# **CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES**

# **TRIP REPORT**

SUBJECT:	CORROSION/2006 Annual Conference and Exposition Project No. 20.06002.01.322; AI No. 06002.01.322.608
DATE/PLACE:	March 12–16, 2006 San Diego, California

# AUTHORS: K. Chiang, D. Dunn, X. He, P. Shukla, and L. Yang

## **DISTRIBUTION:**

Í

DHLWRS	CNWRA/GED	<u>SwRI</u>
W. Reamer D. DeMarco V. Whipple S. Kim L. Kokajko E. Collins M. Bailey K. Stablein A. Campbell J. Guttmann F. Brown T. McCartin D. Brooks	W. Patrick B. Sagar GED Directors GED Managers K. Chiang L. Yang O. Pensado P. Shukla YM. Pan X. He H. Jung G. Cragnolino	Record Copy B, IQS
T A1 -		

- T. Ahn
- D. Galvin

# **CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES**

# **TRIP REPORT**

SUBJECT:	CORROSION/2006 Annual Conference and Exposition Project No. 20.06002.01.322; Al No. 06002.01.322.608
DATE/PLACE:	March 12–16, 2006 San Diego, California
AUTHORS:	K. Chiang, D. Dunn, X. He, P. Shukla, and L. Yang
PERSONS PRESENT:	X. He, P. Shukla [Center for Nuclear Waste Regulatory Analyses (CNWRA)]; K. Chiang, L. Yang (Geosciences and Engineering Division); D. Dunn [(Southwest Research Institute <sup>®</sup> (SwRI <sup>®</sup> )]; and about 5,000 representatives from various countries and organizations

# **BACKGROUND AND PURPOSE OF TRIP:**

The CORROSION/2006 Annual Conference and Exposition featured technical symposia, technical committee meetings, and an exhibitor show. The main goals of attending the conference were to

- Present papers authored by staff working on the CNWRA program
- Attend presentations related to the high-level radioactive waste program
- Gain information on materials and test methods from exhibitors

In addition to presentations in the technical symposia, the CNWRA staff participated in symposia organization and technical committee meetings.

## **MEETING SUMMARY**

The following papers co-authored by the CNWRA staff were presented at the Corrosion/2006 conference:

- (i) Crevice Corrosion Penetration Rates of Alloy 22 in Chloride-Containing Waters authored by X. He and D.S. Dunn
- The Combined Effect of Simulated Bicarbonate and Chloride Ions on the Stress Corrosion Cracking Susceptibility of Alloy 22 authored by K.T. Chiang, D.S. Dunn, and G.A. Cragnolino
- (iii) Surface Analysis of Alloy 22 Under Conditions That Promote Stress Corrosion Cracking authored by D.S. Dunn, Y.-M. Pan, K.T. Chiang, and G.A. Cragnolino

- (iv) Stress Corrosion Model for Alloy 22 in the Potential Yucca Mountain Repository authored by P.K. Shukla, D.S. Dunn, K.T. Chiang, and O. Pensado
- (v) Pb-Assisted Stress Corrosion Cracking Susceptibility of Alloy 22 authored by A. Csontos, Y.-M. Pan, D.S. Dunn, L. Yang, and G.A. Cragnolino

All papers were well received, prompted questions, and generated subsequent discussion.

## **Environmentally Assisted Cracking**

The Environmentally Assisted Cracking Symposium, chaired by D. Dunn, featured 16 papers. Environmentally assisted cracking studies and case histories for nickel-based alloys, stainless steels, and aluminum alloys were included. The symposium also included papers on the stress corrosion cracking of duplex stainless steels and several papers focused on the cracking of alloys used in the oil and gas industry.

R. Rebak (Lawrence Livermore National Laboratory) presented a review of industrial experience on the caustic cracking of stainless steels and nickel alloys. The presentation included a description of the effects of alloying element additions on the stress corrosion cracking susceptibility of the C- family of nickel-based alloys (i.e., Ni-200, Alloy 600, C-276, and C-22) and related alloys used in the chemical process industry.

