# Appendix E

## Nuclear Waste Technical Review Board Correspondence with the Department of Energy

# Nuclear Waste Technical Review Board Correspondence with the Department of Energy

In addition to published reports, the Board periodically writes letters to the Director of the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The letters typically provide OCRWM with the Board's views on specific technical areas earlier than do Board reports. The letters are posted on the Board's Web site after they have been sent to OCRWM. For archival purposes, three Board letters written during the period covered by this report are reproduced here.

OCRWM typically responds to the Board's reports and letters, indicating its plans to respond to the Board's recommendations. Included here are OCRWM's responses that were received during calendar year 2006. Inclusion of these responses does not imply Board concurrence.

- Letter from Paul M. Golan, Principal Deputy Director, OCRWM, to B. John Garrick; May 5, 2006.

  Subject: DOE's responses to recommendations in the December 19, 2005, and March 6, 2006, letters.

- Letter from B. John Garrick to Paul M. Golan, Acting Director, OCRWM; June 14, 2006.

  Subject: DOE's participation at the May Board meeting.

- Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick; August 21, 2006.

  Subject: DOE's responses to recommendations in the June 14, 2006, letter.

- Letter from B. John Garrick to Edward F. Sproat, III, Director, OCRWM; December 14, 2006.

  Subject: DOE's participation at the September Board meeting.

- Letter from B. John Garrick to Edward F. Sproat, III, Director, OCRWM; January 12, 2007.

  Subject: Comments following the Board's September 2006 Workshop on Localized Corrosion.

- Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick; November 20, 2007.

  Subject: DOE's response to recommendations in the January 12, 2007, letter.

- Letter from B. John Garrick to Samuel W. Bodman, Secretary, DOE; February 13, 2007.

  Subject: Comments following the Board's January 2007 meeting.

- Letter from Samuel W. Bodman, Secretary of Energy, to B. John Garrick; April 10, 2007.

  Subject: DOE's responses to recommendations in the February 13, 2007, letter.

- Letter from B. John Garrick to Edward F. Sproat, III, Director, OCRWM; April 19, 2007.

  Subject: DOE's participation at the January Board meeting.

- Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick; November 6, 2007.

  Subject: DOE's responses to recommendations in the April 19, 2007, letter.

- Letter from B. John Garrick to Edward F. Sproat, III, Director, OCRWM; July 10, 2007.

  Subject: Additional comments on the Board's September 2006 Workshop on Localized Corrosion.

- Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick; August 13, 2007.

  Subject: DOE's response to the Board's *Report to Congress and the Secretary of Energy, January 1, 2005, to February 28, 2006.*

**Department of Energy**
Washington, DC 20585

QA: NA

May 5, 2006

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank you for your December 19, 2005, and March 6, 2006, letters providing the Nuclear Waste Technical Review Board's (Board) comments on the information presented by the U.S. Department of Energy at the Board's meetings on November 8-9, 2005, and February 1, 2006, respectively. Our responses to each of the Board's letters are enclosed.

We appreciate the opportunities to inform the Board of the progress of the Civilian Radioactive Waste Management Program. The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on the repository and related issues.

Sincerely,

Paul M. Golan
Principal Deputy Director
Office of Civilian Radioactive
Waste Management

2 Enclosures

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ENCLOSURE 1

U.S. DEPARTMENT OF ENERGY RESPONSES TO THE DECEMBER 19, 2005, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

*Program Overview*

The Board emphasized the need for close coordination and cooperation with the utilities to ensure compatibility of the transportation, aging, and disposal (TAD) canister design(s) with the fuel loading facilities at reactor sites. The Department agrees and activities are ongoing to develop a performance specification for the TAD canister which involve interactions between the Department and the nuclear industry. The Department will consider preclosure operations, handling, transportation, aging, and postclosure performance in development of the specification.

The Department agrees that the thermal management strategy must be clearly defined to provide the technical basis for waste acceptance, transportation, waste handling, and waste emplacement. Postclosure near-field and in-drift conditions affecting performance of the engineered and natural barriers are being addressed in the postclosure elements of the thermal management strategy. This includes the thermal decay characteristics of the waste and temperature limits at key locations such as the waste package wall and drift wall. The Department will consider the Board's recommendation for external review of the TAD canister system development.

*Science Update*

The Department agrees that post-test characterization, especially of longer term *in-situ* tests, can provide valuable and insightful information leading to refinement of process models and reduction of uncertainty. Regarding the Drift Scale Test and the moisture-monitoring activity behind the bulkhead in the Enhanced Characterization of the Repository Block (ECRB), technical work plans are being developed for post-test characterization activities. For the Drift Scale Test, near-term activities include re-entry, retrieval of sample materials, collection of additional samples, and photography. Longer term activities will include coring, rock-bolt pull tests, and investigation of spalling at the drift crown. The objectives for these activities include better understanding of thermal-hydrologic-chemical-mechanical effects on repository performance. Evaluation of the ECRB bulkhead moisture data is planned for fiscal year 2007 to better understand the impact of seepage and condensation processes that occur in the near-field and host-rock.

The Department appreciates the Board's continued support of ongoing scientific investigations by the Office of Science and Technology and International (OSTI). These investigations are focused on evaluating the representation of conservatism in natural barrier system contributions to waste isolation and repository performance. For example, scientific studies at the Peña Blanca natural analog site have yielded valuable data on seepage in unsaturated tuff.

The Department agrees that host-rock thermal conductivity is a key rock property affecting the prediction of thermal-hydrologic conditions in the repository. From sensitivity analyses performed using the Multiscale model [*Multiscale Thermohydrologic Model (ANL-EBS-MD-000049, REV 03)*, Section 8.1], host-rock thermal conductivity and percolation flux are identified as the two principal natural-system parameters affecting peak temperatures and boiling duration. Other model parameters, such as waste package proximity to the edge of the repository layout, are also important.

The *in situ* measurements of thermal conductivity were acquired for the purpose of validating the geostatistical model used to calculate the bulk thermal conductivity of repository units. The model has been developed based on site-specific data including geophysical well logs, physical property measurements on rock cores from surface boreholes, and laboratory thermal conductivity measurements. Because a sequential Gaussian simulation is used, the model provides an appropriate representation of the spatial variability and uncertainty of the underlying data, especially the key input parameters (i.e., matrix thermal conductivity and lithophysal porosity). Both parameters contribute to the spatial variability and uncertainty in the model results, though the dominant influence is from matrix thermal conductivity. Whereas *in situ* tests are useful in evaluating the effects of discontinuities such as lithophysal cavities, laboratory tests are used to measure matrix thermal conductivity, the dominant contributor to spatial variability and uncertainty.

The *in situ* test results are not part of the basis for spatial variability and uncertainty in the model results. The reason is that *in situ* tests by their nature (and cost) cannot be performed over nearly as broad a range of spatial distribution and stratigraphic facies as can be performed using geophysical well logs and core samples. Thus, additional *in situ* tests would not be a practical way to improve the model treatment of spatial variability and uncertainty.

The *in situ* thermal conductivity test results are point measurements that corroborate the geostatistical model. All test results are within the range of values derived from the model. One of the test results is slightly above 1.5 standard deviations of the model-derived mean and the others are within 1 standard deviation. Additional confidence in the model is gained by the validation of methods and models used to estimate matrix thermal conductivity, lithophysal porosity, matrix porosity, and bulk density. The latter two are used to estimate the former two, which are used to obtain bulk thermal conductivity. The Department believes that an acceptable level of model validation has been achieved; and, while potentially useful, further *in situ* thermal conductivity tests are not necessary for this purpose.

The Department shares the Board's view that fundamental understanding of the source term including oxidation, dissolution, and transport is important for predicting repository performance. Current models of these processes provide an adequate level of this understanding for regulatory total-system dose assessment, but the Department plans to continue OSTI investigations in this area for possible future use.

The OSTI Source-Term Thrust Area is dedicated to scientific studies relevant to spent nuclear fuel (SNF) and nuclear waste glass and the critical processes within the waste package and drifts that affect potential radionuclide release from the waste forms and from the engineered barrier system. This program is focused on developing a basic understanding of the fundamental mechanisms of radionuclide release and a quantification of the release as repository conditions evolve over time. The Thrust Area is an integrated set of about 15 research projects involving multiple national laboratories and universities, as well as international collaboration. These projects focus on (1) dissolution mechanisms and rates for SNF, (2) formation and properties of secondary uranyl phases, (3) waste-form and waste-package interactions, and (4) modeling studies to synthesize the understanding of the chemical and physical processes. Integration of the research in this area will be ongoing throughout its progress to determine how the information developed could be used for the Yucca Mountain Project.

There are two ongoing activities related to analyses of Cl-36. The first activity documents the work on the Cl-36 validation activities performed by Lawrence Livermore National Laboratory, U.S. Geological Survey, and Los Alamos National Laboratory that have previously been presented to the Board. A draft report is in review.

The second activity is an independent study of Cl-36 conducted under a Cooperative Agreement between the Department and the University and Community College System of Nevada (UCCSN). The UCCSN scientists collected samples from the Exploratory Studies Facility in 2005, investigated experimental techniques, and started testing rock samples in 2006.

*Drip Shield Design*

The Department agrees that it is important to evaluate factors that will influence the final drip shield design well in advance of repository closure. The Department plans to fabricate prototype drip shields to evaluate operational envelopes and design and installation tolerances in the performance confirmation drifts.

*Localized Corrosion of the Waste Package*

The Department has noted the Board's continued concern regarding screening out from the Total System Performance Assessment (TSPA) localized corrosion initiated by deliquescent brines formed at high temperatures (160°C – 220°C) from airborne dust deposited on the waste package surfaces. We reiterate that the initiation of localized corrosion of Alloy 22 by brine from deliquescent salts has been excluded on the basis of low consequence.

Although the possibility of multisalt deliquescent brine formation at elevated temperatures in the repository does exist, studies show the brines would not be stable due to acid degassing (see *Screening of Features, Events and Processes in Drip Shield and Waste Package Degradation [ANL-EBS-PA-000002 REV 02]* and *Analysis of Dust Deliquescence for FEP Screening [ANL-EBS-MD-000074 REV 01]* ). As acid degassing occurs, typically rapidly at first, the pH increases to near-neutral or alkaline values. Further degassing can result in dryout, producing an assemblage of less-deliquescent salts that yield a higher pH solution (decreasing the likelihood of localized corrosion initiation) when redeliquescence occurs. In addition, the presence of carbonate anions, as well as nitrate anions, inhibit the initiation of localized corrosion on Alloy-22. The limited volume of brine and retention of brine by capillarity in the dust assemblage would also inhibit localized corrosion initiation on dust-covered surfaces. Furthermore, analysis shows that even if localized corrosion initiates, the corrosion products formed would consume some of the aqueous brine phase, thus limiting local corrosion propagation. It is on the bases of the overall analysis, as documented in the referenced reports, that localized corrosion due to dust deliquescence has been excluded from the TSPA.

In further support of the dust deliquescence analysis, the Department is in the process of investigating stifling at higher temperatures (i.e., under dust deliquescence exposure conditions), including the effects of limited availability of reactants. The tests will use methods intended to address the relationship between the amount of dust containing deliquescent salts on the waste package surface and the extent of damage that may occur.

The recent high-temperature corrosion data and their applicability can be discussed at the upcoming corrosion workshop.

*Total System Model*

The Department is pleased that the Board believes that the Total System Model (TSM) has significant potential for simulating and understanding the performance of the waste management system. The Department is prepared to support additional interactions with the Board to further understanding of the capabilities and limitations of the TSM in conducting probabilistic assessments, optimizing the waste management system, and analyzing "what if" operational scenarios.

The results of TSM analyses were used to inform the Department regarding the decision to evaluate a primarily canister-based system using TADs for commercial SNF. Insights from the TSM analyses included, but were not limited to, factors such as dose, thermal management, and waste handling.

Additional TSM analyses are currently underway to support the development of a recommended design solution as part of the Departmental process for formally evaluating and approving the change in technical baseline from a primarily bare fuel handling approach to a primarily canister-based approach. Documentation of these additional TSM analyses is scheduled for completion this summer.

The Department recognizes that information obtained from the utilities is important to the quality of the TSM analyses and success of the primarily canister-based approach. In January 2005, the Department completed a voluntary survey of all reactor operators to gather updated site-specific data, e.g., their respective capabilities to load and transport SNF needed for planning transfer of SNF from each reactor site to the waste management system. Approximately 75 percent of the site operators responded.

The Department has also provided information on the new approach to the cask vendors and nuclear utilities and is evaluating technical issues related to development and licensing of TADs raised by cask vendor and utility representatives. The Department is committed to continuing the close coordination with cask vendor and utility representatives, not only in the development of the performance-based specification for TADs, but also in the subsequent design of the TADs.

*Conservatism in the Total System Performance Assessment for the License Application*

The Department's approach to the TSPA reflects international experience, Nuclear Regulatory Commission (NRC) staff perspectives, and unique challenges of modeling transport in partially saturated fractured rock. The Department believes that the performance assessment supporting the postclosure compliance analyses is reasonable for this application and has been developed cautiously. However, we recognize the Board's perspective that some aspects of the model might be considered unrealistic. Because the approach that the Department is using for postclosure performance assessment has evolved over many years through interaction with NRC staff, and is reflected in the Yucca Mountain Review Plan, it is an integral part of our approach to the license application. The Department is currently undertaking development of a best-estimate total system performance assessment. This best-estimate analysis would be used (1) as a management and communication tool, (2) to build confidence in the estimate of repository performance in the compliance-based analysis, and (3) to quantify and help understand the degree of overall conservatism in the TSPA. We believe this will help to address directly the Board's concerns.

ENCLOSURE 2

U.S. DEPARTMENT OF ENERGY RESPONSES TO THE
MARCH 6, 2006, LETTER FROM THE
NUCLEAR WASTE TECHNICAL REVIEW BOARD

*New Organization*

The Department recognizes your interest in the restructuring of the Office of Civilian Radioactive Waste Management (OCRWM) organization. OCRWM is being reorganized to create a more project-focused approach in the accomplishment of its critical mission. The organizational changes are designed to improve and streamline the structure and processes to more effectively manage the Program through the design, licensing, construction, and operations phases. It should be noted that while the managers of functional responsibilities report to the Director, significant responsibilities will be delegated to the managers. It is the Director's role to hold each manager accountable; accountability is critical for any organization, any program, or any system to be successful.

*Realistic Analysis of Repository Performance*

The Department is currently undertaking development of a best-estimate Total System Performance Assessment (TSPA) that will allow it to investigate conservatism in the component models and build confidence in the postclosure compliance analyses. It is, however, important to recognize that the process models the Department has developed are consistent with information available at the time the models were completed. Some of these models are based on scientific understanding developed over two decades. In the face of large uncertainty or alternate conceptual models, the Department and its contractors will continue to use a "cautious, but reasonable" approach for postclosure compliance analyses to assure that the predicted risk (i.e., the dose to the reasonably maximally exposed individual) is not underrepresented and is not inappropriately diluted.

The Department has experience in evaluating repository performance over the period of peak dose, having done such analyses for the viability assessment, the site recommendation, and the final environmental impact statement. Recent postclosure performance assessment activities and modeling have focused primarily on a 10,000-year compliance period. The Department plans to conduct postclosure performance assessment analyses over the period of peak dose in accordance with final regulations, once they are promulgated.

*Radionuclide Transport*

The Department considers there to be ample information regarding the processes affecting the rate of transport under a range of environmental conditions that are expected in the waste package and the invert. As noted in the presentations, this transport is a function of the mode of degradation of the waste package and the expected environmental conditions, both of which are uncertain. Treatment of this uncertainty has been appropriately included in the models affecting source term releases as presented to the Board. The Department agrees, however, that there is benefit in continuing research in this area to enhance the understanding and evaluate the representativeness of the current results under a reasonable range of repository-relevant conditions. These conditions could be affected by the introduction of the transportable, ageable, and disposable canister concept.

The forms of $^{237}Np$ and $^{242}Pu$ expected to exit the Engineered Barrier System (EBS) were discussed in the February meeting. The form of $^{237}Np$ is a dissolved radionuclide transported by either diffusive or advective processes through the EBS and into the host rock. The form of transported $^{242}Pu$ is both dissolved and colloidal. As presented in the meeting, the significance of these different forms depends on the particular scenario class and the antecedent degradation conditions of other elements of the EBS (notably the waste package and drip shield) and the waste form type (i.e., high-level waste glass or commercial spent nuclear fuel). The Department welcomes additional discussion on this subject in the future to ensure the Board's questions and concerns are adequately addressed.

*Sensitivity of Dose Results to Different Models*

The presentation by Dr. Michael T. Ryan was focused on dose models, in particular biokinetic and dosimetric models. For a given intake of radionuclides, these models determine the expected dose. These models generally reflect well accepted dose transfer coefficients published by such bodies as the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). While these organizations recognize the large uncertainty of such models, they are widely used and accepted by regulatory bodies and agencies that implement the ICRP and NCRP recommendations; i.e., the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency (EPA). The difference in inhalation and ingestion dose is in part affected by the biokinetic and dosimetric models mentioned above and other assumptions related to the biosphere. The Department is, as noted previously, currently undertaking development of a best-estimate TSPA that will allow it to assess conservatism in component models such as dosimetric analyses, and we look forward to interactions with the Board on how best to address this issue.

*Natural Correlations of Parameters*

The Department considers the range of possible advective transport times to be consistent with the range of observations presently available and reasonably represents the current state of knowledge of unsaturated and saturated zone transport. For example, these observations include potentially disparate findings of carbon-14 ages in perched water zones in the unsaturated zone of greater than 10,000 years and possible "bomb-pulse" (less than about 50 years) chlorine-36 observations in samples taken from the Exploratory Studies Facility. This range is reasonably and appropriately captured in the unsaturated zone transport model presented to the Board.

The inferred decoupling of seepage and percolation identified in the Board's comments reflects the assumptions made in the analysis presented in the February 1, 2006, meeting. In the case of the seepage sensitivity analysis, the assumptions associated with whether the drifts were collapsed or not were significantly different. This results in a significant difference in the likelihood and amount of seepage expected. The percolation sensitivity analysis was applied only to the case where the drifts were assumed to have collapsed. In this case, over the range of different percolation values investigated, the resulting differences in seepage amount did not significantly affect the rate of release of dissolved radionuclides because of the range of solubility values used in the analysis. This result and observation is discussed in the report that the Department submitted along with the comments to EPA on the proposed rule. Again, the Department welcomes additional discussion with the Board to explain better its perspectives on the correlations.

*Compliance Period*

The Department is focused on the technical adequacy of the data, parameters, analyses, and models regardless of the time period for the compliance analysis. The Department is also focused on understanding the impact of uncertainty on the results of the relevant analyses and models that support the compliance evaluation and continues to apply the "cautious, but reasonable" philosophy recommended by the National Academy of Sciences and the regulatory guidance contained in the applicable regulations. In addition, as noted above, we are currently undertaking a best-estimate TSPA to build confidence in the estimate of repository performance in the compliance-based analysis and to quantify the degree of overall conservatism in the TSPA.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

June 14, 2006

Mr. Paul M. Golan
Acting Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Golan:

On behalf of the Nuclear Waste Technical Review Board, I thank you and the other Department of Energy (DOE) staff who participated in the Board's meeting on May 9, 2006, in Washington, D.C. The Board welcomed the opportunity to review technical and scientific issues important to the Yucca Mountain program.

