The Use of VCIs in Conjunction with or Replacement of Traditional Corrosion Inhibitors

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The use of traditional corrosion inhibitors in paints and coatings continues to be challenged from both an environmental and performance aspect. End users are demanding better corrosion performance and in many formulations this cannot be achieved with traditional zinc or chromate-type inhibitors. The use of vapor corrosion inhibitors in coating formulations has shown that in many systems, they can replace the older technology or significantly improve the performance of the system by working in synergy with the existing inhibitors.

Vapor phase corrosion inhibitors (VCIs) are a corrosion inhibitor technology that is comprised of very small particles that are attracted to a metal substrate. Once the particles attach to the metal substrate through adsorption, they prevent a corrosion cell from forming. They come in various formulations that are dependent on the type of system they will be used in; for example, films, oils, coatings, cleaners, etc. There are also a variety of formulations that provide protection in ferrous, nonferrous, or multimetal applications. Other variables include the amount of vapor phase compared to contact phase inhibitors.[1] VCIs are widely used throughout a broad range of industries and applications ranging from automotive to processing to preservation and have saved billions of dollars of corrosion-expenses.

VCIs as Alternative Corrosion Inhibitor Technologies

The use of VCIs as alternative corrosion inhibitor technologies in coatings is not a new concept. In the last few years, however, with the growing environmental pressures to reduce the use of traditional inhibitors containing heavy metals, they have gained in popularity.[2]

VCIs as a category are very broad and can be made up of thousands of combinations of raw materials that can have varying rates of effectiveness. Commonly used terms, such as amine carboxylates, cover a broad range of potential formulations. Depending on the formulation, they can vary in their functionality as far as contact vs. vapor phase inhibition. When choosing the right VCI package to formulate into a coating, it is critical to find not only the package that is compatible with the coatings carrier (solvent or water) but also the resin system.

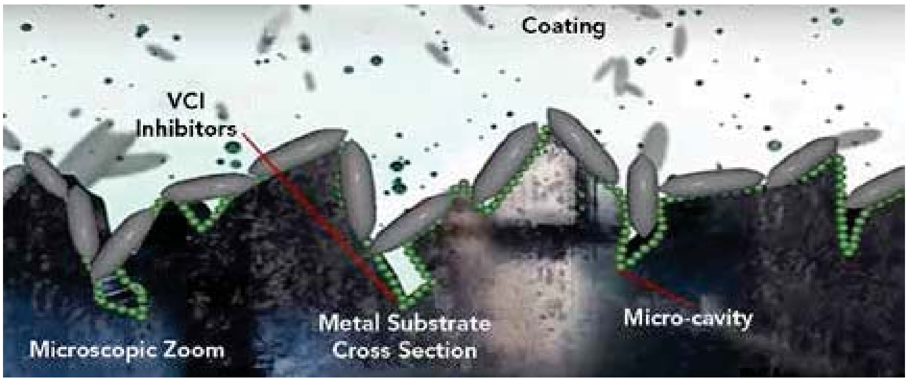

FIGURE 1 Microscopic surface view.

Choosing the wrong inhibitor package can lead to a variety of issues in the coating itself, which include gelling, phase separation, and flocculation. Once these issues have been eliminated, the next stage is testing to determine at which level there is an improvement in the corrosion performance, which is typically done using the salt fog test standard (ASTM B117[3]).

Since VCI particles have a polar attraction to the metal substrate, this allows them to work in the coating without negatively impacting other components of the coating such as defoamers, wetting agents, leveling agents, etc. VCIs are typically added to the formulation in very small amounts by weight of the overall formula. The typical range is from 0.5% to 3%.

The particle size of the VCIs is very small in comparison to the traditionally used inhibitors (Figure 1). This allows the VCIs to migrate into the smaller voids more effectively.

Once the VCIs have adsorbed onto the surface of the metal, they provide an effective barrier that is hydrophobic and prevents moisture from getting through to the metal surface.

