

Report
on
Testing of “Formula 1” Corrosion Inhibitor

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Purchase Order Number: 28040601

Test Report: TR 6060523A

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1.0 Introduction

Sheffield Testing Laboratories were contracted to test the performance of corrosion inhibitor Formula 1 for Aqueous Logic.

2.0 Test Solution

Two stocks solutions were required for the test:

All reagents used were of Analar Grade dissolved in standard laboratory deionised water.

2.1 Stock Solution 1 non-carbonate hardness

To 10 l of deionised water the following was added:

1.7g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$
2.3g $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$
2.0g $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
2.8g $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
6.2g Na_2SO_4

The total hardness of the solution, was 482mg/l.

2.2 Stock Solution 2 carbonate hardness

To 10l of deionised water the following was added:

3.35g CaCO_3
0.90g $\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2$

Carbon dioxide was bubbled through the solution at ambient temperature with constant stirring for at least 6 hours. The hardness of the water, was 448 mg/l. The stock solution was diluted down until a hardness of 390mg/l was achieved.

2.3 Make up of Hard Water

A sample stock solution 2 (carbonate hardness), sufficient for the number tests to be conducted, was diluted with deionised water to achieve a hardness of 375 mg/l. This was mixed in a 2:1 ratio with stock solution 1 (non-carbonate hardness).

The total hardness of the hard water, was 296 mg/l and the total alkalinity was 262 mg/l.

2.4 Make up of Soft Water

A sample of stock solution 2 (carbonate hardness), sufficient for the number tests to be conducted, was diluted with deionised water to achieve a hardness of 37 mg/l. This was mixed in a 2 :1 ratio with of stock solution 1 (non-carbonate hardness).

The total hardness of the soft water, was 82 mg/l and the total alkalinity was 45 mg/l.

3.0 Inhibitor

The client supplied a sample of corrosion inhibitor for testing, identified as Formula 1. The inhibitor was supplied in two parts and was added to the test solution, whilst in the test cells, but before testing was commenced as directed by the client. The dose of inhibitor added to the test solutions was as follows:

Inhibitor FI-85A was added at 17.1g per 1000 g of test solution

Adjunct 2 was added at 1g per 1000g of test solution

4.0 Test Material

Three (3) test materials were used for the immersion tests copper, aluminium and steel. Eight (8) test coupons were used from each material. The test materials were given the STL test numbers F538 to F540, see Table 1, the specimens were measured, degreased, dried and weighed prior to testing.

5.0 Test Procedure

A minimum solution volume to specimen surface area used for the tests was 0.2ml/mm².

Two cells were prepared for the inhibitor under test, one containing “hard water” the other containing “soft water”. The solutions were purged with nitrogen purging.

The inhibitor was added to each cell in accordance with the manufacturer’s specified dose (see Section 3.0).

Duplicate aluminium, copper and mild steel weight loss coupons were placed in each cell (6 coupons in total per cell).

The cells were placed in a water bath and heated to 80°C. A Time switch was used to heat the water bath in a 24 hour cycle of 8 hours at 80°C and 16 hours off. The first test period was for 2 weeks (14 days), with nitrogen continuously purged through the cells.

After two weeks the test coupons were removed and identified as the deaerated test results. The coupons were examined and weight loss and corrosion rates are determined.

A new set of six coupons were added to the cells and the cells purged with air for a further 2 weeks using the same water bath heating cycle. After two weeks, the aerated coupons were removed for examination.

6.0 Post-test Examination of Specimens

After testing the specimens were examined at up to X20 magnification and photographed.

The specimens were then cleaned in accordance with the procedures given in ASTM G1 using acidic solutions. The aim of cleaning was to remove the corrosion product from the specimens with the minimum of sound metal. The coupons were reweighed and corrosion rate calculated for each specimen. Control coupons of each material, that not been exposed to the test environment, were cleaned using the same procedure as the test coupons. The control coupons were used to adjust the weight loss of the tested coupons for the weight loss from the removal of sound material due to the cleaning process.

7.0 Results

The weight loss and corrosion rate data for the test coupons after immersion in the inhibited deaerated and aerated hard and soft waters is shown in tables 2a to 2d.

Figures 1 to 12 show the coupons after exposure to the test environment.

