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THE USE OF VCI INHIBITORS IN CONJUNCTION WITH OR REPLACEMENT OF TRADITIONAL CORROSION INHIBITORS

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ABSTRACT

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 VCIs (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.

Key words: corrosion inhibitors, paints, coatings, environmental, VCI (vapor corrosion inhibitors), synergy

HOW VCIs WORK

VCIs are a corrosion inhibitor technology which is comprised of very small particles which are attracted to a metal substrate. Once the particles attach to the metal substrate thru adsorption, they prevent a corrosion cell from forming. They come in various formulations which 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 which provide protection in ferrous, non-ferrous or multi-metal applications. Other variables include the amount of vapor phase compared to contact phase inhibitors.[i] 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 related 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. [ii]

VCIs as a category are very broad and can be made up of thousands of combinations of raw materials which 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 which is compatible with the coatings carrier (solvent or water) but also the resin system.

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 the testing stage 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).

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% - 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.

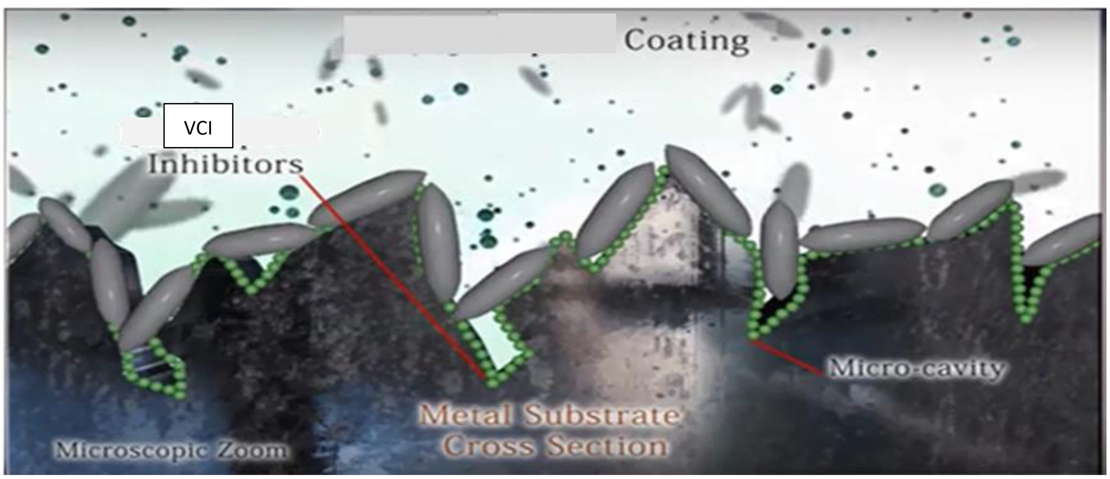

Figure 1(microscopic surface view)

Once the VCIs have adsorbed onto the surface of the metal, they provide an effective barrier which is hydrophobic and prevents moisture from getting thru to the metal surface. Consequently, this prevents the formation of a corrosion cell and renders the moisture ineffective.[iii]

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). ASTM B117 tests products in a 5% 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 .40 drawdown bar. Dry film thicknesses (DFTs) yielded were 0.9-1.2 mils (23-30 microns). Each coating / inhibitor combination was applied in triplicate. Coated panels were air dried in lab conditions at ambient temp, 70 degrees Fahrenheit (20 degrees Celsius) and 50% relative humidity for 7 days before being placed into the B117 chamber.[iv]

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

- Additive Variables:
    - 8 different types of "traditional" inhibitors containing zinc phosphates, calcium phosphates, strontium phosphates, etc…
        - Products are typically added at a %(5%) as a percent by weight of the total coating formula
    - 4 different types of "VCI" inhibitors containing proprietary blends of amine carboxylates
        - Products are typically added at a %(0.5-3%) as a percent by weight of the total coating formula. For this experiment, they were added at 3%
- Coatings contained:
    - 32 Combinations of traditional inhibitors and VCI inhibitors
        - Products were added at a reduced %(3%) as a percent by weight of the total coating formula plus the VCI inhibitors at 3% (Figures 2-9)
    - 2 Combinations with VCI inhibitors only
        - Products were added to a %(0.5 – 2.0%) (Figure 10)

