VCIs - A NOVEL APPROACH TO CORROSION CONTROL IN THE WATER TREATMENT INDUSTRY

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Introduction

Corrosion still remains a significant problem for many industrial systems where water is used. The most common methods of reducing the danger of corrosion are using non-metallic materials, corrosion resistant metals (stainless steel) or the purification of process water, i.e. using de-ionized water instead of tap or sea water, etc. One of the most economical methods of corrosion protection is adding an effective corrosion inhibitor system. Many papers have been published about usage of Volatile Corrosion Inhibitors (VCIs) in different industries [1,2,3,4,5] The goal of this work is to distinguish the effectiveness of four new additives which provide protection in salt and fresh water.

Experimental

Electrochemical analysis was performed using a three electrode system [6], where working electrode was carbon steel, reference electrode-calomel saturated, counter electrode-high density graphite. Measurements were taken using Potentiostat / Galvanstat "Versastat" with corrosion software mode 352/252 SoftCorr™.

Polarization curves were obtained in Tafel Technique at room temperature. The working electrode was polished with 400 grit sand paper.

Corrosion tests were performed on immersed and half-immersed carbon steel and copper panels [7] at room temperature and 50^{o}C. Carbon steel panels were from cold rolled steel, ASTM C1010 provided by the Q Panel Company grounded both sides. Copper panels (CDA110), provided by Metaspec Co., were sanded with 320 grit sand paper. The panels and working electrodes were washed with methanol prior to testing.

All additive packages are technical grade and free from chromate, nitrites and zinc. They are environmentally friendly and easily disposed.

<u>Results and Discussion</u>

To formulate additives which will provide three phase protection (liquid, interface, vapor phase) a balanced combination of vapor phase and contact inhibitors should be used. The ratio of components in the formulation should provide uniform activity at the metallic surface immersed in the solution, at the waterline and in the vapor space above. The effectiveness of an inhibitor in liquid phase can be evaluated using data from electrochemical analysis and immersion testing. The performance of vapor phase and interphase inhibiting effect is evaluated by half-immersion testing. VCI-645 was designed to protect metals in brines, hard and salt waters. The data (Table 1) show that only the complete composition (contact and vapor inhibitor, oxygen scavenger) provides three phase protection. Figure 1 shows that adding VCI-645 influences both the anodic and cathodic reactions and moves the corrosion potential to more negative values. Figure 2 shows that this formulation provides the same protection in sea water.

The study concerning concentration and protection ability (Table 2) suggests that this formulation has limited protection ability at a concentration level less than 0.5% by weight and does not increase protection above that concentration level.

Industry probably uses more water for cooling than for all other purposes combined. Condensers, heat exchangers, cookers, engines, compressors, etc., all need cooling water and the cooling system maintenance can be very costly unless the water is treated to prevent corrosion, deposits and biological growths. Cooling water systems are broadly divided into two main types--once through and re-circulating. VCI-649 was designed to protect re-circulating cooling systems. It is a concentrated composition of water-soluble aminocarboxylates and provides multimetal protection in liquid and vapor phase. The polarization curves (Figure 3) show that blending the two major components of VCI-649 gives a synergistic effect. Data shown in Table 3 provides more information on the corrosion rate and corrosion potential.

The major difference between VCI-645, VCI-649, VCI-646 and S-69 is that in VCI-645 each ingredient plays one function, but in VCI-649, VCI-646 and S-69 some of the ingredients have synergistic effect in the liquid and also vapor phase protection. This allows lowering the concentrations of inhibitors. The polarization curve (Figure 3) obtained in formulation 2 shows that it affects anodic and cathodic reaction but mostly anodic as it moves the corrosion potential in a positive direction.

VCI-646 was designed for open loop cooling systems. It contains inhibitors for ferrous and non-ferrous metals, biocides and an anti-scalant agent. The components of this formulation influence mainly anodic reactions and stabilize the corrosion potential. These formulations provide protection to carbon steel and copper when immersed or half-immersed in tap water at both room temperature and elevated temperatures of 50-80^{o}C (Table 5).

