CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: CORROSION 2001—NACE International Annual Conference and Exposition
Charge No. 20.01402.571 and 20.01402.158
AI 01402.571.007

DATE/PLACE: March 11–16, 2001
Houston, Texas

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

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PERSONS PRESENT: The conference and the exposition was attended by more than 6,600 people, including large number of attendees from Canada, Europe, Asia, and Latin America

BACKGROUND AND PURPOSE OF TRIP:

The objective of CORROSION 2001—NACE International Annual Conference and Exposition is to provide a forum where information and ideas can be exchanged on a variety of corrosion related subjects including corrosion prevention, lifetime prediction of engineered structures and components, coating systems, and corrosion research as well as products and services. In addition to the papers that were presented by the authors in technical symposia, the authors also participated in technical committee activities, and co-chaired the Corrosion Monitoring Session of the Research in Progress Symposium as well as the technical symposium on Environmentally Assisted Cracking.

SUMMARY OF PERTINENT POINTS:

This summary provides an overview of some of the talks that were attended related to NRC activities. Additional details can be obtained by contacting any of the authors.

The Corrosion in Nuclear Systems technical symposium contained twenty-two technical papers and included contributions focused on nuclear power reactors as well as processing and disposal of high-level radioactive waste. Two papers were presented by Center for Nuclear Waste Regulatory Analyses (CNWRA) staff including, "Long Term Dissolution Behavior of Alloy 22: Experiments and Modeling" authored by D.S. Dunn, C.S. Brossia and O. Pensado, and "Effect of Pd on the Localized and Passive Dissolution of Titanium," authored by C.S. Brossia and G. A Cragnolino. Both presentations by SwRI staff were focused on technical issues associated with the disposal of high-level nuclear waste and were well received by the symposium attendees.

Papers focused on corrosion in reactor systems featured a paper by L. Young (General Electric Corporation) on stress corrosion cracking (SCC) where crack tip strain rate was identified as the driving force for SCC by the slip dissolution mechanism. A comparison of crack propagation rates of Alloy 600 with those of

austenitic stainless steel showed similar crack propagation rates; however, the cracks in Alloy 600 tend to stall, particularly in annealed material.

Another paper from General Electric Corporation, presented by T. Angeliu, provided initial results and discussed future investigations aimed at correlating the microstructure and residual stresses in low carbon stainless steels used in boiling water reactors to the occurrence of stress corrosion cracking. Residual stresses in welds, cold work, and thermal non-equilibrium segregation of Cr were identified as factors for intergranular SCC of reactor core shrouds.

An electrochemical noise probe for secondary side stress corrosion cracking of Alloy 600 was presented by G. Quirk (Westinghouse Electric Corporation). The sensor was made using Alloy 600 tubes and crack propagation was sensed by current and potential noise. In addition, a large decrease in potential was observed during crack propagation.

The effect of alloy impurities on the corrosion rate of Fe-18Cr-14Ni alloys was presented by M. Mayuzumi (CRIEPI, Japan). The corrosion rate of a high purity alloy was much lower than that measured for Type 304L stainless steel. The addition of impurities such as phosphorous, carbon, sulfur, and nitrogen was observed to increase the corrosion rate of the high purity alloy; however, the addition of none of these contaminants alone yielded a material with a corrosion rate close to that measured for Type 304L. The conclusion of the study is that the combined effects of the impurities is important to material performance.

Papers focused on waste disposal issues included an update on work conducted by Peter Andersen (General Electric Corporation) on the stress corrosion cracking investigations with engineered barrier system materials considered for the proposed high level waste repository. The results presented showed that cracking could be initiated on both Alloy 22 and Titanium Grade 7 under cyclic loading conditions with a frequency of 0.001 Hz in the basic saturated water derived from J-13 water at about 95 °C. For Titanium Grade 7, the crack continued to propagate after the system was gently transitioned to a static loading condition. On the other hand, cracking did not continue to propagate after the Alloy 22 test specimens were transitioned to a static load. Based on these observations, and the expectation that WPs in the repository can only be loaded as a static system, it was concluded that there was little possibility for SCC of Alloy 22. The importance of inhibiting species such as nitrate on the long term performance of Alloy 22 was also emphasized.