The major topic of the meeting was DOE's proposal to use a transportation, aging, and disposal (TAD) canister system for most commercial spent nuclear fuel. Without the TAD canister, planned operations at the surface facilities of a repository at Yucca Mountain would likely involve removing individual spent-fuel assemblies from transportation casks and placing them in waste packages for disposal or in storage casks or site-specific canisters for aging, which could result in handling an individual assembly as many as four times. The TAD canister system could reduce the number of times individual assemblies are handled because the canister and its contents would be handled in a single action. This could improve facility throughput at Yucca Mountain and reduce the potential for accidents during handling operations. The TAD canister system also has the potential to simplify the design and reduce the cost of repository surface facilities. For these reasons, the Board considers the TAD concept promising.

It became apparent at the meeting that hurdles must be overcome for the potential advantages of a canister-based system to be realized. Particularly important is the timing of the availability of TADs for storage at utility sites. At present, at-reactor spent-fuel storage pools are becoming filled and utilities are purchasing casks for on-site dry storage. Some of these are dual-purpose casks (or use dual-purpose canisters), which can be used for both storage and transport. If TADs are not available for use at utilities for at least 5-6 years, the quantity of spent fuel in dry storage at reactor sites will be significant. How DOE deals with these storage casks and the spent fuel remaining in the spent-fuel pools for blending to DOE requirements will determine whether the TAD concept can accomplish its objective, i.e., avoiding handling of individual fuel assemblies for reblending at Yucca Mountain.

bjg056vf

Also of importance is that the TAD canister concept would be part of a license application for a repository at Yucca Mountain. While performance specifications are being developed for the TAD canister, a final determination on the acceptability of the TAD for disposing of spent fuel will not be known until the conclusion of the licensing proceeding for Yucca Mountain. Therefore, there is considerable risk to DOE, utilities, and cask vendors in moving forward with design and fabrication of TAD canisters without knowing whether they will be approved by the Nuclear Regulatory Commission (NRC) for disposal in a repository at Yucca Mountain.

Complicating this question is DOE's insistence that it can accept only bare fuel ("uncanisterized" fuel) according to its interpretation of contracts it has with utilities. Consequently, using DOE's own bases for acceptance, it appears that DOE will not accept canister-based fuels, which is contrary to the essence of the TAD concept. The Board also was told that, by law, DOE is not permitted to provide TADs to utilities for dry-cask storage. Thus, while the Total System Model (TSM) assumes that it will be possible to place 90 percent of spent fuel at utility reactors in TADs, this assumption may not be realistic because of blending limitations at reactor sites and the amount of fuel in non-TAD storage containers. The Board believes that these fundamental issues need to be understood better and resolved to allow a proper technical assessment of the TAD approach to managing spent fuel for the Yucca Mountain repository.

The Board is interested in the performance specification for the TAD canister and its relationship to the postclosure thermal-management strategy. The Board has a continuing interest in consistency in the multiscale model analysis and the identification of limiting conditions for the thermal loading of the repository. The Board believes that these analyses are keys to understanding postclosure conditions and that such understanding is needed for properly assessing repository performance as it relates to water ingress and temperature limits on materials, drifts, and possible failure modes.

The Board notes that the success of the TAD concept appears to rely on construction and use of a rail line through Nevada for moving transportation casks from existing rail lines to the Yucca Mountain site. The Board has commented previously on the need for contingency planning in the event that construction of the rail line is delayed. To the extent that adoption of the TAD concept also causes changes in the design of the Yucca Mountain surface facilities, DOE's ability to process legal-weight truck casks could be reduced. If so, contingency planning for a rail line delay would be even more important.

Finally, as an overarching concern, the Board believes that the existing litigation between DOE and the nuclear utilities is a significant impediment to the technical resolution of key issues regarding TAD canisters and the overall spent-fuel management system leading to disposal. The Board strongly urges DOE and the utilities to resolve their contractual differences with a sense of the urgent need for finding a waste-management solution.

DOE's TSM analyzed various scenarios involving use of TAD canisters, and the results of some of those analyses were presented at the meeting. The Board applauds DOE's development and use of TSM and encourages additional enhancements of its capabilities. TSM is an excellent tool for evaluating the performance of the waste management system from acceptance to emplacement and under alternative designs, operating assumptions, and constraints. Greater use of TSM is particularly important at this time, because the tool is demonstrating its value in identifying potential disconnects between various components of the waste management system. The Board would like to see a base (reference) case analysis that reflects current system realities and the design of the planned surface facilities at Yucca Mountain. TSM should be used to focus designers on credible scenarios for judging the viability of the waste management system, the design of the surface facilities (including aging pads), and the ability of the utilities to blend fuel so that the size of the aging pads can be minimized.

In addition, the Board recommends adding to TSM the capability to evaluate "upset" conditions, such as equipment breakdowns or closure of transportation routes, but only after the reference case is established. Moreover, implementation of TAD will have implications for the thermal management strategy that do not appear to have been considered fully. Consequently, the Board encourages adding to TSM the functionality to model DOE's thermal-management strategy. That could be accomplished by developing a constraint on waste package emplacement that ensures compliance with DOE's line-load thermal limit for the underground facility. For existing capabilities, as well as those that might be added in the future, realism will be important, if the results of TSM analyses are to be credible. The Board encourages DOE to scrutinize the TSM input assumptions and parameter values to ensure that they realistically represent the system being modeled.

The presentation on surface-facility design did not provide sufficient information for the Board to make any assessment of its feasibility or safety. The Board is interested in the details of the surface-facility design. For example, the Board would be interested in the number of receiving bays under consideration, their function, size of spent-fuel storage pool, dry cask handling facilities, provisions for handling failed fuel, anticipated processing rates, processing uncertainties, and key assumptions. The expectation is that TSM will be used to validate this design. The Board looks forward to receiving and reviewing the documents that support the upcoming CD-1 decision on the design of the surface facilities. The Board hopes to see these documents before the CD-1 submittal.

Despite recent efforts by DOE to reorganize the OCRWM program with the intent of improving Yucca Mountain Project management, the Board remains concerned about whether the appropriate level of Project integration is being achieved. In particular, no definable office exists whose duty and authority is to ensure technical interaction and problem resolution among and between functional elements of preclosure and postclosure activities. We also note that many of the key positions in the new organization chart are either unfilled or filled with people in "acting" positions. For the success of the new organizational approach, we strongly recommend that these positions be filled as soon as possible.

Finally, the Board is concerned that the newly announced Global Nuclear Energy Partnership (GNEP) may negatively affect the technical and scientific focus on Yucca Mountain.

We encourage the Project to monitor the developments in GNEP to be sure that any effects that might occur can be accommodated: for example, a change in the waste form for disposal in the future. The Board would like to have a briefing on the status of this program and possible effects on the Yucca Mountain project.

We look forward to future meetings with DOE during which we can address issues raised in this letter as well as other technical and scientific issues that the Board identifies that pertain to a repository for high-level radioactive waste and spent nuclear fuel repository at Yucca Mountain.

Sincerely,

{Signed by}

B. John Garrick
Chairman

**Department of Energy**
Washington, DC 20585

QA: N/A

August 21, 2006

AUG 25 2006

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. ~~Garrick~~ John:

Thank you for your June 14, 2006, letter providing the Nuclear Waste Technical Review Board's (Board) comments on the information presented by the U.S. Department of Energy at the Board's meeting on May 9, 2006. Our response to the Board's letter is enclosed.

We appreciate the opportunity to inform the Board of the progress of the Civilian Radioactive Waste Management Program. The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on the repository and related issues.

Sincerely,

Ward

Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

Enclosure

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**U.S. DEPARTMENT OF ENERGY RESPONSES TO THE JUNE 14, 2006, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

*Development and Deployment of Transport, Aging, and Disposal Canister Systems*

The Department agrees with the Board's view that the early availability and implementation of transport, aging and disposal canister (TAD)-based systems for additional at-reactor storage of spent nuclear fuel are important to ensure that the benefits of the TAD system are realized at the Yucca Mountain facilities. The Department is considering incentives to ensure that the cask vendor community develops TAD-based systems in a timely fashion, as well as incentives to encourage early deployment of these systems at utility sites.

In developing these concepts to encourage the early development and deployment of TAD-based systems, the Department recognizes that, until the conclusion of the Nuclear Regulatory Commission licensing proceedings for Yucca Mountain, there will be some risk that TAD systems developed in accordance with the Department's performance specifications may not ultimately prove disposable, but no more than any other existing canistered waste form. We believe that by developing robust performance requirements, this risk can be managed. It is the Department's intent to ensure that any risk with respect to the ultimate disposability of the TAD canister be appropriately considered and managed as we refine our acceptance process and criteria.

*Compatibility of Transport, Aging, and Disposal Canister with Standard Disposal Contract*

The Department understands that the utilization of TAD-based systems for the acceptance of spent nuclear fuel may require modifications to the disposal contracts that the Department has with the utilities. The Department believes that it will be able to address these issues with the majority of utilities, and that the goal of receiving 90 percent of the first 63,000 metric tons of spent nuclear fuel at Yucca Mountain in TADs is reasonable. We will design the surface facilities with enough flexibility and redundancy such that a variance from the 90 percent target can be accommodated.

*Transport, Aging, and Disposal Canister Performance Specification Relationship to Postclosure Thermal Management Strategy*

The Department understands that the Board is interested in how the TAD canister performance specification relates to the Department's postclosure thermal management strategy. The performance specification is being developed taking into account all the system requirements from waste acceptance to final disposal. Accordingly, it has been our intent to incorporate requirements that, while ensuring that the thermal performance of the TAD canister system would be consistent with the Department's current postclosure thermal-management approach, would provide sufficient flexibility to accommodate alternative postclosure thermal management strategies. If, as a result of further analyses, the current postclosure thermal management approach is altered, we believe that such changes can be accommodated by altering the manner in which the TAD canister system is operated (i.e., by decreased surface aging), rather than by requiring changes to the TAD canister design.

*Rail Line Contingency Planning*

In a Record of Decision published in April 2004, the Department selected "mostly rail" as the mode of transport both nationally, and in the State of Nevada. The "mostly rail" option includes an expectation that some truck shipments will be made. In a Supplement Analysis to the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F), the Department considered the potential environmental impacts of shipping legal-weight truck casks on railcars. This scenario involved shipments from generator sites to an intermodal transfer station that would be constructed and operated in Nevada and the subsequent transportation of those casks to a repository at the Yucca Mountain site by legal-weight trucks. In the event that the rail line is not completed when the repository begins operations, these truck transportation options would still be available for initial shipments to Yucca Mountain and will have been fully planned and ready for completion by that time. A full range of transportation contingencies are also being considered for shipment of TAD canisters in the event that the Nevada rail line is not available when the repository begins operations. However, we are planning the project to ensure that the rail line will be available at least one year before the repository begins operation.

*Impact of Spent Fuel Litigation on Transport, Aging, and Disposal Canister Development*

The Department disagrees with the Board's representation that the existing litigation between the Government and the nuclear utilities over the delay in beginning the acceptance of spent nuclear fuel in 1998 is a significant impediment to the technical resolution of key issues regarding TAD canisters and the overall spent fuel management system leading to disposal. While the Department continues to encourage and support the resolution of the existing lawsuits through negotiated settlements, only the utilities can determine how they choose to resolve these disputes. Nonetheless, the Department believes that, although they may be complicated by the ongoing litigation, meaningful technical discussions can and do take place. This was demonstrated by recent technical interactions with the industry on the development of the TAD system performance requirements. We will continue to pursue a collaborative design approach with the private sector.

*Total System Model Analyses*

The Department appreciates the Board's support for the Total System Model (TSM) as a tool to understand waste management system performance. The Department plans to continue the integrated systems engineering and analyses approach to gain a greater understanding of the interrelationships between the subsystem components: waste acceptance, transportation, and repository operations. These continuing analyses are expected to provide additional insights as design details are further refined and operational scenarios are more fully defined, but will be sequenced to occur as details and scenarios are deemed ripe for consideration to ensure that realistic representations of the waste management system are analyzed.

As the Board is aware, the Department directed Bechtel SAIC Company, LLC, in October 2005 to update the repository surface facility design and operating concepts for the Yucca Mountain Project to adopt a primarily canister-based approach utilizing the TAD system. In compliance with the Departmental directives for this undertaking, a revised critical decision-1 (CD-1) package was prepared for submittal to the Department's Energy Systems Acquisition Advisory Board (ESAAB) to document and obtain approval for the revised approach. The thorough internal Departmental review and the approval process have been completed.

The CD-1 package contains a suite of documents describing the revised Project technical approach, cost, and schedule, along with documents for impact analysis. Now that approval of the CD-1 package by the ESAAB has been obtained, the baseline or "base (reference) case" analyses, including Total System Model results, will be updated to further analyze design scenarios, and specific details such as fuel blending and aging pad sizing.

The Department plans to continue a stepwise approach using the TSM tool to evaluate interrelationships and system responses with the transportation program. Throughout the TSM design evolution, the Department has briefed the Board on the inherent TSM capabilities to study upset conditions. The TSM design objectives are to ensure this flexibility is available by using an object oriented design approach and commercial off-the- shelf software to build the TSM. As the transportation program further refines its planning bases, logistics, and operational scenario, the Department will use TSM analyses with the same systems analysis approach to gain an understanding of the TAD-based system. Those future TSM studies of transportation scenarios will abstract data from transportation subsystem models when those model results are mature enough to establish realistic scenarios that merit evaluation.

*Surface Facility Design*

The Department appreciates the Board's interest in the surface facility design. Now that we have formal approval from the Department to implement the canister-based approach, we will commence preliminary design, and develop the design and safety analysis needed to support a License Application. We will also provide presentations to the Board describing in detail the design concept for the canister-based approach, including facility functions, layouts, and other items discussed in the Board's letter, as well as the results of the preliminary safety analyses.

The Board's expectation that the TSM is being used to validate the conceptual design is part of our ongoing work in this area. While not complete, the validation of the design concepts using the TSM is occurring at this time. As the design moves through the preliminary design process, the TSM will continue to be used to ensure that the design will meet the Department's requirements.

*New Organization*

The Department understands the Board's concerns with the Office of Civilian Radioactive Waste Management's (OCRWM) new organization and, in particular, the lack of a specific office with the responsibility for Project integration. As was discussed at the Board meeting, while the individual office directors are responsible for coordinating between offices, the Director, OCRWM, retains the ultimate responsibility to ensure overall Project integration. Upon my confirmation as Director, I began an assessment of the OCRWM structure, processes and competencies. The Board will be informed of the results of my assessment at a future meeting.

*Relationship of Global Nuclear Energy Partnership and Yucca Mountain*

The Department's Global Nuclear Energy Partnership (GNEP) is a closely coordinated long-term effort between multiple Program offices and national laboratories. One element of GNEP seeks to realize technologies that could enhance various aspects of the waste management system. There is no near-term impact of GNEP on Yucca Mountain. This is because there is no definition of the ultimate waste form and waste package that will result from the GNEP process. This information will not be developed until some time in the future. When it eventually becomes available, the resultant waste package will be qualified for disposal in Yucca Mountain; and an application for a license amendment will be submitted to allow disposal in the repository. The Department remains fully focused and will continue forward with the technical and scientific efforts to license and operate a geological repository at Yucca Mountain to address the spent fuel management of the current generation of nuclear reactors.

UNITED STATES

NUCLEAR WASTE TECHNICAL REVIEW
BOARD

2300 Clarendon Boulevard, Suite 1300

Arlington, VA 22201

December 14, 2006

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

Thank you very much for attending the U.S. Nuclear Waste Technical Review Board meeting in Amargosa Valley, Nevada, on September 27, 2006, at which the Office of Civilian Radioactive Waste Management (OCRWM) presented its safety case for a high-level radioactive waste and spent nuclear fuel repository at Yucca Mountain. Your update on the OCRWM milestones and objectives related to submitting an application to the Nuclear Regulatory Commission for construction of the repository was very informative, as were your comments on what will be needed to begin repository operation in 2017. The Board also appreciated your participation throughout the meeting and hopes that you found the technical exchanges useful.

The Board believes that the information presented by OCRWM at the meeting may indicate an evolving understanding of the importance of a safety case in building confidence in the Department of Energy's estimates of repository performance. However, the presentations also made clear that work remains to be done in developing key elements of a comprehensive safety case. To be credible and effective in supporting the safety case, each element requires conceptual clarity and strong programmatic commitment. Preclosure operations can have significant implications for postclosure performance; therefore, the integration of preclosure activities with postclosure issues, such as repository design and thermal management, requires careful consideration. Some observations on OCRWM's safety case follow.

**Key Elements of the Safety Case**

An effective safety case should include a total system performance assessment (TSPA) supplemented by additional lines of evidence and argument, including performance-margin analyses, natural analogs, and a well-thought-out performance-confirmation plan.

- TSPA provides quantitative estimates of repository performance that are the core of the safety case. It is the primary tool for analyzing coupled interactions among multiple barriers that affect radionuclide transport, including the engineered barrier system, the unsaturated

bjg058vFzone, and the saturated zone. To increase confidence in repository performance estimates, TSPA should include consideration of all credible and consequential phenomena that significantly affect dose over the period of regulatory compliance. Given the importance of TSPA, the Board is especially interested in the results of new repository system performance assessments and how they affect the repository safety case.

- Assessing the realism of TSPA performance estimates can be challenging because some assumptions may be very conservative while others may be nonconservative. The performance-margin analyses identified at the meeting can be very valuable in assessing the magnitude and effects of conservative and nonconservative aspects of TSPA.
- Natural analogs of many relevant repository phenomena can be used to challenge and evaluate conceptual and numerical models. Analogs that have existed for periods of time commensurate with the regulatory compliance period proposed for the repository provide excellent cases for testing prevailing conceptual and numerical models of radionuclide transport and isolation.
- The purpose of performance confirmation is to critically evaluate analyses and assumptions underlying performance estimates. Thus, the performance-confirmation plan should identify in detail what elements of the performance assessment are to be evaluated, how the elements will be tested or monitored, how information from testing and monitoring will be evaluated, what actions will occur as a result of those evaluations, and how frequently such evaluations will occur.
- Repository design and preclosure operations have significant implications for post-closure repository performance. How decisions related to preclosure operations have been integrated into the postclosure safety case is unclear.

**Science and Technology**

Over the course of repository licensing, construction, and operation, there will be important opportunities for continuous learning and improvement in scientific and technical areas. For example, as pointed out by your staff, prediction of coupled thermal, hydrological, mechanical, and chemical processes poses significant scientific and technical challenges. Together, these phenomena are the environmental controls on waste package and waste form degradation. Thus, they are significant for radionuclide isolation and migration and for dose levels. Investigations currently supported by the science and technology program have the potential over the long term to improve fundamental understanding in key areas and consequently to improve understanding of the repository's ability to isolate radionuclides. It is important that support for investigations sponsored by the Science, Technology and Management group is sustained and that formal links are established between these efforts and performance-confirmation planning. At the meeting, contractor staff identified a long-term science program, which also can help further the goal of continuous learning and improvement.

**Engineering Prototyping**

As mentioned at the meeting, the efficacy of engineering designs—including operational processes—can be tested using prototyping. This is especially important in the case of the Yucca Mountain repository because many of the engineered elements are first-of-a-kind designs.

