SUCKER ROD IMPROVEMENTS FOR DEEP LIFTED WELLS

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ABSTRACT

Occidental Petroleum (Oxy) operates a field encompassing about 200 vertical wells in the Permian Basin. A vast majority of the wells employ sucker rod lift with conventional 640 pumping units, with wellbore construction consisting of 5 1/2" P-110 casing to an average plug-back tubing depth (PBTD) of 11,500 ft. The wells produce from multiple zones at vertical depths between 8,000 and 11,500 ft, with an average seat nipple (SN) depth of 10,500 ft. Pushing the depth limitations of rod lift presents multiple challenges. This paper will discuss some of the lessons learned from our operating practices, in which the use of technology resulted in a 33% decrease in our downhole failure frequency across the field.

HISTORICAL PRACTICES

About 90% of the initial sucker rod designs contained 50% fiberglass rods tapered to 87 steel rods at an average setting depth of 10,000 ft. The fiberglass allowed us to maximize strokes per minute (SPM) and minimize energy cost with the use of the lightweight, elastic fiber material during initial stages of production. As production declined, Oxy gradually laid down the fiberglass rods and switched to 86 steel rods inside 2 7/8" tubing. Along with the added weight from the material switch, Oxy deepened the pumps beneath the perforations to increase pump output, fully maximizing the system loading on the upstroke and downstroke. Unfortunately, failures increased in a certain group of wells as we switched to the all-steel design. Data analysis has indicated over-travel tag from incomplete fillage as the primary cause of the failure.

Oxy's common practice is to use a Pump-Off Controller (POC) with beam pumps. A requirement of a POC is that the system shuts itself down when it registers incomplete fillage. Going through an incomplete fillage cycle means that the plunger slows down while compressing gas, and speeds up when the gas is compressed and the traveling valve ball comes off the seat. This process results in kinetic energy being stored while the gas is compressed, and then it is released when the traveling valve ball comes off the seat. The kickback from the sudden energy swing can result in rod buckling in the bottom taper, and can even reverberate to rod slap in the stiffer tapers depending on the severity of the pound.

Lynn Rowlan demonstrated in his 2017 SWPSC paper (see Reference 1) that severe pump tagging can also occur during the incomplete fillage stroke depending on the velocity of the pump, the severity of the incomplete fillage, and the spacing of the pump at the time of pump-off (see Figures 1 & 2). One way to avoid this is to space the wells out more conservatively. Insufficient spacing can greatly diminish the pump compression ratio and shut the unit down prematurely from gas interference, but tighter spacing leaves the potential for damaged equipment and costly failures.

It is generally recommended to space fiberglass wells more conservatively due to their elastic stretch and the risk of splintering if compression occurs. As much as 50–60" of spacing would be required to prevent tagging with fiberglass rods as the pump draws fluid down. Oxy's initial pump spacing recommendation when we made the switch to the all steel designs called for 15" or 30" from soft tag, depending on SN depth and required inflow/outflow. One area of miscalculation with that recommendation was the stretch induced with the 86 tapered steel strings at plug back tubing depth (PBTD) to keep gearbox torque under the maximum rating with the 640 pumping units. Rod designs have significantly changed from "stiffer" to more "limber" in the last 10 years. This is a result of industry's recognition that the API Modified Goodman Equation ($Sa=(T/4 + 0.562\ Smin)$), agreed to in 1954 by industry experts, was too conservative. Rather, the "High Strength" Equation ($Sa=(T/2.8+0.375\ Smin)SF$) introduced in the mid-1980s should be applied to both high-strength and low-strength metal rods, where:

Sa = Maximum Allowable Stress, psi

$Smin$ = Minimum Allowable Stress, psi

T = Minimum Tensile Strength, psi

SF = Service Factor

The industry now accepts service factors as high as 1.35 for the API Modified Goodman Equation for using the High Strength equation in sucker rod designs. These changes reduced capital installation cost, enabling the use of more limber rod designs and smaller pumping units to move a given volume from a defined depth. An unintended consequence of the more limber rod strings is having difficulty in spacing out the pump in deep wells.

