Cathodic Protection for Steel Water Storage Tanks Pocket Field Guide

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Introduction

As early as 1943, an AWWA technical committee concluded it was necessary to control corrosion of submerged surfaces inside water tanks. At that time, cathodic protection was identified as an effective way to prevent leaks. It wasn't until the 1970s, however, when practical designs for water storage tanks were widely introduced, that cathodic protection began to gain widespread use to prevent corrosion.

Even the best protective coating systems cannot prevent corrosion indefinitely. When cathodic protection is added to a coated tank, however, the advantage achieved by combining the benefits of a protective coating with cathodic protection is significant for owners, doubling or even tripling the life of the coating. Consequently, tank owners view cathodic protection as a low-cost way to safeguard investments in their storage tanks and protective coating systems.

By pairing protective coatings and cathodic protection, it is possible to extend the life of a typical steel water storage tank's coating system for immersion service by as much as 20 years. Without cathodic protection, system failure is likely to occur within 10 years.

Chapter 1

Water Tank Corrosion and Control

Steel water storage tanks are subject to corrosion on all of their external and internal surfaces. The primary focus of this pocket field guide is to provide guidance for cathodic protection of the internal wetted surfaces of steel tanks, but, for comprehensive asset protection, corrosion and corrosion control of all surfaces should be considered.

Most storage tanks are constructed of either steel or steel and reinforced concrete (composite tanks). For composite tanks, it is important that corrosive admixtures be avoided and that the depth of concrete cover over the rebar be sufficient to protect the steel reinforcements by providing a high pH environment over the life of the tank. For stainless steel tanks, a different set of corrosive conditions needs to be evaluated. These include sufficient oxygen in the water to form a protective oxide film and the presence of certain active ions, such as chlorides, that could lead to corrosion pitting of the stainless steel.

There are distinct zones associated with a water tank, each of which requires corrosion protection by a combination of material selection, protective coatings, and/or cathodic protection. The connection of the carbon steel tank shell to different metals should be avoided. This includes copper and stainless steel tubing, ladders, safety rails nozzles, noncompatible weld materials, and the like.

The exterior surfaces of the tank shell and roof exposed to the atmosphere are best protected from corrosion by the use of protective coatings. Many coating systems that have been successfully used include epoxies, polyurethanes, and alkyds, some of which incorporate zinc-rich primers. Section 4.3 of AWWA D102-14 "Coating Steel Water-Storage Tanks" describes seven outside coating systems. For the external surfaces of a flat bottom tank, consideration should be given to the application of cathodic protection to prevent corrosion of the soil side. Accelerated corrosion can occur because of corrosive soils or tank pad material, high moisture content, or connection to copper grounding. Applying a protective coating alone to the soil side of the bottom plates is not an effective alternative because the coating will be damaged during placement and welding. Information on tank bottom cathodic protection can be found in NACE International's RP 0193-2001, "External Cathodic protection of On-Grade Carbon Steel Storage Tank Bottoms."

Inside the tank, corrosion is even more challenging. Connection (metal-to-metal contact) to copper, brass, and stainless steel appurtenances must be avoided. Protective coatings and cathodic protection should both be used. Coating the inside of a tank is not an easy process. Proper surface preparation is essential. Humidity and temperature for proper cure must be closely monitored, recognizing that the side of the tank exposed to the sun can be quite a bit hotter from radiant heating. Surface preparation and quality application of coating the roof, support columns, and purlins is difficult because of impediments to inspection, including access, crevices, and sharp edges. Section 4.4 of AWWA D102-14 "Coating Steel Water-Storage Tanks" describes five inside coating systems consisting of epoxies, polyurethanes, or polyurea. The discussion that follows addresses corrosion and cathodic protection of the internal wetted steel surfaces of carbon steel water storage tanks.

CORROSION OF INTERNAL WETTED SURFACES

In fresh water tanks, corrosion activity on internal wetted surfaces usually results in concentrated pitting attack, which leads to quicker wall penetration than if the corrosion was more uniformly distributed on the metal surface. This is particularly true on tank interiors that are coated, where the corrosion attack is accelerated at holidays or voids in the coating. The attack is initiated by the development of anodic and cathodic areas on the submerged metal surfaces. The anodic areas (e.g., location of coating holiday) will suffer accelerated corrosion (metal loss), whereas the cathodic areas will not corrode (see Figure 1-1).