Examples of specific elements that could benefit from engineering prototyping include waste package fabrication, loading, sealing, and emplacement; robotics; and drip-shield emplacement. Experience gained from engineering prototyping will enable OCRWM to identify potentially high-consequence design and operational flaws in an orderly and efficient manner. For example, contemporary industrial experience has shown that metal fabrication defects can be susceptible to localized corrosion. This has important implications for performance of the repository waste packages. Many engineering design specifications are important to TSPA calculations. Consequently, engineering prototyping can serve as an integrating mechanism and a cross-check for TSPA. Finally, engineering prototyping can be helpful as the repository program moves its focus from research and analysis to implementation.

Thank you again for participating in the Board's meeting on the repository safety case. We look forward to additional interactions with you and your Yucca Mountain Project team on this important topic.

Sincerely,

{Signed by B. John Garrick}

B. John Garrick
Chairman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

January 12, 2007

Mr. Edward F. Sproat III
Director, Office of Civilian Radioactive Waste Management
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

The U. S. Nuclear Waste Technical Review Board's (Board) Panel on the Engineered System conducted a public Workshop on Localized Corrosion of Alloy 22 on September 25-26, 2006, in Las Vegas. Workshop participants included employees and contractors of the Department of Energy, the Nuclear Regulatory Commission, the Center for Nuclear Waste Regulatory Analyses, the Electric Power Research Institute, Nye County, and the State of Nevada. Three Board members, a Board contractor, and I participated in the entire workshop, and three other Board members attended part or all of the workshop.

Following the workshop, Dr. Ronald Latanision and Dr. David Duquette, the two Board members who co-facilitated the workshop, assembled their comments on the issue of screening out deliquescence-induced localized corrosion. Those comments, with which the Board concurs, are attached. As is evident from the attached comments, significant uncertainties in evolution of environments and of corrosion behavior at high temperatures persist, and there are apparent contradictions among some experimental results. Continuing research in deliquescence-induced localized corrosion is clearly warranted.

Unlike deliquescence-induced localized corrosion, which the Project plans to screen out of the total system performance assessment (TSPA), seepage-induced localized corrosion is not screened out of TSPA. Why seepage-induced localized corrosion and deliquescence-induced localized corrosion are not treated consistently in TSPA remains puzzling to us. The important question is, "Does including deliquescence-induced localized corrosion significantly affect the dose received by the reasonably maximally exposed individual?" Even if the effect is not significant, including this phenomenon would add to the completeness, robustness, and credibility of TSPA.

Sincerely,

{Signed By}

B. John Garrick
Chairman

Attachment

bjg060vf

Screening out Deliquescence-Induced Localized Corrosion
Comments Based on Information Conveyed at the Board's
September 25-26, 2006, Workshop on Localized Corrosion of Alloy 22

**Background**

Individuals with a wide range of expertise participated in the workshop to help address the issue of localized corrosion of Alloy 22. Unfortunately, a definitive consensus about whether localized corrosion would occur at waste package crevices did not emerge. The majority of the workshop dealt with the possibility of accumulated dust functioning as a crevice and causing localized corrosion. Considerable data were presented but there was no general agreement on a number of the key issues. Those attending the workshop seemed to have a genuine interest in evaluating the feasibility of the Yucca Mountain waste package design.

As we are all aware, DOE has screened out deliquescence-induced localized corrosion of the waste package's Alloy-22 outer barrier in the repository environment at temperatures to ~200°C. DOE's screening-out approach is based on a decision-tree or events-tree analysis consisting of the following questions [BSC 2005]:

1. Can multiple salt deliquescent brines form at elevated temperatures?
2. If deliquescent brines form at an elevated temperature, will they persist?
3. If deliquescent brines persist, will they be corrosive?
4. If deliquescent brines are potentially corrosive, will they initiate localized corrosion?
5. Once initiated, would localized corrosion penetrate the waste package outer barrier?

According to DOE, if the answer to *any* of these questions is NO, then localized corrosion of the waste package's outer barrier due to deliquescence can be screened out, i.e., excluded from consideration in the total system performance assessment for license application (TSPA-LA).

We agree that DOE's approach is reasonable.

The Board has conducted public meetings on deliquescence-induced localized corrosion twice. The first meeting, which was part of a May 2004 meeting of the Board in Washington, D. C., was on the topic of localized corrosion caused by deliquescence of inorganic divalent chloride compounds, e.g., calcium chloride. On the basis in large part of information conveyed at that meeting, the Board concluded that significant amounts of calcium chloride were unlikely to accumulate on waste package surfaces during the preclosure period and therefore, that significant corrosion during the subsequent thermal pulse due to corrosive calcium-chloride-rich brines formed by the deliquescence of calcium chloride would be unlikely [NWTRB 2004]. In that case, then, the answer to the first question was NO, so there was no need to address the next questions.

The second public meeting was a day-and-a-half corrosion workshop held on September 25-26, 2006, in Las Vegas, Nevada. The workshop focused on deliquescence-based localized corrosion of Alloy 22 at high temperatures. The issue arose because of the determination made by DOE that salt mixtures containing sodium and potassium nitrates and chlorides would deliquesce at atmospheric pressure at temperatures up to and exceeding 200°C, even in the low-relative-humidity environments likely to be present in a repository in Yucca Mountain during the thermal pulse [DOE 2004]. Unlike calcium chloride, these salts are likely to be present in the dusts deposited on waste package surfaces during the preclosure period. The workshop was held because the Board had expressed its opinion, in December 2005, that the technical information available at that time did not seem sufficiently compelling to support screening out deliquescence-based localized corrosion [NWTRB 2005a]. The Board's opinion was based on the lack of corrosion data above 150°C and the questionable relevance of corrosion-stifling data taken at significantly lower temperatures to corrosion at higher temperatures.

**Workshop Observations**

Workshop participants seemed to agree that the answer to the first question was YES. There was less consensus on the other questions, particularly the last two.

DOE's and EPRI's positions are that the answers to the final two questions are NO. Their positions appear to rely on the role of nitrates both in the deliquescence process and in mitigating corrosion, based on the following observations/assumptions:

1. The chemical environment that may exist on the package surfaces is a solution of a multisalt assemblage containing NaCl, $NaNO_3$, $KNO_3$ and $Ca(NO_3)_2$ [Bryan 2006]. These salts are found in small amounts in airborne dusts in the Yucca Mountain vicinity.

2. Any stable chloride-containing brines formed by deliquescence at high temperatures must have significant fractions of nitrates [Rebak 2006].

3. Brines formed by deliquescence at high temperatures may change with time, e.g., by degassing HCl or $HNO_3$ [Bryan 2006; King 2006]. Degassing may result in a decrease in the amount of brine, an increase in pH, and an increase in the nitrate-to-chloride ratio.

4. Only limited amounts of salt and brine are available to initiate corrosion. Calculations indicate that the upper bound of brine volume in the dust deposited on waste package surfaces can be only 1.8 $\mu L/cm^2$, resulting in a brine layer ~18μm thick, assuming no geometric isolation due to inert dust

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particles. (Note that these calculations are for 120°C; volumes should be less at higher temperatures). DOE claims that much of the brine would be held in the dust by capillary forces and that rapid mass transport in the dust would hinder establishing chemical gradients. DOE believes that these effects, coupled with the small volume of aggressive brine, would prevent initiation of localized corrosion [Brown 2006].

5. If corrosion does initiate, progression of corrosion will be stifled because of (a) obedience to a power law corrosion rate for localized corrosion propagation, with the time exponent in the power law being 0.5 or less; (b) physical retention of brine in the corrosion products; and (c) chemical sequestration of brine components in the corrosion products [Brown 2006].

Several possibly conflicting, or at least confusing, data sets and opinions were presented during the corrosion workshop. Among these were the following:

Localized corrosion of Alloy 22 was reported in Na-K-Cl-$NO_3$ brines at 160°C and at 220°C. $NO_3$/Cl ratios of 7.4 and $NO_3$ concentrations as high as 18.5 molal were not sufficient to inhibit localized-corrosion initiation [Rebak 2006].

Alloy 22 general corrosion rates on the order of 1 µm/yr and as high as 10 µm/yr were reported in Na-K-Cl-$NO_3$ brines at 150 – 180°C. However no localized corrosion was observed in these studies [Yang 2006].

Contrary to the apparent implicit assumptions of many workshop attendees that conditions on waste package surfaces during the decline of the thermal pulse evolve slowly and are in thermodynamic equilibrium, corrosion environments may be cyclic because of changes in barometric pressure and differential condensation/evaporation due to temperature-difference-driven gas flows along the drift [Walton 2006].

EPRI presented an analysis that raises questions about whether any nitrate-containing salts would be present in airborne dusts in the vicinity of Yucca Mountain [Arthur 2006; King 2006]. (If no nitrate salts are present, deliquescence would not occur at high temperatures, and the answer to the first question would be NO.)

Although degassing of Na-K-Cl-$NO_3$ brines can be made to occur under certain laboratory conditions, the range of temperatures within which degassing would occur *under conditions that would pertain in a Yucca Mountain repository* is unclear. Rates of degassing are highly uncertain, and it is not known whether HCl or $HNO_3$ preferentially degasses. Degassing was observed in one set of experiments [Yang 2006], but not in another set [Rard 2006].

Initial salt concentrations will not support localized corrosion, because high concentrations of nitrates will effectively displace HCl in crevices [King 2006]. $HNO_3$ is a passivator and will inhibit localized corrosion.

If localized corrosion is initiated, the deepest penetration that will occur will be only on the order of 5 mm after 200 years, assuming diffusive limitation of mass transfer that result in a power-law growth rate with an idealized exponent of 0.5. Experimental results suggest a power-law exponent closer to 0.1, resulting in wall penetration of less than 1 mm in 2,000 years [King 2006].

Apparent stifling of crevice corrosion propagation was reported in 5M NaCl/$2x10^{-4}$M $CuCl_2$ solutions, at 95°C [He 2006].

Stifling of localized corrosion will occur because of cathode current capacity, electrolyte resistance, and incompatibility of anode/cathode coupling [Payer/Kelly 2006].

Crevice corrosion was shown to arrest in 4M NaCl solutions at 100°C [Payer/ Kelly 2006].

**Discussion**

That there are considerable differences of opinion related to the interpretation of experiments conducted to date is obvious. For example, the apparent contradiction in results of localized vs. general corrosion reported by Rebak and Yang was explained by differences in experimental techniques. The experiments presented by Rebak were conducted in autoclaves where acid gases were allowed to reflux, while Yang's experiments were conducted under environmental conditions where gaseous species were allowed to evolve (degas) and were captured in a condenser. The condenser solutions became acidic with time, indicating evolution of acid gases. Few of the experiments that were conducted were performed in environments expected to be found in the repository. For example, the He and Payer/Kelly experiments were conducted in chlorides alone (no nitrates) and at temperatures well below anticipated surface temperatures of the waste packages. Nevertheless, it is possible to address the possibility of screening out localized corrosion during the thermal pulse, based on reasonable interpretations on scientific and engineering results obtained to date, with the *caveat* that experiments and tests currently under way may provide new evidence that will further advance the state of knowledge of the repository environment and its potential effects on the waste packages.

For discussing the possibility of initiating and propagating localized corrosion on waste packages in a repository environment, understanding the current state of the art for the initiation and propagation of localized corrosion in aqueous chloride solutions is important. Passivity on metals and alloys is effected by maintaining an oxidizing potential on the metal or alloy surface. In most engineering situations the oxidizing species is oxygen, dissolved in the aqueous solution from air in contact with the solution. However, in many engineering applications, the oxidizing potential is supplemented by the addition of strong oxidizers, such as nitrates, molybdates, and tungstates. The function of the oxidizing species is to establish a thin, oxygen-rich protective film on the surface and to repair the film if it is chemically or mechanically damaged. When crevices are present on passive metal surfaces, the interior of the crevice becomes depleted in the oxidizer, and the limited diffusion path for admitting more oxidizer establishes a differential oxidation cell. The differential oxidation cell establishes a large surface for reduction of the oxidizer on the passive surface outside of the crevice. The inside of the crevice, depleted of the oxidizer, becomes reducing, resulting in a large cathode (the area outside of the crevice) coupled to a small anode (the area inside of the crevice). Corrosion at the anode accelerates because of the large cathode/anode surface area ratio, which results in the rapid solubilizing of metal ions at the anode.

Initially, the solution in the crevice exhibits approximately the same pH as that outside of the crevice, but metal cations resulting from corrosion in the crevice combine readily with water, and hydrolysis takes place forming hydrated metal hydroxides and hydronium ions, which causes the solution in the crevice to become highly acidic. Thus, a gradient in charge concentration is established between the anode and the cathode. The charge imbalance can be accommodated by the diffusion of negative ions into the crevice. Anions in solution at relatively high concentrations will tend to migrate into the crevice because of conventional concentration gradient considerations. If the anions in the external solution are $Cl^-$, the solution in the crevice will become a concentrated HCl solution. It is well known that HCl is a strongly reducing acid that will dissolve passive films.

In nickel-based alloys, such as the Ni-Cr alloys, there is a further complication that the solutions in the crevice eventually become saturated in metal chlorides. At room temperature, the pH of a saturated $NiCl_2$ solution is 2.7 and that of a saturated $CrCl_3$ solution is -1.4. The crevice-corrosion process then is considered to be autocatalytic in that, while the large cathode-to-small anode couple may be maintained, the solution inside the crevice is sufficiently aggressive that it need not be maintained to support corrosion. The only limiting factor to crevice-corrosion crack growth becomes the continuous supply of $Cl^-$ to maintain the reducing acid inside the crevice. Under laboratory conditions where the crevices are purposefully tightly clamped and times are relatively short, diffusion of chloride into the crevice may be curtailed as the crevice propagates, precipitation of solid corrosion products may occur near the mouth of the crevice where the solution attempts to return to neutrality, and the crevice may effectively be "stifled." In practice, however, the crevice-corrosion propagation rate may slow down until the interior of the crevice can be replenished in chloride, to form HCl and allow the reaction to continue. Crevice corrosion seldom is observed to be stifled under industrial conditions. If it were, crevice corrosion would not be a particular problem for practical applications.

Under repository conditions, where the times will be exceptionally long, it is doubtful that any crevice corrosion that might occur because of chlorides would be stifled because of diffusion considerations. Laboratory studies such as those conducted by He and by Scully [Scully/Bocher 2007][1] do not appropriately model a chloride-induced crevice condition since they are performed with concentrated chloride solutions, often with low pHs. Thus, no appreciable concentration gradients are established.

[1] See page 34 of Joe Payer and Rob Kelly's workshop presentation [Payer/Kelly 2006].

In general, crevice corrosion tests performed in a laboratory are highly useful in determining if crevice corrosion is likely to occur for an environment-alloy couple, assuming that the service environment can be reasonably simulated. Laboratory tests to determine propagation morphology or rates are less useful because of variabilities in crevice geometries, crevice-forming devices, and time constraints. For example, in tests performed specifically for the Yucca Mountain project, just changing the crevice former from a ceramic to PTFE had major consequences in the crevice-corrosion attack observed in simulated repository environments [Payer/Kelly 2006]. Accordingly, the use of laboratory experiments, or exposure tests, to screen out localized corrosion propagation — or even localized corrosion initiation — due to deliquescent salts is highly questionable.

On the other hand, a consideration of the environments likely to be present in the repository suggests that crevice corrosion due to deliquescent salts during the thermal pulse may allow the phenomenon to be screened out under the following circumstances :

1. Concentrated chloride/nitrate brines have been postulated to degas both HCl and $HNO_3$ in the open repository environment, and at least one laboratory test confirmed volatility of some acid species [Yang 2006].[2] Assuming degassing and subsequent volatilization, the questions become (a) the rates of degassing and volatilization and (b) which of the two acids degasses/volatilizes more rapidly. If EPRI is correct in that both acids are highly volatile, the salts in the repository may very well be dominated by sulfates and carbonates, and brines either would not form during the thermal pulse or would be essentially benign. If $HNO_3$ is more volatile, the result would be a concentration of acid chlorides on the waste package surfaces, which would be detrimental. However, if HCl is more volatile, waste package surfaces will become more concentrated in nitrates, and initiation and propagation of localized corrosion due to deliquescence at high temperatures likely would be mitigated.

2. Aqueous nitrates apparently have a higher transfer rate than chlorides [King 2006]. This is an important observation because the charge imbalance in the crevice must be neutralized by the migration of some ion into the crevice. If nitrate exists in concentrations in excess of 1:1, and if it in fact has a higher transference number, the charge neutrality will be achieved by nitrate migration, resulting in a passivating environment in the crevice. Proof of this concept must await an analysis of the crevice chemistry from corrosion tests performed in appropriate environments at appropriate temperatures.

3. It has been postulated that nitrates are effective inhibitors at $[NO_3^-]:[Cl^-]$ ratios as low as 0.5 at temperatures as high as 200°C [King 2006].

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[2] The experiments presented at the workshop by Yang were not at Yucca Mountain conditions. For example, it appeared that the activity of water was higher than would be expected in deliquescent brines. Higher water activity could lead to increased degassing.

4. Individual dust particles may be too small to support crevices, or the dust layer may be permeable to oxygen [King 2006]. Crevices at manufacturing defects and mechanical design features are likely to function very differently than a layer of accumulated dust. At this time, however, no quantitative data have been presented to the Board on the size or shape of the dust particles or on the permeability of dust layers that would deposit on waste-package surfaces.

5. Insufficient liquid water may be present to provide a continuous water film under dust particles, because much of the water will reside in interstices between the dust particles [Bryan 2006].

6. For the environments postulated for the repository, with acid degassing, the evolution of the relative humidity in the repository is such that the package will not be wet until temperatures have declined to the vicinity of 100–120°C — when deliquescence-induced crevice corrosion may be unlikely [King 2006].

**Conclusions**

If any of the conditions cited in 1–6 are met, crevice corrosion due to deliquescence during the thermal pulse period could be screened out. Of each of these six scenarios, preferential charge neutralization by nitrate in the crevice is perhaps the most important, because the nitrate will be an effective inhibitor inside any crevices that are formed, at least for temperatures up to ~160°C.

The Board understands that the chemistry of the crevice environment is currently under study. Demonstrating an adequate technical basis for screening out deliquescence-based localized corrosion during the thermal pulse requires (a) determining the nitrate-to-chloride ratios that are inhibitive for the entire range of temperatures that deliquescent brines may occur on waste package surfaces and (b) confirming the hypothesis that the preferential migration of nitrate ions into the crevice is sufficient to maintain nitrate-to-chloride ratios that are inhibitive.

Although deliquescence can occur at any temperature below about 200ºC, our concern about deliquescence-induced localized corrosion is principally in the higher part of the temperature range, i.e., 150-200ºC. On the other hand, seepage-based corrosion may not occur above approximately 100ºC. Conceivably, deliquescence-based localized corrosion could occur on a waste package and then be followed by seepage-based localized corrosion at the same place on the package later during the thermal decline. Any damage caused by deliquescence-induced localized corrosion could result in earlier penetration by subsequent seepage-based corrosion than would occur in the absence of deliquescence-induced localized corrosion. Cumulative damage due to the combined effects of deliquescence-induced and seepage-based localized corrosion was not discussed at the workshop. However, the topic merits some analysis to determine its possible significance.

As things stand now, seepage-based localized corrosion is included in TSPA and deliquescence-induced localized corrosion is excluded. This always has struck us as incongruous because the processes are the same and particularly because the temperature range of concern about deliquescence-based localized corrosion is higher. We wonder whether the same degree of conservatism that is being applied to "screen out" deliquescence-induced localized corrosion is being applied to "screen in" seepage-based corrosion.

