MINIMIZING FAILURE FREQUENCIES IN THE MIDCON AREA BY ROOT CAUSE FAILURE ANALYSIS (RCFA) METHODS AND DESIGN OPTIMIZATIONS

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ABSTRACT

Deviated wells have been the standard form of drilling to increase well life and production but this creates challenges in the Artificial Lift System, specifically the Reciprocating Rod Lift (RRL). With aggressive drilling deviations rod, string guiding becomes a requirement, landing pumps in 45°- 65° zones is normal and gas mitigation becomes a necessity to achieve target productions.

In 2018, An operator in the MidCon introduced RRL systems to their wells; these (7,000ft) deviated wells utilize conventional pumping units (640 / 912 / 1280’s) and mid-strength sucker rods as the rod of choice. Since then several failures have been observed in the pump, tubing, and most frequently in the sucker rod string which have been fatigue related with corrosion and compression as attributing factors to the break.

Over the past 3 years, the Weatherford team has worked together to optimize the well designs based on past failure history observed. This paper will discuss the challenges observed, actions taken, and positive results which have minimized the failure frequencies significantly.

INTRODUCTION

The beam pump system is still considered the final form of lift for most aging wells. Its ability to produce with lower bottom-hole pressures, decreasing oil cuts, and increasing water and gas content deems the system a reliable choice. From a cost perspective, these systems tend to have a lower operating cost if designed and serviced appropriately[1]. Overall, this reciprocating rod lift system serves as the most widely used artificial lift method when prolonging the life of older wells. Although this system is likely to be the final form of lift, it’s not presumably considered when drilling new wells; instead new drilling methods continue to challenge this mechanical system and its design methods.

Over the past years, Extended Reach Drilling (ERD) has been a common practice for various operators trying to achieve a larger area from one surface location[2] compared to common horizontal drilling; see figure 1. Although successful, it introduces multiple challenges when converted to a beam pumping system as previously mentioned.

These challenges greatly reduce run life of down-hole components from beam pumping systems and increase the operating cost of these wells significantly. If not analyzed and solved, the system challenges can lead an operator in spending more capital expenditure converting its fields to another form of lift; unless practical methods are implemented to combat the challenging wellbore while still achieving the production desired.

CHALLENGES IN ERD

Initial Beam Design

Operator ‘A’ in the MidCon acquired multiple ERD wells in 2018 and began transitioning to beam pumping systems. The production threshold ranged between 150 – 300 barrels of fluid per day (bfpd), and the transition also depended on the failure frequency of the previous form of lift (ESP or Gas Lift). Without any previous beam history on those fields, a standard form of RRL design was implemented.

From surface to down-hole pump; this method consisted on conventional front and rear-mounted pumping units (640 / 912 / 1280's), utilizing API D special mid-strength sucker rods (1" and 7/8" diameters) connected with regular API T-couplings and insert pumps (1-1/4" to 1-3/4" pumps). The tapers for the initial designs were all 87 tapers with molded guides in deviated sections (4-per, 6-per, 8-per). The material used for the rod guides was the standard thermoplastic available at the time in the region, Polyphthalamide (PPA). The speed at which these units were operated reached up to 8 strokes per minute (SPM) with stroke lengths ranging from 144" – 240" in length; see table 1.

Root Cause Failure Overview

After 1 year of run-time and experiencing multiple failures, a complete root cause failure overview was performed. This overview focused on the failed components, failure locations in relation to the well depth, fracture surfaces and metallurgical failure report. A total of 21 wells were identified as problematic, having more than one repeated failure during this time frame. 57 total failures had occurred which were categorized as: pump failures (2), tubing failures (7), and sucker rod failures (48); see Figure 2. When the rod failures were matched with its respective well, it was noticed that approximately half of the rod failures were repeated failures, meaning not the 1st time the rod parts. The repeated failures averaged a run-time of 19 days whereas their 1st time run averaged 228 days; see Figures 3 – 5.

The failures were then plotted based on the rod location in the well. The intention was to determine if there was a failure pattern on higher stress areas; such as tangent sections, heavily guided areas, rod taper transitions or if it truly was random break locations. Based on the various plots completed, a definitive pattern was observed in most of the problematic wells, for example well #12 presented all of its five rod failures within 1,000' section located at the top tangent section; see Figure 6. Another example was well #5 with four of its failures all occurring along a 700' section underneath a heavily guided taper transition zone; see figure 7.

