Total Corrosion Control Methods: AST Tank Bottoms

Scott Paul
CorrTech Inc.
25 South St
Hopkinton, MA 01748

ABSTRACT

Above ground storage tank soil side corrosion, continues to adversely affect tank integrity. Corrosion has been found to exist with a cathodic protection system present, resulting in floor repairs. Inadequate cathodic protection test results have prompted state regulators to seek floor and cathodic protection system replacement. These repairs are costly, both in terms of construction activity as well as down time for the stored product.

This paper will present corrosion control technologies available for new and existing above ground storage tanks. The pros and cons of sacrificial anode cathodic protection, impressed current cathodic protection and corrosion inhibitors will be presented. Basic electrochemistry will be discussed to facilitate technical understanding of these approaches. For decades, the use of cathodic protection has been commonplace to control corrosion on tank bottoms and buried piping systems. They are typically installed during tank construction and retrofitted to existing tanks.

The use of “double-bottom” tank floors on existing above ground fuel storage tanks is a technology that has become more common within the industry. 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.

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.

STATEMENT OF THE PROBLEM

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. Provided with adequate corrosion control technologies and regulated inspection procedures, the service life of the new floor can be extended for many decades.

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 bottom of the floor plate in this environment. Factors that can contribute to the development of active corrosion cells are the presence of moisture or water in the sand, air 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.

Cathodic Protection

For decades, the use of cathodic protection systems has been commonplace in this industry and others to control corrosion on “single floored” tank bottoms and buried piping systems. They are typically installed during tank construction and retrofitted to already standing tanks. Buried fuel piping and tank systems are regulated by many states to require cathodic protection.

The most common type of cathodic protection for tanks of this type is the impressed current system. This system utilizes an inert anode material that is energized by an external power source (rectifier) to deliver protective current to the tank bottom. Depending on individual tank characteristics and system design parameters, impressed current cathodic protection anodes are installed directly below the tank floor, distributed around the outer tank ring wall or installed in wells and stacked at depths ranging to hundreds of feet. Energy for an impressed current system is provided by a power supply or rectifier. This is an electrical device which converts AC power to DC power. The rectifier provides a positive current supply to the anodes and a negative current return from the structure. For this circuit, Ohms law applies: E=IR, where E is the driving voltage or the rectifier output voltage, I is the current magnitude that results from the resistance of the circuit R. Proper system design seeks to minimize the resistance of the circuit through anode ground bed design. Impressed current systems are capable of small to very large energy output levels through proper design. This range of ability allows protection possibilities for poorly coated structures such as tank floor bottom plates.

Sacrificial anode systems do not provide as much energy output as the impressed current system. Therefore, they would not function properly in many applications where cathodic protection would be required. Sacrificial systems generally require that the structure be coated with a tightly adherant coating system and be electrically isolated from all other metallic structures and system components. Sacrificial anode cathodic protection provides protection in the same manner as the impressed current system, except there is no power source or rectifier. Sacrificial anodes are intended through the system design to corrode, thereby protecting the steel structure of interest.

Energy for the sacrificial anode system is provided by the difference in energy level between the anode and the structure being protected. Typically, magnesium anodes are utilized to protect steel structures, as magnesium alloys would corrode preferentially when connected to steel in an underground environment. There is approximately a 1.0 volt difference between these two materials.

A sacrificial anode installation is also a DC circuit with positive current supplied from the anodes and a return negative current supplied from the structure. Again, Ohms law applies: E=IR, where E is the driving voltage of the circuit or approximately 1.0 volts, difference between magnesium and steel, I is the current magnitude that results from the resistance of the circuit R. Proper system design seeks to minimize the resistance of the circuit through anode ground bed design.

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 inability 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.

Regulatory Issue

The lack of acceptable data in these test scenarios often leads to the conclusion that the sand backfill material is dry and therefore not corrosive. Often the cathodic protection system does not meet the polarization criteria listed in NACE RP0169-92. It is considered that the sand layer installed under the new bottom is very dry, and as a result very high in resistivity (inverse of conductivity). This means that the cathodic protection system is not able to provide sufficient current flow to provide cathodic polarization.

It is often considered that this condition has a benefit in that without moisture and oxygen, the corrosion process cannot occur. Therefore it is considered that corrosion of the steel is not occurring at this time. Should moisture get into the interstitial space between the tank floors, the cathodic protection would provide additional protective current and thereby cathodic protection of the steel bottom.

