Prepared by: Tim Whited
Director of Engineering & Field Services
Cortec Corporation

May 10, 2013

Review of CorroLogic™ Systems for Soil-side Corrosion Control on ASTs

INTRODUCTION

The application of Cortec Corporation Vapor Phase Corrosion Inhibitor (VpCI®) chemistry, combined with a corrosion rate monitoring system, produces a proven solution for a major challenge confronting many owner/operators of aboveground storage tanks (ASTs). The Cortec CorroLogic System for ASTs is proven to control of soil side corrosion on the upper floors of double bottom tanks, and on the soil side of single bottom tanks with a HDPE secondary containment liner below the floors. The enclosed interstitial spaces below these tank floors provide the perfect environment for effective corrosion mitigation by vapor corrosion inhibitors.

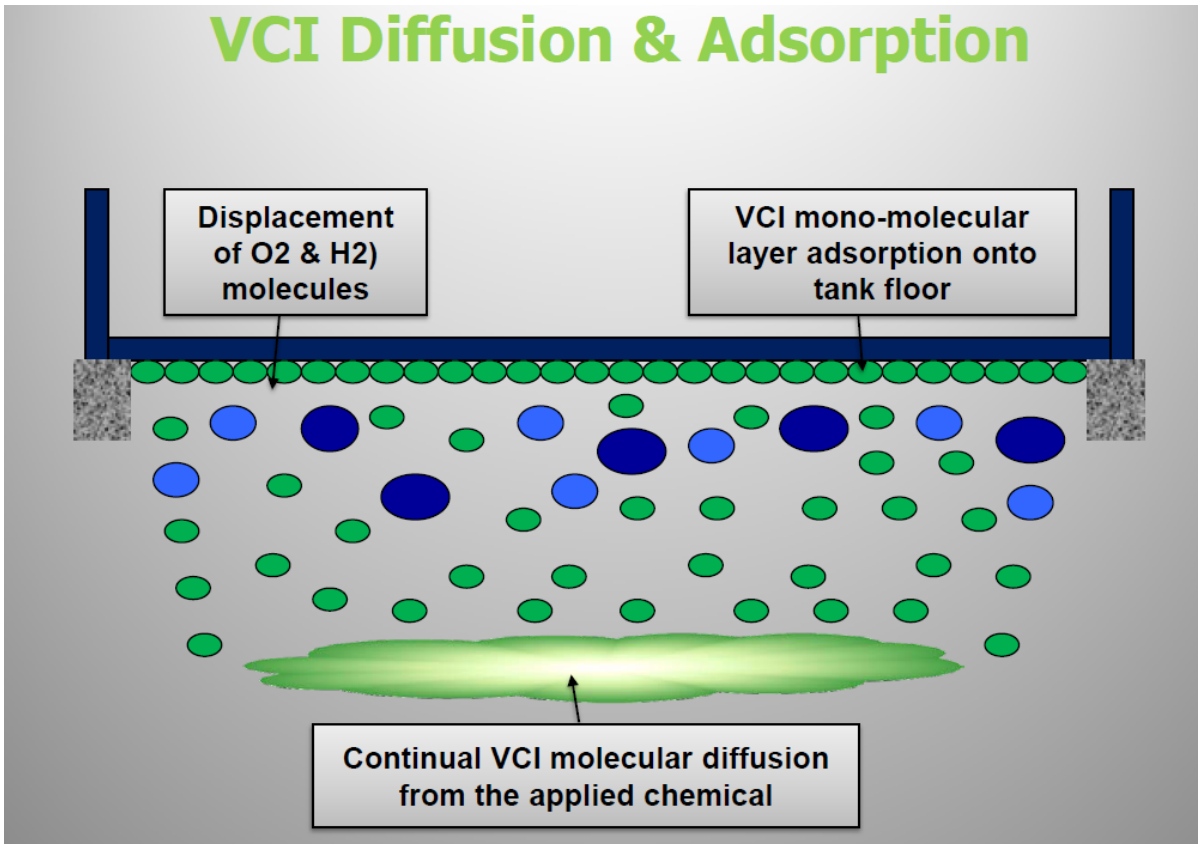
Design, engineering and application of the CorroLogic System for ASTs is managed by Tim Whited who is Cortec's Director of Engineering & Field Services. Tim has spent over 30-years in the corrosion control industry and has focused many of those years on cathodic protection and corrosion inhibitor solutions for ASTs. He has been a NACE certified CP specialist #3245 since 1992. Prior to joining Cortec in 2009 Tim had been actively engineering and developing systems and processes for delivery of vapor corrosion inhibitor chemistry under ASTs for many years.