Along with the visual representation of each failure in relation to the wellbore, a metallurgical failure report was generated on various parted rods to better identify a root cause of failure. Based on the generated reports, it was concluded that most of the failures were corrosion-fatigue related with flexural loading conditions observed. Also observed was the fact that several of these failures were occurring at the end of a molded guide section. Although not necessarily failures, significant corrosion was observed on the T-couplings at the time of the analysis; see figures 8 – 11.

Identified Challenges

After conducting the detailed failure overview, there was enough evidence to identify probable challenges with these wellbore designs. The list of challenges was concluded and shown below:

1. Significantly higher side-loads from rod/tubing wear on the top tangent section.
2. Added frictional forces on the sucker rod string by the required guided sections.
3. Sucker rod buckling tendencies from reduced rod stretch due to high deviations.
4. Accelerated corrosion-fatigue failures from rod bending and compressive forces expanding the high cycle fatigue zone.
5. Incomplete pump fillage from landing pumps in 45° – 65° zones.

<u>CORRECTIVE ACTIONS</u>

Optimized Beam Design

From the identified challenges, several corrective actions were implemented to prevent on-going repeated failures on current beam pumping systems as well as newly converted systems coming from ESP or Gas Lift.

To decrease the higher side-loads on the top tangent sections of the string, a new guide material was implemented for this region; polyphenylene sulfide (PPS). The PPS thermoplastic presented significantly lower coefficient of friction from various lab studies; it also is nonabsorbent unlike PPA which tends to degrade due to its hygroscopic characteristics. Another corrective action implemented was to extend the taper changes occurring at the tangent section at least 250' – 500' from the highest side-load area[3].

To minimize frictional forces from the sucker rod string on guided sections, the number of guides per rod was restricted to 4-per (on areas with inclination from 2.5° - 30° and/or side loads less than 250lbs) and 6-per (on areas with inclination larger than 30° and/or side loads greater than 250lbs); thus eliminating the 8-per guides completely.

The rod buckling tendencies from reduced rod stretch and added drag forces was minimized by installing at least 1,000' of 1" guided rods on bottom (above pump) to serve as weight. Additionally, a rod rotator is implemented to maintain even wear on the guides and prevent pre-mature failures from holes-in-tubing (HIT). In the past two years, no HIT has occurred on from the added 1" section on bottom. The speed at which the system is operated was also reduced to 6.5spm which allows the rod to fall on the downstroke thus further minimizing buckling tendencies[4].

To prevent further corrosion, a batch chemical program has gradually been implemented on most of the reciprocating rod lift wells. Moving away from T-couplings and running spray metal instead has also been another corrective action taken. The rod of choice has been standardized to the KDP (mid-strength) due to its higher impact properties and added strength benefits as compared to the KD. Furthermore, the guide mold has been upgraded from 7" to 9" length low turbulence guide which is molded with a gradual taper at the ends to minimize the turbulent flow and prevent accelerated corrosion.

To conclude, choosing a smaller pump when possible has been implemented to combat incomplete fillage of rod pumps. If the well is known to have high Gas to Liquid Ratio (GLR higher than 1,000), an 1-1/4" insert pump with a longer stroke is used on the design. That in conjunction with slower pumping speeds have allowed these systems to reach up to 90% pump fillage on most instances; see Table 2 for optimized design parameters.

Field Results

All these corrective actions have been implemented on new RRL conversions in 2020 – 2021. Though, on the current beam pumping systems, gradual implementation of these actions has been carried out. It is dependent on the well economics if a new string is installed but so far, the results have been positive as average run-time have increased from 228 to 400 days, see Figure 12.

Further discussion

Additional changes which have positively impacted longer run-times not elaborated on this paper have been the number of rods replaced above and below the rod break. In the past, up to five above and five below was the standard in replacing rods. After identifying on-going failures on short periods of time, it was recommended to replace up to 20 above and 20 below the rod break. In some instances, even replacing complete tapers with numerous rod breaks.

CONCLUSION

Performing a root cause failure analysis focused on the operational parameters, proper material selection, and metallurgical findings of the current failures is vital in optimizing the beam pump system on specific regions. A generic approach to all wells should be avoided as each one is unique and presents its own challenges. These RCFA studies result in lower operating costs and increase system efficiency, as seen with operator ‘A’ in the MidCon region.

REFRENCES

1. Ellithorp, B., Rowlan, O. L., & McCoy, J. N. (2017). Improve horizontal rod pump operations utilizing isolated tailpipe. *Proceedings of the Southwestern Petroleum Shortcourse, Texas Tech University*.
2. Agbaji, A. L. (2011). Optimizing the planning, design and drilling of extended reach and Complex wells. *SPE International*.
3. Rowlan, O. L., Lea, J. F., & McCoy, J. N. (2007). Overview of Beam Pump Operations. *Proceedings of the Southwestern Petroleum Shortcourse, Texas Tech University*.
4. Hein, N. W., Rowlan, O. L. Dog Leg Severity (DLS) and Side Load (SL) Recommendations to Drilling. *Proceedings of the Southwestern Petroleum Shortcourse, Texas Tech University*.