Figures 3-6 demonstrates the stretch effect with 86 steel rods based on Echometer QROD ™ modeling at 11,000 ft with a 1.5" pump. Depending on the rate of inflow and pump capacity required, decreasing the level of buoyancy between the tubing and annulus dictates 42" of additional stretch from static weight and increased over-travel as fluid level reaches pump-off. Echometer QROD ™ does not account for increased over-travel from incomplete fillage. Peak polished rod loading of >34,000 lb is not enough force to exceed the tensile strength of the rods, but the high loading provides enough potential and kinetic energy to transverse several thousand pounds of compressive force even at 90% incomplete fillage.

Realizing the magnitude of the increased stretch of the steel designs, we increased our pump spacing recommendations to ≥40" from soft tag to reduce the potential for tag during incomplete fillage events. Other practices to reduce pound severity included raising SN depths above the top perforation at ~8000 ft and decreasing pumping unit speed to less than 5 SPM. Conventional wisdom maintains that 5 SPM is slow in most beam pumping applications, but the trend is moving towards more conservative pump-offs to minimize the stored energy in our deep lift systems. For low inflow wells, decreasing SPM from 3.8 to 2.8 has had a profound effect on the severity of incomplete fillage, as noted in Figures 7-9. Variable Slippage Pumps (VSP) can remove the risk of pound/tag entirely from the force equation due to the tapered barrel design, albeit at a slightly diminished amount of fluid per stroke. One well in particular went from 4 hole-in-tubing failures in 1 year to a 3-year run life with the use of a VSP.

OTHER TECHNOLOGICAL ADVANCES

We also observed extended run life on deviated wellbores with low inflow with the use of polyketone-lined tubing. The subject wells experienced 50% fewer failures, normalizing the data for the duration of the trial. The reduced friction of the polyketone liner material, and the width of the liner itself, extended the time for the rod couplings to wear on the tubing ID surface. We speculate that this technology minimizes potential on both rod coupling parts and the propagation of ID splits in the tubing based on the two years of data available. The polyketone liner does restrict the 2 7/8" tubing ID to a 2 3/8" ID equivalent, so a 1.5" pump size is the maximum allowable fit. This will also affect the size of the rod guides, the use of 1" rods, and the SN size inside of the tubing.

Continued application of Variable Speed Drives (VSD) on our beams will further drive good results. The reaction time of VSD's to decrease SPM during flumping events to eliminate cycles reduces the potential for undesired pound and the collection of solids during downtime. This technology will also improve our risk tolerance to moving the SN depths back below the perforations to capture missed production from the group of problem wells.

CONCLUSION

Use of a POC is encouraged to minimize backpressure on the formation, but the conventional wisdom of 18–22 hours of runtime and 80-90% pump fillage is less desirable when the stored energy of deep rod lift systems categorizes risk into a higher threshold. Careful evaluation of stretch throughout drawdown with limber yet heavy steel designs and proper pump spacing has reduced our failure frequency by a significant margin.

REFERENCES

1. Rowlan, O.L., Taylor, C.A., and Craig, R.P.: Over-Travel Can Occur on Both the Upstroke and Downstroke, 2017 Southwest Petroleum Short Course.
2. QRod Design Program Download, http://echometer.com/Software/QRod/tabid/130/Default.aspx

