CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: CORROSION/2002 Annual Conference and Exposition

DATE/PLACE: April 7-11, 2002
Denver, Colorado

AUTHORS: C.S. Brossia, G.A. Cragnolino, D.S. Dunn, N. Sridhar, L. Yang

DISTRIBUTION:

CNWRA	DWM	SwRI
W. Patrick	J. Linehan	T. Nagy (contracts)
CNWRA Directors	D. DeMarco	
CNWRA EMs	B. Meehan	
G. Cragnolino	E. Whitt	
P. Maldonado	J. Greeves	
	J. Schlueter	
	K. Stablein	
	B. Leslie	
	S. Wastler	
	A. Campbell	
	T. McCartin	
	T. Bloomer	
	T. Ahn	
	J. Anderson	
	J. Thomas	
	T. Essig	
	A. Henry	
	B. Reamer	

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: CORROSION/2002 Annual Conference and Exposition
01402.571

DATE/PLACE: April 7-11, 2002
Denver, Colorado

PERSONS PRESENT: C.S. Brossia, G.A. Cragnolino, D.S. Dunn, N. Sridhar, L. Yang (CNWRA), Glenn Light and Vic Aaron (SwRI), and about 3500 representatives from various countries and organizations.

BACKGROUND AND PURPOSE OF TRIP:

The annual NACE International corrosion conference and exposition features technical symposia, technical committee meetings, and an exhibitor show. The main goals of attending the workshop were to:

- Present papers authored by the CNWRA staff that were included in several symposia
- Chair Symposia and Technical Committee Meetings
- Attend the presentations from the DOE HLW program and from work supported by the State of Nevada.
- Make contacts with prospective candidates to fill open positions within the CNWRA

In addition to presentations in the technical symposia, CNWRA staff played an active role in the organization of several symposia and participated in technical committee meetings.

MEETING SUMMARY

Papers co-authored by the CNWRA staff and presented at the CORROSION/2002 conference are listed below:

"Assessment of Passive and Localized Corrosion Processes for Alloy 22 as a High-Level Nuclear Waste Container Material", D.S. Dunn and C.S. Brossia. Presented in the Corrosion in Nuclear Systems Symposium.

"Effect of Oxide Thickness on the Localized Corrosion of Zircaloy", C.S. Brossia, G.A. Cragnolino and D.S. Dunn. Presented in the Corrosion in Nuclear Systems Symposium.

"Comparison of Localized Corrosion of Fe-Ni-Cr-Mo Alloys in Chloride Solutions Using a Coupled Multielectrode Array Sensor", L. Yang, N. Sridhar and G. Cragnolino. Presented in the Corrosion in Nuclear Systems Symposium.

"Stress Corrosion Cracking of Nickel-Chromium-Molybdenum Alloys in Chloride Solutions", D.S. Dunn, Y.-M. Pan and G.A. Cragnolino. Presented in the Environmentally Assisted Cracking Symposium.

Other papers, based on work performed outside the high-level waste program, were also presented by CNWRA staff, as listed below:

"Evaluation of Corrosion Inhibitors in Cooling Water Systems Using a Coupled Multielectrode Array Sensor", L. Yang and D.S. Dunn. Presented in the Monitoring and Corrosion in Water Systems Symposium.

"Condition Based Coating Degradation Sensor", C.S. Brossia and D.S. Dunn. Presented in the Military Corrosion Symposium.

"Predicting Localized Corrosion in Seawater Cooling Systems", N. Sridhar, C.S. Brossia, D.S. Dunn, J.P. Buckingham, and A. Andreko. Presented in the Marine Corrosion Symposium.

"Aircraft Corrosion During Depaint Operations", C.S. Brossia and N. Sridhar. Presented in the Military Corrosion Technical Group Meeting (no paper).

Papers presented by the CNWRA staff were well received and prompted questions and subsequent discussion.

Corrosion in Nuclear Systems

The Corrosion in Nuclear Systems Symposia featured 11 papers focused on corrosion in reactors. Included was a presentation on environmentally assisted cracking of nickel alloys (Alloys 182 and 600) presented by Peter Andresen from General Electric Global Research. Other environmentally assisted cracking papers presented by General Electric Global Research staff were focused on the effects of cold work and radiation hardening on the stress corrosion crack growth in stainless steels in high temperature water. Papers presented in the symposium also included a summary of boiling water reactor performance following noble metal chemical addition and examination of surface layers of alloys 600 and 690 in pressurized water reactors.

