

Novel Evaluation of the Failure of Coatings in a Marine Environment

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ABSTRACT

This paper will discuss methods to evaluate the corrosion of substrates and breakdown of protective coatings subject to wet-dry cycling in natural and accelerated environments. Principally the discussion concerns the ability to monitor on-going corrosion deterioration to predict coating failure in a real-world environment without having to accelerate (i.e., artificially harshen) the environment.

BACKGROUND

The author previously introduced a method to evaluate protective coatings using a novel segmented cell approach. (1) Briefly, the technique intended to monitor natural current exchange between isolated segments, coated or uncoated, to supplement visual rankings of coating performance. The goal was to predict failure earlier than might otherwise be visible or to distinguish between coatings that had a similar visual appearance at the end of the proscribed test period. The experimental design also allowed for the instrumented segments, which act as sensors, to be prepared and coated as intended for a real-world industrial exposure, i.e., the metallic surfaces could be abrasive blasted and painted unlike thin-film, foil-like sensors also explored for similar purposes.

The initial work focused on the type of data that might be obtained and demonstrating the utility of the approach. This testing included longer-term data, wherein the segmented cell approach was used to study coatings intended for immersion service. Testing for immersed conditions allowed the inclusion of a continuous water film across the coating surface, simplifying the testing and data analysis. Testing under atmospheric conditions was limited at the time. The present work expands on these earlier presentations.

EXPERIMENTAL APPROACH

Figure 1 provides a plan-view photograph of a segmented-cell design. The design includes seven (7) elements. Each is nominally 0.6-cm thick. The center segment is nominally 14-cm long and 2.5-cm wide. (For some testing, the center segment was 0.6-cm wide; this difference related to fabrication issues and was not deemed significant in the data generated.) The outlying six (6) segments are nominally 4.4-cm long and 2.5-cm wide.