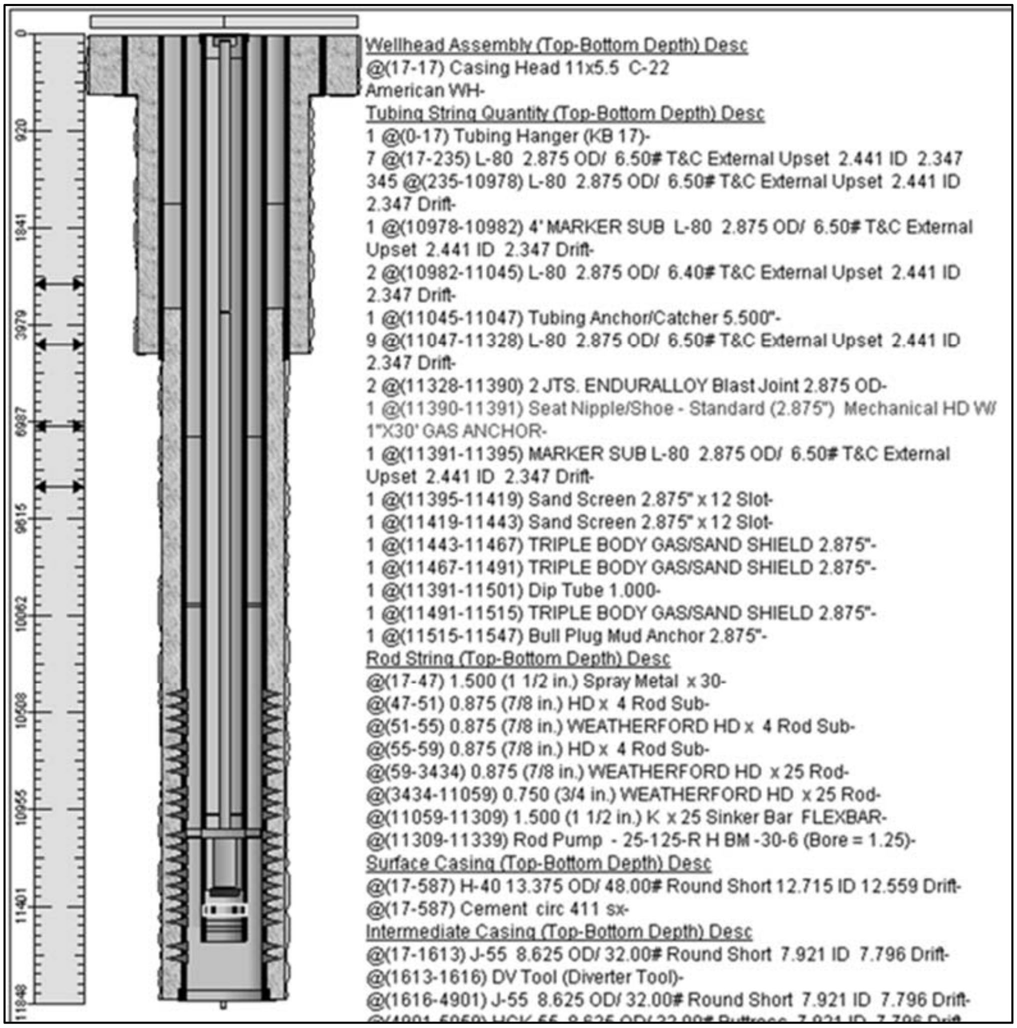

Figure 1: Wellbore configuration on dynamometer card below

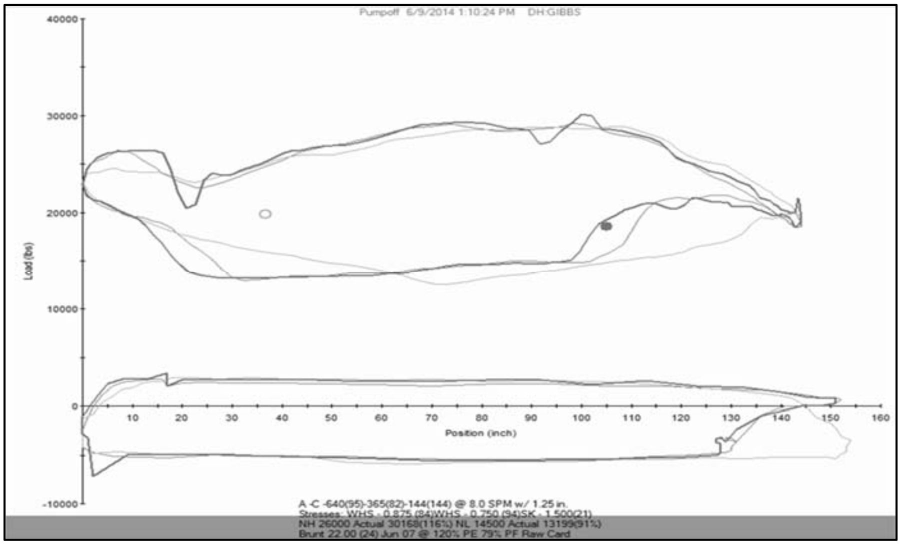

Figure 2: Over-travel tag during incomplete fillage

