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The Effect of Curing Time on the Performance of a Storage Tank Epoxy Coating System

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ABSTRACT

A Pull-off adhesion test and a standard Atlas Cell test were used to evaluate the performance of an Epoxy-based storage tank coating system after curing for 1, 3, 8 days. Adhesion tests were conducted for triplicate samples under ASTM-D4541-09E1 standard at 20°C for the three curing times and results indicated that most of the failures were cohesive in nature. The standard Atlas Cell tests were based on NACE TM 0174 (Method A) with an internal and external temperatures of 60°C and 5°C respectively. Tests were conducted for coated carbon steel substrates at curing times of 1,3,8 days under gas, hydrocarbon and water (15% NaCl) phases for a period of 6 months. Results

of the tested panels were made in the form of EIS Bode plots which indicated that the panels that were cured at 8 days had a higher impedance values that those that were cured at 1 and 3 day

Keywords: Pull-off test, Atlas test, synthetic water, gas phase, hydrocarbon phase.

INTRODUCTION

Epoxy based coating systems are widely used to protect tanks bottoms against corrosion caused by aggressive chemical spices present with crude oil, effluent waters and associated gases. Epoxy linings are economical and hard wearing and can be customized using variety of resins and additives to withstand almost any conditions and tank's contents. In addition, epoxy linings are tough, hard-wearing and handles tank bottom movement well.

This investigation was carried out upon the request of Kuwait Oil Company (KOC) to assess the corrosion performance of several coating systems as a function of their curing time for crude oil storage tanks. A Pull-off adhesion and a standard Atlas Cell tests were used to evaluate the performance of the Epoxy-based coating systems.

In this investigation, electrochemical impedance spectroscopy (EIS) tests [1 -15] were carried out to study the performance of the epoxy coating systems under the three different curing times. Results were shown in the form of Bode plots.

EXPERIMENTAL PROCEDURE

A Pull-Off Adhesion Test

Tests were conducted as per ASTM D4541-09e1 [16] and at 20°C for curing time of 1, 3 and 8 days.

A Standard Atlas Cell Test

Test were conducted as per NACE TM 0174 (Method A) [17] for curing time of 1, 3 and 8 days. The internal temperature was 60°C and the external one was 5°C. The test's hydrocarbon phase was Kerosene to Toleune (1:1) and the water phase was 15% NaCl Solution.

Electrochemical Parameters

The scan range of the frequency for the EIS tests was fixed (20,000 – 0.1 Hz) for all the conditions. The EIS measurements were conducted using an ACM Gill-8 system, and impedance experiments were performed at above mentioned frequency range. The excitation amplitude for these experiments was 5 mV. Bode plots were obtained for the epoxy coating system under the test conditions.

Epoxy coated carbon steel panels were used in this study. The surface of each panel was first cleaned with 5% HCl to remove mill scale (rust), mechanically polished to 1200 silicon carbide paper and finally degreased in acetone and dried with hot air. Then the coating system was applied as per KOC's standards and allowed to cure for 1,3 and 8 days. The measurements were carried out at the open circuit potential for the coated panels.

RESULTS AND DISCUSSION

A Pull-Off Adhesion Test

Most of the epoxy coating failures were cohesive in nature with a range of force of 2273 to 2287 psi for the three curing times. Figure 1 shows the nature of the coating cohesive failure as a function of curing times of 1, 3 and 8 days.

