Paper No.
9142

NACE 2017

High Performance Water Based Coating Enhanced with Nano Vapor Corrosion Inhibitors

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Abstract

The use of single component water based coatings for protection of military metal substrates continues to grow due to their low odor, health and safety advantages, easy cleanup and environmental friendliness. Nevertheless, the challenge continues to find alternatives to the traditional chromate, zinc or similar heavy metal type corrosion inhibitors which tend to rely on passivation or sacrificial cathodic protection[4]. Additionally, ongoing regulatory developments, which require lower VOCs and elimination of carcinogenic materials continue to tighten the usage of products containing these heavy metals thus forcing the need for alternative technologies. The use of nano vapor phase corrosion inhibitors(VCIs) provide an attractive alternative by adsorbing onto the metal substrate and filling the voids or micro-crevices of the substrate and preventing corrosion from starting or growing once the surface of the coating has been damaged. This technology has been proven effective in single component water based coatings at dry film thickness(DFTs) of 1 mil(25 microns)[2,5].

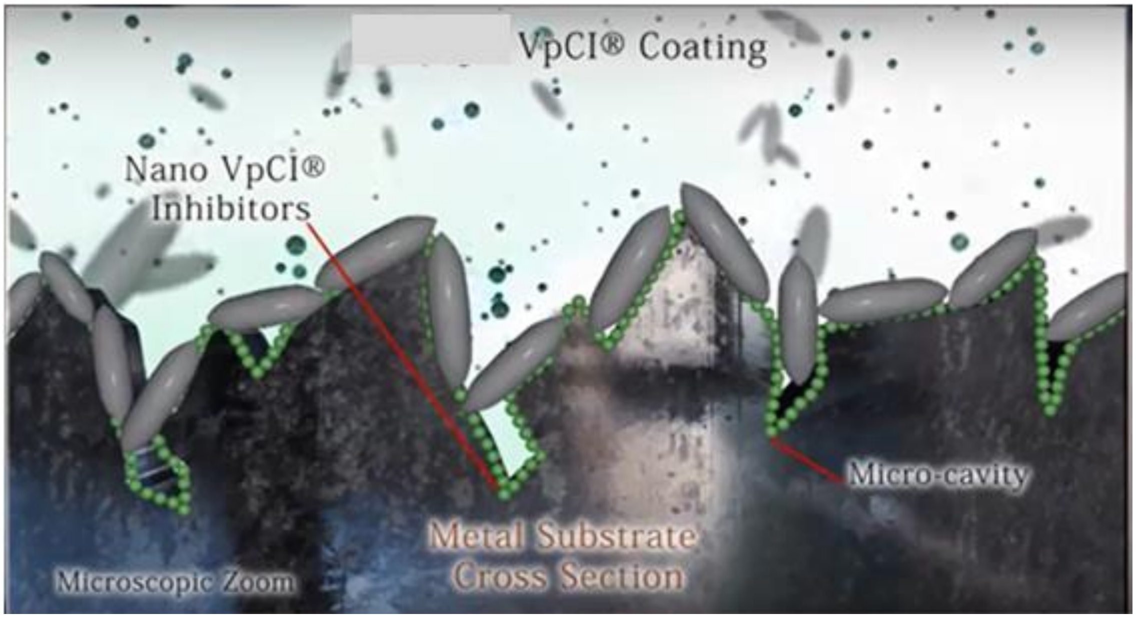
Four Learning Objectives

1. **How VCIs work in a coating**

   VCIs are formulated into a coating thru a complex development process which involves determining chemical compatibility of the VCIs with the other components of the coating such as the resin, solvents, pigments and other additives used for a variety of reasons. VCIs work by adsorbing onto the metal surface in a non-reactive attractive capacity, in other words, they are attracted to the metal thru the particle charge[1].

2. **How VCIs compare to traditional inhibitors**

   VCIs compare with traditional inhibitor systems by using smaller particles as well as relying not only on contact inhibition but also vapor phase inhibition, providing more complete coverage and protection of the surface. This can be illustrated as follows:



The larger platelets are representative of traditional inhibitors which are unable to fill the micro-crevices, leaving gaps where corrosion can start and/or grow[3].

3. **What type of coating systems can use VCIs**

   VCIs can be used with most coating systems. There are many variations of VCIs and the key is to choose the correct VCI for the corresponding coating system by checking compatibility, effectiveness and processability.