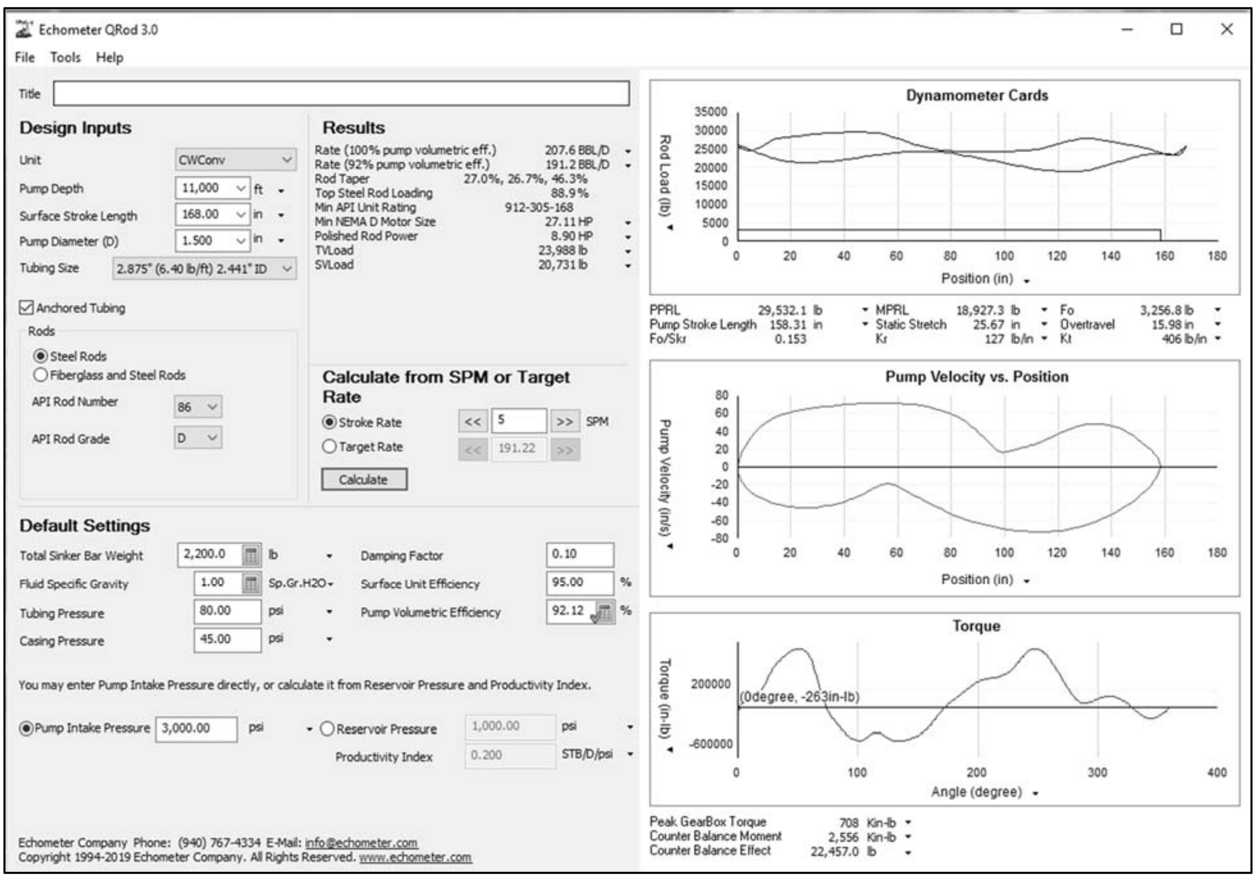

Figure 3: Echometer QROD TM modeling, with initial conditions of 3000 psi of pump intake pressure for an 86 steel string at 11,000 ft and a 1.5” pump.