Table 1
Inhibitor Combinations

Additive	Ident	Inhibitor Co 1(3%) + VCI Inhibitor(3%)	Panel	#	Hrs to Fail	Inhibitor Co 2(3%) + VCI Inhibitor(3%)	Panel	#	Hrs to Fail	Inhibitor Co 1 @ 5%	Panel	#	Hrs to Fail	Inhibitor Co 2 @ 5%	Panel	#	Hrs to Fail	VCI Inhibitor	Panel	#	Hrs to Fail
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					
VCI Inhibitor 1	A2			2				2				2				2					
VCI Inhibitor 2	B2			3				3				3				3					
VCI Inhibitor 3	C2		B+A2	1			B1+A2	1													
VCI Inhibitor 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													

RESULTS

Inhibitor A1 @ 5% compared to Inhibitor A1 in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

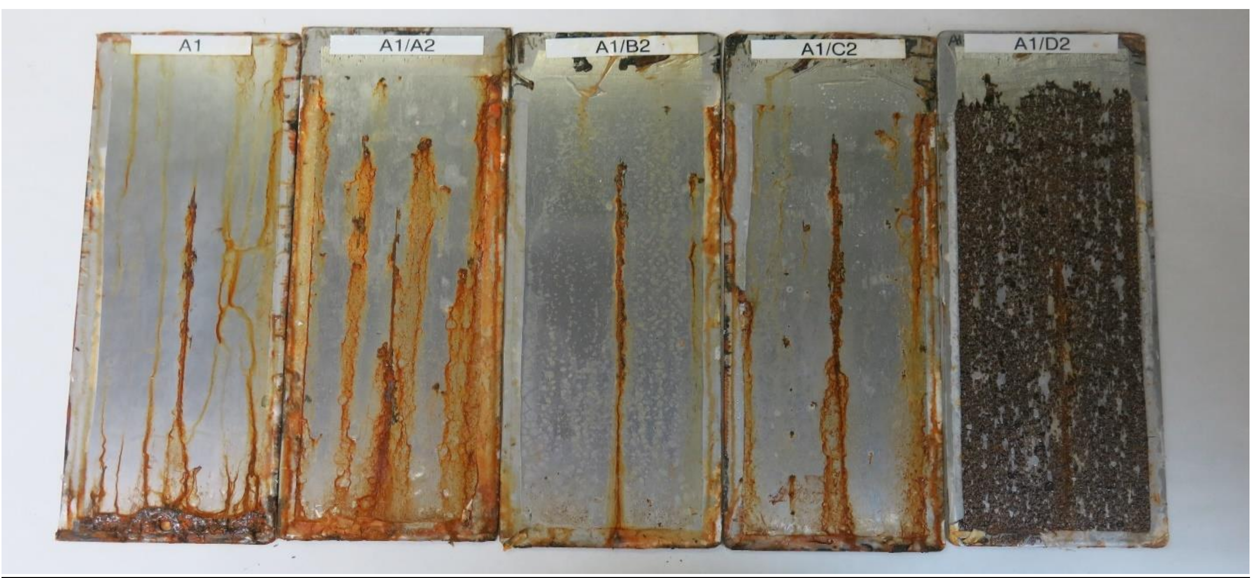

Figure 2

Inhibitor B1 @ 5% compared to Inhibitor B1 in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

