IT'S ALL ABOUT THE END FITTING 3: LESS PRESSURE DROP, EXTRA CORROSION AND EROSION RESILIENCE AND ENHANCED COMPRESSION HANDLING

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ABSTRACT

As fluctuations in oil price continue, the industry has changed and is now demanding improvements from each method of artificial lift. Increasing flow rates associated with longer laterals in new horizontal wells require new considerations in the design and application of artificial lift tools. The rod lift portion of this market is not immune and, as a result, is being tasked to enter the artificial lift cycle earlier on the decline curve. Additionally, wellbore geometries introduce added complexity to these production demands. The fiber reinforced plastic sucker rod (fiberglass, FSR) continues to meet and exceed these ever-increasing design intricacies. The two previous editions of 'IT'S ALL ABOUT THE END FITTING' focused on the design of the new generation of fiberglass rod, the added strength the industry has requested, the benefits regarding the handling of compression, and methods to mitigate uncertainties in wellbore dynamics. This edition will focus on benefits associated with the newest and most technologically advanced generation of the end fitting. It will explain how a new configuration of the wedge profile allows for reduction of pressure drop at each connection and adds to the fitting's corrosion resistance. The new wedge profile also increases the ability of the end fitting to handle compression. Data will be provided in support of increased production. Fiberglass rods have been delivering benefits for over 30 years to the industry and continue to exceed the industry's with growing need for artificial lift innovation. As FSR technology progresses, fiberglass rods are increasingly adopted earlier in the well's life cycle requiring Endurance Lift Solutions to build the technology necessary to RUN LONGER & PRODUCE MORE.

INTRODUCTION

Being the third edition of "It Is All About the End Fitting", the following performance characteristics have been well established [2, 3]: 1)delivering a product with 25 percent improvement in the working load range; 2) a 30 percent increase in the maximum load capacity; and 3) controlling certain potential failure modes. Endurance Lift Solutions, LLC (ELS) is now producing the Series 300 and Series 300 High Flow (HIFL) fiberglass rods as the product offering in the fiberglass rod market. The technical specifications (Diameters, Weights, Operating Parameters, etc.) may be seen in Table 1. These changes resulted from advancements made over the last two years which allow for the same tensile load characteristics in the design while improving corrosion and erosion resistance, plus the ability to flow more produced fluid past the end fitting connection thereby allowing the product to be used in higher volume wells. A secondary effect of improved compression resistance was also realized.

Since the launch of the FSR Series 300, the product has been widely installed throughout North America (Permian Basin, Mid-Continent, Bakken) with positive feedback from our Customer Partners. These Customer Partners are increasing the flow rates of these wells through better design and the higher load handling capacity. The HIFL rods have been recently introduced with documented success. This paper will present pressure drop calculations due to changes in annulus and discuss improved rod fall yielding a higher production as a result of longer stretch in the rod string.

With the introduction of the Series 300 and Series 300 HIFL we continued to optimize the wedge engagement profile which minimizes the impact of potential for compression scenarios [4]. The compression testing has been appended to the data presented in our last paper.

DESIGN AND DEVELOPMENT

The Series 300 and Series 300 HIFL end fittings were modeled in ANSYS to optimize a set of parameters established to provide an iterative change in the end fitting. The focus of the Series 300 and Series 300 HIFL was to increase wall thickness (Series 300 only), minimize epoxy volume, even out the wedge stress distribution, control compression, and reduce pressure drop at each connection (Series 300 HIFL only). To successfully meet all goals, the Series 300 and Series 300 HIFL both utilize a twelve-wedge design to optimize the parameters mentioned. The difference between the Series 300 and Series 300 HIFL is the outside diameter of the end fitting and the coupling pin diameter. The Series 300 product line uses 1" API slim hole couplings as the basis for the OD of the product, while the Series 300 HIFL utilizes a 7/8" full size coupling on a 1.25" rod to reduce the diameter and allow more flow. Technical specifications can be seen in Table 1 at the end of this paper.

