CORRTECH

CORROSION ENGINEERING
INFRASTRUCTURE TECHNOLOGIES

Report for Corrosion Inhibitor Application
Tank 120-8, Valero Facility
Hartford, IL

Prepared for:

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May 2007

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INTRODUCTION

Volatizing corrosion inhibitors have been installed into the double floor interstitial space as a supplement to the operating sacrificial anode system for tank 120-8 located in the Valero Energy Terminal, Hartford IL. This work was completed on July 11, 2006 as CorrTech Job No 1149.

A total of 300-pounds of VpCI 608 powder was mixed with approximately 300-gallons of water for introduction into the interstitial space. The slurry mixture was pumped with low pressure pumps into the 1-inch NPT fittings welded to the tank shell within the space. In December of 2006, an additional 100-pounds of powder was added to the interstitial space.

Following application, a total of four eletronic corrosion rate monitoring probes and two corrosion coupons were installed in the 1-inch NPT fittings around the tank. These are utilized to monitor corrosion rates over time

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CONCLUSIONS

Based on field testing of the electronic corrosion rate monitors and the metal coupons, the following conclusions are made.

1. Corrosion rates determined from laboratory assessment of the corrosion coupons indicate corrosion rates of 0.735 and 2.156 mils per year. This verifies that corrosion controll is in place in the interstitial space associated with tank 120-8. See Appendix I for corrosion rate summary.

2. Corrosion rates monitoring for the electronic devises indicate corrosion rates ranging from less than 1.00 to 11.66 mils per year. Probe number 1 has been removed as it is considered to have failed. See Appendix I for corrosion rate summary.

3. Corrosion is being controlled within the interstitial space of tank 120-8 as evidences by the corrosion coupon analysis.

RECOMMENDATIONS

Based on the critical nature of the stored product and NACE International recommended practices, the following recommendations have been developed.

⇨ Monitor the corrosion rates over time with both the electronic rate monitors and the corrosion coupons.

DISCUSSION

Volatizing corrosion inhibitors have been installed into the double floor interstitial space as a supplement to the operating sacrificial anode system for tank 120-8 located in the Valero Energy

Terminal, Hartford IL. This work was completed on July 11, 2006. A total of 300-pounds of VpCI 608 powder was mixed with approximately 300-gallons of water for introduction into the interstitial space. The slurry mixture was pumped with low pressure pumps into the 1-inch NPT fittings welded to the tank shell within the space. In December of 2006, an additional 100-pounds of powder was added to the interstitial space.

Following application, a total of four eletronic corrosion rate monitoring probes and two corrosion coupons were installed in the 1-inch NPT fittings around the tank. These are utilized to monitor corrosion rates over time. The corrosion cupons provide a physical piece of steel within the environment that can be removed and evaluated in a laboratory to determine corrosion rate. The electronic corrosion rate monitoring probes are more sophisticated devises that monitor corrosion losses. These devises utilize electrical resistance technology to determine corrosion loss, and therfore rate.

The electrical resistance (ER) technique is an "on-line" method of monitoring the rate of corrosion and the extent of total metal loss for any metallic equipment or structure. The ER technique measures the effects of both the electrochemical and the mechanical components of corrosion such as erosion or cavitation. It is the only on-line, instrumented technique applicable to virtually all types of corrosive environments.

Although universally applicable, the ER method is uniquely suited to corrosive environments having either poor or non-continuous electrolytes such as vapors, gases, soils, "wet" hydro-carbons, and nonaqueous liquids. An ER monitoring system consists of an instrument connected to a probe. The instrument may be permanently installed to provide continuous information, or may be portable to gather periodic data from a number of locations. The probe is equipped with a sensing element having a composition similar to that of the process equipment of interest.

Principles of Operation

The electrical resistance of a metal or alloy element is given by:

$$R = r \cdot \frac{L}{A}$$

where:

L = Element length
A = Cross sectional area
r = Specific resistance

Reduction (metal loss) in the element's cross section due to corrosion will be accompanied by a proportionate increase in the element's electrical resistance.

Practical measurement is achieved using ER probes equipped with an element that is freely "exposed" to the corrosive fluid, and a "reference" element sealed within the probe body. Measurement of the resistance ratio of the exposed to protected element is made as shown in Figure 1.