Table 1 – Initial beam design parameters utilized.

CATEGORIES	OPERATIONAL PARAMETERS		
SURFACE UNITS	640-365-168	912-365-168	1280-365-240
STROKE SPEED (SPM)	up to 8		
SUCKER RODS	KD (115ksi min)	KDP (125ksi min)	
TAPERS	87 (1” – 7/8” to bottom)		
NUMBER OF GUIDES	4-per	6-per	8-per
GUIDE GEOMETRY	King Cobra (7”)		
GUIDE MATERIAL	PPA		
PUMP SIZE	1-1/4"	1-1/2"	1-3/4"

Table 2 – Optimized beam design parameters after identified challenges.

CATEGORIES	OPERATIONAL PARAMETERS		
SURFACE UNITS	640-365-168	912-365-168	1280-365-240
STROKE SPEED (SPM)	up to 6.5		
SUCKER RODS	KDP (125ksi min)		
TAPERS	78 (7/8”, 1” on bottom)	878 (1”, 7/8”, 1” on bottom)	
NUMBER OF GUIDES	4-per	6-per	
GUIDE GEOMETRY	King Cobra Low Turbulence (9”)		
GUIDE MATERIAL	PPS		
PUMP SIZE	1-1/4"	1-1/2"	1-3/4"

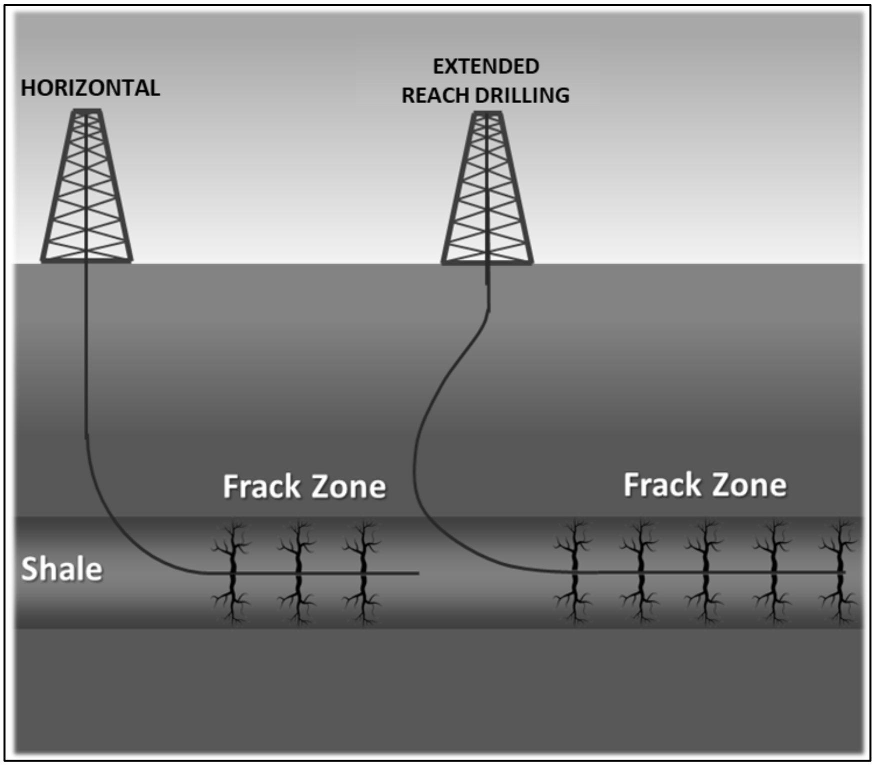

Figure 1 – Model showing the larger frack zone obtained with Extended Reach Drilling.