PRESSURE DROP

During the operation of a rod lift type well the produced fluid moves between the rods and the inner diameter of the tubing. Competition in the FSR industry has traditionally focused on strength of the individual rod. With the Series 300 and Series 300 HIFL a more systematic approach was taken to also look at expanding the operating window of the rod lift wells. Traditionally rod lift wells using steel sucker rods have been limited by the strength and weight of the rod such that production volumes did not require examining the back pressure associated with each connection. However, as rod pump wells are moving higher in production volumes the back pressure associated with each connection could create a concern. Currently, our Customer Partners are routinely implementing rod lift designs that are producing over 500 to 600 barrels per day. At these production levels the back pressure savings calculated by moving to the Series 300 HIFL from the Series 300 is approximately 10 PSI per connection (See Figure 5 and Figure 6). The flow area increased by 47 percent by moving from a 1" slim hole coupling diameter of 2" to a 7/8" full size coupling diameter of 1.8125". This allows more area for fluid flow and particulates and decreases the pressure drop by 62%. The reduction in diameter also assists wells that routinely face paraffin problems because there is less of an obstruction to pack the paraffin into a plug. While only recently introduced, preliminary results from the Series 300 HIFL reveal that less tubing back pressure is required to produce these wells at, or near, the pumped off condition.

INCREASED CORROSION AND EROSION RESILIENCE

A further advantage of using FSR Series 300 HIFL is a reduction in erosional velocity and improved flow profile (laminar vs. turbulent) of the produced fluid across the end fitting. This is simply due to increased annulus and reduction in fluid flow velocity variations as the fluid passes across each end fitting connection (in particular, the transition area from the wrench flats back to full outside diameter of the end fitting). Using FSR Series 300 HIFL, the change in average velocity of the fluid across the connection is reduced by approximately 31 percent [1]. As a result, the inertial forces of the fluid are reduced and the effect of the fluid particles on the boundary surfaces, such as the internal diameter of the tubing and the outer diameter of the end fitting, have a reduced erosion contribution. Naturally, this phenomenon will be more profound in higher volume wells.

TESTING COMPRESSION

ELS performed compression testing as a part of continuous product improvement and understanding the full potential of FSR Series 200 rods. We continued this testing with the FSR Series 300 rods as well as the HIFL rods. The testing took place in the ELS Big Spring, TX laboratory and focused on simulating well scenarios where the rods were exposed to recoil and compression loading. The test setup consisted of a tensile machine (capable of loading a specimen up to 225,000 pounds), a pneumatic quick release, an anchor point (for recoil loading to act against), and newly produced FSR Series 300 and Series 300 HIFL rods (6' long specimens only). The published recommended stress range diagram for ELS fiberglass rods, as seen in Figure 1, shows the bottom minimum stress lower limit at 1250 psi [2]. However, scenarios exist that could drive the bottom minimum stress below the recommended limit and/or into compression. Any fiberglass rods operating at those stress levels can experience forces within the cavity of the end fitting that could be detrimental to the wedge mechanics and the integrity of the epoxy. In the laboratory, the recoil forces were selected (16,000 pounds, 26,000 pounds, 31,000 pounds, and 51,000 pounds) to mimic recoil loads generated during a shear tool failure.

A graphical representation of the setup can be seen in Figure 2. Five test specimens were preloaded to each of the specified recoil loads. Once the set load was reached the quick release was activated and the rod would recoil into the hard anchor. After completion of these steps the specimen was then tested One-Time-Pull-To-Failure (OTPTF) and both elongation and ultimate load data was recorded. The aggregated OTPTF loads were then plotted with respect to the recoil load and compared. This paper includes Series 300, Series 300 HIFL, as well as the Series 200 and Series 100 rod data presented in the last paper.

A graph of the results, normalized by FSR Series 300 ultimate load, can be seen in Figure 3. As anticipated, the recoiled FSR Series 300 and Series 300 HIFL compared favorably to both the Series 200 and Series 100 designs tested previously. The Series 300 rods pulled more consistently and had less degradation in load handling capacity after a recoil event. For example, the FSR Series 300 did not have any noticeable degradation until the 31,000 pounds and 51,000 pounds recoil events. The results for the Series 300 HIFL were impressive because the results were controlled by the 7/8" pin rather than the glue joint so there was no loss in holding strength due to compression. There is a decrease in the average holding strength on a one time pull load at 77 percent of a Series 300 API end fitting. The decrease in area of the pin does not affect the working load of the rod because it is not encountering the cyclic loading due to the coupling torque [4].

