Summary

The thirty-one (31) papers in this book have been divided into the following three sections: (1) the design and interpretation of laboratory tests, (2) laboratory tests for specific environments, and (3) laboratory tests for specific types of corrosion. Since most papers on laboratory corrosion testing address all three subject areas, the papers have been divided according to their principle emphasis. An Appendix containing the standards most often referred to in the papers is included.

The section on Design and Interpretation of Laboratory Tests begins with a paper by Treseder that discussed the problem of engineer-user acceptance of laboratory corrosion tests. Examples of test methods for evaluating stress corrosion cracking and crevice corrosion were used to illustrate the problem of making engineering decisions based on laboratory tests. The author stressed the need for improved definition of the limits of tests, use of rank ordering, correlation of laboratory data with field experience, and standardization of the tests.

Development of an accelerated corrosion test for materials for naval aircraft was described by Ketcham and Jankowsky. Experiments were conducted with periodic injections of sulfur dioxide gas into a salt fog chamber. Results from these tests correlated well with aircraft carrier exposure for most materials, however, the test gave misleading results for some materials. It was concluded that a single accelerated test could not be used to evaluate all materials for aircraft service and that it is essential to correlate test results with service exposure.

Tipton described the use of computers in corrosion research for data acquisition and processing. In addition to presenting typical hardware and software considerations, the author described uses for computers in corrosion research such as potential, current, potentiodynamic polarization, current distribution, and fatigue crack growth measurements.

The topic of corrosion under heat-transfer conditions was covered by Yau and Webster. Their test loop consisted of heat exchanging tubes that contained wire specimens that were not subject to heat transfer. Their results showed that heat flux does not play an important role in zirconium corrosion.

Accelerated corrosion tests for coatings on steel were addressed in two papers. Warwick and Hampshire described an accelerated test for tinplate and compared it with industrial experience with containers. The accelerated test provided a reliable way of reducing the need for pack testing. Berke and Friel used the linear polarization technique as a screening tool for predicting the relative atmospheric corrosion performance of metallic coated steels. Relative corrosion rates determined with this technique were found to be in general agreement with long-term marine and industrial exposures.

Laboratory electrochemical tests were covered in a number of papers. Electrical resistance tests, tafel extrapolation, linear polarization, potentiodynamic polarization, corrosion behavior diagrams, and AC impedance were covered in a review paper by Siebert. Particular attention was given to scan rate effects and the development and interpretation of corrosion behavior diagrams. Hakkarainen described a novel method of determining pit nucleation and repassivation potentials using a multilayered textile tape. The author applied this method to stainless steel plates and welds as well as prestressing steel wire. Galvanostaircase and potentiostaircase polarization techniques were described by Hirozawa. He concluded that the galvanostaircase technique provided more accurate values for the breakdown and protection potentials of aluminum in inhibited solutions and that potentiostaircase polarization gave more accurate values for polarization resistance. The corrosion behavior of polybutadiene coatings on bare and conversion coated steel, commercial conversion coatings on aluminum alloys, and anodized aluminum alloys was investigated by Mansfeld and Kendig using electrochemical impedance measurements. The authors developed models for the impedance behavior of the coating systems and methods for analysis of experimental impedance diagrams in terms of coating and interface properties and their changes during exposure to corrosive environments.

The final paper in this section by Suga described improvements to the apparatus for light and water exposure of nonmetallic materials (ASTM Recommended Practice for Operating Light- and Water-Exposure Apparatus [Fluorescent UV-Condensation Type] for Exposure of Nonmetallic Materials] [G 53]). These improvements resulted in a more uniform, higher level of irradiance of the test specimens.

The section on Laboratory Tests for Specific Environments contains papers on tests developed to evaluate the corrosion performance of materials in a specific environment. In the paper by Nielsen corrosion testing in potable waters was reviewed. The influence of water composition on corrosion and the difficulty of developing a comprehensive test were discussed. The paper also includes a review of corrosion problems with the metals and alloys commonly used for construction of potable water systems. Francis and Mercer found that dissolution of borosilicate glass in water above 60°C lowers the corrosion rate of steel in distilled water. They described a new apparatus to overcome this problem and determined that, above a critical level, oxygen has a passivating effect on steel in potable water while the chloride ion is aggressive.

Bogar and Peterson compared the actual corrosion rates of mild steel in seawater with those obtained using the linear polarization technique. They found good agreement between the rates for up to 60 days however after 120 days the rates differed substantially. They also found that the polarization resistance was semilogarithmically related to the scan rate. Nye et al cathodically polarized mild steel in once-through and recirculated seawater. The films formed in once-through seawater polarized the cathodic reactions more effectively than those formed in artificial or recirculated natural seawater. The calcareous deposit formed on the mild steel resulted in an 86% reduction of the cathodic current density in once-through seawater at − 1.0 V versus the standard calomel electrode (SCE).

