CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: ASTM Meeting of Committee G01: Corrosion of Metals
Project No. 20.06002.01.322; AI No. 06002.01.322.711

DATE/PLACE: May 22–24, 2007, Norfolk, Virginia

AUTHOR(S): T.S. Mintz

PERSONS PRESENT: T.S. Mintz, Center for Nuclear Waste Regulatory Analyses (CNWRA), and a number of attendees from various countries and organizations.

BACKGROUND AND PURPOSE OF MEETING/TRIP:

The ASTM Meeting of Committee G01: Corrosion of Metals featured a technical symposium and technical subcommittee meetings. The main goals of attending the conference were to

- Attend and participate in the Symposium on Advances in Electrochemical Techniques for Corrosion Monitoring and Measurement
- Attend and participate in the G01.11 subcommittee meeting on Electrochemical Measurements in Corrosion Testing

SUMMARY OF PERTINENT POINTS:

The following papers presented at the ASTM G01 Symposium were relevant to the degradation of engineered barriers:

(i) Department of Energy (DOE)-Funded Symposium papers

Use of Coupled Multi-Electrode Arrays to Advance the Understanding of Selected Corrosion Phenomena authored by J.R. Scully, N.D. Budiansky, F. Bocher, H. Cong, and M.F. Hurley. Presented by F. Bocher and H. Cong of the Center for Electrochemical Science and Engineering at the University of Virginia, Charlottesville, Virginia.

Measuring the Repassivation Potential of Alloy 22 by a Potentiodynamic-Galvanostatic-Potentiostatic Method authored by K.J. Evans and R.B. Rebak. Presented by R.B. Rebak of Lawrence Livermore National Laboratory, Livermore, California.

(ii) Other Symposium Papers

Electrochemical Techniques in Corrosion; Status, Limitations and Needs authored and presented by G.S. Frankel of the Fontana Corrosion Center, Ohio State University, Columbus, Ohio.

The following discussions during the ASTM G01.11 Electrochemical Measurements in Corrosion Testing Subcommittee were relevant to the degradation of engineered barriers: There were discussions on the status of a new standard, which is examining a technique to measure the repassivation potential. The repassivation potential is a measurement that is commonly used to determine the electrochemical potential range, for a particular set of environments conditions, where localized corrosion may be expected to occur for a given material. In addition to the new standard, there was some discussion on how to incorporate the definition of repassivation potential from an experimental point of view into any of the current standards. Initially, it was thought that it should be included in the terminology standard, but later it was decided that it would be more appropriate in the standard on convention. The next and more difficult step would be determining how the repassivation potential should be defined experimentally.

A Symposium on Advances in Electrochemical Techniques for Corrosion Monitoring and Measurement

Twenty-six papers were presented in the Symposium on Advances in Electrochemical Techniques for Corrosion Monitoring and Measurement: 3 on general electrochemical techniques and needs; 2 papers on electrochemical techniques used to evaluate Yucca Mountain materials; 2 papers on electrochemical techniques to monitor the inside of oil and gas pipelines; 4 papers on electrochemical techniques to examine insulated material; and 15 papers on other various topics.

Papers focused on the potential geologic repository at Yucca Mountain included one authored by J.R. Scully, N.D. Budiansky, F. Bocher, H. Cong, and M.F. Hurley (University of Virginia) and one authored by K.J. Evans and R.B. Rebak (Lawrence Livermore National Laboratory). These two papers are discussed in the next two paragraphs.

F. Bocher and H. Cong (University of Virginia) presented the use of coupled multielectrode arrays to advance the understanding of selected corrosion phenomena. Coupled multielectrode arrays are useful tools for understanding corrosion processes that are highly localized. The materials that were discussed in the presentation included Alloy 316 stainless steel and Alloy 625. The crevice corrosion properties of these materials were examined using the multielectrode arrays. The results indicated that the crevice corrosion occurred at the crevice opening on the 316 stainless steel, while the crevice corrosion took place deeper inside the crevice for Alloy 625. One of their experiments attempted to mimic corrosion under dust particles by holding the alloy material adjacent to the crevice mouth at a cathodic potential. The results from this study showed that it takes a much higher potential in this type of crevice to initiate localized corrosion. During the followup discussion, it was explained that Alloy 22 is currently being examined, but no data was presented at the current time. The data suggested that the cathodic nature and material properties outside the crevice may affect where and how crevice corrosion proceeds. CNWRA staff is currently evaluating this area with ongoing work that had been initiated before attending this meeting.