Table 1 Test Materials

Material	Test Numbers	Environment
Mild Steel	F538A	Deaerated Hard Water
	F538B	
	F538C	Deaerated Soft Water
	F538D	
	F538M	Aerated Hard Water
	F538N	
	F538O	Aerated Soft Water
	F538P	
Copper C106	F539A	Deaerated Hard Water
	F539B	
	F539C	Deaerated Soft Water
	F539D	
	F539M	Aerated Hard Water
	F539N	
	F539O	Aerated Soft Water
	F539P	
Aluminium AA6063	F540A	Deaerated Hard Water
	F540B	
	F540C	Deaerated Soft Water
	F540D	
	F540M	Aerated Hard Water
	F540N	
	F540O	Aerated Soft Water
	F540P	

Table 2 Test Results

Table 2a Hard Water Deaerated

Material	Test Number	Mass Before (g)	Mass after (g)	Mass Loss (g)	Blank Mass Loss (g)	Adjusted Mass Loss (g)	Surface Area (cm ²)	Corrosion Rate (mm/yr)
Steel	F538A	13.6837	13.6803	0.0034	0.0006	0.0028	27.28	0.0034
	F538B	13.6267	13.6242	0.0025	0.0006	0.0019	27.30	0.0023
Copper	F539A	16.2468	16.2455	0.0013	0.0001	0.0012	27.37	0.0013
	F539B	16.2589	16.2576	0.0013	0.0001	0.0012	27.35	0.0013
Aluminium	F540A	5.4101	5.3994	0.0107	0.0079	0.0028	27.60	0.0098
	F540B	5.4072	5.3947	0.0125	0.0079	0.0046	27.63	0.0161

Table 2b Soft Water Deaerated

Material	Test Number	Mass Before (g)	Mass after (g)	Mass Loss (g)	Blank Mass Loss (g)	Adjusted Mass Loss (g)	Surface Area (cm ²)	Corrosion Rate (mm/yr)
Steel	F538C	13.7438	13.7389	0.0049	0.0006	0.0043	27.28	0.0052
	F538D	13.7085	13.7054	0.0031	0.0006	0.0025	27.28	0.0030
Copper	F539C	16.2800	16.2793	0.0007	0.0001	0.0006	27.36	0.0006
	F539D	16.2617	16.2610	0.0007	0.0001	0.0006	27.39	0.0006
Aluminium	F530C	5.3822	5.3721	0.0101	0.0079	0.0022	27.58	0.0077
	F540D	5.4156	5.4065	0.0091	0.0079	0.0012	27.63	0.0042

Table 2c Hard Water Aerated

Material	Test Number	Mass Before (g)	Mass after (g)	Mass Loss (g)	Blank Mass Loss (g)	Adjusted Mass Loss (g)	Surface Area (cm ²)	Corrosion Rate (mm/yr)
Steel	F538M	13.7411	13.7387	0.0024	0.0006	0.0018	27.21	0.0022
	F538N	13.7076	13.7053	0.0023	0.0006	0.0017	27.23	0.0021
Copper	F539M	16.2671	16.2663	0.0008	0.0001	0.0007	27.38	0.0007
	F539N	16.2806	16.2798	0.0008	0.0001	0.0007	27.35	0.0007
Aluminium	F540M	5.4545	5.4436	0.0109	0.0079	0.0030	27.68	0.0105
	F540N	5.3916	5.3779	0.0137	0.0079	0.0058	27.62	0.0203

Table 2d Soft Water Aerated

Material	Test Number	Mass Before (g)	Mass after (g)	Mass Loss (g)	Blank Mass Loss (g)	Adjusted Mass Loss (g)	Surface Area (cm ²)	Corrosion Rate (mm/yr)
Steel	F538O	13.7436	13.7422	0.0014	0.0006	0.0008	27.22	0.0010
	F538P	13.7885	13.7871	0.0014	0.0006	0.0008	27.30	0.0010
Copper	F539O	16.2059	16.2048	0.0011	0.0001	0.0010	27.38	0.0011
	F539P	16.2670	16.2659	0.0011	0.0001	0.0010	27.39	0.0011
Aluminium	F530O	5.4548	5.4440	0.0108	0.0079	0.0029	27.71	0.0101
	F540P	5.4539	5.4420	0.0119	0.0079	0.0040	27.71	0.0139



Figure 1 Steel Specimens – Hard Water Deaerated



Figure 2 Copper Specimens – Hard Water Deaerated



Figure 3 Aluminium Specimens – Hard Water Deaerated



Figure 4 Steel Specimens –Soft Water Deaerated



Figure 5 Copper Specimens –Soft Water Deaerated



Figure 6 Aluminium Specimens –Soft Water Deaerated



Figure 7 Steel Specimens – Hard Water Aerated



Figure 8 Copper Specimens – Hard Water Aerated



Figure 9 Aluminium Specimens – Hard Water Aerated



Figure 10 Steel Specimens –Soft Water Aerated



Figure 11 Copper Specimens –Soft Water Aerated



Figure 12 Aluminium Specimens –Soft Water Aerated