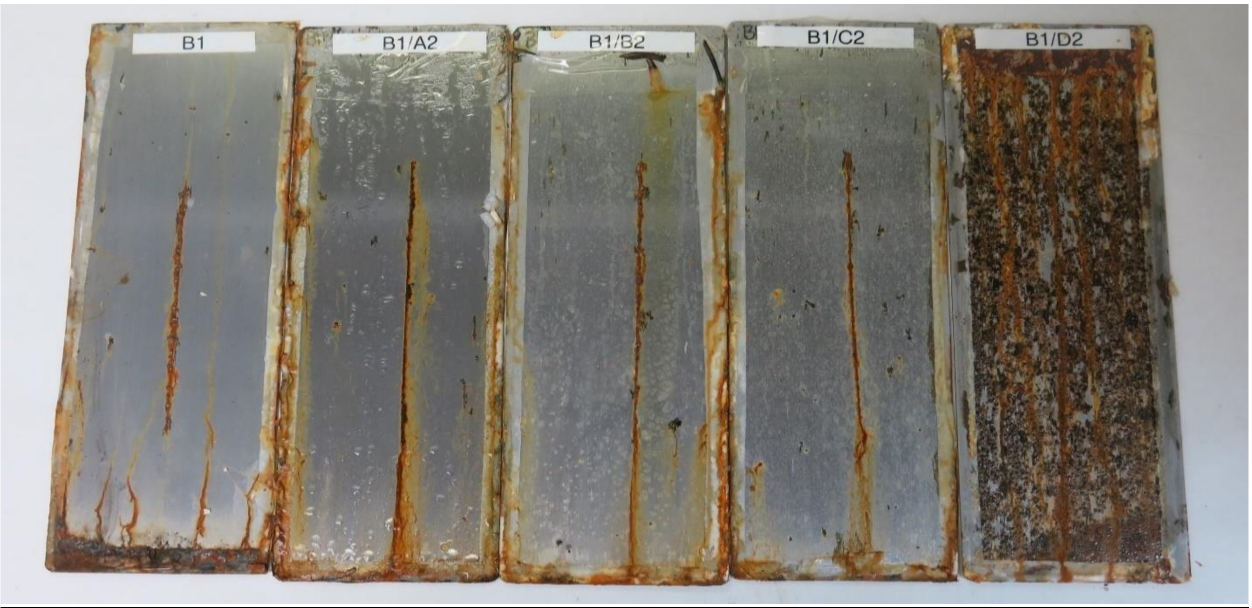

Figure 3

Inhibitor C1 @ 5% compared to Inhibitor C1 in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

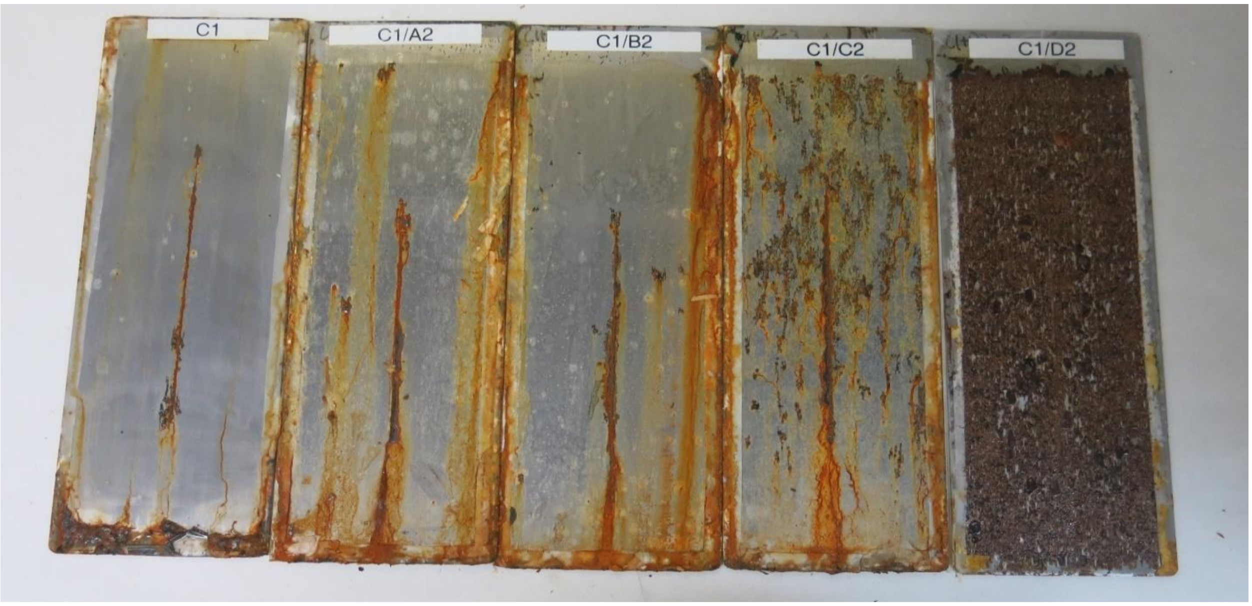

Figure 4

Inhibitor D1 @ 5% compared to Inhibitor D1 in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

Figure 5

Inhibitor A @ 5% compared to Inhibitor A in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