The above testing was not performed to lead one to believe that FSR should be able to handle compression events, but rather to continue the process of understanding how the joint works while loading in a wellbore. Therefore, the testing on the Series 300 HIFL was increased using the same setup as above, but instead of one compression event a series of four compression events was introduced. The results show that controlling the failure mode with the pin break is effective enough to minimize the detrimental effects of compression to an unmeasurable level. All Series 300 HIFL rods measured at approximately 77 percent of the rated load of the Series 300 API rod and all broke in the pin section. This effectively minimizes the sensitivity of the FSR to uncertainties of the manufacturing process with respect to the epoxy.

CONCLUSION

Over the past 5 years, advancements in fiberglass sucker rods have delivered an improved product with increased performance characteristics versus previous generations. As promised in the last paper, the Endurance Lift Solutions team, through continued research of the end fitting, developed the Series 300 and Series 300 HIFL to address future production requirements. In doing so, the Series 300 has longer lasting corrosion and erosion wear surfaces resulting from thinner, more effective wedges. The Series 300 HIFL removed extra wall thickness to provide an end fitting that has less pressure drop per produced barrel of fluid, and in high producing wells will provide a measurable difference in production due to better rod fall characteristics and smaller hydro-dynamic losses. Initial installations have shown favorable results as the wells have been easier to operate while simultaneously achieving the pumped off condition; however, with the decline curve, we need more data before stating how much added production one may attain.

Operating parameters within the wellbore may create a scenario when continuous or one-time recoil or compressive load is applied to the rod taper. Within the ELS laboratory, a test scenario was created to study this type of compression event and how it affects the overall performance of the product. The results of the simulated recoil events confirm that compressive loads can impact the performance of fiberglass rods. However, the reduction in performance can be greatly abated by use of the FSR Series 300 rod. ELS operating procedures instruct that any rods subjected to such loading shall be inspected and tested prior to redeployment into the wellbore. Single event recoils within the range of 16,000 pounds have a minimal impact on the load handling capacity for the FSR Series 300 and Series 300 HIFL.

REFERENCES

1. API 14 Committee. (1991). Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems. API RP 14E, 5th Edition.
2. Gernentz, R., Hricisak, K., & Alzoubi, M. (2015). It's All About the End Fitting: Advanced Testing and Design Improves Fiberglass Sucker Rod. Southwestern Petroleum Short Course., (p. Online). Lubbock.
3. Gernentz, R., Hricisak, K., & Ocando, J. (2017). It's all about the end fitting asdfasd. Southwestern Petroleum Short Course (p. Online). Lubbock: Southwestern Petroleum Short Course.
4. Shigley, J., & Mischke, C. (2001). Mechanical Engineering Design. New York, NY.: Mc Graw Hill Higher Education.