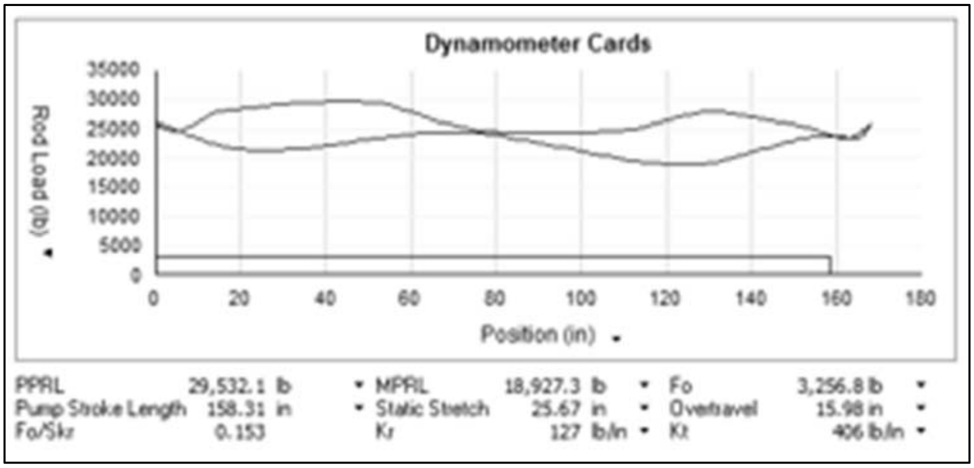

Figure 4: Static stretch is 25.67”, and overtravel is 15.98” at 5 SPM and a 168” stroke length.

