



Corrosion Control for Aboveground Storage Tanks: Part 1 - Causes and Controls

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Continuing Education

This is the first of a two-part article on solving corrosion problems related to aboveground storage tanks (ASTs). This article reviews the various types of corrosion and describes the four major methods of corrosion control in existence today as they pertain to ASTs. In the December issue, Corrpro's Dean Flessas will discuss the AST testing necessary to ensure proper use and performance of corrosion control methods.

For decades, the oil and gas industry has viewed corrosion in storage systems as a major cause of releases and equipment failure. In order to protect the investments associated with building large fuel storage tanks, owners often included some method of corrosion control to extend the life of the tank or at least the tank bottom. Over the past 15 years or so, the emphasis on corrosion control in storage tank systems has shifted from asset management to environmental protection. In 1984, the EPA included corrosion control as a major part of the requirements for underground storage tank systems (USTs). Since that time, several states, including New York, Alaska and Florida, have required corrosion control as part of their regulations for aboveground storage tank systems (ASTs).

Basic corrosion

To understand how to control corrosion, we must first have a basic understanding of what corrosion is. Corrosion is defined as the degradation of a material or its properties due to a reaction with its environment. This includes not only "rusting steel," but also metals and plastics that are incompatible with certain chemical compounds. However, for the purposes of this article, we will limit the discussion to corrosion in metals.

Corrosion in metals is a natural phenomenon. As we excavate iron ore and process the ore into a steel plate or pipe, we add energy to the metal. Since all materials tend to remain at the lowest possible energy state, the energy that we have introduced into the metal is released through the electrochemical reaction of corrosion. The higher the energy level in the metal, the more likely it is to corrode. This energy level can be measured using a voltmeter set to DC (direct current) Volts and a

stable reference.

Corrosion in metals is an electrochemical reaction, which means a chemical reaction takes place that creates direct electric current flow. While there are various types of corrosion, all require four basic components to be present for corrosion to occur: the anode, the cathode, the metallic path and the electrolyte (**see Figure 1**).



Magnesium	-1.75 volts
Zinc	-1.10
Aluminium	-0.40 to -.060
Copper	-0.20
Carbon	+0.30
Silver	+0.80
Platinum	+1.20
Gold	+1.60

Table 1: Galvanic Series

Chemical reactions take place on both the anode and cathode. The reaction at the anode releases electrons through the metallic path. This allows the metal atoms to break loose and bond with oxygen in the environment, thus resulting in metal loss. The reaction at the cathode takes place in the electrolyte adjacent to the metal, usually breaking down the water molecules; this process allows electrons to flow from the metal of the cathode. Direct Current (DC) flow is typically shown as moving in the opposite direction from electron flow.

While much of the science of the corrosion reaction is not important to the typical tank owner, understanding that electric current flows off of the anode (the component that corrodes) through the electrolyte and onto the cathode (the component that is not corroding) is essential. The higher the current flow, the faster the corrosion rate at the anode. By controlling this current flow, we can control the corrosion on tanks and associated piping.

Types of corrosion

When we look at the causes of corrosion, we can limit much of the discussion to three primary causes:

- bi-metallic couples,
- non-homogeneous environment and
- microbially induced corrosion.

The most common of these is the bi-metallic couples.

Bi-metallic couples

Different metals have different energy levels based upon the amount of work required to transform a metal from ore to its pure metal useable form. Table 1 lists several common metals and their corrosion potential, which is the energy level relative to a copper/copper sulfate reference electrode. The metals with greater negative numbers are more active materials and, therefore, more likely to corrode. When connected to a metal lower on the list in a common environment, the more active metal will become the anode and the other will become the cathode.

A common example of a bi-metallic couple is a bronze check valve in a steel piping system. If the pipe and valve are buried, the steel will corrode and actually protect the bronze valve. The rate of the corrosion will be affected by the ability of the current to flow through the environment (measured in resistivity), the relative size of the two materials and the difference in the energy levels of the two metals (driving potential).

Non-homogeneous environment

In environments where the oxygen concentration varies from one point to the next, corrosion cells can be created on the surface of a single metal. This difference in oxygen levels in soil applications is usually due to a mixture of soil types, contaminants in the soil or the groundwater table. More often than not, this occurs when clumps of clay are mixed into a clean sand fill material. When a clump of clay is positioned against a tank, a lower oxygen level is created at the surface of the steel under the clay relative to the level in the sand. The anode will be formed under the clay, where the oxygen level is lower.

Microbially induced corrosion

Microbially induced corrosion (MIC) is probably the least common (and least understood) type of corrosion in tank applications. More often, MIC will be a factor on the interior rather than the exterior, or soil side, of the tank. In short, the growth of colonies of bacteria will create microscopic zones of non-homogeneous electrolyte similar to the clump of clay. In addition, their biological processes may create a more corrosive environment, which will accelerate localized corrosion on the metal surface. There are differences in the details, but MIC is not a situation in which the bacteria eats the metal.