APPENDIX

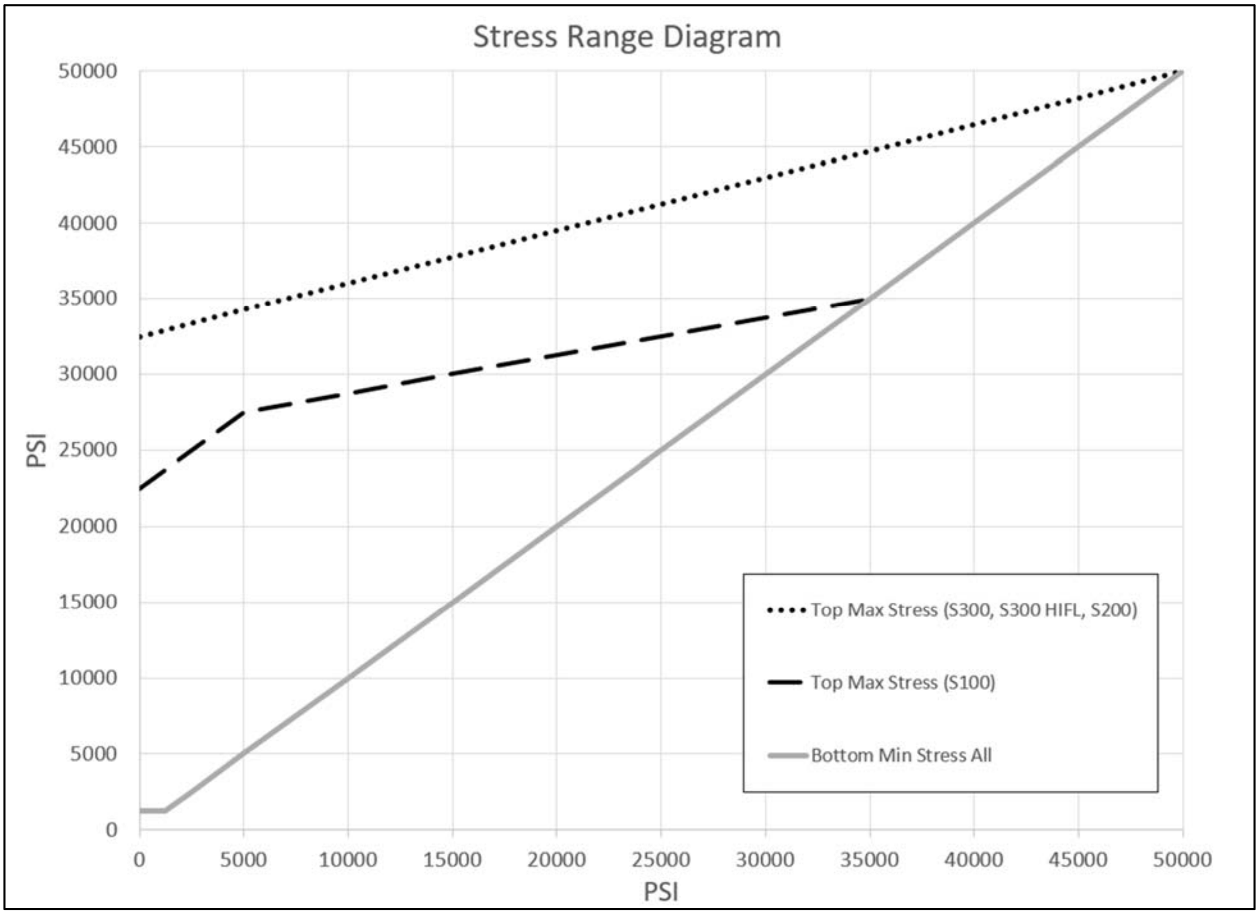

Figure 1, Stress Range Diagram

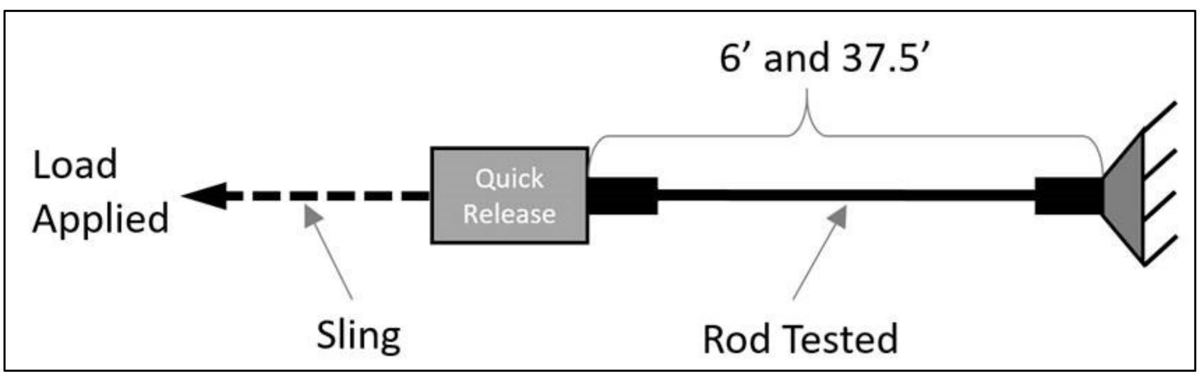

Figure 2, Compression Testing Setup

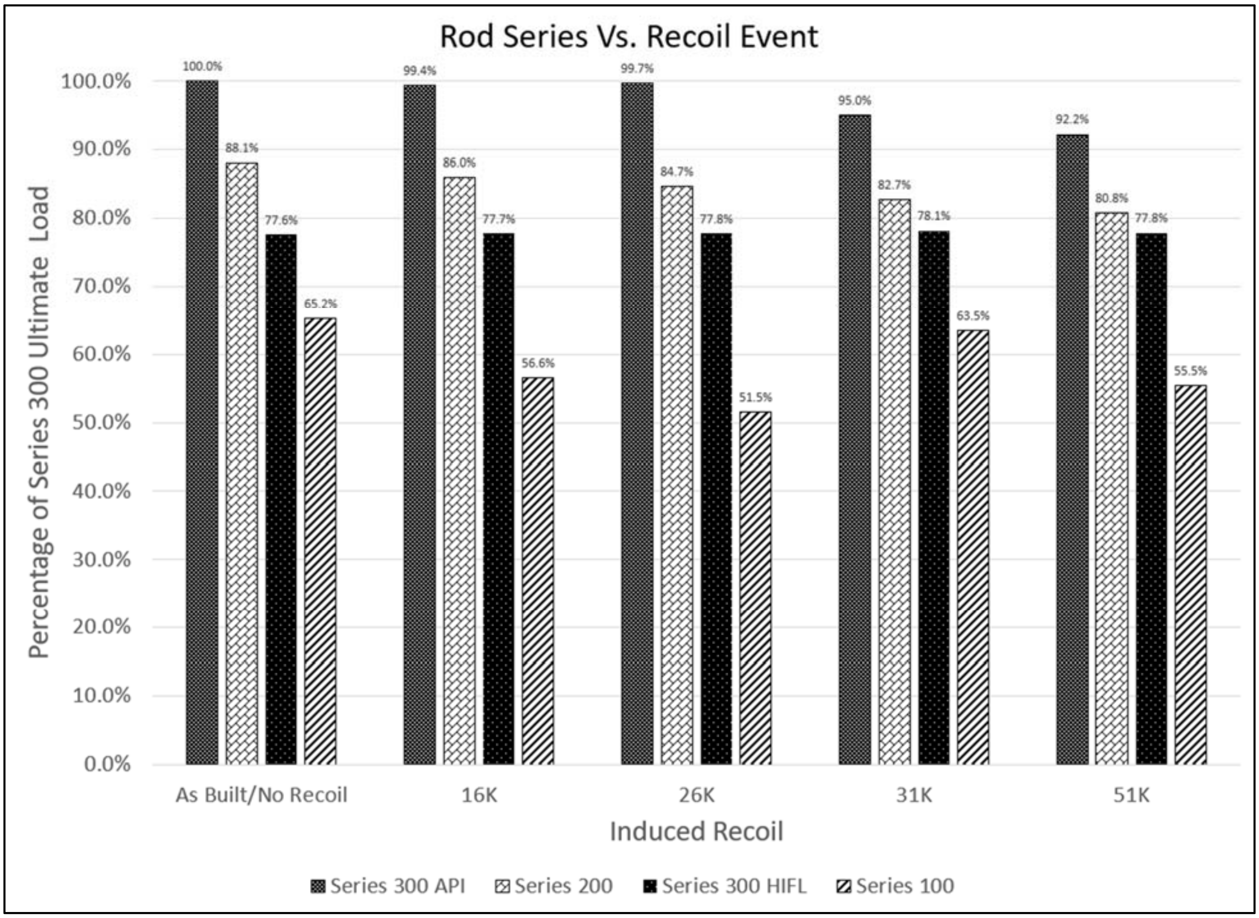

Figure 3, Compression Testing Results

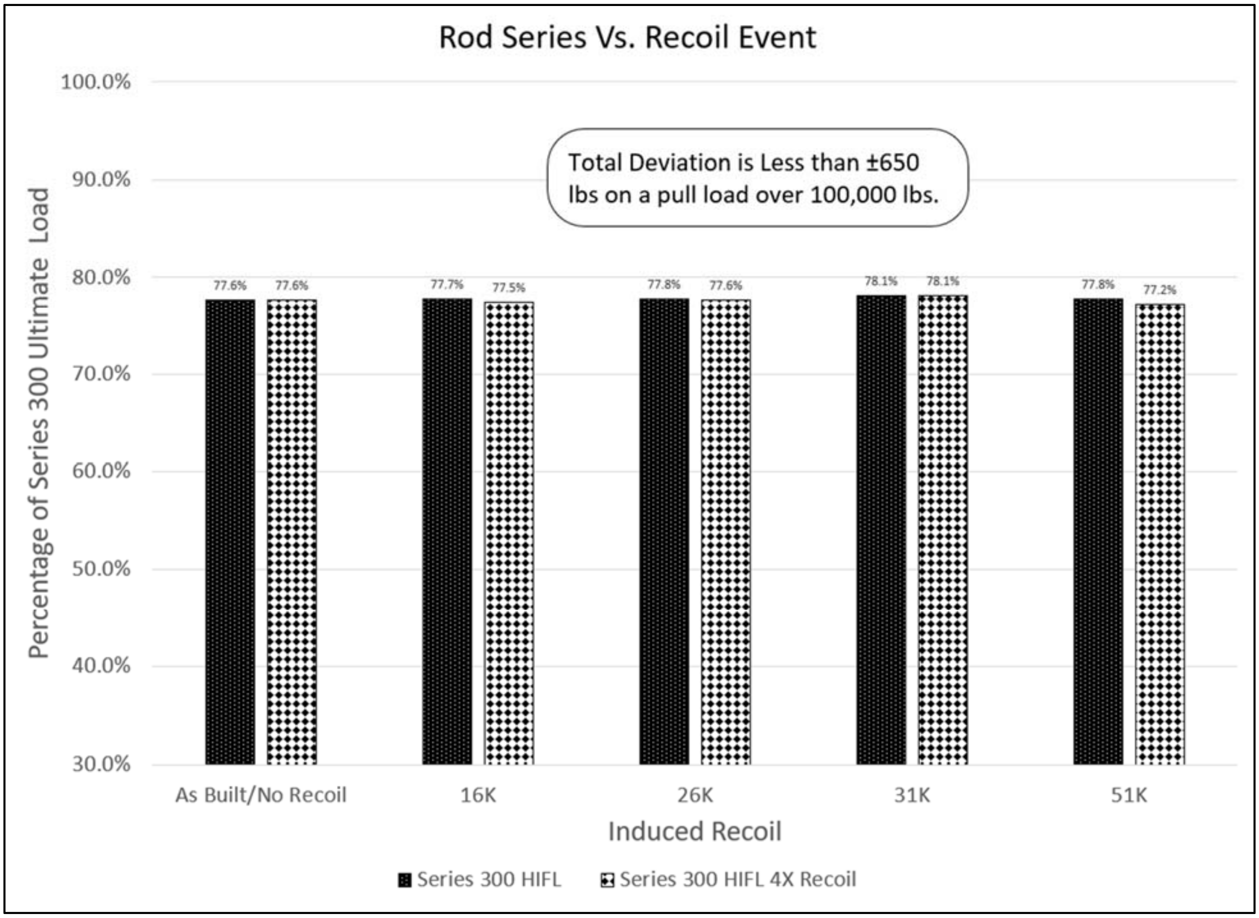