4. **The environmental advantages of VCIs over traditional inhibitors**

   Traditional inhibitors containing heavy metals are becoming increasingly more regulated and often are no longer allowed to be used due to the negative impact they have on the environment and as carcinogens for workers exposed to them. The environmental advantages of using VCIs are that they are non-toxic, do not contain heavy metals, and have no adverse effect due to their low usage concentrations. VCIs have long been used in other products such as PE films, foams, powders and liquids to provide a vapor phase of corrosion protection without impacting the environment.

Experiment

This study examines the effectiveness of various types of corrosion inhibitors in a waterborne styrenated acrylic coating, based on salt fog results, (ASTM B117). All of the samples were made using high speed dispersion.

Each coating was applied in triplicate on 4in X 12 inch cold rolled steel(CRS) panels, (SAE 1010), using a 40 RDS draw down bar. This produced a dry film thickness of 1.0 mils +/- 0.2 mils.

A list of samples prepared is shown in Table 1

Table 1: List of Coating Formulations

Sample #	Description	Corrosion Inhibitor	Percent of total formula weight	Coating thickness (mils)
1	Control	D	0 %	0.9-1.2
2	Exp. 1	A	3 %	0.9-1.2
3	Exp. 3	A+C	5 %	0.9-1.2
4	Exp. 2	B	3 %	0.9-1.2
5	Exp.4	B+C	3 %	0.9-1.2

Corrosion Inhibitor Detail

Corrosion Inhibitor	Description
D	Organic/Inorganic Corrosion Inhibitor
A	Amino Carboxylate Salt
A+C	Amino Carboxylate Salt + Nano Inhibitor
B	Liquid Sol Gel
B+C	Liquid Sol Gel + Nano Inhibitor

Testing Procedures

Panels were prepared according to ASTM B117 and allowed to cure at ambient temperature for seven days. After the curing cycle, the panels were scribed with a single diagonal scribe per method described in ASTM D1654. All of the edges and backs of the panels were taped to prevent any corrosion creep from uncoated surfaces.

Panels were then placed in a 5% NaCl salt fog chamber, per ASTM B117. The test panels were checked periodically for blisters, creep from scribe and degree of rusting.

Results

The purpose of this experiment was to investigate the effectiveness of nano VCI's when added to waterborne acrylics. The ultimate goal was to achieve 1,000 hours in a salt fog chamber, (ASTM B117), on CRS, with a high gloss clearcoat of less than 2.0 mils DFT.

Normally this kind of performance can only be achieved with highly pigmented coatings using corrosion inhibitors that are toxic, or at the very least not environmentally friendly.

The control panels failed at approximately 168 hours in the salt fog cabinet, as can be seen in figure 1.