VAPOR PHASE CORROSION INHIBITOR BASICS

It is important to recognize that vapor phase corrosion inhibitor chemistry / technology is very mature and well proven. Cortec has researched, invented, innovated, manufactured and applied environmentally-friendly vapor phase corrosion inhibitor chemistry for over 30- years to solve many basic corrosion control challenges on metallic surfaces. Cortec VpCI® chemistry is delivered through more than 450 products. VpCI® solutions for corrosion mitigation are utilized by many major corporations every day - in most regions of the world - for an amazingly wide variety of applications. Thus, proof of concept is repeatedly accomplished in real-time both visually and analytically - every day. Numerous technical literature on corrosion inhibitors is available on the Cortec website at www.cortecvci.com

The enclosed interstitial spaces below these tank floors provide the perfect environment for effective corrosion mitigation by vapor corrosion inhibitors. An amine-carboxylate based vapor phase corrosion inhibitor (Cortec VpCI 609) is used beneath the ASTs. These environmentally-friendly products are effective for prevention of metal corrosion in three phases: on the surface of the steel in contact with the sand tank pad materials, at the air/sand interface, and in the

vapor space above the sand. When VpCI® is delivered and released within an AST interstitial space, protective vapors disseminate until equilibrium determined by the partial vapor pressure is reached. The mechanism for corrosion control is the formation of a monomolecular layer throughout the soil-side surface of the tank floor. VpCI® molecules adsorb on the steel surface to suppress both metal dissolution and the reduction reaction, in other words both: anodic and cathodic processes. This adsorption is accomplished without the need for direct contact of the VpCI® chemical on the metal surface.



HISTORY WITH VPCI® IN ABOVEGROUND TANKS

- In 1993, Rials & Kiefer of Conoco Oil published a technical paper presenting results from testing a variety of corrosion control options for double bottom tanks.[1] One of the corrosion prevention methods tested included Cortec vapor phase corrosion inhibitor mixed with a typical tank pad material. Corrosion was monitored and measured over an extended time period. Almost no corrosion developed in the presence of the VpCI®.

- One of the first known AST applications of the VpCI® technology in the U.S. was by Motiva in Florida. Cortec VpCI 609 was installed in a water slurry mixture under (17) ASTs in Florida between the years of 2000 - 2001. Electrical resistance corrosion rate probes were installed under each tank to monitor the inhibitor effectiveness. Approximately 5-years after VpCI®

application the corrosion rate probe data was provided by Motiva. The corrosion rates were still very low. The rates ranged from 0.150 mils per year to 0.720 mils metal loss per year.

- Currently about (12-15) major pipeline companies operating ASTs in the U.S. utilize VpCI® chemistry to control corrosion on tank floors. These include Plains All American, Buckeye Pipeline, Centurion Pipeline, Holly Frontier, Valero, NuStar and TransMontaigne.

- It is estimated that over (300) ASTs have Cortec VpCI 609 applied below the floors.

- Saudi Aramco has utilized Cortec corrosion inhibitors for a number of years to control corrosion in many applications. For many years Aramco tank inspection programs had identified severe corrosion on tank bottoms leading to the costly replacement of bottom plates. The soil-side surfaces of the bottom plates were designed to be protected by impressed current cathodic protection (CP) systems. The oily sand layer and air gaps under the bottom plates reduced CP effectiveness and resulted in severe corrosion.