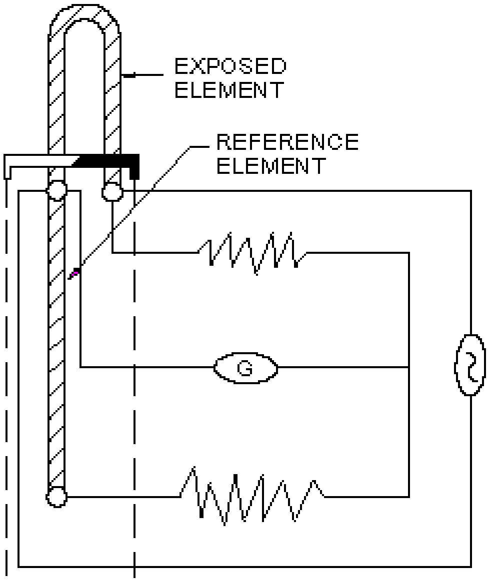


Figure 1. Probe / Instrument

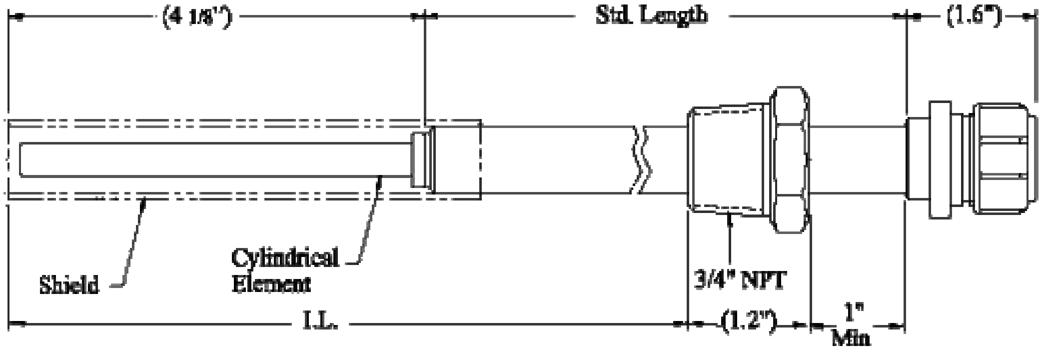
Since temperature changes affect the resistance of both the exposed and protected element equally, measuring the resistance ratio minimizes the influence of changes in the ambient temperature. Therefore, any net change in the resistance ratio is solely attributable to metal loss from the exposed element once temperature equilibrium is established.

All standard Metal Samples Corrosion Monitoring Systems ER probes incorporate a third element called the "check" element. Because the check element is also sealed within the probe body, the ratio of its resistance to that of the reference element should remain unchanged. Any significant change in this ratio indicates a loss of probe integrity.

Metal Samples Corrosion Monitoring Systems ER instruments will produce a linearized signal which is proportional to the metal loss of the exposed element. The rate of change in the instrument output is a measure of the corrosion rate.

E/R Sensing Elements

Sensing elements are available in a variety of geometric configurations, thicknesses, and alloy materials. The probes used for the Valero Hartford project utilize mild steel cylindrical elements that is very similar to the type of steel used on the tank floors. The probes are manufactured by welding a reference tube inside of a tube element. This element has an all welded construction which is then welded to the probe body.



Model ER2100 used for this project is a fixed-length, electrical resistance probe with a 3/4" NPT pipe plug. The all-welded construction allows the probe to be used in harsh environments. The probe assembly consists of an insertion rod with an element, a hermetically sealed connector, and a 3/4" NPT pipe plug, which are all welded in place.

Corrosion Rate Calculation

When measuring the ER probe, the instrument produces a linearized signal (S) that is proportional to the exposed element's total metal loss (M). The true numerical value being a function of the element thickness and geometry. In calculating metal loss (M), these geometric and dimensional factors are incorporated into the "probe multiplier" (see Table 1), and the metal loss is given by:

$$M = \frac{S \times P}{1000}$$

Both S and P are dimensionless. Metal loss is conventionally expressed in mils (0.001 inches), as is element thickness.