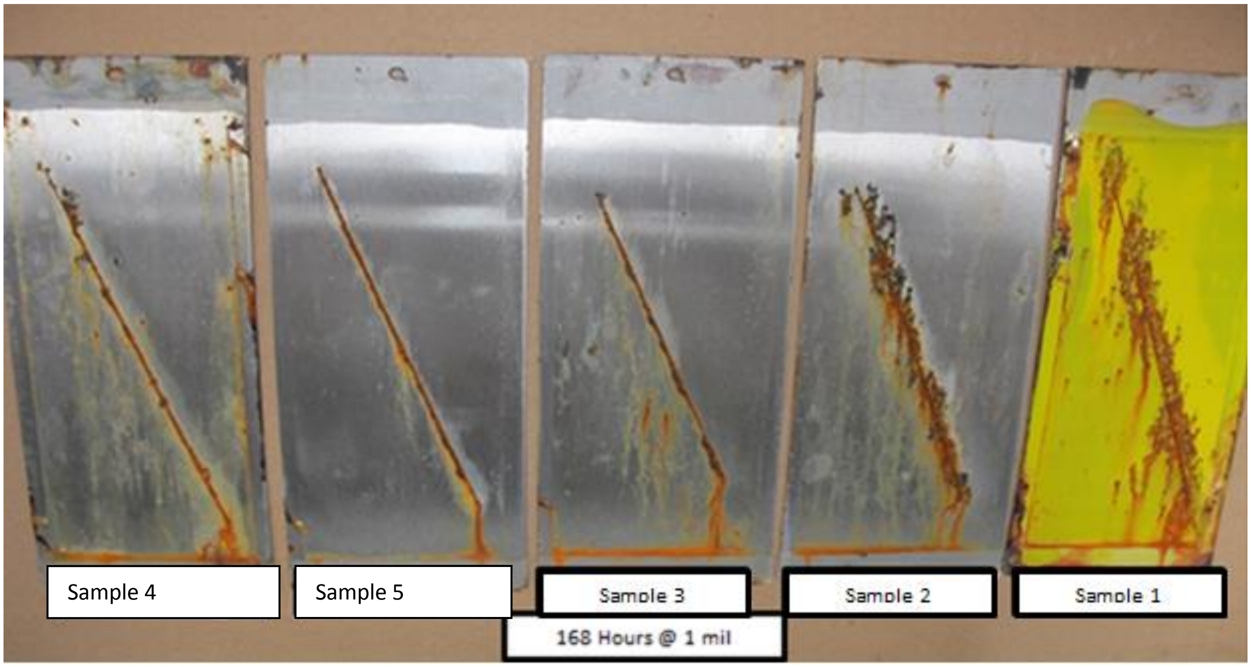


Figure 1

Table 2: ASTM B117, 168 HOURS Salt Fog Resistance

Sample #	Film Thickness (Mils)	Corrosion Rating	Scribe Rust
1	0.9-1.2	5	5
2	0.9-1.2	8	5
3	0.9-1.2	9	9
4	0.9-1.2	8	8
5	0.9-1.2	10	10

ASTM D 1654-92 Procedure B rating of unscribed areas
10 = no corrosion, 5 = 11to 20% corrosion 0 = 75% + corrosion
ASTM D 1654-92 Procedure A rating of failure at scribe
10 = no creepage, 5 = 0.125-0.1875 in., 0 = 0.625 + in.

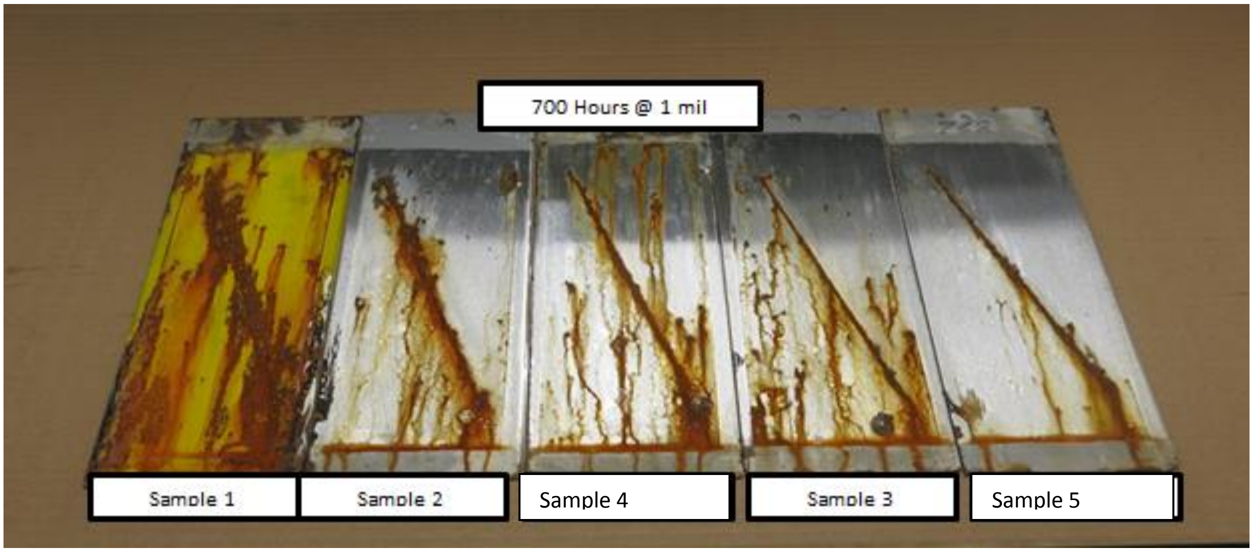


Figure 2

Table 3: ASTM B117, 700 HOURS Salt Fog Resistance

Sample #	Film Thickness (Mils)	Corrosion Rating	Scribe Rust
1	0.9-1.2	1	0
2	0.9-1.2	8	5
3	0.9-1.2	8	8
4	0.9-1.2	8	5
5	0.9-1.2	10	9

ASTM D 1654-92 Procedure B rating of unscribed areas
10 = no corrosion, 5 = 11to 20% corrosion 0 = 75% + corrosion
ASTM D 1654-92 Procedure A rating of failure at scribe
10 = no creepage, 5 = 0.125-0.1875 in., 0 = 0.625 + in.