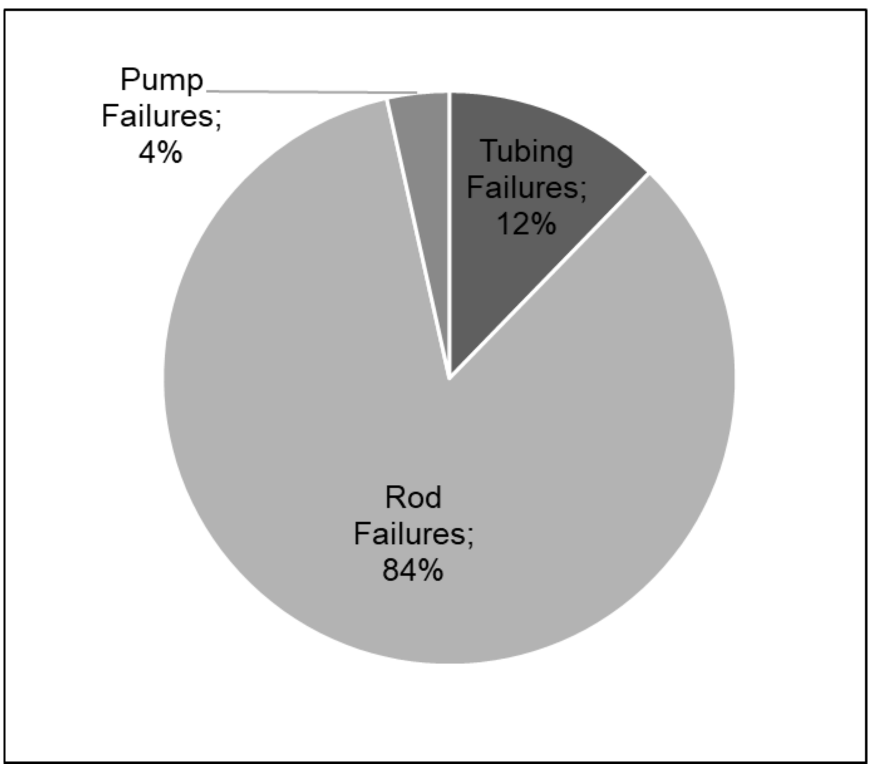

Figure 2 – Failure categories observed in the 1-year failure review.