Corrosion rate (C) is derived by:

$$C = \frac{P \times 365\,(S_2 - S_1)}{\Delta T \times 1000}$$

T being the lapse time in days between instrument readings S_1 and S_2.

For the Valero Hartford project P = 10.

S_1 and S_2 are obtained from the MS1500E instrument.

MS1500E Handheld ER Corrosion Data Logger

For this project a MS1500E hand-held, battery-powered, corrosion meter is used to measure the electrical resistance and obtain the data necessary to determine the corrosion rate of the interstitial space environment at the probe location. The instrument is light weight, microprocessor-based, and features a simple, menu-driven interface using a 12-key keypad and a 4-line LCD display.

GENERAL

Corrosion rate measurements are made using the electrical resistance method. Essentially, the instrument measures the resistance of the probe element which changes over time, as metal loss occurs. The rate of change is directly proportional to corrosion rate. After taking a reading, the instrument displays metal loss in mils and corrosion rate in mils per year (mpy).

The area between the underside of the new tank floor and the HDPE liner is commonly referred to as the “interstitial space”. It is this space that is the subject of concern to tank operators and regulatory agencies because of the potential for corrosion of the underside of the new floor plates. Although the backfill material is typically high resistance sand and under most circumstances can be considered non-corrosive, several instances can occur where active corrosion cells can manifest on the exterior tank floor plate in this environment. Factors that can contribute to the development of active corrosion cells are the presence of moisture in the sand, voids, pockets of differential backfill material and “clumping” of the sand. Any of these factors, operating alone or in concert can act to corrode the steel floors, even, where cathodic protection systems are in place. The volatizing corrosion inhibitor has been provided to supplement the existing cathodic protection system.

The corrosion inhibitors installed satisfy the technical requirements of the NACE International Recommended Practice RP 0487, “Considerations in the Selection and Evaluation of Rust Preventives and Vapor Corrosion inhibitors for Interim Corrosion Protection”.

Electrical resistance corrosion rate monitoring relies on changes in the cross sectional area of the electrical resistance conductor. These are manufactured in a variety of geometric shapes and configurations to facilitate the anticipated corrosion rates and probe life. The primary corrosion mechanism monitored by this method is general corrosion rates

Included with this report are the following:

1. Product information on Cortec VpCI 608 powder
2. MSDS sheet on Cortec VpCI 608 powder
3. Standard Operating Procedure

The follow standard procedure was followed for the corrosion control monitoring at this location. Before going into the field to perform set up and perform corrosion rate monitoring, the following items need to be considered:

- Design drawings for the structure under study
- Listing of materials of construction and corrosion control methodologies
- Suitable ER probes for application: NPT sized and length

- Suitable corrosion coupon probes, NPT sized and length
- Corrosion probe installation sketch

As the resistance of the ER probes and corrosion coupon probes can be adversely effects by external damage, it is important not to handle them properly. They should not be touched by any materials or contaminant films to impart foreign matter, including hands, scratches or other mechanical damage is to be avoided.

PROCEDURE

The following procedures are established to ensure accurate installation and results:

Clean the corrosion rate probes in accordance with manufacturers recommendations

Install probes in the structure under test in accordance with the probe installation plan and sketch

Allow a minimum of 4-hrs initiation to acclimate the probes, longer time for acclimation is acceptable

Measure the ER probes with the hand held unit. Determine corrosion rate based on time, and resistance characteristics (automatic calculation within hand held, refer to unit O&M). Measure the ER probes with the hand held unit at the prescribed time intervals i.e., monthly, quarterly etc. Download historical probe data into Excel format for plotting corrosion rate over time. Inspect the corrosion coupon probe as required to verify corrosion control method effectiveness, submit to manufacturer for analysis as required

Prior to installation of the corrosion inhibitor on July 11, 2006, corrosion rate probes and a corrosion coupon were installed into the NPT fittings welded to the tank shell within the space on June 21, 2006. In accordance with monitoring protocol, these were checked initially with a handheld Metal Sample S1500E hand-held, battery-powered, corrosion mete. This devise is used to measure the electrical resistance and obtain the data necessary to determine the corrosion rate of the interstitial space environment at the probe location.

