



High Rate Rod Lift Conversions with Long Stroke Units and Continuous Rod

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Converting to Rod Pump

- Nearly all liquid producing wells will convert to rod pump later in life
- Rod pump is the most efficient method for producing liquids at low rates
- Positive displacement gives rod pumped wells strong drawdown to maximize production
- Easily customizable systems with relatively low workover costs
- Even gassy wells often are produced most efficiently with rod pump, especially if gas lift infrastructure is not in place
- Converting earlier gives the additional efficiency from rod pump, and saves another costly workover on ESP equipment

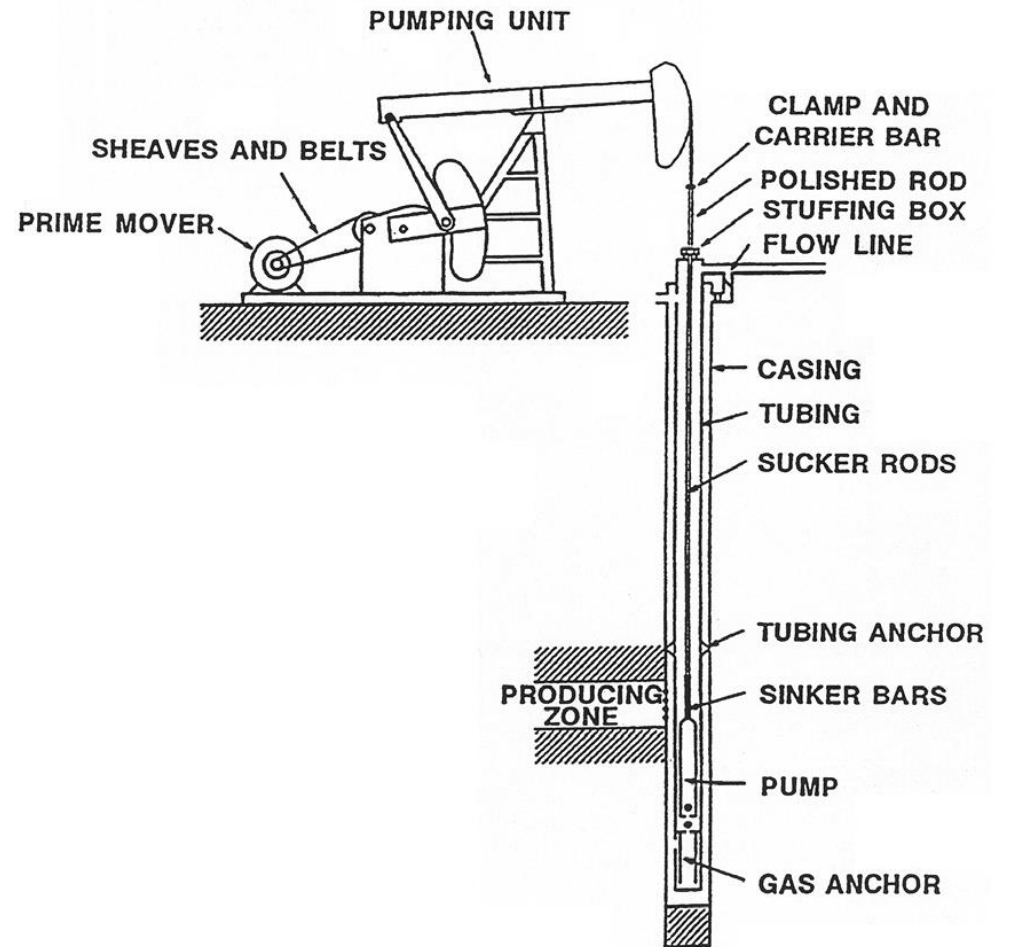


Figure courtesy of Lufkin Automation

When is Conversion Possible?