Coating side Fixture Coating side Fixture

After 1 Day Curing

Coating side Fixture Coating Side Fixture

After 3 Days Curing

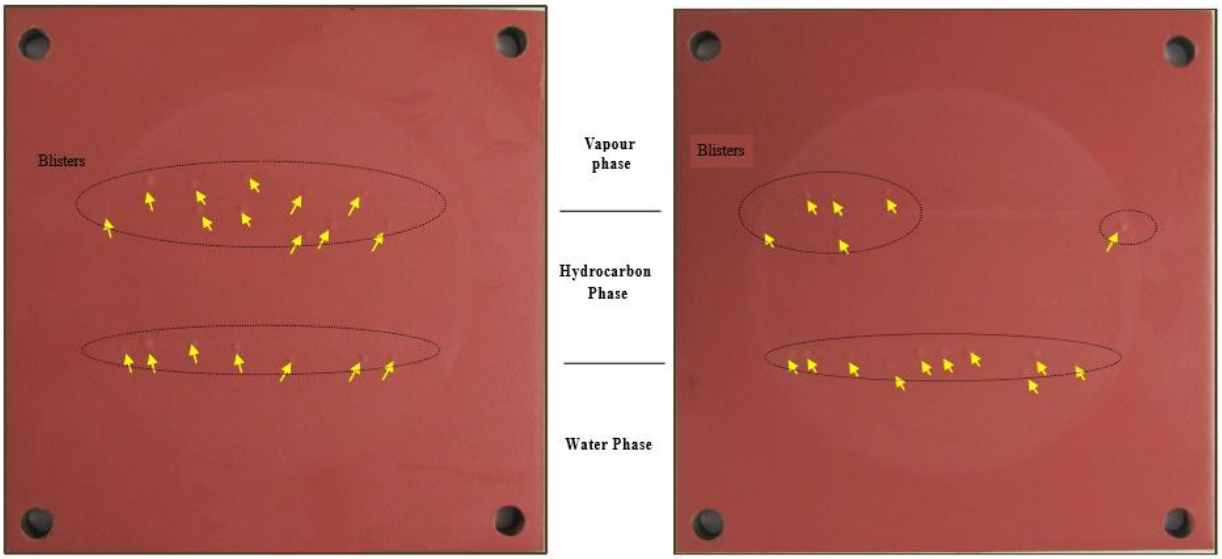
Coating Side Fixture Coating side Fixture

After 8 Days Curing

Figure 1: Pull-off Adhesion Evaluation of the Applied Tankguard Storage Coating System after Curing for 1 Day, 3 Days and 8 Days for two sets of samples.

A Standard Atlas Cell Test

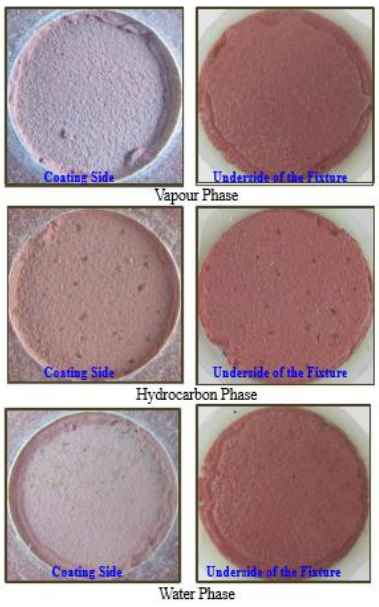
The coated panels cured for 1,3 and 8 days were exposed to test conditions for a duration of six months. Visual observation evaluation and EIS analysis were conducted after 1, 3 and 6 months. The adhesion test was only conducted for these sets of panels after six months of exposure. Results of these tests are shown in figures 2-8.



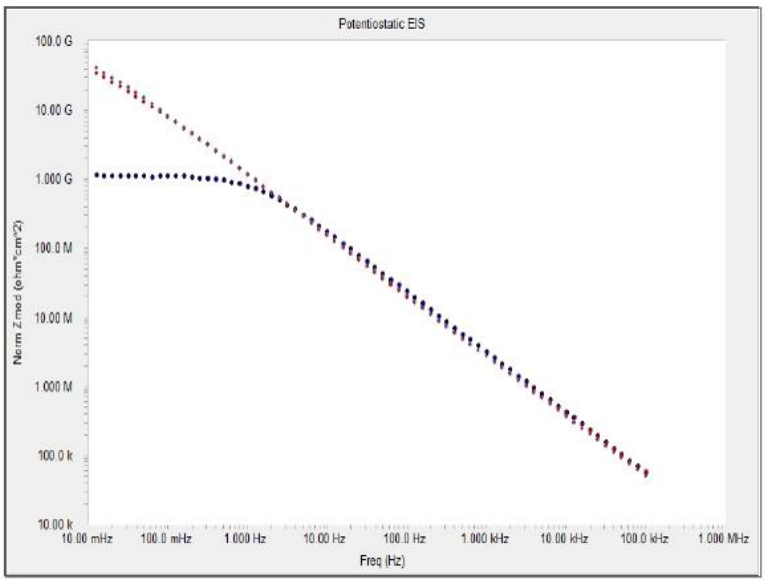
After 6 Months Standard Atlas Cell Exposure

Figure 2: Standard Atlas Cell Test of the Applied Tankguard Storage Coating System after Cu ring
for 1 Day.