S-69 was designed as a “building block” for water treatment formulations. It protects steel and non-ferrous metals in tap water at a wide range of temperatures. It is also compatible with a majority of anti-scalants and biocides. The data obtained from electrochemical and corrosion tests is shown in Tables 4 and 5 and Figure 3.

Formulations VCI-649, VCI-646 and S-69 provide good protection to steel and copper in tap water at varying temperatures.

Table 1

VCI-645: Protection ability of inhibitor for brines and salt water. Tested for carbon steel and copper. The solution used 3.5% NaCl + 0.5% inhibitor + tap water.

Immersed

Material	**Time Before Corrosion (days)**
Contact inhibitor	10+
Contact inhibitor + oxygen scavenger	10+
VCI-645	10+/10+*
Control	<1/<1*

* The upper data shows protection to carbon steel, the lower for copper (carbon steel/copper).

Half-Immersed

	Time Before Corrosion (Days)		
Material	In solution	Waterline	Above Waterline
Contact inhibitor	10+	<1	3
Contact inhibitor + oxygen scavenger	10+	10+	7
VCI-645	10+/10+*	10+/10+*	10+/10+*
Control	<1/<l*	<1/<1*	<1/1*

* The upper data shows protection to carbon steel, the lower for copper (carbon steel/copper).

Table 2

Study of concentration dependency on protection ability of VCI-645 tested for carbon steel. The solution used was 3.5% NaCl + tap water.

Concentration (%)	Rest Potential (mv)	Corrosion rate, mpy
Control	-450	2.934×10^{3}
0.1	-510	805.3×10^{-3}
0.5	-660	60.82×10^{-6}
0.75	-660	63.82×10^{-6}

Table 3

Synergistic interaction of the components within VCI-649

Material	Corrosion Potential (mv)	Corrosion Rate (mpy)
500 ppm A + Tap water	-375	1.725
500 ppm B + Tap water	-678	3.099
250 ppm A + 250 ppm B + Tap water	-246	261.7×10^{-3}

Table 4

Electrochemical Study of the Effectiveness of VCI-646, VCI-649 and S-69 Tap Water

Material	Corrosion rate (mpy)	Protection power (Z%)*	Corrosion Potential (mv)
Control (Tap water)	5.361	-	-630
VCI-649	0.3569	93	-375
VCI-646	0.2827	95	-303
S-69	1.007	87	-378

*Protection power calculated from the following equation:

$$Z = \frac{CR\ w/o\ inh - CR\ w/\ inh}{CR\ w/o\ inh} \times 100\%, \text{ where}$$

CR w/o inh = Corrosion rate in the medium without an inhibitor.
CR w/inh = Corrosion rate in the medium with inhibitor.

Table 5

Study of the performance of the formulations 2, 3, and 4 in tap water.
Concentration level 0.1% by mass.

Copper (Immersed)

	Time before corrosion (days)	
Material	**Ambient Temperature**	**50°C**
VCI-649	60+	60+
VCI-646	60+	60+
S-69	60+	60+

Carbon Steel (Immersed)

	Time before corrosion (days)	
Material	**Ambient Temperature**	**50°C**
VCI-649	40+	40+
VCI-646	40+	40+
S-69	40+	40+

Carbon Steel (Half-immersed)

	Time before corrosion (days)	
Material	**Ambient Temperature**	**50°C**
VCI-649	40+	20+
VCI-646	40+	20+
S-69	40+	20+

Conclusion: VCI technology was used to develop four new non-toxic, environmentally friendly effective corrosion inhibitors for multimetal protection. Their performance was confirmed using electrochemical and corrosion test method.

