CAUSTIC SOLUTION REPLACEMENT
(Mud Safe CR)
CORROSIVITY TESTING

Cormetrics Job #: 13-207

Prepared for: Heartland Energy Group Ltd.

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Revision 2

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1. Introduction

A synthetic caustic solution replacement product was submitted for corrosivity evaluation by Heartland Energy Group Ltd. The caustic solution replacement was evaluated in the autoclave apparatus according to the protocol developed by Heartland Energy and Cormetrics Ltd. The product tested is listed in Section 2.1.

2. Test Conditions

2.1. Synthetic Caustic Replacement

Product Name
Mud Safe CR

Table 1 – Synthetic Caustic Product

The synthetic caustic product was not purged prior to use in the test. The pH of the solution as measured by pH strips was 14.

2.2. Autoclave Test Apparatus

The autoclaves used by Cormetrics Limited are constructed of Hastelloy 276-C and have a capacity of approximately 300mL. The tests were carried out with 250 mL of synthetic caustic product in each cell (approximately two-thirds full).

A Teflon sleeve was inserted into the base of the autoclave. The synthetic caustic fluid was then poured into this Teflon cup a three-electrode assembly is suspended from the lid of the autoclave, keeping the bottom clear for a Teflon-coated magnetic stir-bar. The configuration of the electrodes is a closely spaced equilateral triangle, with each cylindrical electrode having a 0.25” x 1.5” geometry. The reference electrodes are made from Hastelloy 276-C, while the working and counter electrodes are 1018 carbon steel. The electrodes are solvent rinsed and weighed prior to the commencement of the test period. A surface area of 7.92 cm^2 has been used throughout for corrosion rate calculations.

The temperature of the fluid in the autoclave is sensed by a thermistor probe, held at the center of the cell by a Hastelloy sleeve. Charging of the autoclave is by means of an offset Hastelloy tube, fitted with a pressure gauge and sour-service needle valve. Each cell is also equipped with a pressure relief valve which is used when purging the test liquids directly in the cells.

2.3. Autoclave Pressuring

Once the cells had been filled and sealed they were charged with 500 psi of pure nitrogen. Once pressurized, the autoclave cells were then placed inside individual heating mantles and brought to 149°C (300°F) via proportional temperature controllers. The fluids were stirred at a rate of 200 rpm for the entire test period. The Gamry instrument was then programmed to start collection of LPR data.

3. Results Summary

3.1. Gravimetric and Visual Analysis

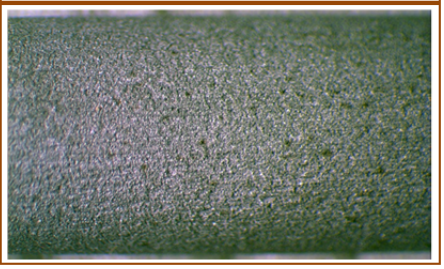
Inhibitor	Weight Loss (mg)	Weight Loss Corrosion Rate (mm/yr)	Visual Description	Pit Depth (mils)	Pit Rate (mpy)	Electrode Photo (Full)	Electrode Photo (Close-up)
Mud Safe CR	326.15	6.34	Overall surface etch.	N/A	N/A		

Figure 1 – Electrode Photographs and Weight Loss Data

3.4 pH Data

Initial pH of Mud Safe CR	Final pH of Mud Safe CR
14	13-14

Table 2 - pH Values

pH values were determined via use of pH test strips.

4. Discussion

- The high corrosion rate is likely due to the very high test temperature. The weight loss corrosion rate was 6.3 mm/yr (249.5 mpy) and the electrode had an overall surface etch. Additionally a large amount of iron corrosion products covered the magnetic stir bar at the end of the test period.

5. Conclusions

Based on testing performed in our laboratory under these conditions the Mud Safe CR product is corrosive to low carbon steel. The dominant anodic reaction in caustic environments is thought to be as follows:

$$Fe + 2(OH^-) \rightarrow Fe(OH_2) + 2\,e^-$$

The passivity of mild steel in caustic environments is normally associated with the formation of a protective film on the surface. In de-oxygenated alkaline solutions this is most likely due to the formation of a magnetite (Fe_3O_4) scale. Additionally at elevated temperatures carbon steels are at risk of Caustic Stress Corrosion Cracking (CSCC) in regular caustic solutions. Literature values indicate the upper safe limit of low carbon in 50% caustic solutions is ~65°C (150°F) before CSCC is a risk.

Sincerely,

Cormetrics Limited

Mike Koldijk, B.Sc.

Frank Hornsby

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