In addition to reactor oriented papers, the Corrosion in Nuclear Systems Symposium also included 14 papers focused on corrosion in nuclear waste disposal systems including the three papers presented by CNWRA staff. An overview of the DOE program was presented by Dan

McCright. The presentation was focused on the approach used and provided only limited details of the results obtained from the Lawrence Livermore National Laboratory long-term corrosion test facility. It was reported that results obtained from five-year exposure specimens will be available soon. The specimens were tested in several solutions that have been considered in the DOE program to be similar to the composition of water that may exist near the proposed repository horizon or evolve as a consequence of evaporation on the waste package surface.

Other results from Lawrence Livermore National Laboratory tests included a presentation of Alloy 22 stress corrosion cracking tests by Raul Rebak. Significant transgranular stress corrosion cracking was reported in slow strain rate tests in simulated concentrated water at both 73 and 86 °C when the material was maintained at anodic potentials above the corrosion potential measured in an air saturated solution. No stress corrosion cracking was observed at lower potentials closer to the corrosion potentials. The susceptibility of Alloy 22 to stress corrosion cracking was attributed to the combination of chloride and fluoride as well as to the severity of the slow strain rate tests which introduces significant plastic deformation at a very low elongation rate. Subsequent discussion after the presentation focused on the need for additional tests to assess the effects of temperature and variations in solution composition. A following presentation by Gabriel Ilevbare also from Lawrence Livermore National Laboratory showed that at anodic potentials in the range where stress corrosion cracking was observed, molybdenum in the oxide layer is oxidized from a valence state of +4 to +6 and nickel is oxidized from +2 to +3. Additional papers supported by the DOE high level waste disposal program included presentations by Fred Hua from McDermott Technology Incorporated, Peter Lin from Integran Technologies Incorporated and Young-Jin Kim from General Electric Global Research. These additional investigations were limited to the same standard test solutions used in the long term corrosion test facility at Lawrence Livermore National Laboratory.

Two papers were presented by April Pulvirenti from Catholic University of America. The work presented was funded by the Geosciences Management Institute under contract to the Nevada Agency for Nuclear Projects. A study designed to determine the susceptibility of Alloy 22 and Titanium grade 7 to localized corrosion and stress corrosion cracking was presented first. Tests were conducted in autoclaves at temperatures in excess of 200 °C in very aggressive solutions at extreme pH values. Although localized corrosion was reported for both materials, the extremely aggressive conditions used are not easily translated to conditions expected on the surfaces of engineered barriers in the proposed repository. The second paper focused on the localized corrosion and stress corrosion cracking of titanium grade 7. Pitting corrosion on disk specimens and stress corrosion cracking of U-bend specimens were reported in a solution containing 35,500 ppm chloride (1 molar chloride) and 1,900 ppm fluoride (0.1 molar fluoride). Pitting was initiated in times as short as 16 days in pH 7.2 solutions maintained at 105 °C. Stress corrosion cracking was reported after 155 days.

The Corrosion in Nuclear Systems Technical Committee was highlighted by a presentation by Barry Gordon from Structural Integrity Associates on the recently discovered boric acid corrosion found at Davis-Besse nuclear power plant. Discussions also included preparation for

the Corrosion in Nuclear Systems Symposium at CORROSION/2003. Darrell S Dunn will be chair of this symposium.

Environmentally Assisted Cracking

Seventeen papers were presented in this symposium, which was organized and chaired by Gustavo Cragnolino. This symposium was well attended with an average of 50 to 60 people. The papers covered a wide range of problems encountered in a variety of industrial applications. In the first paper, Roger Staehle (Consultant and University of Minnesota) discussed the application of Weibull distribution to the analysis of early failures promoted by stress corrosion cracking. In order to develop predictions of early failures (those which occur with a probability of 10^{-4} to 10^{-2}), both the mean and the Weibull scale and shape parameters should be known. Staehle discussed the physical meaning and some mechanistic interpretations of the shape parameter using examples form laboratory and field studies, mainly originated in the nuclear power industry where recurrent SCC cases have been observed (e.g. steam generator tubing). There were a couple of presentations on environmentally assisted cracking of composite materials, but the rest of the papers were devoted to SCC of metallic materials including ferritic and austenitic stainless steels, carbon steels, zirconium alloys, copper and aluminum alloys.