**Additional Observations**

The topic of general corrosion arose during the workshop in conjunction with experiments to obtain information about localized corrosion. Localized corrosion was observed in the LLNL autoclave experiments [Rebak 2006], so general corrosion would be expected to occur, also. However, no useful data on general corrosion could be obtained from those experiments. In contrast, localized corrosion seemed not to occur in CNWRA experimental results obtained under somewhat similar conditions [Yang 2006], but general corrosion was observed. The rates of general corrosion rates derived from that data were unexpectedly high and showed a maximum with respect to temperature, which also is unexpected. These anomalies require explanation. In any case, particularly since the proposed regulations for Yucca Mountain [70FR173, pp 53313-53320] require general corrosion to be modeled in TSPA, deliquescence-based general corrosion should be included in such modeling.

Mill-annealed and welded specimens prepared for the experiments discussed at the workshop generally were polished to a uniform surface finish before being placed in the experimental apparatus. The polishing step is useful for helping compare results within a laboratory or among laboratories. However, the actual waste packages emplaced in a repository will have been treated to remove the scale caused by heat treating by, e.g., blasting with abrasive particles or electropolishing, and will have scratches, dents, etc. from handling. Although some experimental investigation of the effects of surface condition on Alloy 22 corrosion has been undertaken, we are not sure that the effects have been investigated adequately. The discussion of the effect of surface condition on corrosion in the Alloy 22 corrosion AMR [BSC 2004], for example, is brief and is limited to the effect of surface condition on crevice corrosion.

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## REFERENCES

[70FR173 pp53313-53320]. Federal Register (Volume 70, Number 173). September 8, 2005. Proposed rule. Nuclear Regulatory Commission. Implementation of a Dose Standard After 10,000 Years.

[Arthur 2006]. EPRI-sponsored studies on the evolution of environments at Yucca Mountain. Randy Arthur. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 25, 2006

[Brown 2006]. Development and Implementation of the Localized Corrosion Model. Neil R. Brown. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[Bryan 2006]. Evolution of Waste Package Environments. Charles R. Bryan. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 25, 2006

[BSC 2004]. *General Corrosion and Localized Corrosion of Waste Package Outer Barrier*. Bechtel SAIC Company LLC. ANL-EBS-MD-000003 REV 02. October 2004

[BSC 2005]. *Analysis of Dust Deliquescence for FEP Screening*. Bechtel SAIC Company, LLC. ANL-EBS-MD-000074 REV 01. August 2005

[DOE 2004]. Letter dated January 26, 2005, from Margaret S. Y. Chu, Director of OCRWM, to B. John Garrick, Chairman, NWTRB

[He 2006]. Localized Corrosion Initiation and Propagation Tests. Xihua He. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[King 2006]. EPRI's Analysis of the Potential for Localized Corrosion of Alloy 22 Waste Packages in Multi-salt Deliquescent Brines. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[NWTRB 2004]. Letter dated July 24, 2004, from David J. Duquette, Chair of the NWTRB Executive Committee, to Margaret S. Y. Chu, Director of OCRWM

[Payer/Kelly 2006]. Localized Corrosion Data and Analyses from the Materials Performance Thrust of the OCRWM Science and Technology Program. Joe H. Payer and Robert G. Kelly. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[Rard 2006]. Boiling Temperature and Reversed Deliquescence Relative Humidity Measurements for Mineral Assemblages in the $NaCl + NaNO_3 + KNO_3 + Ca(NO_3)_2 + H_2O$ System. Joseph A. Rard, Kirk J. Staggs, S. Dan Day, and Susan A. Carroll. In *Journal of Solution Chemistry* 35:1187-1215. August 2006

[Rebak 2006]. Newer Alloy 22 Data and Their Relevance to High-Temperature Localized Corrosion. Raul B. Rebak. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[Scully/Bocher 2007]. __________________. John R. Scully and Florent Bocher. Submitted for publication in Electrochemical Society Transactions. May 2007

[Walton 2006]. Effect of cyclic, sporadic, or episodic processes on evolution of environments in a repository in Yucca Mountain. John Walton. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

[Yang 2006]. Corrosion of Alloy 22 in Salt Environments at Elevated Temperatures. Lietai Yang. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006

**Department of Energy**
Washington, DC 20585

QA: N/A

November 20, 2007

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

In a letter dated January 12, 2007, the Nuclear Waste Technical Review Board (Board) provided a summary of its observations regarding the Workshop on Localized Corrosion of Alloy 22, held on September 25-26, 2006. The breadth of opinions and supporting data shared at the workshop and in the Board's letter are instrumental in assuring a thorough assessment of the likelihood of localized corrosion under deliquescent conditions. A follow-on letter regarding the effects of organic materials on nitrate/chloride ratios was transmitted on July 10, 2007.

The enclosure to this letter provides discussion of five key areas identified by the Board, in its January letter, as issues associated with the treatment of localized corrosion under deliquescent conditions, and the issue of effects of organic materials as described in the July letter.

We look forward to continuing this dialogue with future technical exchanges. If you have any questions concerning this letter, please contact Claudia M. Newbury at (702) 794-1361.

Sincerely,

Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Printed with soy ink on recycled paper

Enclosure

## U.S. DEPARTMENT OF ENERGY RESPONSE TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD'S COMMENTS FROM THE SEPTEMBER 25-26, 2006 WORKSHOP

The following five topical discussions refer to comments received from the Nuclear Waste Technical Review Board (Board) on January 12, 2007:

(1) why seepage-induced localized corrosion and deliquescence-induced localized corrosion are treated differently,
(2) the U.S. Department of Energy (Department) perspectives on the study of the six circumstances identified by the Board for screening localized corrosion due to deliquescence,
(3) the impact of cumulative damage of deliquescence-induced and seepage-based localized corrosion,
(4) inclusion of deliquescence-based general corrosion in the modeling, and
(5) experimental investigation of the effects of surface condition on Alloy 22 corrosion.

The last topic of discussion, the effect of organics on nitrate to chloride ratios, is in response to additional comments received on July 10, 2007.

**Why Localized Corrosion is Treated Differently under Seepage and Deliquescent Conditions**

The Board points out that different approaches are used to address the potential for corrosion under seepage and deliquescent conditions. The Department concurs with this observation, but has determined that two separate analyses are warranted - and needed - due to the underlying differences presented by these two types of environments. These differences can be categorized as (1) differences in physical environment and (2) differences in the composition of the electrolyte and differences in uncertainty of the composition of the electrolyte.

Although the probability of seepage contacting a waste package is low during the period when the waste packages are still at elevated temperature, if dripping water does contact the waste package, the local environment may have characteristics of an inundated system. In such a case, a local corrosion site will be able to draw cathodic current from the surrounding material defined by the wetted area and conductivity of the electrolyte. Additionally, if dripping continues in the same location, a continuous supply of chloride and other ions is available to participate in electrochemical reactions. In the case of a deliquescent environment, the volume of electrolyte is predicted to be very small, thus communication between a corrosion site and the surrounding material will be severely limited in comparison to the seepage condition. The more critical difference, however, is the limited amount of reactants available in the deliquescent case. The makeup and quantity of solid components of the dust layer are nominally determined by the duration of the ventilation period and the composition of the repository air during this time. Once the waste package reaches a temperature-relative humidity condition where deliquescence is possible, the total available quantity of reactants (mass per unit area) is fixed and does not increase. Any corrosion process that results in consumption of aggressive species will be limited by the initial quantity of reactants and brine volume. The deliquescent environment differs from the seepage environment as limitations on reactants are not as well defined in the seepage case. Consequently, the corrosion model under seepage conditions does not take credit for this damage-limiting mechanism.

A significant difference also exists in the range of possible compositions for seepage environments compared to deliquescent environments. The seepage environment can contain a wide range of dissolved salts; and the final composition will be determined by the initial seepage waters, the effect of salt separation, and the degassing behavior of the system. A high degree of uncertainty dominates the prediction of any particular environment for a specific time and location in the repository. The Department's analysis of the deliquescent environment concludes that this environment is comprised of $NaCl + KCl + NaNO_3 + KNO_3$ (Bryan 2006). The composition of deliquescent environments is bounded because for each temperature-humidity condition there is a minimum $NO_3$:Cl ratio required for deliquescence (Rebak 2006). Any liquid with a lower $NO_3$:Cl ratio will evaporate and concentrate to maintain the minimum ratio. In the case of salt degassing, either the Cl salts degas more rapidly resulting in a higher $NO_3$:Cl ratio or the $NO_3$ salts degas more rapidly resulting in evaporation and concentration. The implication is that the environments associated with deliquescent salt mixtures are constrained while those associated with seepage are much more uncertain. This difference in level of uncertainty justifies treating the two environmental conditions with different corrosion modeling approaches.

**Study of Six Circumstances for Screening Localized Corrosion Due to Deliquescence**

The Department appreciates the Board's suggestions for potential areas of discovery and analysis that can improve the confidence in the decision to screen out localized corrosion under deliquescent conditions. The Department recognizes that there are a number of approaches to reaching this goal and that an open discussion of the available alternatives will aid in building consensus within the scientific community. Although the Department may or may not pursue a particular line of investigation, the discussion of these strategies helps to identify and clarify the important issues.

**1. Degassing of HCl and $HNO_3$** - The Board suggested two possible paths for the evolution of the deliquescent brine environment based on the relative rates of acid degassing. If HCl can be shown to degas more rapidly than $HNO_3$ then the brine composition will evolve to a high-pH, nitrate rich composition, and localized corrosion will be mitigated. The Board postulates that if $HNO_3$ degasses more rapidly then the resulting environment will contain a high concentration of acid chlorides, an aggressive condition.

The EQ3/6 calculations in the dust deliquescence feature, event, or process (FEP) screening report (BSC 2006) suggest that HCl degasses more readily than $HNO_3$. These calculations are based on thermodynamic data in the Yucca Mountain Project Pitzer database, from Barin and Platzki (Barin 1995), a widely used compilation of thermodynamic data. An examination of the log(K)-temperature grids shows that HCl is predicted to degas more readily than $HNO_3$ over the entire temperature range from 25°C-300°C. Experimental results have been observed that both agree and disagree with this analysis. The formation constants of HCl(g) and $HNO_3$(g) were measured at Oak Ridge National Laboratory (ORNL) with the results agreeing with the analysis in the dust deliquescence FEP screening report (BSC 2006). This work yielded a relative ranking of volatility (decreasing) (Cole 2006):

$$HF >> HCL > HNO_3 >> H_2SO_4$$

However, other work at ORNL, which was conducted under the Office of Science and Technology and International Program, indicated that $HNO_3$ degassed more rapidly than HCl. This result was based on monitoring the gas composition that formed from heating a 0.4-mol/kg ionic strength solution of approximately equimolal nitrate, chloride, and sulfate.

Regardless of whether HCl or $HNO_3$ degasses more rapidly, the effect of degassing will be a beneficial rise in pH resulting in less corrosive brines. Additionally, it has been shown (Rebak 2006) that deliquescent brines have a minimum $NO_3$ to Cl ratio that is temperature-dependent. Brines that would have a more aggressive composition will evaporate and concentrate, leaving smaller volumes of brine that maintain the minimum $NO_3$ to Cl ratio. In the limiting case of complete loss of $HNO_3$ or HCl, the remaining brine is likely to dry out, leading to an environment on the waste package surface that cannot support electrochemical reactions.

While the Department agrees with the Board that an increased understanding of the absolute and relative degassing rates of HCl and $HNO_3$ would aid in improving confidence in screening out localized corrosion due to dust deliquescence, the current understanding is adequate for the analysis.

**2. Transference Rate of Nitrate and Chloride -** The Board references the Electric Power Research Institute (EPRI) presentation (King 2006) with respect to the relative transference rates within a brine of nitrates compared to chlorides. The postulate is that a higher transference rate for nitrate will result in an increase in nitrate to chloride ratio in a crevice. Such a process would result in maintenance of a passive environment. If it can be conclusively demonstrated, such a process could add confidence to the screening justification. However, the Department is not in possession of data that unequivocally support this mechanism. The mobility of $Cl^-$ is slightly higher than that of $NO_3^-$ at room temperature in dilute solutions, but they are close enough to be considered equivalent for a qualitative discussion. Taking the mobilities as equal, the transference numbers will be a function of the concentrations in solution. If the nitrate to chloride ratio is high in solution, it follows that the charge carried will be greater for nitrate than chloride and a high ratio will be maintained in the crevice chemistry. However, no data were presented at the September 2006 workshop that allows quantification of mobilities in concentrated, high temperature brines. In the absence of these data, the prediction of relative concentrations of species in the crevice remains speculative. For this reason, the Department does not rely on a relative transference number justification for supporting the decision to screen out localized corrosion due to dust deliquescence.

**3. Inhibition by Nitrates at Elevated Temperature -** The presentation from EPRI (King 2006) includes a plot of critical temperature versus nitrate to chloride ratio which shows the critical temperature to be in excess of 200°C for a nitrate to chloride ratio of 0.5. The Department's data from cyclic polarization experiments (Rebak 2006) show a beneficial effect from $NO_3^-$ at temperatures up to 150°C. The Department concurs that validating the beneficial impact of $NO_3^-$ at elevated temperatures could strengthen the screening justification.

**4. Properties of the Dust Layer that Impede the Formation of Localized Corrosion Cells -** The Board makes an important distinction that crevices due to dust accumulation will differ significantly from those from manufacturing defects or design features. The size of dust particles that will be transported into the drifts is analyzed in the dust deliquescence FEP screening report (BSC 2006), and the case is made that annular droplets of brine beneath such small particles cannot support the diffusive chemical gradients necessary to initiate or sustain localized corrosion. The porosity of the dust is very high (50% or higher), which is an indicator that the permeability will be very high as well. There is insufficient salt in the dust for deliquescent brines to cause saturation so the dust environment is unsaturated and the gas phase should exchange readily.

**5. Insufficient Liquid Water to Form a Continuous Water Film Under the Dust Particles –** The Department concurs with the Board's assessment that it is likely there will be insufficient water to form a continuous water film under the dust particles. As was noted in the September 2006 workshop, the Department conservatively estimates the quantity of deliquescent brine at 120°C and applies this volume to higher temperatures where the quantity will be even less than the bounding estimate of an 1.8 $\mu L/cm^2$ (an 18 μm thick layer). Furthermore, much of this solution will be bound within the dust layer itself and within the resulting corrosion products (if any).

**6. Limited Temperature Range for Deliquescent Environments Due to Acid Degassing –** The Department concurs with the Board's assessment that should degassing result in dry-out of brines at higher temperature; deliquescence leading to localized corrosion would only be an operative mechanism at lower temperatures. However, the data presented at the September 2006 workshop and discussed in this letter do not provide conclusive evidence that the rates or extent of brine degassing is known for the environments relevant to the repository. Should conclusive data become accessible, the Department will use this information to strengthen the justification for screening out localized corrosion under deliquescent conditions.

**Impact of Cumulative Damage of Deliquescence-Induced and Seepage-Based Localized Corrosion**

The Board raises the issue of the impact of coupling corrosion under deliquescent conditions with corrosion under seepage conditions. This is an important issue to consider irrespective of the result of the analysis. The three main concerns are (1) the possibility that deliquescence-induced corrosion lowers the barrier for localized corrosion under seepage conditions, (2) that a residual chemical effect results from the deliquescent environment, and (3) that the barrier capability for corrosion resistance has been reduced resulting in overestimation for the time until penetration under seepage conditions. The Department's position is that none of these concerns will impact the performance of the engineered barrier for the following reasons:

The most probable mechanism for corrosion under deliquescent conditions to lower the barrier for initiation of localized corrosion is by forming a repassivated oxide that has less resistant properties than the native oxide. However, although a repassivated oxide might be less resistant than an air-formed oxide, the model for localized corrosion initiation used in the Total System Performance Assessment (TSPA) is not linked to the oxide properties or to oxide breakdown. The parameter used for prediction of localized corrosion under seepage conditions is the crevice repassivation potential -- a parameter which is evaluated under experimental conditions (active crevice) where there is no metal oxide present.

The environment on the surface of the waste package in the post-deliquescent period will be determined by the composition of the seepage water that contacts the package. The mass per unit area of salt available from dust decorating the package surface is insignificant in comparison to the quantity of salts in the seepage waters. As the corrosion models assume an excess of available aqueous environment (data for the model are collected under fully immersed conditions), any increase in reactants available from the dust layer will be insignificant compared to the experimental conditions used.

In order to determine how degradation under deliquescent conditions contributes to decrease in barrier capability it is necessary to review how failure occurs for both localized corrosion and general corrosion in the modeling. In the case of localized corrosion, the TSPA assumes that after initiation, localized corrosion continues at an extremely rapid rate until failure of the waste package occurs. Thus, any additional change in the thickness of the material, due to generalized corrosion, will have an unnoticeable impact on when a package fails. Additionally, the available quantity of reactants is extremely limited such that the extent of any localized corrosion damage during the deliquescence period would be very small in magnitude compared to the dimensions of the barrier.

**Inclusion of Deliquescence-Based General Corrosion in the Modeling**

The Board makes the observation that general corrosion processes may be relevant under conditions of dust deliquescence. The same reasoning for limiting localized corrosion can be used to propose limits on the total extent of general corrosion possible under dust deliquescence environments. In the absence of a source of reactants, the corrosion processes (localized and uniform) will be bounded by the initial surface concentration of contaminants. Although by this reasoning, uniform corrosion will not significantly degrade the waste package under deliquescent conditions, the model for general corrosion is invoked during the entire repository lifetime.

The only data presented at the September 2006 workshop that suggests high corrosion rates are those from the Center for Nuclear Waste Regulatory Analyses (CNWRA) (Yang 2006). The Department does not have confidence that those experiments accurately reflect the environment expected in the repository during the thermal pulse. The difference in quantity of available reactants – extremely low in the case of the dust layer vs. essentially infinite in the case of the CNWRA test – calls into question the applicability of CNWRA's results in predicting degradation under deliquescent conditions.

The Department's model for general corrosion accumulates damage throughout the repository lifetime based on the general corrosion model which is applied for all repository conditions, including the thermal pulse where the maximum modeled corrosion rate at 200°C is on the order of 10 μm/year. In order for the barrier capacity to be reduced by deliquescence-induced corrosion beyond the extent already captured in the TSPA, the uniform corrosion rate under deliquescent conditions would need to be higher than that predicted from inundated experiments. As the quantity of reactants is severely limited under deliquescent conditions and essentially infinite under inundated experimental conditions, the Department maintains that the current model implementation adequately accounts for this damage process.

**Investigation of the Effects of Surface Condition on Alloy 22 Corrosion**

With regards to surface condition, the Department considers its current models to be conservative and appropriate. Most of the samples used for model development include welds, while only a small portion of the waste package is welded. Furthermore, by using the Alloy 22 crevice data for weight loss, the model overestimates the expected corrosion rates because these samples were not polished on the backside resulting in an overestimate of the corrosion rates as compared to samples that were polished on both sides. However, the Department agrees that the effects of surface condition should be further studied and plans are under development for future testing of surface condition effects.

**Effect of Organics on Nitrate To Chloride Ratios**

Dust samples from the Drift Scale Test (DST) heated drift have been analyzed by the U.S. Geological Survey (USGS) both for bulk dust compositions and for leachate compositions for soluble components. These compositions show some differences from the dust samples collected within the Exploratory Studies Facility (ESF) outside of the DST heated drift. The DST dust sample leachate compositions show higher chloride to nitrate ratios than the ESF samples (and than samples of ambient surface dust). The DST dust appears to have accumulated in an environment heavily influenced by the local materials and relatively isolated from ambient dust, which is introduced into the ESF via active ventilation. There are a number of possible sources of chloride in the materials, for example, the concrete liner cement, but no currently identified sources of nitrate. Both the DST bulk dust compositions and the leachate compositions show variations related directly to whether they were in the concrete lined section or not. Given this, and the discussion below, it does not appear that the DST dusts ever had higher nitrate content than measured currently, and it does not appear that the thermal evolution caused a change to that content.

