XYZ COMPANY

ROTATING CYLINDER ELECTRODE CORROSION INHIBITOR EVALUATION

Report by:
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1 INTRODUCTION

Two continuous and two batch corrosion inhibitors were submitted for third party evaluation by XYZ Company. The inhibitors are to mitigate downhole corrosion in producing gas wells. Due to high flow rates and CO_2 the production tubing is experiencing aggressive corrosion. The inhibitors were evaluated in the Rotating Cylinder Electrode (RCE) apparatus to determine corrosion performance under high shear conditions.

2 BRINE

Synthetic brine was prepared for use in the testing based on analysis of the field brine. The composition of the synthetic brine is shown in Table 1 below.

Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Chloride (mg/L)	Bicarbonate (mg/L)	Sulphate (mg/L)
2140	17	78	9	2750	900	124

Table 1: Synthetic Brine Composition

The water was purged for a minimum of 2 hours with pure CO_2 and the pH was measured at 5.91.

3 INHIBITOR SAMPLES

The following table lists the products received for use in the RCE evaluation.

Chemical	Product Type	Test Treatment
A	Continuous Inhibitor	25 & 50 ppm
B	Continuous Inhibitor	25 & 50 ppm
C	Batch Inhibitor	1:1 with Diesel
D	Batch Inhibitor	1:1 with Diesel

Table 2: Products Received

4 ROTATING CYLINDER ELECTRODE TEST PARAMETERS

4.1 Purge Gas

A 100% carbon dioxide gas purge was started in the cells prior to transferring the synthetic brine. This same purge gas was maintained at a high rate for the duration of the test.

4.2 Test Temperature

A temperature range through the tubing string of 27 °C to 90 °C is expected in the field. A temperature of 45°C was selected for the test to reduce formation of protective iron carbonate scales and correlate with the worst case temperature for corrosion activity based on field observations of the tubing string.

4.3 Continuous Inhibitor Application

The continuous inhibitors were initially treated at a 25 ppm dose into the test cells prior to immersion of the electrode. A subsequent 25 ppm dose was applied prior to the increase in rotation rate at 18 hours.

4.4 Batch Inhibitor Application

The batch inhibitors were both diluted 1:1 with diesel. Electrodes were dipped in the batch solution for 10 seconds followed by a 1 minute drip. This was followed by 2 consecutive rinses in fresh purged synbrine for a minute each. The rotators were set at 100 rpm during the batch filming procedure.

4.5 Shear Application

Assessment of inhibitor performance under shear was evaluated by varying the rotation speed of the RCE test apparatus. The initial 4 hours were under high shear with the rotation rate set at 5000 rpm. The rotation and shear were reduced overnight with the rpm set at 2000. Rotation was then increased again to 5000 rpm for another 4 hours and then reduced to 2000 rpm for the final 2 hours of the test. The following chart outlines the simulated shear stress applied during the test.

Rotation Speed (rpm)	Laminar Velocity at Electrode Surface (m/s)	Wall Shear (Pa)
2000	1.2	6.7
5000	3.1	31.9

Table 3: Applied Shear Stress

5 RCE TEST APPARATUS

Synthetic brine was added to the jacketed RCE cells and heated by circulation of a water/glycol solution to maintain the test temperature of 45°C. A 100% CO_2 flow into each cell was established by means of a purge tube and maintained at a high rate until the experiment had concluded.

RCE counter electrodes are constructed from graphite, while the reference electrodes are single junction silver-silver chloride. The working electrodes are cylinders of 1018 carbon steel (8 x 12 mm diameter). The electrodes are degreased in solvent and weighed immediately prior to beginning the RCE test. The electrodes have a surface area of 3 cm^2 and this value is used for corrosion rate calculations. Each working electrode is mounted on a Teflon sleeve, attached to a Pine Instruments AFMSRX rotator.

LPR measurements are obtained by connecting the electrodes in each cell to a Gamry PC4-300 potentiostat and controller, via a Gamry ECM8 multiplexer. Data acquisition was by means of Gamry's DC105 software package. At the completion of the test period the working electrodes were cleaned, reweighed and examined under a low magnification optical microscope. Graphs of the LPR data, photographs of each electrode and gravimetric results are included with this report.