- Maximum production rate is highly dependent on pump depth, fluid properties, and deviation
 - 7,000 ft pump depth, 100% water, moderate deviation for example cases
 - Assume 2-7/8" tubing
 - Maximize production through typical design methods without overloading any component
- Design options
 - Conventional Pumping Units with Stick Rod
 - Enhanced Geometry Units with Stick Rod
 - Any Unit Geometry with Fiberglass and/or Continuous Rod
 - Long Stroke Pumping Units with Continuous Rod

Long Stroke Pumping Units



Image courtesy of Liberty Lift

- Stroke lengths up to 366” allow for a higher rate of production
- Production is easily adjusted as well declines by changing speed or pump size
- Slower strokes potentially reduce the wear seen in the system, including rod and tubing wear
- Automation allows the unit to slow in corners, reducing the risk for buckling
- Longer stroke increases the compression ratio in the pump, potentially improving gas breakout issues

What is Continuous Rod?

- Only two connections: the top and bottom of the rod string
- Rod is coiled on a reel for transportation and installed into the well using a specialized injector
- Like stick rod, different grades exist to match the well profile
- Tapers are welded together to give rod string a smooth profile



Continuous Rod vs Stick Rod

Continuous Rod

- Eliminates all the couplings along the entire wellbore, distributing side load over entire string
- Eliminate care & handling failures and improper makeup
- 8-12 % lighter than conventional rod string
- Fast, simple installation
- No reduced flow area around couplings and rod guides
 - Reduce breakout of corrosive elements due to turbulent flow around couplings and rod guides
 - Potentially increase production with less flow restriction in the tubing

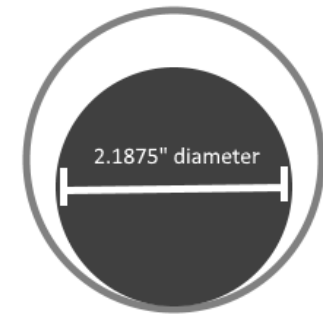
Stick Rod

- More service units available
- Wide knowledge base due to many years of service in every field

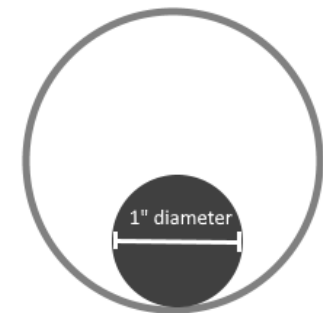
Increased Production with Continuous Rod

- Continuous rod string is slightly lighter than conventional rod string due to lack of couplings and rod guides
- Rod guides have a friction coefficient higher than steel on steel. Along with the increased weight, stick rod often has loads 8-12% higher than continuous rod
- Gearboxes are typically the limiting factor in production rates, so lower rod loads directly correlate to higher production
- 1-1/8" continuous rod can be used in 2-7/8" tubing whereas conventional rod would be limited to 1"