It does not appear at this time that the observed variation in chloride/nitrate ratio for these DST dusts was due to evolution of the salts during heating. Rather the variation is more likely due to the relatively isolated nature of the heated drift from the ventilation system for the ESF. That is, there does not appear to be a large, if any, contribution of the outside natural ambient dust within the DST dust samples. What is clear, as indicated in the Marshall and Peterman (2007 USGS) Goldschmidt meeting abstract, is that the DST dust samples contain constituents derived from the concrete liner (occupying the last 10 meters of the heated drift), as well as from the steels within the heated drift. Preliminary evaluation of the DST liner concrete (and the cement in it) indicates that the DST dust compositions lie on a mixing trend between the rocks of the Topopah Spring Welded hydrogeologic unit, the ESF tunnel dust, and the concrete liner. The DST dust contains a larger fraction, based on calcium and silica content, of cement/concrete compared to the ESF dust. Even within the DST dust, the variation in the concrete liner contributions can be seen by comparing the bulk composition of the dust sample in the unlined section and the composition of the two samples that were within the concrete lined section. Although this does not directly account for the chloride and nitrate contents in the soluble fractions of the DST dust, it does establish that this environment was sufficiently isolated from the ESF itself to develop a locally derived composition. This is not surprising given that the ESF tunnel dust itself shows location dependent compositional variation.

A number of other specific materials may have contributed to the chloride, bromide, and fluoride contents that appear to be enriched in the soluble fraction of the DST dust relative to the mean ESF dust leachate composition. These include (a) the LiBr traced construction water used in the excavation of the heated drift and emplacement of ground support and (b) volatiles released from packer/gasket materials in the rock close to wing heater boreholes that achieved higher temperatures than the drift heaters. Given the additional materials in the DST, it is not a direct representation of the expected material environment within the emplacement drifts at post-closure. Because much of the nitrate within the dust expected to be in the post-closure emplacement environment would come from atmospheric dust pulled into the active ventilation stream and deposited on the waste packages over the 50-year ventilation period, the starting dust composition is expected to be different from that collected in the DST.

The Department appreciates the thought that has gone into the Board's suggestions for potential areas of discovery and analysis that can improve the confidence in the decision to screen out localized corrosion under deliquescent conditions. The Department recognizes that there are a number of approaches to reaching this goal and that an open discussion of the available alternatives will aid in building consensus within the scientific community. Although the Department may or may not pursue a particular line of investigation, the discussion of these strategies helps to identify and clarify the important issues.

**References**


Barin 1995. Thermochemical Data of Pure Substances. (3rd Edition). Barin, I., Platzki, G., Weinheim, Germany; New York, NY: VCH. TIC: 251934.

Bryan 2006. Evolution of Waste Package Environments. Charles R. Bryan. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 25, 2006

BSC 2006. Analysis of Dust Deliquescence for FEP Screening. ANL-EBS-MD-000074 REV 01. Las Vegas, Nevada: Sandia National Laboratories.

Cole 2006. High-Temperature, Multi-Species Solution Properties and Behavior . David R. Cole, Donald A. Palmer, Lawrence N. Anovitz, Mostafa Fayek, Miroslaw S. Gruszkiewicz, Lee R. Riciputi, David J. Wesolowski, George Engelhardt, Digby D. Macdonald. *Office of Science and Technology and International Annual Report 2005*. U. S. Department of Energy, Office of Civilian Radioactive Waste Management. Washington D.C. 2006.

King 2006. EPRI's Analysis of the Potential for Localized Corrosion of Alloy 22 Waste Packages in Multi-salt Deliquescent Brines. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006.

Rebak 2006. Newer Alloy 22 Data and Their Relevance to High-Temperature Localized Corrosion. Raul B. Rebak. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006.

Yang 2006. Corrosion of Alloy 22 in Salt Environments at Elevated Temperatures. Lietai Yang. Presentation at the NWTRB Workshop on Localized Corrosion of Alloy 22 in Yucca Mountain Environments. Las Vegas, Nevada. September 26, 2006.

[Marshall/Peterman 2007]. Dust Chemistry and Accumulation Rate in a Long-Term Full-Scale Heater Test at Yucca Mountain, Nevada, USA. Brian D. Marshall and Zell E. Peterman. Presented at 17th Annual V. M. Goldschmidt Conference, August 20-24, 2007, Cologne, Germany. Journal of Conference Abstracts p. 626.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

February 13, 2007

The Honorable Samuel W. Bodman
Secretary
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary Bodman:

The U.S. Nuclear Waste Technical Review Board held its first public meeting of 2007 on January 24 in Las Vegas, Nevada. At the meeting, senior managers from the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) presented a series of updates on the status of the Yucca Mountain repository program. The Director of OCRWM, Edward Sproat, led the presentations with an overview of his management objectives for the program. An important part of the meeting was a presentation on newly configured surface facilities that take into account the potential implementation of the transportation, aging, and disposal canister concept.

On the basis of information presented at the meeting and the Board's ongoing technical and scientific review, the Board believes that the new OCRWM leadership is moving the technical aspects of the program positively toward achieving DOE's mission of safely disposing of spent nuclear fuel and high-level radioactive waste in a deep geological repository. We are encouraged by the greater responsiveness recently shown by OCRWM management to Board suggestions for ways to enhance the technical basis for DOE's repository performance estimates. The Board sees such enhancements as important in establishing a credible safety analysis and in engendering public confidence in DOE's technical work.

The Board also views sustained support of a viable science and technology (S&T) program as critical to strengthening basic knowledge associated with the safety analyses of repository design and operations. Thus, we are disappointed that DOE's fiscal year 2008 budget request for OCRWM proposes to eliminate funding for the S&T program and postpones activities carried out under the auspices of the program until FY 2009. Although the principal goals of the S&T program are long term in nature, information derived from S&T investigations already has increased confidence in the technical bases for aspects of the license application that OCRWM intends to submit in June 2008. The Board is concerned that large funding variations for the S&T program may make it difficult to attract and retain high-quality scientific and technical investigators.

bjg063vF

The Board urges DOE to continue assigning high priority to work on the repository. We realize that DOE must consider and perhaps accommodate new options for reducing the volume of spent fuel that will require disposal. However, any such option would still require a repository for disposing of nuclear waste. Delays in progress toward achieving the goal of developing a safe repository would be counterproductive, especially now that there are strong indications that OCRWM is working toward resolving outstanding issues in a focused way.

The Board looks forward to continuing its ongoing review of DOE's technical activities related to managing and disposing of spent nuclear fuel and high-level radioactive waste. We are pleased that Mr. Sproat has indicated his willingness to engage with the Board on key issues to ensure that DOE's technical basis for estimating repository performance is sound.

Sincerely,

{Signed by}

B. John Garrick
Chairman

bjg063vF

**The Secretary of Energy**
**Washington, D.C. 20585**

RECEIVED APR 18 2007

April 10, 2007

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, Virginia 22201-3367

Dear Dr. Garrick:

Thank you for your February 13, 2007, letter providing the Nuclear Waste Technical Review Board's views on the Office of Civilian Radioactive Waste Management Program as presented to the Board at its January 24, 2007, meeting in Las Vegas, Nevada.

I am pleased with your assessment that my management team led by Mr. Edward Sproat, Director, Office of Civilian Radioactive Waste Management, is moving the technical aspects of the program in a positive direction and that you are encouraged by the team's responsiveness to suggestions for improvements. Mr. Sproat and the program have my full support in their efforts to complete and submit a license application to the Nuclear Regulatory Commission that satisfies all regulatory requirements by June 30, 2008.

I share your view on the need to continue to maintain progress in the development of a safe repository for disposing of nuclear waste. To that end, I will continue to assign high priority to work in support of funding, licensing, constructing, and beginning operation of the Yucca Mountain repository expeditiously.

If you have any questions concerning the above, please contact Mr. Sproat at (202) 586-6842.

Sincerely,

Samuel W. Bodman

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

April 19, 2007

Mr. Edward F. Sproat III
Director
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

Thank you very much for participating in the U.S. Nuclear Waste Technical Review Board's meeting in Las Vegas, Nevada, on January 24, 2007. The Board appreciates the efforts of Office of Civilian Radioactive Waste Management (OCRWM) senior managers in presenting an overview of the Yucca Mountain Project. The Board believes that the Department of Energy's (DOE) proposed management initiatives — establishing a nuclear culture, initiating effective integration of preclosure and postclosure safety, and integrating the science and engineering programs — will enhance the technical basis of DOE's work at Yucca Mountain.

Your presentation made it clear that the Project's key milestones and issues are tied to the goal of submitting a license application (LA) by June 30, 2008. The Board recognizes your commitment to implementing initiatives that will help meet that objective and supports the Project's long-term emphasis on fostering intellectual continuity from repository licensing to closure. The Board also believes that the appointment of a director for the Office of Quality Assurance is a positive step. We look forward to hearing more about the Project's strategic licensing decisions and how those decisions will influence the repository design.

**Waste Management System**

It is clear from the waste management system (WMS) presentation that considerable progress has been made in designing repository surface facilities. The Board looks forward to continuing its review of the surface facility conceptual design. We are particularly interested in obtaining information on how the design will conform to preclosure safety requirements (i.e., the event sequences that require analysis and the implications for dose from those events).

The Board continues to believe that a "systems" analysis is needed to evaluate the interrelationships among diverse components of the WMS. The Total System Model can play a valuable role in analyzing the operational interdependencies of the WMS and the utility of the transportation, aging, and disposal (TAD) canister. Improvement is needed in developing a well-thought-out and clearly articulated thermal management strategy that forms the basis for integrating waste management activities. It is not clear, for example, how the Initial Handling Facility (IHF), used solely to handle canisterized high level waste and naval spent fuel fits into the Project's thermal-management strategy. In general, the role of the IHF needs to be explained

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more fully. The Board also believes that lessons learned from associated activities can be used to assess the interactions of WMS components. Accordingly, the Board is interested in hearing how experience gained from safety and facility maintenance in the Exploratory Studies Facility could be applied to subsurface repository design and operations.

The Board encourages DOE to evaluate surface-facility designs and operational concepts for opportunities to reduce the number of times waste is handled. For example, DOE should assess the need for and, to the extent practicable, limit the size of large aging pads called for in the current surface facilities design. An issue not covered at the meeting that may affect the number of times that waste is handled is disposal of spent fuel currently stored in dual-purpose canisters (DPC's). The Board urges DOE to evaluate the safety, operational, and economic issues related to opening, unloading, and disposing of empty DPC's in comparison to possible direct disposal of DPC's in Yucca Mountain. DOE's position on the related issues of criticality and burn-up credit should be clarified in the LA as part of an assessment of the feasibility of direct disposal of DPC's. In addition, the Board requests an explanation of the technical basis for the selection of borated stainless steel as a neutron absorber in TAD canisters.

The Board notes with some concern the following: First, while technical interaction between DOE and the nuclear utilities is ongoing, it is not apparent to the Board that this dialogue includes all key issues warranting coordination within a successful waste management system. Second, DOE has assigned postclosure planning responsibility to the Office of the Chief Scientist, while preclosure planning responsibility has been assigned to the Office of the Chief Engineer. The Board has not observed a systematic or comprehensive linking of these two components or recognition by DOE of the interdependencies of important repository design and operating elements (e.g., thermal management). Finally, the Board notes that DOE preclosure safety analysis starts with shipment receipt at the surface facility and does not take into consideration safety factors related to waste transportation or waste acceptance sites. Consequently, DOE waste-management strategies that might reduce risk at surface facilities but increase risk during waste acceptance would be viewed as a reduction of risk rather than a transfer of risk.

The Board is encouraged by the Project's efforts in developing a strategic transportation plan and will follow with interest the evolution of the national and Nevada transportation systems. DOE should monitor the upcoming Department of Homeland Security and Pipeline and Hazardous Materials Safety Administration rulemakings on routing criteria and route risk assessments involving radioactive material shipments by rail. DOE should also monitor the anticipated changes being made by the Federal Motor Carrier Safety Administration concerning security route risk assessments for motor carrier transport of radioactive materials to ensure that DOE's approach is consistent with this legislation and guidance.

**Office of the Chief Scientist**

The Board found interesting the presentation on science investigations supporting the LA and believes that maintaining a core scientific effort is very important. The technical and scientific activities assigned to the Office of the Chief Scientist are numerous but necessary in supporting performance and operational concepts.

New estimates of infiltration of precipitation into the hydrogeologic unsaturated zone are higher than previously estimated. For example, the mean present-day infiltration rate was reported to be 13.4 mm/year—approximately 3 times higher than previously estimated. Because the rate of infiltration is a factor in controlling radionuclide transport and dose, the Board wants to understand thoroughly, the technical basis of DOE's new infiltration estimates. The Board's panel meeting on infiltration on March 14, 2007, in Berkeley, California, provided an excellent forum for addressing and discussing these issues.

The engineering update highlighted the importance of understanding the long-term cumulative effects of seismicity on the geologic environment. The Board realizes that seismic risks are generally of low probability but that such events could diminish waste isolation during the postclosure period, especially if the repository compliance period is extended to 1 million years. Estimates of seismic ground motion during the period of repository operation significantly affect the engineering design of surface facilities. For example, for meeting current preclosure safety requirements, the current surface facility design includes structural walls made of steel-reinforced concrete that are more than 4 feet thick. The Board long has encouraged DOE to develop more-realistic estimates of ground motion for both preclosure and postclosure periods and supports DOE scientific and engineering activities aimed at developing such realistic estimates.

The Project is to be commended for the sustained support of the Probabilistic Volcanic Hazard Assessment Update (PVHA-U). That long-term effort benefits from a rigorous, well-defined, and state-of-the-art methodology and from careful examination of a number of potential buried basaltic volcanic deposits (or "anomalies") that were delineated through a high-resolution aeromagnetic survey. Many of those anomalies have been investigated by drilling into them, and the preliminary conceptual and numerical models have been updated to reflect the results of the investigation. This investigation is proceeding on its own schedule, independent of the LA, but may be completed in 2008. When the PVHA-U becomes available, it will aid in a realistic assessment of the significance of low-probability volcanic hazards at Yucca Mountain.

The Project has continued to evaluate the $^{36}Cl$ problem. The most recent studies have not determined conclusively the origin of sporadic measurements of $^{36}Cl$ in samples collected from within Yucca Mountain. This remains an outstanding issue whose resolution could greatly enhance confidence in understanding fluid flow within Yucca Mountain.

**Science and Technology (S&T) program**

The Board strongly supports scientific activities currently performed under the S&T program. The Board is concerned, however, that budget constraints in fiscal year (FY) 2007 and the elimination of funding for this purpose in OCRWM's budget request for FY 2008 will negatively affect the continuation of these activities that otherwise might support the technical basis of important elements of the LA. Of particular importance is work on the source term, natural barriers, and materials performance. Scientific efforts in other areas also are potentially important. DOE appears to be making progress on waste package corrosion, potential use of cementitious materials in the repository, and understanding how heat and water vapor will move in three dimensions through the mountain for hundreds to thousands of years after the waste is emplaced in the drift tunnels. The Board also is interested in recent results from the backfill thermal conductivity test, which seem to point to a potential means of mitigating both seismic and igneous consequences by using backfill.

In general, in reviewing the information presented at the January meeting, the Board is encouraged by project management initiatives and progress made in addressing technical and scientific issues.

Sincerely,

{Signed By}

B. John Garrick
Chairman

bjg068vF

**Department of Energy**
Washington, DC 20585

QA: N/A

November 6, 2007

RECEIVED NOV 08 2007

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Thank you for your April 19, 2007, letter providing the Nuclear Waste Technical Review Board's (Board) views on the Office of Civilian Radioactive Waste Management (OCRWM) Program, as presented to the Board at its January 24, 2007, meeting in Las Vegas, Nevada. As always, I appreciate the opportunity to interact with the Board.

The Program remains on track to complete the key milestones and meet its strategic objectives, as I outlined in my presentation.

In your letter, the Board raised some additional questions and asked for clarification of some of our plans. The enclosure to this letter provides detailed responses to the Board's inquiries.

If you have any questions concerning this letter, please contact Claudia M. Newbury at (702) 794-1361.

Sincerely,

Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Printed with soy ink on recycled paper

**ENCLOSURE**

**Response to Nuclear Waste Technical Review Board Comments from January 24, 2007, Board Meeting**

1) **The Nuclear Waste Technical Review Board (Board) noted that it was "interested in obtaining information on how the design will conform to preclosure safety requirements (i.e., the event sequences that require analysis and the implications for dose from those events)."** The following discussion provides information on level of design detail and implementation of the Preclosure Safety Analysis (PCSA).

The U.S. Department of Energy (Department) is developing the design for its License Application (LA) to the level of detail necessary to assure the availability of structures, systems and components (SSCs) as modeled in the PCSA. The level of design information will conform to the U.S. Nuclear Regulatory Commission (NRC) staff guidance including HLWRS-ISG-02 PCSA – Level of Information and Reliability Estimation. This approach will include a greater level of design detail for Important to Safety (ITS)/Important to Waste Isolation (ITWI) components than there will be for Non-ITS/Non-ITWI components. For example, Piping and Instrumentation Diagrams, Ventilation and Instrumentation Diagrams, electrical single line diagrams, and logic diagrams for ITS/ITWI SSCs will include sufficient component information to allow modeling for reliability assessment. Another example is that structural design for the Canister Receipt and Closure Facility (CRCF), the Receipt Facility (RF), and Wet Handling Facility (WHF) will include design details such as lumped mass, multi-stick model with soil springs; peak accelerations at mass nodes; typical thicknesses and rebar patterns for shear walls, floor and roof slabs; typical details for penetrations; foundation (basemat) thickness and rebar patterns; assessment of building stability for sliding and overturning effects; and sizing of principal structural steel members. The results of the analyses will be included in the LA submittal scheduled for June 30, 2008. Schematics with sufficient mechanical handling equipment component detail to support reliability assessment of speed control, brakes, travel limits, and the ability to hold load on loss of power will be included. The PCSA will include reliability assessment, including human reliability, for such items as ITS Heating, Ventilation and Air Conditioning (HVAC), ITS electrical power, WHF pool and support systems, and movable shield doors in addition to the mechanical handling equipment. Design calculations and drawings will be sufficient to allow the NRC to verify that the PCSA is adequate.

10 CFR 63.111(c) requires performance of a PCSA of the geologic repository operations area. The PCSA calculations and analyses are developed, reviewed, and approved in accordance with the overall design control and configuration management procedures Coordination and integration between the PCSA analysts and design engineering is accomplished as an integral part of daily routine activities similar to the interface between the separate engineering disciplines within an engineering, project and construction organization.

The PCSA process is iterative and includes analysis of evolving design information, site characteristics, and operational features to evaluate the potential hazards, potential event sequences, and calculate the radiological consequences for operations of the geologic repository operations area. As the design and the PCSA progress, there is continuous feedback from PCSA analysts to designers regarding the safety functions of SSCs and target reliabilities being modeled in the PCSA. PCSA analyses are revised, as necessary, to maintain consistency with repository design. When the LA is submitted, the design and PCSA will be based on the same design information.

