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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Nuclear Waste Technical Review Board (NWTRB) Meeting of the Panel on the Engineered Barrier System (EBS): Current and Planned EBS Research
20-5704-042

DATE/PLACE: Pleasanton, CA
March 10, 1994

AUTHOR: Gustavo Cragnolino

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PERSONS PRESENT:

CNWRA	NRC-NMSS
G. Cragnolino	C. Interrante

The meeting was attended by approximately 50 people. The list of all the attendees at the meeting is included as Attachment A.

BACKGROUND AND PURPOSE OF TRIP:

The Panel on the EBS of the NWTRB organized the meeting according to the agenda included as Attachment B. The aim of the meeting was to obtain, from the presentations of U.S. Department of Energy (DOE) and Lawrence Livermore National Laboratory (LLNL) representatives, information on the DOE strategy and timing for determining the long-term performance of EBS materials, the current and planned linkage between EBS research and performance assessment, and the corrosion models to be used in the next subsystem and total system performance assessments. The meeting was followed the next morning by a tour of the facilities of LLNL dedicated to the Yucca Mountain project. The agenda of the tour is included as Attachment C.

SUMMARY OF PERTINENT POINTS:

Presentations were directed toward the board, followed by questions from the panel members and the board technical staff. Due to time limitations, short questions and comments from the audience were allowed occasionally and prior to the final round-table discussion. Transcripts of the meeting will be available on computer disk in the near future. Copies of the viewgraphs used by the presenters are available from the author of this report. All individual presentations are summarized below.

E. Verink (EBS panel chair) opened the meeting indicating that after several years of a very low level of effort on waste package (WP) materials for the EBS, there were positive signs that DOE is reversing this trend with an emphasis on a more robust design as suggested by NWTRB in reports to the Congress.

M. Smith [DOE, Yucca Mountain Project (YMP); replaced W. Simecka] presented a brief overview of the progress made in the WP design since the Site Characterization Plan (SCP) conceptual design to the current Advanced Conceptual Design (ACD) stage. According to him, the adoption of the multi-purpose

canister (MPC) as the baseline design has resulted in a focused ACD approach. He emphasized that the design assumptions will be substantiated through studies conducted separately at LLNL (using other national laboratories as subcontractors) and the M&O.

D. Stahl [M&O, Babcock & Wilcox (B&W) Fuel Company] presented the revised R&D needs for the WP design in terms of meeting the regulatory requirements and establishing an adequate justification for the high thermal loading strategy. The current conceptual design, based on drift emplacement of a multiple barrier container, is being evaluated with the goal of attaining a 10,000-yr containment period. He described the interactions between the various project activities in relation to WP design, testing and modeling, and performance assessment. In addition to the information contained in his viewgraphs, Stahl pointed out, answering to board questions, that a range of environmental conditions are being considered in relation to various water contact modes with the WP. He also pointed out that enough time is allowed in the planning of the activities for modifications in the WP design.

W. Clarke (LLNL) described in general terms the YMP activities at LLNL. These activities include characterization of the WP environment, characterization of performance for materials used for WPs and associated EBS components, characterization of degradation and performance of radioactive waste forms, and development of models and computer codes to predict performance of WPs and EBS components. Among the accomplishments, he listed the development of PANDORA, a code describing the evolution with time of a single WP, the advances in the Yucca Mountain Integrated Model (YMIM), and the publication of reports during FY 94 on Engineered Materials Characterization (to be essentially devoted to carbon and low-alloy steels) and on Non-Metallic Barrier Systems.

W. Lin (LLNL; replaced D. Wilder) presented a detailed review of the plans, schedule, and status of the large-block heater test at Fran Ridge. The significance of heater tests at the lab scale (small blocks) to be conducted at LLNL and the development of appropriate instrumentation were described. In his presentation, Lin stated that specimens of candidate container materials (i.e., carbon steel) will be exposed at various locations corresponding to different temperatures and degrees of humidity. Pre-test model calculations of temperature profiles, liquid saturation, and moisture saturation were presented. He emphasized that the validity of current models has not been demonstrated, and the issues related to refluxing of water and condensate drainage/shedding need to be adequately addressed.

