between conventional and continuous rods, but the contact area leads to vastly different pressures between materials.

Table 1. Calculated values using Equations 1-3 for a 1” conventional rod coupling and 1” continuous rod.

Type	L_C **(ft)**	W_r **(lbs)**	**s**	A_C **(ft²)**	F_N **(lbf)**	σ **(Pa)**
Conventional Rod	0.33	72.80	0.05795	0.01912	411	21,505
Continuous Rod	25.00	66.75	0.02199	0.54978	377	685

The discrepancy in pressure found relates to an effective load reduction and reduced wear on the mechanical components of the rod pump system over time under similar operating conditions to that of a conventional rod string. There are ways to reduce wear in conventional rod systems, such as sucker rod guides, but these components can increase friction or introduce additional flow disruption dependent upon design. This equivalent load distribution and friction reduction, when combined with improved flow potential, makes continuous rod a viable solution for improved lifting capacity.

Significance of Deviation Survey Interval

Understanding the potential side load on a rod string and tubing is heavily dependent upon the resolution of deviation surveys. This component is crucial for designing effective rod lift systems and predicting potential failures. As shown in Figure 3, the dogleg severity based on the deviation survey can be considerably different between something measured while drilling (MWD) compared to that of a gyro survey ran at varying increments.

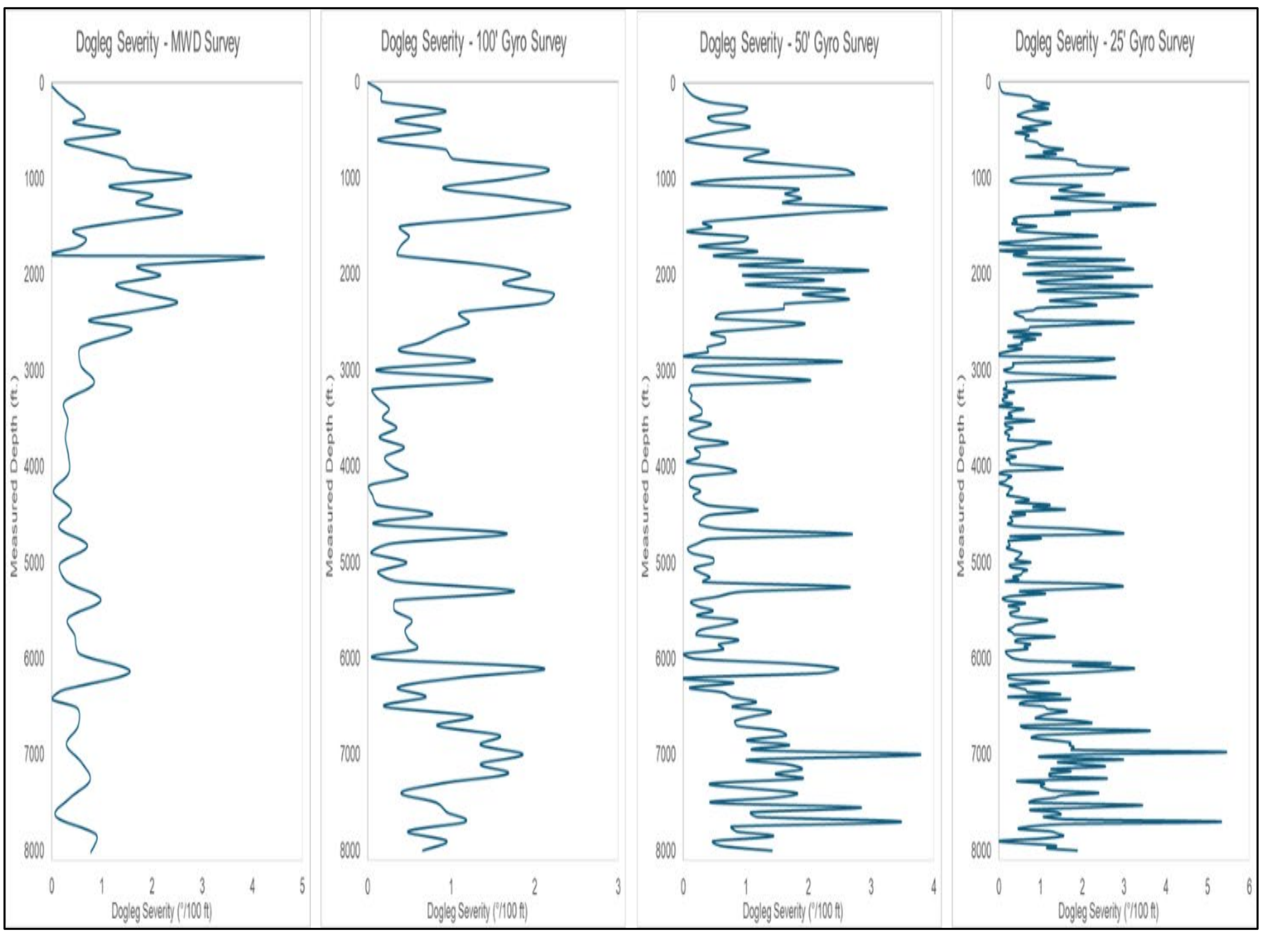

Figure 3. Comparison of MWD dogleg severity for the same well using varying gyro survey intervals.

In this case, there are several areas of concern identified with the gyro survey that are not seen in the original MWD deviation profile. When considering converting to a rod lift system sooner, it’s essential to account for the introduction of mechanical wear earlier in the well's life. Higher loads and quicker well operations can impact the longevity of the installed system, which is influenced by the well's deviation. As drilling techniques improve, wells are often drilled more quickly, which can result in considerable deviations that have to be taken into account. Understanding these factors is crucial for production planning, and investing in accurate data at the start can yield significant benefits over the well's lifespan.

EVALUATION

This study targeted wells in an attempt to convert from ESP to rod pump in the Delaware Basin. Ahead of installation, several well design scenarios were evaluated using industry available rod software to predict maximum production without overloading any component in the system. For each well, standard inputs were followed with a conservative approach to model a low-end production value. This meant using 200 psi for the pump intake pressure and 100% water for the produced fluid. Additionally, the tubing size was restricted to 2-7/8”. Four cases were run per well, implementing the various pumping units and rod types available for the field. Table 2 displays the resulting pumping unit and rod type combination for each scenario analyzed.

