

Improved Cathodic Protection Current Distribution for Above Ground Storage Tank Bottoms Due to Low Resistivity Vapor Corrosion Inhibitor Use

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ABSTRACT

The close anode ground bed cathodic protection (CP) system design for the Aboveground Storage Tank (AST) bottoms uses the area of influence surrounding each anode ground bed, in contributory area design, to provide adequate CP. The area of influence surrounding each anode ground bed, mainly depends on the adopted CP criteria, and is greatly affected by the changing electrolyte resistivities of the AST tank pads and the distance between the anode and the structure. Accommodating for changing electrical properties is a standard requirement for CP designs and the spacing of anodes is adjusted to get proper current distribution coverage. In case of a deficient CP design, where the design parameters are not cautiously considered or when the field parameters change considerably from the design assumptions, CP will be inadequate.

In this paper, the CP current distribution with changing resistivities and the area of influence required to meet effective CP criteria, is studied. The results indicate that the tank pad electrolyte resistivity plays a significant role in achieving uniform CP current distribution. The paper also explores the use of Vapor Corrosion Inhibitor (VCI) and its effect on electrolyte resistivity and the resulting CP current distribution.

Key words: Cathodic Protection, MMO Anodes, Current Distribution, Soil Resistivity, Above Ground Storage Tanks, Vapor Corrosion Inhibitors.

INTRODUCTION

The design guidelines for cathodic protection (CP) current distribution in an anode ribbon grid system for AST bottom plate protection uses two factors. The first is the distance between the anode and the bottom plate, which is a known factor, and the second factor is the expected anode throw from each anode, to determine the anode coverage length.¹ The coverage length from each anode is the contributory area of the AST plate receiving cathodic protection current. The cathodic current densities across electrolyte/structure interface will be higher on top of the anode and will be lower at the point furthest away from the anode in the contributory area configuration. The polarization levels required for effective cathodic protection mainly depend on the cathodic current densities occurring across the electrolyte/structure interface. When the CP current is applied, primary current distribution happens by relative resistivities of the current paths and secondary current distribution happens with the buildup of cathodic reaction products. In an anode grid system, the adjacently spaced anodes are designed to provide adequate current densities at the point furthest away from the anode location and meet the required polarization criteria. However, the presence of contaminants in the tank pad will further affect the pad electrolyte resistivities and the localized polarization levels.

CP system design considerations as recommended by NACE SP0193² and API⁽¹⁾ 651 standards for AST soil-side bottom cathodic protection requires tank pad material to meet certain chemical and electrical properties. Washed river sand is the preferred tank pad material for AST bottoms. For chemical properties, concentration thresholds have been established for chlorides, sulfates, sulfides and pH for the source sand material. If the source sand material does meet the required thresholds, washing of sand is recommended to conform to the established requirements. For electrical properties thresholds, API 651³ recommends a value of 10,000 ohm-cm and NACE SP0193 recommends a value of 5,000 ohm-cm. Even though both standards use different thresholds for sand electrical resistivity, the consensus is that high sand resistivity is favorable for lower corrosion. The strict thresholds established on sand material quality causes the tank pad electrical resistivity to be high during installation. The API 651 standard allows the use of Portland cement and limestone to increase the pH of the sand pad. The use of cement and limestone significantly help in increasing the pH of the sand pad. However, on the other hand, they lower the electrical resistivity of sand pad due to their ion concentrations. Higher pH values of tank pad material are desired for corrosion protection of carbon steel.⁴

As per API 651, a sand electrical resistivity value of 10,000 ohm-cm or greater is recommended. The electrical resistivity test is conducted in the laboratory at saturated conditions (100% saturation). Most tank owner specifications restrict the sand moisture content to 10% or lower when installed in the field under tank bottoms. Hence, the resultant field installed sand resistivity could be anywhere from 30,000 ohm-cm or higher. Even though the clean sand helps in reducing contaminants from the sand pad, it requires higher driving voltages to generate sufficient CP current due to the resulting high resistivity. With a high resistive sand pad, the anode ground bed resistance to the tank (structure) is high, which in turn increases the total circuit resistance of the CP system. In order to address this underlying high resistivity problem it raises the question on how to lower the electrical resistivity of the tank pad material, and yet conform to the established chemical thresholds established by recommended practices. The methods to lower the electrolyte resistivity are discussed below.