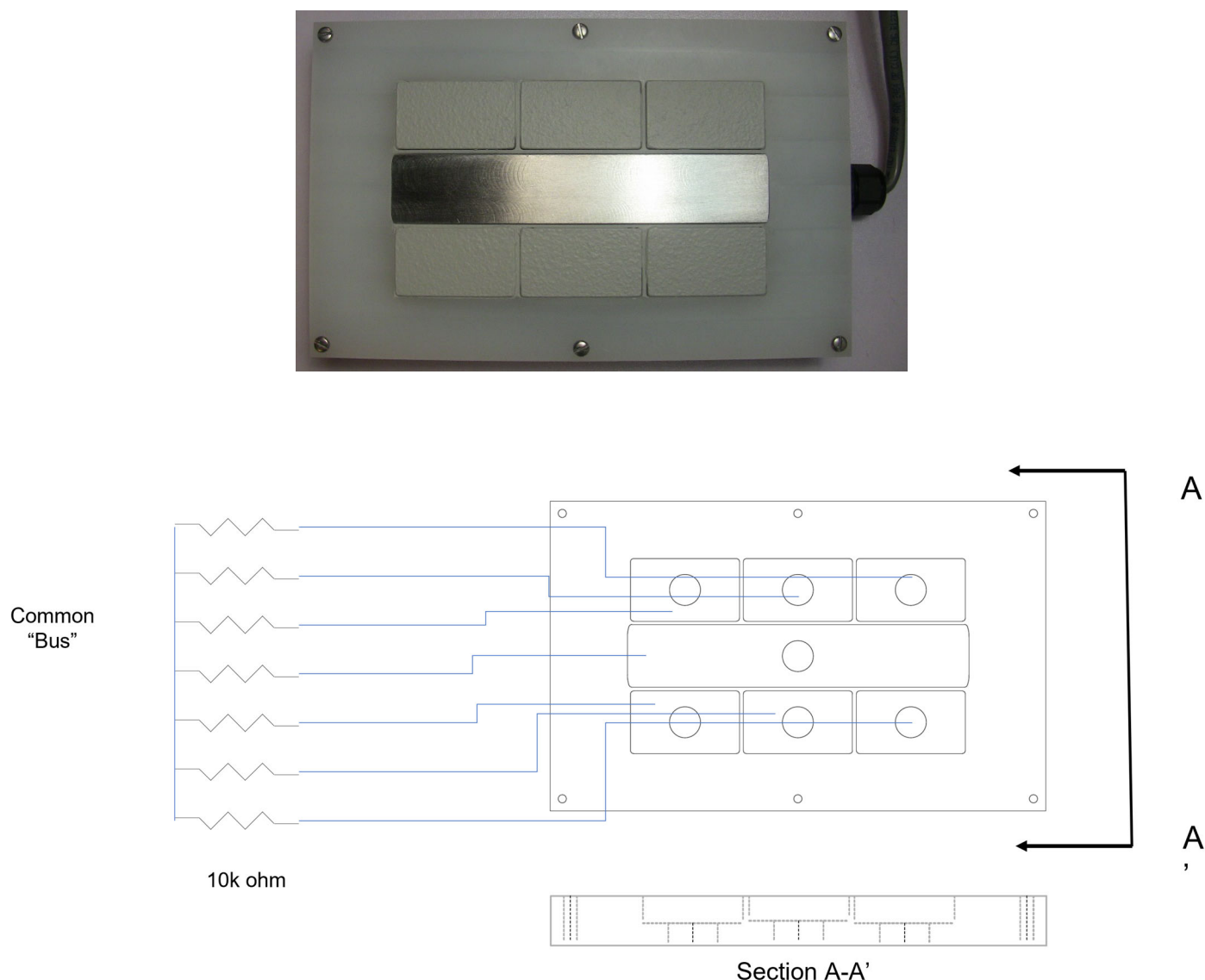


Figure 1. Plan-View Photograph and Circuit of Segmented Cell

Previous designs cast the segments into an epoxy resin. The present improved design includes a non-metallic face fabricated to hold each segment. The face comprises one side of an enclosure. The entire system may be reused with the application of new coatings or the use of new coupons, reducing the overall system cost.

In the work discussed herein, the center segment is always left uncoated, intending to function as a “scribe” or intentional holiday in a coating system. Coatings are applied to the surrounding segments using conventional surface preparation and coating application procedures. The individual surrounding segments can be abrasive blasted before being installed into the coupon holder. Paints are applied after the coupons are installed with the center segment suitably masked.

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Each segment has a lead wire connected to its base. The seven (7) leads comprise a cable bundle that leads outside the box via a water-tight compression fitting. The box top to base closure includes an O-ring groove and a Viton gasket. The lead wires carry signals to an electronic data acquisition (DAQ) system. At the DAQ, the peripheral segments are connected to the central segment across 10,000-ohm shunt resistors (Bourns 4100R Series, 2% tolerance), thus forming a pseudo-parallel circuit. Voltages at the shunts are read via a gang of NI 9205, C Series Voltage Input Modules. These are 16-bit A-to-D devices. Data were captured via a custom LabView program. Current data were captured every five (5) minutes. These are the net anodic and cathodic currents between these segments. (There can also be local anodic / cathodic reactions on each sample that are not represented.) Algebraically, the total current is “zero.” With “fully intact” coatings, the shunt resistor does not dominate the current exchange. As a coating would degrade, the shunt may impact the current more significantly.

For the data presented herein, all the exposures concern samples placed into a natural atmospheric environment (urban Northern Virginia) and subject to a periodic wetting with a substitute seawater solution to stimulate corrosion. Various coating systems are discussed as presented. The focus is on the cell performance, not the coating per se.

RESULTS

Figure 2 shows the current exchange at 5-minute intervals for a thermal-spray aluminum coating applied to steel and coated with a nominal 6-mil thick epoxy seal coat. Negative currents indicate anodic behavior. Given the significant electrochemical potential difference between the active thermal spray coating and the steel center scribe, this example provides a good basis to establish an understanding of the impact of the local environment.

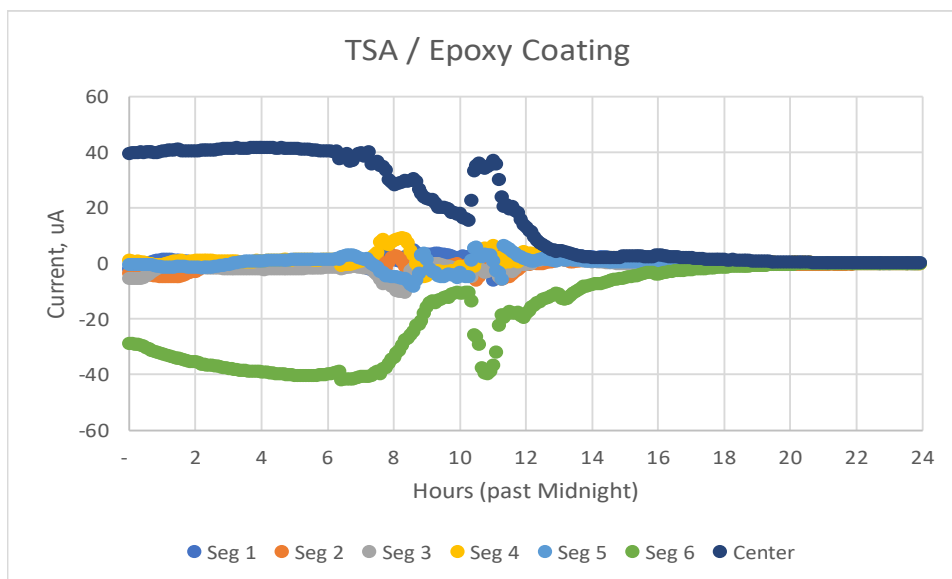


Figure 2. Current Exchange to a Central Bus, Thermal Spray Aluminum / Epoxy Coated Steel to Scribe, Day 5 of Exposure