THE USE OF POLISHED ROD VELOCITY AND MPRL/PPRL RATIO AS AN INDICATOR OF FAILURE FREQUENCY

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ABSTRACT
During the study of ~6,000 beam-pumped wells in the Permian Basin, it was found that polished rod velocity and the ratio of minimum to peak polished rod loading could be used as a tool for predicting failure frequency. Failure frequency is a main driver for operational expenses and well performance predictability; proper design steps can be made to extend well runtimes, reduce operating expenses, and increase oil production volumes. This paper will focus primarily on polished rod parameters including loading and velocities and how proper analysis can provide guidelines for wellbore designs.

MPRL/PPRL
The ratio of the Minimum Polished Rod Load to the Peak Polished Rod Load (MPRL/PPRL) should be considered when designing beam pumping systems. This study was run to analyze the hypothesis of failure frequency (FF) increasing when specific ratio thresholds are reached. A regularly used rule of thumb advises that the MPRL/PPRL threshold should be greater than or equal to 0.1 per every 2,500 ft of depth, or MPRL/PPRL ≥ 0.00004*Depth (in ft). For example, the threshold for a 10,000-ft-deep well would be greater than or equal to 0.4.

As shown in Figure 1 and Figure 2, the operator developed historical plots of failure frequency vs. MPRL/PPRL. The data are also grouped into a) metal rods with conventional pumping units, b) metal rods with special geometry units, and c) fiberglass rods with conventional pumping units. These groupings are broken out in the figures. The data were compiled for wells completed at similar depth intervals corresponding to the operator's most common Permian Basin producing reservoirs:

1. Reservoir A: pump depth < 6,000 ft
2. Reservoir B: 6,000 ft < pump depth < 8,000 ft

The failure data include all *non-corrosion* tubing leaks and rod body failures occurring over a 12-month period.

The recommended thresholds based on the data trends are relatively consistent with the aforementioned rule of thumb:

1. Reservoir A wells should stay above an MPRL/PPRL of 0.3.
2. Reservoir B wells should stay above an MPRL/PPRL of 0.4.
3. It appears that special attention should be paid to Special Geometry Pumping Units installed in Reservoir B wells, as they appear to have higher associated failure rates than the Conventional Units.
4. Fiberglass rods in the Reservoir B were associated with the lowest overall failure rates at low MPRL/PPRL ratios.

The primary contributors or drivers to the MPRL/PPRL ratio were determined to be pump size and SPM. Figure 3 and Figure 4 illustrate how pump size affects this ratio. Figure 3 shows the distribution of MPRL/PPRL for Reservoir A wells broken out by pump size categories. Figure 4 shows the same information for Reservoir B wells. All else being equal, a one-size pump increase can result in a decrease in MPRL/PPRL ratio of around 0.05. This suggests that larger pump sizes would also be expected to have increased failure rates (all else being equal). The expected magnitude of this shift was confirmed theoretically by using various examples in a rod design software program. Increases in SPM were found to have a similar influence on this ratio; as SPM increased, the MPRL/PPRL ratios decrease. Another parameter to note: increases in stroke length resulted in lower MPRL/PPRL ratios, although to a lesser degree than either pump size or SPM changes.

In conclusion, if a design falls below the preferred cutoffs noted above, options to consider would be: (1) decreasing the pump size, (2) lowering the speed, or (3) decreasing the stroke length.

POLISHED ROD VELOCITY

The most significant cause of failure outside of the operator's control is high-volume wells. An inherent characteristic of these wells is high fluid volume and associated high Polished Rod Velocity (PRV). In this situation options are limited, as conditions require operating system components near—and sometimes above—their design limits.

In this category, well conditions may dictate high polished rod velocity to adequately pump off the well. For this correlation, PRV is defined as SPM × stroke length (SL) for convenience (definition used by Norris). As noted in the previous section, a high SPM decreases the MPRL/PPRL ratio and thus increases failure frequency. Therefore, the operator must recognize that high volumes stress the entire system and drive higher failure rates.

For units with stroke lengths greater than 100 in., the Norris rule of thumb sets the maximum recommended velocity for conventional units at 1,500 in./min and for Mark units at 1,200 in./min. However, the study of ~6000 Permian Basin wells indicates that the failure rate has a linear relationship with PRV. The data seen in Figure 5 were pulled from January 2012 through September 2016. Unlike the Norris rule of thumb, unit geometry was not considered, and only mechanical failures of the rods and tubing were analyzed in the study.