The results of work supported by Lawrence Livermore National Laboratory and conducted at the University of Virginia, was presented by J. Scully. Crevice corrosion stabilization and repassivation potentials were measured for both Alloys 625 and 22. The relative performance of the alloys was compared through the use of survival probabilities and crevice corrosion generation rates as a function of potential, electrolyte composition, and temperature. As expected the performance of Alloy 22 was better than that of Alloy 625. The authors attributed the increased performance of Alloy 22 to the increased molybdenum concentration compared to Alloy 625. Increased survival probabilities and decreased crevice corrosion generation rates were observed with both materials with decreasing potentials and temperatures. Electrolytes with chloride to nitrate ratios of 100:1 were much more aggressive than solutions with either 10:1 or 1:1 chloride to nitrate ratios.

A comparison of the relative performance of Alloy 22 to Alloy 59, as possible materials for the waste package at the proposed repository at Yucca Mountain, was provided by D.C. Agarwal (Krupp VDM Technology Corporation). For the most part the performance of the materials were compared using short term tests

(standard , industrial or developed by alloy manufacturers). These tests often include extremely corrosive mixtures of oxidizing acids with high chloride concentrations at high temperatures. Alloy 59 was shown to be more resistant to localized corrosion under certain conditions.

A paper from Lawrence Livermore National Laboratory on the microbial corrosion of titanium was presented by J.A. Horn. Tests were conducted with *Thiobacillus Ferroxidans* which oxidized Fe(II) to Fe (III) and uses reduced sulfur species as energy sources and also fixed CO_2 as a source of carbon. Tests were conducted using Titanium alloy and Alloy 22 in both control and inoculated solutions that contained 2,260 ppm thiosulfate. Alloy 22 was found to exhibit some staining in both the control and the inoculated media. Titanium was reported to show signs of corrosion after testing in the inoculated media. The scanning electron microscope and atomic force microscope images were not completely convincing and there is some doubt about the validity of the claim that corrosion of the titanium alloy was observed. In any event, additional testing will be conducted at Lawrence Livermore National Laboratory.

An evaluation of the possible behavior of Zr cladding in the proposed repository was given by Te-Lin Yau (Consultant working with Framatome). He and his co-authors provided an overview of how different alloying elements may play a role in determining the corrosion behavior of Zr. He discussed the effects of various environmental variables, such as pH, chloride, hydrogen peroxide and fluoride. In discussing the effects of fluoride, it was noted that a dramatic increase in the corrosion rate was only noted at low pH (< 3.2). At higher pHs, especially at low temperatures, little effect of fluoride was observed. Based on the tenacity and protectiveness of the oxide film, they concluded that Zr would unlikely suffer from localized corrosion or SCC/HIC under anticipated repository conditions. His presentation provides explanation and views about Zr corrosion similar to those presented in the DOE AMRs on cladding corrosion.

John Mickalonis (Westinghouse Savannah River) discussed current efforts examining the effects of neutron absorbers on the corrosion behavior of the melt-dilute Al-clad spent nuclear fuel waste form. Unfortunately, due to some complications, testing had only just begun and thus no corrosion data was presented. Rather a discussion of the microstructure of the resultant phases and partioning of the absorbers was conducted. It was observed that Gd was predominantly located in the U-rich particles whereas Hf partioned more towards the Al matrix. Based on this work, it was concluded that perhaps a mixture of both would provide the most benefit for criticality control and is thus being examined.

Narasi Sridhar presented an invited paper, coauthored by D.S. Dunn, C.S. Brossia, and G. A. Cragnolino and titled "Stabilization and Repassivation of Localized Corrosion", in the Research Topical Symposium on Localized Corrosion. In this paper fundamental aspects of pitting and crevice corrosion were discussed on the bases of experimental and modeling work conducted at the CNWRA. This symposium, which includes papers on pitting, crevice and intergranular corrosion, casts light on the recent approaches and mechanistic understandings that characterize the current status of the field of localized corrosion through presentations of well recognized investigators.