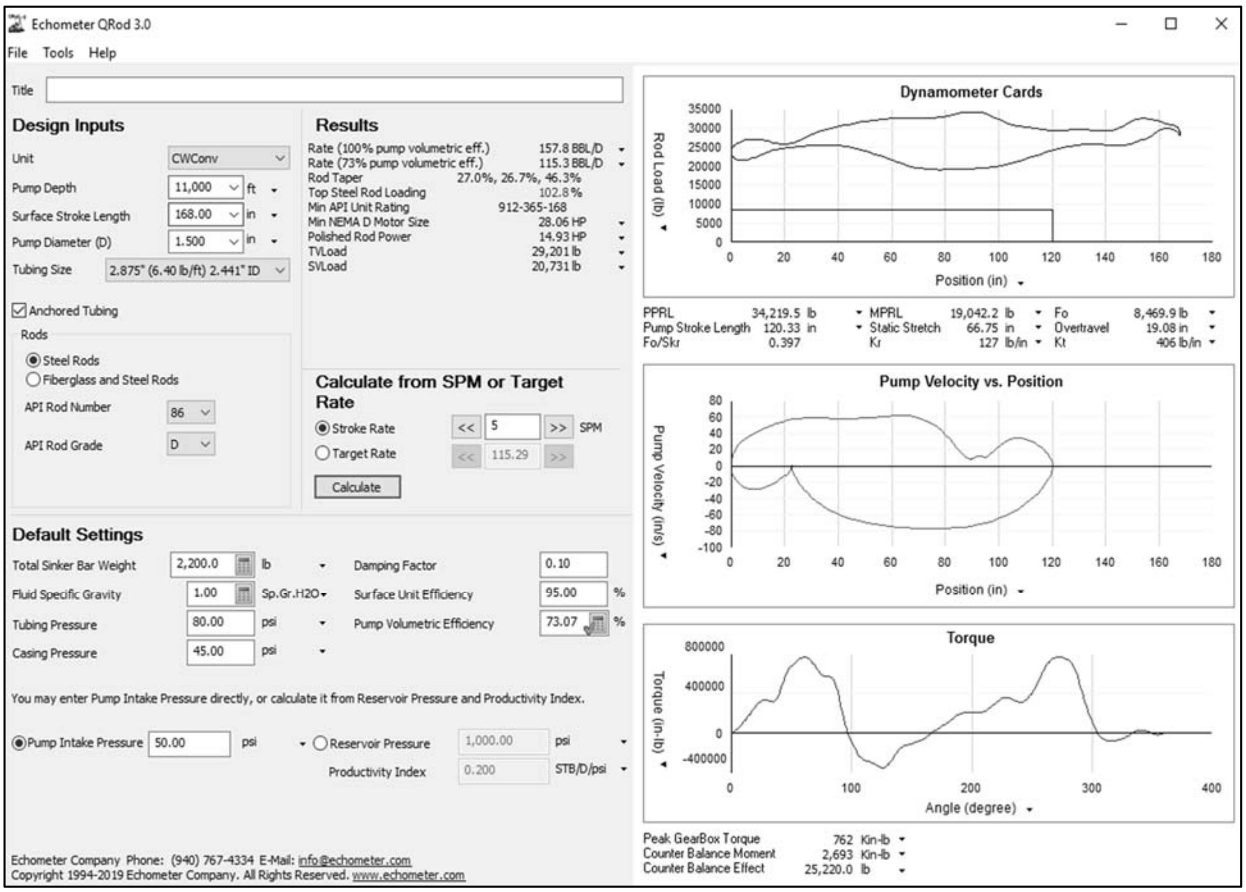

Figure 5: Same Echometer QROD ™ design, with final conditions at 50 psi of pump intake pressure.

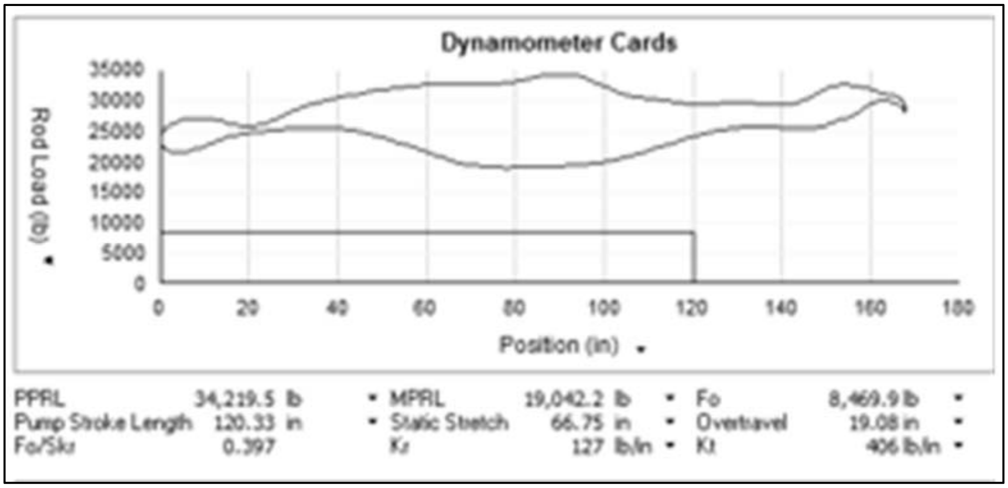

Figure 6: Static stretch has increased to 66.75", and over-travel is now 19.08". Peak polished rod load is 34,219.5 lb.