Conventional 1" Coupling

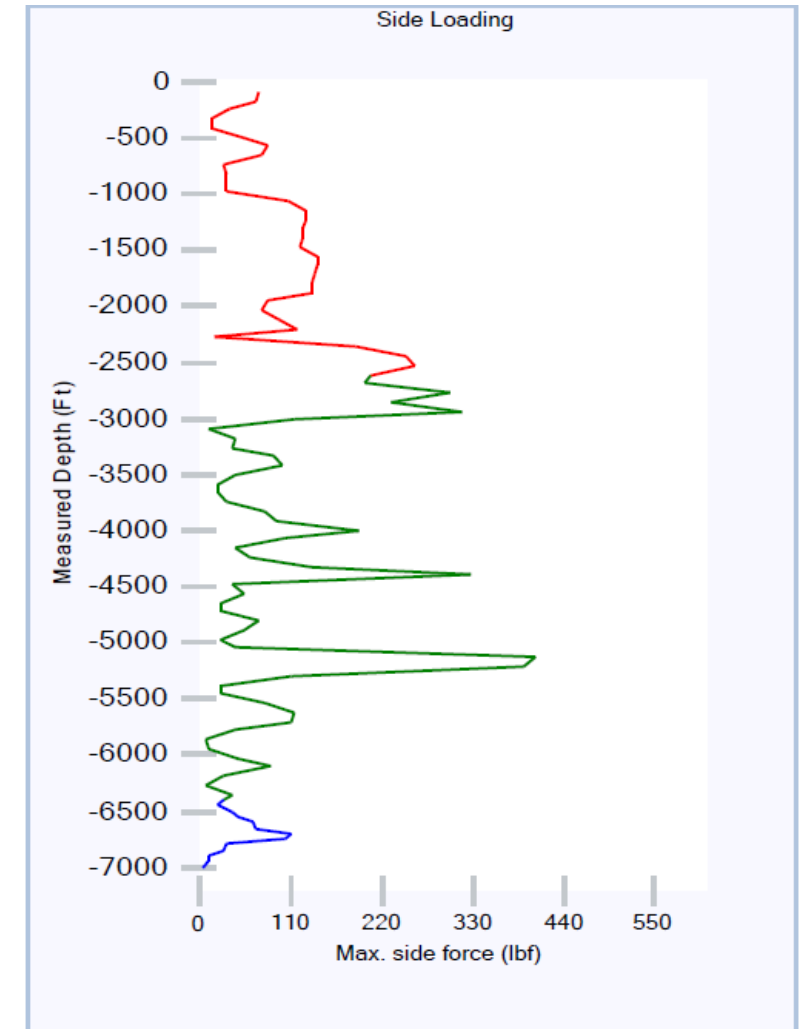


1" Continuous Rod



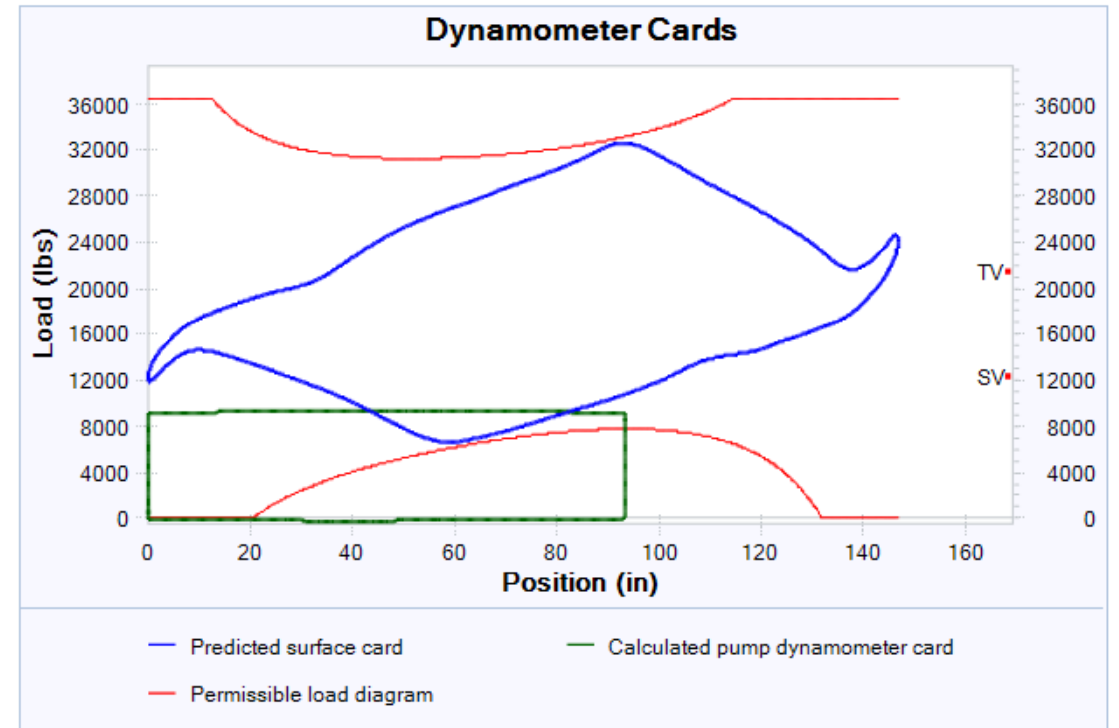
Hypothetical Designs Using RODSTAR

- Deviation survey from actual well in long stroke project
- Each of the four configurations were designed to maximize production without overloading any component
- Conservative values were used, so actual designs could likely produce more fluid
 - 2-7/8" tubing
 - 200 psi intake pressure
 - 100% water cut