Where state regulations require cathodic protection in accordance with NACE International recommended practices, these tanks technically are out of compliance. This creates a conflict between the requirement for adequate corrosion control and the professional's consideration that corrosion is not likely in the created environment.

All of this is not to imply that cathodic protection is totally ineffective in these applications. However, serious considerations must be given as to the traditional techniques and methodologies employed to interpret field data in an effort to demonstrate effectiveness.

Corrosion Mitigation With Volatizing Corrosion Inhibitors

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.

VCI 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.

VCI 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".

VCI 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 prevent 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.

Research and fieldwork indicate that adequate corrosion control can be provided to the tank bottom. These results have been obtained over 15-years of study and evaluation. Recently, the process was approved by the State of Florida DEP as an acceptable procedure for the corrosion protection of above ground storage tanks.

Corrosion Monitoring

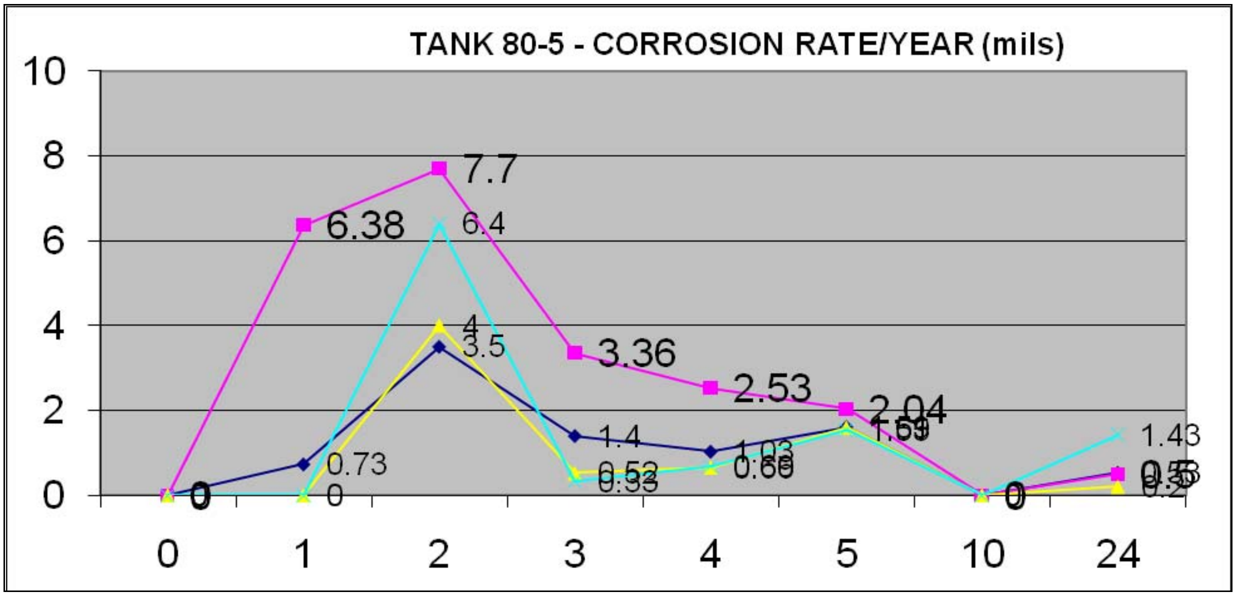
The effectiveness of the volatizing corrosion inhibitors can be monitored by several methods. These methods include primarily electrical resistance monitoring probes and corrosion coupon evaluation. Electrical resistance devices utilize calibrated elements made from the same material as the tank floor. 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 cohesive corrosion mitigation and monitoring program. Should corrosion rates become unacceptable, corrosion inhibitors can be re-introduced to preempt corrosion degradation of the floor.

The following chart represents typical electronic corrosion rate probe rates before and after the introduction of corrosion inhibitor into the double floor space. In month 2, VCI corrosion inhibitor was introduced at a time where corrosion rates were between 3.5 and 7.7 mils per year. After approximately 2-years, corrosion rates were reduced to 0.20 to 1.43 mils per year

CHART I
CORROSION RATE MONITORING



Summary

The effectiveness of volatizing corrosion inhibitors in controlling corrosion of steel has been documented over the last 15-plus years. Where the environment in the interstitial space beneath AST floors is intended to be homogeneous and non-corrosive, in many cases the opposite is true. Volatizing corrosion inhibitors, through their vapor pressure characteristics, reach homogeneous equilibrium in the interstitial space thereby controlling corrosion of all metallic components in the space. This technology provides a proven method to replace ineffective cathodic protection systems on existing tanks and an effective technology for new installations.