Lowering the tank pad electrical resistivity:

- Additives such as Portland cement and lime are used to modify the sand pad quality and raise the pH of sand pad. As a result of higher ion concentration from the additives, the tank pad electrical resistivity is lowered.

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- Vapor Corrosion Inhibitors (VCIs) are also added to the AST tank pad to mitigate soil-side corrosion.⁵⁻¹⁰ VCIs have higher ion concentration and they serve as dual purpose when used with CP systems. First, they lower the resistivity of the tank pad electrolyte and second, they vaporize and protect void areas under the AST bottom where the plate loses contact with the electrolyte and the CP is, therefore, ineffective. Recent studies on the use of amine carboxylate based VCI reported that VCI in combination with CP does not adversely affect the CP system in meeting the NACE CP criteria.⁶⁻⁸ The limited literature studies on the combine use of VCI and CP mainly involved the use of MMO anodes, reporting a synergistic effect. One study showed that certain VCIs improved the cathodic polarization process and reduced the CP current required to achieve effective cathodic protection.⁶ The laboratory studies on galvanic anode compatibility with VCIs show that VCIs can de-passivate the oxide layer on zinc and keep it active to function as an anode for galvanic CP systems used in interstitial space of AST bottoms.⁹ VCIs are shown to prevent the corrosion of steel in the presence of moisture and oxygen.¹⁰
- The naturally occurring contaminants in the source sand will lower the resistivity of the tank pad, however this is not desired as the contaminants will accelerate corrosion of the bottom plate.

In this paper, the relationship between AST bottom tank pad electrolyte resistivity and CP current distribution is investigated as it applies to bottom plate CP system design. The technical information provided in this paper can be used as a basis for designing AST soil-side bottom plate CP systems to achieve uniform CP current distribution. The low resistivity of tank pad with VCIs is investigated for the long-term performance of the CP systems with lower voltage requirements and for uniform CP current distribution throughout the AST bottom.

EXPERIMENTAL PROCEDURE

The experimental procedure involved investigating CP current distribution in anode grid system for tank bottom plates in high and low resistivity electrolytes. A test cell, large enough to represent the field installed anode grid system pattern and to obtain convenient current-density gradient on steel plate, was used. Figure 2 shows the test setup schematics for CP current distribution. A wooden box of dimension 3 m x 0.9 m x 0.39 m (10 ft. x 3 ft. x 1.3 ft.) was used. The inside of the box was lined with dielectric liner and was completely isolated from external circuits. The wooden box was filled with water up to 30 cm (1 ft.) height. MMO anode ribbon was used for applying cathodic protection current, the MMO anode was installed in a grid system with spacing of 1.5 m (5 ft.) between the anodes, a current distribution bar was also installed to connect the anode grid. A36 grade steel plate (UNS K02600) of dimensions 3000 mm long x 150 mm wide x 6.35 mm thick (120-inch x 6-inch x 0.25-inch) was used to represent the tank bottom plate. The plate was placed at 30 cm (1 ft.) height from the MMO anode. A36 grade steel coupons of dimensions 50 mm x 50 mm (2-inch x 2-inch) were spaced at 0.3 m (1 ft.) intervals and connected to the steel plate with an electric wire. The current flowing between the plate and coupon was measured using a micro ammeter. A portable DC power supply (constant voltage rectifier) was used to power the CP system. Copper-copper sulfate reference electrode (CSE) was used for electrical potential measurements at various locations on the steel plate.

Contributory Area of CP Grid System

In the experimental setup, the expected anode coverage length was 5 ft. The anode spacing was designed to provide protection at a distance of 2.5 ft. in both directions with the anode in center.

