EVALUATION OF GRADE C SUCKER ROD AND T-COUPLING USAGE IN SAN ANDRES

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ABSTRACT

In 2016, a recommendation was made to begin utilizing API Grade C when replacing sucker rods in San Andres wells, or in wells less than 5,000 ft in total depth. This recommendation was primarily driven by lower material cost compared with the Grade D and KD sucker rods that were standard at the time (equivalent to API Grade D Alloy and API Grade D Special, respectively). **Tables 6 and 7** provide the chemical and mechanical properties of these rod grades. Additional benefits of switching to API Grade C rods were thought to be equal or better corrosion resistance and tubing leak reduction, both related to the lower hardness rating of the rods. It was also recommended that Class T Couplings be considered as an alternative to Spray Metal couplings, as the hardness of the Spray Metal coating may lead to an increased rate of tubing leaks, which have higher repair costs than rod failures.

As with any initiative that deviates from familiar practices, there is some concern about widespread use until sufficient data are gathered to prove the benefits and ensure the correct decision is being made. Because failure frequency is a key metric when evaluating artificial lift performance, and because it can take several years to develop sufficient data, it was preferred to evaluate shorter-term performance to accelerate implementation. This was accomplished by developing statistical data for sucker rod and coupling installations and failures over a specific period, then comparing the failure rate of the Grade C rods and Class T couplings with the Grade KD rods and Spray Metal couplings that had previously been the standard. Analysis revealed that over the period evaluated, the Grade C rods and Class T couplings were not showing an increased failure rate, thereby providing support to start expanding their use in Permian San Andres wells, which is expected to result in significant cost savings.

To aid in understanding the corrosion differences between Grade C rods and Grade KD rods, corrosion coupons were constructed from sections of actual rods and placed in several wells of varying characteristics (lift type, corrosion program, etc.). The results of this testing proved that there was not a significant difference in corrosion between Grade C and Grade KD sucker rods.

INTRODUCTION

When standardizing equipment, there is always a balance between developing a limited inventory of options while optimizing overall cost. In the fields where Grade C rods are now being considered, Grade D and KD rods had been the long-time standard, as they had the load capacity to meet most applications. Grade C rods have a minimum tensile strength of 60 ksi (kips per square inch), whereas Grade D rods have a minimum tensile strength of 90 ksi. There was also a concern about the use of Grade C rods in CO_2-flooded fields, as there might be increased corrosion and therefore more rod failures. As recent lower oil prices have driven cost reduction efforts, we re-evaluated whether Grade KD rods were necessary in shallower San Andres wells or if there might be an opportunity to reduce costs by switching to Grade C rods.

When evaluating the impact of any artificial lift equipment on total operating expense (Opex), one must consider both the initial material cost and the impact on the well's full lifecycle cost. If the cost savings of using a less expensive material is offset by a shorter usable life and increased well intervention costs, then it does not make economic sense to adopt the use of that material. When considering the switch to Grade C rods, there were several cost-saving opportunities identified. The first was the material cost itself. Another was a potential reduction in tubing-related failures, as Grade C rods have a lower hardness than Grade KD sucker rods. Total intervention costs for a tubing failure are about 30% higher than those of a parted rod, so there is a significant cost-saving opportunity by having rods fail rather than the tubing.
There was some concern about increased corrosion of Grade C rods in CO_2 applications, because several of the San Andres units are CO_2 floods. While most vendors market Grade K and Grade KD rods as being

more appropriate for corrosive applications, our internal materials expert determined that the alloy content should be greater than 5% to have a meaningful impact on corrosion resistance, whereas the American Petroleum Institute (API) Specification 11B only requires 1.15% alloy content for Grade KD Special Alloy rods. However, the alloy additions for the high-strength grades are for hardenability (attaining strength and toughness), and not for corrosion resistance improvement. The lower hardness of Grade C rods should also reduce the susceptibility to hydrogen sulfide (H_2S) embrittlement. It is estimated that steels with a Rockwell C hardness greater than 23 are susceptible to H_2S embrittlement. Typically, API Grade C sucker rods have a Rockwell C hardness less than 23, while API Grade D sucker rods normally have a Rockwell C hardness greater than 23, so API Grade C sucker rods should be less susceptible to H_2S embrittlement.

IMPLEMENTATION

The two units selected to pilot the use of Grade C Rods and Class T Couplings are both San Andres CO_2 floods with a typical producing interval depth of approximately 5,000 ft. In both of these units, Grade KD rods and Spray Metal couplings were being utilized for most applications. Wells with sucker rods pumps in these fields are treated for corrosion by applying batch treatments of corrosion inhibitor. The installation of Grade C rods and Class T couplings was done during workovers after equipment failures.

In pilot field #1, 45 installations of Grade C rods were completed over a period of about 18 months. During this same period, 212 installations of non-Grade C rods were installed, most of which were Grade KD. For the analysis, installations of both new and re-run rods were included, assuming the re-run rods were properly inspected to ensure they were free of corrosion and defects prior to installation. During this period, 23% of the installations utilizing non-Grade C rods experienced a failure, compared to only 18% of the installations using Grade C rods. Failures classified as parted rods were similar for both groups, with 8% of the non-Grade C rods parted versus 11% for the Grade C rods. For the wells with Grade C rods and Class T couplings, only 2% resulted in a tubing leak, compared with 7% for the wells with non-Grade C rods and Spray Metal couplings.

In pilot field #2, 20 installations of Grade C rods were completed over a 12-month period, during which there were 238 installations of non-Grade C rods, again mainly Grade KD rods with Spray Metal couplings. The failure statistics for this pilot were similar to the field #1 results, with the Grade C rods and Class T couplings having failure statistics similar to the non-Grade C rods and Spray Metal couplings.