Consequently, this prevents the formation of a corrosion cell and renders the moisture ineffective.[4]

Experimental Procedure

These studies examine the effectiveness of various types of corrosion inhibitors in single-component, waterborne acrylic coatings, based on salt fog results (ASTM B117).

TABLE 1 Inhibitor Combinations in the Study

Additive	ID	Inhibitor Co 1(3%) + VCI Inhibitor (3%): Panel	#	Inhibitor Co 2(3%) + VCI Inhibitor (3%): Panel	#	Inhibitor Co 1 @ 5%: Panel	#	Inhibitor Co 2 @ 5%: Panel	#	VCI Inhibitor: Panel	#
Inhibitor Co 1	A	A+A2	1	A1+A2	1	A	1	A1	1	386	1
Inhibitor Co 1	B		2		2		2		2		2
Inhibitor Co 1	C		3		3		3		3		3
Inhibitor Co 1	D	A+B2	1	A1+B2	1	B	1	B1	1	ECO386	1
			2		2		2		2		2
Inhibitor Co 2	A1		3		3		3		3		3
Inhibitor Co 2	B1	A+C2	1	A1+C2	1	C	1	C1	1		
Inhibitor Co 2	C1		2		2		2		2		
Inhibitor Co 2	D1		3		3		3		3		
		A+D2	1	A1+D2	1	D	1	D1	1		
Inhibitor Co 1	A2		2		2		2		2		
Inhibitor Co 2	B2		3		3		3		3		
Inhibitor Co 3	C2	B+A2	1	B1+A2	1						
Inhibitor Co 4	D2		2		2						
			3		3						
		B+B2	1	B1+B2	1						
DFT1.0-1.2 on all panels			2		2						
			3		3						
		B+C2	1	B1+C2	1						
			2		2						
			3		3						
		B+D2	1	B1+D2	1						
			2		2						
			3		3						
		C+A2	1	C1+A2	1						
			2		2						
			3		3						
		C+B2	1	C1+B2	1						
			2		2						
			3		3						
		C+C2	1	C1+C2	1						
			2		2						
			3		3						
		C+D2	1	C1+D2	1						
			2		2						
			3		3						
		D+A2	1	D1+A2	1						
			2		2						
			3		3						
		D+B2	1	D1+B2	1						
			2		2						
			3		3						
		D+C2	1	D1+C2	1						
			2		2						
			3		3						
		D+D2	1	D1+D2	1						
			2		2						
			3		3						

ASTM B117 tests products in a 5% sodium chloride (NaCl) salt fog chamber with continuous exposure as per the ASTM standard.

Each coating was applied on cold-rolled steel (CRS) panels (SAE 1010), using a 0.40 drawdown bar. Dry film thicknesses (DFTs) yielded were 0.9 to 1.2 mils (23 to 30 µm). Each coating/inhibitor combination was applied in triplicate. Coated panels were air dried in lab conditions at an ambient temperature of 70 °F (20 °C) and 50% relative humidity for seven days before being placed into the B117 chamber.

A matrix (Table 1) was designed to track the various coating/inhibitor combinations as follows:

- Additive variables:
  - Eight different types of "traditional" inhibitors containing zinc phosphates, calcium phosphates, strontium phosphates, etc.
    - Products are typically added at a wt% (5%) of the total coating formula.
  - Four different types of VCIs containing proprietary blends of amine carboxylates.
    - Products are typically added at a wt% (0.5 to 3%) of the total coating formula. For this experiment, they were added at 3%.
- Coatings contained:
  - 32 combinations of traditional inhibitors and VCIs.
    - Products were added at a reduced wt% (3%) of the total coating formula plus the VCIs at 3%.
  - Two combinations with VCIs
    - Products were added to a wt% of 0.5 to 2.0% (Figure 2).