References

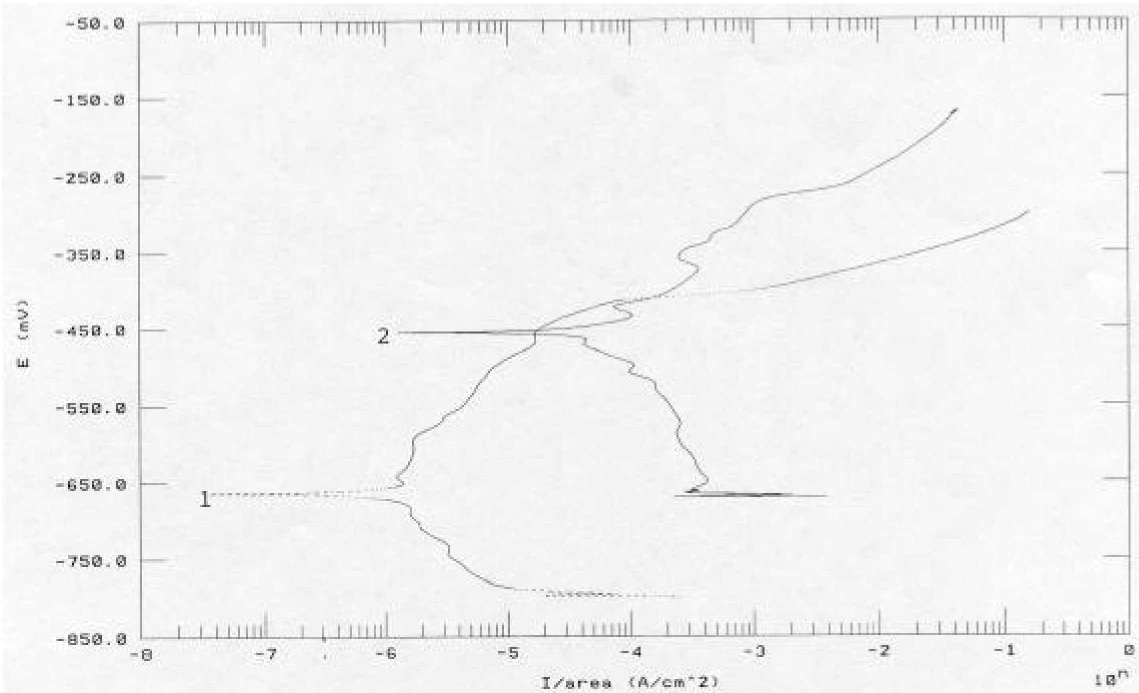
1. Miksic, B. A. Use & Nature of VCIs, April 83, Anaheim. NACE. Corrosion 83, National Association of Corrosion Engineers, Use of Vapor Phase Inhibitors for Corrosion Protection of Metal Products.

2. Eydelnant, A. Chandler, C., Miksic, B. A., VCIs in Petrochemical, Dec. 92, Bombay National Corrosion Council of India, VCIs, A Novel Approach to Corrosion control in the Petrochemical Industry.