Staff also attended the session on Environmentally Assisted Cracking of the Research in Progress (RIP) Symposium, as well as the technical symposium in the same subject. In the RIP symposium a paper was presented by B. Ikeda (AECL) on SCC of pure copper in nitrite/chloride mixtures dealing with potential for cracking under disposal conditions typical of HLW repositories in the saturated zone. In the technical symposium papers in a variety of areas related to pipeline SCC were presented. C. Briant (Brown University) presented a paper on the hydride cracking of Ti Grade 2 and Grade 3 exposed to a simulated sea water

environment at cathodic potentials. The most important observation is that Ti Grade 3 (a CP Ti containing higher level of impurities than Ti Grade 2) exhibit a significantly higher susceptibility to hydride cracking than Ti Grade 2 because impurity segregation and intermetallic precipitation favored the nucleation of hydride ahead of the crack tip.

In the session on Corrosion Monitoring of the RIP symposium sensors and monitoring techniques used in a variety of industries were discussed. Some of the monitoring devices evaluated for other purposes can be applied to the repository conditions during the performance confirmation period. Vinod Agarwala (Naval Air Systems Command) discussed a thin film galvanic corrosion sensor sensitive to atmospheric corrosion composed of two types of metal electrodes. The cathode is made of a noble metal and the anode of the metal or alloy of interest. The sensor is simple and it can be made robust enough to survive in the repository environment. The construction is similar to the one currently used at CNWRA to monitor wet/dry conditions in the simulated heater test.

Young-Jun Tan (Nanyang Technological University, Singapore) presented the wire beam electrode sensor. In this sensor, many wire electrodes of identical or dissimilar metals are connected together to simulate a single piece of metal Because of the lack of uniformity in the electrochemical properties of the wires in a corrosive environment, the potentials of some of the wire electrodes differ driving a current that flows through an external circuit. The current, measured with a zero-resistance-ammeter, is a indicator of localized corrosion processes. Because only metallic wires and an insulating material are used in the construction of this sensor, it can be made sufficiently robust to withstand the repository conditions.

In the same session, Oliver Moghissi discussed advances in corrosion monitoring for the pipeline industry and Robert Kelly (University of Virginia) addressed current issues and research applied to the infrastructure.

SUMMARY OF ACTIVITIES:

Gustavo A. Cragnolino was honored at the annual NACE banquet as an elected Fellow of NACE International for his lifelong contributions and research work associated with nuclear reactors and high-level radioactive waste disposal issues. The Corrosion in Nuclear Systems technical exchange group was attended by Darrell S. Dunn and Gustavo A. Cragnolino. This technical exchange group's primary function is to prepare for and plan the corrosion in nuclear systems technical symposium. D.S. Dunn will be vice chairman for the CORROSION 2002 symposium. The Corrosion and Corrosiveness Sensor Development technical exchange group meeting was attended by D.S. Dunn. Plans for a technical symposium for the CORROSION 2003 conference and exposition were discussed. Gustavo Cragnolino attended the meeting of the technical exchange group on SCC and Corrosion Fatigue where plans for future symposia were discussed. G.A. Cragnolino will be chairman of the technical symposium on Environmentally Assisted Cracking to be held during CORROSION 2002.

CONCLUSIONS:

Attendance at NACE provides a valuable forum for the exchange of ideas as well as constructive criticisms and reviews of the work we are engaged in. It also provides an opportunity to follow and evaluate the activities of other researchers who are working in the nuclear waste area and in the corrosion field in general. Areas of particular interest are localized corrosion, stress corrosion cracking and corrosion monitoring.

Our yearly participation in this conference enhances confidence within the corrosion community on the NRC work conducted at the CNWRA that is intended to provide solid technical assessment of the proposed engineering barriers designed for the protection of public health and safety.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

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

SIGNATURES:

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3/29/01
Date

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3/29/01
Date

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