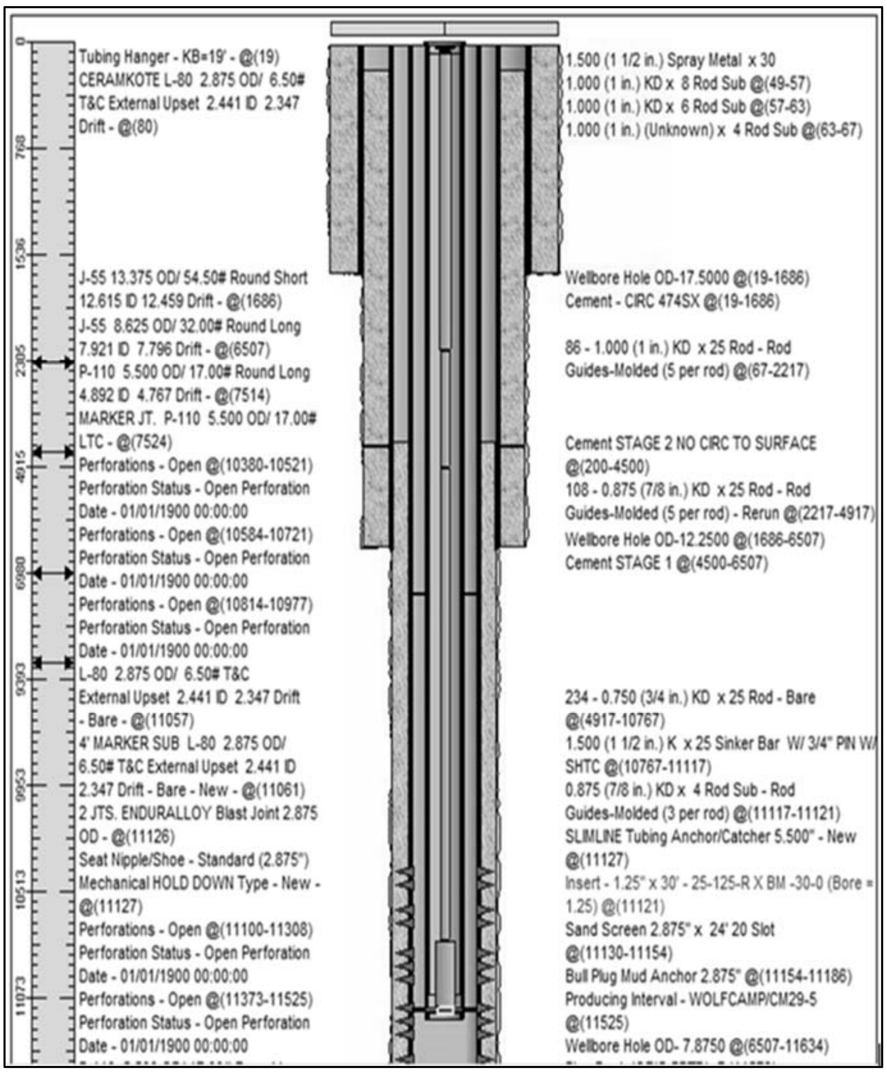

Figure 7: Wellbore configuration for dynamometer analysis below

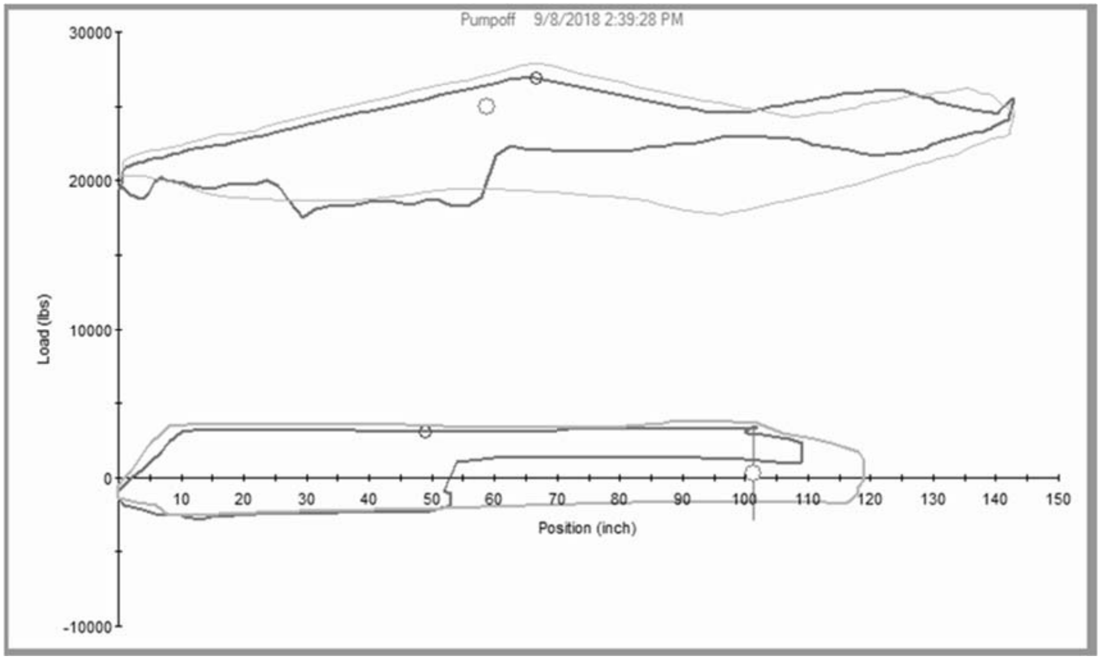

Figure 8: Incomplete fillage reached >50% at 3.8 SPM. Pump-off setpoint was 95% on downhole control.