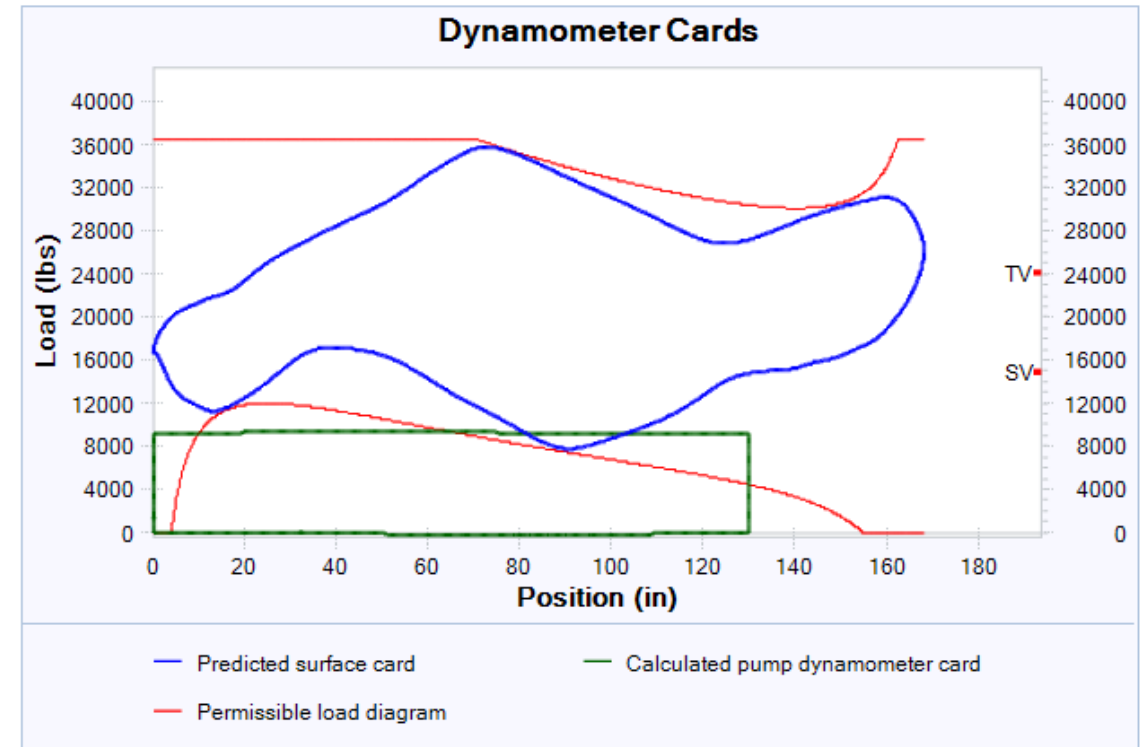
Conventional Unit with Stick Rod

- Lufkin C912-365-192 Unit
- Maximum Production: 295 bfpd
- Peak Polished Rod Load: 32,613 lbs
- Production could be increased to 389 bfpd by omitting rod guides, but this would lead to premature rod or tubing failure