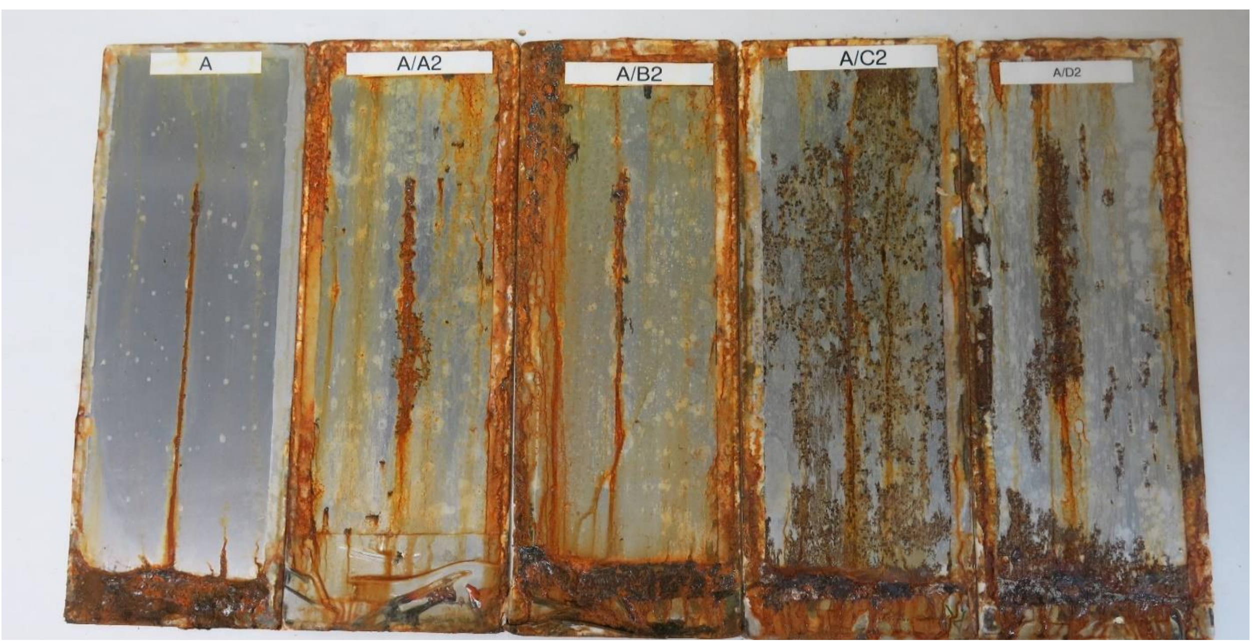

Figure 6

Inhibitor B @ 5% compared to Inhibitor B in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

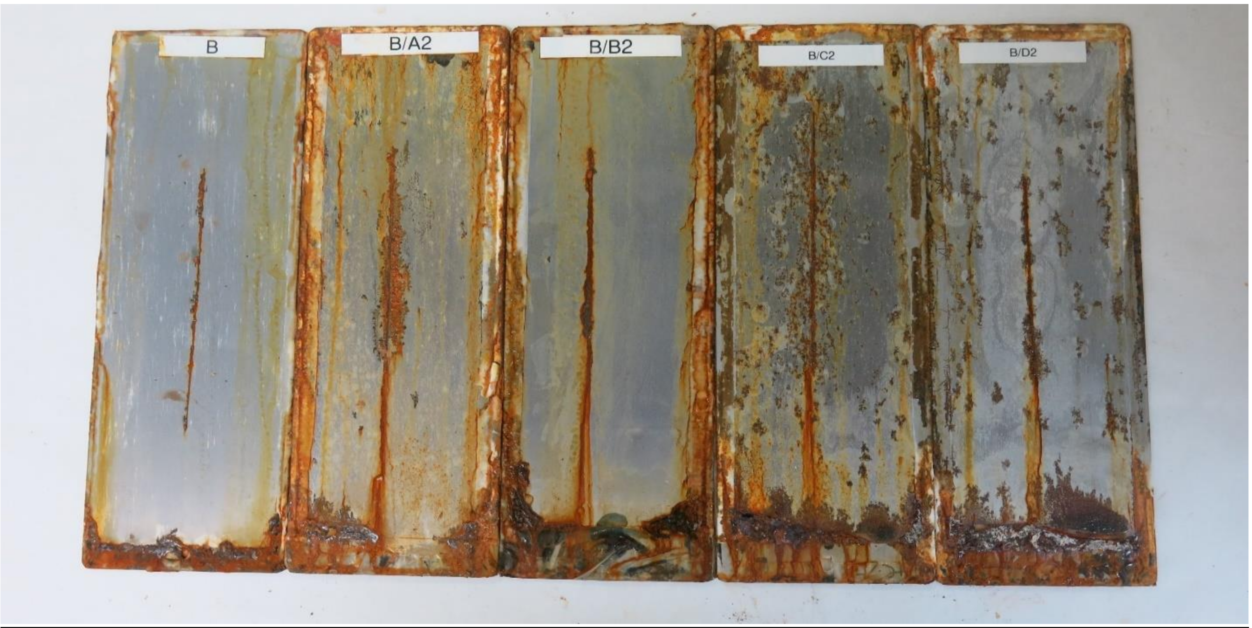

Figure 7

Inhibitor C @ 5% compared to Inhibitor C in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