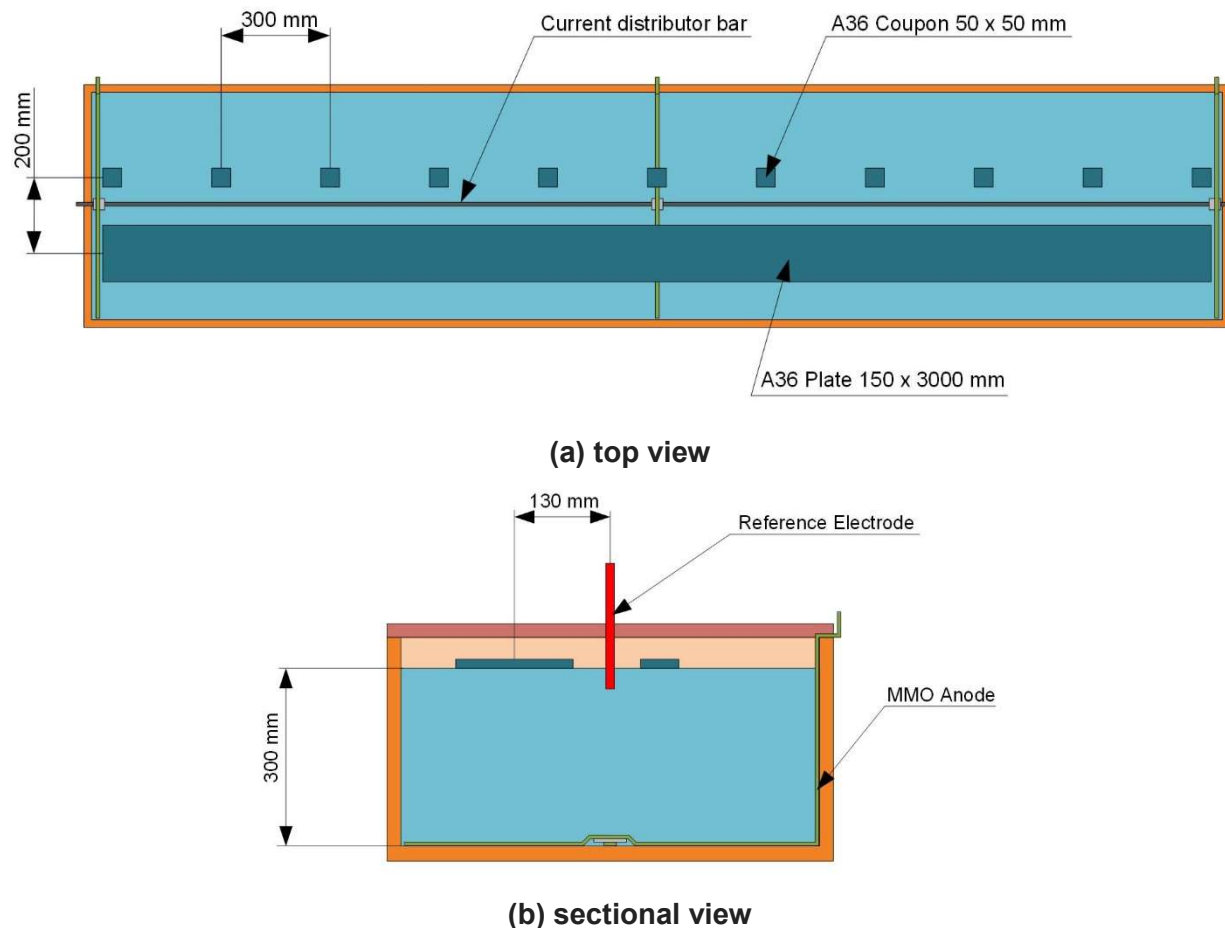


Figure 2: Water bath test setup to measure electrical potential and current distribution along the steel plate

RESULTS

Cathodic Protection Current Distribution

A large-scale test was conducted to evaluate the cathodic protection current distribution on the steel plate in three different electrolyte resistivities. The electrical resistivity of electrolytes as shown in Figure 3 was measured using a soil resistivity meter in the large-scale water bath test setup. The A36 grade steel coupon at 0.3 m (12 inch) spacing were used for 4-pin electrolyte resistivity test method. The electrolyte resistivities were changed by mixing deionized water and potable water to obtain the high resistivity of 53480 ohm-cm and average resistivity of 26740 ohm-cm values. To obtain the low resistivity value of 6685 ohm-cm, VCI was mixed with deionized water. The electrolyte resistivity levels were rounded off and categorized as high resistivity (55,000 ohm-cm), average resistivity (26,000 ohm-cm), and low resistivity (6,000 ohm-cm) for discussion purposes in this paper.