There were two papers related to the SCC of materials to be used for HLW containers in the proposed Yucca Mountain repository. One of them was presented by Denny Jones (University of Nevada at Reno) and dealt with film rupture and repassivation on stainless steel and alloy 22 electrodes. The purpose of this work, sponsored by the YM program, is to provide parameters for the slip dissolution model. However, the study is still in its preliminary stage and the information presented was rather limited. In addition, the approach adopted in these measurements is subject to criticism because the data obtained in these measurements of current in straining electrodes cannot be directly used as input parameters in the model. Darrell S. Dunn (CNWRA) presented a paper on the stress corrosion cracking of type 316L stainless steel and alloy 22 in concentrated chloride solution. Test were conducted using precracked specimens at relatively high stress intensities The main purpose of the paper was to demonstrate that at applied potentials lower than the repassivation potential for crevice corrosion, crack growth can be slow down significantly and even arrested. Contrary to the case of type 316L stainless steel, no crack growth of alloy 22 was observed even under cyclic loading.

An interesting paper was presented by S. Farina (Atomic Energy Commission of Argentina). The SCC of Zirconium and Zircaloy -4 in iodine was studied in solutions of I_2 in various alcohols. It was claimed that, on the basis of the surface mobility model of SCC developed by J. Galvele (one of the coauthors of the paper), the crack growth rate was controlled by the steric hindrance effect caused by the size of the alcohol molecule chemically bounded as a complex to I_2. A paper presented by A. Rojnov (Moscow State Institute) on the use of acoustic emission to study SCC in a similar metal/solution system was an good complement of the previous paper .

The Technical Committee Meeting on Environmentally Assisted Cracking did not have any technical presentation. The organization of next year symposium was coordinated.

Other Symposia

The authors also attended other corrosion sessions including microbially influenced corrosion (MIC), corrosion in military systems, corrosion in the oil and gas industry, and corrosion monitoring and testing. In the MIC areas, several topics of conversation were explored including effective test methods for measuring the effects of MIC as well as possible ways to distinguish between biotic (MIC) and abiotic (non-MIC) corrosion. Military corrosion sessions had several papers on anti-corrosion methods, ways of monitoring corrosion in military systems, and life/cost benefit analyses on military assets. In addition, Sean Brossia was elected chair of NACE Specific Technology Group (STG) 62 on Corrosion Monitoring and Testing Methods. Involvement in these other areas provides a broader exposure to corrosion concerns in general and further enhances the reputation of the CNWRA corrosion efforts on behalf of the NRC repository and other programs.

Gerald Gordon (Betchel SAIC Co) received the Speller Award for his contributions to corrosion engineering and presented a well attended lecture on Corrosion Considerations Related to Permanent Disposal of High-Level Radioactive Waste. He presented a comprehensive review of the materials work conducted for the Yucca Mountain project which provides an excellent summary to the attendees that were not well aware of the advances in the DOE program..

CONCLUSIONS

With respect to the corrosion of candidate engineered barrier material for high level waste disposal at the proposed repository at Yucca Mountain, it was noted that the presentations funded by the DOE were limited to a narrow range of solutions with favorable ratio of inhibiting oxyanions (i.e. nitrate and sulfate) to chloride. While DOE sponsored investigations have demonstrated that localized corrosion of Alloy 22 and titanium grade 7 do not occur in these solutions in relatively short term simplified tests, it was shown that slight changes in solution chemistry or changes in the corrosion potential of the material can significantly alter the localized corrosion and stress corrosion cracking susceptibility of Alloy 22 and titanium grade 7. Characterization of the expected environment at the repository horizon, effects of groundwater chemistry on the localized corrosion and stress corrosion cracking susceptibility, and measurement of critical potentials for the engineered barrier materials are covered by agreements reached at NRC/DOE technical exchanges. Overall, there was an increased visibility and recognition with respect to previous conferences of all the current corrosion work related to the proposed repository at Yucca Mountain.

PROBLEMS ENCOUNTERED

None

PENDING ACTIONS

None

RECOMMENDATIONS

Continued participation and attendance at the annual NACE International Conference is important in relation to all engineered aspects of the high level radioactive waste program. Presentation of papers and activities in committees contribute to the visibility and recognition among peers of the corrosion related activities conducted at the CNWRA.

SIGNATURE

C. Sean Brossia

Gustavo A. Cragnolino

Darrell S. Dunn

Narasi Sridhar

Letai Yang

Vijay Jain
Manager, Corrosion Science and Process Engineering

Budhi Sagar
Technical Director