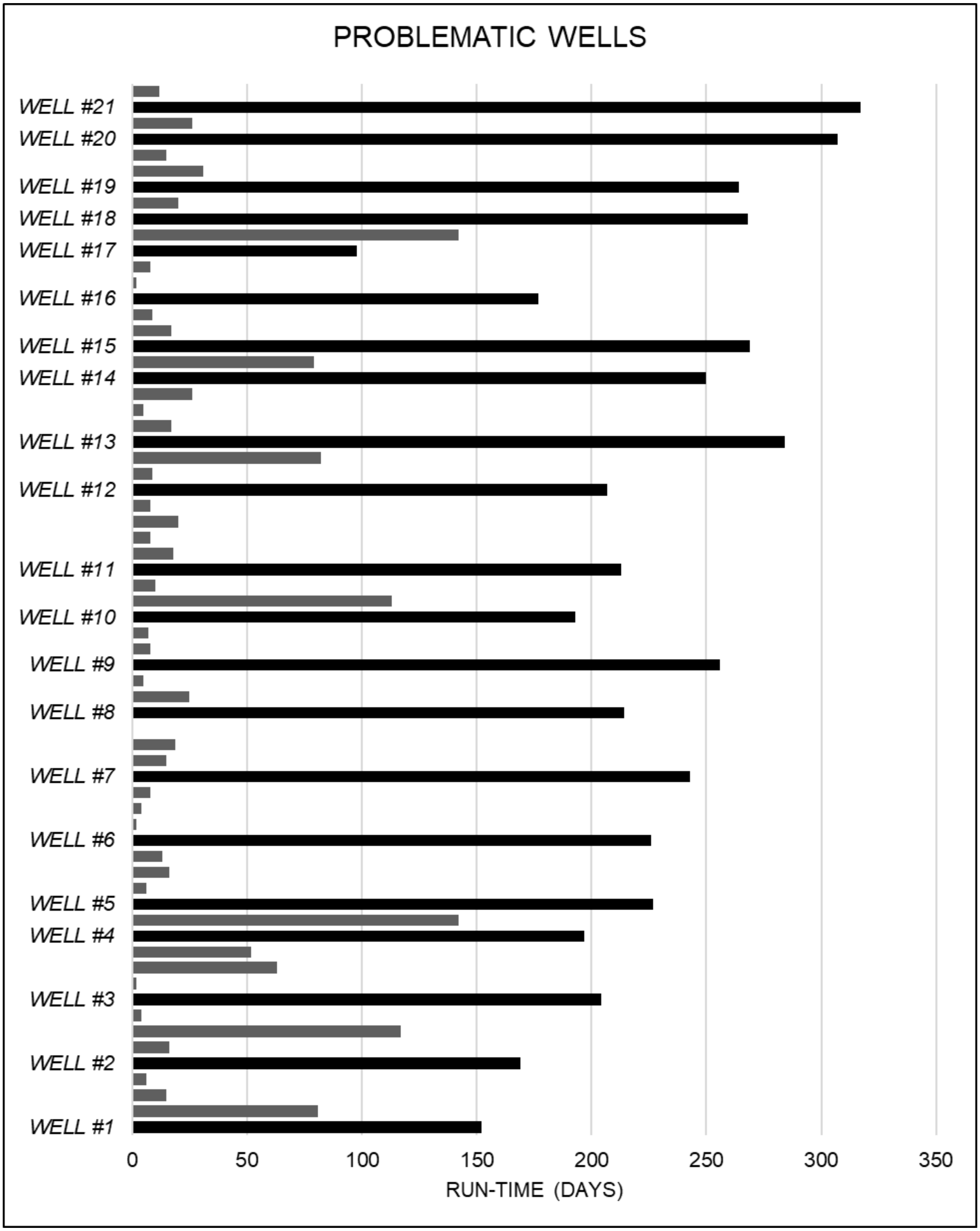

Figure 3 – Problematic wells identified with its 1st time run times (black) and repeated failures (gray).

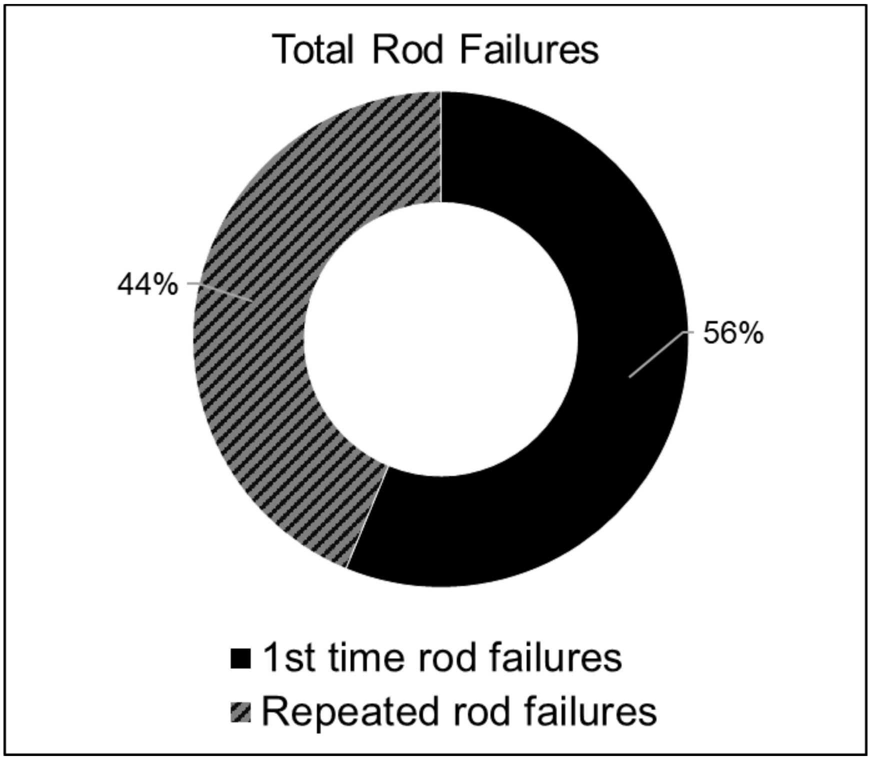

Figure 4 – Total rod failures showing the breakdown of repeated failures.

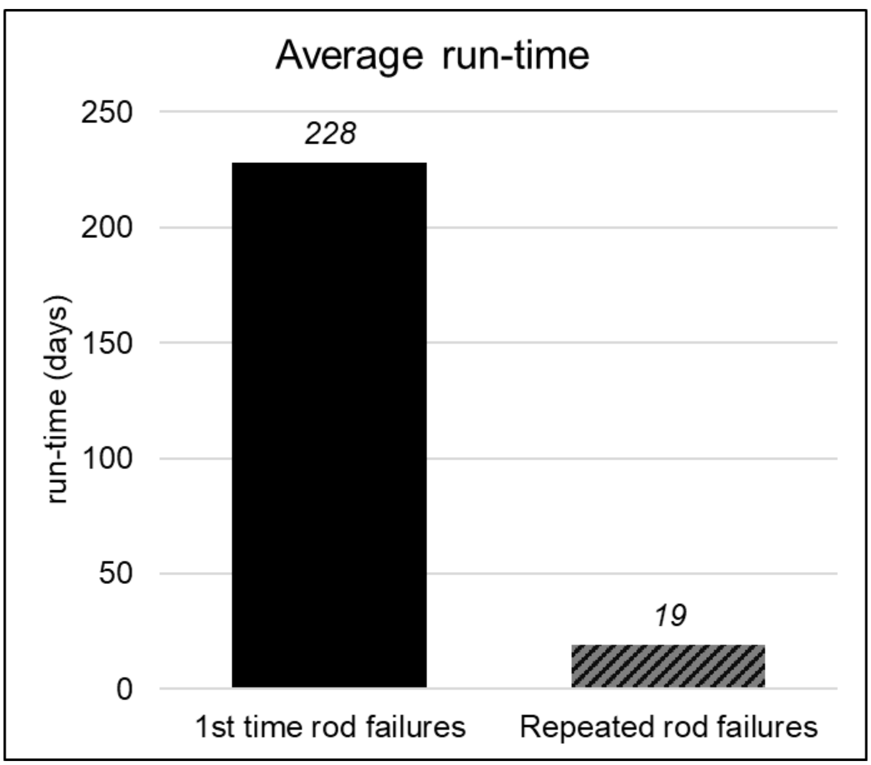

Figure 5 – Total rod failures showing the breakdown of repeated failures.

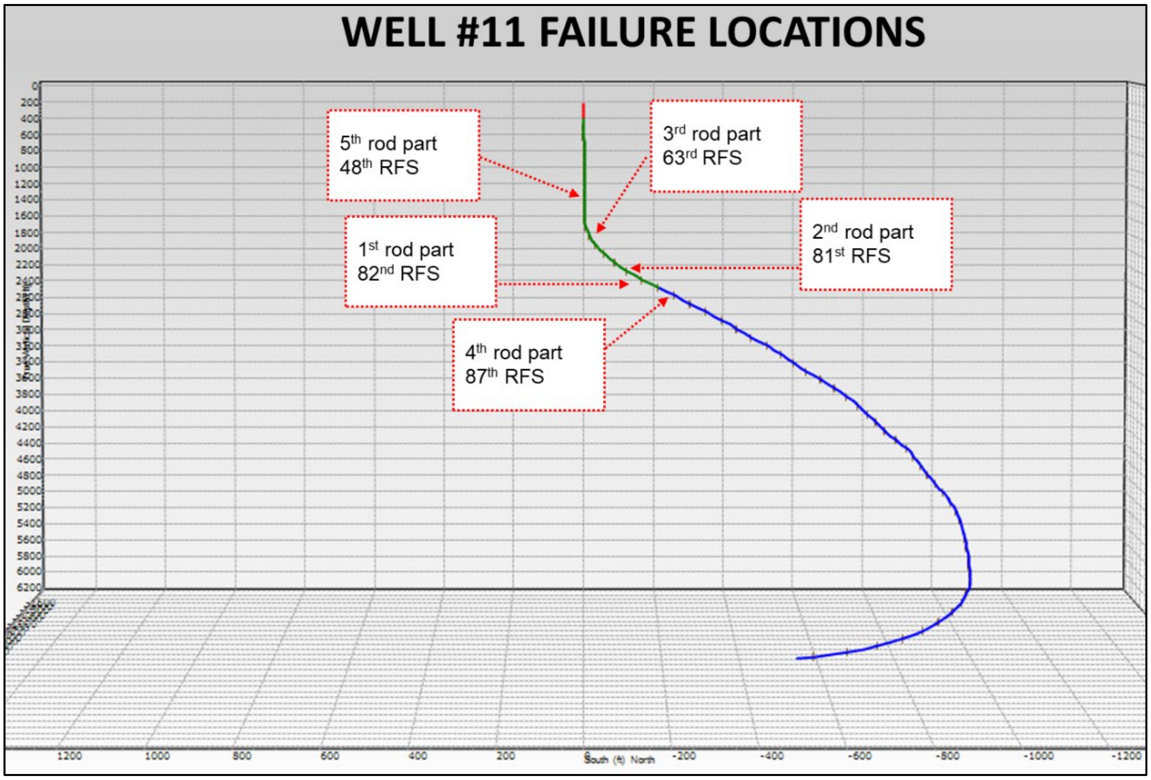

Figure 6 – Well #11 wellbore deviation with its five rod failure locations plotted.

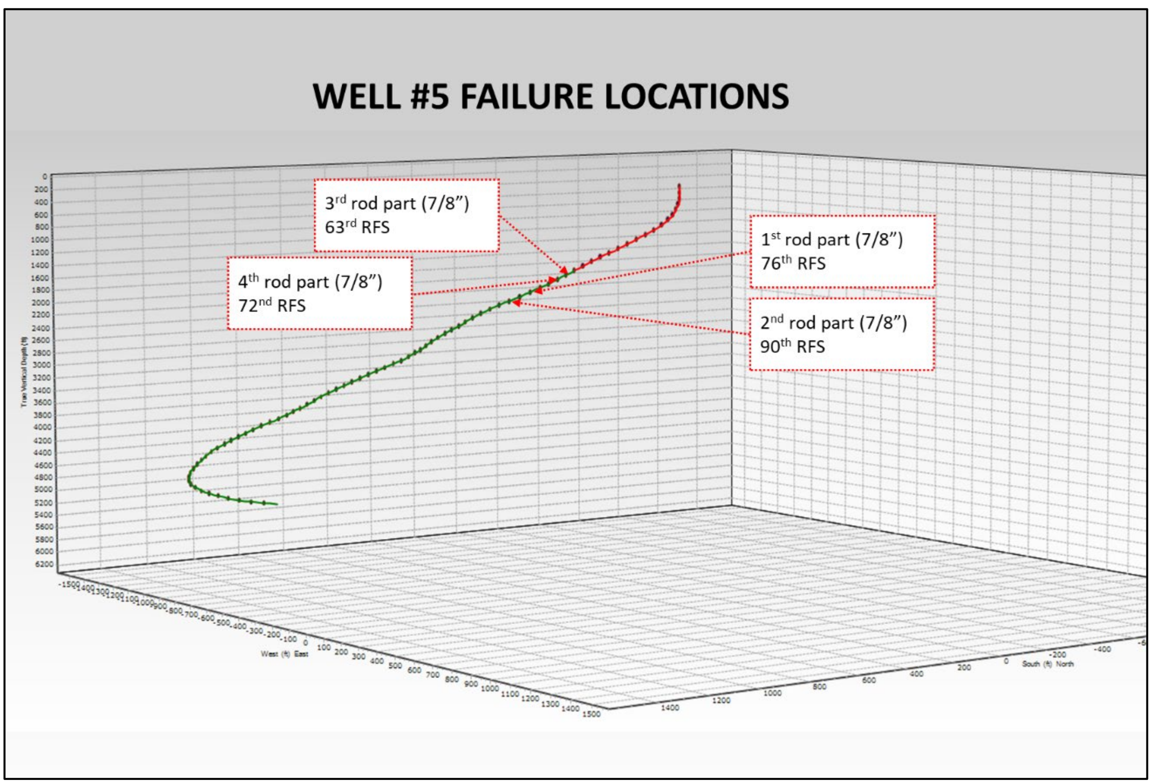

Figure 7 – Well #5 wellbore deviation with its four rod failure locations plotted.

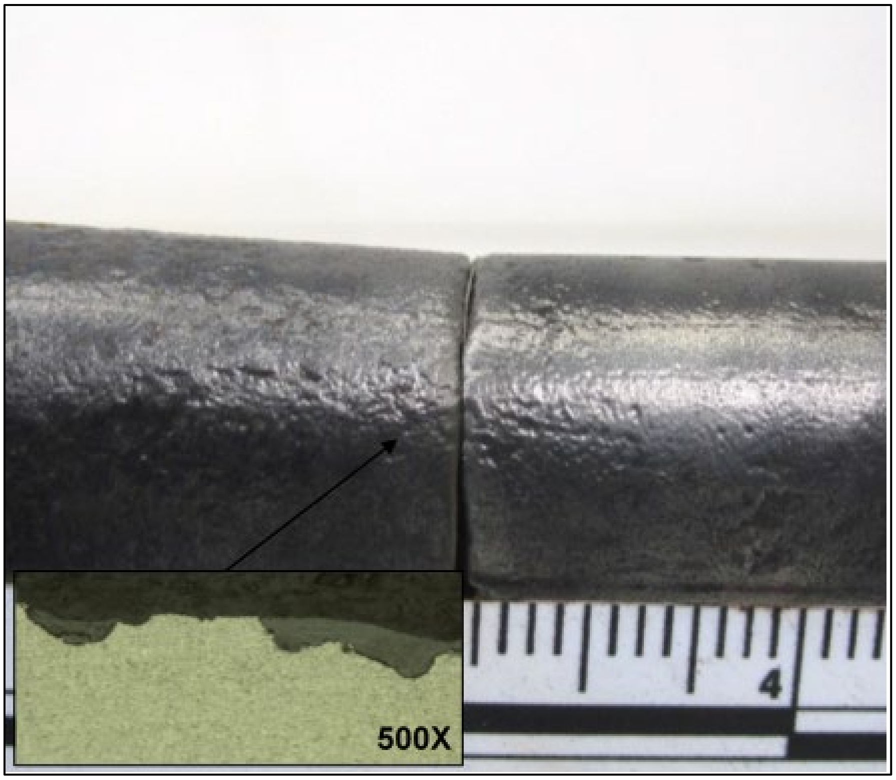

Figure 8 – Rod break presenting corrosion, metallurgical analysis confirming pitting (bottom left).

Figure 9 – Rod break presenting corrosion at initiation and flexural loading conditions (dual shear-lips).

Figure 10 – Rod break occurring at end of molded guide section with flexural loading conditions.

Figure 11 – Significant corrosion attack on T-coupling observed.

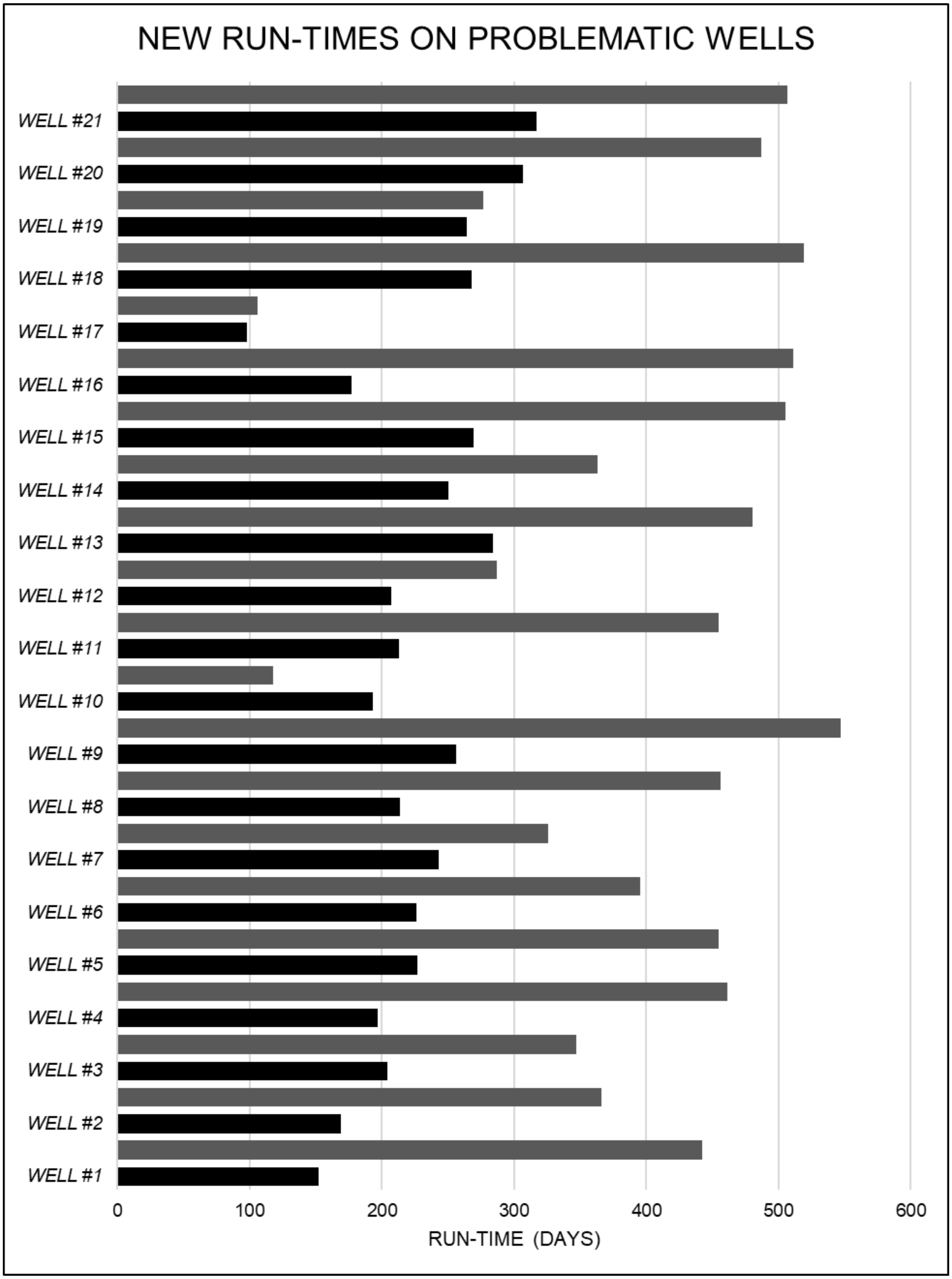

Figure 12 –Post- corrective actions, wells identified with its 1st time run (black) and new run-times (gray).