NACE TM 0174 Method A: Internal Temperature at 60°C and External Temperature at 5oC for 6 Mo nths



Pull-off adhesion on Panel SAC2



EIS measurement on Panel SAC1

Figure 3: Pull-off Adhesion Test and EIS Measurements on the 6-Month Standard Atlas Cell Tested Panels of Epoxy Storage Coating System after Curing for 1 Days.

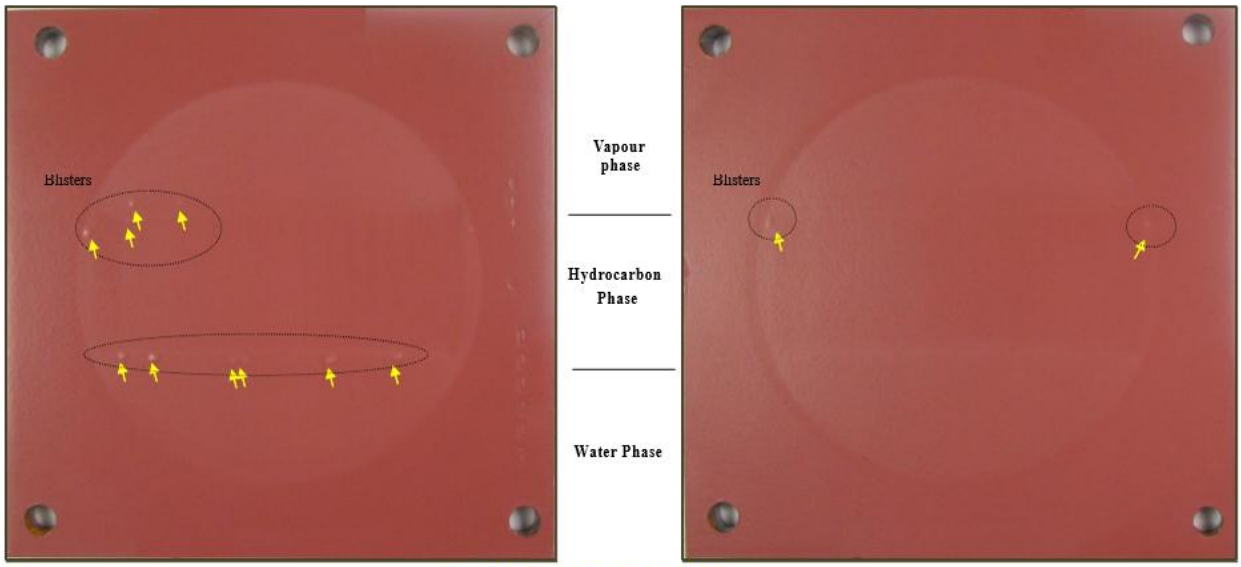
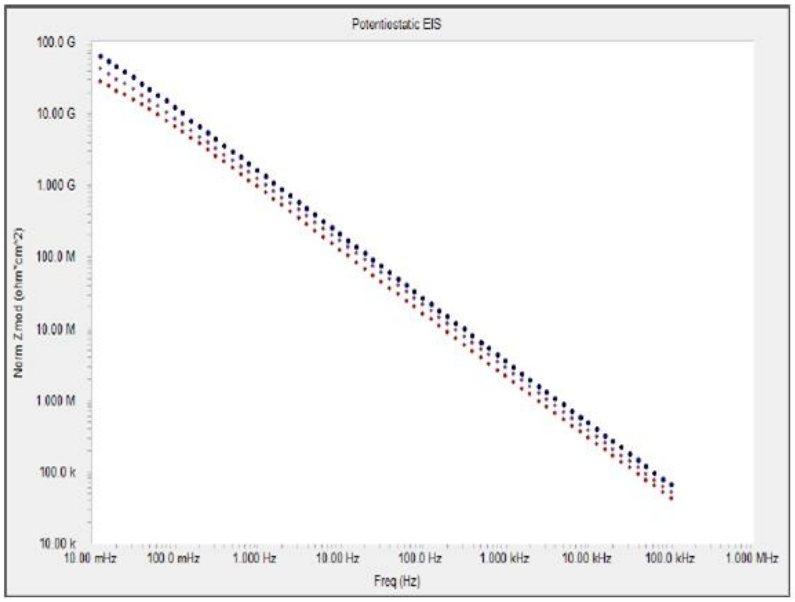


Figure 4: Standard Atlas Cell Test of the Applied Tankguard Storage Coating System after Cu ring
for 3 Days.