A total of 300-pounds of VpCI 608 powder was mixed with approximately 300-gallons of water for introduction into the interstitial space. The slurry mixture was pumped with low pressure pumps into the 1-inch NPT fittings welded to the tank shell within the space. Following application, all NPT fittings were sealed.
The corrosion rate probes were also measured with the Metal Sample S1500E handheld devise on July 11, 2006.

The attached table summarizes the data obtained.

During the activities on July 11th, the corrosion coupons were removed for observations. Rust was observed on the coupon sample estimated to be 10% of the total surface area. This had occurred in the 20 days that the coupon had been installed.

The use of “double-bottom” or “false bottom” floors on existing above ground fuel storage tanks is a technology that has become more common within the industry since the early 1990s. The technique has been implemented on those tanks where environmental considerations or inspection data indicate the original floor plates of the tanks to be compromised. Under conditions conducive to corrosion, the steel floor plates corrode in such a manner as to expose the surrounding soil to possible contamination as the stored product leaks.

A common solution is to install a secondary floor, impervious liner, environmental monitoring systems and sand padding. In order to install a new bottom, the tank is first drained and cleaned. A cut is made in the vertical wall plates typically 6-8 inches above the existing floor around the entire circumference of the tank. A HDPE liner is usually installed over the existing floor and the space between the liner and the elevation of the new floor plates is filled with a high resistivity, sand backfill material. This material is leveled with the elevation of the wall cut and new floor plates are welded in place. This procedure will effectively extend the service life of the tank and is far less expensive than total tank replacement.

The area between the underside of the new tank floor and the HDPE liner is commonly referred to as the “interstitial space”. It is this space that is the subject of concern to tank operators and regulatory agencies because of the potential for corrosion of the underside of the new floor plates. Although the backfill material is typically high resistance sand and under most circumstances can be considered non-corrosive, several instances can occur where active corrosion cells can manifest on the exterior tank floor plate in this environment. Factors that can contribute to the development of active corrosion cells are the presence of moisture in the sand, voids, pockets of differential backfill material and “clumping” of the sand. Any of these factors, operating alone or in concert can act to corrode the steel floors, even, as demonstrated in this paper, where cathodic protection systems are in place.

With the advent of “double-bottom” tanks, new challenges were posed to designers of cathodic protection for these structures. Conventional impressed current systems as described above are ineffective in protecting the new tank floors because of shielding characteristics inherent in the tank floor configuration. Anode systems had to be designed so that they could be readily installed in the interstitial space above the existing floor (and liner) and below the new floor. Several types of impressed current systems and sacrificial system began to make their way into the marketplace. Each system had its own inherent deficiencies. Impressed current systems had to be designed so that the anode material string was electrically continuous and could never actually come into physical contact (“short”) with the tank floor. Monitoring was accomplished by placing one or more permanent reference electrodes, each with a finite service life, alongside the anodes. These systems, once installed, could never practically be repaired should a component failure occur. Power costs and external maintenance of the power unit was also an undesirable characteristic.

Galvanic or “sacrificial” systems have also been installed as an alternative to impressed current. These system, have the advantage of not requiring an external power source, however the same sorts of problems are encountered relative to short circuits and monitoring as was evidenced in the impressed current systems. Additional problems associated with sacrificial anode systems relate to their functional ability to produce sufficient current to provide adequate cathodic protection under dry or damp conditions.

This paradox is further complicated by the anode resistance to electrolyte, when sand is used as backfill. Even when saturated to 20% or more with water, the sand resistivity is too high to allow sacrificial anodes to sufficiently generate adequate protective current density to the tank bottom. This condition has been observed where tank bottom plates have failed API 653 inspection thickness requirements, floor sections were removed to find damp sand and brand new sacrificial anodes in place.

Conventional methodologies of monitoring and data interpretation were, more often than not, inconclusive in establishing the effectiveness of these systems in actually controlling corrosion on these structures. The majority of the data obtained during these surveys do not satisfy the requirements of NACE International recommended practice.

Volatizing vapor phase corrosion inhibitors have proven effective in arresting corrosion of steel and other metallic materials in a confined space. This technology provides an effective solution to the corrosion activity that has been observed in some new tank floor installations where moisture was present and the cathodic protection system was ineffective in controlling the resulting corrosion. This corrosion mitigation method offers an economic solution to ineffective cathodic protection systems for existing tanks and a proven corrosion mitigation technology for new installations.