R. Rebak (Lawrence Livermore National Laboratory) presented one paper on measuring the repassivation potential of Alloy 22 by a potentiodynamic-galvanostatic-potentiostatic method. Currently, the repassivation potential has been measured by using potentiostatic tests or potentiodynamic tests. One method is to use a cyclic potentiodynamic polarization method described in ASTM G 61; however, the test sample may spend too much time in the

transpassive region before crevice corrosion nucleates and propagates. A method that is now being used, but which had been proposed in 1980 by scientists in Japan, measures the repassivation potential by combining potentiodynamic, galvanostatic, and potentiostatic techniques. This method was called the Tsujikawa-Hisamatsu Electrochemical technique in honor of the scientists who first proposed it. Tests were conducted on Alloy 22 in 1 M NaCl solution at 90 °C [194 °F]. The initial results were irregular, and no repassivation potential could be measured. The tests were then switched to a 5 M $CaCl_2$, which in turn gave repeatable results. Because of the conflicting results, it was believed that the potential of the sample in the NaCl tests was too close to the transpassive region, so the tests were redone in NaCl using an adjusted procedure and repeatable results, and repassivation potentials were obtained. The results obtained using the Tsujikawa-Hisamatsu Electrochemical method in NaCl were similar to the repassivation potential results from potentiodynamic tests. At low temperatures in the 5 M $CaCl_2$ solution, the results from the Tsujikawa-Hisamatsu Electrochemical method had lower repassivation potentials than the potentiodynamic tests. However, the Tsujikawa-Hisamatsu Electrochemical results in the same solution at higher temperatures had higher repassivation potentials than the potentiodynamic tests. Scanning electron microscopy images were also compared between the potentiodynamic tests and the Tsujikawa-Hisamatsu Electrochemical method. The degradation found during the potentiodynamic tests occurred all over the surface of the sample and not just in the crevice. While using the Tsujikawa-Hisamatsu Electrochemical method, the degradation occurred only in the crevice region. Therefore, Rebak and coauthors believed that the Tsujikawa-Hisamatsu Electrochemical method provides a more accurate account of crevice corrosion repassivation potential. With respect to the Yucca Mountain project, a further evaluation of the different methods for measuring repassivation potential is currently being examined.

In addition to the presentations directly related to high-level waste disposal research, there were several presentations on general electrochemical techniques and future needs. One of these presentations was given by G.S. Frankel (Fontana Corrosion Center), which discussed the status, limitations, and needs for electrochemical techniques. Corrosion areas were broken into four categories: coated and uncoated surfaces in either solution or atmospheric conditions. A great deal of information and techniques exists for uncoated surfaces in solutions, and very little exists for coated surfaces in air. Two of the challenges that will have to be dealt with in electrochemistry are determining correct equivalent circuits to use for electrochemical impedance spectroscopy and making long lifetime predictions (e.g., the engineered barrier system for the potential repository at Yucca Mountain). D.A. Eden (Honeywell International) gave a presentation on the multiple types of electrochemical techniques available. These included linear polarization resistance, harmonic distortion analysis, and faradaic rectification. S.W. Dean (Dean Corrosion Technology) presented an overview of the last 40 years of electrochemical standards development. Some issues were raised that questioned which current standards, if any, should be updated or discarded.

There was interest in the oil and gas pipeline corrosion (internal and external) at the symposium. These presentations were given by C. Mendez (CC Technologies), W. Shen (Eastern Michigan University), A.S. Khanna (Indian Institute of Technology), and S. Papavinasam (CANMET Materials Technology Laboratory). These papers discussed topics such as (i) comparison between using linear polarization resistance and electrochemical impedance spectroscopy to evaluate corrosion under insulation; (ii) use of local electrochemical impedance spectroscopy to evaluate defects in coatings; (iii) corrosion monitoring by inserting coupons at eight different locations along various offshore platforms; (iv) use of electrochemical

impedance spectroscopy to monitor uptake of water in external polymeric pipeline coatings; (v) measurement of corrosion potentials on the internal surface of pipelines; and (vi) use of quartz crystal microbalance to monitor diffusion through external polymeric pipeline coatings.

In addition to the areas previously discussed, there were presentations covering a wide range of topics. The topics discussed included but were not limited to the use of electrochemical frequency modulation, benefits and drawbacks from using electrochemical impedance spectroscopy, use of electrochemical noise, biosensors for sulphate-reducing bacteria, localized and passive corrosion of alpha titanium alloys, coupled multielectrode array sensors, phosphoric irons and commercial grade steels, and ways the reference electrode is taken for granted and may be inappropriately used. Attachment 1 provides a complete list of presentations made at the symposium.