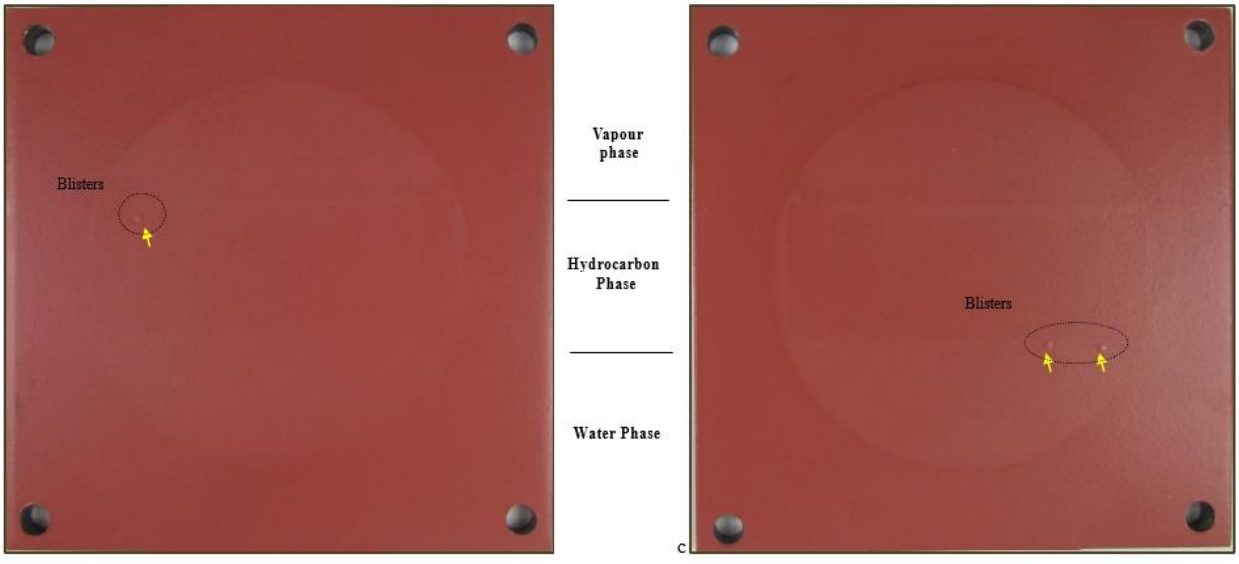
NACE TM 0174 Method A: Internal Temperature at 60°C and External Temperature at 5oC for 6 Months

Pull-off adhesion on Panel SAC4



EIS measurement on Panel SAC5

Figure 5:
Pulloff Adhesion Test and EIS Measurements on the 6Month Standard Atlas Cell Tested for Panels of Epoxy Storage Coating System after Curing for 3 Days.



After 1 Month Standard Atlas Cell Exposure

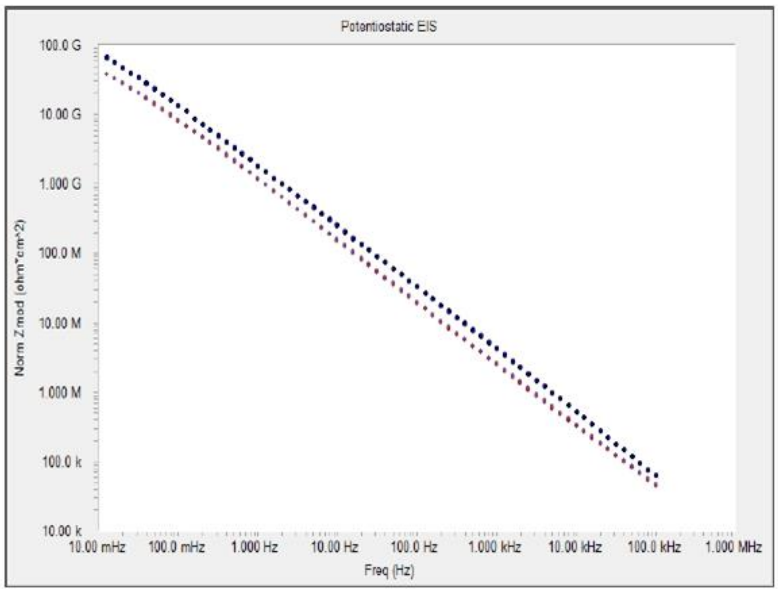
Figure 6: Standard Atlas Cell Test of the Applied Tankguard Storage Coating System after Curing
for 8 Days.