Figure 4, Increased Recoil on Series 300 HIFL

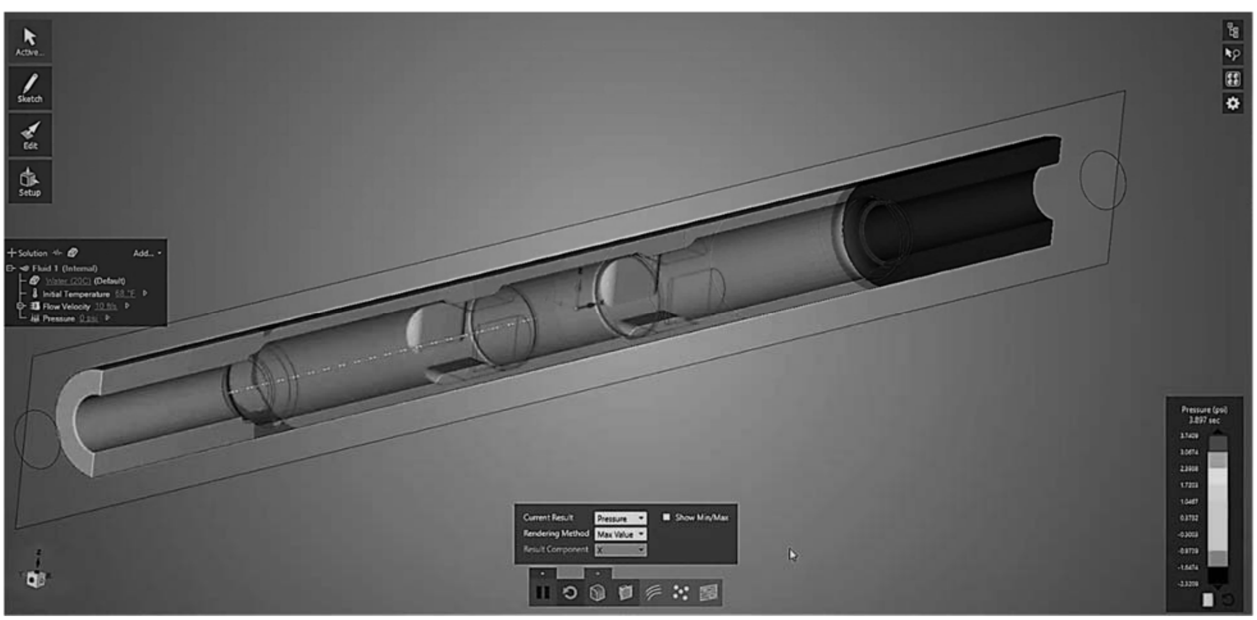

Figure 5, Pressure Drop Across Series 300 HIFL @ Approximately 500 BBL/day

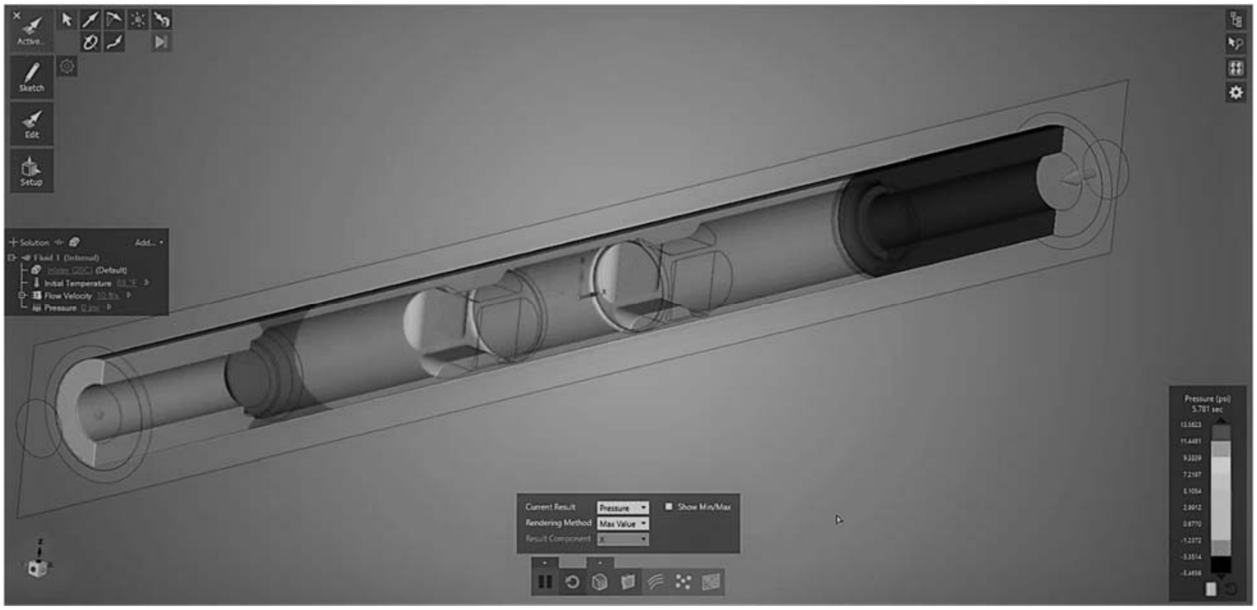

Figure 6, Pressure Drop Across Series 300 @ Approximately 500 BBL/day

Table 1, Specification and Properties

Physical Specifications			
Nominal Rod Diameter (in.)	1.00	1.25	1.25
End Fitting Type	API	API	HIFL
End Fitting Diameter (in.)	1.625	2.000	1.8125
Rod Weight @37.5' W/O Couplings (lbs.)	30.71	48.27	46.50
Rod Body Area (in2)	0.75	1.17	1.17
Weight per Foot @ 37.5' W/O Couplings (lb./ft)	0.82	1.29	1.24
Operating Properties			
Standard Maximum Operating Temperature (deg. F)	185	185	185
High-Temperature Maximum Operating Temperature (deg. F)	285	285	285
Maximum Working Strength (psi)	50,000	50,000	50,000
Maximum One Time Pull Load (lbs force)	50,000	80,000	65,000