6. ASTM G 5-87 “Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements”

7. ASTM G 31-72 “Standard Practice for Laboratory Immersion Corrosion Testing of Metals”

Figure 1A

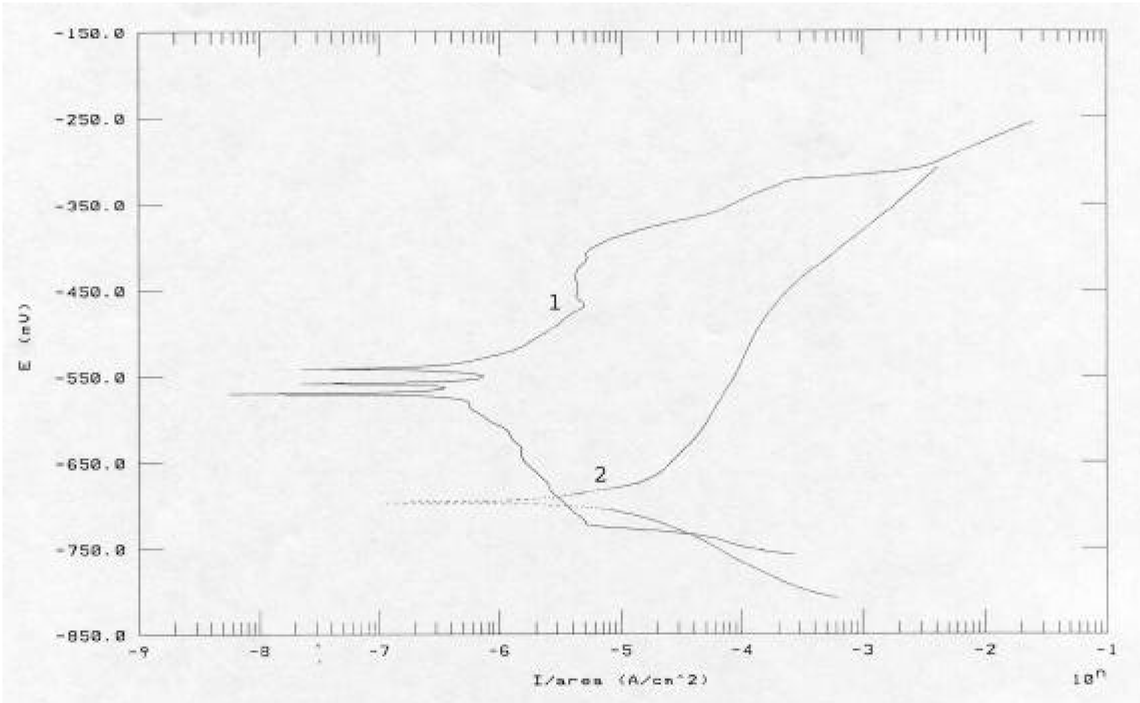


Effectiveness of VCI-645 + 3.5% NaC1 + Tap water
Carbon steel, concentration 0.5%