Corrosion control

To stop a tank from corroding, we have to control the corrosion process. This can be done by removing any one of the four components of the corrosion cell or by modifying the corrosion cell by adding new pieces. The four major methods of corrosion control are:

Electrical isolation—In electrical isolation, we separate the different metals. In the example of a bronze valve in a steel piping system, we can install a dielectric (non-conductive) fitting between the bronze and the steel so that while the pipe will still contain the product, the two metals do not physically touch.

Dielectric coatings—Coatings isolate the metal from the electrolyte. A good quality coating can reduce the amount of metal on a pipe in direct contact with the soil by as much as 98 percent, depending on the quality in the coating and its application. As a result, this is an effective means of corrosion control on new structures. In the desired configuration, the cathode of the cell is coated. If the anode is coated, a “concentration effect” will likely occur. This causes what seems to be a higher corrosion rate in the anode, localized to the point of a coating defect.

Cathodic protection—With cathodic protection, a new component is introduced into the corrosion cell that is aimed at the structure we want to protect— the cathode of the corrosion cell. This practice

does not stop the corrosion; rather, it simply redirects the corrosion to a component that we can sacrifice and replace at a lower cost than the tank. It should be noted that cathodic protection only protects those surfaces exposed to the common electrolyte such as the anodes (i.e., external cathodic protection will not protect against internal corrosion).

Environmental controls—This option deals with changing the electrolyte to increase or decrease the corrosion rate. It is usually not an effective tool in underground environments. The most common example in the tank market is the use of non-corrosive materials as fill between two floors of a double bottom tank or use of a chemical additive to prevent internal corrosion problems.



Figure 2: Stray Current Corrosion



**Figure 3: Distributed Anode Bed
Cathodic protection**

There are two types of cathodic protection. The first is galvanic, which relies upon the energy level in different materials to provide the driving potential; the second is impressed current flow, which uses an outside source to provide the power.

Galvanic protection utilizes installation of a metal with a higher energy level than either the existing cathode or anode to make both the cathode. In the case of underground or soil applications, magnesium and zinc are the most common anode materials used to protect steel. This type of system requires virtually no maintenance, but will require periodic replacement of the anodes.

The limitation of this type of protection is that only small amounts of current can be achieved from the anodes. The driving potential is set by the energy level of the material. This type of protection is, therefore, typically limited to small surface areas or coated structures. In addition, electrical isolation is often included in the design to ensure the anodes are only protecting the desired structures.

An impressed current protection system involves taking electric power from a local AC power source, converting the electric power to a direct current with a rectifier and distributing it from anodes installed in the soil. The types of materials used for impressed current anodes are selected for their low consumption rates to ensure a long life even at high current outputs.

Because the power comes from an unlimited supply, the output is also unlimited. Very large areas of metal exposed to the soil can be protected with this type of system. In addition, the anode materials and configurations available today allow for a great deal of flexibility in providing localized protection in very complex situations.

When designing and installing impressed current cathodic protection systems, care should be taken to ensure that all structures in the area are electrically continuous with the system so that it does not damage adjacent structures. This type of damage is often called stray current or interference corrosion. It is caused by current from the cathodic protection anodes flowing onto an isolated

structure, along the structure and then discharging to return to the tank being protected (see Figure 2). At the point of discharge, the isolated structure is corroding at an accelerated rate. If necessary, there are methods to maintain isolation of these other structures, but detailed testing must be included in the system evaluation to ensure that the system is not causing more problems than it solves.

Aboveground tank corrosion control

Now that the basics are out of the way, let's look at how the different technologies can be applied to aboveground tank systems. There are differences in protection options for small, shop-fabricated tanks and the larger field-erected tanks. Small tanks are typically easier to provide with a reliable level of corrosion control.

Small tank protection—Shop-fabricated tanks for aboveground applications offer the ability to effectively isolate the tank from the soil by installing a horizontal tank on saddles or by setting a vertical tank on structural members. By keeping the tank away from the conductive electrolyte, the corrosion issues then to be controlled are atmospheric, which are typically handled with good quality coatings.

A shop-fabricated tank can also easily be coated with a durable dielectric coating to minimize the soil contact if it is to be installed on a conductive base. It is often said that placing a tank on a solid concrete pad will eliminate the corrosion concern.

Conceptually, this is true, but the concrete pad must be designed to channel liquids away from the tank, not allowing water to collect in between the tank bottom and the pad. If water collects, corrosion will likely occur, resulting in a shorter life for the tank than may have been achieved by setting the tank on a sand bedding. The pad also has to remain intact, with no cracks to allow soil contact.

If the tank is set on soil, then a good quality coating combined with cathodic protection is the best long-term corrosion protection method. If the tank can be electrically isolated, galvanic anodes will provide a low cost, low maintenance method of corrosion control. Small shop-fabricated tanks set within a larger fuel terminal are often tied into the impressed current system for the facility. This will allow protection to be achieved with or without a good quality external coating on the bottom.

Field-erected tank protection—Because of the large size and field assembly requirements, this type of tank offers a different situation than the small shop-fabricated tanks. For starters, it is generally not feasible to coat the external side of a tank floor. The tank would have to be lifted after assembly to allow for the coating to be applied. If the plates were precoated, the joint configuration and field welding of the joints would damage the coating, thus creating localized corrosion cells that could not be protected by other means.