Interface activities are coordinated to ensure the design of the repository is consistent with the PCSA. This includes inputs from designers that are necessary to perform the preclosure safety calculations and analyses. The products developed by design engineering (e.g., project design criteria, system description documents, and drawings) and by the PCSA analysts (e.g., radiological hazards analyses and event sequence categorization) are closely coordinated between the respective organizations, and are subjected to procedurally required interface and interdisciplinary review before their issue.

The technical interface requirements between PCSA and design engineering are formally documented in the Preclosure Nuclear Safety Design Bases. This quality-affecting document provides the classification of systems, structures, and components ITS or not important to safety along with the associated safety function based on the results of completed event sequence analysis for each nuclear structure, and for subsurface areas and intra-site operations.

Overview of PCSA Process

In the PCSA required by 10 CFR 63.21(c)(5) and 10 CFR 63.112, an assessment of the safety of the geologic repository operations area is made and the ITS SSCs that are required to ensure that the credited safety functions can meet the performance objectives of 10 CFR 63.111 are identified. The four major portions of the analysis are (1) initiating events identification and event sequence development, (2) event sequence analysis and categorization, (3) radiological consequence, and (4) identification of SSCs ITS and specification of the nuclear safety design bases and procedural safety controls. The nuclear safety design bases for ITS SSCs and the procedural safety controls provide means to (1) prevent or reduce the likelihood of event sequences and (2) mitigate or reduce the consequences of event sequences.

Initiating events are considered only if they are reasonable (i.e., based on the characteristics of the geologic setting and human environment, and consistent with precedents adopted for nuclear facilities with comparable or higher risks to workers and the public (10 CFR 63.102(f)).

Initiating Events Identification and Event Sequence Development

To assess potential external and internal hazards, PCSA evaluates the site and uses descriptions of the repository facilities (surface and subsurface), SSCs, operational process activities, and characteristics of the waste stream to identify applicable hazards that may result in reasonable, credible, initiating events to be considered in further analyses. Examples of the internal hazard categories analyzed include, but are not limited to, collisions, drops, system failures (e.g., HVAC), floods, and fires. Master logic diagrams and process flow diagrams are being used to identify internal hazards and initiating events. Examples of external hazard categories analyzed include, but are not limited to, natural phenomena such as tornadoes and seismic events, and human activity such as aircraft crashes that could impart sufficient energy to be hazardous to a waste form.

Event Sequence Identification and Categorization

Potential event sequences are developed by safety analysis and evaluated based on the identification of credible potential external and internal initiating events. The event sequence analyses process quantifies (determines the overall probability or frequency) the sequences of events that lead to a potential radiological release or criticality. Event sequences are categorized in accordance with definitions of Category 1 and Category 2 event sequences in 10 CFR 63.2. Event sequences that have less than one chance in 10,000 of occurring during the preclosure period are screened out and categorized as beyond Category 2 event sequences.

Radiological Consequence Analyses

Analyses of radiological consequences of potential radionuclide releases and direct exposures from normal operations of repository surface and subsurface facilities, Category 1 event sequences, and Category 2 event sequences are performed as required by 10 CFR 63.111(c). Radiological consequences are calculated for workers and members of the public during normal operations and are added to the radiological consequences from the Category 1 event sequences to demonstrate compliance with 10 CFR 63.111(a) and (b).

For Category 2 event sequences, offsite public radiological consequences are evaluated for each Category 2 event sequence, individually. No worker radiological consequences are required to be calculated for Category 2 event sequences to demonstrate compliance with 10 CFR 63.111(b)(2).

Identification of SSCs ITS and Specification of the Nuclear Safety Design Bases and Procedural Safety Controls

The SSCs that perform safety functions credited in event sequence analyses and radiological consequence analyses are classified as ITS. The credited safety functions are documented in preclosure nuclear safety design bases.

For certain ITS SSCs, the PCSA specifies required reliability values for equipment or operator performance (or both) to ensure that event sequences involving those SSCs are prevented, the likelihood of occurrence is reduced, or the consequences are mitigated. The reliability specified by PCSA analyses is an engineering design requirement that is included in the preclosure nuclear safety design bases.

SSCs credited with preventing or ensuring that an event sequence is beyond a Category 2 event sequence are also identified as ITS with specific safety function design requirements.

**2) The Board stated that improvements should be made in the thermal management strategy that forms the basis for integrating waste management activities and requested clarification of how the Initial Handling Facility (IHF) fits into the Department's thermal-management strategy and the role of the IHF in general.** The following discussion provides additional information on the thermal management strategy and the role of the IHF.

With the change to the primarily canister-based approach relying on the use of Transport, Aging and Disposal (TAD) canisters, the Department plans on receiving up to 90% of the Commercial Spent Nuclear Fuel (CSNF) in TAD canisters loaded by the utilities. The Standard Contract (10 CFR Part 961) requires that the CSNF assemblies be a minimum of five years time out of reactor for classification as Standard Fuel; however, the Standard Contract does not impose any thermal limit on the CSNF to be accepted by Office of Civilian of Civilian Radioactive Waste Management (OCRWM). Selection of the CSNF assemblies to be delivered rests with the utilities.

Further, the Department's draft performance-based specification for the TAD canisters imposes temperature limits for protection of cladding at the utility sites, during transportation, and for the preclosure and postclosure periods at the repository. The performance-based specification imposes heat flux vs. canister-wall temperature limitations for the TAD canister at the time of emplacement. Other than these temperature limits, the thermal limits on CSNF that the Department must accept from the utilities are the NRC-approved individual assembly and total canister thermal limits from 10 CFR Part 71 Certificates of Compliance (CofC) for the TAD-based transportation systems (consisting of a TAD canister and its transportation overpack) that are determined by the TAD vendors.

Accordingly, with no set upper thermal basis and a lack of certainty of the specific thermal power of the TAD canisters, the Department is developing a thermal management strategy. It includes establishing thermal limits for handling of the TAD canisters and includes considerations for the design to allow for flexibility in the handling of the TAD waste stream to achieve thermal emplacement requirements.

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There are several operational approaches, as part of the thermal management strategy, that are being planned for use at the repository. They include:

- Establishing a broad envelope for the emplacement process, that satisfies the TSPA constraints
- Allowing for the aging of TAD canisters to allow decay heat of the TAD canisters to achieve the thermal limits for emplacement
- Using low thermal power naval Spent Nuclear Fuel (SNF) and U.S. Department of Energy (DOE) High-Level Waste (HLW)/ SNF codisposal packages to blend the average thermal power in the emplacement drift to meet emplacement constraints
- Accounting for the decay of waste from its date of actual emplacement and the effects of ventilation during the preclosure period

As part of this strategy, the capability of the surface facilities is considered with respect to:

- Designing facilities that can meet potential thermal limits for receipt and handling of the TAD canister
- Accepting CSNF to meet DOE receipt rates
- Evaluating the capabilities of the facilities for the rates associated with closure of the waste package and subsequent emplacement in the proper thermal arrangement
- Evaluating the size of the aging facilities with respect to various waste streams

Each of the facilities has specific roles in the thermal strategy with respect to receipt of the TAD canisters, performing waste package closure, transporting TAD canisters to the aging facilities, and then returning them for handling and emplacement.

The IHF, in particular, receives and places the naval SNF canister into a waste package with subsequent closure, and has the capability to handle and close waste packages containing HLW, thus reducing the complexity of the Canister Receipt and Closure Facility. Waste packages are then placed into the transport and emplacement vehicle for emplacement in accordance with the thermal limits.

A thermal management study, using the above concepts to establish appropriate thermal emplacement limits, is currently underway to demonstrate the viability of a range of waste streams to meet the receipt and emplacement thermal limits for the repository.

A preliminary evaluation of proposed site operations, with these thermal constraints, has shown that there is considerable flexibility in the thermal limits for the waste packages and the thermal line load. Accordingly, there is considerable flexibility to receive waste streams of varying thermal characteristics while still meeting the preclosure and postclosure temperature and thermal limits used in the repository design and the 100-year preclosure operations period. Similarly, the Aging Facility has been shown to be of adequate size for a range of thermal powers associated with different waste streams. Since the thermal characteristics of the as-received waste stream is uncertain, the Department plans to perform a drift-by-drift analysis of the thermal loading to demonstrate preclosure and postclosure performance based on the as-received waste once the facility begins operations. This is similar to the nuclear industry's approach to conduct a core reload analysis of a reactor following refueling.

One of the results of the adoption of the TAD canister concept for simplifying repository waste handling operations was the segregation of functions to different waste handling facilities. The WHF is designed to receive CSNF and repackage it into TAD canisters. The CRCF are designed to receive disposable canisters (TAD, DOE SNF, and HLW) and transfer them into waste packages. The RF is designed to receive TAD canisters and dual-purpose canisters (DPC) and transfer them to aging overpacks to de-couple CSNF receipt from emplacement. The Initial Handling Facility is designed to receive disposable canisters (naval SNF and HLW) and transfer them into waste packages. The IHF reduces the operating load, complexity, and cost of the CRCF by processing all of the naval SNF. The IHF can process all 400 Naval Spent Nuclear Fuel Canisters in 17 years. The IHF also has the ability to process HLW canisters. There is a 300 ton crane in the IHF that is required to handle the transportation cask in which the naval SNF will be shipped. The CRCF design only requires a 200 ton crane with a lower maximum hook height than the IHF to handle the waste that it will receive, which has resulted in a less expensive and less complex design for the three CRCF. Also, since processing naval SNF in the CRCF would require removal of other waste forms from staging areas to ensure criticality safety, elimination of the naval SNF from the CRCF mitigates the resultant operational delays associated with clearing the CRCF of other waste forms prior to handling naval SNF, allowing increased throughput for the CRCF.

In the IHF, the radiation source terms from naval SNF and high-level radioactive waste are sufficiently low that mitigation is not required to meet site boundary dose limits. All other waste forms to be handled at the repository require mitigation to meet site boundary dose limits. Consequently, the IHF does not require the confinement function of the other waste handling facilities and can be constructed primarily from structural steel. This allows the IHF to be constructed considerably faster than the other waste handling facilities which are primarily built of reinforced concrete. The current schedule is for the IHF to be completed a year before CRCF 1. This period will be used to demonstrate equipment operations and refine operating procedures for cask handling, canister transfer, and waste package loading, closure and loadout. Lessons learned in the year will be applied to the other handling facilities. The IHF provides for an improved throughput of Naval SNF, while simplifying operations in the CRCF.

Therefore, throughput is improved for Naval Spent Nuclear Fuel and for waste going through the CRCF.

**3) The Board requested information on experience gained from safety and facility maintenance in the Exploratory Studies Facilities (ESF) could be applied to subsurface repository design and operations. The following information may be helpful in this regard.**

In the summer and fall of 2006 the Department conducted two workshops with outside experts in underground construction and environmental safety and health. A hazard analysis of current ESF operations and construction practices was also completed, and the result of these two efforts was the development of an Underground Safety and Health Requirements Document (DOE/RW-0586), issued in January 2007. This document was intended to be applied to continued site operations until construction authorization. Some specific experience gained from safety and facility maintenance in the ESF includes the following:

- Nominal excavation airflow design volumes are based on the 150 ft/min velocity established during ESF construction
- Drift orientation (azimuth 252) based on post excavation ESF information
- Measurements of steel set loads indicate no evidence of long-term time-dependent effects. The rock at the repository host horizon demonstrates a good self-supporting capacity, rock bolts with wire mesh are an adequate ground support system, and steel sets with lagging are a very conservative ground support system
- The two ground support systems, namely: the friction-type expandable rock bolts and cast-in-place concrete liner installed in the heated drift, performed very well while subjected to up to 200 degree C temperatures, supporting the use of that type of rock bolt in the ground support system proposed for emplacement drifts
- Lithophysal rock exposure in the ESF, particularly in the ECRB cross drift, revealed all the challenging rock mechanical aspects of testing the lithophysal rock, and the importance of integrating field activities such as mapping, in situ measurements, and field observations in the process of characterizing the lithophysal rock mass thermo-mechanical performance
- Use of a blowing system to deliver fresh air directly to the TBM face, so workers at the face will be in cleaner air. (An Exhaust system was used during ESF operation, intake air went to the working face through the TBM tunnel, where the airflow picked up a lot of dust in the tunnel)

- Use of 1,000-ft flexible tube segments for minimizing air leakage. (Compared with 20-ft steel duct segments used in ESF, this eliminates majority of the vent-line joints that are potential source of air leakage)

- Covered muck cars (instead of conveyer used in ESF, which was a major source of dust).

**4) The Board encouraged the DOE to evaluate surface-facility designs and operational concepts for opportunities to reduce the number of times waste is handled.** The Board suggested that DOE should, for example, assess the need for and, to the extent practicable, limit the size of large aging pads called for in the current surface facilities design. The current status of the repository design as modified to accommodate the TAD is described below.

The current design of the surface facilities has resulted in a significant reduction in the number of times the waste is required to be lifted and handled as compared to the previous repository design. As an example, in the former Dry Transfer Facility a loaded waste package was lifted by a crane a minimum of three times, and as many as six times, during handling. In the current design of the surface facilities, all crane lifts of a loaded waste package have been eliminated.

The current 21,000 MTHM capacity of the aging pads uses Total System Model delivery predictions that are based on a waste package thermal limit at emplacement of 11.8 kW. Evaluations are currently underway to determine the effect of increasing the thermal limit at emplacement on the postclosure analyses. If the Department chose to increase the waste package thermal limit at emplacement, more TAD canisters could be directly loaded into waste packages, thereby reducing the required capacity of the aging pads. Any such change would necessitate discussion with the NRC.

As discussed above, as part of the thermal strategy, the aging pads are a part of the overall program to handle the wide variability of the potential waste streams to be received. Evaluations of waste stream in the past with different waste package designs and thermal emplacement constraints identified that the 21,000 MTHM capacity (approximately 2500 "spots" for TAD canisters or dual-purpose canisters (should DOE accept them) may be needed to allow for thermal decay. Current evaluations suggest that the needed capacity of the aging facilities could possibly be reduced by as much as 50%, depending on the thermal characteristics of the waste stream and the emplacement strategy employed, even if emplacement of the lower thermal waste is deferred until the end of the emplacement period. Included in this consideration for this sizing is queuing of waste based on the throughput capability of the facilities. The uncertainty of the waste stream thermal characteristics and the thermal capability of the TAD canister causes the repository to retain the facilities' capacity of 21,000 MTHM as part of the current design. As the design matures, with respect to the throughput capability of the facilities, the TAD thermal capabilities as identified by the vendors, emplacement strategies during preclosure for postclosure acceptance are accepted by the NRC, and the characteristics of the waste stream become more certain, the Department will re-evaluate the need for the capacity of the aging facilities and adjust their capacity as necessary to support operations. Aging capacity will be developed in phases.

**5) While not directly discussed at the January meeting, the Board urged the DOE to evaluate the possible direct disposal of DPCs in Yucca Mountain (YM).** The Board suggested that the DOE should clarify its position regarding criticality and burn-up credit as part of an assessment of the feasibility of direct disposal of DPCs. DOE's plans with respect to DPCs are described below.

Should the Department accept DPCs, the direct disposal of existing DPCs is not planned and disposal of DPCs is not included in the LA. DOE does not currently plan that DPC disposal would be included in any amendments to the LA until the DPCs have been analyzed for postclosure criticality and other considerations. Several existing DPC designs rely on internal geometry and flux traps as well as neutron absorbers. During the postclosure period, internal geometry is lost due to material degradation, therefore credit is not taken for geometric controls. Also, any neutron absorber currently in DPCs may not have the same high level of corrosion resistance as the neutron absorber being specified for the TADs (borated stainless steel). If future analyses determine that direct disposal of DPCs is feasible, then the Department could propose an amendment to the license. However, currently the plan is to cut open DPCs in the WHF and transfer the fuel assemblies from DPCs to TADs. DOE intends to include burn-up credit in its evaluation of postclosure criticality and would expect burn-up credit to be considered in any direct disposal DPC analysis performed in the future.

**6) The Board also requested an explanation of the technical basis for the selection of borated stainless steel as a neutron absorber in TAD canisters.** The technical basis is described below.

The Department completed a comprehensive sensitivity study as documented in the calculation, "Evaluation of Neutron Absorber Materials Used for Criticality Control in Waste Packages" (CAL-DS)-NU-000007). This calculation looked at a range of absorber specifications, concentrations and geometric arrangements. The final recommended neutron absorber material for the TAD was borated stainless steel with a boron loading of 1.16 wt % at a minimum thickness over 10,000 years of 0.6 cm. The basis for the recommendation, as taken directly from the calculation, is as follows:

- Commercial experience with fabricability, commercial availability, and neutronics experience of absorber materials containing boron is much broader than with the Ni-Gd alloy. Also, ceramic based materials (B4C) would need special cladding and welding to ensure that they remain in place over long time periods of corrosion

- There are a relatively large number of criticality benchmark experiments with boron absorber in geometries representative of the TAD than with Gd absorber

- Expected corrosion rates for the Ni-Gd alloy and the borated stainless steel using powder metallurgy are expected to be relatively similar for the in-package pH ranges expected in the repository provided with boron loading is kept a relatively low levels

- A minimum absorber plate thickness of 0.6 cm with a credited boron loading of 0.87 wt% with natural boron provides a loading curve that is nearly identical to the proxy TAD configuration loading curve. This is the minimum thickness required after being subjected to 10,000 years of corrosion

- Further, additional corrosion testing of borated stainless steel have corroborated the expected corrosion rates.

**7) The Board expressed concern that, while technical interaction between DOE and the nuclear utilities is ongoing, it is not apparent to the Board that this dialogue includes all key issues warranting coordination within a successful waste management system.**

The Department believes that its current level of dialogue with nuclear utilities has been both appropriate and constructive. For example, the Department's discussions with both utilities and cask vendors has led to the successful development of the Preliminary Performance Specification for the canister. The Department also has continuing interactions with utilities on numerous topics including of nuclear operations, licensing, emergency preparedness, training, and configuration management. Additionally, the Department, with the assistance of the Electric Power Research Institute and the Nuclear Energy Institute, is working with a group of utilities to obtain additional data on spent nuclear fuel characteristics that it believes will be helpful in efforts to obtain an NRC license for the construction and operation of repository at YM.

The Department intends to expand the ongoing dialogue with nuclear utilities on additional issues as the program progresses into the licensing phase of the repository and beyond.

**8) The Board expressed concern that DOE has assigned postclosure planning responsibility to the Office of the Chief Scientist (OCS), while preclosure planning responsibility has been assigned to the Office of the Chief Engineer (OCE).** The Board indicates that it has not observed a systematic or comprehensive linking of these two components or recognition by DOE of the interdependencies of important repository design and operating elements (e.g., thermal management).

The Environmental Protection Agency, in 40 CFR 197, and the NRC, in 10 CFR 63, provide different standards and expectations with regard to pre- and post-closure safety.

The Department's organizational structure is reflective of these differences in requirements and associated areas of expertise. However, the Department has long recognized that these topics are not totally divorced from each other and require close coordination of activities and clear definition of interfaces. The OCE has been given responsibility for the development and control of top-level requirements documents including management of the technical change control process. This ensures consistent assignment and integration of requirements throughout the program, establish single point accountability for managing changes within the program, and develop a clearinghouse for integration at the management level.