W. Halsey (LLNL) presented the approach adopted for the EBS Subsystem Performance Assessment, indicating that the YMIM was improved and modified to provide the source term for the Total System Performed Assessment (TSPA) exercise conducted by Sandia National Laboratory (SNL) in 1993. The multiple barrier package in a drift emplacement was considered, in addition to the SCP design, in TSPA-1993. For the WP performance, a simple dry-oxidation model extrapolated from high temperature was used, combined with a general-corrosion model for aqueous conditions and a localized-corrosion model using the corrosion damage function approach developed by Macdonald and adopted by Henshall. This was a good overall presentation in which the limitations in several of the analyses included in the TSPA were recognized.

K. McCoy (M&O, B&W Fuel Company) discussed the consideration of the Zircaloy fuel cladding as a disposal barrier, suggesting that cladding could be a potentially important barrier for radionuclide release and a redundant barrier for containment. After a brief review of various processes and mechanisms responsible for cladding degradation, creep rupture through diffusion-controlled cavity growth (DCCG) was considered to be the dominant mechanism, on the basis of NRC and Pacific Northwest Laboratory (PNL) studies applied to dry storage. On the basis of limited modeling using DCCG concepts, McCoy

concluded that cladding can survive 10,000 yr at the calculated temperatures of disposal, but to obtain cladding credit may be difficult due to cladding variability and the fact that cladding characterization is expensive and time consuming.

W.J. O'Connell (LLNL) also discussed the effect of creep of the Zircaloy cladding on the performance during transportation and during the containment period. Several issues related to data variability, particularly for creep rate, were reviewed, including the effect of irradiation and accumulation of fission gases. It was emphasized that there was a need for further experimental work to correlate creep rate with creep lifetime. It was apparent from this presentation that extensive characterization work is needed before claiming the cladding to be an additional barrier.

The presentation of T. Doering (M&O; B&W Fuel Company) dealt with long-term criticality considerations in the development of WPs. Several sets of criticality calculations were presented assuming burnup credit for the MPC design with and without the presence of neutron absorbers. It appears that the long-term performance of neutron-absorber materials is important to attain a low probability of criticality events. Doering concluded that burnup credit is important for WPs with more than four PWR assemblies for long-term criticality control.

D. McCright (LLNL) reviewed the current and planned research in materials, covering essentially metallic container materials and briefly nonmetallic barriers. He described the multibarrier approach, considering, as an example, a corrosion-allowance material as an outer barrier and a corrosion-resistant material as an inner container, followed by a listing of alloys considered, as well as combination of materials for both barriers. A brief summary of the conclusions of the survey on degradation modes of ferrous materials was presented, followed by a listing of current and planned activities. The lack of a clear strategy and focus in the DOE program regarding container materials was apparent in this presentation. The need to consider environments representing concentrated solutes as affected by "upset" thermal/chemical conditions was clearly recognized. Modeling activities appear to be confined to the stochastic approach for pitting corrosion.

G. Gdowski (LLNL) presented the approach and experimental facilities for conducting thermogravimetric studies of oxidation in air/water mixtures at 75-300 °C at various partial pressures of water. Results arising from a literature review of atmospheric corrosion were discussed to illustrate the significance of the proposed study. There are interesting aspects in this activity, but other areas of metal/environment interactions should receive more attention at the current time as a result of their greater impact on materials performance (e.g., crevice and galvanic corrosion).

J. Park [Argonne National Laboratory (ANL)] presented the results of the experimental program conducted at ANL on crack growth rate measurements for types 304L and 316L stainless steels and alloy 825 using compact tension (CT) specimens. No crack growth was observed after 19,000 h (2.2 yr) testing, indicating that the crack growth rate is lower than 8×10^{-3} m/s if SCC indeed occurs in the environment tested. However, the only environment tested is J-13 well water, and, therefore, this carefully conducted experimental work has no value for predicting the behavior of the materials studied under variations in the environmental conditions. Park noted that ANL is now proposing to study variations in the environment associated to wet/dry cycles and compositional changes.