NACE TM 0174 Method A: Internal Temperature at 60°C and External Temperature at 5oC for 1 Month

Figure 7: Standard Atlas Cell Test of the Applied Epoxy Storage Coating System after Curing for 8 Days.

NACE TM 0174 Method A: Internal Temperature at 60°C and External Temperature at 50°C for 6 Months.

Pull-off adhesion on Panel SAC6



EIS measurement on Panel SAC5

Figure 8: Pull-off Adhesion Test and EIS Measurements on the 6-Month Standard Atlas Cell Tested Panels of Epoxy Storage Coating System after Curing for 8 Days.

MAIN FINDINGS AND DISCUSSIONS

1. Curing time of 1 day

After 1 month exposure:

- Both test panels showed no cracking, delamination or swelling in any of the test phases, but slight discoloration in the vapor and water phases.
- One panel showed five size #4 blisters at the vapor/hydrocarbon interface and one size #4 blister at the hydrocarbon/water interface

After 3 months exposure:

- No significant change was noted on one panel and slight increase in number of blisters was observed on another panel.
- The second panel showed six size #4 blisters at the vapor/hydrocarbon interface and four size #4 blisters at the hydrocarbon/water interface.

After 6 months exposure:

- Increase in number of blisters at the vapor/hydrocarbon interface for both panels and at the hydrocarbon/water interface for second panel.

- EIS measurements indicated that the gas phase log Z=9.89, hydrocarbon phase Log Z=9.04 and water phase log Z= 9.92

- Pull-off adhesion results was 2208 psi in the gas phase with 100% cohesive failure; 2778 psi in the hydrocarbon phase with 98% cohesive failure and 2% glue failure; 1956 psi in the water phase with 100% cohesive failure.

2. Curing time of 3 days:

After 1 month exposure:

- Both test panels showed no cracking, delamination or swelling in any of the test phases, but slight discoloration in the vapor and water phases.

- No blistering was observed on one panel, but the second one showed two size #4 blister at the vapor/hydrocarbon interface and five size #4 blisters at the hydrocarbon/water interface.

After 3 months exposure:

- One panel showed three size #4 blisters at the vapor/hydrocarbon interface and six size #4 blisters at the edge of the hydrocarbon/water interface. The second panel showed two size #4 blisters at the edge of the vapor/hydrocarbon interface zone.

- No other changes were noted for these panels.

After 6 months exposure:

- No significant changes were noted on both panels.

- EIS measurements indicated that the gas phase log Z=9.82, hydrocarbon phase Log Z=10.10 and water phase log Z= 9.93

- Pull-off adhesion results was 2745 psi in the gas phase with 95% cohesive failure; 2802 psi in the hydrocarbon phase with 60% cohesive failure and 40% glue failure; 2808 psi in the water phase with 100% cohesive failure.

3. Curing time of 8 days:

After 1 month exposure:

- Both test panels showed no cracking, delamination or swelling in any of the test phases, but slight discoloration in the vapor and water phases.

- Only one size 4 blister was observed at the vapor/hydrocarbon interface for one panel and the second contained Two size #4 blisters at the hydrocarbon/water interface.

After 3 and 6 months exposure:

- No further changes were observed on both panels.
- EIS measurements indicated that the gas phase log Z=9.91, hydrocarbon phase Log Z=10.13 and water phase log Z= 9.93
- Pull-off adhesion results was 3103 psi in the gas phase with 98% cohesive failure and 2% glue failure; 3421 psi in the hydrocarbon phase with 95% cohesive failure and 5% glue failure; 2534 psi in the water phase with 95% cohesive and 5% glue failure.

CONCLUSIONS

1. The overall corrosion performance for the panels cured for 1,3 and 8 days are very close in value.
2. The Bode plots also indicated that the coatings impedance are also close in value for the three curing times.
3. The Pull-off adhesion values for the panels cured for 8 days are higher than those cured for 1 and 3 days indicating that the longer the curing time the better the adhesion of the coating to the steel substrates.

ACKNOWLEDGEMENTS

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