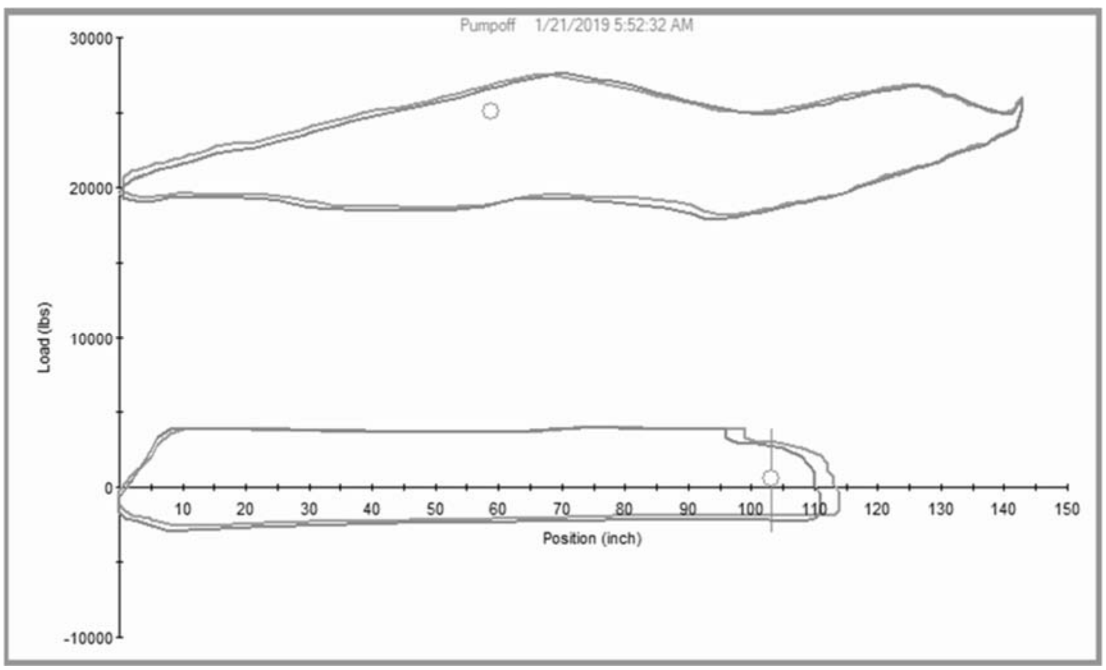

Figure 9: Same well, 4 months later. Speed reduced to 2.8 SPM. Pump-off is less frequent, and fluid load remains the same at pump-off without excessive pound.