A. Meike (LLNL) described the activities conducted to address the effect of introduced materials in the post emplacement environment and the possible consequences of their degradation. These materials, among others, include diesel fuel, lubricants, shotcrete, and emplacement materials. Although the

importance of these studies cannot be denied, it appears that the scope of this program is not well defined, and the relative importance of the different materials and their degradation products has not been properly addressed.

K. Jackson (LLNL) presented results on an experimental investigation on the hydrous pyrolysis of diesel fuel. Although the formation of carboxylic acids was mentioned as a possible consequence of the degradation process noted above, no clear evidences were shown in the results presented to corroborate that presumption.

P. Amy (University of Nevada at Las Vegas; invited by NWTRB) presented an overview of the potential for microbial activity in an unsaturated repository, based partially on her own work at Rainier Mesa. It was a good presentation covering heterogeneity, survival, metabolic products, and other aspects of microbial activity, but lacking any significant evaluation of microbial influenced corrosion (MIC). When questioned about MIC, she refereed to the CNWRA report as an extremely good review of the subject, specifically applied to unsaturated repository site conditions.

During the limited time reserved to questions and comments from the public, questions were raised regarding the validity of using geothermal fields in New Zealand for evaluating the behavior of man-made materials as well as for the validation of geochemistry codes. Other questions referred to the consideration of creep rupture as the prevailing damaging process for fuel cladding, the importance of the formulation and chemical composition of the cement to be used in the underground facilities, etc. Although the LLNL investigators addressed the questions posed at the meeting, there were no clear and convincing arguments offered to respond to programmatic and technical issues.

In the round-table discussion, the main theme revolved around the MPC design and the necessary testing of the component materials in relation to the tight schedule to complete the required activities before 1988. Stahl emphasized that the MPC is part of an evolving design for the WP in which one of the main issues is the burnup credit. Clarke insisted on the budgetary constraints that are still limiting the necessary EBS research, arguing that the qualification of a material for an important component of the WP requires at least $5 M/yr.

A tour of the LLNL facilities involved in the YMP took place the following morning. Most of the experimental work in the area of thermohydrology seems to be well defined and progressing in support of the large-block heater test at Fran Ridge according to the needs of the program. The geochemistry experimental work is focused on the development of an appropriate thermodynamic database for the YMP, including radionuclide speciation and solubility. However, the corrosion-related work seems to be lacking a clear direction; it is not well focused and progressing slowly. For example, the environmental and corrosion-sensor development effort, included as part of the tour, is not connected to the development of techniques for monitoring the performance of WPs or the planned research needed in WP materials. Very slow progress was noted in the other two experimental facilities devoted to material/environment interactions, which included the vapor oxidation and the stress corrosion cracking studies. This part of the trip report cannot be considered complete without providing anecdotic information that may have additional implications. B. Viani noted that bacterial growth blocked water paths in flow experiments through tuff, affecting hydraulic conductivity. Beware of the bugs!

IMPRESSIONS AND CONCLUSIONS:

The message that DOE is moving more actively in the areas of research related to the EBS was conveyed by DOE and LLNL presenters during the meeting, reflecting the adoption of the MPC as a baseline design for the WP. However, the DOE approach to research in WPs, as conducted at LLNL, does not seem to be clearly connected with the development of the MPC. Materials evaluation work for the MPC, besides the literature reviews, is not well integrated. Multiple choices of materials for the MPC and the outer container were identified without an appropriate definition and listing of the important issues in terms of containment. The corrosion models included in the performance assessment exercise need a careful re-evaluation that apparently is not currently done. The selection of materials for the MPC, in addition to the design, seems to be left to the contractor without the appropriate input of LLNL. Also, the limited time available within the planned schedule may limit the possibility of needed research in this area.