Large field-erected tanks are often protected using impressed current cathodic protection systems as the primary means of corrosion control. The cathodic protection can be applied either at the time of tank construction or afterwards, depending upon the tank configuration. There are several different

anode configurations that can be employed to provide current to the tank bottom. The best one for a site varies, depending upon the number of tanks to be protected and the site characteristics.

When protecting aboveground tanks, the question of current distribution becomes important. The goal is to protect the entire floor. The most common anode configuration (and typically the least expensive) is the shallow distributed anode bed (Figure 3).

The problem with this configuration is that most of the current goes to the closest point on the tank, usually the perimeter. As a result, many tanks with this type of anode configuration are not protected in the center of the tank. Installation of permanent reference electrodes or a slotted monitoring tube under the tank will allow for evaluation of the protection at the center of the tank.

Semi-deep or deep anode beds (Figure 4) will often minimize the question of effective current distribution, but will introduce other possible problems related to current flowing onto other structures that may not be part of the system. This situation can create severe corrosion where the current flows off of the other structure to return to the system. Deep anode beds must be constructed properly around fuel tanks to ensure that a “drain” for a release into the ground-water was not been created when the well was drilled. There are sealing technologies available today to prevent this situation.

In areas where deep anodes cannot be used due to soil conditions or the site configuration, horizontally installed anodes (Figure 5) offer an effective solution. In this scenario, the anodes are installed directly beneath the tanks, thus ensuring effective current distribution to the entire tank floor.



Figure 4: Deep Anode Bed



Figure 5: Under Tank Anodes

The anodes can either be installed at the time the tank is constructed or later using directional drilling equipment. Typically, the anodes are installed in a slotted tube to allow for replacement in the future. The downside to this design option is cost. Using horizontally installed anodes is the highest cost alternative, but it may be the only one available to achieve effective protection.

The last scenario that requires discussion is a tank with a containment barrier under the tank floor. Most containment barriers used today are made of a non-conductive, plastic material. This material, if installed between the anode and the tank bottom, will shield the tank from the protective current. Many new construction tanks are being installed with a containment membrane inside the tank foundation. In this situation, the cathodic protection anodes must be installed between the tank and the membrane (Figure 6). Permanent reference cells and possibly a monitoring tube must also be installed to allow for monitoring the effectiveness of the cathodic protection.

It is important when investigating the application or effectiveness of cathodic protection that an experienced corrosion engineer be involved. Because improper application of these systems can

cause serious corrosion damage to other structures, it is critical that the corrosion engineer know what to look for and how to evaluate the options and test for problems.

NACE International (previously known as the National Association of Corrosion Engineers) has established a certification program to help identify individuals who are qualified to design cathodic protection systems. Having a NACE Cathodic Protection or Corrosion Specialist with documented experience in aboveground tank system design is highly recommended. It is also important to use a company that can stand behind its products and design work, both today and in the future.

Concrete and asphalt pads can be installed in field-erected tank applications. It is critical, however, to construct a solid concrete pad that will not allow water to accumulate under the tank and crack, allowing moisture and soil to come from beneath to contact the tank bottom. This technology has been developed by one major oil company in the United States as a corrosion control method. While they have documented some life extension over their previous practice of no corrosion control at all, the life extension benefit does not equal that of other methods. Further, if a tank was set upon a solid concrete or asphalt pad, it is not possible to effectively monitor the effectiveness of the approach or to apply other alternatives at a later date.



Figure 6: Anodes Within Containment

Effective cathodic protection monitoring

As mentioned above, cathodic protection systems can be monitored for effectiveness. NACE International developed a recommended practice, RP-0193, which provides guidance in the practice of designing and installing cathodic protection for on-grade storage tanks. While the design guidance is very general and allows the designer much flexibility in the details, it defines the criteria to be used to determine if the cathodic protection is truly protecting the structure.

Industry practices like the NACE RP and those published by the American Petroleum Institute all recommend that the cathodic protection system be evaluated once a year by a qualified individual. Further, if impressed current systems are employed, a monthly inspection of the rectifier to ensure it is operating within established parameters is critical to ensure corrosion control. Stay connected for Part 2 Corrosion control on aboveground storage tanks has been in practice for over 30 years. While the original intent of life extension is still important, today's environmental protection programs have moved this facet of facility management to a higher priority.

If a release can be prevented by effective maintenance of the assets using corrosion control, one can reduce the risk of the release and, thus, operational costs. Of the methods available, cathodic protection is the most common and most effective method of corrosion control for large fuel storage tanks. In the next edition, Part 2 of this series will deal with the monitoring and evaluation of cathodic protection systems in more detail. This article will provide the latest information on how to measure the effectiveness of the cathodic protection system and will also provide case histories of actual measurements and results.

J. Dean Flessas is a Senior Technical Marketing Specialist with Corpro Companies, Incorporated, in Conyers, GA.