  Cortec worked closely Saudi Aramco to complete a 2011 pilot project utilizing Cortec VpCI 609 corrosion inhibitor to mitigate soli side tank floor corrosion. An electrical resistance (ER) probe corrosion monitoring system was also installed underneath the tank. Effectiveness of the VCI treatment was monitored using the ER probe system. Corrosion rate data from ER probes indicated that VCIs were effective in mitigating corrosion on carbon steel bottom plates during the first year after application.

  Saudi Aramco engineers Andy Yu and Robin Tems combined with Tim Whited of Cortec to co-author a technical paper on this pilot project. The NACE paper is #2242 “Mitigating Soil-Side Corrosion on Crude Oil Tank Bottoms Using Volatile Corrosion Inhibitors”. The paper was presented at the 2013 annual NACE conference in Florida.

VPCI® APPLICATIONS FOR DIFFERENT TYPES OF AST CONSTRUCTION

- The majority of U.S. installations have centered on double bottom tanks; and single bottom tanks with HDPE liners beneath the floor. Cathodic protection is still the primary corrosion control solution for single bottom tanks on sand foundations.
- The CorroLogic system is effectively used for new construction tanks, in-service tanks and out of service tanks.
- In the Middle East a majority of ASTs are constructed on oiled sand tank foundations. Corrosion is usually severe under these tanks and cathodic protection is normally not effective. Custom CorroLogic system designs are used for these tanks also.

CORTEC
CORROSION ENGINEERING
& FIELD SERVICES

ER PROBE DATA FROM ASTS WITH CORROSION INHIBITOR SYSTEMS

The data table below provides the real-time rates of corrosion as of December 2012at each ER probe installed under (22) tanks having corrosion inhibitor systems. These tanks are all located at a large terminal in the Midwest. The tanks all have single bottoms with an HDPE liner installed 6”-12” below the floors.

Impressed current CP grid systems were installed during tank construction but they all failed. The CorroLogic system was then applied to provide effective control of tank floor corrosion and maintain regulatory compliance. The year of inhibitor application is provided. The data indicates exceptional performance of the corrosion inhibitor systems.

Tank	Inhibitor Install Year	December 2012 ER Probe Real-time Reading (Mils / Year)					
		Probe 1	Probe 2	Probe 3	Probe 4	Probe 5	Probe 6
1	2006	0.0	0.1	0.3	0.3		
3	2006	0.9	0.0	0.0	1.0		
6	2006	0.3	0.0	0.5	2.1		
16	2006	1.2	0.1	0.6	0.5		
17	2006	3.1	0.0	0.3	1.2		
2	2009	0.7	0.7	1.9	0.0		
4	2009	1.0	0.0	0.0	0.3		
8	2009	4.1	2.1	0.0	0.5		
13	2009	0.0	0.9	0.0	1.0		
18	2011	0.0	0.5	0.0	1.2		
20	2011	0.2	1.4	0.0	0.0	0.0	0.0
22	2011	0.0	0.0	2.4	0.0	1.2	0.2
24	2011	0.2	0.0	0.7	1.5	0.0	0.3
25	2011	0.0	0.0	0.0	0.0	0.3	0.0
29	2011	0.2	1.4	1.5	0.0	0.9	0.0
34	2011	0.0	0.9	0.7	0.0	1.4	0.0
19	2012	0.0	2.4	0.0	0.0	0.7	0.0
21	2012	0.0	1.4	0.0	0.0	0.0	0.3
23	2012	0.0	0.2	0.0	0.0	0.3	0.0
26	2012	0.0	1.4	0.0	0.2	0.0	0.0
27	2012	0.0	0.0	0.0	1.2	0.0	0.5
28	2012	0.5	0.9	0.0	0.0	0.5	0.0

SUMMARY

When steel is exposed to properly applied Cortec vapor corrosion inhibitor chemistry, the corrosion is significantly mitigated. This has been proven in a wide variety of applications for many years throughout the world. The use of VpCI technology and systems for aboveground tanks in the U.S., as well as internationally, is maturing and expanding. Cortec has extensive experience with ASTs and are confident that we have the design, engineering and service delivery skills, combined with the most effective VpCI products, to provide our customers with effective AST floor corrosion control solutions.

By: Tim Whited
Director of Corrosion Engineering & Field Services
Cortec Corporation