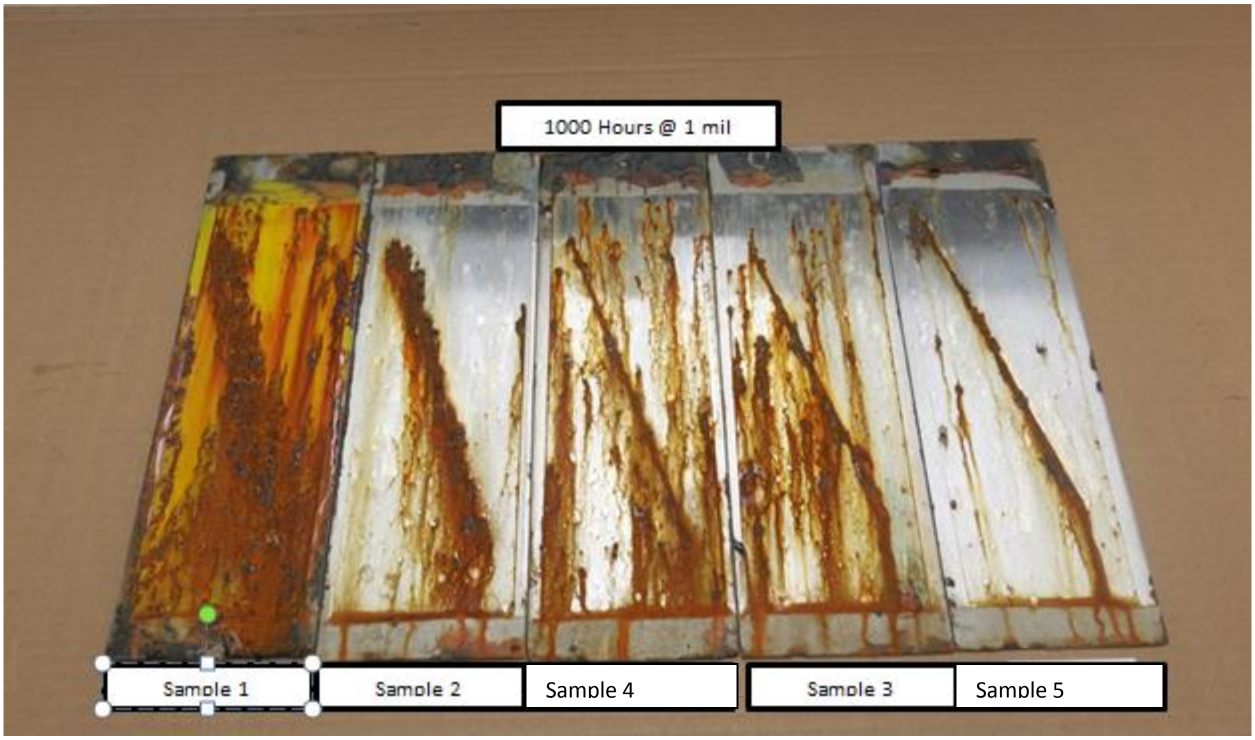


Figure 3.

Table 3: ASTM B117, 1,000 HOURS Salt Fog Resistance

Sample #	Film Thickness (Mils)	Corrosion Rating	Scribe Rust
1	0.9-1.2	0	0
2	0.9-1.2	5	2
3	0.9-1.2	3	4
4	0.9-1.2	3	4
5	0.9-1.2	9	9

ASTM D 1654-92 Procedure B rating of unscribed areas
10 = no corrosion, 5 = 11to 20% corrosion 0 = 75% + corrosion
ASTM D 1654-92 Procedure A rating of failure at scribe
10 = no creepage, 5 = 0.125-0.1875 in., 0 = 0.625 + in.

Conclusion

With the DOD(Department of Defense) estimating that corrosion costs in the military are in excess of $20 billion, there is a need, for environmentally friendly, low VOC, waterborne coatings that can be applied at a thin film thickness, (1.0 mils) which provide excellent corrosion protection.

This paper shows, through research, that the combination of nano VCI's and non-toxic metal complex inhibitors forms a synergistic effect that now allows for water based acrylics to reach 1,000 hrs of salt fog testing at less than 1.5 mils (ASTM B117). The DTM(direct to metal) aspects of these coatings results in direct cost savings by reducing the amount of material needed, reducing the application time and labor due to fewer coats and finally reducing the time and expense of equipment cleanup due to the environmentally friendly nature of the waterborne systems. Applications range widely from equipment to vehicles to infrastructure where CARC(chemical agent resistant coatings) are not specified/required.

Acknowledgements/References

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