Recent CNWRA experimental and modeling results of stress corrosion cracking susceptibility of Alloy 22 in relevant Yucca Mountain groundwater environments were presented in three related papers. K. Chiang presented stress corrosion cracking susceptibility of Alloy 22 with respect to solution chemistry, electrochemical potential, and temperature. The results of surface analyses of Alloy 22 showing the effects of bicarbonate, chloride, and potential presented by D. Dunn were well integrated with the slow strain rate testing results presented by K. Chiang. Conditions that promote stress corrosion cracking of Alloy 22 were also shown to have a significant effect on both the composition and thickness of the oxide film. P. Shukla presented the paper Stress Corrosion Model for Alloy 22 in the Potential Yucca Mountain Repository. In the subsequent discussion, a question concerning the effect of alpha and gamma radiation on corrosion penitential of Alloy 22 was raised. The author's response was that radiation will be absorbed inside the waste package and will not be significant enough to affect the corrosion potential.

### **Corrosion in Nuclear Systems**

The Corrosion in Nuclear Systems Symposium contained 5 papers focused on corrosion in nuclear reactors; 5 papers on corrosion monitoring and assessment in radioactive waste storage systems; 3 papers on corrosion study of rock bolt materials in simulated Yucca Mountain water; and 10 papers, including one from the CNWRA staff, on engineered barrier materials for the potential geologic repository at Yucca Mountain.

Papers focused on the geologic potential repository at Yucca Mountain included a presentation by G. Gordon (Framatome Cogema Fuels) on the U.S. Department of Energy (DOE) approach to

evaluate the degradation modes of Alloy 22 in Yucca Mountain repository conditions. The information presented was consistent with that previously included in DOE technical basis documents on Alloy 22. R. Rebak (Lawrence Livermore National Laboratory) presented one paper on long-term corrosion potential and corrosion rate of creviced Alloy 22 in chloride plus nitrate brines and two papers on the influence of black annealing oxide scale on the corrosion performance of Alloy 22. Comparative tests showed that the solution annealed Alloy 22 with black oxide scale has similar corrosion resistance as mill-annealed Alloy 22. Three other papers from Lawrence Livermore National Laboratory discussed the effects of solution annealing temperatures, fluoride concentration, and organic acids on Alloy 22 localized corrosion performance. It was reported that fluoride inhibited Alloy 22.

Papers on radioactive waste storage systems included presentations by authors from Idaho National Laboratory, Pacific Northwest National Laboratory, and Westinghouse Savannah River Company. M. Flitton (Idaho National Laboratory) presented the results of underground metal corrosion. Underground pitting corrosion occurred on carbon steel, beryllium, and aluminum coupons, whereas stainless steels, nickel chromium alloy, and zirconium alloy showed nonreportable corrosion.

Papers on reactor systems focused on stress corrosion cracking and other corrosion issues in pressurized water reactors and boiling water reactors. Materials covered in the presentations included stainless steels (e.g., Types 304 and 316) and nickel-based alloys (e.g., Alloy 600). Y. Kim (GE Global Research Center) presented papers on (i) the novel approach to life extension of components in boiling water reactors and (ii) oxide fouling and its mitigation method in high temperature water. T. Masuoka (Tokyo Institute of Technology) presented a paper on the effect of cold rolling on stress corrosion cracking propagation in Type 316L SS under simulated boiling water reactor conditions. Another paper on Type 316L SS stress corrosion cracking was presented by T. Terachi (Institute of Nuclear Safety Systems, Inc., Japan). D. Morton (Lockheed Martin) presented a paper on the stress corrosion cracking growth rate of nickel alloys.