PENDING ACTIONS:

The CNWRA should request a technical exchange with DOE to address the orientation of the planned research in support of the WP development and, in particular, the MPC concept. A number of technical considerations, beyond burnup credit, criticality, and assignment of credit to the cladding as a barrier, should be addressed in relation to the development of the WP.

RECOMMENDATIONS:

The CNWRA should be represented in future NWTRB meetings to remain informed of the DOE position and the role of the national laboratories in providing scientific basis and data to the YMP, with the aim of influencing the scope and focus of the planned research on EBS.

PROBLEMS:

None.

SIGNATURE:

Gustavo Cragnolino
Principal Scientist

4/14/94
Date

CONCURRENCE SIGNATURES:

Prasad K. Nair
Element Manager, EBS

4/14/94
Date

Budhi Sagar
Technical Director

4/15/94
Date

Page 1 of ____

Meeting Date: 3/10/94

NUCLEAR WASTE TECHNICAL REVIEW BOARD
EBS Panel Meeting

Sheraton Inn
5115 Hopyard Road
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(510) 460-8800
March 10, 1994

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✓ GUSTAVO CRAGNOLINO	Principal Scientist	CNWRA-SWRI	6220 Culebra Road SAN ANTONIO, TX ~~78238~~	78238	(210) 522-5539	✓
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✓ MacKaye Smith	Cty Sci	DOE/YAP	101 Conv. Ctr Dr Las Vegas NV 89109	89109	702-794-1935	✓
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✓ JOHN COWLES	CHIEF ENGINEER	M&O/TRW	2650 PARK TOWER DRIVE Vienna VA 22180	22180	703 204 4566	✓

ATTACHMENT L

Meeting Date: 3/10/94

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Kevin McCoy	Program EPO	M&O/BWFC	101 Convention Ctr Dr Ste PHO Las Vegas NV 89019		702 794-1939	Sheraton
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NUCLEAR WASTE TECHNICAL REVIEW BOARD
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NUCLEAR WASTE TECHNICAL REVIEW BOARD
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Edward Taylor	Sr Scientist	M&O/TRW	Vienna, VA	22124	703 204 8108	
Greg Gdowski	P.I	KMI/LLNL	P.O. Box 808 L-591 Livermore CA	94551	510 423-2113	
Monica Michewicz		DOE	Washington, DC	20585	202-586-9738	
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Tom Bruno	Engineer	M&O/TRW	600 Maryland Ave Suite 695 Washington D.C.	20024	202 488 2810	✓
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Meeting Date: 3/16/94

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NUCLEAR WASTE TECHNICAL REVIEW BOARD
EBS Panel Meeting

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ATTACHMENT B

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

Agenda
Meeting of the
Panel on the Engineered Barrier System (EBS)

Current and Planned EBS Research

March 10, 1994

Sheraton Inn
5115 Hopyard Road
Pleasanton, CA 94588
(510) 460-8800

8:30 A.M.	Welcome Ellis Verink, panel chair Nuclear Waste Technical Review Board (NWTRB)
	OVERVIEW
8:35 A.M.	Impacts of evolving waste package/repository designs on EBS research William Simecka Department of Energy (DOE) Yucca Mountain Site Characterization Project Office David Stahl Management & Operating Contractor (M&O) B&W Fuel Company (BWFC)
9:05 A.M.	Overview of OCRWM-sponsored activities at Lawrence Livermore National Laboratory (LLNL) Willis Clarke, LLNL
9:35 A.M.	Large Block Test Materials Study Plans Dale Wilder, LLNL
10:00 A.M.	BREAK (15 minutes)

Telephone: 703-235-4473 Fax: 703-235-4495

Continued

WASTE PACKAGE PERFORMANCE ASSESSMENT

10:15 A.M.	**Session introduction** Dennis Price, session chair, NWTRB
10:20 A.M.	**Corrosion models in performance assessment** William Halsey, LLNL
10:45 A.M.	**Zircaloy cladding as a disposal barrier** Kevin McCoy, M&O (BWFC)
11:10 A.M.	**Zircaloy cladding performance in dry storage** William O'Connell, LLNL
11:35 A.M.	**Criticality control in a repository** Thomas Doering, M&O (BWFC)
12:00 P.M.	**LUNCH (1 hour, 15 minutes)**