ASTM G01.11 Subcommittee Discussions: Electrochemical Measurements in Corrosion Testing

Attachment 2 provides the agenda for the subcommittee meeting. For the old business, the topics were organized into task groups. One of the task groups that is relevant to the work being conducted at CNWRA was task group six (TG06), which is examining crevice corrosion. The comments during this task group dealt with the new Tsujikawa-Hisamatsu Electrochemical method previously discussed. Because the Tsujikawa-Hisamatsu Electrochemical method is a new method that is currently being developed, there were discussions about what should be included in a standard for measurement of the repassivation potential using this technique. In addition to the discussion on the Tsujikawa-Hisamatsu Electrochemical method, the subcommittee conducted some round robin tests to evaluate this method for determining the crevice repassivation potential of Alloy 22 and other corrosion-resistant alloys. S. Dean (Dean Corrosion Technology) is currently conducting a statistical analysis of the round robin data. Once this has been completed, it will be submitted for feedback. The main issue is how to determine the proper way for measuring the repassivation potential for highly corrosion-resistant materials.

Under other business, there were some discussions on the pitting resistance equivalency number. A proposed pitting resistance equivalency number still had to go to ballot, which is the next step. Another discussion on the repassivation potential for crevice corrosion was discussed at this point, with regard to how the definition should be incorporated into the standards. There was some discussion that it should be placed in the terminology section, but it was later decided that the convention's standard was more appropriate.

The next ASTM meeting is being planned for November 2007 in Tampa, Florida. A symposium will be held during this meeting that will present papers on lifetime predictions.

SUMMARY OF ACTIVITIES:

Symposium and Subcommittee Activities

T.S. Mintz participated in the Symposium on Advances in Electrochemical Techniques for Corrosion Monitoring and Measurement where various electrochemical techniques and their applications were discussed. T.S. Mintz also participated in the Subcommittee on Electrochemical Measurements in Corrosion Testing. During the subcommittee meeting, the

standard for the new Tsujikawa-Hisamatsu Electrochemical method for measuring repassivation potential was discussed. In addition, there was some discussion on the standard for a pitting resistance equivalency number.

IMPRESSIONS/CONCLUSIONS:

The conference provided an opportunity to follow some of the activities related to the potential geologic repository at Yucca Mountain. In addition, the symposium presented papers relevant to electrochemical techniques that are used to evaluate the performance of engineered materials in reactors and radioactive waste management. Relevant discussions on fundamental aspects of passivity, localized corrosion, and stress corrosion cracking were useful to assess advances in the application of new techniques and in mechanistic understanding of these corrosion processes.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

Attendance and participation in the symposium and selected subcommittee meeting at the International ASTM meeting were useful to follow what standards have been or are being developed that relate to the experimental techniques that will be used to support the potential Yucca Mountain license application. Staff attendance at the next meeting is recommended.

REFERENCES:

None.

Attachments 1 and 2

Attachment 1

List of Presentations made at Symposium on Advances in Electrochemical Techniques for Corrosion Monitoring and Measurement

Title	Authors
Electrochemical Techniques in Corrosion; Status, Limitations and Needs	G.S. Frankel (Fontana Corrosion Center, Ohio State University)
Use of Coupled Multi-Electrode Arrays to Advance the Understanding of Selected Corrosion Phenomena	J.R. Scully, N.D. Budiansky, F. Bocher, H. Cong, and M.F. Hurley (Center for Electrochemical Science and Engineering, University of Virginia)
Comparison of Corrosion Rate Measurement Using Electrochemical Frequency Modulation and Traditional Methods	D. Loveday and B. Rodgers (Gamry Instruments, Inc.)
An Electrochemical Investigation of the Degradation of Friction Stir Welds	D.B. Mitton, M. Cavalli, and D.A. Larson (University of North Dakota) V.J. Gelling (North Dakota State University) R. Mishra (University of Missouri) J. Ridt (Alion) F. Bellucci (University of Naples, Italy)
An Account of Benefits and Drawbacks of Using EIS in Corrosion Investigations	J.K.-J. Lee and S. Nesic (Chemical Engineering Department, Ohio University)
Application of Electrochemical Techniques to a Corrosion Under Insulation Study	C. Mendez, J.R. Vera, and G. Ruschau (CC Technologies)
Study of Initiation of Corrosion of a Steel Panel from a Defect in Coating Using Localized Electrochemical Impedance Spectroscopy (LEIS)	X. Wu, E. Montalvo, and W. Shen (Surface Science and Nano-Tribology Laboratory, Eastern Michigan University)
The Challenges of Applying Laboratory Quality Electrochemical Corrosion Measurements in the Field	D.A. Eden (Honeywell International)
Using Electrochemical Noise to Understand Corrosion in Engineering Applications	R.E. Ricker and U. Bertocci (National Institute of Standards and Technology)
Corrosion Monitoring—Application to Offshore Pipelines	A.S. Khanna (Indian Institute of Technology, Bombay, India)
An Electrochemical Biosensor for Online Monitoring of Sulphate Reducing Bacteria	R.D. Sooknah, S. Papavinasam, M. Attard, and R.W. Revie (CANMET Materials Technology Laboratory) D. Gould and O. Dinardo (CANMET Mining and Mineral Sciences Laboratory)
Electrochemical Impedance Spectroscopy (EIS) Technique to Monitor Water Uptake of External Polymeric Pipeline Coatings	S. Papavinasam, M. Attard, and R.W. Revie (CANMET Materials Technology Laboratory)