A number of papers dealt with corrosion in unique environments. Baboian and Haynes described the development of an environmental wear corrosion test for coinage materials. The behavior of coins in the test mechanistically and visually duplicated the behavior of coins in circulation. Noble steel clad (steel cored) sandwich coins had similar performance to their respective noble monometal coins in the wear tests. A test for the corrosiveness of fibrous insulations was described by Crume. He concluded that the test provided consistent and reproducible results but suffered the limitation that it required subjective visual ranking of the specimens. Rosskopf and Virnelson described a galvanostatic technique for identifying environments that effect the passivity of steel embedded in concrete. Results of test using this technique were correlated with observations of concrete structures. Dial et al described the corrosion induced deformation behavior of brick masonry wall panels. They found that corrosion of embedded steel plates resulted in an expansion behavior of the brick masonry.

Electrochemical methods for evaluating corrosion inhibitors in strong acid systems were evaluated by Dean et al. They found that the correlation between mass loss measurements and electrochemical corrosion rates was poor. The return potential corrosion rate from the reverse scan polarization technique did provide a qualitative measure of pitting tendency that agreed with surface examination. Mack et al described test methods for weight loss, pitting, crevice corrosion, and environmentally assisted cracking in environments containing hydrogen sulfide. A strong emphasis was placed on safety including selection of materials for containment vessels, flow lines, disposal of hydrogen sulfide, and training of personnel.

The section on Laboratory Tests for Specific Types of Corrosion contains papers on tests for crevice corrosion, erosion corrosion, stress corrosion cracking, and intergranular corrosion. Kain and Lee described test techniques utilizing a remote crevice assembly and a compartmentalized cell. These techniques allowed the measurement of corrosion potentials, current data, mass loss, and penetration data while having the advantage that neither required the application of external current. The relative effects of bulk environment chloride level, dissolved oxygen content, and crevice solution pH on crevice initiation and propogation for a number of stainless steels were evaluated with these techniques. Hubbell et al reviewed the four techniques that have been used to determine the protection potential of stainless steels. They compared their results using these techniques with longer term potentiostatically derived protection potentials and concluded that the longer term tests produced more conservative results. Jain et al described an autoclave assembly containing high magnesium nearly saturated brine and equipment for measuring current and potential variations to monitor the progress of crevice corrosion under hydrothermal conditions. The final pH of the crevice solution and the decoupled potentials of the cathode and anode were used to provide information about the mechanisms of corrosion. Grade −12 titanium was found to be much less susceptible to crevice corrosion than Grade −2 titanium in some of their experiments.

A jet-in-slit test that causes oxide film fracture by impulse force in addition to shear stress was developed by Matsumura et al. The test was used to evaluate erosion corrosion of brass in sodium chloride solution. Comparison of results from this test with those from conventional impingement tests indicated that the jet-in-slit test more closely duplicated erosion corrosion that has been observed in condenser tubes. Treseder and Kachik described five test procedures used to rank materials for resistance to general corrosion, crevice corrosion, and stress corrosion cracking by the chemical process industry. A critical value of a test variable (temperature, concentration, and so forth) was used to rank the corrosion resistance of each alloy.

Three papers dealt with tests for stress corrosion cracking. Whitehead and Baloun used potentiostatic anodic polarization to study pitting resistance of AISI 420 (Unified Numbering System [UNS] 542000) stainless steel in simulated sweet and sour well environments. Total alkalinity and chloride concentration had more influence on pitting resistance than hydrogen sulfide in their tests. Constant applied potential step stress tests showed that pitting was necessary for cracking to occur. Rosborg and Rosengren conducted slow strain rate tests in high purity water using a closed-loop oxygen dosage and electrode potential control system. The electrode potential below which intergranular stress corrosion cracking of AISI 304 (UNS 530400) stainless steel did not occur was −250 mV (standard hydrogen electrode) [SHE] at 200°C. Gálvez et al studied the stress corrosion cracking behavior of prestressing steels using a slow strain rate test in an aqueous solution of calcium hydroxide with small additions of sodium chloride. The slow strain rate technique was superior to constant load tests. Steels failed because of hydrogen embrittlement at potentials more negative than −0.9 V (SCE) while a second regime of cracking was found at potentials more positive than −0.8 V (SCE).

An improved intergranular corrosion test for HASTELLOY ® Alloy C276 was described by Manning. The new test consistently detected undesirable microstructural problems in mill-produced material that were not detected by the ferric sulfate-sulfuric acid ASTM Detecting Susceptibility to Intergranular Attack in Wrouht Nickel-Rich, Chromium-Bearing Alloys (G 28). The former provided a step function increase in corrosion rates on sensitized material while a high and variable uniform corrosion rate in the latter masked the intergranular corrosion rate. Schluter and Chivinsky reported the results of a round-robin study of ASTM Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels (A 262). The test data indicated that the reproducibility of Practice C was excellent for any given surface preparation, however, variations in surface preparation were found to have a significant effect on test results.

This STP on laboratory corrosion tests and standards presents comprehensive and balanced coverage of the subject. In addition to describing new test procedures the authors addressed the limitations of accelerated tests as well as the relevance of many widely used tests. Many of the test procedures were correlated with the actual service environment. The severity of the environments ranged from relatively benign to extremely corrosive. The techniques covered ranged from very basic ones, such as immersion tests, to highly sophisticated ones, such as electrochemical techniques. This book truely defines the state of the art in laboratory corrosion testing.

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