Table 2. Breakdown of pumping unit and rod type used for each scenario evaluated per well.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Pumping Unit	Conventional Unit	Enhanced Geometry	Enhanced Geometry	Long Stroke Unit
Rod Type	Steel Sucker Rods	Steel Sucker Rods	Fiberglass Rods	Continuous Rod

Each configuration was designed to maximize production, with conservative values used to represent worst-case scenarios. This method was followed to better understand the limits of each of these approaches. Table 3 depicts an example case of one of the wells evaluated as a reference for the varying levels of production obtained and which component of the system is the limiting factor.

Table 3. Production comparison based on various pumping units and rod configurations for a single well.

Production Comparison	Conventional Unit Steel Sucker Rods	Enhanced Unit Steel Sucker Rods	Enhanced Unit Fiberglass Rods	Long Stroke Unit Continuous Rod
Production (BPD)	295	340	400	670
Pumping Unit	C912-365-192	M912-365-168	M912-365-168	XL320-500-366
SPM	8	6.5	8.5	4
Pump Bore Size	2.00"	2.00"	1.75"	2.25"
Rod Loading	100%	81%	79%	95%
Gearbox Loading	97%	99%	97%	84%
Structure Loading	89%	98%	76%	82%

It became clear that Scenario 4 would be necessary to meet the desired production. From there, the design was dialed into the actual characteristics for the well, adjusting pump intake and water cut percentage accordingly. At this point, it can be predicted if a well is expected to produce sufficient volumes to justify an earlier transition from ESP to rod pump.

RESULTS

Following this approach, seven wells were identified as candidates for conversion, with pump depths ranging between 7,500-10,600 feet. Targeted production volumes spanned 550 to 770 barrels per day, with lower production volume targets associated with deeper well depths. Tubing pumps were used to obtain the desired rates. In certain wells, the deviation presented significant challenges, with some wells experiencing up to 600 pounds of side load. For this reason, two of the wells also incorporated thermoplastic lined tubing in areas of higher deviation to further prevent wear on tubing. Aside from these select sections, all wells were installed with 2-7/8” bare tubing. Most strings followed a traditional taper design with 1” rod on top, followed by a section of 7/8”, and a transition back to 1” continuous rod on bottom for weight. However, there was three wells that required 1-1/8” rod at the top of the string before following the same setup as the others. Taper lengths were specific to the needs of each well and optimized using the predictive rod software. High strength rod was necessary in each well, with both 41 and 43 series steel used based on the fluid characteristics of each individual well. Table 4 provides the production details for each well in the study along with relevant design and loading values calculated.

Table 4. Production comparison of all seven wells installed, along with relevant design data.