6 RCE DATA AND DISCUSSION

Appendix I contains graphs of the Linear Polarization Resistance (LPR) corrosion rate measurements from inhibitor testing. Weight loss corrosion rates and electrode photographs are located in Appendix II. The following table summarizes RCE test data:

Cell	LPR Corrosion Rate (mpy)					Weight Loss Corrosion Rate (mpy)
	Initial	Prior to overnight speed reduction (After 4 Hours)	Prior to speed increase (After 18 Hours)	End of speed increase (After 22 Hours)	Final	
Blank	103.11	67.63	44.58	41.39	39.55	43.91
A	10.81	2.36	1.59	2.17	0.84	3.66
B	9.84	0.34	0.15	0.29	0.14	2.44
C	1.65	0.06	0.06	0.12	0.05	3.05
D	3.58	1.01	0.26	0.47	0.25	4.27

Table 4: Inhibitor Evaluation Data Summary

6.1 Inhibitor Testing

The blank had a downward LPR trend throughout the test. This likely indicates the buildup of a passivating iron carbonate scale. The LPR corrosion rate increased and decreased with the altering of the electrode rotation rate. The overall trend was continually decreasing and did not stabilise. This shows that the passivating scale was never fully protective. The electrode had an overall moderate surface etch and a weight loss corrosion rate of 43.9 mpy.

6.1.1 Continuous Products

The continuous products both reduced the observed LPR corrosion rate to low levels in the initial high shear conditions of the test.

Continuous inhibitor A had and initial LPR corrosion rate of 10.8 mpy and decreased throughout the test. A small increase was noted in the second period of increased shear and dropped with the return to the lower shear conditions of 2000 rpm. The decreasing LPR trend suggests the product did not achieve a fully protective inhibitor film. The electrode had a mild surface etch and weight loss corrosion rate of 3.7 mpy.

Inhibitor B had an initial LPR corrosion rate of 9.8 mpy that quickly fell and stabilised below 0.5 mpy. This indicates the product provides a rapid film that is able to provide a protection under elevated shear conditions. The film displayed minimal disruption with the application of the second round of high shear. The weight loss corrosion rate was 2.4 mpy with no visible corrosion damage on the electrode surface.

6.1.2 Batch Products

Both batch inhibitors lowered the observed blank corrosion rate to low mpy values. Final LPR values were both below 0.3 mpy versus 39.6 mpy seen in the blank.

Batch product C had a low initial LPR corrosion rate of 1.7 mpy. It quickly fell and stabilised under 0.1 mpy during the initial high shear conditions of 5000 rpm. For the remainder of the test the LPR corrosion rate was 0.06 mpy with slight perturbation noted with the second period of increased shear. The electrode had a very mild surface etch with a weight loss corrosion rate of 3.1 mpy. Of note Inhibitor C batch solution displayed some separation tendency at the prescribed dilution ratio when allowed to settle. See photograph Appendix 3.

Inhibitor D had an initial LPR corrosion rate of 3.6 mpy that decreased to 1.0 by the end of the initial high shear phase. Reducing the applied shear resulted in a drop of the observed corrosion rate as the inhibitor provided a more protective and stable film. The corrosion rate increased with the second application of high shear. It recovered once the shear was reduced. The weight loss corrosion rate was 4.3 mpy and the electrode had a mild surface etch with some edge attack noted.

7 CONCLUSION

Both batch and continuous inhibitors were effective in mitigating the high corrosion rates noted in the blank. Of the 2 continuous inhibitors evaluated B would be considered the superior performer. It was able to quickly develop and maintain a protective film under high shear conditions.

Batch inhibitor C would be considered the better performer of the 2 batch inhibitors evaluated. The film applied during the batching process offered excellent protection and showed a high resistance to removal in extended periods of elevated shear. Batch inhibitor C when diluted at a 1:1 ratio in diesel will allow some separation in a stagnant batch solution. This characteristic should be noted to field personnel, ensuring that the solution is circulated to allow a homogenous solution prior to application in the wells.

Sincerely,
Cormetrics Limited

Frank Hornsby
President
Cormetrics Limited

Please note, all inhibitor samples and electrodes are stored for 6 months prior to disposal.