Attachment 1

Development of Electrochemical Standards for Corrosion Testing—Forty Years of Progress	S.W. Dean (Dean Corrosion Technology, Inc.)
Monitoring and Prognostication of Localized Corrosion— A Review	N. Sridhar, D.S. Dunn, G. Tormoen, and J.A. Dante (Southwest Research Institute)
Measuring the Repassivation Potential of Alloy 22 by a Potentiodynamic-Galvanostatic-Potentiostatic Method	K.J. Evans and R.B. Rebak (Lawrence Livermore National Laboratory)
Generation of Damage Functions for the Localized and Passive Corrosion of Alpha Titanium Alloys	D.W. Shoesmith (Department of Chemistry, University of Western Ontario)
Coupled Multielectrode Array Sensors for Corrosion Monitoring	L. Yang (Southwest Research Institute)
The Reference Electrode: Taken for Granted, Ignored, Abused!	R.S. Rodgers (Gamry Instruments)
Corrosion Behavior of Novel Phosphoric Irons and Commercial Grade Steels in Simulated Concrete Pore Solutions	G. Sahoo and R. Balasubramaniam (Department of Materials and Metallurgical Engineering, Indian Institute of Technology)
New Faster Measurement Methods of Polarization Resistance in the Non-Steady State Period: Application to Reinforcement Corrosion	S. Garcia and C. Andrade (Institute of Construction Science, Madrid, Spain)
Examples of Monitoring of Corrosion Parameters by Embedded Sensors in Real Structures and a Methodology to Obtain a Representative Corrosion Rate Value	I. Martinez and C. Andrade (Institute of Construction Science, Madrid, Spain)
Comparison of Measurement Provided by Several Corrosion Rate Meters with Modulated Confinement of the Current	I. Martinez, C. Andrade, and N. Rebolledo (Institute of Construction Science, Madrid, Spain) E. Marie-Victoire (Institut de Restauration, Paris, France) V. Bouteiller (Laboratoire Central des Ponts et Chaussées, Paris, France)
Electrochemical Behavior of Anodized Aluminum Alloys: Electrochemical Impedance Spectroscopy Versus Optical Techniques	K. Habib (Materials Science Laboratory, KISR, Kuwait)
Measurement of Corrosion Potentials of the Internal Surface of High Pressure Operating Oil and Gas Pipelines	A. Demoz and K. Michaelian (CANMET Energy Technology Centre) S. Papavinasam and R.W. Revie (CANMET Mining and Mineral Sciences Laboratory)
Modified Electrochemical Potentiokinetic Reactivation Method for Evaluation of Steam Turbine Blades	J. Strejcius (Skoda Research Ltd., Czech Republic)
Electrochemical Quartz Crystal Microbalance Technique to Monitor Diffusition Through External Polymeric Pipeline Coatings	S. Papavinasam, M. Attard, and R.W. Revie (CANMET Materials Technology Laboratory)

Attachment 2

ASTM Subcommittee G01.11.00
Electrochemical Measurements in Corrosion
Meeting Agenda
Thursday, May 24, 2007
8:00-10:00

1. Call to order

2. Approval of minutes from 2006 November Atlanta Meeting

3. Old Business
   a. Task Group Status Reports:
      TG 01: Scanning Reference Electrode Techniques (SRET)
      TG 02: G108
      TG 03: G69 Surface Treatments
      TG 04: Electrochemical Noise
      TG 06: Crevice Corrosion
      TG 07: G5 Experiments

4. New Business
   a. Standard for Electrochemical Quartz Crystal Microbalance
   b. Standard for Reference Electrode
   c. Standard for Microelectrodes
   d. Stress-Corrosion Cracking of Stainless Steel in Clear Brine Fluids

5. Other Business
   a. Updates from the 2-day Electrochemical Techniques Symposium
   b. Definition of pitting resistance equivalency number

6. Next Meeting

7. Adjournment