Volatizing corrosion inhibitors provide total corrosion control on structures and equipment in a wide variety of environments. These products provide an effective and economic solution to the atmospheric and submerged corrosion exposures for the environment under the AST tank floor. In addition, the system does not have to be completely tight for the inhibitors to function properly.

VpCI™ inhibitors provide continuous protection and are self replenishing for uninterrupted protection in contact and vapor phase exposures. These products do not contain chromates or other heavy metals, nitrates or chlorinated hydrocarbons. They are environmentally safe for both on-site personnel and the environment.

VpCI™ inhibitors satisfy the technical requirements of the NACE International Recommended Practice RP 0487, “Considerations in the Selection and Evaluation of Rust Preventives and Vapor Corrosion inhibitors for Interim Corrosion Protection”.

VpCI inhibitors can be provided to both new floor installations as well as existing double floor installations where the cathodic protection system has been tested to be ineffective in providing corrosion control. They would be introduced in powder form in the sand padding during new floor installations. For existing floor systems the inhibitors would be introduced in a liquid form by pumping into the interstitial space through the vapor sampling ports. The application procedure should seek to deliver the inhibitors in an even pattern across the tank floor.

Volatizing corrosion inhibitors provide protection through the ability of the amine carboxylate salt to readily volatize in the space where they have been applied. Due to high vapor pressure characteristics, the amine salt molecules volatize into a vapor phase reaching equilibrium in the enclosed space of the double floor tank environment.

Where corrosion becomes active on the tank bottom surface, the anodic and cathodic corrosion cells, positive and negative charge, attract the amine salt molecule ionic positive and negative charge components. Once attached to the steel surface, a monomolecular layer of ions thus preventing water and other corrosive constituents from contacting the steel surface. The result is an acceptably low corrosion rate of the steel surface.

The amine salt is supplied in sufficient quantity to allow continued volatilization over a five-year period. Where corrosion sites occur on the steel surface, additional inhibitors are available within the space to arrest the activity. Volatizing corrosion inhibitors, VCI, have been shown to be effective in controlling corrosion in this setting where CP has, in many cases, found to be ineffective.

CORROSION MONITORING

The effectiveness of the volatizing corrosion inhibitors can be monitored by several methods. These methods include primarily electrical resistance monitoring probes and corrosion coupon evaluation. Electrical resistance devices utilize calibrated elements made from the same material as the tank floor. As the calibrated element experiences corrosion, the cross sectional area resistance of the element changes. Through the calibration and correlation of the instrument, a corrosion rate can be determined. Where no corrosion occurs, the resistance of the probe remains constant.

Corrosion coupons utilize steel components that are introduced into the monitored space. The coupons are pre weighted prior to installation on special holding racks. Following exposures of different time periods, the coupons are cleaned and measured. Weight loss data is then converted into corrosion rate information.

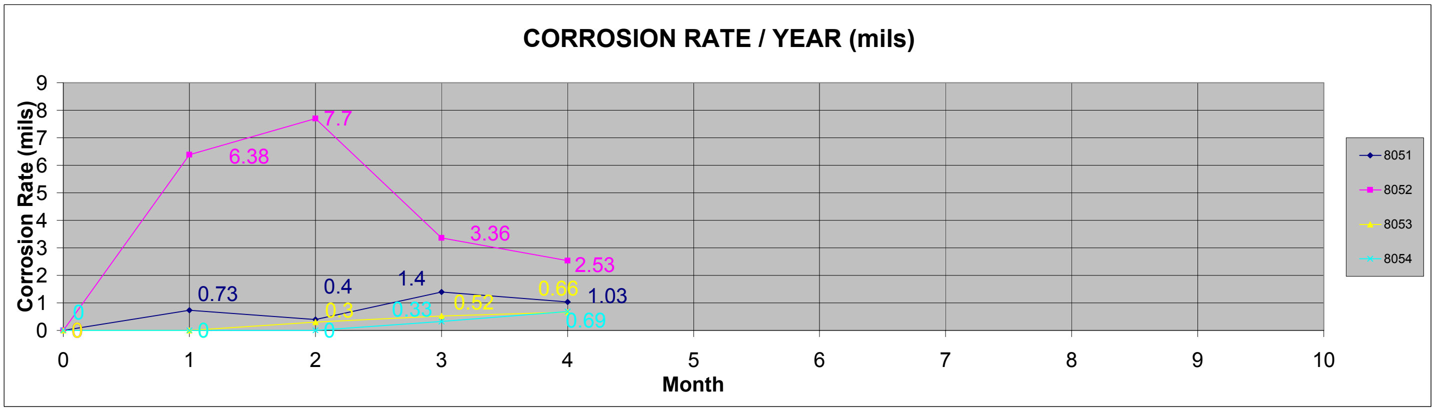
Several corrosion rate units should be considered for each tank as well as verification by both electrical resistance and coupon devices. This data can be utilized in concert with API 653 inspection data in determining the interval for the next inspection. Periodic monitoring of the corrosion rate probes allows historical monitoring of corrosion rates under the tank floor as part of a cohesive corrosion mitigation and monitoring program. Should corrosion rates become unacceptable, corrosion inhibitors can be re-introduced to preempt corrosion degradation of the floor.