1. VCI-645

2. Control

Figure 1B

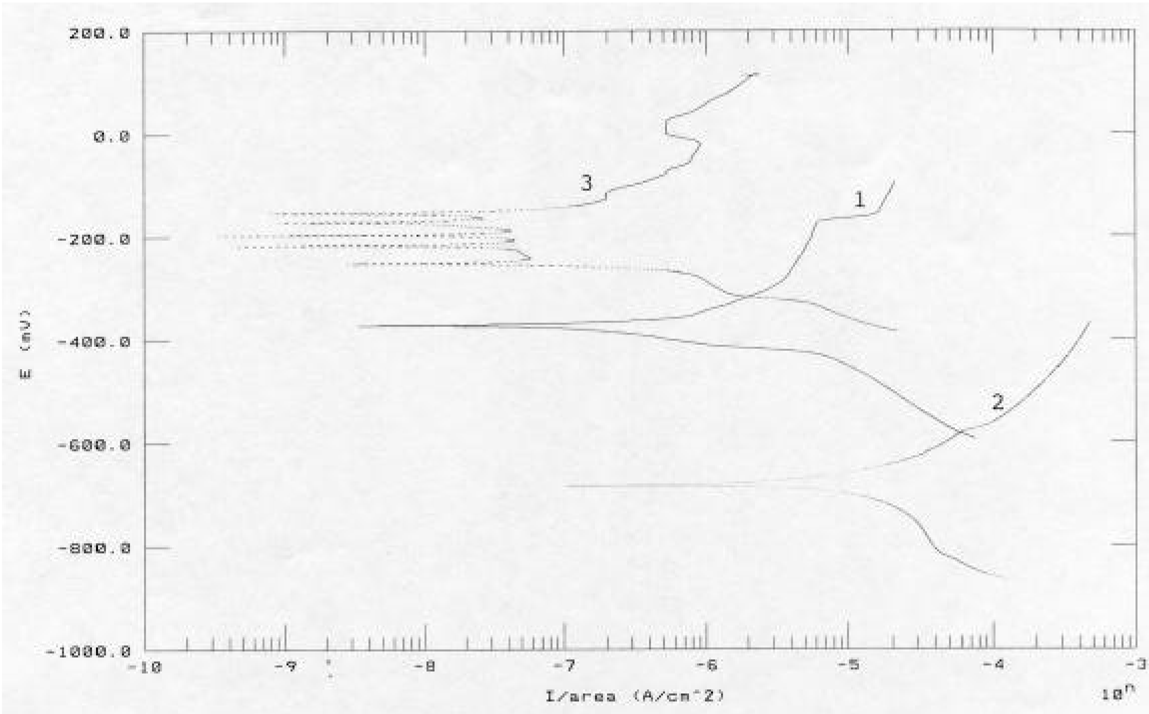


Effectiveness of VCI-645 in Sea Water
Carbon Steel, concentration 0.5%

1. VCI-645

2. Control

Figure #2

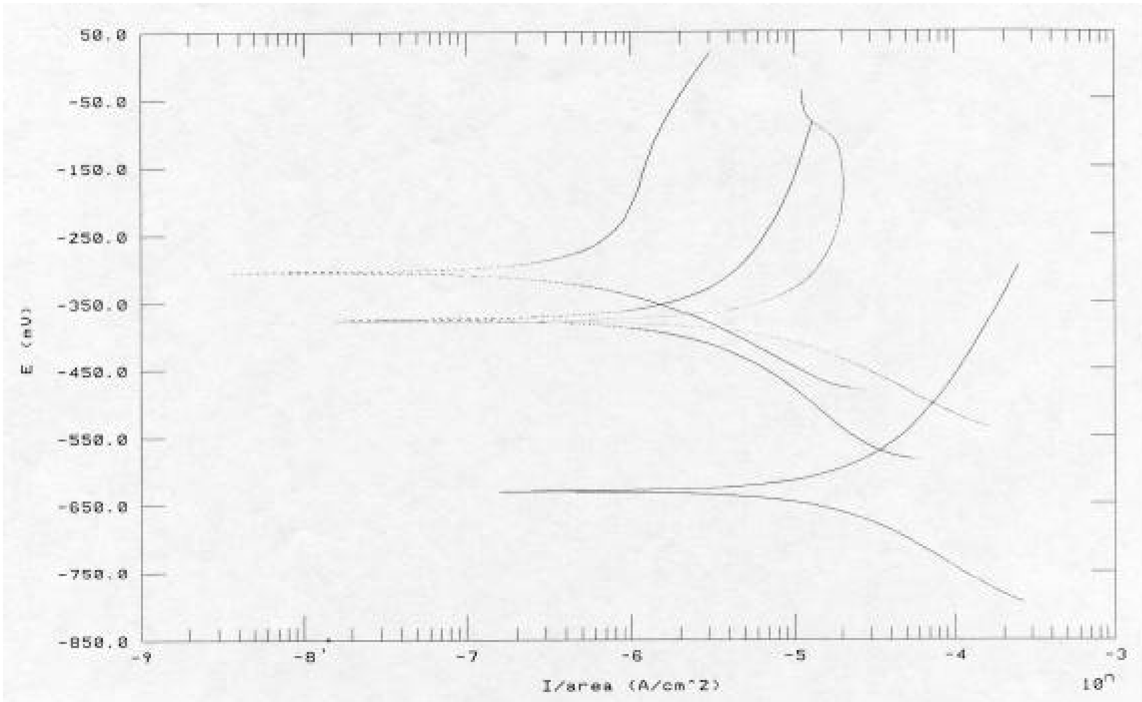


1. 500ppm component A + Tap water

2. 500ppm component B + Tap water

3. 250ppm component A + 250ppm component B
+ Tap water

Figure #3



Effectiveness of VCI-646, VCI-649 and S-69 in Tap water
Carbon steel, concentration 0.1%

1. VCI-649
2. VCI-646
3. S-69
4. Control