APPENDIX I - LPR DATA

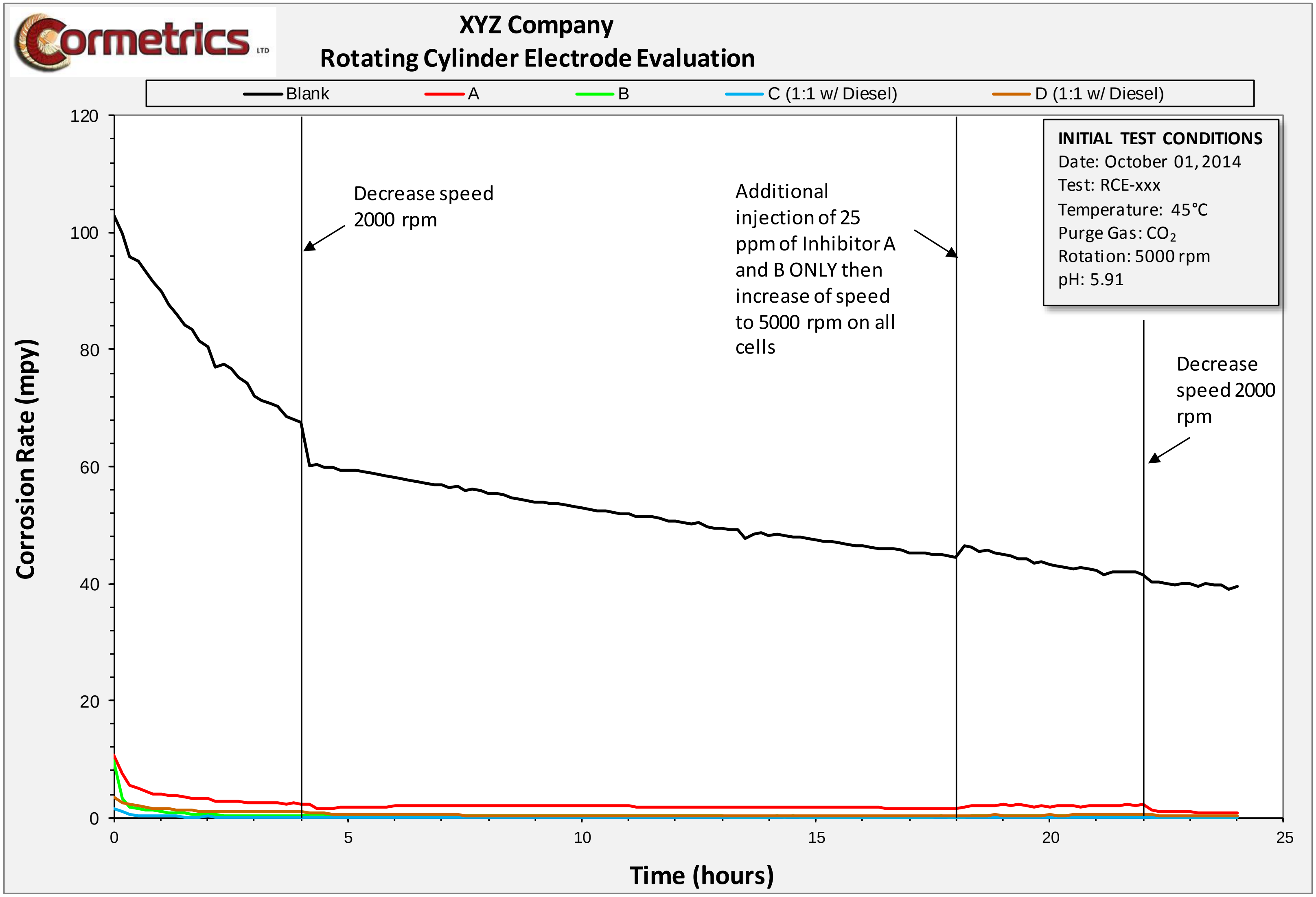


Figure 1: LPR Data

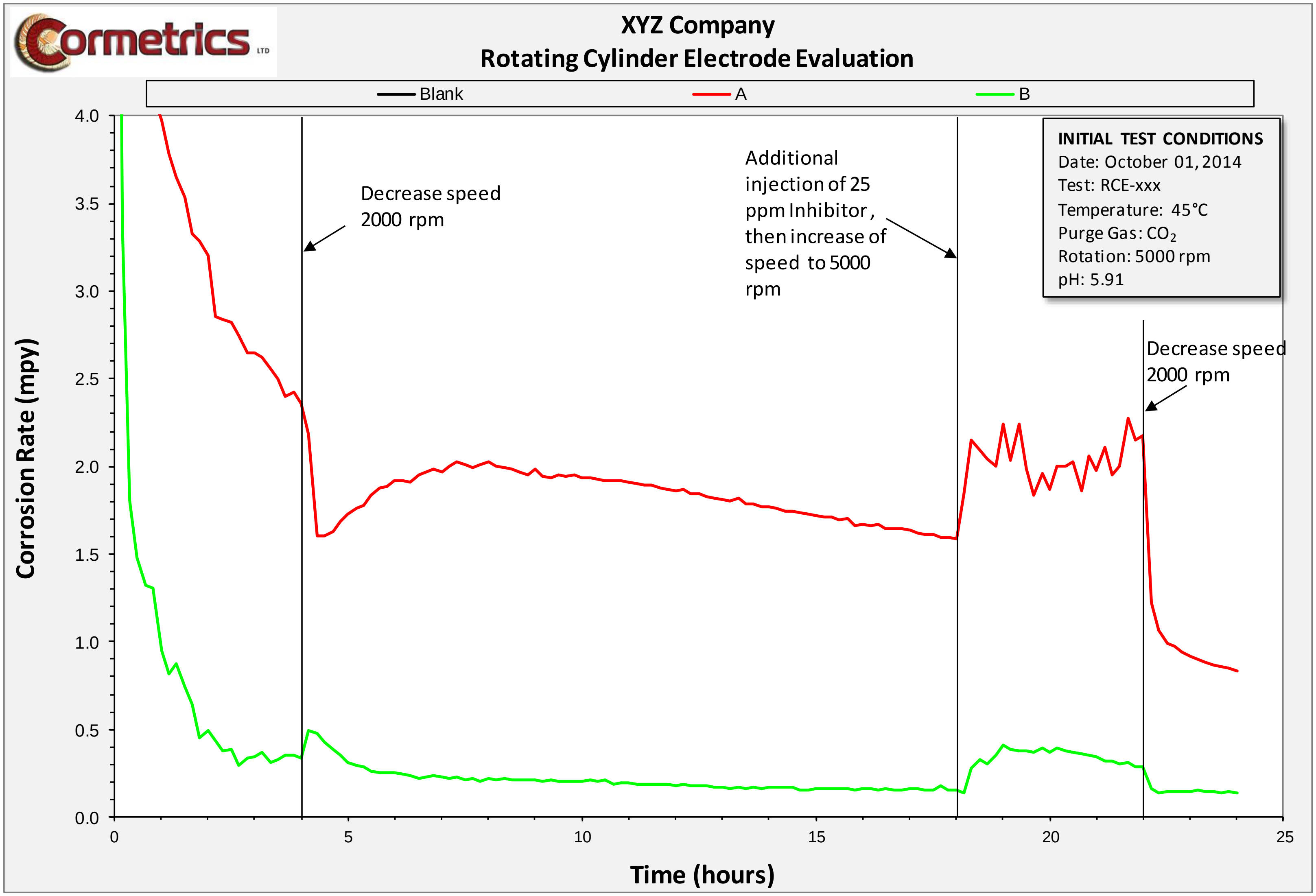


Figure 2: Continuous Inhibitors LPR Data

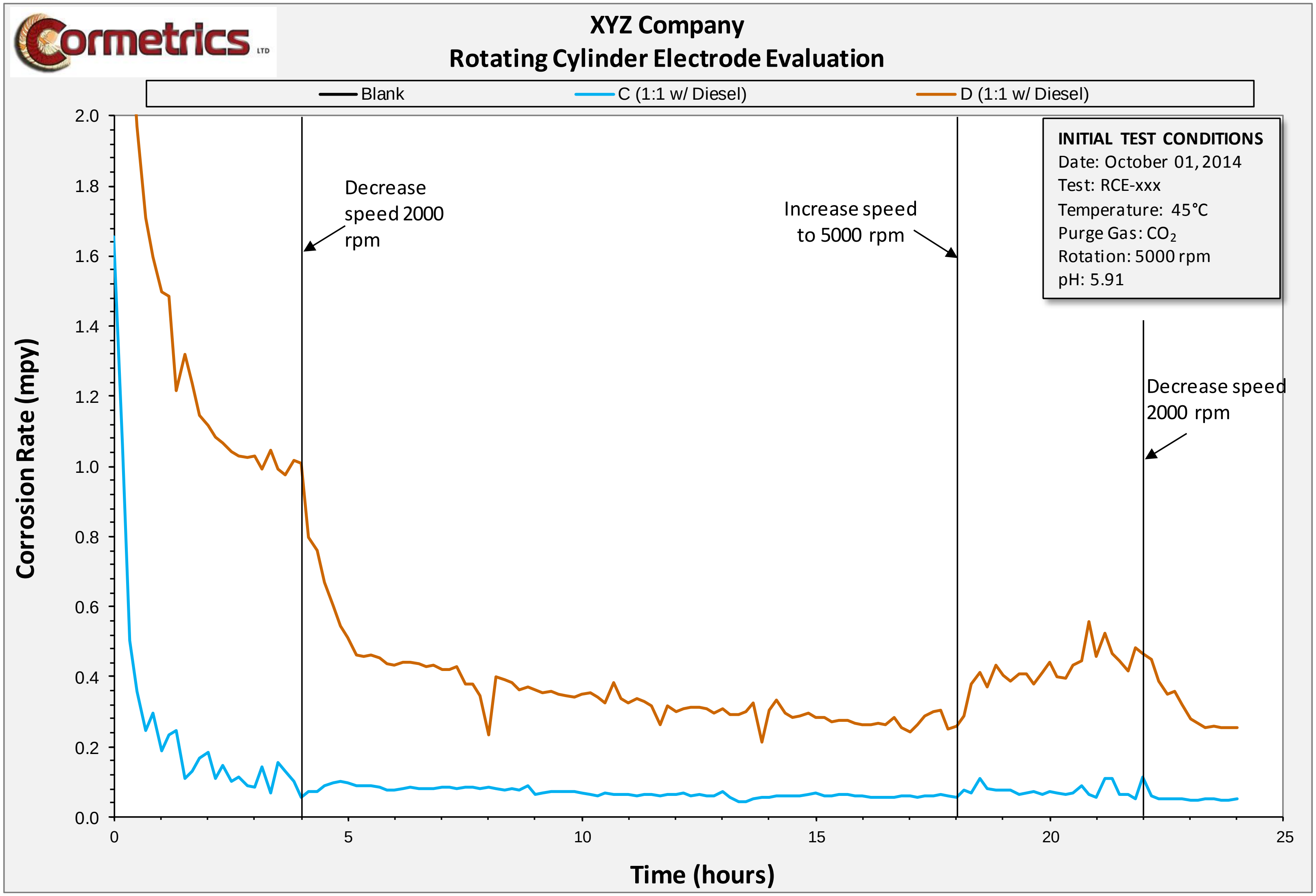


Figure 3: Batch Inhibitors LPR Data

APPENDIX II - WEIGHT LOSS & VISUAL DATA

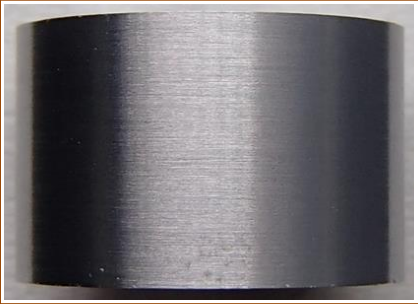
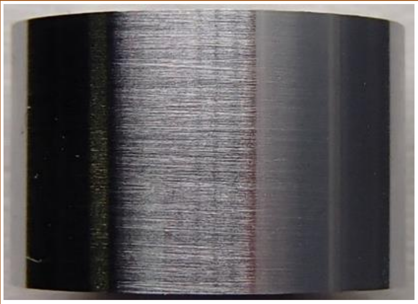