Currently, the interface between postclosure activities performed under the direction of the OCS by the Lead Laboratory (LL), and preclosure activities performed under direction of the OCE by Bechtel SAIC Company, LLC (BSC), is managed through several processes and management actions, including the following:

- The LL and BSC have established a formal process for information exchange. Interface Exchange Drawings (IEDs) have been issued to document and control the exchange of information across the organizational boundary between preclosure functions (e.g., repository engineering, design, operations, and preclosure safety and criticality analyses) and post-closure and scientific investigation functions (e.g., post-closure performance modeling and assessment, post-closure criticality analyses, and site-specific geotechnical, environmental, meteorological, and seismic investigations). Control of the exchange of information across this boundary is necessary to ensure compatibility between the design of systems, structures and components and interfacing processes and scientific analyses.

- An additional document that ensures consistency and integration between the LL and BSC design is the Postclosure Modeling and Analysis Design Parameter Report, which augments the IEDs by documenting a review of Analysis and Model Reports to identify parameters and constraints to design (e.g., design bases that must be met by the design). These constraints to design are included in the design requirements documents, thus assuring that postclosure modeling and performance analyses bases are being met.

- The contractors exchange review copies of in-process technical documents for inter-contractor review if there are impacts on either the content of an IED or the Post Closure Modeling and Analysis Design Parameter Report.

- A joint management review in the Technical Review and Management Board is performed by the LL and BSC on any proposed changes to the IEDs or the Post Closure Modeling and Analysis Design Parameters Report.

- A regularly scheduled Subsurface Integration Meeting is hosted by BSC engineering with Department and LL attendees. The purpose of the meeting is to provide a means to discuss specific issues that affect both preclosure and postclosure work.

The need for integration between offices is not limited to just the OCS and the OCE, particularly with regard to the Board's example of thermal management. The OCS, OCE, and Office of Waste Acceptance and Management are jointly developing the Thermal Management Strategy discussed above. An integrated team evaluated potential waste streams and associated parameters, and set bounds for the thermal envelope in the facility preclosure operations while meeting the initial conditions for the TSPA for postclosure. This was a significant integration effort that is now being implemented. Those parameters, defined in the study are being included into the control documents described above, for implementation into the ongoing design and TSPA analyses.

**9) The Board suggested that DOE monitor the upcoming rulemakings by the Department of Homeland Security and Pipeline and Hazardous Materials Safety Administration and the Federal Motor Carrier Safety Administration to ensure that DOE's approach is consistent with new regulations.**

Current and proposed rulemakings and legislation related to hazardous materials transportation security may impact the Department's system planning, and will be closely monitored by DOE. Accordingly, the Department will continue to closely follow developments in this area.

**10) The Board discussed the importance of developing more-realistic estimates of seismic ground motion for both preclosure and postclosure periods and noted its support for scientific and engineering activities aimed at developing such realistic estimates.**

During the last year work has been ongoing to refine seismic analyses. To address the evolution of the area where surface facilities will be sited, ground motions for design and preclosure safety analyses have been updated. In updating these ground motions, an alternate approach to incorporating site response has been implemented that results directly in a site-specific seismic hazard curve. In addition, reasonable limits to extreme (very low probability) ground motions at YM are directly incorporated. Limits are assessed both on the basis of geologic evidence that indicates a level of ground motion that has not been experienced at the site and on an evaluation of earthquake source parameters that are consistent with the geologic setting of the site.

Analyses and modeling of seismic consequences during the postclosure period are being updated to take into account the transportation, aging, and disposal canister concept and to evaluate performance for the period after 10,000 years. As part of this work, response to seismic loading is being assessed for additional states of degradation and failure of the engineered barrier system and for the effects of multiple seismic events.

**11) The Board considers the question of $^{36}$Cl measurements an outstanding issue whose resolution could greatly enhance confidence in understanding fluid flow within YM.**

The Cl-36 studies can be viewed as consistent in one important aspect which is that the studies conducted to date consistently indicate that fast pathways, as indicated by bomb-pulse Cl-36 are either rare or non-existent. This is consistent with the way the unsaturated zone is modeled in process models and the TSPA, in which a small percentage of fast pathways are included in the models for unsaturated zone flow. Links to the completed reports on the work conducted by DOE investigators, including conflicting results and interpretations, were provided in a presentation at the January 24, 2007 Nuclear Waste Technical Review Board meeting.

**12) The Board expressed concern that budget constraints in fiscal year (FY) 2007 and the elimination of funding for this purpose in OCRWM's budget request for FY 2008 will negatively affect the continuation of the Science and Technology (S&T) program.**

Funding constraints will cause the Department to reduce or eliminate funding for the independent S&T program. The Department is investigating other avenues, such as the DOE Office of Science and cooperative research programs, to maintain the capability to investigate new and unproven techniques and technologies.

UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201

July 10, 2007

Mr. Edward F. Sproat III
Director, Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Sproat:

The U.S. Nuclear Waste Technical Review Board held a public workshop on localized corrosion of Alloy 22 on September 25-26, 2006, in Las Vegas, Nevada. Following the workshop, the Board conveyed its comments and conclusions on screening out deliquescence-based localized corrosion in a letter to you dated January 12, 2007. The Board stated in that letter that "demonstrating an adequate technical basis for screening out deliquescence-based localized corrosion during the thermal pulse requires (a) determining the nitrate-to-chloride ratios that are inhibitive for the entire range of temperatures that deliquescent brines may occur on waste package surfaces and (b) confirming the hypothesis that the preferential migration of nitrate ions into the crevices is sufficient to maintain nitrate-to-chloride ratios that are inhibitive." The following extends and supplements the Board's January 2007 letter.

In addition to (a) and (b) above, the Board believes that the technical basis for screening out deliquescence-induced localized corrosion would be strengthened by showing that inhibitive nitrate-to-chloride ratios would persist during the thermal pulse under expected repository conditions. The importance of establishing the continued presence of inhibitive nitrate-to-chloride ratios was reinforced by the results of recent analyses of dust collected from the cool-down phase of the drift-scale thermal test, which show that nitrate may have been depleted under the testing conditions. The Board believes that factors and processes that contribute to a decline in nitrates under potential repository conditions should be analyzed and understood.

An example of such factors is the composition of dusts that will be present in the repository. Most of the nitrate in deliquescent brines comes from inorganic salts contained in dust that deposits on waste package surfaces, primarily during the ventilation period. However, the dust also contains organic materials and carbon that have not been included in DOE's representation of dust likely to be present in repository tunnels. DOE should evaluate the potential effects of the depletion of nitrate that would occur from a reaction with organic material under repository conditions during the thermal pulse.

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As discussed in the Board's January letter, screening out localized corrosion requires determining the nitrate-to-chloride ratios that would exist in brines on waste package surfaces under varying repository conditions during the thermal pulse. Providing convincing evidence that inhibitive nitrate-to-chloride ratios will persist under repository conditions could strengthen the technical basis for screening out localized corrosion. Therefore, DOE should analyze the effects of the full range of factors that would affect such ratios (e.g., organics in dust, acid-gas devolatilization, radiolysis).

Sincerely,

{Signed by}

B. John Garrick
Chairman

**Department of Energy**
Washington, DC 20585

August 13, 2007

QA: N/A

RECEIVED AUG 16 2007

B. John Garrick, Ph.D.
Chairman
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Garrick:

Your 2006 Report to the U.S. Congress and the Secretary of Energy describing the activities of the Nuclear Waste Technical Review Board (Board), as well as more recent correspondence, raised a number of technical issues to which the Office of Civilian Radioactive Waste Management has responded in the enclosed table. The table summarizes the issues raised, the U.S. Department of Energy (DOE) responses to the Board's concerns, and DOE's current work activities in these areas.

We appreciate this opportunity to communicate with the Board regarding issues of importance to the Yucca Mountain Project and look forward to future exchanges. If you have any questions concerning the enclosed table, please contact me or Russ Dyer, Director, Office of the Chief Scientist, at 702-794-1408.

Sincerely,

Edward F. Sproat, III, Director
Office of Civilian Radioactive
Waste Management

Enclosure

Printed with soy ink on recycled paper

**NUCLEAR WASTE TECHNICAL REVIEW BOARD ISSUES RAISED IN 2006 REPORT TO CONGRESS AND IN RECENT CORRESPONDENCE WITH DOE, AND DOE RESPONSES TO THESE ISSUES**

| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
| --- | --- |
| **The Capability of Natural Barriers to Isolate Radionuclides** | |
| The Board believes…that additional work on radionuclide transport is needed – in particular, research on secondary mineralization. This area of investigation relates to what is more generally referred to as the radionuclide source term, the understanding of which is critical to assessing the overall performance of the repository. If these investigations determine that the neptunium and plutonium leaving the EBS are captured in the secondary mineral phases, the possibility exists that the natural system's capability to isolate the dose-contributing radionuclides ($^{237}$Np and $^{242}$Pu) could be greatly increased. Further work investigating matrix diffusion, colloid-facilitated transport, or other processes that might significantly affect the rate at which dose significant radionuclides are transported also could yield important insights. In addition, the Peña Blanca analogue site in Mexico provides an opportunity to test models and methods for predicting radionuclide migration and retention processes at Yucca Mountain. The Board encourages the Project to continue studies at that location. | The DOE Office of the Chief Scientist, Science, Technology and Management (OCS/STM) funds independent work in a number of "Thrust Areas". The Source-Term Thrust Area is dedicated to scientific studies relevant to spent nuclear fuel (SNF) and nuclear waste glass and the critical processes within the waste package and drifts that affect potential radionuclide release from the waste forms and from the engineered barrier system.<br><br>Source Term research studies include: 1) actinide thermodynamics at elevated temperatures; 2) impact of uranyl alteration phases of spent fuel on mobility of neptunium and plutonium; 3) effect of deliquescence and decay heat on source term degradation; 4) spent fuel dissolution mechanisms and rates; 5) in-package sequestration of radionuclides; and 6) long-term corrosion of spent nuclear fuel; 7) natural sequestration of radionuclides in volcanic tuff and secondary phases; 8) in-situ spectroelectrochemical study of Np redox, dissolution, and precipitation behavior at corroding commercial spent nuclear fuel (CSNF)/Alteration phase interface; 9) migration of the release of I-129 from SNF via uptake by uranyl alteration phases; 10) actinide adsorption to U(VI) silicates; 11) direct determination of the thermo-dynamic properties of uranyl minerals important to repository performance; 12) surface charge and radionuclide adsorption characteristics of U(IV/VI) and metal corrosion oxides at 25°-150°C under repository chemical environments.<br><br>OCS/STM work also includes work at the Peña Blanca natural analogue site.<br><br>OCS/STM activities have been reduced in FY 2007 and will not be funded in FY 2008, due to budget constraints. |

1

| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| | The Office of the Chief Scientist, Repository Science and Integration (OCS/RSI) directs the scientific program that supports the DOE's licensing case. OCS/RSI work includes incorporation of kinetics of filtration of irreversible colloids in the unsaturated and saturated zones through the "colloid diversity model". The approach (1) recognizes variability (diversity) in the attachment/detachment rate constants resulting from differences in colloid size, mineralogy, surface charge, and characteristics of sorption sites, (2) treats these variations with a distribution of retardation factors for colloids, and (3) develops the distribution of retardation factors as a function of transport time through the UZ and SZ. This work involves an abstraction of kinetic colloid filtration into the FEHM software to replace the current equilibrium approach.<br><br>New data related to the performance of the natural barrier system are evaluated on an ongoing basis. For example, results from Alcove 8/Niche 3 tests are being utilized to more realistically take into account matrix diffusion in UZ flow and transport using an enhancement factor to the matrix diffusion coefficient estimated with the dual permeability model and possibly employing the MINC (multiple interacting continua) method. More realistic accounting of the role of matrix diffusion in radionuclide transport through the unsaturated zone will be evaluated and documented in the *Particle Tracking Model and Abstraction of Transport Processes* (MDL-NBS-HS-000020) AMR. |
| The Board is skeptical about the Project's claim to have found evidence of a "reducing curtain" in the saturated zone. | The evidence behind the notion that there may be areas of 'reducing ground waters' in the saturated zone is discussed in the BSC 2005 report: *Impact of Solubility and Other Geochemical Processes on Radionuclide Retardation in the Natural System.*<br><br>A sensitivity study is planned for this year to evaluate the impact of potential 'reducing conditions' on radionuclide transport in the saturated zone through Monte Carlo simulations using the SZ flow and transport abstraction model for a range of reducing conditions. |

2

| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| The Board remains puzzled by the Project's inability to put to rest the issues related to the bomb-pulse chlorine-36 ($^{36}Cl$) observed in the proposed repository horizon and to the water found behind the bulkhead in the sealed section of cross-drift. Inconsistencies in past studies of $^{36}Cl$ raise questions about the technical basis of model predictions of water flow and radionuclide transport. In the case of the water found in the cross-drift, the Project has not developed and tested a hypothesis that explains all of the physical and chemical data collected. The Board recommends that work be expedited to resolve both of these issues to enhance confidence in both the quality and the conclusions of the Project's technical analyses. | Work performed as part of the $^{36}Cl$ validation activities by the Lawrence Livermore National Laboratory, the U.S.Geological Survey, and the Los Alamos National Laboratory have been documented in a report which is available on the OCRWM web site at http://www.ocrwm.doe.gov/documents/design/35641/index.htm. An independent study of $^{36}Cl$ issues has been conducted under a cooperative agreement between the Department and the Nevada System of Higher Education (NSHE) Scientists have collected samples from the Exploratory Studies Facility, evaluated experimental techniques, and tested rock samples in 2006.<br><br>NSHE has submitted the results of their independent study of $^{36}Cl$. The results were inconclusive and the report recommended additional work. DOE has not planned additional work on the $^{36}Cl$ issue. The report is available on the NSHE web site. |
| **Thermal-Management Strategy** | |
| The Board has concerns about the technical basis behind the Project's thermal management strategy…. First, the technical basis for the Project's choice of thermal criteria to limit temperature is not well-defined. For example, the 11.8 kW/waste package limit appears to have been based arbitrarily on the average power of a PWR SNF assembly plus 20 percent. A more technically valid approach might be to derive the maximum waste package-surface temperature limit from limits on drift wall temperature. The Board believes that the Project should articulate in a transparent way the basis for its thermal criteria. | The Department agrees that the thermal management strategy must be clearly defined to provide the technical basis for waste acceptance, transportation, waste handling, and waste emplacement. Postclosure near-field and in-drift conditions affecting performance of the engineered and natural barriers are being addressed in the postclosure elements of the thermal management strategy. This includes the thermal decay characteristics of the waste and temperature limits at key locations such as the waste package wall and drift wall.<br><br>The FY 2007 work scope is addressing these thermal management issues. |
| Second, the implications for thermal management of the Project's provisional decision to implement the TAD concept do not seem to have been evaluated fully. In particular, the Board is concerned about the ability of the utilities to blend the spent nuclear fuel to the required thermal loading, given the spent nuclear fuel available in spent-fuel pools, the increasing volume of spent nuclear fuel in dry storage at reactors, and the trend towards higher burn-up fuel…. Moreover, the Board is | The performance specification is being developed taking into account all the system requirements from waste acceptance to final disposal. Accordingly, it has been the Department's intent to incorporate requirements that, while ensuring that the thermal performance of the TAD canister system would be consistent with the current postclosure thermal management approach, would provide sufficient flexibility to accommodate alternative thermal management strategies. If, as a result of further analyses, the current postclosure thermal management approach is |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| concerned that the constraints imposed by line-load during emplacement have not been fully represented or understood in terms of surface facility design and operation. | altered, the Department believes that such changes can be accommodated by altering the manner in which the TAD canister system is operated, (i.e. by decreased surface aging), rather than by requiring changes to the TAD canister design.<br><br>The Department is developing an updated thermal management strategy to reflect commercial spent nuclear fuel (CSNF) forecast at somewhat higher burnup and earlier time out of the reactor than previously considered. This strategy is intended to maximize operational flexibility and minimize the related need for canister thermal limits. Using postclosure process models and parameters from alternative waste streams, sensitivity analyses will be performed to evaluate effects of a broader range of variables affecting thermal performance. |
| Third, the Board is not persuaded that the thermal-hydrologic models being used to predict postclosure temperature, relative humidity, and vapor transport within the drifts have a strong technical basis. For example, the thermal conductivity of the rock at Yucca Mountain is important for predicting thermohydrologic conditions in the proposed repository. Uncertainty in the thermohydrologic conditions, especially during the thermal pulse that last about 1500 years, arises in part from the scarcity of *in situ* measurements of thermal conductivity in the lower lithophysal rocks where approximately three-quarters of the repository might be constructed. More data on thermal conductivity could reduce this uncertainty…In addition, further analysis of data obtained from the Drift-Scale Heater test might be helpful in reducing the uncertainty in thermohydrologic conditions during the thermal pulse. | The geostatistical model used to calculate the thermal conductivity of the repository horizon rocks has been developed based on site-specific data including well logs and measurements of physical properties and thermal conductivity on rock cores from boreholes. Because a sequential Gaussian simulation is used, the model provides an appropriate representation of the spatial variability and uncertainty of the underlying data, especially the key input parameters (i.e., matrix thermal conductivity and lithophysal porosity). Both parameters contribute to the spatial variability and uncertainty in the model results, although the dominant influence is from matrix thermal conductivity. Whereas, *in situ* tests are useful in evaluating the effects of discontinuties such as lithophysal cavities, laboratory tests are used to measure matrix thermal conductivity, the dominant contributor to spatial variability and uncertainty.<br><br>The *in situ* test results are not part of the basis for spatial variability and uncertainty in the model results. The reason is that *in situ* tests by their nature (and cost) cannot be performed over nearly as broad a range of spatial distribution and stratigraphic facies as can be performed using geophysical well logs and core samples. Thus, additional *in situ* tests would not be a practical way to improve the model treatment of spatial variability and uncertainty. |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| | The in situ thermal conductivity test results are point measurements that corroborate the geostatistical model. All test results are within the range of values derived from the model. One of the test results is slightly over 1.5 standard deviations from the model-derived mean and the others are within one standard deviation. Additional confidence in the model is gained by the methods and models used to estimate matrix thermal conductivity, lithophysal porosity, matrix porosity, and bulk density. The latter two are used to estimate the former two, which are used to obtain bulk thermal conductivity.<br><br>For the Drift-Scale Heater Test, activities such as re-entry, retrieval of sample materials, collection of additional samples, and photography have been deferred for budgetary reasons. Longer term activities will include coring, rock-bolt pull tests, and investigation of spalling at the drift crown. The objectives of these activities include obtaining a better understanding of the thermal-hydrologic-chemical-mechanical effects on repository performance.<br><br>The thermal-hydrologic model to predict postclosure temperature, relative humidity, and vapor transport in the emplacement drifts is being revised to support the license application.<br><br>No additional *in situ* thermal conductivity tests are planned. The Department believes than an acceptable level of model validation has been achieved. While potentially useful, further *in situ* thermal conductivity tests are not necessary for this purpose. |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| [T]he Project is conducting three-dimensional analyses to complement its two-dimensional multi-scale model of water and vapor flow. The Board plans to review those analyses to determine what impact, if any, they might have on the safety case. In particular, the Board would like to see how energy and mass balances are achieved and how these results are integrated into performance assessment. Due to the importance of the multiscale model, the Board also recommends that it be reviewed by independent experts. | DOE does not plan to conduct an external review of the multiscale model.<br><br>The OCS/STM Program has funded an integrated in-drift/near field flow and transport model with reactive chemistry. This includes an integrated thermal hydrologic chemical model with a rigorous mass balance. |
| **Range of Possible Near-Field Environments that Might Occur and the Effect of Those Environments on the Integrity of the Engineered Barrier System** | |
| The Project maintains that potential localized corrosion of Alloy-22 at elevated temperatures can be excluded from its performance-assessment calculations. The Board believes that the technical basis for the exclusion is not compelling, partly because only very limited corrosion data have been collected at temperatures above 150°C, and partly because data showing cessation (stifling) of localized corrosion at lower temperatures may or may not be relevant to all conditions under which localized corrosion could occur in the proposed repository. The Board strongly urges the Project to continue collecting data that might justify its assumption that localized corrosion will not occur at temperatures as high as 200°C. | Further work on the role of stifling has been planned for FY 2007, and will be included in planning for the long-term corrosion test facility. Collection of dust samples and studies of the role of dust deliquescence on localized corrosion are also expected to continue. |
| Some previous performance assessment models have assumed that general corrosion of Alloy-22 *does not occur above 120°C*, presumably based on the assumption that aqueous conditions do not exist above this temperature. Because aqueous conditions *can* exist at elevated temperatures-as Project researchers have demonstrated- future performance assessments should not exclude general corrosion at elevated temperatures when aqueous conditions are predicted to be present. The Board strongly urges the Project to continue to collect data to resolve the issue of whether general corrosion occurs at temperatures as high as 200°C. | In the current TSPA simulations, general corrosion of both waste package and drip shield materials is assumed to occur at all temperatures. The Alloy 22 general corrosion model is temperature-dependent and the temperature dependency is represented by an Arrhenius relationship. The titanium alloy general corrosion rate is taken to be independent of temperature in agreement with the experimental results of Smailos and Köster (1986 IAEA-TECDOC-421).<br><br>General corrosion data for Ti Grades 7 and 29 (as well as some analogue alloys) has been collected at 150°C. These data were found to be consistent with the Project's existing models for Ti Grade 7. The data indicated that the Project's model for Ti Grade 29 was somewhat |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| | conservative. The Project will continue to collect general corrosion data in high temperature environments. |
| [F]or Yucca Mountain environments above 160°C, only limited SCC data exist for Alloy-22. Given that the susceptibility of metals to SCC generally increases with temperature, the Project will have to obtain relevant data under higher-temperature conditions, assume that SCC will occur, or use a different approach. | SCC requires 1) a susceptible material; 2) a critical environment; and 3) a source of stress. The Project's SCC models assume that waste package and drip shield materials are susceptible to SCC and that a critical environment exists at all temperatures. SCC initiation is subject to a threshold stress and SCC propagation is subject to a threshold stress intensity factor. Current models use SCC initiation data acquired in solutions at temperatures up to 165°C in aggressive SCW solution. Limited crack growth rate data collected in SCW solutions at 175°C agree with more extensive data collected at 150°C.<br><br>In FY 2007, testing of Alloy 22 specimens containing simulated weld flaws will be continued. These tests are used to evaluate whether SCC will initiate at defect sites.<br><br>During FY 2007, Alloy 22 U-Bend specimens, exposed for times up to ~9 ½ years, will be evaluated for evidence of SCC initiation and growth. |
| The Board continues to believe that SCC in titanium alloys cannot be dismissed. | SCC is not expected for the as-emplaced drip shields as they have undergone stress relief treatments (no source of stress is available to drive crack growth). SCC of the drip shield materials can occur under seismic loadings. After seismically-induced cracks penetrate, only limited water flow is expected because cracks in passive materials are tight and tortuous, water would be flowing against a thermal gradient, and there is potential for crack plugging by mineral precipitation and/or corrosion products.<br><br>During FY 2006/2007, Ti Grades 7 and 29 specimens continue to be tested at General Electric. These data will produce information useful in understanding titanium alloy SCC (e.g., stress and stress intensity thresholds and crack growth rates). During FY 2007, titanium alloy U-Bend specimens, exposed for times up to ~9 ½ years, will be evaluated for evidence of SCC initiation and growth. |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| | Testing of titanium alloy specimens containing simulated weld flaws will be continued. These tests are used to evaluate whether SCC will initiate at defect sites. |
| [T]here is considerable uncertainty about the source term incorporated into the TSPA. To address this uncertainty or lack of detailed analysis, the Project has made simplifying assumptions that need to be reviewed carefully for their effects on the fuel degradation and radionuclide migration processes. | DOE agrees.<br>Although the simplifying assumptions are conservative, they will be examined in light of the best available data.<br><br>The OCS/STM has a number of research studies in the areas of source term, spent fuel degradation, and radionuclide migration. |
| **The Postclosure Risk Associated with the Proposed Repository** | |
| The Board appreciates the fact that the Project is in the midst of preparing a license application for its repository system. Not surprisingly, the Project is motivated to advance a licensing case whose main–and possibly sole–objective is to demonstrate compliance with the applicable regulations via an intense legalistic process. Consequently, when faced with gaps in understanding, "bounding" conservative approaches are often adopted. What is difficult to assess is the degree of total conservatism that exists when scientists add their own conservatism in the chain of integrated analyses that form the performance assessment.<br><br>For that reason, the Board remains concerned that by adopting a conservative compliance-focused approach, the Project discounts the importance of letting policy-makers, the public, and the broader technical and scientific community know what the Project's experts believe are the intrinsic capabilities of the proposed repository at Yucca Mountain. Having a more-definitive information on the adequacy of the natural system and the levels of conservatism involved, for example, may well provide all interested and affected parties with important and relevant information.<br>Thus, the Board believes that the DOE should carry out a realistic performance assessment in parallel with its efforts to develop a compliance case. Such a realistic performance | The Department's approach to the TSPA reflects international experience and Nuclear Regulatory Commission (NRC) staff perspectives, and the unique challenge of modeling transport in partially saturated fractured rock. The Department believes that the performance assessment supporting the postclosure compliance analyses is reasonable for this application and has been developed cautiously. However, Department recognizes the Board's perspective that some aspects of the model might be considered unrealistic. Because the approach that the Department is using for postclosure performance assessment has evolved over many years through interaction with NRC staff and is reflected in the Yucca Mountain Review Plan, it is an integral part of our approach to development of the license application. The Department is currently undertaking development of a performance margin analysis of system performance. This would be used (1) as a management and communication tool, (2) to build confidence in the estimate of repository performance in the compliance-based analysis, and (3) to quantify and help understand the degree of overall conservatism in the TSPA.<br><br>The Department plans to complete performance margin analyses that will use available data to evaluate the extent of conservatism and/or non-conservatism in the conservative compliance-focused analyses. These analyses will complement the TSPA for compliance. |

| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| assessment would establish a "baseline" for measuring how "conservative" or "non-conservative" DOE's licensing case might be. Although some assumptions still may be required, they, too, will need to be well justified if this realistic assessment is to be carried out credibly. Thus the Board reiterates its view that fundamental understanding is important and encourages the Project to fill in areas where significant gaps in such understanding occur.<br><br>Further, to address what now appear to be the critical radionuclides contributing to peak dose, the Board recommends that the DOE prepare full and realistic process models that account for the transport of the two radionuclides in question, neptunium-237 and plutonium-242. Such an effort should trace the radionuclides from when they leave the degraded fuel pellet until they are taken up by the "reasonably maximally exposed individual". These analyses should be consistent with the thermal hydraulic analyses used in the thermal management strategy with the calculations extending until the time of peak dose or 1,000,000 years. | |
| **Design and Operation of Surface and Subsurface Facilities** | |
| [The] Board remains concerned that the Project has not fully evaluated the range of consequences associated with implementation of the TAD concept, especially with respect to thermal management.<br><br>Thus, the Board recommends that the Project carry out a formal analysis that addresses, among other things, the following areas:<br><br>What are the performance specifications of the TAD? How were they derived?<br><br>How does the introduction of the TAD affect logistic capabilities and limits? | The Department will continue the integrated system engineering and analyses approach to gain a greater understanding of the interrelationships between the subsystem components: waste acceptance, transportation, and repository operations. These continuing analyses are expected to provide additional insights as design details are further refined and operational scenarios are more fully defined, but will be sequenced to occur as details and scenarios are deemed mature for consideration to ensure that realistic representations of the waste management system are examined.<br><br>The Department accepted the preliminary TAD performance specifications submitted by BSC. The Department is currently tailoring those specifications to support a procurement action for a TAD conceptual design which, when completed, will address the Board's questions. |

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| BOARD FINDINGS AND RECOMMENDATIONS | DOE RESPONSE |
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| What constraints on SNF blending does the TAD create? How does the TAD affect surface facility design and operation?<br><br>How does the TAD affect the sequencing of waste emplacement necessary to maintain the specified line load of 1.45 kW/meter?<br><br>….Such an analysis should take into consideration a full complement of scenarios that can evaluate various design and operational assumptions associated with waste acceptance, transport, receipt, and processing at the surface facilities, and emplacement. | The Department has completed its Critical Decision-1 (CD-1) process which included a description of surface facility design and operation effects from the TAD. The Department has approved introduction of a canister-based system into the baseline. CD-1 authorized the preliminary TAD design which is underway. |
| The Board believes the Project needs to refine its drip shield design and implementation approach….Although the Project has produced some analytical results that it believes show that the drip shield interlocks will withstand seismic events, it is hard to believe that the drip shields will maintain their "as-installed" configuration even as those same events cause the waste packages to fail. Further, the Board believes that the Project needs to address issues related to in-drift operational envelopes and installation tolerances that could potentially increase the difficulty of installing the drip shields remotely. Finally, because the drip shields will not be installed until just before repository closure,…the Project should evaluate now what factors will effect the final design of this EBS component and explain how, when, and by whom decisions about installing drip shields will be made, including whether to install them at all. | The Department agrees that it is important to evaluate factors that will influence the final drip shield design well in advance of repository closure. The Department plans to fabricate prototype drip shields to evaluate operational envelopes and design and installation tolerances in the performance confirmation drifts.<br><br>In addition, a revision to the *Seismic Consequences Abstraction*, MDL-WIS-PA-000003, is planned to account for drip shield damage as a function of thinning due to corrosion and response to seismic events in intact and collapsed drifts. |
| **Plans for the Waste-Management System** | |
| The Board considers the Total System Model (TSM) being developed by the DOE to have significant potential as a tool for understanding the performance of the coupled waste-management system. The TSM can be used to examine system | The results of TSM analyses were used to evaluate a primarily canister-based system using TADs for commercial spent nuclear fuel (CSNF). Insights from the TSM analysis included, but were not limited to, factors such as dose, thermal management, and waste handling. The Department |

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| throughput, identify possible "choke points", and show where various design and operational elements are incompatible. To maximize the value of the TSM, however, the input data must be based on the most up-to date information; critical modeling assumptions must be confirmed; there should be an ability to represent off-normal conditions; and all components of the waste-management system, including emplacement, need to be incorporated in the model.<br><br>Further, the Board recommends that the Project enhance the TSM in the following ways to increase the model's utility in evaluating the waste-management system:<br>• Add a system optimization module<br>• Allow for stochastic processing times<br>• Incorporate the effects of contingent events, such as major storms, bridge collapses, and delays in the construction of key facilities and system components.<br><br>The Board recommends that that the TSM be used by designers of surface facilities and all other components of the waste-management system to determine needs and capabilities and to eliminate problems or constraints in the future. | recognizes that information obtained from the utilities is important to the quality of the TSM analyses and success of the canister-based approach. The Department has provided information on the new canister-based approach to cask vendors and nuclear utilities and is evaluating technical issues raised by them regarding developing and licensing of TADs. The Department is committed to continuing the close coordination with cask vendor and nuclear utility representatives, not only in the development of the performance-based specification for TADs, but also in the subsequent design of the TADs.<br><br>The Department will continue the integrated system engineering and analyses approach to gain a greater understanding of the interrelationships between the subsystem components: waste acceptance, transportation, and repository operations. This will be done in close cooperation with the utilities and cask vendors. |
| [T]he Board believes that the DOE should move expeditiously to perform a comparative risk analysis of alternate rail corridors that might be used to move spent nuclear fuel and high-level radioactive waste to Yucca Mountain. Once that risk analysis has been completed, the DOE should inform all interested and affected parties what route(s) it prefers. In addition, the DOE should develop a contingency plan for greater use of legal-weight and heavy-haul trucking. | In a Record of Decision published in April 2004, the Department selected "mostly rail" as the mode of transport, both nationally and in the State of Nevada. The "mostly rail" option includes an expectation that some truck shipments will be made. In a Supplement Analysis to the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F), the Department considered the potential environmental impacts of shipping legal-weight truck casks on railcars. This scenario involved shipments from generator sites to an intermodal transfer station that would be constructed and operated in Nevada and the subsequent transportation of those casks to a repository at the Yucca Mountain site by legal-weight trucks. In the event that the rail line is not completed when the repository begins operations, |

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| | these truck transportation options would still be available for initial shipments to Yucca Mountain and will have been fully planned and ready for completion by that time. A full range of transportation contingencies is also being considered for shipment of TAD canisters in the event that the Nevada rail line is not available when the repository begins operations. However, the Department is currently planning the project, subject to available funding, to ensure that the rail line will be completed at least one year before the repository begins operation.<br><br>Analyses completed for the Final Environmental Impact Statement (FEIS) considered alternative rail corridors with the contingency for some truck shipments. |
| **Localized Corrosion** | |
| Unlike deliquescence-induced localized corrosion, which the Project plans to screen out of the total system performance assessment (TSPA), seepage-induced localized corrosion is not screened out of TSPA. Why seepage-induced localized corrosion and deliquescence-induced localized corrosion are not treated consistently in TSPA remains puzzling to us. The important question is, "Does including deliquescence-induced localized corrosion significantly affect the dose received by the reasonably maximally exposed individual?" Even if the effect is not significant, including this phenomenon would add to the completeness, robustness, and credibility of TSPA. (Garrick, 2007) | The analysis performed by the Project to date concludes that Na-K-Cl-$NO_3$ (plus other dust components) will define the starting composition of the deliquescent brines that form during the thermal pulse. Any deliquescent brine will contain a temperature-dependent minimum value of $NO_3$:Cl. The effects of degassing will be to reduce the volume of deliquescent brine and in the limit cause dry-out, or increase $NO_3$:Cl and the electrolyte pH. Results from experiments conducted at temperatures up to 150°C (Reebak 2006) support the conclusion that localized corrosion will not initiate under deliquescent conditions due to the high $NO_3$:Cl. Localized corrosion initiation and propagation under deliquescent conditions is further inhibited by the small cathode-to-anode ratio, the lack of oxygen diffusion gradients in the dust layer, the limited quantity of reactants (namely chloride) and the absence of a physical crevice (except in the case of the waste package contacting the pallet). As identified by the Board, the conditions for which data are most limited are for temperatures between 150°C and the maximum predicted waste package temperature of approximately 205°C. Strengthening the Project's position for screening out localized corrosion during the thermal pulse can be achieved by testing under these conditions. |

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| | To meet this goal the Project is pursuing a collaborative testing strategy that is being implemented at Lawrence Livermore National Lab (LLNL) and Sandia National Lab (SNL). The driver for this testing is to obtain additional crevice corrosion data under conditions that are representative of the repository during cool down. Thin-film experiments being performed at LLNL are designed to assess the crevice corrosion behavior of Alloy 22 and analogue material at temperatures up to 180°C while maintaining ambient pressure. The strategy is to put representative (or bounding) salt assemblages on the samples, and then expose the samples to RH levels sufficient to allow deliquescence at temperatures up to 180°C. Post-test examination will be used to determine if localized (or uniform) corrosion has occurred on these samples.<br><br>A complementary effort at SNL involves conducting tests in repository-relevant environments at temperatures up to and exceeding 200°C. Importantly, the environmental chamber is capable of maintaining these conditions at ambient pressure and in an open flow-through system (thus preventing artifacts due to uncontrolled evolution of the test environment). Another aspect of the SNL experiments is the option to monitor initiation and propagation in-situ through the use of a direct-current potential-drop (DCPD). DCPD may be applied to both creviced and uncreviced samples of Alloy 22 and less-resistant analogues in an effort to understand the parameters that control initiation and stifling. Instrumentation may also be included that enables monitoring of deliquescence in parallel with monitoring the damage state of exposed materials. |

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| **Prototype testing** | |
| As mentioned at the meeting, the efficacy of engineering designs—including operational processes—can be tested using prototyping. This is especially important in the case of the Yucca Mountain repository because many of the engineered elements are first-of-a-kind designs.<br><br>Examples of specific elements that could benefit from engineering prototyping include waste package fabrication, loading, sealing, and emplacement; robotics; and drip-shield emplacement. Experience gained from engineering prototyping will enable OCRWM to identify potentially high-consequence design and operational flaws in an orderly and efficient manner. For example, contemporary industrial experience has shown that metal fabrication defects can be susceptible to localized corrosion. This has important implications for performance of the repository waste packages. Many engineering design specifications are important to TSPA calculations. Consequently, engineering prototyping can serve as an integrating mechanism and a cross-check for TSPA. Finally, engineering prototyping can be helpful as the repository program moves its focus from research and analysis to implementation. | The DOE agrees with the NWTRB recommendations on engineering prototyping and is currently prototyping various equipment. The objective of this work is to gather information to supplement the design, ensure safety requirements are met and to reduce risk for development of unique first-of-a-kind items. In the near term, prototyping is focused on waste package closure equipment and prototyping the waste package, pallet, and drip shield.<br><br>Note that most spent fuel will be shipped in transportation, aging, and disposal containers (TADs); however, some fuel is expected to arrive in dual purpose containers (DPCs). These DPCs will need to be opened for transfer of contents into TADs. Existing technology for opening DPC's and for opening a sealed waste package needs to be more fully developed; therefore, DPC and waste package opening are planned for prototyping in the future.<br>A waste package closure system (WPCS) is being prototyped. This system performs the operations required to complete closure of the waste package after it has been loaded with TAD canisters, navy canisters, DOE Spent Nuclear Fuel (SNF) canisters, or High Level Waste (HLW) canisters containing SNF or HLW.<br><br>The objective of prototyping the WPCS is to design, develop, and construct the complete system required to successfully close a loaded waste package. An iterative process of revising and modifying the WPCS design will be part of the prototype process. When construction is finalized, a demonstration of closure operations will be performed on a full-scale mock-up of the waste package. The mock-up will be full diameter but not full height of a waste package. This mock-up will not contain nuclear waste but will be heated to simulate the calculated, loaded waste package temperatures. The purpose of the demonstration is to verify that the individual subsystems and the integrated system function in accordance with the design requirements and to establish closure operations procedures. This program is in progress and is also closely coordinated with the waste package design and prototype program. |

**References**


Garrick, B.J., 2007, Workshop on Localized Corrosion of Alloy 22, Letter from B. John Garrick, Chairman, NWTRB to Edward F. Sproat, Director, OCRWM, January 12, 2007.

Garrick, B.J., 2006, Key Elements of the Safety Case, Letter from B. John Garrick, Chairman, NWTRB to Edward F. Sproat, Director, OCRWM, December 14, 2006.

NWTRB (U.S. Nuclear Waste Technical Review Board) 2006. *Report to the U.S. Congress and the U.S. Secretary of Energy, June 2006.* Arlington, Virginia: U.S. Nuclear Waste Technical Review Board.

Sproat, E.F., Letter from Edward F. Sproat, III, Director, OCRWM, to B. John Garrick, Chairman, NWTRB, May 14, 2007 with enclosure "U.S. DEPARTMENT OF ENERGY RESPONSES TO THE DECEMBER 14, 2006, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD".