CATHODIC PROTECTION OF COILED ROD STRINGS IN RECIPROCATING APPLICATION

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ABSTRACT

Building upon the successes of cathodically protected rod strings in rotary applications, this study extends the evaluation to reciprocating operations using anode-coated coiled rod strings. The paper presents results from a pilot project involving four wells for a large California oil and gas producer, in one case, achieving a remarkable 11-fold improvement in Mean Time to Failure (MTF) compared to historical performance. Prior to the trial, wells with high water-cut and elevated CO_2 content experienced frequent rod string failures—typically within six months—despite optimized rod compositions, use of both rod and tubing rotators, and corrosion inhibition treatments. The introduction of anode-coated rod strings combined with lined tubing reversed this trend, prompting the deployment of over 20 additional installations.

OPERATING CONDITIONS

A large oil and gas producer in California experienced recurring issues across several reciprocating wells in two mature waterflood fields characterized by elevated CO_2 levels. One of the fields also consisted of an unconsolidated sand formation. The fluid composition from wells in these fields yield over 95% water, necessitating high fluid handling rates. As a result, several wells required frequent workover of various components within the downhole system. Commonly degraded components included the tubing string, on-off tool, rod string, and downhole pump. Solutions to failures included upgrading the material used for the component, which included converting bare to lined tubing as a proactive measure. The high produced fluid volumes rendered the use of corrosion inhibitor economically impractical. The following tables present details of the fluid composition, downhole conditions, tubing design, and pump data for four wells from these fields:

Table 1 Fluid composition and downhole conditions

Well ID	1	2	3	4
API Gravity	29.0	28	24	24
Oil Rate (bbl)	20	30	9	45
Water Rate (bbl)	500-550	920	750	1400
Water Cut (%)	95	97	98	96
Overall production rate (bbl/d)	520 - 570	950	759	1445
Solids content	Moderate	Moderate	Light	Moderate
Wellbore maximum DLS (°/100-ft)	8.6	N/A	9.74	N/A
Downhole temperature (°F)	130	130	160	130
Continuous Inhibition	YES	NO	NO	NO

Table 2 pump data and production tubing design

Well ID	1	2	3	4
	Pre-Trial	Pre-Trial	Pre-Trial	Pre-Trial
Rod Rotator (Y/N)	Y	Y	Y	Y
Rod Description	KD 8-6 taper	1-in. AISI 4120M	D - 1-in.	D - 1-in.
Tubing Design	Polylined J-55	Polylined J-55	Polylined J-55 3.5/2.65	Polylined J-55
Tubing Rotator Y/N	NO	NO	NO	NO
String Length (ft)	3200	2872	3200	2112
Pump Depth (ft)	3200	2972	3295	2212
Pump type/model/size	30-275 SWOS 24-3-3	25-275 SWOS 24-3-3	30-225 THPV 24-3-3-0 (POSITIVE STANDING VALVE)	30-325 SWOS 24-3-3
Pumpjack type	C640-365-168	C640-365-168	C912-365-192	C1280-365-192
Stroke rate (spm)	6.9	7.3	7.8	7.8
Stroke Length (in.)	168	168	192	192

TRIAL STRING INSTALLATIONS

Representatives from the producer attended SWPSC in 2022 and learned of an innovation which incorporated cathodic protection together with coiled rod strings through the use of an anodic metallic coating in PCP trial applications. Subsequently, over a six-month period, the producer acquired and deployed four anodic coiled rod strings as a trial of the technology in the previously described wells. Three of the wells were located in one field and the fourth was located in a second nearby field.

In December 2022, the first of four 1-inch diameter trial strings of D-grade low strength AISI 4320M base rod composition with anodic coating was installed. By May 2023, all four wells were operating with anodic rod strings. Based on historical performance, the producer also upgraded tubing strings with poly-lined tubing prior to these installations.

TRIAL STRING PERFORMANCE BY WELL

Well 1

Table 3: Well 1 Operating details and string design

Well 1		
	Pre-Trial	Trial
Improvement in MTF	Historical	8X
Rod Rotator (Y/N)	Y	Y
Rod Description	KD 8-6 taper	1-in AISI 4320M "D" with anode
Tubing Design	Polylined J-55	Ultratube J-55 3.5/2.5
Tubing Rotator Y/N	NO	NO
String Length (ft)	3200	3010
Pump Depth (ft)	3200	3090
Pump type/model/size	30-275 SWOS 24-3-3	30-275 SWOS 24-3-3
Pumpjack type	C640-365-168	C640-365-168
Stroke rate (spm)	6.9	6.9
Stroke Length (in.)	168	168

Prior to the trial, the production tubing in this well experienced above-average rates of damage as a result of considerable deviation. Coiled rod strings had been previously used but the repetitive contact between the rod and tubing would remove the naturally occurring protective surface film produced by corrosion, advancing the rate of degradation of these areas of the rod strings. Due to the repetitive contact, in addition to high production volumes, corrosion inhibition was not practical and average run time between workovers was lower than average.

A few months after deployment of the anodic string, the well required a workover due to failure of a different downhole component. During the workover, there were observations of damage to the rod string. After further evaluation, areas of the rod string exhibited MIC-related damage despite the anodic coating remaining intact. The affected rod was replaced with new rods, and a biocide treatment was performed. The treatment successfully terminated the bacterial source and permitted 17 consecutive months of service. Overall, the anodic rod string increased run time by over 8X, operating without failure prior to retirement. Disposal of the retired rod string followed standard procedures for sucker rods.

Well 2

Table 4: Well 2 Operating details and string design

Well 2		
	Pre-Trial	Trial
Improvement in MTF	Historical	11X
Rod Rotator (Y/N)	Y	Y
Rod Description	1-in. AISI 4120M	1-in AISI 4320M "D" with anode
Tubing Design	Polylined J-55	Polylined J-55 2.875/1.90
Tubing Rotator Y/N	NO	NO
String Length (ft)	2872	2877
Pump Depth (ft)	2972	2977
Pump type/model/size	25-275 SWOS 24-3-3	25-275 SWOS 24-3-3
Pumpjack type	C640-365-168	C640-365-168
Stroke rate (spm)	7.3	7.3
Stroke Length (in.)	168	168

Well 2 historically suffered worn out pumps due to a high concentration of sand and contained the highest concentration of CO_2 within the trial, at over 12%. This well started operating with lined tubing as a preventive, however declining performance over time led it to become a trial candidate. The anodic rod string improved performance by almost 11X. After the eventual rod failure, the rod was repaired simply by welding it back together and was reinstalled and operated with the same anode-coated rod string for an additional 230 days.

Well 3

Table 5: Well 3 Operating details and string design

Well 3		
	Pre-Trial	Trial
Improvement in MTF	Historical	4X
Rod Rotator (Y/N)	Y	Y
Rod Description	D - 1-in.	1-in AISI 4320M "D" with anode
Tubing Design	Polylined J-55 3.5/2.65	Polylined J-55 3.5/2.65
Tubing Rotator Y/N	NO	NO
String Length (ft)	3200	3200
Pump Depth (ft)	3295	3295
Pump type/model/size	30-225 THPV 24-3-3-0 (POSITIVE STANDING VALVE)	30-225 THPV 24-3-3-0 (POSITIVE STANDING VALVE)
Pumpjack type	C912-365-192	C912-365-192
Stroke rate (spm)	7.8	7.7
Stroke Length (in.)	192	192

This well was situated in a different field from the other three in the trial. The flood may be described as a water flood with 8 – 10% CO_2. The fluid had light solids and this well utilized a large pumping unit system to produce high fluid volumes. The previous coiled rod string suffered pitting after a short period and was replaced in April 2023 with the trial anodic coiled rod string. The trial string performed 4X as long as historical performance and during this time the well was not serviced at all. The rod string was surfaced after eventual rod failure in April 2025 and subsequently retired. As with Well 1, disposal of the retired rod string followed standard procedures for sucker rods.

Well 4

Table 6: Well 4 Operating details and string design

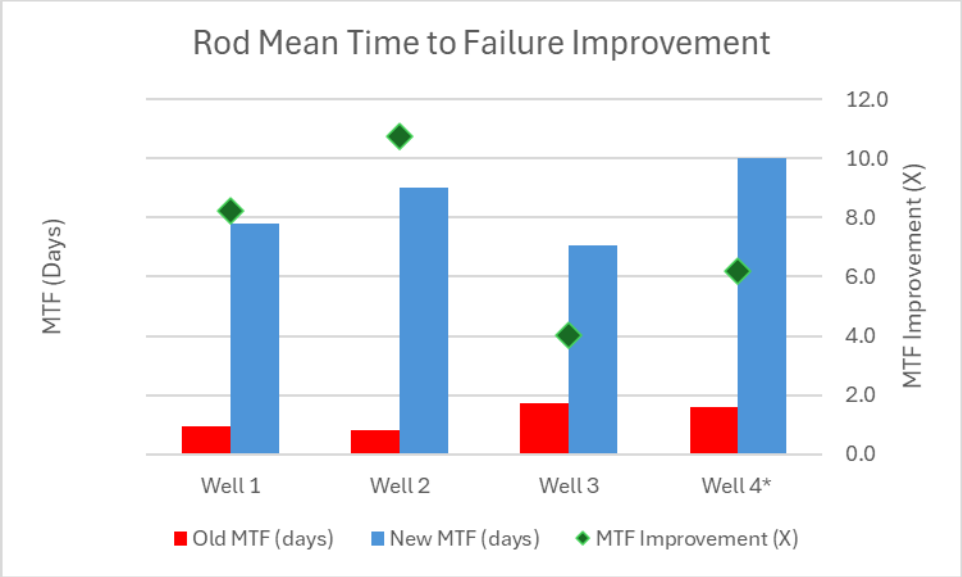
Well 4		
	Pre-Trial	Trial
Improvement in MTF	Historical	6X
Rod Rotator (Y/N)	Y	Y
Rod Description	D - 1-in.	1-in AISI 4320M "D" with anode
Tubing Design	Polylined J-55	Polylined J-55
Tubing Rotator Y/N	NO	NO
String Length (ft)	2112	2639
Pump Depth (ft)	2212	2745
Pump type/model/size	30-325 SWOS 24-3-3	30-325 SWOS 24-3-3
Pumpjack type	C1280-365-192	C1280-365-192
Stroke rate (spm)	7.8	7.8
Stroke Length (in.)	192	192

Historical problems with this location involved primarily pump issues and difficulties with the on-off tool (switched to “On-only” tool). There were also 4 failures attributed to the previous rod strings and 2 workovers due to tubing holes. Following installation, the anodic rod string has surpassed previous run time by over 6X and continues to operate at the time of this writing.

CONCLUSIONS

The wells selected by the producer were historically impacted with costly recurring operating problems, involving sand and corrosion. Each of the four trial wells’ anodic strings was considered successful in minimizing rod string failures and associated workover expenses. The trial anodic rod strings resulted in improvements in rod MTF between 4X and over 11X baseline performance.

Figure 1 MTF Improvement



Consequently, and despite the operational challenges, these locations are viable with the improvement in rod string performance. With the accomplishments of these trial wells regarded favourably, the producer has extended the deployment of the anodic coiled rod strings into over 20 additional well locations.