Another facet of this study was performed by comparing the Failure Frequency (FF) of wells pumping with minimum cycling to those pumping with normal cycling (average of 17 cycles per day). Figure 6 compares the FF of wells pumping with an average runtime of 23.5 hours or more per day to wells running less than 23.5 hours per day over the same 4.75-year time period. In both data sets, the failure frequency is plotted versus the PRV. Figure 6 shows a dramatic difference between the two failure rates observed. The average FF of the wells with few incomplete fillage cycles (i.e., run time of at least 23.5 hours per day) is about 0.1 failures/year, while the average for a more normal cycle is about 0.25 failures/year. In addition, as polished rod velocities increase, the magnitude of the difference in failure rates also increases.

The data from Figure 6 was reformatted to develop a Mean Time Between Failures (MTBF) chart. Figure 7 shows the relationship between polished rod velocity and MTBF. Figure 8 shows the relationship between stroke length, pumping speed, and MTBF. For a long time, there has been a disagreement over the recommended practice of operating sucker rod lifted wells "short and fast" or "long and slow." Figure 8 displays the solution to this disagreement. If the operator desires a long operating life of 10 years MTBF, then a "short and fast" stroke length of 62 in. at 12 SPM results in the exact same failure frequency of a stroke length of 168 in. at a 4.4 SPM pumping speed. Operational results displayed in Figure 8 show both "short and fast" and "long and slow" can result in a low failure frequency. When long run life is important, if a long stroke length is desired, then a slow pumping speed should be maintained, and if a fast pumping speed is desired, then a short stroke is a must.

INCOMPLETE FILLAGE

Industry experts agree that there is a direct relationship between failure frequency and incomplete fillage cycles. Figure 9 illustrates use of the use of a rod design software program to show the buckling effects of a complete fillage cycle versus an 80% full cycle. In this example, the rods in the full pump do not go into compression. On the other hand, all three tapers in the 80% complete fillage cycle go into compression, and a buckling force of 80 pounds is predicted at about 3,000 ft. As a result, the probability of failure will increase with each incomplete fillage cycle.

Additional work was done to the original PRV vs. FF study to determine if failure frequency increases as the number of cycles increases. The initial hypothesis (Figure 10) was that cycles per day would show a linear relationship with failure frequency. However, Figure 11 shows that there is not a linear correlation between failure frequency and the number of cycles.

Figure 11 shows that although cycling in beam wells does not have the exact effect we expected, it does indeed affect failure frequency. Since cycling is an indication of pumped-off conditions, and a pumped-off condition is indicated when at least one incomplete fillage cycle occurs, we can see from Figure 9 that there can be an effect on failure frequency. Because there may be a relationship between incomplete fillage cycles and FF—and downhole maintenance cost increases as FF increases—the management of pump-off conditions has a significant influence on the annual downhole maintenance expense for beam wells.

<u>CONCLUSION</u>

It is vital that downhole design, starting with the polished rod parameters, be carefully examined. As a result of the above analysis, investigating how polished rod operational properties effect failure frequency and downhole pump conditions, pilot projects have been initiated to learn how to minimize incomplete fillage cycles. These pilot projects are outlined in the following SWPCS papers: “Gentle Pump-Offs Can Reduce Operating Expenses,” and “Controlling Pumping Wells Utilizing Calculated or Measured Downhole Pressure.”

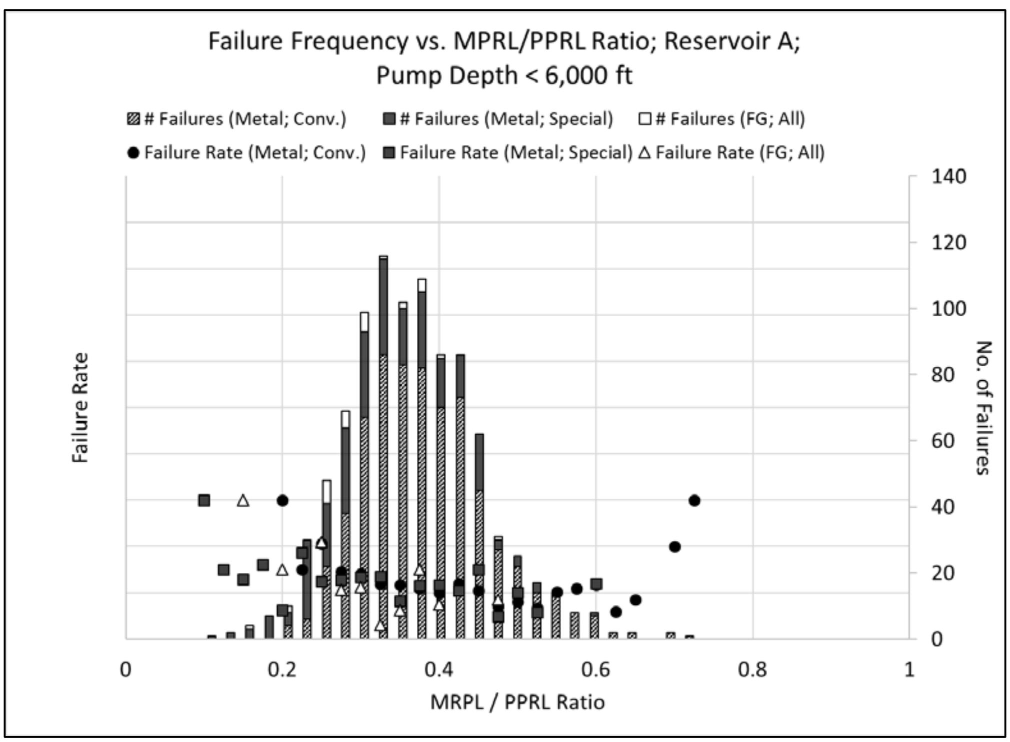

Figure 1: Failure Frequency, Shallow Depth Reservoir A (dots indicate failure rates on left Y-axis, bars indicate number of failures on right Y-axis)

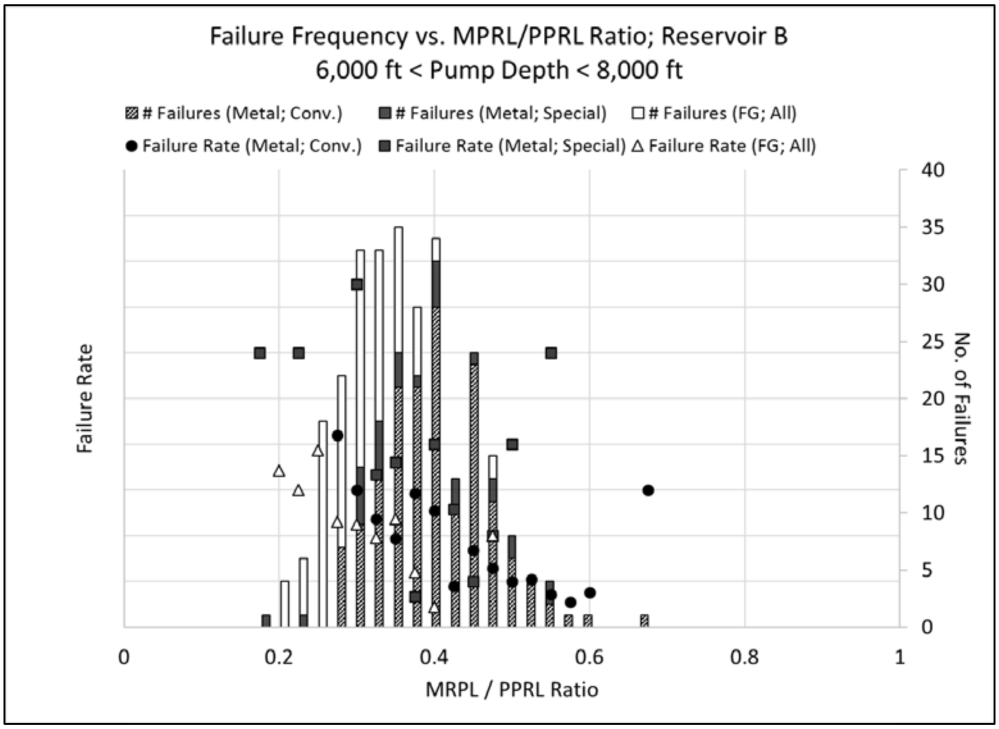

Figure 2: Failure Frequency, Moderate Depth Reservoir B (dots indicate failure rates on left Y-axis, bars indicate number of failures on right Y-axis)

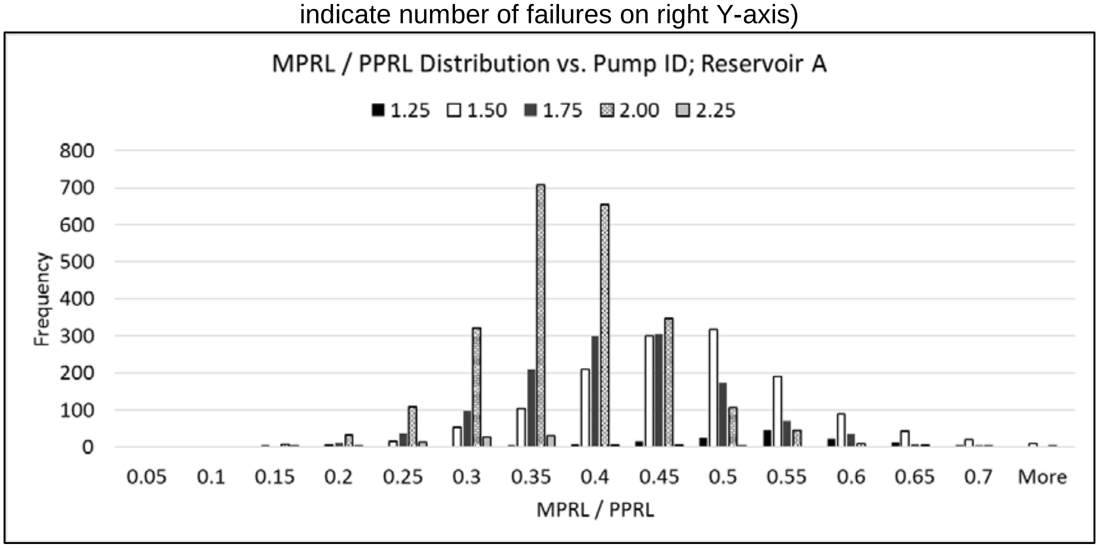

Figure 3: MPRL/PPRL Distribution for Reservoir A Wells by Pump Size

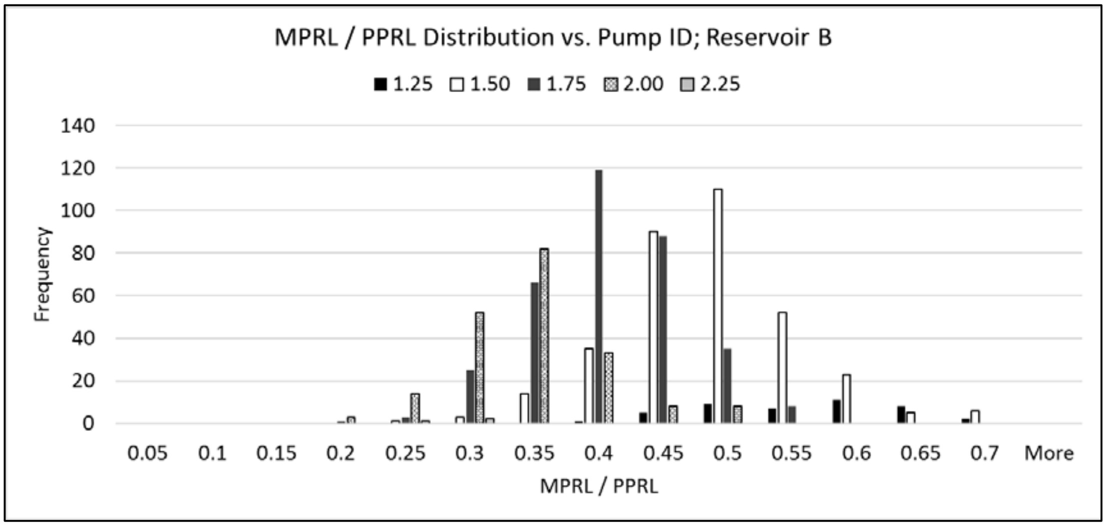

Figure 4: MPRL/PPRL Distribution for Reservoir B Wells by Pump Size

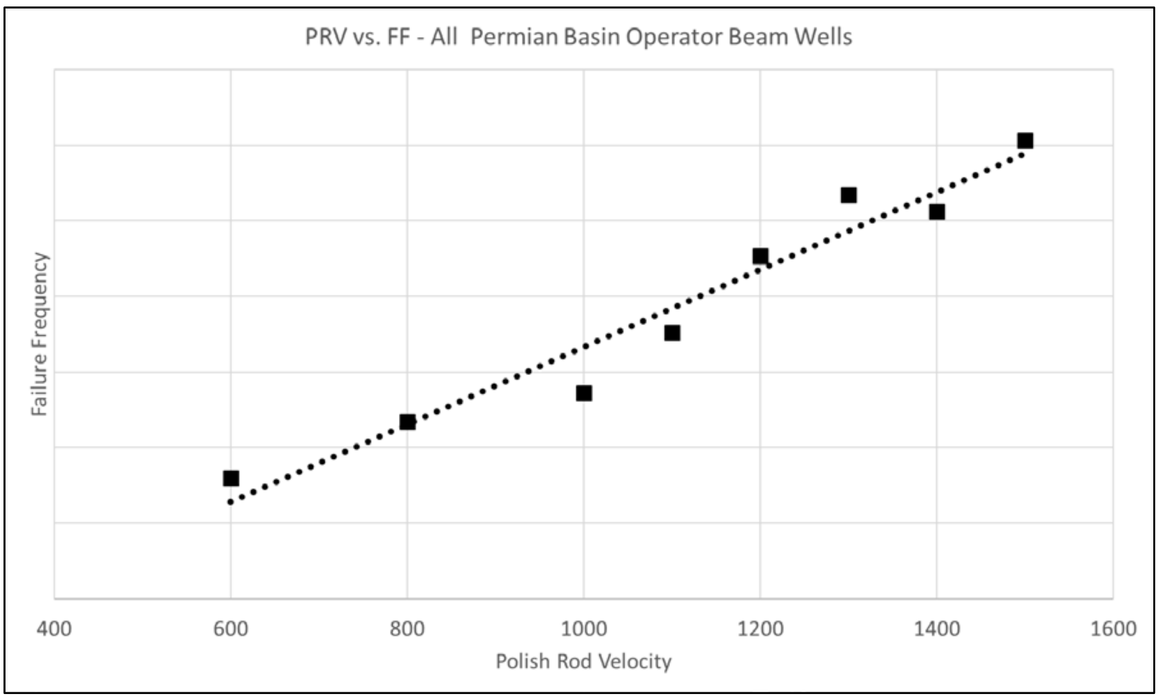

Figure 5: Plot of PRV vs. FF for All of the Operator's Permian Basin Beam Wells

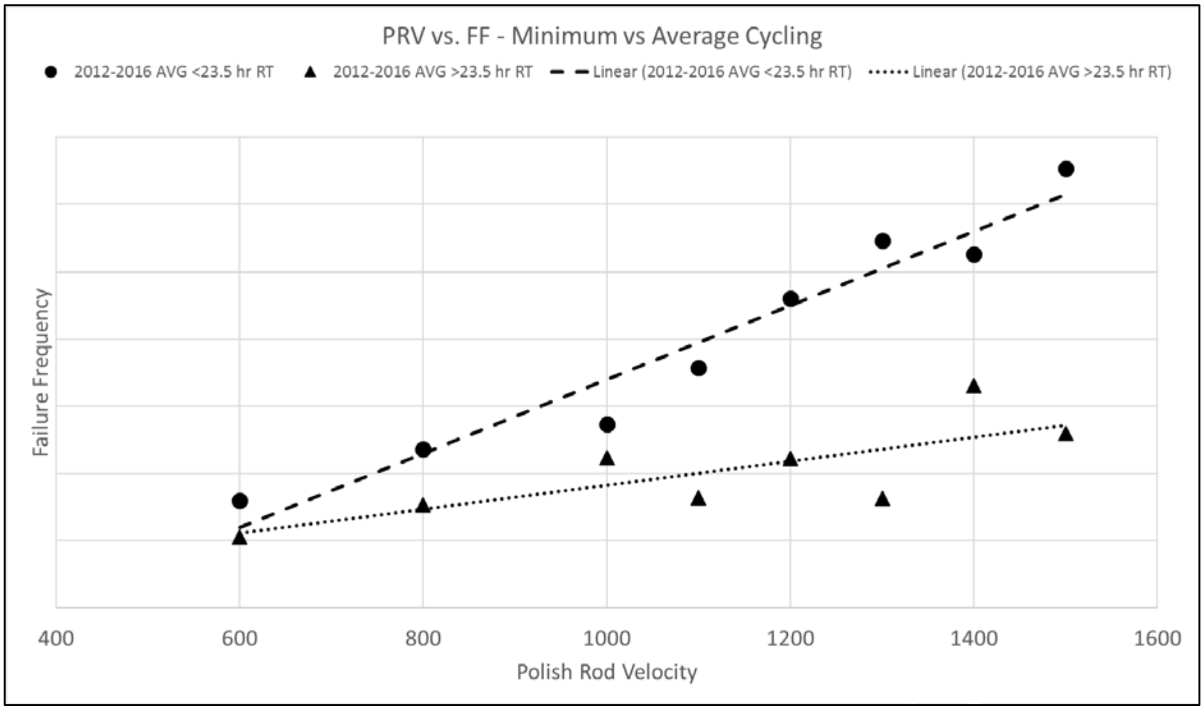

Figure 6: Polished Rod Velocity vs. Failure Frequency

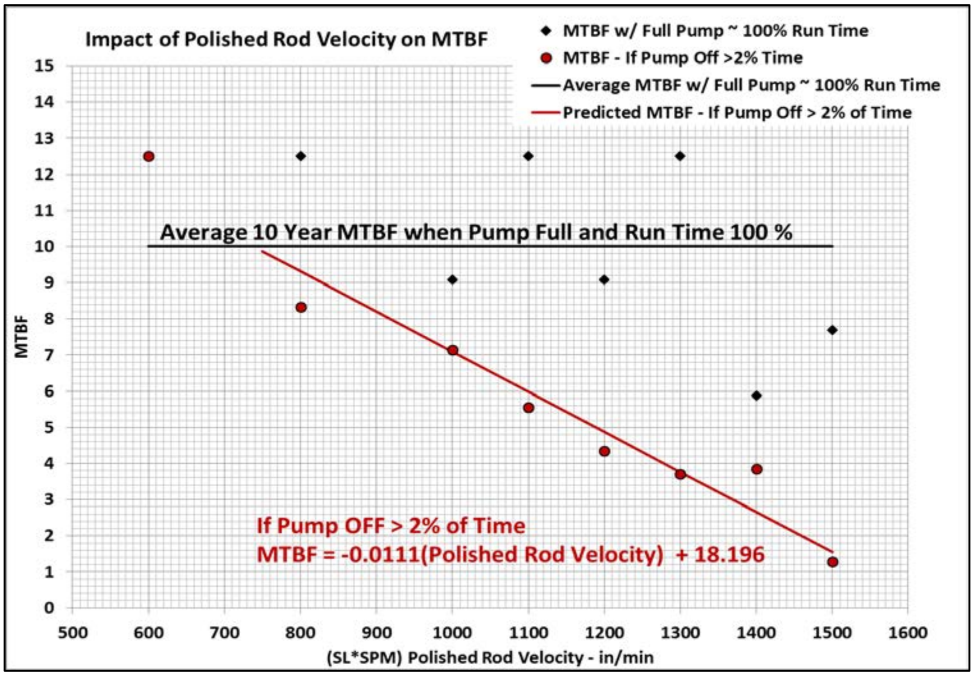

Figure 7: Relationship Between Polished Rod Velocity and Mean Time Between Failures

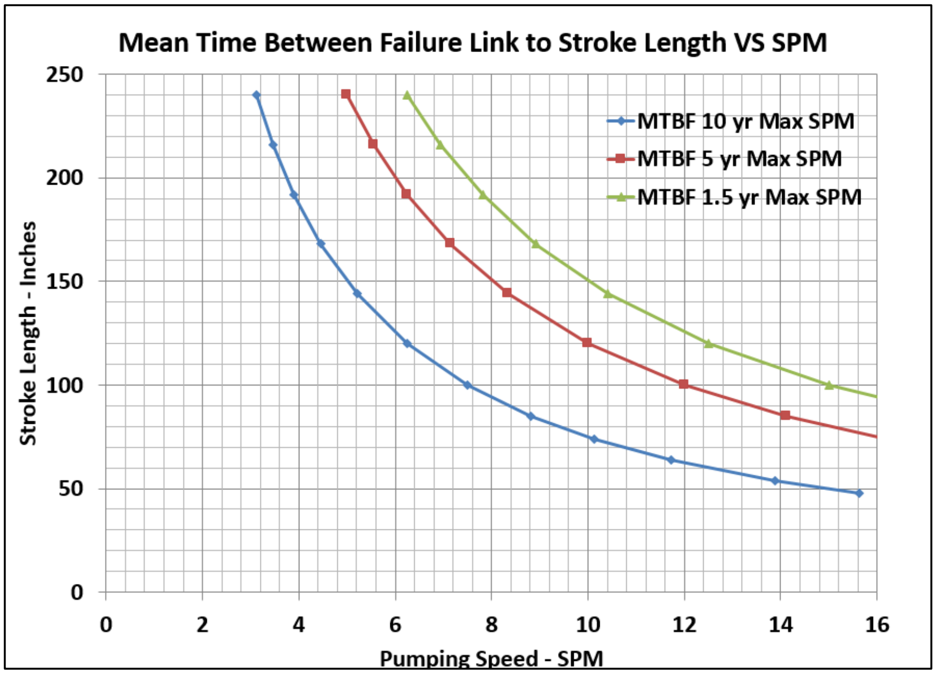

Figure 8: Relationship Between Stroke Length, Pumping Speed, and MTBF

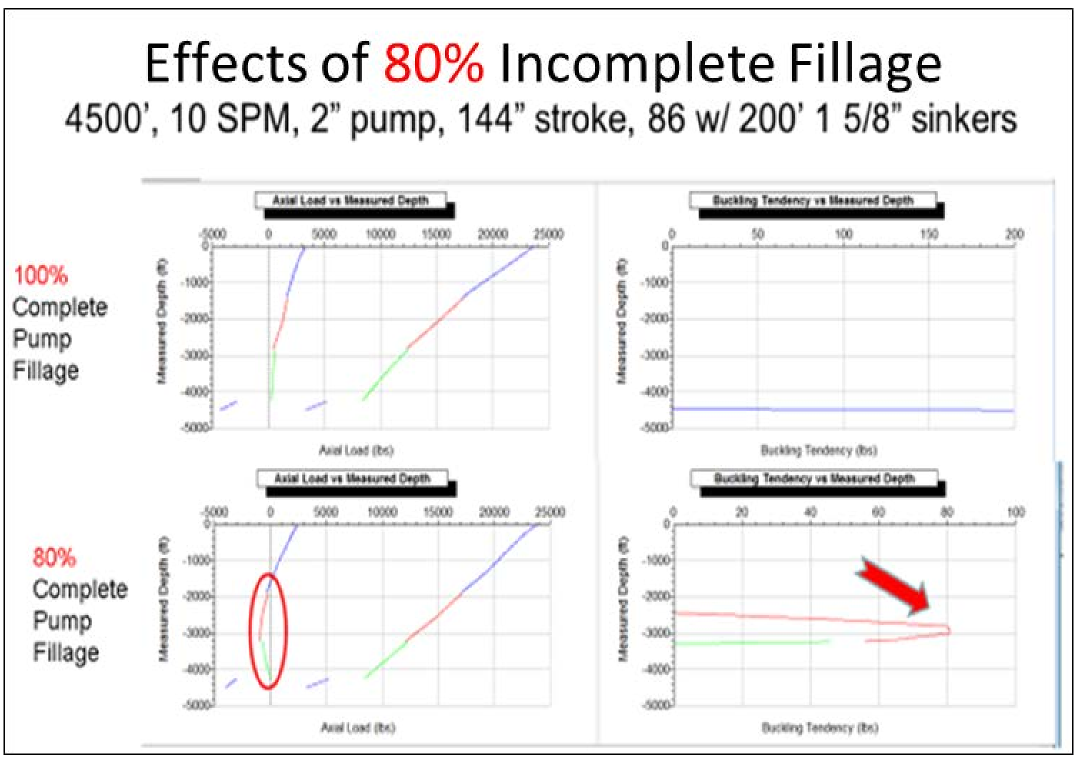

Figure 9: Complete Pump Fillage vs. 80% Pump Fillage

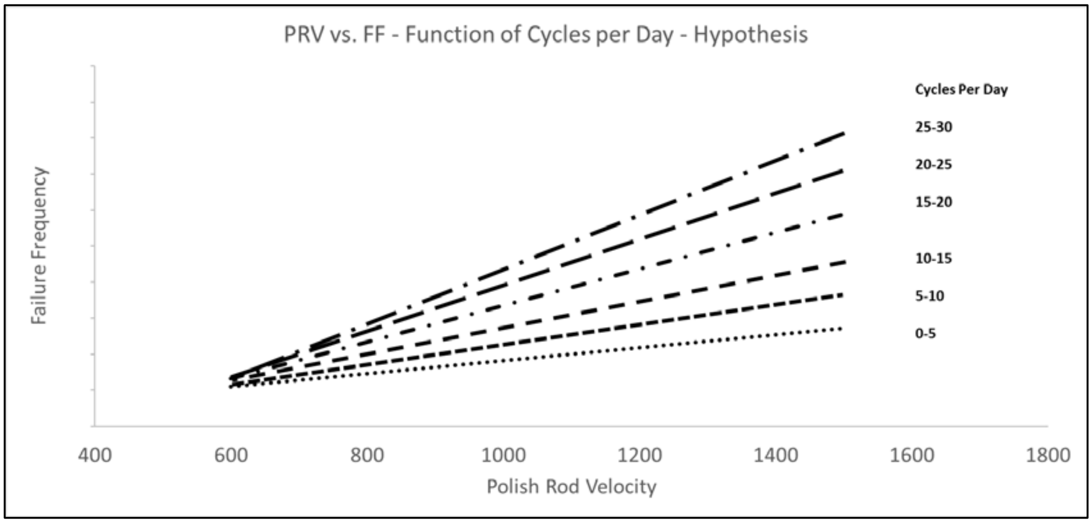

Figure 10: Expected Polished Rod Velocity vs. Failure Frequency as a Function of Number of Cycles Per Day

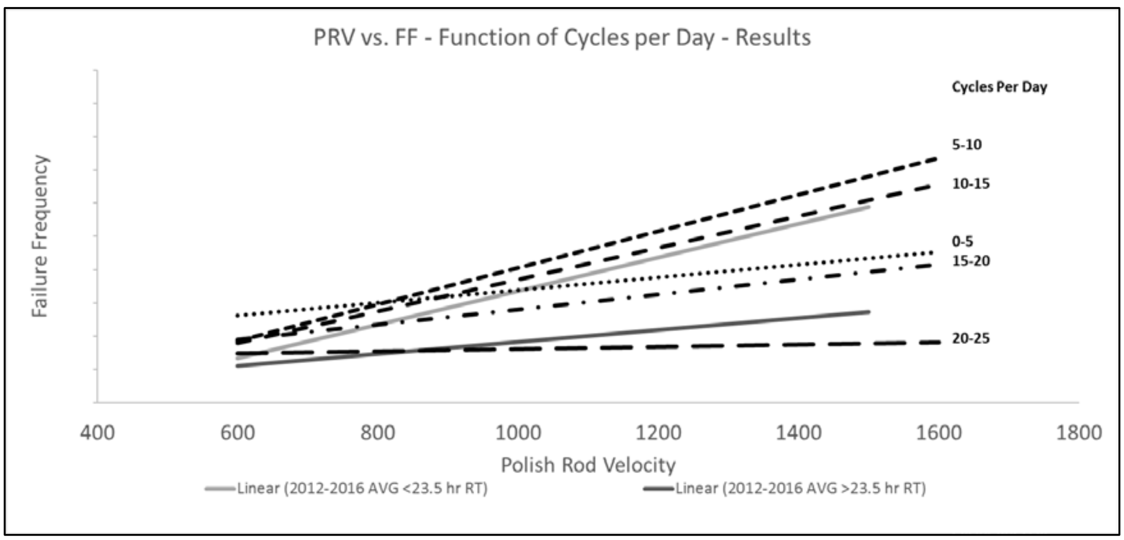

Figure 11: Polished Rod Velocity vs. Failure Frequency as a Function of Number of Cycles Per Day (25-30 cycles shows a negative trend line due to lack of subject wells)