Inhibitor	Weight Loss		Visual Description	Pitting		Electrode Photo
	(mg)	(mpy)		(mils)	(mpy)	
Blank	7.20	43.91	Overall moderate surface etch	N/A	N/A	
A	0.60	3.66	Overall very mild surface etch	N/A	N/A	
B	0.40	2.44	Overall shiny surface	N/A	N/A	

Table 5: Continuous Inhibitors Weight Loss & Visual Data

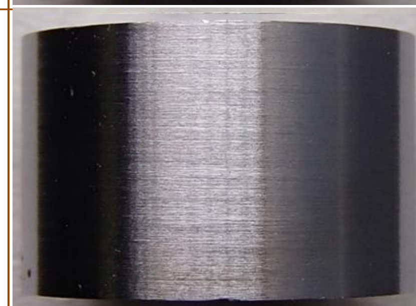
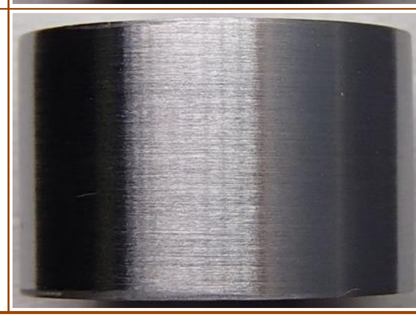
Inhibitor	Weight Loss		Visual Description	Pitting		Electrode Photo
	(mg)	(mpy)		(mils)	(mpy)	
Blank	7.20	43.91	Overall moderate surface etch	N/A	N/A	
C (1:1 w/ Diesel)	0.50	3.05	Overall very mild surface etch.	N/A	N/A	
D (1:1 w/ Diesel)	0.70	4.27	Overall very mild surface etch with edge attack.	N/A	N/A	

Table 6: Batch Inhibitors Weight Loss & Visual Data

APPENDIX III – TEST PHOTOGRAPHS

Figure 4: Separation of 1:1 Batch Solution Inhibitor C in Diesel