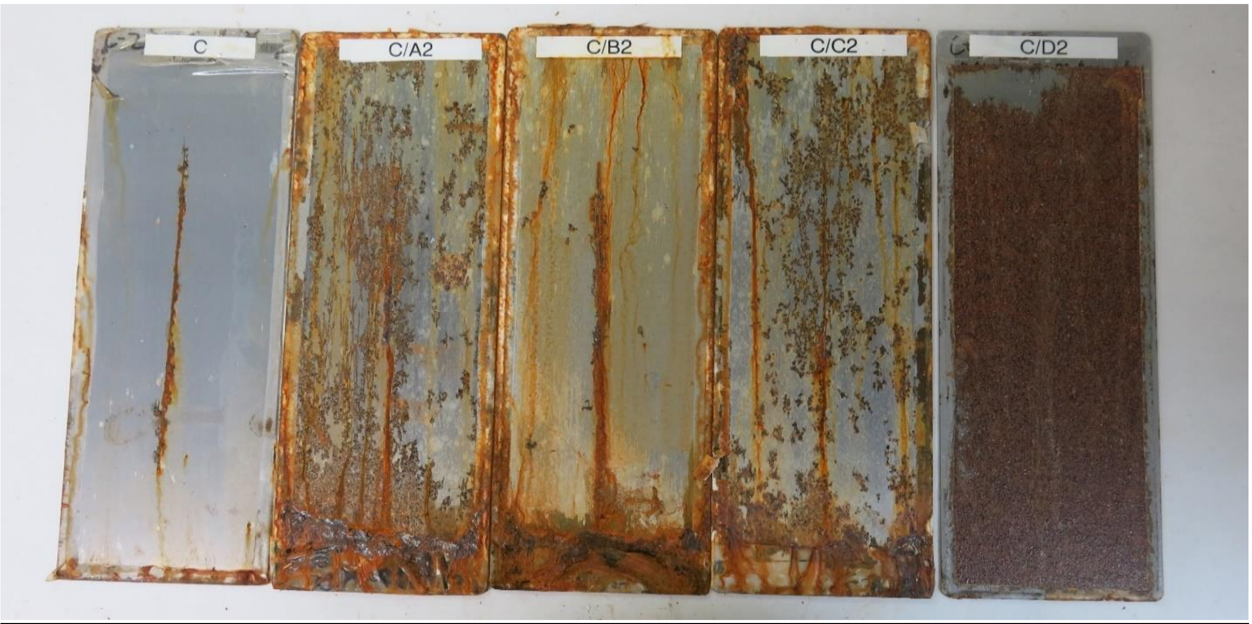

Figure 8

Inhibitor D @ 5% compared to Inhibitor D in combination with VCI inhibitors at 3% and 3%.

20 days = 480 hrs

Figure 9

VCI inhibitors A and B only

30 days = 720 hrs

RESULTS

The results shown in Table 2 were based on a visual inspection and rating. From the testing which was done, it is clear that VCI inhibitors are a viable solution for use as corrosion inhibitors in coatings. Figure 9 shows that VCI inhibitors by themselves have the ability to provide excellent corrosion protection. There is also evidence as shown throughout Figures 1-8 that various combinations of VCI inhibitors with traditional corrosion inhibitor additives can greatly outperform the traditional inhibitors by themselves. 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 formula weight) and adding the VCI inhibitor (at 3% by total formula weight). This is illustrated in the chart below 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 inhibitor only provided the best results in this system.

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						

A, B, C and D are traditional inhibitors

A1, B1, C1 and D1 are traditional inhibitors

VCI A and VCI B are VCI inhibitors

CONCLUSION

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 which 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 which have been used for many years. This paper shows, through research, that the use of VCI inhibitors 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.

ACKNOWLEDGEMENTS

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