WASTE PACKAGE MATERIALS RESEARCH

1:15 P.M.	**Session introduction** Ellis Verink, session chair, NWTRB
1:20 P.M.	**Current and planned materials research** R. Daniel McCright, LLNL
1:50 P.M.	**Thermogravimetric studies** Gregory Gdowski, LLNL
2:15 P.M.	**Accelerated stress corrosion cracking studies** Jangyul Park Argonne National Laboratory
2:40 P.M.	**BREAK (15 minutes)**

WASTE PACKAGE ENVIRONMENT RESEARCH

2:55 P.M.	**Session introduction** Donald Langmuir, session chair, NWTRB

Continued

3:00 P.M.	**Impact of introduced materials on repository performance** Annemarie Meike, LLNL
3:25 P.M.	**Hydrous pyrolysis of diesel fuel** Kenneth Jackson, LLNL
3:50 P.M.	**Microbially influenced corrosion in an unsaturated repository** Penny Amy University of Nevada at Las Vegas
4:20 P.M.	**BRIEF BREAK (10 minutes)**

PUBLIC COMMENT, ROUND-TABLE DISCUSSION, AND CLOSING REMARKS

4:30 P.M.	**Comments from the public** Members of the audience
4:45 P.M.	**Charge to the round-table participants** Ellis Verink, NWTRB
4:45 P.M.	**Round-table discussion** Participants will include today's speakers and members and staff of the Panel on the Engineered Barrier System.
5:25 P.M.	**Closing remarks** Ellis Verink, NWTRB
5:30 P.M.	**ADJOURN**

LLNL/YMP Laboratory Tour for the

United States Nuclear Waste Technical Review Board (NWTRB)/Engineered Barrier System (EBS) Panel Meeting

March 11, 1994

8:15a - 8:30a LLNL Westgate Badge Office - Lobby
(Vasco Road & Westgate Drive)

8:30a - 9:20a Bldg. 281 [Taxi from Westgate Badge Office]

- o Cindy Palmer (Bldg. 281, Rm. 1184)
  — "Variable Temperature Speciation and Solubility Data to Support the YMP Thermodynamic Database"
- o Ken Jackson (Bldg. 281, Rm. 1158)
  — "Experimental Hydrothermal Geochemistry Laboratory"
- o Brian Viani (Bldg. 281, Rm. 1323)
  — "Integrated Testing to Support the YMP Near-Field Engineered Barrier System Task"

9:30a - 10:15a Bldg. 241 [Taxi from Bldg. 281]

- o Dan McCright (Bldg. 241, Rm. 1868)
  — "Cahn 131 Thermogravimetric Analysis Unit: Corrosion/Oxidation Rates of Container Materials in Humid Atmospheres
  — "General Electric Reversing DC Slow Crack Growth Monitoring System: Stress Corrosion Cracking of Container Materials in Aqueous Environments"
- o Bob Glass (Bldg. 241, Rm. 1883)
  — "Environmental and Corrosion Sensor Development"
- o Wunan Lin (Bldg. 241, High Bay Area)
  — "Topopah Spring Tuff Moisture Retention Measurements Using Low Temperature/Constant Humidity Chambers to Support the YMP Near-Field Hydrology Task"

10:20a - 11:00a Bldg. 243 [Walk From Bldg. 241]

- o Wunan Lin (Bldg. 241, Rm. 1016)
  — "Monitoring of Moisture Content Distribution in Topopah Spring Tuff Using Electrical Resistance Tomography"
  — "Laboratory Study of Hydrologic Properties in Topopah Spring Tuff to Support the YMP Near-Field Hydrology Task"
- o Steve Blair (Bldg. 241, High Bay Area)
  — "Laboratory Scale Block Tests to Support the YMP Near-Field Geomechanics Task"

11:00a - 11:15a Westgate Badge Office [Taxi from Bldg. 243]

ATTACHMENT C