#### **Research in Progress Symposium on Passivity and Localized Corrosion**

This symposium included three presentations on crevice corrosion of Alloy 22 funded by the DOE Office of Science and Technology and International (OST&I) multi-university materials performance program. J. Payer (Case Western Reserve University) gave a presentation on the effect of a crevice former on corrosion damage propagation in Alloy 22. He reported that crevice former material affected the susceptibility of Alloy 22 crevice corrosion. The ceramic washer wrapped with polytetrafluoroethylene tape is the most aggressive crevice former to initiate Alloy 22 crevice corrosion. D. Macdonald (Pennsylvania State University) gave a presentation on a post-Pourbaix view of passivity. The kinetic stability diagrams that McDonald developed predicted that Alloy 22 maintains passivity in a wider range of environments than what predicted by the Pourbaix diagram. T. Lian (Lawrence Livermore National Laboratory) presented his recent work on electrochemical studies on the inhibitive effects of nitrate on the crevice corrosion of Alloy 22 in high-concentration Na-K-NO<sub>3</sub>-Cl brines between 90 and 150 °C [194 and 302 °F]. This study showed that at temperatures greater than 120 °C [248 °F], the concentrated solution

was  $NO_3^-$  dominant and Alloy 22 maintained high corrosion resistance. At temperatures less than 120 °C [248 °F], the solution was Cl<sup>-</sup> dominant.

## **Microbiologically Influenced Corrosion**

Eleven papers were presented in this symposium. P. Linhardt (Vienna University, Austria) presented a paper, Microbially Influenced Corrosion by Manganese Oxidizers: The Performance of Stainless Steels and the Cathodic Behavior of Biomineralized Mn-Oxides which is of particular interest to the Yucca Mountain project. He concluded that manganese oxidizing microorganisms were the cause for the chloride-induced corrosion of stainless steels (Types 304 and 316) in freshwater systems at low chloride levels that is normally considered noncritical.

## **Multielectrode Corrosion Sensors**

Laboratory and field applications of multielectrode sensors symposium, chaired by L. Yang, included 10 presentations. The majority of the papers were on the use of multielectrode arrays as real-time sensors for localized or microbially influenced corrosion or electrochemical tools for studying the process of localized corrosion.

## **Technical Committee Activities**

K. Chiang participated in the Technical Committee Meeting on Environmentally Assisted Cracking. The Technical Committee Meeting on Corrosion in Nuclear Systems was attended by K. Chiang and X. He. During the meeting, B. Gordon (Structural Integrity Associated, Inc.) made an invited presentation entitled Renaissance of Nuclear Energy. The chairman of the committee announced that in 2007 the symposium will be focused on advances in new nuclear power development. L. Yang chaired the Technical Committee Meeting on Sensors, Multielectrode: Laboratory and Field Applications. X. He was invited to attend the research committee meeting.

## CONCLUSIONS

The conference provided an opportunity to follow the activities related to the potential geologic repository at Yucca Mountain. In addition, many symposia had papers that were relevant to the performance of engineered materials that are used in reactors, as well as those that may be used in the potential Yucca Mountain geologic repository.

## PROBLEMS ENCOUNTERED

None.

## **PENDING ACTIONS**

None.

#### RECOMMENDATIONS

Attendance and participation in selected committee meetings at annual CORROSION conferences is highly recommended.

## SIGNATURE

the Nos

Xihua He, Research Scientist Corrosion Science and Process Engineering

Shull

Pavan Shukla, Research Engineer Corrosion Science and Process Engineering

K.J. Chianf

Ken Chiang, Senior Research Scientist Geosciences and Engineering Division

Lietai Yang, Senior Research Engineer Geosciences and Engineering Division

Darrell Dunn, Principal Engineer Southwest Research Institute

4/13/06

Date

9/13/06 Date

4/13/06

Date

4/13/06 Date

4/13/06

6

**CONCURRENCE:** 

i

۱۱

Vijay Jain Manager Corrosion Science and Process Engineering

Sitakenta Mohan

Sitakanta Mohanty Assistant Director Engineering and Systems Assessment

4/14/06 Date

<u>4/14/2006</u> Date