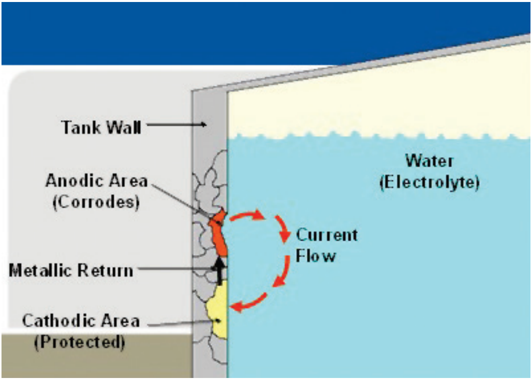

FIGURE 1-1 Anodic and Cathodic Areas on Tank Wall

The corrosion is often made even worse by the small anode-large cathode area effect (see Coating Pinhole Corrosion).

There are a number of mechanisms that can initiate and sustain corrosion of the submerged steel in water tanks.

Uniform Corrosion

Although steel visually appears to be homogenous, close inspection reveals that it is quite irregular, consisting of numerous grains of metal that are electrically different from each other. Thus, some will be anodes, whereas others will be cathodes.

The corrosion attack will usually appear as randomly, closely spaced pits.

Stressed Metal

Usually steel that is under stress will be anodic to unstressed steel. In tanks, these stresses can be caused by such things as welding (where the area immediately adjacent to the weld becomes stressed), bending or forming without stress relieving, and bolting and riveting (usually the fastener will be anodic to the adjacent plate).

Dissimilar Metal Corrosion

The use of different metals in direct contact with each other will establish a corrosion cell where the more noble metal will be cathodic and the more active metal will be anodic. Examples of such cells in tanks include the use of copper or stainless steel heater coils, stainless steel ladders, stainless steel nozzles, and weld seams where the metallurgy of the welding rod differs from the base plate metal (see Figure 1-2).

Crevice Corrosion

This corrosion cell develops at crevices that create oxygen concentration or ion entrapment cells. Generally, the corroding (anodic) area will be in the crevice with the nearby surface area's cathodic. In water tanks, these develop most commonly between

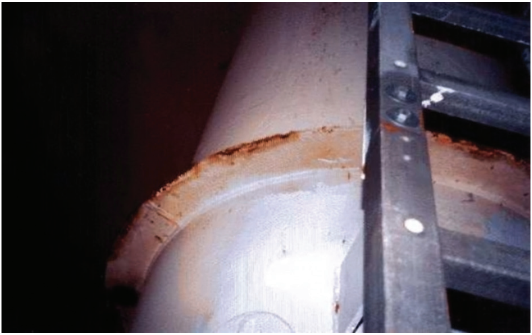

FIGURE 1-2 Galvanic Corrosion between Coated Carbon Steel and Stainless Steel Ladder

the head and plate of bolted or riveted plates and between the overlapping areas of unsealed plates.

Differential Oxygen Concentration

When steel is immersed in water and where some of the steel surface is exposed to a relatively oxygen-enriched water as compared with other steel surfaces, the area deprived of oxygen will be anodic with respect to those surfaces exposed to the abundantly oxygenated water. This phenomenon is often observed in poorly coated tanks where the lower submerged surfaces are heavily corroded (lower oxygen levels with depth), whereas the upper areas show little corrosion. Even more common is the appearance of vertical striation

FIGURE 1-3 Vertical Corrosion of Interior Tank Wall

corrosion where deep vertical gouges (sometimes several inches or feet long) are observed on the submerged surfaces of the tanks (see Figure 1-3). This common corrosion phenomenon is caused by the development of an initial corrosion pit generating soft, flowing corrosion products. Gravity causes these products to migrate down the side of the tank wall and shield the lower surface from oxygen, rendering it anodic. The shielded surface begins to corrode, generating more corrosion products with the process continuing over and over down the wall of the tank.

FIGURE 1-4 Corrosion at Coating Holidays

Coating Pinhole Corrosion

When the internal tank surfaces are coated with a dielectric material (e.g., epoxy), the corrosion activity will be concentrated at the holidays (holes) in the coating. The breaks in the coating may result from mechanical damage, improper surface preparation, or merely microscopic voids in the coating surface. The corrosion currents will concentrate at the holidays and result in higher corrosion current densities at these locations. Even though a good coating will reduce the total metal loss, a complete penetration of the metal surface will occur more quickly than if the tank were not coated (see Figure 1-4). Many other factors can influence the rate at which corrosion will proceed in water tanks. The most significant factors are:

water flow rates, relative surface area of anodes to cathodes, active ion concentrations, temperature, turbulence, and water level fluctuation.

Virtually all potable waters are corrosive with regard to steel. Thus, the question is not one of whether water tanks are subject to corrosion, but rather, what is the most effective and economic means of corrosion protection?