Results

The results shown in Table 2 were based on a visual inspection and rating. From the testing that was done, it is clear that VCIs are a viable solution for use as corrosion inhibitors in coatings. Figure 2 shows that VCIs by themselves have the ability to provide excellent corrosion protection. As evidenced, salt spray performance in many cases was matched by reducing the percentage of traditional inhibitor used (recommended dosage of 5% by total formula weight to 3% by total

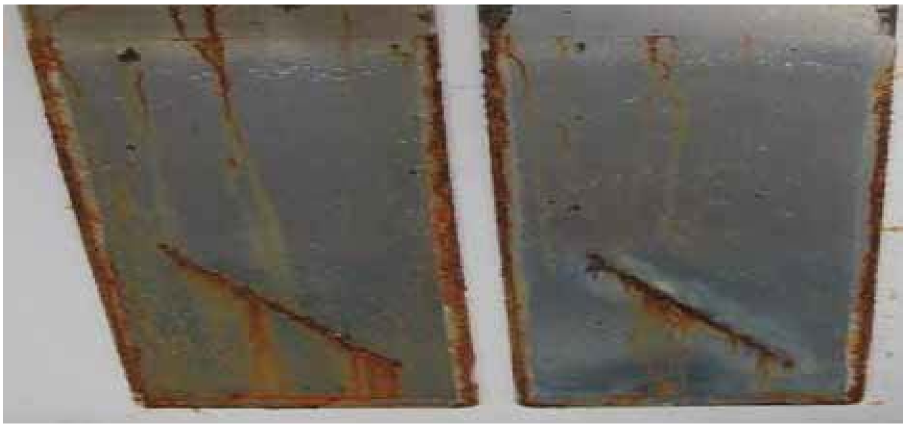

FIGURE 2 VCIs A and B only, 30 days = 720 h.

formula weight) and adding the VCI (at 3% by total formula weight). This is illustrated in Table 2 with the positive performing synergies highlighted. These synergies allow for reduced usage of inhibitors that may have to meet stricter environmental limits while possibly providing cost savings as well.

Combinations of B2 with various traditional inhibitors seemed to consistently provide comparable results, while the use of the VCI only provided the best results in this system.

Conclusions

Customers are becoming more and more demanding and are expecting their coatings to last longer. With the ongoing performance and environmental challenges in the coatings industry, there continues to be a need for new technologies that can provide better performance.

Stricter regulations limiting the use of certain products continues to make this more difficult as formulators are having to find alternatives to the products that have been used for many years. This article shows, through research, that the use of VCIs can match or improve the corrosion resistance of coatings either used by themselves or in combination with existing inhibitor technologies, thus reducing the environmental concerns without sacrificing performance.

Acknowledgments

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TABLE 2 Combination Results

Hours	Combo	Hours	Standard	Result		Hours	Combo	Hours	Standard	Result
480	A+A2	480	A	worse		480	A1+A2	480	A1	worse
480	A+B2	480	A	worse		480	A1+B2	480	A1	same
480	A+C2	480	A	worse		480	A1+C2	480	A1	worse
480	A+D2	480	A	worse		480	A1+D2	480	A1	worse
480	B+A2	480	B	worse		480	B1+A2	480	B1	same
480	B+B2	480	B	same		480	B1+B2	480	B1	same
480	B+C2	480	B	worse		480	B1+C2	480	B1	same
480	B+D2	480	B	worse		480	B1+D2	480	B1	worse
480	C+A2	480	C	worse		480	C1+A2	480	C1	worse
480	C+B2	480	C	worse		480	C1+B2	480	C1	same
480	C+C2	480	C	worse		480	C1+C2	480	C1	worse
480	C+D2	480	C	worse		480	C1+D2	480	C1	worse
480	D+A2	480	D	worse		480	D1+A2	480	D1	worse
480	D+B2	480	D	same		480	D1+B2	480	D1	same
480	D+C2	480	D	worse		480	D1+C2	480	D1	worse
480	D+D2	480	D	worse		480	D1+D2	480	D1	worse
		720	VCI A	better						
		720	VCI B	better						

Notes: A, B, C, and D are traditional inhibitors; A1, B1, C1, and D1 are traditional inhibitors; VCI A and VCI B are VCIs. The positive performing synergies are highlighted.