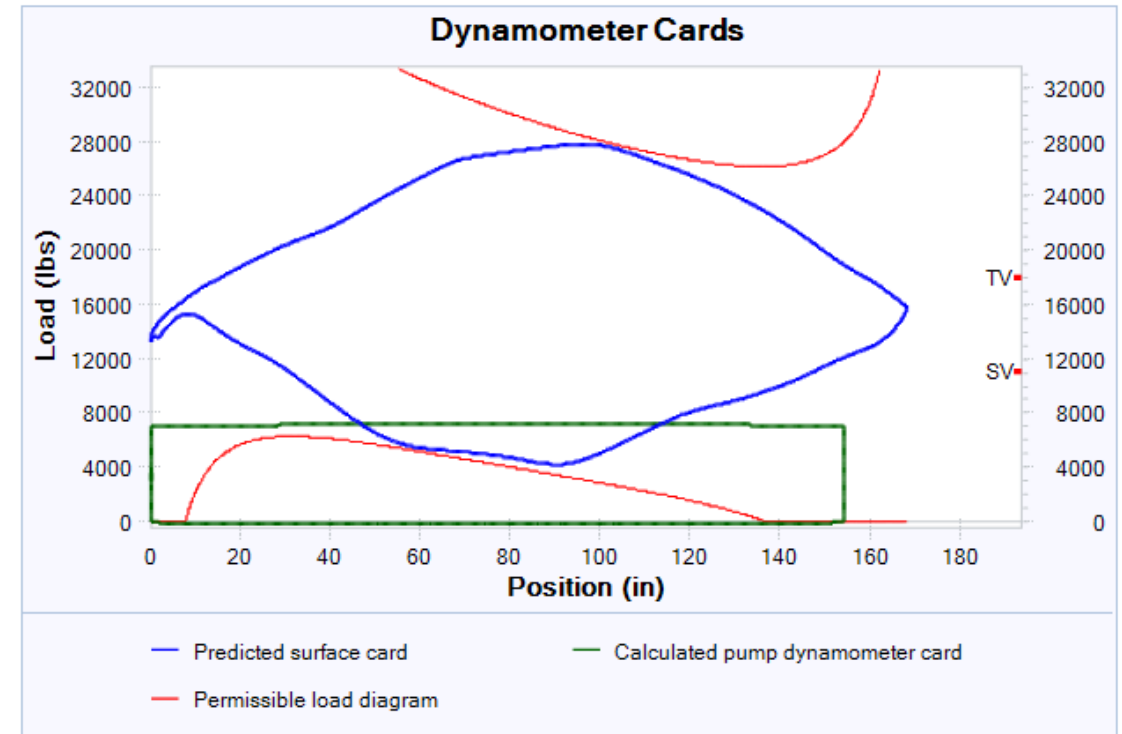
Enhanced Geometry with Stick Rod

- Lufkin M912-365-162
- Maximum Production: 339 bfpd
- Peak Polished Rod Load: 35,819 lbs
- Gearbox geometry allowed for use of 1" rods without overloading the unit



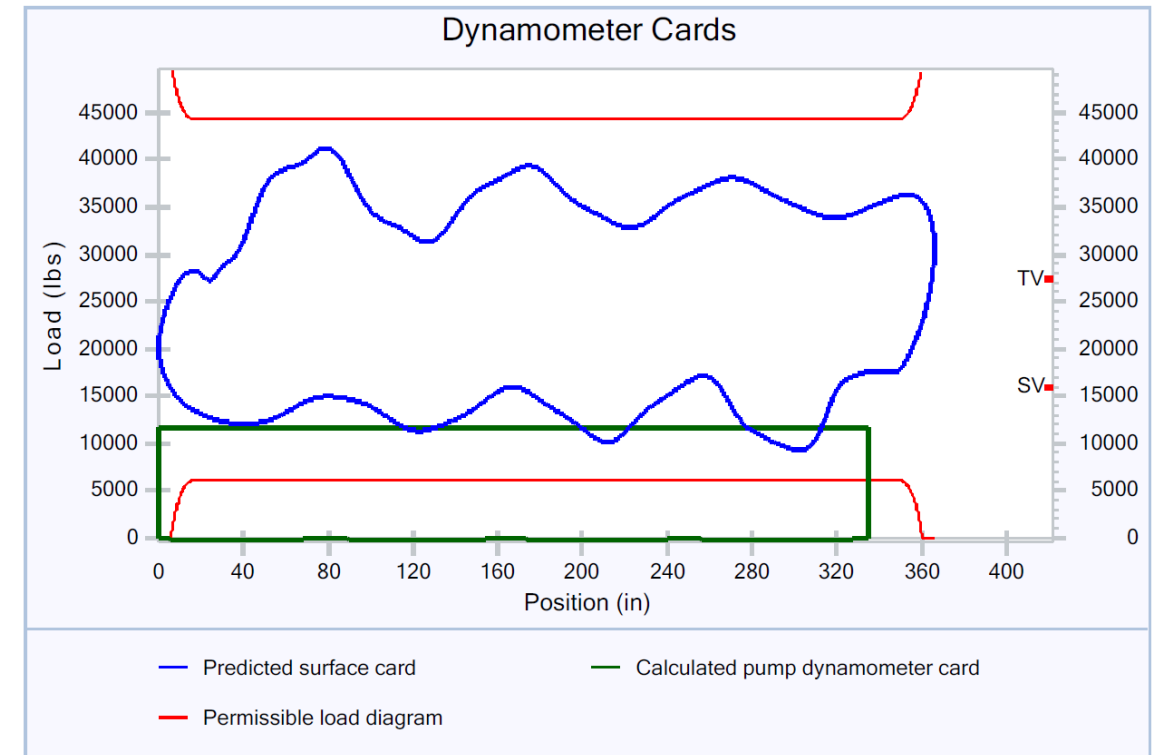
Enhanced Geometry with Fiberglass & Continuous Rod