Production Comparison	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7
Production Target (BPD)	550	550	550	550	650	760	770
Pumping Unit	320-500-366	320-500-366	320-500-366	320-500-366	320-500-366	320-500-366	320-500-366
Rod Design	HS 9878	HS 9878	HS 9878	HS 878	HS 878	HS 878	HS 878
Pump Depth	10,500'	10,600'	10,100'	10,300'	7950'	7500'	7900'
Pump Bore Size	2.25"	2.25"	2.25"	2.25"	2.25"	2.75"	2.75"
SPM	3.6	3.6	3.6	3.6	3.5	3.4	3.6
Max. Rod Loading	97%	82%	84%	97%	93%	98%	100%
Gearbox Loading	80%	77%	79%	73%	75%	92%	86%
Structure Loading	96%	95%	94%	86%	78%	85%	86%

Based on these evaluations, all wells successfully met their production target, validating that actual volumes matched the design software modeling. Thus proving that high rates could be achieved with this system and allowing for conversion to rod pump earlier in the life cycle of the well. An example of the input data and calculated results in the software model can be seen in Figure 4, representing the highest targeted production rate of the seven wells installed.

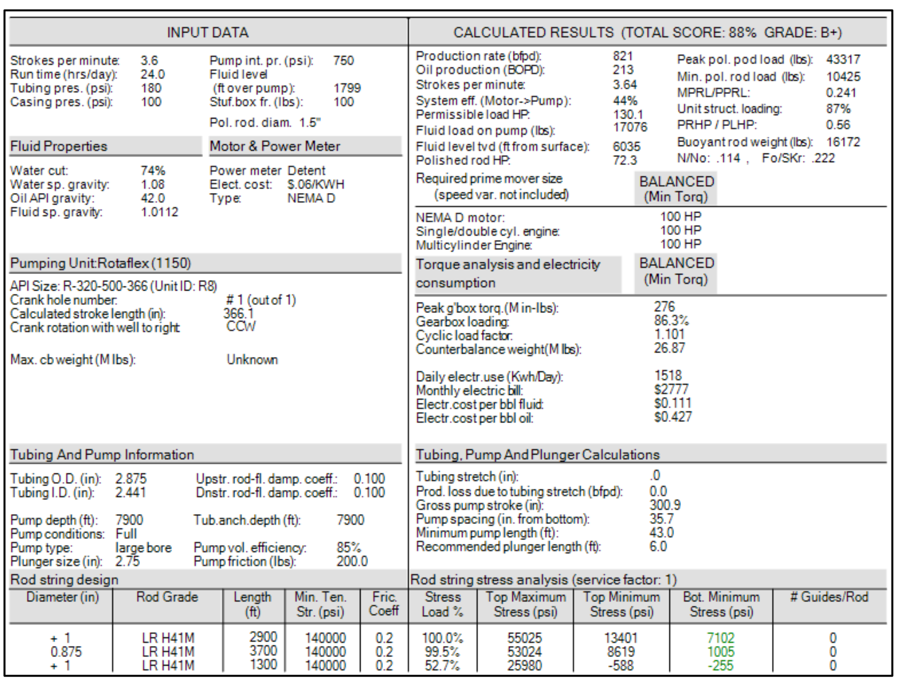

Figure 4. Example well design taken from Well 7, displaying inputs and calculations.

This design resulted in a predicted production volume well above the target rate, indicating that similar wells could likely be converted at higher rates or sooner in the life cycle of the well. Unfortunately, the ownership of these wells has changed since they were installed, resulting in difficulty capturing run-time performance data. However, one of these wells did fail in late 2024 after running for over 1,000 days. This data point, while isolated, implies that significant run times are achievable post-conversion.

CONCLUSIONS

The conversion of liquid-producing wells to high-rate rod lift systems using long-stroke units and continuous rods has demonstrated significant benefits in optimizing production and reducing operational costs. By leveraging the advantages of continuous rods, such as reduced string weight, improved flow characteristics, and better load distribution, operators can achieve higher production rates and extend the lifespan of their rod pump systems. The study's successful implementation in the Delaware Basin, with wells meeting or exceeding production targets, validates the effectiveness of this approach. Despite the challenges posed by well deviation and the need for precise design considerations, the results indicate that early conversion to rod pumps can be a viable strategy for enhancing well performance and minimizing future artificial lift conversion costs. Continued monitoring and data collection will be essential to refine these methods further and ensure long-term success in various well conditions.

ACKNOWLEDGEMENTS

Thank you to SWPSC for allowing us to contribute to this year’s publication and presentation offering. This would not have been possible without the input from key individuals at LPS and the operators we have worked with over the years. We always strive to make a positive impact on our industry and greatly appreciate your support in our efforts.