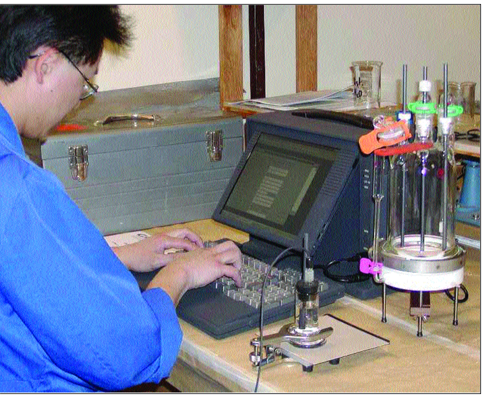
Testing Coatings with EIS for Rapid Immersion

By Anita Socci, Assistant Editor

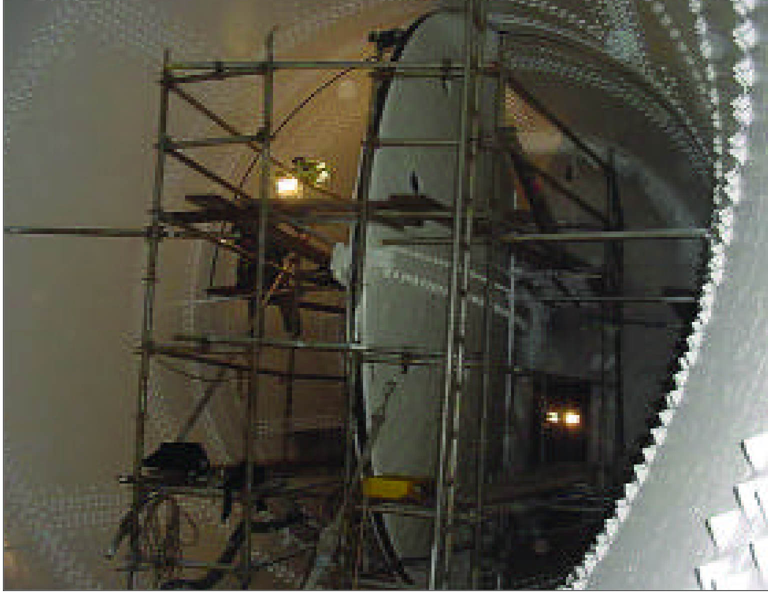
Electrochemical Impedance Spectroscopy (EIS) is described by SSPC 2003 authors Mike O'Donoghue, Ron Garrett, Vijay Datta, Peter Roberts, and Terry Aben as a "proven and powerful technique to rapidly, quantitatively, and non-destructively evaluate the electrical and barrier performance of coated metals and under-film corrosion processes." In "Electrochemical Impedance Spectroscopy—Testing Coatings for Rapid Immersion Service," the authors use laboratory test results and data from coating performance in the field to make their case.



EIS equipment

The performance of two coatings—a modified phenalkamine epoxy (applied in two coats) with final dry film thicknesses (DFTs) between 24 and 28 mils was compared to a 100% volume solids polyamide epoxy (applied in one coat) with final DFTs between 35 and 45 mils. Each system was immersed in distilled and deionized water after a brief cure time of 24–48 hours. The coatings were selected because of their different curing agents, presence or absence of solvent, and tolerance to rapid water immersion.

An accelerator was added to the 100% solids polyamide epoxy to assist in cure characteristics; however, the authors report that the addition of accelerators could render the coating prone to blistering and embrittlement. In comparison, the phenalkamine epoxy contained an internal accelerator as part of the structure of the curing agent, eliminating the need for



Penstock at generator station where modified phenalkamine was applied for rapid immersion service
Photos courtesy of Mike O'Donoghue

adding catalysts or accelerators, the authors report.

The authors give a brief account of organic coatings and how they act as barriers between the metal substrate and the environment. The barrier properties of organic coatings also create a high electrical resistance across the coating thickness. According to the authors, as coatings age in a corrosive environment, the interconnecting pores within the coating become saturated with water, salts, etc., exposing the metal substrate. The metal / coating system is seen as an element in an electric circuit consisting of a network of resistors and capacitors, the authors say. This network is representative of the various physical processes occurring in the coating film.

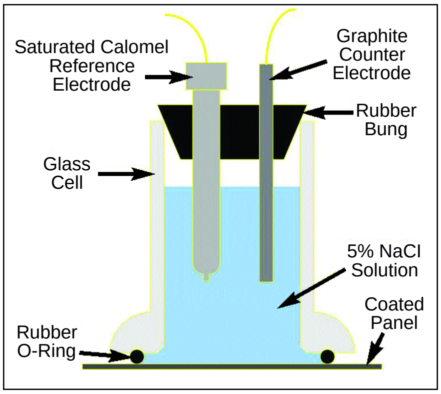
Pioneering work in 1948 showed that anticorrosive barrier properties for a coating film were good if the electrical resistance was greater than 108 cm^2. If electrical resistance was less than 106 cm^2, the film exhibited very poor barrier properties. According to the authors, it is now recognized that when resistance exceeds 109 cm^2, the coating film exhibits excellent barrier properties.

The authors detail the test program. Each coating was applied to several 4x8 in. cold rolled steel panels abrasive blasted to SSPC-SP 10 / NACE No. 2, Near White blast cleaning. The phenalkamine epoxy was applied in two coats with final DFTs ranging from 24 to 28 mils. The polyamide epoxy was applied in a single coat with final DFTs ranging from 35 to 45 mils. The coated steel panels were separated into six different exposure streams—three were immersed in hot water (40 C) after different cure times (168, 48, and 24 hours); and three were immersed in ambient water (25 C) after different cure times (168, 48, and 24 hours). All panels

Continued

were allowed to cure at 25 C in 40 to 60% relative humidity before immersion in distilled, deionized water. Hot water immersion at 40 C was used to accelerate the degradation of the coatings. Because higher temperature exposure also increased the possibility of accelerating the cure of an otherwise uncured coating, exposure in ambient temperature immersion was used to ensure that any beneficial effects were not the result of higher temperature, the authors explain.

EIS measurements were taken at 192 hours (8 days), 528 hours (22 days), and 1,000 hours (approximately 42 days). Impedance measurements were made by attaching a glass cell containing a counter electrode, a reference electrode, and a conductive solution (5% NaCl) to the coated metal panels. The parameters for each EIS measurement are given. A section on "Results and Observations" discusses each coating system, explains impedance measurements, and lists observations about each exposure stream (steel panel). Curing characteristics of each system are also discussed.



Schematic of EIS cell

The authors then present two case histories that demonstrate the successful use of the modified phenalkamine epoxy in rapid immersion service on a penstock lined with a red lead coating and on a pulp mill clarifier in Canada.

The authors conclude the article with two observations: 1) EIS measurements revealed significant non-visual differences in the performance of rapid-immersion-grade coatings as they cured under water. The early onset of underfilm corrosion processes beneath the 100% solids polyamide epoxy coating was readily detected using EIS. In contrast, a modified phenalkamine epoxy achieved full cure under water just as if it had cured under normal ambient conditions. 2) The EIS technique enables specification authorities a more judicious means for coating evaluation and selection where rapid immersion service is required.

The complete article and images can be found on the SSPC 2003 Technical Presentations CD (www.sspc.org). A shorter version has been published in *Materials Performance*, September 2003.