Although this study was of short duration, both pilots showed there was no increase in failures for the Grade C rods and Class T coupling installations compared with the Grade KD rods and Spray Metal couplings. This type of analysis can help justify the continued and potentially expanded use of Grade C rods and Class T couplings to take advantage of the material cost savings. Performance will continue to be monitored to determine whether these trends continue. The results of these two pilots are summarized in **Tables 1-4**.

ADDITIONAL CORROSION TESTING

Given the successful performance of the Grade C rods in these pilots, we still needed to understand their corrosion properties compared with the Grade KD rods, because both of these fields are CO_2 floods, which have high corrosion potential. To do this, we made corrosion coupons out of both Grade C and Grade KD rods (2" sections) and placed them in identical positions on the flow lines of six wells in pilot field #2. To test a variety of conditions, the wells were selected with varying gas/liquid ratios. Two of the wells were selected because they did not have an active corrosion inhibition program. The coupons were precisely weighed before installation so we could accurately measure the metal loss over time. The coupons were installed and left in service for 90 days before being pulled and precisely weighed again.

The results of this corrosion test, as summarized in **Table 5.** showed higher corrosion of the Grade C rods in three wells, lower corrosion of the Grade C rods in two wells, and an undetermined result in one well due to the coupon becoming dislodged, which may have impacted the results. Excluding that well, only one of the wells showed any corrosion, i.e., it exceeded the corrosion rate of one MPY (mil/year). According to our corrosion expert, these results show there is not a discernable difference in the corrosion properties of Grade C rods and Grade KD rods.

SUMMARY

Lower material cost and reduced potential for failure associated with the lower hardness of Grade C rods and Class T couplings make them more attractive than Grade D Alloy rods and Spray Metal couplings for San Andres wells, which are relatively shallow and have a low load requirement. Pilot tests were conducted in two fields for over a year, and in both cases there was no discernable difference in failure statistics when comparing Grade C and Grade KD rods or Class T and Spray Metal couplings. To understand the corrosion properties of Grade C versus Grade KD rods, corrosion coupons were constructed of actual rod pieces and placed in the flow lines of six wells. The results of the corrosion testing showed there was no discernable difference in the corrosion rates between Grade C and Grade KD rods in those wells.

REFERENCES

1. API SPEC 11B: Specification for Sucker Rods, Polished Rods and Liners, Couplings, Sinker Bars, Polished Rod Clamps, Stuffing Boxes, and Pumping Tees, 27th Edition (With Errata 1, October 2010, Errata 2, February 2011)

2. https://petrowiki.org/Sucker_rods

Table 1 – Failure Statistics for Rods in Pilot Field #1

Field #1 Rod Results					
Rod Type	Installs	Failed	Failure %	Rod Parts	% Rod Parts
Non C-Rod	212	48	23%	16	8%
C-Rod	45	8	18%	5	11%

Table 2 – Failure Statistics for Couplings in Pilot Field #1

Field #1 Coupling Results							
Coupling Type	Installs	Failed	Failure %	Tubing Leaks	Tubing Leaks %	Coupling Failure	Coupling Fail %
Spray Metal	212	48	23%	14	7%	2	1%
Class T	44	6	14%	1	2%	1	2%

Table 3 – Failure Statistics for Rods in Pilot Field #2

Field #2 Rod Results					
Rod Type	Installs	Failed	Failure %	Rod Parts	% Rod Parts
Non C-Rod	238	24	10%	9	4%
C-Rod	20	3	15%	1	5%

Table 4 – Failure Statistics for Couplings in Pilot Field #2

Field #2 Coupling Results							
Coupling Type	Installs	Failed	Failure %	Tubing Leaks	Tubing Leaks %	Coupling Failure	Coupling Fail %
Spray Metal	238	24	10%	10	4%	0	0%
Class T	26	3	12%	1	4%	0	0%

Table 5 – Results of Rod Coupon Corrosion Pilot

	Grade D Alloy				Grade C			
Well	Initial Weight	Final Weight	Weight Loss	Corrosion rate (mils/yr.)	Initial Weight	Final Weight	Weight Loss	Corrosion rate (mils/yr.)
1**	147.00	146.88	0.13	0.67	150.53	150.31	0.22	1.17
2	149.07	149.05	0.01	0.08	145.89	145.86	0.03	0.15
3	148.10	147.93	0.18	1.11	*145.16**	*142.58**	*2.58**	*16.06**
4	148.11	148.08	0.02	0.13	145.88	145.85	0.03	0.18
5	149.71	149.68	0.03	0.15	149.66	149.64	0.02	0.13
6	152.20	152.16	0.04	0.21	146.61	146.79	N/A	N/A
* Grade C coupon was found to have dislodged from choke and therefore would have had larger surface area exposed to production fluids. **Flowing well with no corrosion inhibitor program. mils = 0.001 inch								

Table 6 – API Spec 11B Sucker Rod Chemical Composition

Grade	Chemical composition
K	AISI 46XX series steel*
C	AISI 10XX series steel*
	AISI 15XX series steel*
D carbon	AISI 10XX series steel*
	AISI 15XX series steel*
D alloy	AISI 41XX series steel*
D special	Special alloy shall be any chemical composition that contains a combination of nickel, chromium, and molybdenum that total a minimum of 1.15 % alloying content.
* Or an equivalent international series number steel.	

Table 7 – API Spec 11B Sucker Rod Mechanical Properties

Grade	Minimum Yield (0.2 % offset)		Minimum Tensile		Maximum Tensile	
	psi	MPa	psi	MPa	psi	MPa
K	60,000	414	90,000	621	115,000	793
C	60,000	414	90,000	621	115,000	793
D	85,000	586	115,000	793	140,000	965