- Lufkin M912-365-162
- Maximum Production: 393 bfpd
- Peak Polished Rod Load: 27,868 lbs
- Continuous rod below fiberglass allows for elimination of rod guides, and 1" continuous rod can withstand some buckling forces



Long Stroke with Continuous Rod

- Liberty XL320-500-366
- Maximum Production: 671 bfpd
- Peak Polished Rod Load: 41,206 lbs
- 2.25" tubing pump allows for much greater production. The long stroke unit can handle the higher fluid loads
- Rods become limiting factor, but 1-1/8" continuous rod can be used if necessary



Design Comparison

| | Conventional | Enhanced | Fiberglass | Long Stroke w/ Continuous |
|----------------------------|--------------|----------|------------|---------------------------|
| Production, bfpd | 295 | 339 | 393 | 671 |
| Surface Stroke Length, in | 146.8 | 168.0 | 168.0 | 366.0 |
| Downhole Stroke Length, in | 93.2 | 129.8 | 154.1 | 334.5 |
| SPM | 8.0 | 6.6 | 8.4 | 4.0 |
| Pump Bore Size, in | 2.0 | 2.0 | 1.75 | 2.25 |
| Rod Loading, % | 100.0 | 81.3 | 78.9 | 95.4 |
| Gearbox Loading, % | 96.6 | 99.0 | 97.3 | 83.8 |
| Structure Loading, % | 89.0 | 98.0 | 76.0 | 82.0 |

Advantages & Disadvantages

Advantages

- Slower pumping speed saves strokes, slowing wear on pump, rods, and tubing
- Small number of long stroke units can be moved around field as production declines
- Future rod pump workovers often much less costly than ESP workovers

Disadvantages

- Field personnel may be unfamiliar with long stroke units
- Initial unit cost higher than a conversion at lower rates

Current Installs with LPS Continuous Rod

- Beginning in November 2019, LPS began working with two customers in the Permian Basin to implement designs with long stroke units, continuous rod strings, and tubing pumps
- Maximum production of 851 bfpd from 7,500 feet
- In reality, the wells are producing even higher rates than designed for, most likely due to gas production
- Run lives are short, but to date, none of the wells have experienced a failure in the new designs

Additional Considerations

- Higher loads could lead to more frequent failures than typical rod wells, though this has not been proven yet
- Automation is required to produce at the highest rates due to cornering on long stroke units

Future Work

- Establish failure rates over 18-24 months of run times in a large sample of wells
- Determine ROI for high rate rod pump applications vs ESP
 - Failure rates & average cost of failure
 - Install cost vs ESP
 - ROI will likely be dependent on the ability to move long stroke units around field as needed
- Investigate other technologies as possible compliments
 - Thermoplastic liners
 - Downhole Separators

Conclusions

- Long stroke pumping units and continuous rod can be used in tandem to bridge the gap between traditional ESP and Rod Pumping rates
- Installations have already been shown to successfully produce at rates at or above the designed fluid rates
- With less than 6 months run times, there have been no failures, indicating that the system has the potential to save significant cost
- A small number of long stroke units can be used in a field and moved around as needed
- More time is needed to fully understand the application and the potential return on investment for operators

Questions?