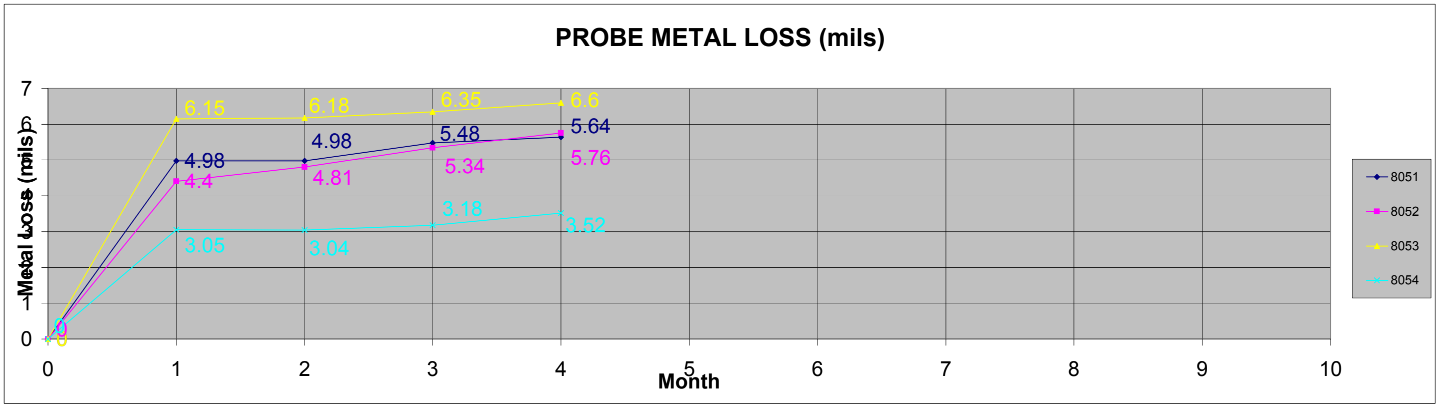
APPENDIX I

Test Results

Data Summary Report

Tank 80-5 Hartford	Probe ID: Serial Number / ID #										
	P1: M229 / 8051		P2: N248 / 8052		P3: M228 / 8053		P4: M227 / 8054		P5:		
Month	Corrosionn Rate (Cri)	Probe Metal Loss (M_i)	Corrosionn Rate (Cri)	Probe Metal Loss (Mi)	Corrosionn Rate (Cri)	Probe Metal Loss (Mi)	Corrosionn Rate (Cri)	Probe Metal Loss (Mi)	Corrosionn Rate (Cri)	Probe Metal Loss (Mi)	
0	0	0	0	0	0	0	0	0			
1	0.73	4.98	6.38	4.4	0	6.15	0	3.05			
2	0.4	4.98	7.7	4.81	0.3	6.18	0	3.04			
3	1.4	5.48	3.36	5.34	0.52	6.35	0.33	3.18			
4	1.03	5.64	2.53	5.76	0.66	6.6	0.69	3.52			
5											
6											
7											
8											
9											
10											
11											
12											





CRi = Corrosion Rate / Year (mils
Mi = Probe Metal Loss (Mils)